THE DEVELOPMENT OF THE SANTA FE

1935 - 1948

by

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Thesis
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August 15, 1949

Professor Joseph S. Newell,
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Professor Newell:

In accordance with the requirements for graduation, I herewith submit a thesis entitled "The development of the Santa Fe, 1935-1948."

The friendly cooperation and helpful interest of the officers of the Santa Fe Railway was invaluable in the preparation of this report. I wish to make grateful acknowledgement of this assistance, both for its own direct aid and because of the encouragement which it afforded me in fulfilling this assignment.

Through the courtesy of the President of the Atchison, Topeka & Santa Fe Railway, Mr. F. G. Gurley, I was accorded an opportunity during September, 1948, to make an all daylight trip of inspection of the line from Los Angeles to Chicago, via the Southern District, through Amarillo. I was accompanied by officers of the railway who were considerate and painstaking in their explanation of the engineering, operating and traffic characteristics of the line. I was allowed to repeat that experience a second time in January, 1949; going out to California via La Junta and returning again over the one through Amarillo.

The descriptive material for the text is based on the information gained on those several trips which was amplified and analyzed by the study of engineering and operating data in the Santa Fe headquarters in Chicago during December and January and at intermittent subsequent opportunities. I was given the privilege of desk space in the Engineering Department to compile the statistical and descriptive material included in this thesis and was allowed to have continuous access to members of the organization whose knowledge and experience I sought in the interpretation and presentation of this comprehensive subject.

I am indebted to so many persons in the Santa Fe organization that a list which appears long will not be complete. Reflecting upon the details of the work reminds me to express my thanks in particular to the following Santa Fe officers who gave me the necessary authority and introductions to make this study, arranged or accompanied me on trips, assisted me in the procurement of data, answered an endless flow of questions, and finally helped me to check and edit the tables and manuscripts:

Messrs. F. G. Gurley, President, Chicago
G. H. Minchin, Vice President-Operation, Chicago
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J. P. McDonald, Assistant General Auditor, Chicago
E. S. Marsh, Vice President-Finance, Chicago
T. A. Blair, Chief Engineer, Chicago
J. E. Inman, Office Engineer, Chicago
E. Osland, Office Engineer, Chicago
C. E. Peterson, Assistant Engineer, Chicago
E. G. Allen, Special Engineer, Chicago
R. A. Van Ness, Bridge Engineer, Chicago
C. H. Sandberg, Assistant Bridge Engineer, Chicago
W. E. Robey, Bridge Construction Engineer, Chicago
G. K. Thomas, Signal Engineer, Topeka
O. L. Gray, General Manager, Topeka
F. D. Kinnie, General Chief Engineer, Eastern Lines, Topeka
G. R. Buchanan, General Manager, Western Lines, Amarillo
E. P. Dudley, Assistant General Manager, Western Lines, Amarillo
F. N. Stuppi, Superintendent, Plains Division, Amarillo
H. A. Appleby, Signal Engineer, Western Lines, Amarillo
E. E. McCarty, General Manager, Coast Lines, Los Angeles
L. E. Olsen, Assistant General Manager, Coast Lines, Los Angeles
H. F. Mackey, Master Mechanic, Clovis, New Mexico.

While I am deeply indebted to each of the men listed above, and to others, too, I would be remiss in a particular obligation if I did not mention that Mr. J. E. Inman, Office

Engineer on the staff of the Chief Engineer, gave me the greatest total amount of his personal time and assistance in this work. Therefore I wish to acknowledge my special sense of gratitude for his extraordinarily patient and friendly and interested aid.

Very truly yours,

John W. Barriger IV

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1935 - 1948

Chapter I

INTRODUCTION

The Atchison, Topeka and Santa Fe Railway, which has long been in the forefront of railway progress, has been carried forward within the past few years by a dynamic combination of favorable traffic factors and aggressive and courageous management to the position of leadership within its industry. The phenominal economic development and growth of population in California and Texas, together with the extraordinary expansion of transcontinental railway traffic required to fight global World War II, provided the basis for the rapid increase in the capacity of the Santa Fe's main lines and additions to its plant and equipment which is the subject of this thesis. Its purpose is to outline the recent spectacular improvements made on this largest of American railway systems (from the standpoint of mileage operated by a single management).

Successive annual programs of comprehensive and coordinated additions and betterments, however, are not new events in Santa Fe history. Those outlined herein follow policies and traditions firmly established in the record of this railroad during the brilliant administration of Edward P. Ripley. He assumed the Presidency of the newly incorporated Atchison, Topeka and Santa Fe Railway Company which on December 12, 1895, succeeded after foreclosure and reorganization to ownership and operation of the properties of the original Atchison, Topeka and Santa Fe Railroad Company that had fallen into bankruptcy during the depression of 1893.

Mr. Ripley was succeeded by William B. Storey on Jan. 1, 1920, who served as President until May 2, 1933. During the first twelve years of Mr. Storey's administration, capital expenditures for gross additions and betterments of the railway system, (i.e. before writing off book value of property retired or replaced by the improvement) averaged $40,000,000 annually until the deepening depression brought all major projects to a halt by the end of 1931. Over the next four years, 1932 - 35, inclusive, the Santa Fe's budget for such purposes averaged less than $5,000,000 annually. It was during this period that on May 2, 1933 Mr. Storey retired and was followed as President by Samuel T. Bledsoe, who served in this capacity for the next six years.

Recovery began to appear in Santa Fe traffic and earning power late in 1935 after the Italian invasion of Ethopia produced a sudden European demand for grain, meat and metals which moved in large quantities for export from Santa Fe territory. Important capital improvements to track, facilities, and equipment followed the next year. These were stimulated by the operating results of 1936 and 1937 and by the growing interest of the Santa Fe in high speed streamlined passenger services which is dated from 1934 by the success in that year of Burlington's three car Diesel powered "Pioneer Zephyr" and Union Pacific's first streamliner of like size, the "M-10,000," later christened "The City of Salina." The Santa Fe soon became a leader in the development of long distance Dieselized passenger trains. A faster railroad and improved equipment were needed to fulfill its ambitions for these services and for the freight schedules required to meet the growing competition of long distance highway freight transportation.

This recovery of 1936-37 was soon followed by the recession of 1938-39 and Santa Fe's capital appropriations reflected these trends (See table I , page 4-A). The opening of World War II on

Sept. 1, 1939 produced one of the most rapid advances ever recorded in railway traffic. While the eastern lines felt the stimulus first, the effect was general and from that time forward the Santa Fe improvement program was continued at a high level of activity under the administrations of the next two Santa Fe Presidents;

Edward J. Engel (March 28, 1939 - August 1, 1944).

Fred G. Gurley, (August 1, 1944 - - - - - - -).

However, the greater part of this recent chapter in the history of the development of Santa Fe was accomplished by Mr. Gurley both as President since August 1, 1944 and the creative genius sponsoring the principal projects authorized in 1942 and 1943. The then President, E. J. Engel, was temporarily stricken by a heart attack in October 1942. Mr. Gurley, who had been summoned from the Burlington to a Santa Fe Vice Presidency in June 1939, became, in effect, acting President during the succeeding months of Mr. Engel's illness. Upon election to the Board of Directors during that period, Mr. Gurley promptly obtained its approval of a program of comprehensive additions and betterments to roadway, structures and equipment for which an appropriation of more than $20,000,000 was made at the first meeting of the Board, in November 1942, in which he sat as a member.

Manifold individual projects, all part of a coordinated plan of development, have transformed the Santa Fe into a railway of great potentialities to move trains efficiently and economically and maintain superior standards of service. The nature and extent of what the Santa Fe has done will be described from the dual standpoints of "qualitative" and "quantitive" analysis and be related to the railway of 1935 as a base in order to measure the progress of the subsequent years.

Changes in an individual cannot be observed within a day or even a year but over a span of time they become clearly apparent. Railways, too, are continuing living organisms of such vast scope and dimension that single events and developments seem imperceptible but when accumulated over years, they become striking.

A study of this broad subject must begin with a resume' of the history of the railway to which it relates. It is essential to know how and when the institution was created and grew; what were its periods of progress and adversity; what was its physical extent and condition; what special problems confronted it and opportunities were ahead of it when it entered the period of development which is the center of this study's attention.

The principal chapter of this thesis will set forth the additions and betterments to equipment and to fixed plant and facilities which have been provided over the past 13 years (1936 - 1948, inclusive) in order to give the Santa Fe greater capacity and enable it to haul traffic faster and more economically.

The story of this multiple achievement is the detailed record of new equipment acquisitions and the work done to provide more and better main tracks, yards and terminals, switching, signal and communication facilities and all of the other components of a great modern railway. These improvements were not concentrated within a single location but were diffused where needed over a system serving an area 2,000 miles in length and 1,000 miles in width. This report, therefore, entails a study not alone of what was done but where it was done; what was the cost and what benefits were obtained.

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The age of mechanical power began in Great Britain in 1774 when James Watt developed the first successful reciprocating steam engine which was originally used to pump water—out of coal mines and to drive textile machinery. Efforts were soon made to utilize this new source of power for transportation on land and water. It was, however, on an experimental basis in the latter service until Robert Fulton's "Claremont" made its first successful trip from New York to Albany on August 7, 1807. Twenty-two more years passed before George Stephenson's locomotive, "Rocket," met the requirements of the Liverpool & Manchester Railway in tests made on Rainhill, hear Liverpool, England, in October, 1829.

A number of earlier locomotives had been built and actually ran but the "Rocket" was the first that was proved to be commercially practicable. One of the earlier machines was the "Stourbridge Lion" which had been brought to America from England for service on the tramway of the Delaware & Hudson Canal Company provided to haul coal over the watershed between the tributaries of the two rivers named in its corporate title. On August 8, 1829 this dimunitive "Stourbridge Lion" gained the distinction of turning the first power driven railway wheel on the western hemisphere but it did little more and failed to achieve the results expected of it, among other reasons, because it was too heavy to run over the flimsy trestles used to carry the tracks of that line over the small watercourses which it crossed.

The first locomotive in America which earned revenues for its owner was the "Best Friend of Charleston." It achieved this distinction in January, 1831, for the Charleston & Hamburg Railroad of South Carolina, a line that is now part of the Southern Railway System. Railway history in this country, however, is usually considered to have begun with the incorporation of the Baltimore & Ohio Railroad on February 28th, 1827.

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Ralph Waldo Emerson observed that institutions are but the lengthened shadow of a man. If so, the Santa Fe may be regarded as a living monument to Cyrus K. Holliday. He was born in Carlisle, Pa. on April 3, 1826 and educated as a lawyer at Meadville College in the town of that name situated in northwestern Pennsylvania. Graduating in 1852 at the age of 26, he married and first resided there. Within the next two years, he gained $20,000 of capital from successful participation in the development of a local railway and soon after set out, alone, for Kansas with high ambitions to build a railway across the State and on to romantic Santa Fe. He hoped that doing so would save Kansas as a "Free Soil" State from the pro-slavery forces as well as bring fame and fortune to himself and open up a great expanse of wilderness for settlement.

Holliday was active in the development of the territory of Kansas and the selection of Topeka as the site of the capital. On February 11, 1859 he incorporated the Atchison & Topeka Railroad Company. Drought and Civil War shut off access to the capital required to build any tracks but Holliday's ambitions were not daunted and even before any construction had been started he disclosed his real objectives on November 24, 1863 by changing the company's name to the Atchison, Topeka & Santa Fe Railroad Company.

The record of the growth and development of a company of such magnitude must be condensed and tabulated; otherwise, it would become the principal narrative itself and not be the background of it; which is necessarily the place of such a history in this report.

The expansion of Santa Fe mileage over the years and the major events punctuating its growth are tabulated as Appendix "A." A table of the succession of the company's Presidents is as necessary a part of the history of the company as the expansion of its mileage, for the latter is primarily dependent upon the courage, foresight and ability of the man in charge of the enterprise. Such a list is therefore included as Appendix "B." Attention is also invited to Exhibits 1 and 2 which together show the present mileage and territorial extent of the Santa Fe. The foregoing data will be compressed into a thumbnail sketch which embodies the salient features of the Santa Fe history relating to the lines directly considered in this report.

The Pacific Railroad Bill approved by Congress on July 1, 1862 established the Federal Land Grant Policy and pursuant to its terms the Santa Fe obtained the assistance of a Land Grant to aid in the construction of its line across Kansas, subject to reaching the boundary of Colorado Territory by March 1, 1873. Construction finally began at Topeka during November, 1868, nearly ten years after the original incorporation of the company. The line was completed across the state from Atchison to a point near the present station of Granada, Colorado, by the end of 1872. Subsequent extensions took the railway to Pueblo in 1876 and from LaJunta to Trinidad in 1878; on to Las Vegas, New Mexico, in 1879; to Santa Fe and Albuquerque in 1880, and to El Paso, Texas, in 1881.

The intense national interest in the construction of railroads from the Mississippi or Missouri Rivers to the Pacific Ocean crystalized in an Act of Congress passed on March 3, 1853, directing the Secretary of War, who at that time was Jefferson Davis, to make three separate surveys that would provide a northern, a central and a southern transcontinental route. This work was embodied in ten massive volumes of "Pacific Railroad Reports" submitted to Congress in 1855. The southern survey was made in 1853 and '54 under the direction of Lieutenant A. W. Whipple, along the 35th parallel of latitude from Fort Smith to Los Angeles. The Santa Fe

Railway follows it from the present station of Isleta, N. M., to Victorville, Calif.

Authority to build this southern route from Springfield, Missouri, as the eastern terminus and to secure the land grant authorized for it was granted to the Atlantic and Pacific Railroad Company by an Act of Congress which chartered it on July 27, 1866. In 1870 control of the Atlantic and Pacific passed to South Pacific Railroad Company which then operated a line from Pacific, Missouri, the appropriately named junction with the Pacific Railroad of Missouri (now Missouri Pacific) 34 miles west of St. Louis, through Springfield, in the southwestern portion of the state, and on towards the boundary of the Indian Territory. This work was carried on by the Atlantic and Pacific Railroad to a connection with the Missouri, Kansas and Texas Railroad at Vinita, Indian Territory (now Oklahoma) in 1872.

The South Pacific Railroad was engulfed in the depression which followed the panic of 1873 and its affiliated Atlantic and Pacific Railroad followed in 1875. Both companies were reorganized in 1876. The line in Missouri was transferred to a new corporation, the St. Louis & San Francisco Railway Company, while the Atlantic and Pacific Railroad retained both the railway west of Seneca, Missouri, near the boundary of the Indian Territory and the franchise to extend it on to Los Angeles and the land grant to aid in that work. However, the St. Louis and San Francisco Railroad held stock control of the Atlantic & Pacific Railroad.

The Santa Fe became interested in the Atlantic & Pacific's charter as offering the best access to the Pacific Coast. It opened negotiations with the Frisco that were consummated on January 31, 1880 by an agreement between the two companies, whereby construction of the Atlantic & Pacific might be expedited through the aid of the Santa Fe's superior financial resources. Upon completion, this line was to be operated jointly by the two proprietary companies, and all traffic moving over it for thirty years was to be routed via the Santa Fe as far as Newton or Wichita, Kansas, where it would divide; Chicago cars continuing over the Santa Fe, and St. Louis tonnage moving via the Frisco through Springfield, Missouri.

Construction on the Pacific Coast outlet was immediately undertaken, and by August, 1883, the line, which became known as the Western Division of the Atlantic & Pacific, was completed from Isleta, New Mexico, to the Needles, California, 536 miles. During construction, matters were somewhat complicated by a Huntington (S.P.) - Gould (Mo.P., et al.) purchase of the controlling interest in Frisco, in January, 1882, in order to block the extension of both the Santa Fe and the Frisco into areas already served by the railroads in which these two men were individually interested.

This attempt to obstruct the new transcontinental was finally arbitrated by Huntington, of the Southern Pacific and Strong, of the Santa Fe in the latter part of 1882. It was agreed that the Atlantic and Pacific would be extended only to the Needles, whence Southern Pacific would build a branch to a connection with its California lines at Mojave and through traffic arrangements would be established. Southern Pacific then liquidated its Frisco interest, and in 1890 the Santa Fe, itself, purchased control, presumably as a guaranty against recurrence of the threat to its transcontinental position. Meanwhile, the Atchison, Topeka & Santa Fe and St. Louis & San Francisco had entered into an agreement with the Southern Pacific dated August 20, 1884 providing for the purchase of the Mojave-Needles line by Atlantic & Pacific. As the title could not pass until 1905 owing to mortgage technicalities the line was to be leased in the interim. In addition, the Atlantic & Pacific or the Santa Fe and/or

Frisco, as successors, were to have trackage rights from Mojave to San Francisco, on 12 months' notice, at a rental of $1,200 per mile. The Atchison and Frisco also agreed to purchase $3,096,768 par value of Atlantic and Pacific securities at cost of $1,524,356 from a Southern Pacific holding company.

The Santa Fe and its subsidiary, the Frisco, then became engulfed in the depression that began in 1893, and both passed into receivership along with many other American railroads. In the subsequent reorganizations, the Santa Fe laid the base for the development of its great present-day strength, but the Frisco emerged, in 1896, with an increased capitalization, and its original ambitions of transcontinental scope drastically circumscribed. Santa Fe ownership of the Frisco was surrendered, and the community of interest between the properties terminated. The Atlantic & Pacific was dismembered and liquidated; the Western Division from Isleta, New Mexico to the Needles, California, 536 miles, going to the Santa Fe to form its main line across western New Mexico and Arizona, and the Central Division from Seneca, Missouri, to Sapulpa, Oklahoma, 112 miles, was purchased by the Frisco at foreclosure. This division of the properties ended whatever transcontinental aspirations had been held for the Frisco.

William B. Strong became President of the Santa Fe in 1881. When he took charge of the railroad, it extended only from Atchison and Topeka, Kansas, to El Paso and Pueblo, Colorado. When he retired in 1889, the Santa Fe owned and operated more than 7,000 miles of railroad and ran its own trains into terminals at Chicago, Galveston, El Paso, Deming, N.M.; Superior, Nebraska; Denver, Colorado; San Diego and Los Angeles, Calif. and Guymas, Mexico. It also had started building a line west from St.Louis towards Kansas City. Work on the latter was stopped by Santa Fe's receivership in 1893 before it reached its objective, and after the reorganization of the owner, this line was sold by the successor Santa Fe Railway and subsequently acquired by the Rock Island.

Differences of opinion over financial policy led Mr. Strong to submit his resignation in 1889. Two successive changes in management were unsuccessful in avoiding bankruptcy which followed the "Panic of 1893." The Santa Fe passed into receivership on Dec. 23rd of that year and emerged on Dec. 12, 1895. The plan of reorganization had been formulated by Victor Morawetz, a lawyer of Boston, and its beneficial results have led it to be considered an outstanding achievement in corporate finance. The reorganized Santa Fe retained stock control of the Atlantic & Pacific but relinquished that of the St. Louis & San Francisco (in receivership), the Colorado Midland (acquired in 1890) and the Sonora Railway in Mexico.

The Atlantic & Pacific was promptly merged into the Santa Fe but the other three lines were not retained in the system. The Colorado Midland and the Sonora Railway were sold; the latter to the Southern Pacific, in exchange for the Mojave Division which is now the Santa Fe's main line between Needles, Barstow and Mojave. The Santa Fe holdings were not protected in the 1897 reorganization of the Frisco.

During the Ripley administration, more than 4,000 miles of lines were added to the Santa Fe system most of which represented new construction; the more important routes built during that period were:

1. Line from Seligman, later from Ash Fork, to Phoenix.

2. Line from Wickenburg, Ariz. on the former route, west across the Colorado River at Parker, and on to a main line junction at Cadiz, Calif.

3. The branch from Williams to Grand Canyon, Ariz.

4. The Transcontinental Short Line connecting the main line at Dalies, N. M. with the line previously built across the Texas Panhandle to Clovis, N.M. and thence to Roswell and Pecos, Texas.

5. Connection between the Transcontinental Short Line at Texico, Texas, and the Gulf Lines at Coleman, Texas.

A significant purchase was made in 1898; the San Francisco and San Joaquin Valley Railway. It had been completed between Oakland and Bakersfield in the preceding year. The new owner secured trackage rights to use the Southern Pacific's line across the Tehachapi Mountains between Mojave and Bakersfield and commenced running its own trains to the shores of San Francisco Bay on May 1st, 1900.

The achievements for which the Ripley administration is so widely acclaimed were not so much the additions to Santa Fe mileage, as important as they were, as the physical improvement made in the development of the railway lines comprising this system and the equipment used in performing its freight and passenger train services. In 1896, the tracks, bridges, structures, facilities, cars and locomotives of the Santa Fe generally represented minimum standards, even for that day. When Ripley relinquished executive direction of the system at the end of 1919 the Santa Fe embodied the best standards found on western railways at that time. The first chapter in the intensive internal development of the Santa Fe had been brought to a brilliant conclusion!

The second forward surge of development occurred during the Storey administration up until the end of 1931 when, as previously stated, the depression temporarily halted its program of development, a little more than a year before this President retired.

The third chapter in Santa Fe progress is the one on which the attention of this study is focused. The preceding periods, however, are necessary to give a proper background for the narrative and provide a basis for subsequent comparisons. It is for this reason that so much attention has been given to those earlier years in these introductory pages and why subsequent ones will make frequent and often detailed reference to them.

Chapter II

GENERAL OBSERVATIONS ON

(1) Traffic Density
(2) The Organization of the Operating Department
(3) The Physical Characteristics of Railroads

(1) Traffic Density

Large railroads comprise many lines and routes; some being much more important than others. While Santa Fe tracks interlace twelve great states with over 13,000 miles of line, the importance and prestige of this great system arises from being the only one line carrier between Chicago and California and so permits the proud slogan, "Santa Fe - All the Way."

This study is necessarily focused upon the transcontinental main lines. These represent less than one-third of the system's total but produce more than four-fifths of the service which it performs. The Freight Traffic Density Map* (Exhibit 3) proves this significant fact, by showing the relative freight traffic density, in each direction, expressed in net ton miles per mile of line moving over every portion of the system during the year 1941.

Exhibit 4 supplements Exhibit 3 by summarizing the percentage of total Santa Fe mileage which has traffic densities, as shown on the 1941 chart, of the increments of tonnage listed on the table from minimum to maximum limits. Another column on Exhibit 4 accumulates the percentage of total freight transportation service performed on mileage having traffic density up to and including that of the line of the table on which this figure appears.

* Used by permission of H.H. Copeland & Sons, New York.

By noting the difference in the accretions of proportionate mileage and the proportionate totals of freight service performed with successive advances in unit density, one can determine at a glance what percentage of system lines have any stated level of freight traffic density and what proportion of the system total of freight transportation is produced on lines of that traffic classification.

Exhibits 3 and 4 relate to 1941 since current data is not available but these are nevertheless very informative charts. A careful study of them will be repaid through having this "traffic picture" to serve as a background against which the reading of subsequent pages may be projected. It is well known that there have been important increases in Santa Fe traffic over recent years. In 1941, the average freight traffic density on all Santa Fe lines was 1,400,000 net ton miles per mile of line. This was doubled by the peak traffic of the war which produced average Santa Fe tonnage densities in excess of 2,800,000 net ton miles per mile of line in 1945. It held above the 2,500,000 level in 1947 and '48.

A chart of last year's traffic would show that the increase in the system average freight density was not equally distributed but was due to more than proportional growth of business on the transcontinental lines. The effect of this is to accentuate the very point which this chart is introduced to prove and which is repeated for the sake of emphasis, i.e. the Santa Fe's transcontinental main lines, which represent less than one-third of the total mileage, produce two-thirds of the freight, and an even higher proportion of the passenger revenues. It follows that the secondary routes and branch lines which represent more than two-thirds of the total mileage lend their primary value to the system as feeders of traffic to the main lines rather than for their importance as producers of revenues directly on this less extensively used trackage.

It should be pointed out that only a small proportion of the branch line trackage has too little traffic gathering or revenue producing power to be of value to the system. The stress placed on the importance of the primary main lines constitutes no reflection upon the value of the subordinate mileage. The latter is necessary to help secure much of the business which makes the more important routes such busy and profitable ones. Since this is a transportation rather than a traffic study, attention must necessarily be centered on the main lines. This point is stated to explain omission of 9,000 miles of secondary mileage from this analysis.

(2) The Organization of the Operating Department

Railway operations comprise three separate functions:

1. Transportation (C. T.)
2. Maintenance of Way (M. W.)
3. Maintenance of Equipment (M. E.)

Separate departments are created to organize and supervise the work within each classification. The three must be closely co-ordinated through an "Operating Department" which embraces all. The territorial extent of a great railway system necessitates the subdivision of each department into divisional units, representing logical distributions of mileage for purposes of direct supervision. Each department, C. T., M. W. and M. E., has its own divisional chief* who reports to a system (or regional) department head in respect to matters of standard practices and methods and performance. Under a "divisional" plan of organization, the Operating Department assigns a divisional officer, termed a Superintendent, with jurisdiction over all three of the separate components of the operating department within his territory. In a "departmental" plan of organization, no divisional operating office has such coordinating authority, which is confined to the Chief Operating Officer of the system or a major regional unit thereof.

While departmentally organized railways invariably have "Division Superintendents," their functions are limited to transportation and do not embrace maintenance of way or maintenance of equipment. The experience of American railways indicates that the departmental plan of organization is most effective and economical on railroads of small or intermediate size, and it has been the exclusive method of organization used on British railways of all size, from the outset of their history.

* Trainmaster, Division Engineer and Master Mechanic, respectively.

The divisional plan is universally used by all the large systems of the United States, except the New York Central and Chicago and North Western, which follow their Vanderbilt traditions that were originally based upon English practice.

For purposes of planning and supervising operations, the 13,000 miles of the Santa Fe Railway are subdivided into 20 operating divisions, each being assigned to the jurisdiction of a Superintendent. Since it would be impracticable to have so many operating units, as well as chiefs of the component departments, i.e. M. W., M. E. and C. T., report to a single Vice President in charge of Operation, these twenty divisions are first combined into four regional groups, viz. (1) Eastern Lines, (2) Western Lines (including Panhandle and Santa Fe Railway*) (3) The Gulf, Colorado and Santa Fe Railway*, and (4) the Coast Lines.

Four General Managers, immediately subordinate to the Vice President-Operation, are in charge of each of these four regional groups of divisions. The Chief Engineer, Chief Mechanical Officer and General Superintendent of Transportation also report to the Vice President-Operation in reference to matters relating to their respective departments and supervise their regional and divisional staff counterparts on matters of standards, methods and performance. The Vice President is an executive or administrative officer; the General Managers and Superintendents are "line" officers and the Chief Engineer, Chief Mechanical Officer and General Superintendent of Transportation and their regional and divisional equivalents are "staff"officers. The terms "line" and "staff" are used with their conventional military distinctions of direct administration

* Wholly owned subsidiaries operating the Texas mileage of the system in accordance with the laws of that State.

and performance of work being the function of the "line" officers and planning and development of methods and techniques and analysis of performance being the work of the "staff."

The Eastern Lines and the Western Lines comprise greater mileage and traffic than the other two regions and likewise have a larger number of component divisions. Therefore both Eastern Lines and the Western Lines are subdivided into districts which are under separate Assistant General Managers, through whom the Superintendents report to the General Manager. While the Coast Lines are not formally subdivided into districts, the Albuquerque and the Arizona Divisions are assigned to the jurisdiction of one Assistant General Manager and the Los Angeles Division and the Valley Division to another.

The importance of the divisional and regional composition of the Santa Fe system requires that it be noted in detail, viz.

REGION		DISTRICT		DIVISION	
Name	Headquarters	Name	Headquarters	Name	Headquarters
Eastern Lines	Topeka	Eastern	Topeka	1. Illinois*	Chillicothe, Ill.
				2. Missouri*	Marceline, Mo.
				3. Eastern*	Emporia, Kans.
		Western	Topeka	4. Middle	Newton, Kans.
				5. Oklahoma	Arkansas City, Kans.
Western Lines (Including Panhandle and Santa Fe Ry)	Amarillo	Northern	La Junta	6. Western	Dodge City, Kans.
				7. Colorado**	Pueblo, Colo.
				8. Denver**	Pueblo, Colo.
				9. New Mexico	Las Vegas, N.M.
		Southern	Amarillo	10. Panhandle	Wellington, Kans.
				11. Plains	Amarillo, Tex.
				12. Slaton	Slaton, Tex.
				13. Pecos	Clovis, N. M.
Gulf, Colorado and Santa Fe Ry	Galveston	——	——	14. Northern	Ft. Worth, Tex.
				15. Southern	Temple, Tex.
				16. Gulf	Galveston, Tex.
Coast Lines	Los Angeles	——	——	17. Albuquerque	Winslow, Ariz.
				18. Arizona	Needles, Calif.
				19. Los Angeles	San Bernardino, Calif.
				20. Valley*	Fresno, Calif.

* Terminals at Chicago, Kansas City and San Francisco - Oakland - Richmond are operated as separate divisions under Terminal Superintendents.

** The Colorado and the Denver Division are operated by a single Superintendent and his organization.

Since the detailed analysis of the Santa Fe improvement program which follows is related to the divisional components of the system, it is particularly important that the divisional distribution of mileage is fully understood and kept continuously in mind. This can best be done by reference again to the Santa Fe system map shown as Exhibit 1 which delineates the scope of each division by distinctive colors.

Each division and district and region may be considered as a railroad complete in itself. All of the various units have their own departmental organizations at their respective divisional, district, regional and system levels in order to provide for the necessities of every function of the operating department's manifold duties and responsibilities. In this way, the Superintendents, Assistant General Managers and General Managers, as well as the Vice President-Operation, have separate staff organizations adequate for their necessities of planning, co-ordinating, supervising, and analyzing the phase of the operations entrusted to each of them.

All of this is necessary for the efficient and effective administration of this gigantic 13,000 mile system as one completely integrated and unified whole which is continuously responsive to the policies, methods and ambitions of the President and the Board of Directors.

(3) Physical Characteristics of Railroads

Adequate understanding of the Santa Fe improvement program and benefits flowing from it also make it desirable to outline in simple terms some of the technical principles which relate to the physical characteristics of railways.

Railroad transportation utilizes the mechanical forces produced by locomotives to overcome the resistences which oppose the movement of cars. The magnitude of these negative forces is principally determined by the basic physical characteristics of the line which fixes the amount of work that must be done to run trains between any two places on it.

The physical characteristics of a railroad are:

1. Distance. The purpose of transportation is to take freight to the place where it is needed or people to the place where they wish to be. Railway service therefore is principally related to the distances which must be traversed in moving traffic; both freight and passenger. The locomotive must overcome the frictional resistances of the train (measured in pounds per ton of weight) throughout the entire length of its run.

2. Grades. Land surfaces crossed by railroads are seldom flat. Elevations must be surmounted; some are gently rising plains or low hills; others are more abrupt slopes increasing to high mountains. In ascending any of these, the force of gravity (also measured in pounds per ton of train weight) becomes an additional element of resistance to train movement which is measured by the gradient and must also be overcome by the power of the locomotive.

3. Curves. add a third factor of resistance to the movement of a train as the outer rail of the track deflects the wheels from a straight line;

i.e. tangent. This introduces additional frictional resistances, but these are expressed in terms of the grade equivalent of curvature as will be outlined on a subsequent page.

Distance may be regarded as the first dimension of the railroad since it relates to length.

Curvature diverts the track from a straight line and thereby carries the railroad over an area and so into the second dimension.

Elevations raise railroad trains into space and so bring the third dimension into railway operation. Changes in elevations are overcome by grades.

Railway operation may therefore be regarded as a three dimensional problem while considerations of speed project it on into the fourth dimension which is measured in time.

The first theorem of geometry states that a straight line is the shortest distance between two points. It follows from the foregoing outline of the three physical characteristics of a railroad that the ideal track is straight and flat, i.e. contains neither grades nor curves. Very little land surface is level so railway routes must be adapted to its contour. Nearly all track must be laid on inclinations which introduce grades. Railways which cross broad areas of sparsely populated plains may have as little as 10% of the total length on curved alignment. On the other hand, less than 10% of the road may be straight track on routes which cross mountain ranges or follow tortuous river valleys. Between these two extremes wide variations are found.

It should be pointed out that level track may be found on curves while the track on grades may be straight. It follows that reference to straight track and to level track relate to separate characteristics in the horizontal and in the vertical planes respectively. A change in the one does not necessarily affect the other.

The perfect railroad would have neither grades nor curves and the distances would be the geometric minimum (i.e. a straight line) between its terminals. It is obvious that the necessity of laying railroad tracks over hills and mountains and across valleys and following the courses of rivers and streams, together with the desirability of reaching centers of population and traffic not on the direct course between terminals, are the primary influences in introducing excess distance, grades and curves. The latter are handicaps which add to the cost of actual operation compared with the minimum expenses that would be incurred if the physical characteristics of railways were perfect; i.e. their lines were straight and flat.

The cost of railway operation is primarily determined by the length or distance of the haul and the grades and the curves traversed by the line. These, along with the additional power required by high speed, establish the amount of work required of a locomotive to move a train and this, in turn, is the basic component of operating expense. Relative increases in any of the foregoing factors of distance, grades and curves will adversely affect costs and it follows that decreases in them will facilitate more economical operation.

The effect of relative differences in physical characteristics on original construction expenditures is invariably opposite to its influence on operating costs. Reduction of grades and curves and excess distance in the original line would require a greater outlay for building but permit more economical operation. For a given volume of traffic there is always an optimum stage of development, with its resultant minimum total of both operating expenses and capital charges, that will permit the maximum percentage of return on the actual investment.

Managers must therefore give continuous careful study to the questions involved in balancing the interest cost of the additional investment required to improve physical characteristics of lines against the operating economies which will follow them. If traffic is light, as is usually the case when railroads are new, little expenditures can be justified over the bare minimum necessary to provide a route of whatever maximum grades and curvature and excess distances may be required to fit the track into the topography of the country crossed. As traffic develops, it has been the practice of railway managements to improve profile and alignment and shorten distances, wherever the resultant reductions in operating expenses exceed the interest and taxes on the additional investment required for these improvements.

Differences in elevation are overcome by introducing grades into a railroad track. These are shown by a "profile" of the line. The profile of the Santa Fe's transcontinental lines appears as Exhibit 5.

Grades may be classified as follows:

Classification	Rate of grade in percent	Increase in Elevation in Feet: Per 100 ft. of Distances	Increase in Elevation in Feet: Per Mile of Distances	Resistance interposed by gravity to train movement In Lbs. Per Ton
"Water Level" grades	Level - 0.3%	0 - 0.3'	0 - 15.8'	0 - 6.0
Light	0.3% - 0.5%	0.3' - 0.5'	15.8' - 26.4'	6.0 - 10.0
Moderate	0.6% - 0.9%	0.6' - 0.9'	26.4' - 47.5'	12.0 - 18.0
Heavy	1 % - 1.5%	1.0' - 1.5'	52.8' - 79.2'	20.0 - 30.0
Mountain	Over 1.5%	Over 1.5'	Over 79.2'	Over 30.0

A railroad's location is its constitution. This will determine the traffic that it can obtain and the cost at which it can operate. Given a strong constitution a railroad will prosper in spite of economic or other vicissitudes which may bring temporary misfortunes.

Wellington in his classic "Economic Theory of Railway Location" (1887) has proved that from the standpoint of operating expenses, the physical characteristics of railroads may be divided into two classifications, viz.:

1. Details of primary importance are those which limit the gross weight of a train that can be hauled by each class of engine, and hence determine the number of trains which must be run in order to carry the volume of traffic available. On most railway mileage, grades establish the tonnage hauling limit of a locomotive. In exceptional cases, very sharp curves are the controlling factor.

2. Details of secondary importance are those which affect the cost of running each train, but do not affect its gross weight, (i.e., the number of trains operated) viz:

(a) Comparative length of route in relation to air-line distance;

(b) Curvature or amount of angular deviation between straight portions of the track;

(c) Rise and fall. This is the amount of vertical distance which each train must be raised or lowered in the course of its movement between terminals.

The cost of operating a freight train per mile with a given locomotive is substantially a fixed amount and for this reason the gradients (or very occasionally sharp curves on lines located in river valleys which may provide easy grades but follow tortuous courses) which limit the train weight are of major importance. They determine the number of trains that must be operated to haul its average daily tonnage of freight. The grades which establish the maximum tonnage on an engine district are therefore termed "ruling grades."

Ruling grades are not necessarily the maximum grades on the line as will be pointed out in a subsequent paragraph touching on "pusher or helper grades" and the practice of "doubling the hill." In addition, some grades in excess of the ruling grade are operated as "momentum grades," by utilizing the kinetic energy of the train, moving at average speed at the base of the ascent, to supplement the force of the locomotive to haul the cars over a short grade, the rate of which is greater than that on which the engine could pull them by its tractive power alone.

Details of secondary importance have considerably less influence upon operating costs. While affecting the cost of operating each train, they do not determine the tonnage limits and hence the number of trains run. Operating costs as a whole are much more affected by number of trains run than by variations in costsper train.

Magnitude of resistances, whether of grade or of other classification, is measured by the force in pounds necessary to overcome them. The work performed is the amount of this force multiplied by the distance over which it acts (giving a product in foot pounds). Power is the rate at which the work is done, i.e., work per unit of time (one horsepower equals 550 ft. lbs. of work done per second).

Gradients, or rates of grade, are expressed in percent of rise or fall per unit of distance. Thus a grade of 1 percent rises 1 ft. per hundred or 52.8 ft. to the mile, a grade of 0.5 percent is 26.4 ft. per mile, etc. The absolute effect of gradients to increase the load on the engine is constant and is easily determined under the general theory for the equilibrium of forces applied to the inclined plane to be 20 lbs. per ton for a grade of 1 percent and in arithmetic proportion for all other rates of ascent.

An ascent of 0.3 percent or less is usually considered to be a "low grade" line, while a rate of 1 percent and over is a heavy grade. Grades between 0.6 percent and 1 percent may be said to be "moderate." L. F. Loree in "Railroad Freight Transportation" remarks, "It used to be said, when I was a youngster, that no road with grades not exceeding 0.5 percent ever went into the hands of a receiver. I do not know whether this was literally true but certainly the transportation and cost advantage of a superior grade line give its possessor a commanding advantage over a less fortunate competitor."

Grades have two effects upon operating expenses:

1. The established "ruling grade" determines the train weight which an engine can haul over this ascending line, and hence the number of trains required to move the available traffic.

2. The direct expense for fuel and maintenance is increased by ascending and descending a vertical distance (rise and fall) instead of running on continuously level track.

These two distinct considerations are so totally divergent that it is merely incidental that both are related to rates of grade. Grades other than ruling grades (i.e., details of secondary importance as per definition) are considered only as so much rise and fall but ruling grades must be analyzed from the dual standpoints of (1) effect of rise and fall on costs as well as for (2) the determination of train load, hence the number of trains required per day for varying volumes of traffic.

Ruling grades seldom extend over an entire engine district or division of a railroad. If the elements of expense of running trains on ruling grades are examined, it appears that the principal influence of these grades on cost does not result as much from working the engine at full capacity while ascending them, as from the loss in potential hauling capacity on the other long sections of the line where the locomotive has a large unused surplus capacity which continuously incurs its full pro rata of expense. If the extra motive power required on ruling grades can do its work in one limited area where its full capacity is continuously utilized, the excess cost of ascending high summits on increased rates of grade can be greatly curtailed compared with longer ascents on more moderate grades, much of which is below the ruling rate.

This fact released the locating engineer from the most perplexing difficulties incident to ascending high elevations and enabled him to concentrate his attention, i.e. capital, on the more tractable portions of the line where small improvements in gradient may have very great proportional value. In practice this idea is developed by the use of assisting or helper engines operating on "pusher" or "helper grades." Such grades are heavier than "ruling grades" but are in no sense considered in the latter class since they do not determine the gross tonnage hauling capacity of road engines operating over the entire engine district. Should traffic be so light as not to warrant pusher service, it is often desireable to resort to the practice of "doubling the hill" in which case the road engine carries its train over the grade in two or more sections. "Doubling the hill" obviates light loading of trains over a division in order to prevent the maximum grade becoming established as the ruling grade.

Experience and technical analysis prove that it is advisable to build to the lowest feasible through grade over as long a mileage as possible and concentrate principal ascents into maximum grade resistances over a limited section. Here helper engines can be provided which are accurately adapted to the service and these locomotives can be kept fully at work over the entire distance where used. Accomplishing this makes the pusher gradient a matter of comparative indifference alongside the resultant advantages of reduced ruling grades on the through line; moreover, the higher permissible pusher grades secure important construction economies where the alternative would usually involve very expensive grade reductions.

Steam locomotives, save for the limited exception provided by booster equipped engines, cannot exert any greater power for short periods of time than they can in sustained operations. Therefore, steam locomotives have no reserve to meet the requirements of helper grades in excess of ruling grades and helper engines must be added to move trains over them. All-electric locomotives and Diesel-electric locomotives have short term ratings in excess of their continuous ones. As a result of this, dieselization or electrification of train movement introduces its own distinctive economic and operating characteristics which arise from elimination, as helper districts, of grades that would require an assistant engine if steam locomotives were used on the run. It follows that one of the great economies of Diesel operation is its elimination of helper locomotive mileage over mountain crossings. However, the general observations on using helper grades to reduce ruling grades which was made in the foregoing paragraph, to summarize Wellington's conclusions that necessarily related to design of railroads to meet steam locomotive practice, are confirmed by the characteristics of the Diesel. These continue to make it better to concentrate rise and fall than to diffuse it; although it is better still to reduce it to minimum limits and proportions and lower ruling grades, too, where economically practicable.

Curvature is occasionally a primary, but usually is only of secondary importance in the sense in which Wellington uses that term to designate factors which do not establish the number of trains required to haul a given volume of traffic. Trains are diverted from a straight line by curves. A curve has two primary characteristics, both of which are expressed in degrees. One is the sharpness of the curve, or its radius, the other is the central, or interior, angle which measures the quadrant through which the direction of trains is turned in traversing the curve.

The basic measurement of a curve is its radius. It might be assumed that this would be expressed in linear measurement, or feet, rather than circular measurement, or degrees. However, it is customary to designate curves by the degree of the central angle subtended by a chord 100 feet in length in railroad practice. To illustrate the application of circular measurement to the radius of a curve, consider a chord 100 feet in length, subtended at the gauge of the rail by a steel measuring tape. If the radii of the curve at the points of intersection of the 100 foot chord are extended to the center of the circle, the angle which they subtend will be the measure of the curve, expressed in degrees, minutes and seconds of circular measurement. Likewise, the circular measurement of a curve registers the angular deviation of each 100 foot chord of the circle.

A curve of one degree radius, which is the present desired standard for high speed lines, has a central angle of 1° subtended by the radii drawn to the points of intersection of a 100 foot chord with the curve. The radius of a 1° curve is 5730 ft., or 1.09 miles, in length. Curves within the ordinary limits of main track practice have radii varying in inverse proportion to the degrees of the curve; to wit:

Degree of curve	Length of Radius
2°	2,665 ft.
3°	1,910 ft.
4°	1,433 ft.
5°	1,146 ft.
6°	955 ft.

In addition to measurement of the rate of curvature, the total amount of its angular deviation, or central angle, must also be established. This is likewise expressed in degrees but it normally involves so much larger figures than the rate of curvature that no confusion will arise between the two applications for which the single term of circular measurement is used.

A line having 360 degrees of central angle of curvature makes angular deviations equivalent to one complete circle. If at the same time all of this curvature is at the rate of three degrees, the radius is 1,910 feet and the diameters and circumferences are equivalent lengths. The relative sharpness of curvature of the track introduces resistance to train movement. The theorectical mechanics of curve resistance and actual tests of it by dynamometer cars attached to trains have led to the establishment of a factor of 0.8 lbs. resistance per degree of curve per ton of train weight (although this is slightly variable in contrast to the constant measurement of grade resistance).

This resistance per degree of sharpness of the curve is the same magnitude of resistance as that interposed by a grade of 0.04 per cent or 2.0 ft. per mile. It is most convenient to consider curvature in terms of equivalent grade which is done by multiplying the number of degrees of curvature by the constant factor 0.04 percent grade. Thus a 6-degree curve (955 ft. radius) offers the resistance of an 0.24 percent grade or 4.8 lbs. per ton and a 10-degree curve is equivalent to an 0.4

percent grade or 8.0 lbs. per ton of train weight. Curves of from 6 to 10 degrees are the sharpest normally found in main line tracks in other than mountainous regions and 1 to 3 degrees represents best standard practice. A curve of 1 degree, super-elevated 6 inches (a subject mentioned in a later paragraph) insures safe and comfortable operation of trains at speeds of 100 miles an hour.

Under three circumstances, however, curvature may limit train weight, viz.:

1. When curves are introduced on a ruling grade without reducing the rate of the latter by what is called compensation for curvature so as to keep the aggregate maximum resistance constant on both curves and tangents.

2. When a line is level or nearly level and extends through a region requiring much curvature (as in narrow river valleys) resistance of curvature may readily exceed the resistance of low grades.

3. (Very occasionally) Restriction of use of heavy motive power because of sharp curves rendering their operation unsafe.

To ascertain the effect of curvature it is necessary to superimpose the additional grade equivalent of any curved section of track on the profile of an ascending grade. As curvature resists the action of gravity on the descending train, the profile must show the negative (subtracting) effect of curved track. An equated profile prepared in this manner is necessary to convey the true graphic total of the combined magnitude of resistances of curvature and gradients, and a separate chart is needed to delineate this for both directions. The grade line of the equated profile, reflecting the combined effect of ascending grade and curve resistances, should not exceed the maximum ruling grade at any point.

Considerations of curvature are of secondary importance in railway location for curves do not establish train weight but do have the following adverse influences on operations:

1. Add to train resistance even though in an amount insufficient to affect train load.
2. Add to cost of maintenance of way and patrolling of track.
3. Add to maintenance of equipment expense.
4. Increase possibility of accident.
5. Entail speed restrictions unless of very long radius.
6. Cause cars to lurch and jolt which can damage freight and produce adverse mental reactions in travelers.

Trains rounding a curve exert a centrifugal force against the outside rail which tends to overturn it. This force varies as the square of the speed and inversely with the radius. It must be counterbalanced by superelevating the outside rail, up to the limit of $5\frac{1}{2}$ or 6 inches. This represents the maximum inclination of the track that can be made without risking the possibility that freight cars carrying top heavy loads might overturn if a train stops on the curve. Moreover, higher superelevation causes excess pressure and wear on the inside (or low) rail of curves by trains moving around them at the rates of speed below the maximum for which this heighth is calculated.

The following table shows the maximum speeds at which it is safe and comfortable for passenger trains hauled by steam and Diesel locomotives to traverse curves of the indicated degree with a 5" superelevation:

Maximum comfortable speed for passenger trains traversing curves.

	Radius	Speed
1°	5,730 ft.	100 MPH
2°	2,865 ft.	80
3°	1,910 ft.	65
4°	1,433 ft.	55
5°	1,146 ft.	45
6°	955 ft.	40

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Most railroads were first built before machinery was available to move earth and rock. Construction of the original roadways was a pick and shovel job, assisted only by black powder for blasting and horses and mules, with wagons or wheeled scrapers, to move material out of cuts or onto fills. It was essential to reduce earthwork to a minimum. This necessitated keeping the cross sectional area of cuts and fills as small as possible and that in turn was primarily regulated by the depth of the excavations and the heighth of embankments.

The erosive forces of wind and water on the slopes of earthwork and the lines of transmission of forces through earthen fills both require that the sides shall have not an inclination steeper than the rate of 1½ feet of horizontal distance to each one foot of vertical distance. Since there are two slopes for each cut or embankment, it is obvious that the cross sectional area, which measures the amount of material to be moved, increases very rapidly as the former becomes deeper and the latter higher. The original width of the top of a single track railway fill or the bottom of a single track railroad cut was generally 16 feet. The present standard is from 20 to 26 feet in order to give additional stability to the subgrade under the fast movement of heavy trains.

Each additional foot of heighth or depth therefore adds three feet to the width of the base of a fill or the top of a cut. Cuts and fills for double track lines are widened to permit 14' spacing of track centers.

It follows that as cuts and fills became more than 10 feet in heighth or depth, their cross sectional areas increase very rapidly with resultant effects on construction costs. Economy of building the original lines was largely a matter of securing a location that would hold cuts or fills in excess of 10 or 15 feet depth or length, respectively, to absolute minimum aggregate lengths.

When declivities greater than 20 to 25 feet below the grade of the track were crossed, it was customary in the early days of railroad construction to build a trestle or some other form of structure in order to avoid the use of earthwork. Similarly when the grade of a railroad had to be located at that depth, or more, below the surface of the ground it usually required boring a tunnel unless the earth was loose and easily removable. Trestles, bridges and tunnels are very expensive to build and maintain so the aggregate length of them is necessarily kept as low as possible. The problem of the early railroad builders was therefore one of keeping cuts and fills to moderate proportions, i.e. below 10 feet and avoid bridges and tunnels wherever practicable.

It was inevitable that the urgent necessity for building the early railroads at minimum cost lead their locating engineers to use 1% grades and 6° curves freely ~~used~~ unless the favorable nature of the terrain permitted more favorable physical characteristics to be obtained without material additions to construction costs. In mountainous country, grades up to 2.2% are commonplace and ones as steep as 3 percent and even higher are found in some places, (e.g. the Santa Fe's crossing of the Raton and Glorietta Mountains).

Likewise, difficult terrain frequently forced the use of 9° and 10° curves and one of 14° and 16° were occasionally required.

The prevailing maximum grades on the mountain crossings of many western railways is 2.2 percent or 116 ft. per mile. This rate was established by the use of that maximum ascent on the Baltimore & Ohio Railroad's crossing of the Allegheny Mountains between Cumberland, Md. and Parkersburg, W. Va. The terms under which the United States government gave land grants and other forms of federal aid to some of the transcontinental railways provided that their gradients should not exceed those utilized on the Baltimore & Ohio (unless specific authority was granted to the contrary).

The physical development of the American railroads has not only been marked by continual improvement in their track structures, facilities and equipment, but likewise by concurrent improvement in the physical characteristics of many miles of lines on which grades and curves have been reduced as the growth of traffic has permitted. Construction of a second track presents opportunities for reducing grades and curves. Improvementsof this character also permit minor contraction of distances to be made through line changes and cut-offs.

Chapter III

DESCRIPTION OF SANTA FE TRANSCONTINENTAL LINES

The influence of geography on history and on politics is now well recognized. The researches and writings of the British scholar, Mackinder, and the German, Haushoufer, had profound affect upon the policies and ambitions of the rulers of the European totalitarian states and so upon current history. Just as one may study the "geopolitiks" of nations, one also may observe the parallel applicability of this practical type of analysis to railway development. History and geography have been notable factors in the development of the Santa Fe.

A. Kansas City to Los Angeles via La Junta

The Santa Fe Railway is so intimately associated with the Santa Fe trail that a present traveler on its trains instinctively believes he is riding along its very pathway all the way west but this occurs only for 528 miles between Kinsley, Kansas, (36 miles east of Dodge City) and Canyoncito, New Mexico, where the two routes are closely parallel although, of course, they do not coincide. The latter station is near the western outlet of the Apache Canyon, 5 miles east of Lamy, the junction with the branch to the historic city of Santa Fe.

The Santa Fe Trail began at Independence, Missouri, and at Westport Landing, the latter site being within the present Kansas City. This historic route extended on a relatively straight line across the narrowest distance between the Missouri and the Arkansas Rivers. The present stations of Olathe, Gardner and Edgerton on the Santa Fe Railway's present "Ottawa Cut-off" are now located at points that would have been on the Santa Fe Trail had they existed in those early days. It crossed the route of the present main track between Topeka and Emporia where

Burlingame is now situated. The Santa Fe Trail met the Arkansas River at Great Bend and followed it to Los Animas before turning in a southwestwardly direction down the valley of the Purgatoire River* towards the present city of Trinidad.

The Santa Fe Trail itself was opened by the initial trip of Captain William Becknell in the fall of 1821. Soon after that William and Charles Bent and Cerain St. Vrain built a trading post that became known as Bent's Fort located in the Arkansas River Valley not far from its confluence with the Purgatoire River.* This is at the present station of Los Animas. Bent's Fort played a prominent part in the development of the Southwest up to the time of the Mexican War. The owner, William Bent, generously turned the fort over to the United States Army during that conflict. After the war the United States offered to buy Bent's Fort but named a price so ridiculously low that the owner, disgusted by this ingratitude, in 1852 moved all of his belongings out and destroyed the building with the powder stored in them.

After the Santa Fe was built across Kansas its first extension beyond was to Pueblo which was reached in 1876. Events soon lead that railroad to build to Santa Fe and on beyond to the settlements in the Rio Grande River Valley at Albuquerque and El Paso. The junction between the two seperates routes to Pueblo and to Albuquerque and is located at La Junta which is 19 miles west of Los Animas, where it will be recalled the old Santa Fe Trail left the Arkansas River and turned southward towards Santa Fe.

The availability of water along the Santa Fe Trail was so important to wagon trains as they toiled west from the 100th Meridian that the difficult passage of the Raton Mountains was initially made in preference to the southern route. The latter avoided this high range but passed through the very dry land that became the

* Locally called "The Picket Wire."

"dust bowl" of the 1930's. Later, however, adventurous travelers both shortened the trip and avoided the Raton Mountains by following the "Cimarron Cut-off." This alternate route crossed the Arkansas River at Ingalls, 6 miles west of the present Santa Fe station of Cimarron, which in turn is 25 miles west of Dodge City, and headed in nearly a straight line to its southern junction with the main Santa Fe Trail. The well-known wagon-shaped butte, less than a mile east of the Santa Fe's station at Wagon Mound, New Mexico, (45 miles northwest of Las Vegas) marks the point where the Cimarron Cut-off joined the main trail on its way to Santa Fe.

No hill or mountain impeded the development of either the Santa Fe Trail or the Santa Fe Railway across the State of Kansas, although the elevation gradually rises across this 500 mile-long state from 750 feet at the Missouri boundary to nearly 3,500 feet at the Colorado line. Eastern Kansas is so flat that it was seldom necessary to deviate far from a direct line in order to follow a watercourse. The western half of the State does not appear rugged to the eye but its topography would have handicapped the early railroad builders had not the Arkansas River provided a natural pathway for the railroad for more than 400 miles west from Hutchinson, Kansas, to La Junta, Pueblo and Canon City, Colorado.

The 100th Meridian of longitude marks the transition to high and semi-arid land in each state which it crosses. West of this imaginary line, the elevation of the land begins to rise more abruptly. The Santa Fe main line crosses the 100th Meridian at Dodge City, a factor which established this small, but historic city as the place "where the west begins" to the traveler over this popular route. Eastward and westward ruling grades across Kansas and on beyond through the Arkansas River valley to La Junta never exceed 0.6% and usually are only 0.5%.

The elevation rises more than 1500 feet in the 82 miles of distance from La Junta to the base of the Raton Mountains at Trinidad. The ascent is not gradual and continuous but presents a "saw tooth" profile. While the line is generally descending eastward, the short ascents are on 0.6% ruling grades. Ruling grades westward across this part of the line are 1.1%, compared with 0.5% westward to La Junta. This abrupt change in gradient necessitated either the reduction of the tonnage of trains or the use of heavier power westward out of La Junta than into it. Such an operating factor as this along with its being the junction of important routes naturally made it a division point.

The Raton Mountains are an east-west offshoot of the Rockies which lay as an immense barrier against the Santa Fe Trail and the Santa Fe Railway. While these are known only locally and the distance across is short, the grades required to cross them present the most difficult obstacle confronting the Santa Fe at any place on its system. Engine terminals are usually located at the base of mountain crossings to service helper locomotives and to facilitate changes in the tonnage rating of trains. Trinidad, Colorado, is the Santa Fe terminal at the base of the north (or westward) approach to the Raton Mountains and the town of Raton, New Mexico, serves the similar function on the other side of this range. Primary physical characteristics of the line over Raton Pass follows:

	Elevation
Trinidad, Colorado	5989 ft.
Lynn, New Mexico (west end of Raton Pass Westward tunnel)	7587 "
Lynn, New Mexico (west end of eastward tunnel)	7623 "*

* Highest point reached by AT&SF Railway.

	Distance	Ascent	Max. Grade Ascending
Trinidad to Lynn	16.0 mis.	1598 ft.	3.5%
Raton to Lynn	6.8 "	989 "	3.3%

The original line across Raton Pass was completed on December 7, 1878. It utilized "switch backs" to reach the summit on 4% grades in order to avoid delay awaiting operning of the single track tunnel, 2040 feet in length on July 7, 1879. This tunnel and the companion one 2789 feet in length, placed in service in 1908, to provide for the second track and now used for westward trains, are the longest ones on the Santa Fe with the exception of the 5600-foot bore where the "Valley Division" penetrates the Coast Range of California at Glen Frazier, 18.3 miles east of Oakland.

The 3.3% and 3.5% grades on Raton Mountain and the 3.0% grade eastward over the Glorietta Mountains, mentioned in a later paragraph, are the maximum ascents on the Santa Fe. Grades of this severity are not found on any other main line of railway in the United States, except the Denver & Rio Grande Western Railroad where the grade is 3.0% on the 20-mile ascent from Minturn, Colorado, to the summit of the Rockies at Tennessee Pass at elevation 10,200 feet, and of the Southern Railway's 4% climb over Saluda Mountain on its line from Spartanburg, South Carolina, to Asheville, North Carolina.

Just as those who drove wagon trains over the Santa Fe Trail developed a Cimarron Cut-off to avoid the Raton Mountains, so the Santa Fe Railway likewise was ultimately forced to build a detour around them in its great "Transcontinental Short Line" or Belen Cut-off which was first opened as a continuous through route in 1908. This provides an alternate railroad from Ellinor, Kansas, through Amarillo, Texas, to Belen and Dalies, New Mexico, a distance of 765 miles on the "cut-off," compared with 787 miles on the original main line via La Junta and Trinidad. The latter, however, is still used by all of the Santa Fe's fastest passenger trains; but for more than 40 years, Santa Fe's transcontinental freight trains have been routed over this lower grade line via Belen. It will be described in subsequent pages.

In 1925 the Santa Fe extended a branch line westward from Dodge City, Kansas, for more than 200 miles, to Farley, New Mexico. It was projected over the remaining distance of only 40 miles to Colmor, New Mexico, a station on the Santa Fe main line, 50 miles southwest of Raton. This was intended to play the same role which the Cimmaron Cut-off did for the Santa Fe Trail in Santa Fe Railway operation but this track was never completed. While it would avoid the Raton Mountains, it did not circumvent the almost equally difficult Glorietta Range. The Transcontinental Short Line did both and hence became the principal factor in the development of the Santa Fe east of the Rio Grande River.

The line between Raton, New Mexico, and the engine and crew terminal at Las Vegas, New Mexico, generally traverses open country with mesas and mountains forming the background of a continuously beautiful panaroma but presenting no serious barriers to the railway's path. The Canadian River is followed from Otero, New Mexico, to French, New Mexico, 26.3 miles. A branch of the Southern Pacific extending into the coal fields of Northern New Mexico crosses both the Santa Fe Railway and the Canadian River at the latter station. It is the last foreign railroad* that will be seen until Daggett, California, is reached, 950 miles away. Wagon Mound, 65.7 miles from Raton, is one of the oldest settlements along the line and derives its name from the resemblance of a nearby butte to a covered wagon top. It will be recalled that this point is the southern junction of the Cimmaron Cut-off of the old Santa

* If the little Apache Railway, a "feeder" which connects with the Santa Fe at Holbrook, Arizona, and has no other outlet, may be considered as constituting no exception to this statement.

Fe trail from Dodge City. Wagon Mound is 15.3 miles southwest of Colmor, the proposed junction of the Santa Fe's railways once projected equivalent of the Cimmaron Cut-off.

The most significant natural formation affecting the location of the railway between Raton and Las Vegas is the 10-mile long Shoemaker Canyon of the Mora River, 27 miles north of Las Vegas. This is the first defile traversed by the railway on the transcontinental trip west. Leaving Las Vegas the railway descends on a 1.6% grade to its crossing of the Pecos River at Ribera, 29.1 miles distant. A notable feature of the line is an unusually large and complete horseshoe curve, a short distance east of this station. Leaving the Pecos River the train commences a 25-mile climb from elevation 6,030 feet on 1.7% maximum westward grades to the summit of the Glorietta Mountains at the station of that name at elevation 7455. This is the second and last offshoot of the Rockies encountered by the Santa Fe Railway. The Glorietta Mountains separate the valleys of the Pecos and Rio Grande Rivers and present difficult operating conditions.

Throughout the ride of 54.5 miles from Las Vegas to Glorietta the magnificent Sangre de Cristo Mountains are in continuous view. Their forest covered slopes stretch on up to timberline which is well below the highest peaks; snow covered throughout most of the year. The westward descent from Glorietta is on a 3% grade. The track finds lodgment in the narrow and tortuous Apache Canyon, remembered as a site of military importance in the Mexican and the American Civil Wars and in Indian fighting as adversarys in each of these conflicts struggled for the mastery of this strategic point on the route to Santa Fe.

The railway bridge which carries the track from one wall of the Apache Canyon to the other at its deepest and narrowest point is one of the principal points of scenic and historic interest on the entire line of the Santa Fe. The small but picturesque junction of Lamy*, 9.7 miles from Glorietta, is the base of the 3% eastward pusher grade to the summit and so is a terminal for helper engines as well as the junction of the 18.1 mile branch to Santa Fe. This little town, nestled in the Sangre de Cristo Mountains, 500 feet above Lamy, is too inaccessible from the east to have been on the main line. The first train ran over the branch into Santa Fe on February 19, 1880. This brought the romantic history of the Santa Fe trail to a close after it had been used for nearly 59 years (since 1821.)

The railway follows Galisteo Creek, flowing down from Santa Fe, to descend on 1.42% grades from Canyoncito through Lamy on to the Rio Grande River at Domingo. The Valley of this historic stream provides a natural route for the railway on to Albuquerque, New Mexico's largest city and on beyond it for 253 miles to El Paso. In the vicinity of Albuquerque, the Sandia Mountains, on the east, are the most prominent features of the scenery. Isleta, 12.6 miles below Albuquerque and one of the most typical and picturesque of the pueblos, is at the junction established in 1880 between the original Atlantic & Pacific Railroad and the Santa Fe's original line on down the Rio Grande Valley to El Paso.

Santa Fe trains follow the valley of the San Jose River on the 120.5 mile climb up to the Continental Divide at Gonzales, New Mexico. The elevation at Isleta is 4,895 feet and at Gonzales 7,250 feet. The ascent is 2,355 feet or approximately 20 feet to the mile. This would

* Appropriately named for the first and greatest Archbishop of the See of Santa Fe; who is well known in literature as the lovable Padre of Willa Cather's popular novel, "Death Comes for the Archbishop."

require only a 0.4% grade if the track were on a continuous ascent, but for reasons of economy the original line was constructed on 1.0% grades. When the second track was added, it was laid on a 0.6% ruling grade westward (32 feet to the mile) and is used by westward trains.

Construction of the second track invariably provided an opportunity to improve the original ascending gradient wherever it exdeeded the later standard ruling grade. The first track with the heavier grade was thereafter assigned to the current of traffic in the descending direction. In building the second track on the Santa Fe, for 393 miles west from the Rio Grande River Valley at Belen* and Dalies** to Pineveta, Airzona, beyond Ash Fork, it was invariably located north of the original line on eastward ascents and south of it when the climb was westward. This requires left hand assignment of current of traffic on the double track lines between those stations.

The differences in gradient between the original single main track, assigned to the current of traffic in the direction of the descending grade, and the newer one providing a reduced ruling grade frequently necessitate their being on non-parallel locations. This is required to provide the additional distance needed to overcome a given change in elevation at a lower rate of grade. These non-parallel locations of second track are listed in Table 2 on pages 49 and 50.

While all of western New Mexico and eastern Arizona traversed by the Santa Fe is high rugged country and is interspersed with mountains and mesas, the ranges are not continuous and the railway has a broad open

* Rio Grande River crossing of the Transcontinental Short Line and its junction with the El Paso-Albuquerque line, 30 miles south of the latter city.

** Junction of Transcontinental Short Line with the main line, 14.0 miles west of Isleta. Dalies is also 10.3 miles west of Belen.

Table II

NON-PARALLEL LOCATIONS OF SECOND TRACK
Chicago - Los Angeles

Division	From	M.P.	To	M.P.	Dist.	Grade See Notes (1)	Grade See Notes (2)	Reasons for Non-Parallel Track (See notes E and W)
Ill.	Plaines	40.9	Pequot	57.2	16.3	0.8%	0.5%	AT&SF uses GM&O tracks for eastward main.
Mo.	Dean Lake	370.3	Bosworth	373.8	3.5	0.8%	0.5%	W
Mo.	Bosworth	375.3	Bosworth	378.1	2.8	0.8%	0.5%	E
Mo.	Standish	381.1	Carrollton	385.5	5.6	0.8%	0.5%	E
Mo.	W. B. Jct.	388.7	Hardin	404.6	15.9			Paired track with Wabash-AT&SF owns eastward-Wabash westward.
Mo.	Congo	444.2	Sheffield	446.1	1.9			AT&SF owns and operates single track. When traffic requires, AT&SF uses Mo Pac 1st and 2nd main tracks from Sheffield to Congo.
Eastern	Gardner	34.6	Edgerton	39.7	3.1	0.7%	0.4%	E
Eastern	Wellsville	46.4	Le Loup	49.5	3.1	0.75%	0.45%	E
Eastern	Melvern	79.7	Ridgeton	87.6	7.9	0.6%	0.4%	W
N. Mexico	Wootton	650.8	Lynn	653.4	2.6			To carry lines through separate single track Raton Tunnels.
Albuq.	Rio Puerco	33.9	Suwanee	46.6	12.7	1.0%	0.6%	W
Albuq.	Baca	115.9	Thoreau	125.2	9.3	1.0%	0.6%	W
Albuq.	Gonzales	129.3	Ciniza	142.8	13.5	1.0%	0.6%	E
Albuq.	Winslow	288.6	Winslow	290.8	2.2	1.0%	0.6%	W
Albuq.	Moqui	295.1	Dennison	297.4	2.3	1.4%	0.6%	E
Albuq.	Maine	362.6	Maine	364.1	1.5	1.8%	1.42%	E
Albuq.	Maine	365.5	Maine	366.5	1.0	1.85%	1.42%	E
Albuq.	Supai	382.1	Welch	391.7	9.6	2.6%	1.8%	E

Table II

NON-PARALLEL LOCATIONS OF SECOND TRACK
Chicago - Los Angeles (Cont.)

Division	From	M.P.	To	M.P.	Dist.	Grade See Notes (1)	Grade See Notes (2)	Reasons for Non-Parallel Track (See notes E and W)
Albuq.	Pinevita	410.5	Crookton	418.3	7.8	2.8%	1.42%	Reduce westbound grade. Westbound passes under eastbound at Pinevita for right hand running to Victorville.
Albuq.	Pan	425.1	Seligman	426.8	1.7	1.75%	1.42%	E
Ariz.	Chino	432.7	W. Chino	435.9	3.2	1.42%	1.0%	E
Ariz.	Fields	457.5	Nelson	460.2	2.7	1.8%	1.42%	E
Ariz.	Louise	514.1	Griffith	526.8	12.7	1.8%	1.42%	E
Ariz.	Needles	579.1	W. Needles	580.1	1.0			Eliminate central angle of curvature on eastbound track.
Ariz.	Siberia	677.3	Klondike	683.0	5.7	2.30%	1.42%	W
L.Angeles	Victorville	39.3	Thorn	40.8	1.5			Elevate westward track over eastward track for left hand running.
L.Angeles	Summit	57.3	Cajon	63.2	5.9	3.0%	2.2%	E

(1) Grade on original track assigned to current of traffic in descending direction.

(2) Grade on second track assigned to current of traffic in ascending direction.

Where no grades are shown, neither of the tracks are on ruling grades and non-parallel location is due to other factors stated.

E — Reduce westward grade.

W — Reduce eastward grade.

route before it from Isleta on west across the state to the next engine terminal at Gallup and then to the succeeding one at Winslow. The Rio Puerco is crossed at the station of that name, 11 miles west of the junction of Dalies. The Zuni Mountains parallel the railway on the south.

A succession of Indian pueblos follows in the irrigated valley of the San Jose. The "Sky City" of Acoma, which is the oldest continuously inhabited settlement within the United States and antedates its history, is 18 miles south of the railway station of Laguna.

Mt. Taylor, 11,389 feet, in the San Mateo Mountains north of McCartys is the highest peak in the state and a landmark of the trip. The Continental Divide on the Santa Fe at Gonzales is 27.0 miles east of Gallup and as previously stated is at elevation 7,250 feet. It is not, as might be expected, a mountain pass but is in relatively open country with the mountains evident only in the distance.

The westward descent from the Continental Divide lies in the valley of the Rio Puerco of the West which is the same name as the stream crossed at the station of that designation west of Dalies. The railway follows the Rio Puerco for 124.3 miles where it flows into the Little Colorado at Holbrook, Arizona. The Little Colorado River is crossed east of the town of Winslow where it turns north to flow across the Painted Desert to its confluence with the main Colorado at the eastern entrance to the Grand Canyon.

Winslow at an elevation of 4,855 feet is at the eastern base of the great Arizona plateau. The summit of the railway crossing of this immense height of land is at Riordan, 65.0 miles to the west where the elevation is 7,310 feet. This ascent of 2,455 feet entails a westward gradient of 1.42% or 75 feet to the mile.

The most conspicuous point of interest to tourists across this part of the route is Canyon Diabalo, 17 miles west of Winslow, a deeply eroded gorge in the Kaibab limestone. The railway crosses it on a double track steel arch 540 feet long which carries the rails 225 feet above the Canyon floor. This is the third structure over this defile and was completed in 1947.

The little city of Flagstaff with a population of 7,500 in 1940 is the largest community located on the Santa Fe main line across Arizona. Riordan, Arizona, at mile post 350.8 (from Albuquerque) is 7,310 feet above sea level. The Santa Fe crosses the Colorado River at Topock, Arizona, near Needles, California, at mile post 565.9 and elevation 572 feet. A descent of 6,738 feet is thus accomplished in 215 miles. Were this all on a continuous grade, an ascent of only 0.6% would raise the train from Topock to Riordan in that distance.

The difference in elevation between two points divided by the distance between them indicates the "natural" or minimum gradient between them. If a river has cut a valley which can be continuously followed by the railroad track, it is possible to have the actual grade closely approach the natural one. However, when nature does not accommodate the railway locating engineer in this respect, he must follow the general topography which seldom is regular. In practice it will be found that a railway cannot secure a ruling grade that is less than twice the natural grade in rough country without incurring extraordinarily heavy construction costs. It is therefore a tribute to the skill of those who built and rebuilt the Santa Fe to find 1.42% ruling grades and a 1.8% maximum grade across the Arizona divide.

Nature did not accommodate the easy and economical procurement of satisfactory physical characteristics for the Santa Fe's crossing of the Arizona Plateau and unlike the Raton Mountains it covered too great an area to be short-circuited by a new line.

The topography across northwestern Airzona does not permit an even grade but introduces a jagged profile which subdivides the descent between Riordan and Topock into three distinct steps. The route has been described in the westwardly direction of travel, since that facilitates the historical and geographical aspects of the narrative but the principal problem of operation over the Arizona Divide is the long eastward climb from Topock to Riordan. Therefore, attention will be shifted to the west end of this important section of the line in order to begin the description from there and proceed to the summit in the eastwardly direction.

The ruling grade ascending through this long climb is 1.42% except for the ascent on the third step between Ash Fork and Supai where the grade increases to 1.8%.

The summit of each eastward step on this giant railway "staircase" is marked by a short sharp descending grade. The westward trains, conversely, must toil up these minor summits, usually with the assistance of helper engines, until the advent of the Diesel.

The first step is a long continuous climb from Topock to Louise. The descent from Louise for 10.9 miles to a point 1.7 miles west of Walpai entails a drop in elevation of 235 feet. A minor summit is crossed at Antares, 6.2 miles away and a 6 mile descent follows to Hackberry. The second major step begins there and the grade continues unbroken to its summit at Yampai - elevation 5630 and mile post 451.9.

Here descending grades take the line down to elevation 5197 at Audley, mile post 439.8 (distance 12.1 - drop in elevation 433 feet.) Short climbs are required over two summits at Chino (elevation 5395 mile post 432.7) and Crookton (elevation 5741 milepost 418.2). A long descent follows from the latter station to Pineveta before starting the major climb through Ash Fork to the top of the third step at Supai only 3 miles from Williams, the gateway to the Grand Canyon but 189 feet below it on a 1.42% grade.

From Williams to the summit at Riordan is only 27 miles in distance and 553 feet in elevation but the profile is of a saw tooth type and grades are 1.42% ascending and descending in both directions. The ascending steps are shown in Table 3, page 55.

Where the original single track line was built on a grade in either direction that exceeded the present 1.42% ruling grade across western Arizona, the construction of a second track afforded an opportunity to hold the gradient on the new construction to this maximum ascent. Upon completion of the new track, the old one in the original location was assigned to the current of traffic in the descending direction. This general practice has led to the construction of the second track entailing left hand operation between Belen, New Mexico, and a point near Pineveta, Arizona, (10.1 miles west of Ash Fork) a distance of 400.8 miles and on the 27.3 mile ascent from San Bernardino up over the Cajon Pass and also for 14.8 miles down the east slope as far as Thorn, a total distance of 42.1 miles. These two sections of left hand operation total 442.9 miles while the length of line between Thorn and Pineveta operated in the customary manner of the current of traffic being on the right hand track is 370.7 miles.

The climb up the Arizona divide is a trip which is both a laboratory exercise in railway engineering and operation, and a lesson in physical geography and geology. Above all, however, it is a kaleidescopic panorama of untold mountain and desert beauty, finally

TABLE III

ASCENDING THE WESTERN SLOPE OF THE ARIZONA DIVIDE TOPOCK TO RIORDAN

Station Near Base Name	M.P. *	Elev.(ft)	Station Near Summit Name	M.P. *	Elev.(ft)	Distance Between Sta. (Mis.)	Total Ascent (ft)	Total Descent (ft)	Eastward Ruling Grade (%)	Maximum Eastward Descdg. Grade(%)	Westward Ruling Grade(%)	Maximum Westward Descending Grade(%)
						(Major Continuous Ascents)						
Topock	565.0	531	Louise	514.5	3,546	50.4	3015	0	1.42	-	-	1.80
Hackberry	489.2	3586	Yampai	451.7	5,630	37.5	2,044	0	1.42	-	-	1.80
Ash Fork	400.6	5,172	Supai	381.6	6,990	22.3	1,818	0	1.80	-	-	2.60
				Total		110.8	6,877					
						(Intermediate Steps or Minor Ascents)						
Louise	514.5	3,546	Hackberry	489.2	3,586	25.3	364	324	1.35	1.00	1.00	1.35
Yampai	451.7	5,630	Ash Fork	400.6	5,172	48.7	896	1,354	1.42	2.80	1.42	1.80
Supai	381.6	6,990	Riordan	350.8	7,354	30.7	945	581	1.42	1.42	1.42	1.84
					Total	104.7	2,205	2,259				
					Grand Total	215.5	9,082	2,259				

* — From Albuquerque.

ending in the parklike pine forests which crown the upper 1000 feet of the plateau. The territory surrounding the Colorado River is barren desert with less than 10" of rainfall per annum. As the train toils to higher levels the influence of increasing altitudes upon wind currents gradually draws more and more moisture from the billowy clouds which sail the blue sky overhead. This gradually increases the vegetation seen along the route and the transition continues until the 6000 feet level is attained above Ash Fork between the stations of Daze and Corva, where the diminutive pinions give way to lofty pines.

While the line continues at or above this level for 70 miles from Daze, Arizona, to Angell, Arizona, the train passes through unbroken stands of these magnificent trees. The summit at Riordan, 7310 feet is the second highest point reached by the Santa Fe; being exceeded only by the Raton Pass Tunnels above 7,600 feet.

While the passenger is aware of the rapid ascent and descent of the train, depending upon its location and direction, he gains this from the sensations of the locomotive variously exerting its maximum pulling power or resisting the accelerating force of gravity through application of the brakes. The railway tracks generally are in wide expanses of territory flanked by mountains and other immense geological formations, but usually these are miles away and most of the valleys are long and wide. Therefore, when canyons are traversed these are features of special interest to the traveler.

Leaving Topock on the long climb up to the Arizona Divide the railroad runs through the broad expanses of the Sacramento Wash continuously up to Franconia, 13.1 miles, touching the southern end of the Black Mesa near Haviland. This wash, dry for many consecutive years, was turned into a raging torrent in 1938 which destroyed the

the line and lead to the reconstruction of much of this section of the route with resultant improvement in the alignment and protection against a repetition of this disaster in future years.

The first canyon traversed is one on either side of the little city of Kingman. It is the first community passed since leaving Needles that is more than a tiny settlement of railway maintenance employees. The eastward track through Kingman Canyon is built to the standard 1.42% grade. This necessitated a separate location on the east wall of the Canyon generally far above that of the westward descending track on the opposite side which uses the original right-of-way with 6.7 miles of 1.8% descending grade.

The Walpai Valley is crossed between Louise and Antares and Hackberry. This marks the transition between the first and the second steps of the ascent up the Plateau. This second step of continuous ascent passes through a five mile long granite gorge between Hackberry and Valentine and there runs headlong into the Grand Wash Cliffs. The narrow Crozier Canyon, formed by the Truxton Wash, has cut a path for the railway but its tracks are generally on opposite sides of this 6 mile long defile. Crozier Canyon ends at the station of Truxton where the railway enters the 10 mile wide Cherokee Valley and crosses it to Peach Springs. There the valley narrows to canyon-like proportions through Nelson and on up to the summit an Yampai, 14 miles distant. A tunnel 414 feet long was built to carry the second track on the gradient of 1.42%.

Yampai at mile post 451.9 and elevation 5630 is the top of the second step up to the summit of the Arizona Plateau. It is 23.3 miles west of the division point of Seligman which is at elevation 5284. Pinevita at milepost 409.2 and elevation 5147 and Ash Fork at mile post

400.5 and elevation 5172 feet are the bases of the third major step. The distance between Pinevita and Yampai is 40.3 miles and the difference in elevation is 483 feet. The intervening descent is not continuous but is broken by two minor summits, at Chino and Crookton.

The railway lies in the Aubrey Valley from Yampai to Seligman, 23.1 miles. This great open expanse of land is bounded on the east by the Aubrey Cliffs which extend for many miles across the plateau region on both sides of the Grand Canyon. These cliffs are the western edge of the great sheet of Kaibab limestone that caps the Arizona Plateau. The minor summit at Chino at elevation 5395 lies on the heighth of land between the Aubrey Valley and Chino Wash. The railway division point of Seligman is situated at the confluence of these two natural openings.

The crossing of the heighth of land between Mt. Floyd on the north and Picacho Butte on the south requires a climb of 457 feet in 10.9 miles to Crookton at elevation 5741. The ascending grade is on the 1.42% standard in both directions but the original 7.1 miles westward ascent of 587 feet from Pineveta at elevation 5147 on the east slope to this summit, was at the difficult rate of 2.8%. This roadway is now used for eastward trains descending while the second track assigned to westward movement required a length of 9.5 miles to hold the grade to the lesser standard rate of climb (1.42%). The westward track follows a route that diverges from the eastward one and incorporates a great horse shoe curve at an advantageously high elevation which affords a remarkable vista of the great expanse of land spread out to the east and south. The non-parallel location extends all of the way from Crookton to Pineveta. Near the eastern end of the separated lines, the westward track crosses over the eastward one to return from a right hand to a left hand location on the double track right-of-way. This continues on east to Belen, New Mexico.

The third major step lifts the railway on a 1.8% grade up 1818 feet from Ash Fork to Supai. The original route used is now the westward or descending track which extends through Johnson Canyon. One of the Santa Fe's two tunnels in Airzona is located here. It is 397 feet long and is on a 2.10% grade. Johnson Canyon is one of the important sites of scenic interest on the trip. The eastward track, however, must develop additional distance to flatten the grade so is located north of the Canyon. From Supai it is but a short descent of 189 feet within a distance of 3.4 miles to Williams, the well known junction point for the line to the Grand Canyon. The town of Williams is located on the north slope of Bill Williams Mountain, a landmark of the vicinity. From Williams to the summit at Riordan is but a continuation of 1.42% grade up through the increasingly thick masses of lava covering the floor of wide parks or open spaces of pine forests.

The reader's attention is now turned back to the Santa Fe's division point at Needles, California, on the Colorado River which is one of the best known railroad towns in the United States. Its fame is enhanced by being in the midst of one of the most arid districts of the country and also one of the hottest. The railroad at Needles is at an approximate elevation of 475 feet. Barstow is the next division point 165.7 miles to the west and is situated at an elevation of 2101 feet. The route between Barstow and Needles is devoid of population except those few who service the railroad or work in small desert mines.

The route westward from Needles ascends a low mountain crossing at Goffs, 30.9 miles distant and at elevation 2584 feet on the familiar 1.42% grade which is again encountered on the 16.8 mile climb from Cadiz to Ash Hill. Eastward trains ascend to Goffs on a 1% grade. Eastward ruling grades between Barstow and Needles do not exceed 1%.

Barsotw is in the heart of the Mojave Desert. The bed of the Mojave River lies alongside of the Santa Fe tracks between Daggett, 11 miles east of Barstow and Victorville, 36.4 miles west. Daggett is a notable desert station because it is the junction of Union Pacific's "Los Angeles & Salt Lake Railroad" which uses Santa Fe trackage westward for 101 miles through Barstow, across the Cajon Pass to San Bernardino and thence to the western junction with Union Pacific at Riverside.

Barstow is the junction of the Santa Fe's routes to southern and to northern California. Both must cross high mountain ranges which separate the desert country of eastern California from the productive and densely populated area in the western part of the state. The Santa Fe's principal route goes on to Los Angeles, crossing the San Bernardino Range at Cajon Pass; elevation 3823 feet.

Following the Mojave River west from Barstow to Victorville, 40.7 miles, elevation 2718 feet, the ascending grade is 0.6% to Victorville where helpers are attached to assist freight trains with full tonnage rating for the remaining 15 miles up to the summit on a 1.6% grade. The eastward ascent from San Bernardino at 1073 feet to the summit is on a 2.2% grade. As in the case of other second track construction in mountainous territory, the later one, incorporated the lesser grade and so is used in the ascending direction. The track on the original location has 3% grades and so is now assigned to westward descending movements.

At San Bernardino the Santa Fe divides into two routes into Los Angeles. The shorter line, 59.8 miles in length, passes through Azusa and Pasadena. Most of the passenger trains are sent over the

Pasadena line because of the advantage of its shorter distance and the traffic of that important Los Angeles suburb. It has maximum ascending eastward grades of 2.2% between Los Angeles and Pasadena and 1.6% east of the latter station. Maximum westward grades are 1.5%. The route via Fullerton is 72.2 miles long but has 1% maximum grades so is used by through freight trains.

DESCRIPTION OF TRANSCONTINENTAL LINES

B. Barstow to San Francisco Bay

Just as the main line to Los Angeles must cross the mountain wall which separates the desert from the intensively developed and thickly populated lands extending from the foot of these ranges down to the sea-coast, so the line which runs from the important junction of Barstow to San Francisco Bay must surmount a mountain range that obstructs its path to the north.

Barstow is situated at an elevation of 2105 ft. The San Francisco line extends 72 miles westward to Mojave across the deserts of that name which here include the dry beds of prehistoric lakes. These are immense surfaces, flat as a billiard table, which provided natural sites for great air training and experimental bases, particularly around Muroc, 20 miles east of Mojave. The mine which now produces the principal borax supplies of the United States is located at Boron, 38 miles west of Barstow. It is owned by the Pacific Coast Borax Company which developed the original source of this mineral in Death Valley that for so many years was well publicised by the familiar "20 Mule Team" trade mark; emblematic of the means through which borax once began its long trip to market.

The Tehachapi Range separates the Mojave Desert of southern California from the great valley running longitudinally through the center of the state which takes the name of the rivers which occupy it; viz. the San Joaquin in the south and the Sacramento in the north. These valleys are naturally arid but the high Sierra Nevada Mountains form their eastern boundary and store the moisture from the winter snowfalls. This provides water to irrigate this vast area; one of the most productive agricultural districts in the United States. It produces the largest volume of fruits and vegetables of any single region of this country and much of it moves by rail to distant consuming centers.

It will be recalled that the introductory chapter on the history of the Santa Fe stated that the line from Needles through to Mojave had been built originally by the Southern Pacific. This route, in turn, was an extension of the latter's railroad from San Francisco Bay down through the San Joaquin Valley. At the southern or desert base of the pass over the Tehachapi mountains, the Southern Pacific's line divided at the junction called Mojave; one route turning southwest to enter Los Angeles, 102 miles away, and the other going 240 miles east to meet the Santa Fe at Needles. In a memorable trade, the Santa Fe exchanged its mileage between Nogales, Arizona, and Guymas, Mexico, to the Southern Pacific, along with a cash consideration, for this now extremely important main line from Needles to Barstow and Mojave.

The Southern Pacific was entirely without competition in northern California until an independently and locally owned and operated railway called the San Francisco and San Joaquin Valley Railway, was completed in 1897 from Richmond to Bakersfield, in the south end of the San Joaquin Valley. The Santa Fe purchased this in December 1898 and on May 1, 1900, secured trackage rights over the Southern Pacific between Bakersfield and Mojave. This permitted Santa Fe trains to run on to San Francisco Bay. Previously it had only been able to participate in the traffic of northern California through interchange of freight cars with the Southern Pacific at Mojave.

The line between Mojave and Bakersfield is one of the most interesting mountain lines in the United States. While it is of Southern Pacific ownership, since the Santa Fe runs its trains over this line, its operating characteristics are as important to a study of the Santa Fe's transcontinental services as though it owned the lines itself. The line from Barstow to

Bakersfield, 141 miles, is operated as one engine district. It lies in the Mojave desert between Barstow and Mojave, 72 miles, and there has ruling grades of 0.7% in each direction. The ascent from Mojave to Tehachapi is just 18.3 miles but requires a climb of 1288 ft. on a 2.2% helper grade. The line is in open country with the relatively smooth slope of the mountain providing a natural pathway for easy construction of a double track road that is free of excessive curvature, either in radius or total central angle. However, the 35.4 mile descent from the summit of Tehachapi Pass at elevation 4025 ft. to the base beyond Bena at elevation 2839 ft. is located on precipitous mountain sides which necessitated the construction of a number of tunnels to provide a foothold for the line. The famous Tehachapi Loop was built on this part of the route in order to develop the additional distance necessary to hold the grade to the 2.2% maximum. From Bena the 1.5% eastbound and 1.3% westbound grade continues 13 miles to Kern Jct. but on a double track line free of sharp curvature.

From Bakersfield at elevation 538 ft. water level grades and very light curvature characterize the entire line down the San Joaquin Valley. Estuaries bring the salt water of San Francisco Bay inland to the fabulously fertile delta of the Sacramento River. The Santa Fe crosses this delta on a series of fills and trestles carrying a line which is advantageously located to secure the routing of much of the produce which is grown in it. The mountains of the Coast Range extend to the edge of San Pablo and Suisun Bays and allow room for but one railroad system along the shore. The Southern Pacific preempted this more advantageous location. The builders of the San Francisco and San Joaquin Valley Line were therefore forced to find an interior route through the coast range which necessitated the construction of the single long tunnel found on the Santa Fe System, the 5596 ft. bore at Glen Frazier. A long steel viaduct at its eastern outlet is also used to carry the line across the valley at Muir where the oil refineries at Martinez on Suisun Bay and the Southern Pacific Bridge over the Straights of Carquinez can be seen in the distance.

The section between Maltby and Herpoco (named for the nearby plant of Hercules Power Company) introduces a 325 ft. summit with grades of 1%. The Santa Fe parallels the main line of the Southern Pacific over the last 30 miles of the Valley Division into Oakland, but occupies an interior location which is inaccessible to most of the industries in that area. However, the Santa Fe owns the extensive tide lands between Richmond and Oakland which can ultimately correct this traffic disadvantage and place it on a parity with its traditional rival, the Southern Pacific, in this important area.

DESCRIPTION OF TRANSCONTINENTAL LINES

C. Ellinor and Newton, Kansas, to Dalies, New Mexico

Via Transcontinental Short Line
or Southern District

Wichita's stragetic location on the Arkansas River assured its commercial importance and growth of population. It was a natural focal point to which railway mileage was built and became the second railway center of the state; Kansas City, Mo.-Kan. being first. Wichita's economic importance is reinforced by the natural wealth of the rich areas surrounding it where grain, live stock and natural gas and petroleum are produced in abundance. The processing of these has made Wichita an important manufacturing center and recently its activities in this respect have been broadened by diversified manufacturing, particularly of aircraft, unrelated to these basic Kansas commodities.

The original Santa Fe main line across Kansas first touched the Arkansas river at Hutchinson and so passed north of Wichita but a 27-mile branch south from Newton brought the Santa Fe into that city in the same year: 1872. This entrance into Wichita sowed the first seeds of the subsequent development of two long extensions of the Santa Fe, both through Oklahoma and Texas; one heading south to the Gulf and the other southwest across the Panhandle and on to a connection in the far away Rio Grande Valley with the main line to California.

Wichita was the Santa Fe's southern terminus for seven years but in 1879 its lines were extended down the east bank of the Arkansas River valley to Mulvane (15.6 miles) and Arkansas City (41 miles). Another branch was built from Mulvane across the Arkansas River at Belle Plaine and on to Wellington (16 miles). Mulvane became an important junction and Arkansas City and Wellington are of particular importance because the former is the Santa Fe gateway to its Gulf, Colorado and Santa Fe Railway* to Oklahoma City, Fort Worth, Houston and Galveston, while the latter is the point from which the Transcontinental Short Line was developed westwardly first via the Panhandle and Santa Fe Railway across the Texas Panhandle to Amarillo, thence to Clovis and finally on to Belen and Dalies on the main line to California. The last segment of the new route was opened in 1908.

The "Transcontinental Short Line," or "Southern District" of the western lines as it is usually termed includes all this mileage used by Santa Fe freight or passenger trains running from Ellinor or Wichita, Kansas, via Amarillo to Belen and Dalies. The mileage between Ellinor or Newton and Wellington is part of the Middle Division which in turn is a component of the Eastern Lines, under the jurisdiction of a General Manager at Topeka.

When the Southern District is referred to in this report, it relates to the main line of the Panhandle Division from Wellington to Waynoka 106.6 miles; Plains Division, 309.2 miles from Waynoka through Amarillo to Clovis; and the Pecos Division which extends over the remaining 239.8 miles to Belen, N. Mex. This totals 655.6 route miles under the jurisdiction of the Southern District of the Western Lines. The headquarters of the General Manager of the Western Lines and the Assistant General Manager in direct charge of its Southern District are both located in Amarillo.

The mileages run by Transcontinental Freight and Passenger Trains via the "Southern District" from the eastern junctions at Ellinor and Wichita to the western one at Dalies are shown on the next page (subject to modifications explained in the chapter on transcontinental distances.)

* G.C.&.S.F. ownership begins at Purcell, Oklahoma, 33 miles south of Oklahoma City and extends south ~~to~~ Ft. Worth, Houston and Galveston.

ROUTE FOR FREIGHT TRAINS

Ellinor - Wellington	99.9* miles
Wellington - Belen	655.6
Belen - Dalies	10.3**
Ellinor to Dalies	765.8

ROUTE VIA PASSENGER LINE

Ellinor - Newton	59.7* miles
Newton - Wichita	27.2*
Wichita - Wellington	34.1*
Ellinor to Wellington	121.0*
Wellington - Belen	655.6
Belen - Dalies	10.3**
Total:	786.9 miles

At the outset all freight and passenger trains going south along the routes of the Gulf, Colorado and Santa Fe to Arkansas City, Fort Worth and Galveston and west to the Taxas Panhandle, and on to what is now the Transcontinental Short Line, branched off the main line at Newton and came down to Wichita. The mass of the Santa Fe mileage in eastern Kansas permitted a detour to be developed to allow freight trains to pass around Wichita and avoid the delay of running through this congested railway center. The freight trains left the main line at Florence, Kansas, and came down to Eldorado, 31.1 miles, from Florence. In 1924, this main line junction was moved east to the station of Ellinor, Kansas, 13.3 miles east of Emporia, through construction of mileage required to supplement

* - On Middle Division of Eastern Lines.
** - On Albuquerque Division of Coast Lines.

existing trackage and provide a continuous line to Eldorado. The original detour around Wichita continued from Eldorado on through Augusta, 11.3 miles, to Mulvane, 21.2 miles. Mulvane was mentioned in a previous paragraph as the point where lines from Wichita, Wellington and Arkansas City converge. The passenger line from Newton via Wichita and the freight route from Ellinor, via Eldorado, meet at Mulvane.

Freight trains operating between the main line of the Santa Fe and its two Texas subsidiaries, the Gulf, Colorado and Santa Fe to south Texas ans the Panhandle and Santa Fe, which forms part of the Transcontinental Short Line to the west, use the same route for 60.2 miles from Ellinor through Eldorado to Augusta, Kansas. The latter station is 21 miles due east of Wichita on the St. Louis San Francisco Railway but the Santa Fe has no direct line between those two points. Augusta is the junction of the Santa Fe's lines to Arkansas City and to Mulvane; the former being on the main line to south Texas and the latter on the route to Amarillo, Belen and Los Angeles.

From Augusta the route of the Transcontinental freight trains continues southwest for 21.2 miles to Mulvane where it crosses and connects with the line coming south from Wichita to Arkansas City which is used by Santa Fe passenger trains to south Texas or to Los Angeles via Amarillo running through Newton as the main line junction. The trains between Chicago and Kansas City and Oklahoma City, Houston and Galveston join (northward) or leave (southward) the route used by the two daily transcontinental trains, in each direction, running via the Southern District at this station of Mulvane. From Mulvane it is but 18.5 miles further in a southwesternly direction to Wellington which is the connection with the Panhandle Division where the Southern District begins. This line between Mulvane and Wellington is the first mileage traversed since leaving

Ellinor that is used by both the freight and the passenger trains running between California and Kansas City.

It will be recalled that the primary purpose of the construction of this alternate route, originally known as the Transcontinental Short Line, and now generally referred to as the Southern District, was to serve as the Santa Fe Railway's equivalent of the Cimarron Cutoff of the Santa Fe trail, built to avoid the Raton Mountains. This railway route did even more: it obviated the crossing of the Glorietta Mountains and provides an 0.6% ruling grade in both directions except for 20 miles of 1% grade ascending westward out of the Cimarron river valley beyond Waynoka to Curtis and 40 miles of 1.2% grade eastward from the Rio Grande River to the crossing of the Manzano Mountains at Mountainair. This is the last range seen on an eastward journey and the first range met on a westward one, but the westward ascent of its east slope is made on the standard 0.6% grade.

The line of the Southern District or Transcontinental Short Line across Kansas, Oklahoma and Texas is devoid of outstanding physical features, a fact which may lead to some monotony of scenery but greatly facilitates railway construction, operation and maintenance. Those in charge of running railways will willingly exchange plains for mountains even though the latter have greater attraction for tourists. The territory traversed is generally flat except where erosion has produced some areas that appear rough and broken but only in relation to the remarkably level country that stretches out elsewhere to the horizon, particularly in the Texas Panhandle where the train runs for miles across lands that appear to be as smooth as a billiard table.

Rivers are the principal points of geographical interest along this section of the trip. The Arkansas is crossed between Mulvane and

Belle Plaine. A tributary, Salt Creek, is spanned at Alva, Okla., and the Cimarron, west of Waynoka. The new timber bridge under construction there is mentioned in the chapter on that subject. The Canadian River Bridge is at the Texas town of that name, 97.9 miles east of Amarillo. Two rivers, the Pecos and the Rio Grande, which are closely associated with the west are crossed in eastern and central New Mexico, respectively, near the stations of Fort Sumner and Belen. The latter marks the division point between the Southern District of the Western Lines and the Coast Lines.

Between Pampa, Texas, and Amarillo, 54 miles, the line passes through one of the greatest oil and gas fields of the world as well as one of its most prodigiously productive areas for growing wheat. Both of these aggregate millions of acres in extent. They determine the economic life of the area and the economic development of Amarillo and its vicinity is characterized by evidences of the industries related to storing and milling grain and processing natural gas and petroleum. The otherwise clear skies in this country are blackened in the distance by great plumes of smoke, miles in length, representing the unburned waste of carbon black plants.

The 100th meridian which was referred to in the description of the line across Kansas as being the geographical location of "where the west begins" appropriately forms the boundary line between the Texas Panhandle and Oklahoma. However, the familiar arid aspect of the appearance of the country which one associates with the west, is not observed until after the train passes into New Mexico. Fields of grain continue a short distance west of Clovis but beyond there the land can be used only for grazing unless water is brought onto it through irrigation as it is in the valley of the Pecos River at Fort Sumner.

The 240 mile run across New Mexico from Clovis to the Rio Grande Valley is subdivided into two crew districts with Vaughn being the midpoint and a terminal. The Santa Fe crosses over the Southern Pacific's Golden State Route there. This is the last time another Class I railroad will be seen until the Union Pacific comes on to Santa Fe trackage at Daggett, Calif., 832 miles away.

The line is generally rising all the way west; broken only by descents into the several river valleys crossed. As previously stated, however, the country accommodated railway construction so ruling grades are held to 0.6% in both directions, with the two exceptions noted. There is a long climb from Ft. Sumner at M. P. 716.8 elevation 4062 ft. up to the pass through the Manzano Mountain at Mountainair, N. Mex.; elevation 6491 ft., M.P. 855.7, representing an ascent of 2429 feet in 138.9 miles. The line then descends 1697 feet in 40.8 miles to reach the banks of the Rio Grande which is crossed a mile east of the station at Belen. The route on the west side of the Monzano mountains follows the tortuous canyon of Abo Creek. The term canyon, however, should be qualified to state that while it is narrow and several hundred feet deep in places, it is by no means a spectacular defile. When the traveler looks north up the picturesque Rio Grande Valley, the Sandia Mountain on the east side of the river and opposite Albuquerque, 30 miles away, is the most conspicuous object in view.

DESCRIPTION OF TRANSCONTINENTAL LINES

D. Kansas City to Chicago

The original Santa Fe freight and passenger terminals in Kansas City, Mo., were located on the west side of the city. When the Santa Fe decided in 1886 and '87 to extend its line east to Chicago, the bottom lands between the meandering Missouri River and the bluffs on which Kansas City is located had already been preempted by other railroads. Santa Fe, therefore, procured trackage rights over its affiliated Kansas City Belt Railway*, a predecessor of the present Kansas City Terminal Railway Company, which provided a very direct eastern outlet across Kansas City, south of its business district. These trackage rights were used for 1.4 miles from a junction with the Santa Fe's lines in Kansas City, to the site of the present Union Station and thence for 4.7 miles to Sheffield, an important junction point with routes of several railways diverging to the north, east and south. The route between Kansas City Union Station and Sheffield contains 0.95% eastward and 0.8% westward grades. The former required helper engines to be used on tonnage trains hauled by steam locomotives.

From Sheffield to Congo, 2.2 miles, the Santa Fe is a single track line that lies immediately south of the group of railway tracks of other ownership which it parallels. The Santa Fe's track climbs the side of

* - The Kansas City Belt Railway was incorporated in 1882 to build a line from connections with the AT&SF and Kansas City, Ft. Scott and Memphis Railways (now part of the Frisco) near the Union Stock Yards in Kansas City, Kansas, for 7 miles due east to Big Blue Junction on the opposite boundary of the city to junctions with lines diverging to the east from there. In 1886-87 the Santa Fe owned 50% of the capital stock of this company and the Kansas City, Ft. Scott and Memphis and the Kansas City Union Stock Yard Company held the balance of it. The Kansas City Belt Railway was subsequently made the basis of the present Kansas City Terminal Railway which is jointly owned by all of the line haul carriers entering Kansas City.

the bluff to gain elevation to cross over these other lines on a bridge which provides a fine view of the Rock Creek Junction, the eastern end of the Kansas City Terminal Railway.

The junction known as Congo lies at the base of the descent from this bridge. There connections are established between Santa Fe and Missouri Pacific. The latter's trains run over the Santa Fe for 7.7 miles east to Eaton as a short link in the Missouri Pacific's river route via Booneville to Jefferson City and St. Louis; used principally by freight trains as a low grade line in preference to the more direct passenger route through Jefferson City and via Sedalia. The Santa Fe also uses Missouri Pacific trackage for one mile between Congo and the connection with the Kansas City Terminal Railway at Rock Creek Junction. This permits freight trains to avoid the Santa Fe's own "high line" with its 0.8% eastward and 0.6% westward grades and also avoids detentions that might be caused awaiting opposing movements to clear this single track line.

The Santa Fe clings to the south bank of the Missouri River from Congo to Sibley, 17.5 miles and passes two notable industries immediately east of Congo; the refinery of the Standard Oil Company of Indiana at Sugar Creek and the Missouri Portland Cement Company at Courtney.

The Wabash Railroad follows the north shore of the Missouri River, east from North Kansas City and parallels the Santa Fe for 29.5 miles from CA Junction, which is 8.5 miles east of Sibley, and 1.3 miles west of Camden, Missouri, to WB Junction which, in turn, is 2.3 miles west of Carrollton, Missouri. Between CA Junction and Hardin, Missouri, 12.8 miles, the Santa Fe double track is used by the Wabash. The latter's main track between those common points is on a circuitous alignment so is used by both roads only as a long siding for meeting and passing trains.

Between Hardin, Missouri and WB Junction, 16.7 miles, the Wabash and Santa Fe operate paired double track lines. The Santa Fe track is assigned to the westward current of traffic and the Wabash provides the eastward track.

The Santa Fe's route across Missouri leaves the river valley east of Carrollton and traverses rolling country which introduces considerable rise and fall and necessitates the utilization of 0.8% ruling grades across the "First District" between Marceline, the division headquarters, and Shopton, Iowa, near Fort Madison. This is the only deviation from the 0.6% ruling grades which otherwise is the standard east and west between Winslow, Ariz. and Chicago; via the "Southern District" through Amarillo (with 1.25% helper grades eastward between Belen and Mountainair and 1% westward from Waynoka to Curtis).

No cities are located on the Santa Fe line across Missouri. The Des Moines River has cut a wide and deep valley in the land to form the northeastern tip of the state, 200 miles from Kansas City. The important division terminal of Shopton, Iowa, near Fort Madison, is 15 miles further east on the shores of the Mississippi river.

The Illinois Division which extends from Shopton, Iowa, through Ft. Madison and across the river to east Ft. Madison and thence for 231 miles to Chicago is built to 0.6% ruling grades in both directions except for a 1% grade ascending the eight mile Edelstein Hill westward out of the Illinois River bottoms at Chillicothe, Ill. Chillicothe is the headquarters of the Illinois Division and an important yard and engine terminal is located here. The line crosses the Illinois river on a long double track viaduct east of the station.

As the train moves east the frequency of stations seen along the line increases together with the population of the countryside. Railway crossings both at grade and with separated grades, become increasingly numerous.

The Santa Fe and the GM&O (Alton) operate a paired double track line* for 16.2 miles between Pequot and Plaines; the latter station being 3.5 miles west of Joliet. The latter, in turn, is 38 miles west of Chicago and is the junction with the important Elgin, Joliet and Eastern Railway, the "outer belt line," which marks this station as the beginning of the Chicago Terminal District.

The Santa Fe follows the Chicago Drainage Canal and the Illinois-Michigan canals into Chicago, crossing over them on swing bridges to follow the north bank of these waterways between Lemont (Chicago 25.1 miles) and Nerska (Chicago 7.2 miles). At McCook, 13 miles west of Chicago, two important outer belt lines, the Indiana Harbor Belt and the Baltimore and Ohio Chicago Terminal are crossed which make this one of the Santa Fe's most important interchange points within the Chicago Terminal District.

Corwith Yard is the Chicago terminal of Santa Fe's freight train operations. Curiously enough, Corwith Yard is located at right angles to the Santa Fe main line, rather than parallel to it. This fact is traceable to its purchase from the Grand Trunk Western at the time the Santa Fe first entered Chicago in 1888 and bought the former's properties which were not required after the Grand Trunk began to use the Chicago & Western Indiana Railroad to provide passenger terminal facilities. The Grand Trunk tracks acquired by the Santa Fe included not only the Corwith Yard but all of the lines now comprising the Illinois Northern, except the latter's tracks east of Western Avenue, Chicago. The Santa Fe leased to

* - Santa Fe track lies to the north of the one of Alton ownership so the former is used in the westward and the latter in the eastward direction.

the Illinois Northern**—all of those tracks which had been acquired from the Grand Trunk that lay north of the AT&SF's own line. The Illinois Northern Railway crosses the Santa Fe at the east end of Corwith Yard.

The 6 miles of line between Corwith and Dearborn Station, Chicago, is one continuous succession of railroad crossings and junctions. The first one reached, 1.5 miles east of Corwith, is the intersection with the Pennsylvania's Panhandle Route, Baltimore & Ohio Chicago Terminal Railroad and the Chicago River and Indiana (New York Central affiliate), all double track lines, making this a six track crossing. Unfortunately, it is not protected by an interlocking plant and so requires a safety stop.

Track connections are made here with the Chicago Produce Terminal, jointly owned by the Santa Fe and the Illinois Central, which is located immediately east of this crossing. Its broad expanse of team tracks are designed to facilitate inspection and unloading of perishable products arriving for sale or delivery in Chicago over all railroads.

At the west end of this Produce Terminal, the Illinois Central's western lines come in from a northwestwardly direction to connect with the Santa Fe and the Gulf, Mobile and Ohio (Alton Route) merged with it from the southwest to cross the south branch of the Chicago River on a common double track bascule bridge, 1.5 miles east of the Panhandle crossing.

Over the mile and a half of distance between this bridge and 22nd Street, Chicago, where the Santa Fe's ownership of track ends, the Gulf, Mobile and Ohio (Alton Route), the Illinois Central and the Santa Fe have parallel double track lines in that order of location from the north.

** - Illinois Northern Railway is now owned and operated by the International Harvester Corporation. However, recent notices in the press refer to the possibility of negotiations being in progress for its sale to the Santa Fe and the Burlington.

At 22nd Street, the Alton swings north to join the Pennsylvania, entering Chicago from the east. The Pennsylvania intersects the Santa Fe at 22nd St. and both of these railroads cross the main line of the Chicago & Western Indiana Railroad which while paralleling the Pennsylvania south of 22nd Street, makes a 60° curve to the east at that point to head towards Dearborn Station. The Santa Fe connection and the Illinois Central - Western Lines - crossing is included in the maze of frogs, switches and tracks that makes 22nd Street the busiest railway grade crossing and junction in the United States.

The last 1.3 miles into Dearborn Station utilizes trackage rights over the owner of that depot, the Chicago & Western Indiana Railroad. Santa Fe occupies its property as a tenant between 22nd Street and Polk Street, the terminus of the line. The Santa Fe's large Chicago coach yard lies in the triangle between the Chicago & Western Indiana and the Pennsylvania Railroad at 22nd Street. In addition to this facility, team tracks, a Diesel locomotive shop and miscellaneous passenger car servicing buildings and a new car and locomotive washer are among the important Santa Fe adjuncts to its Chicago Terminal operations which are seen at this point.

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This description of the Santa Fe Transcontinental Lines has necessarily been brief and is largely confined to the physical and geographic features of the railroad that are necessary to provide a background for the subsequent chapters. No attempt has been made to mention details of trackage and facilities along the line in this section. To do so in systematic order and with completeness, would be a thesis in itself. For the same reason, little attention could be given to cities and towns and traffic sources along the route. This interesting subject is fully and entertainingly covered by Santa Fe advertising publications, notably its travel brochure "Along the Way."

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Grade characteristics of the transcontinental route from Chicago to Los Angeles via the Southern District are summarized in Table IV.

TABLE IV

THE ATCHISON, TOPEKA & SANTA FE RAILWAY

Summary of Grade Characteristics

Chicago - Los Angeles

Via Ottawa Cutoff; Eldorado, Kans.; Belen, N. M.; Fullerton, Calif.

Condensed Profile and physical characteristics DES 30168 Sheets 1, 2, 3.

DIVISION	Distance Via Westward Track: Mileage	Terminals	Ruling Grades: East	Ruling Grades: West	Helper Districts (See Note): Max. Ascend. Grade	Length	Direction	Limits	Miles Ascending Grade 1 - 2%: EB	1 - 2%: WB	Over 2%: EB	Over 2%: WB	Ascent: EB	Ascent: WB
		Chicago-Chillicothe	0.5%	0.5%										
Illinois	231.84	[illegible]						Chillicothe-						
		Chillicothe-Ft.Madison	0.6%	0.6%	1.1%	8 Mi.	WB	Edelstein						
	218.28	Ft. Madison-						Rothville-						
Missouri		Marceline	0.8%	0.8%	0.8%	7.30	EB	Marceline					3960	4101
		Marceline-			0.8%W			Sheffield-						
		Kansas City	0.6%	0.5%	0.9%E	6.10	EB WB	Kansas City						
Eastern	115.59	Kansas City-Emporia	0.4%	0.6%									660	1039
Middle	107.66	Emporia-Wellington	0.4%	0.6%									772	868
Panhandle	105.51	Wellington-Waynoka	0.6%	0.6%									819	1061
		Waynoka-						Waynoka-						
Plains	310.53	Clovis			1.0%	21.6	WB	Curtis, Okla.		8.07			1603	4392
			0.6%*	0.6%	0.6%	17.8	EB	Canadian-						
								Coburn						
Pecos	240.23	Clovis-Belen	0.6%	0.6%	1.2%	40.8	EB	Becker(Belen)-Mountainair	16.4				2846	3384
		Belen-						Belen-						
Albuquerque	413.19	Winslow	0.6%	0.6%**	1.25%	10.3	WB	Dalies	10.3					
		Winslow-						Ashfork-						
		Seligman	1.42%	1.42%	1.8%	22.9	EB	Supai	34.0	45.6			5188	6046
		Seligman-						Seligman-						
Arizona	317.33	Needles	1.42%	1.0%	1.42%	23.1	WB	Yampai						
		Needles-Barstow	1.0%	1.0%	1.42%	31.1	WB	Needles-Goffs						
					1.42%	38.6	WB	Cadiz-Ash Hill	89.3	65.8			9218	6176
Los Angeles	152.03	Barstow-San Berd.	0.6%	0.7%	2.20%	27.3	EB	San Berd.-Summit						
		San Berd.-						Victorville-						
		Los Angeles	1.0%	0.7%	1.60%	19.2	WB	Summit	16.6	13.8	17.3		4038	2215
								Total Ascent — Chicago - Los Angeles					29104	29282

* 0.4% eastbound Amarillo-Canadian; 97.9 miles.

** 0.5% westbound Gallup - Winslow; 127.2 miles.

Note: Helper districts related to steam operation. Diesel operation between Chicago and Kansas City and west of Belen obviates all helpers except over Cajon Mountain between San Bernardino and Summit and Victorville and Summit and eastward from Ash Fork to Supai.

Chapter IV

TRANSCONTINENTAL DISTANCES

The through freight and the fastest passenger trains do not use the same route throughout the run between Los Angeles and Chicago. The lines which are used in common and the others used separately are shown below:

Chicago - Los Angeles Transcontinental Trains

Limits of Run	Routes Used By: All Trains Via	Through Freight Via	Principal Passenger Trains Via
	(Eastward (E) and Westward (W) mileages are shown in figures below each route.)		
Chicago, Ill. to Ellinor, Kans.		Ft.Madison, Ia. Kansas City Olathe, Kan. (See Note A) W - 574.81 Mi. E - 575.22 Mi	Ft.Madison, Ia. Kansas City Olathe, Kan. (See Note A) W - 574.81 Mi. E - 575.22 Mi.
Ellinor, Kans. to Dalies, N.M.		Eldorado, Kan. Augusta, Kan. Wellington, Kan. Waynoka, Okla. Amarillo, Tex. Belen, N. M. (See Note B) W - 765.34 Mi. E - 764.60 Mi.	Hutchinson, Kan. Dodge City, Kan. La Junta, Colo. Albuquerque, N.M. Isleta, N.M. W & E - 789.37 Mi.
Dalies, N.M. to San Bernardino, Calif.	Winslow, Ariz. Barstow, Calif. W - 800.57 Mi. E - 802.73 Mi.		
San Bernardino, Calif. to Los Angeles, Calif.		Colton Fullerton W & E - 71.35 Mi.	Pasadena W & E - 59.54

Notes A. and B. The present principal direct lines between Holliday, Kan. (13.1 miles west of Kansas City) and Emporia, Kansas, and between Ellinor, Kansas (13.1 miles west of Emporia) and Mulvane, Kansas, are via cutoffs built to reduce the mileage and grades on the original routes respectively through Topeka, the capital of the State and its third largest center of population and through Wichita, the second center of population in Kansas.

Notes A. and B. (continued)

(A) All passenger trains operate via Topeka except the Transcontinental and Texas streamliners and the Fast Mail Express Trains 7 and 8 which use the "Ottawa Cutoff."

Use of the "Ottawa Cutoff"reduces the distance between Kansas City and Emporia by 15.0 miles and lowers the ruling grade in both directions from 1% to 0.4%.

Comparison of route between Holliday, Kan.* and "N R Tower" ** Emporia

Passenger route Via Topeka	Freight Route (also used by Transcontinental and Texas Streamliners and Fast Mail Express Trains 7 and 8, via Ottawa Cutoff, through Olathe)
112.8 miles	97.8 miles

* 13.1 west of Kansas City

** 1.1 mile east of Emporia

(B) No through passenger trains are run over the freight line between Ellinor and Augusta and Mulvane. All passenger trains between Chicago, Kansas City, Oklahoma City and Texas and the two (out of seven) transcontinental trains, the "Scout" and the "Grand Canyon" (#1-2 and #23-24, respectively) which run via Amarillo and Belen, go from Ellinor to Newton and then via Wichita to Mulvane, the junction of the lines to Ft. Worth and Galveston and to Amarillo and Belen. West Junction, 1.5 miles west of Mulvane on the route to Amarillo, is the connection with the freight cutoff from Ellinor.

Comparison of route between Ellinor,* Kansas and West Junction, Mulvane,** Kansas

Passenger route via Wichita	Freight Route, Via Bazar, Eldorado and Augusta
102.5 miles	81.5 WB 81.0 EB

The freight line is 21.0 miles shorter westbound and 21.5 miles shorter eastbound (on account of using Mulvane District on eastbound movements), and provides more favorable ruling grades than on the route through Wichita and Newton.

* 13.3 miles west of Emporia

** 15.6 miles south of Wichita

On those sections of the line where all transcontinental trains use the same route, there is a continuous double track.* Where there are separate routes, single track prevails on each except over Ottawa Cutoff in eastern Kansas which has two tracks throughout its entire length of 97 miles.

It has been explained that the construction of a second track frequently offers opportunities to obtain an improved profile and alignment and to make minor reductions in distance. In some cases the old line and/or grade have been entirely abandoned in the double tracking. In other instances, sections of the original single track line which are laid on grades in excess of the "ruling grade" used as standard for the current and future development of the railroad, were continued in service but assigned to the current of traffic in the descending direction. When a grade reduction is made which necessitates lengthening the line of the new track, in relation to an existing one that will be continued in use for trains in the descending direction of movement, a non-parallel location of the new second track is required in order to obtain the additional length needed to lessen its rate of ascent. Each of the non-parallel locations of the Santa Fe's two track lines have been listed in table 2 on pages 49-50. These produce a slight difference in directional mileages over all divisions where they occur.

* - Except to the extent that the gauntlet bridge over the Missouri River at Sibley, Mo., and the 2.2 miles of single track between Congo and Sheffield, 5 miles east of Kansas City, constitute a partial exception. However, in the latter instance, the Santa Fe runs any train which might be delayed by an opposing movement over the parallel double track line of the Missouri Pacific over which it has trackage rights for that purpose.

Since the non-parallel location of two tracks usually result from reductions in grades, they occur more frequently in the mountainous areas than on the double track routes across other less difficult terrain east of Colorado and New Mexico.

Paired double track lines, i.e. created by operating adjacent single track lines, usually of separate ownership, as a two track railroad for the trains of both companies also provide non-parallel location of the tracks through all or part of the route. On its transcontinental routes, Santa Fe operates a paired double track with the Wabash between Camden and Carrollton, Mo. (29.5 miles), and with the Alton Route of the Gulf, Mobile & Ohio Railroad for 16.2 miles between Pequot and Plaines, Ill. (3.5 miles west of Joliet). The use of the Missouri Pacific for 2.2 miles between Congo and Sheffield which has been previously mentioned constitutes trackage rights for the second track rather than a paired track arrangement because it is not a reciprocal one; i.e. Missouri Pacific does not have similar use of the Santa Fe.

It follows that the distance between Los Angeles and Chicago varies somewhat not only between the several lines but is also affected by the direction of movement. The mileage between Los Angeles and Chicago cannot be accurately stated by a single figure but requires tables of distances to be used. Tables V and VI which follow together show total mileages via the several principal combinations of routes and also separate these into divisional components.

TABLE V

DISTANCES

Chicago - Los Angeles

Via various combinations of routes used by through freight and passenger trains

Route (Note 1)	Distance via Eastward Track on Two Track Lines	Distance via Westward Track on Two Track Lines	Used by (Note 2)
Ottawa Cutoff-LaJunta-Pasadena	2226.86	2224.29	#8-17-18-19-20-21-22
Ottawa Cutoff-LaJunta-Fullerton	2238.67	2236.10	#7
Topeka-LaJunta-Pasadena	2241.86	2239.29	#3-4
Topeka-Newton-Wichita-Belen Fullerton	2250.40	2247.87	#23
Topeka-Newton-Wichita-Belen Pasadena	2238.59	2236.06	#1-2-24
Ottawa Cutoff-Eldorado-Belen Fullerton	2213.90	2211.87	Freight trains (Note 3)

Note 1: There are other possible combinations of the several routes than those shown herein but these are omitted since they are not used by established through freight or passenger services.

Note 2:

Train Numbers	Train Names
1-2	"The Scout"
3-4	"California Limited"
7-8	"Fast Mail Express"
17-18	"Super Chief"
19-20	"Chief"
21-22	"El Capitan"
23-24	"Grand Canyon"

Note 3. Mileages shown use Dearborn Station, Chicago, and Los Angeles Union Passenger Station as terminals in computing distances. Freight trains, however, operate in and out of Hobart Yard, Los Angeles, 6.6 miles east of the passenger terminal and to and from Corwith Yard, 5.9 mi. west of Dearborn Station, Chicago. This shortens the freight train distance 12.5 miles below that reported. The adjusted transcontinental freight mileage betwen Hobart Yard, Los Angeles and Corwith Yard, Chicago, is 2201.40 mi. eastbound while westbound it is 2199.37.

TABLE VI

TABLE OF DISTANCES

Chicago - Los Angeles

Subdivided to show mileage:

1. Over each component division
2. Via separate routes between Ellinor, Kans. and Belen, N.Mex. and between San Bernardino and Los Angeles.
3. Via eastward and westward tracks over two track lines
4. In year 1948 compared with 1935, indicating reduction due to line changes.

The transcontinental mileages are subdivided in the supplementary table which follows in order to report the distances between the division points over each of the major components of the several routes and also to record these data for both the years 1935 and 1948 in order to show the reduction, if any, which followed recent line and grade changes.

			DISTANCE VIA		ADDITIONAL MAIN TRACK		
Division	Between	Year	Westbound Track	Eastbound Track	3rd	4th	
Illinois	Chicago	1935	231.98	231.99	.64	.64	
	Ft.Madison	1948	231.84	231.86	.61	.58	
Missouri	Ft.Madison	1935	218.82	218.96	14.77		
	Kansas City	1948	218.28	218.43	19.11	4.97	
Eastern	Kansas City	1935	115.62	115.84	16.34	9.16	
	Emporia	1948	115.59	115.83	17.12	9.91	
Middle	Emporia	1935	9.10	9.10	9.15		
	Ellinor	1948	9.10	9.10	9.15		
Total	Chicago	1935	575.52	575.89	40.90	9.80	
	Ellinor	1948	574.81	575.22	45.99	15.46	
VIA NORTHERN DISTRICT							
Middle	Ellinor	1935	63.12	63.12			
	Newton	1948	63.11	63.11			
Western	Newton	1935	152.18	152.18	1.68		
	Dodge City	1948	152.16	152.16	1.68		
Colorado	Dodge City	1935	202.28	202.28			
	La Junta	1948	202.91	202.91			
New Mexico	La Junta	1935	357.97	357.97			
	Isleta	1948	357.06	357.06			
Albuquerque	Isleta	1935	14.72	14.72			
	Dalies	1948	14.13	14.13			
Total	Ellinor	1935	790.27	790.27	1.68		
	Dalies	1948	789.37	789.37	1.68		
VIA SOUTHERN DISTRICT							
Middle	Ellinor	1935	98.62	98.05 *			(* Via Mulvane Dist.
	Wellington	1948	98.56	98.07 *			(Normally used for (E.B. Movements)
Panhandle	Wellington	1935	105.52	105.52			
	Waynoka	1948	105.51	105.51			
Plains	Waynoka	1935	311.03	311.03			
	Clovis	1948	310.53	310.53			
Pecos	Clovis	1935	240.49	240.49			
	Belen	1948	240.23	240.23			

(Continued on Page 87)

	Division	Between	Year	DISTANCE VIA Westbound Track	DISTANCE VIA Eastbound Track	ADDITIONAL MAIN TRACK 3rd	ADDITIONAL MAIN TRACK 4th
	Albuquerque	Belen	1935	10.29	10.29		
		Dalies	1948	10.31	10.26		
	Total	Ellinor	1935	765.95	765.38		
		Dalies	1948	765.14	764.60		
	Albuquerque	Dalies	1935	402.57	406.05		
		Seligman	1948	402.88	404.15	See Note	
	Arizona	Seligman	1935	317.25	315.96		
		Barstow	1948	317.33	316.19		
	Los Angeles	Barstow	1935	80.68	82.59		
		San Bernardino	1948	80.36	82.39		
	Total	Dalies	1935	800.50	804.60		
		San Bernardino	1948	800.57	802.73		
A	Los Angeles	San Bernardino	1935	59.84	59.84		
d Dist.		Los Angeles	1948	59.54	59.54		
A	Los Angeles	San Bernardino	1935	70.33	70.33	1.02	
d Dist.		Los Angeles	1948	71.35	71.35	1.47	

Via Northern District and Pasadena (Transcontinental Passenger Route)

	Division	Between	Year	Westbound Track	Eastbound Track	3rd	4th
	Total	Chicago	1935	2226.13	2230.60	42.58	9.80
		Los Angeles	1948	2224.29	2226.86	47.67	15.46

Via Southern District and Fullerton (Transcontinental Freight Route)

	Division	Between	Year	Westbound Track	Eastbound Track	3rd	4th
	Total	Chicago	1935	2212.30	2216.20	41.92	9.80
		Los Angeles	1948	2211.87	2213.90	47.46	15.46

Note: The Coast Line mileages for 1934 and 1948 are not comparable because 1934 reporting was on basis of 1st and 2nd Main Tracks, while 1948 is on basis of Eastward and Westward Main Tracks.

~~[illegible]~~

Reference:
Maintained and Operated Mileage Record
Dec. 31, 1934
Dec. 31, 1948

See Exhibit 4 for details of location of 2nd track on transcontinental Lines.

Chapter V

TRACK STRUCTURE

The purpose of track is to provide a structure that will both sustain the weight and guide the direction of movement of the flanged wheels of locomotives and cars. The same fundamental engineering principles enter into the design and specifications of the track structure as those which govern the similar characteristics of bridges and buildings.

Track is an assemblage of parallel lines of comparatively short lengths of rail, now usually 39',which are formed into a continuous structural member by rail joints tightly held by 4 or 6 bolts to the ends of two adjoining rail sections (unlessjoined by welding; a practice of growing importance and great future promise). The rail is attached to wooden (or occasionally metal or concrete) ties, usually by spikes (but in some instances, by bolts or miscellaneous patented clips, clamps or other devices). The two parallel lines of rail are spaced to provide the standard gage of 4'8½" between the inside face, or gage, of the rail head. A tie plate is interposed between the rail and tie to increase the bearing service of the latter and improve the holding power of spikes and the precision of the gage. Rail anchors are also applied to prevent the rail from slipping or "creeping" longitudinally under the reaction of passing trains, and lock washers are generally used to hold nuts and bolts tight.

The heaviest modern locomotives carrying their maximum capacity of coal and water, weigh up to 500 tons, although most of even the larger locomotives now in service weigh between 250 and 350 tons. Such weights, moving at maximum speeds, ranging from 50 to over 100 miles per hour, are equivalent to from three to nearly five tons per linear foot of over-all wheel base of engine and tender and are carried on from 6 to as many as

12 or 14 axles under the locomotive and 4, 6 or 7 supporting the tender, and lead to maximum locomotive driving axle loads of 75,000 pounds, although these are exceptional and such weights usually are held to 65,000 pounds. The trailing load ranges from 1,000 pounds per linear foot for empty freight cars to one ton per linear foot for Pullman cars and two or more tons per linear foot for heavily loaded cars of coal and ore. These axle weights of locomotives and cars are transmitted to the track by two supporting wheels. There is a narrow line or band of rolling contact between the bearing surfaces of wheels and rail. This has an area of but a small fraction of a square inch and so produce extremely high unit pressures in the head of the rail.

The basis of safety and economy of track maintenance is a track structure which is rigid and immobile within very small limits of flexibility, yet unlike bridges and buildings, the foundations of track cannot be driven deep into the ground down to solid rock or be carried on piling. Instead, the weight of passing trains, except on bridges or other special structures, must be transmitted into a subgrade, which is usually only compacted earth that is unable to bear more than nominal surface pressures per square inch without danger of subsidence or internal disturbances which would jeopardize the integrity of the track. The very high wheel pressure per square inch set up at the point of contact with the rail must be reduced to a very low pressure per square inch at the point at which these forces pass into the earthen face of the subgrade. The track structure does this.

Rail serves as a girder to distribute wheel loads throughout its entire length and on into the adjoining rails in order that these weights will be carried on many ties rather than by the one or two immediately adjacent to, or under, each wheel. The heavier the rail and the greater its girder strength (stiffness) the greater the length and the evenness of the distribution of the load. The stiffness of rail joints is also a very important factor in the transmission of such forces beyond a rail end and into an adjoining rail even though the latter may not be sustaining a direct weight. A weak joint, irrespective of the girder strength of the rail, will concentrate forces at the rail end and cause excessive rail wear and batter, on which the effect of the inevitable jar from wheels passing over the rail ends adds a cumulative destructive action, greatly shortening rail life and adding to maintenance costs.

The weight carried by the rail is transmitted into the ties. It is obvious that the greater the size, strength and number of ties per rail panel the more evently wheel pressures will be distributed throughout the length of each tie. Tendencies of ties to bend and thereby concentrate loads will be correspondingly reduced or avoided altogether. A tie plate of adequate dimensions and strength will increase the area of the bearing surface on the tie beyond that of the base of the rail itself, and by broadening the contact will proportionately reduce the magnitude of pressures and also permit more even distribution of the live loads passing through the tie and on into the ground. Spiking a rail through a tie plate affords a fastening superior to that possible without it and thereby improves riding qualities and economy of maintenance. Likewise, use of a tie plate permits more accurate gaging and alignment of the rail.

If the ties rest in dirt or on thin layers of poor ballast, pressures per square inch will be transmitted directly into the ground and these will inevitably be of greater magnitude per square inch than the earth surface of the subgrade can absorb unmoved. To reduce these pressures so that even under the heaviest trains, the live loads passing into the subgrade will not be in excess of a fewpounds per square inch, a layer of from 6 to 18 or more inches of some hard, impervious material, such as gravel, slag or, best of all, crushed rock is placed under the track as ballast. A track structure built up of heavy rail of sections weighing either 115# or 132# per yard, spiked through heavy tie plates to first quality ties seven inches by nine inches in cross section and eight and one half or nine feet in length, and which are embedded in 12 inches or more of crushed stone ballast, will diffuse 80,000 pound axle loads over a broad supporting area.

The weight of a 500-ton locomotive, approximately 115 ft. long, when running over a track built to the foregoing standards, will have its million pounds evenly distributed over the area of the base of the ballast section; i.e. approximately 120 feet long by 12 feet wide. This contains 207,360 sq. in. which will dilute the 1,000,000 lbs. live load to 5 lbs.per sq. in. of bearing surface of the ballast on the earth subgrade and this will be well below the permanent pressures produced by the dead weight of the ballast, ties and rail.

The weight of rail section which prevails on any line of railway is the most important element determining the physical standards of the track structure. The usual maximum rail weight sections are 115# and 132# per yard although some heavier types are used on the Pennsylvania and the Lehigh Valley. The increasing use of Diesel locomotives is actually reducing the necessity for the heaviest sections of rail. The New Haven and Boston & Maine Railway some time ago discontinued the installation of 131# rail in favor of 112# - 115# section and some other railroads are doing likewise.

The 250,000 main track miles of American railways contain 45,000 track miles laid with rail weighing between 110# and 119# per yard and an equal aggregate length weighing more than that.

Table VII

This table lists the mileage of Santa Fe main tracks laid with varying weights of rail as of December 31, 1939, 1943 and 1948, for comparative purposes.

Pounds Weight Per Yard	Miles of Main Track Laid with Rail of Various Sectional Weights as of December 31st		
	1939	1943	1948
130 - 132	71	632	2515
112 - 115	1495	2052	2346
110	3647	3245	1776
90	5453	4947	4395
85	1647	1578	1481
Under 85	2468	2085	1996
TOTAL	14781	14539	14509
Rail weighing 110# per yard or more	5213	5929	6637
Rail weighing 90# per yard or less	9568	8610	7872

The record of initial use by the Santa Fe of rail of various sectional weights per yard follows in summary form:

Section	Remarks
75#	Earliest available records of rail sections laid on the Santa Fe show 192 feet of 75# rail placed in service through Kansas City in 1889.
85#	The first 85# rail was rolled for the Santa Fe in 1903 and placed in service the following year.
90#	The first 90# rail was rolled for the Santa Fe in 1909 and placed in service the following year. Used as main line standard until 1925.
110#	Rail section adopted by AREA (American Railway Engineering Association) in 1915. First Santa Fe 110# rail was rolled in 1924 and laid in 1925 in the westward track from Supai to Ash Fork, Arizona.
130#	Rail section adopted by AREA in March 1920. 1500 feet placed in service in 1924 at Chapelle, N. M. In 1928, 130# section was adopted for all renewals on mountain grades.
112#	Rail adopted by AREA in 1934. Extensive use was made of this section starting in 1934 to replace the 110# section.
115#	Adopted by Santa Fe for certain main tracks in 1947.
131#	Rail section adopted in 1933. Small mileages were placed in service in 1934 and succeeding years on mountain grades but not used extensively in main line service until 1940. After that most of each year's rail purchases were of this sectional weight.
132#	AREA section adopted by Santa Fe in 1947.

Tables VIII, IX and X, which appear on the following pages, summarize annual tie insertions and rail renewals since 1935 and give the total of these. The "Form A Report" of the I. C. C. indicates that 59,622,893 cross ties (virtually all treated timber) were laid under Santa Fe tracks as of Dec. 31, 1948, not including bridge ties and switch ties.

The 1935 - 48 tie insertions, totaling 25,946,334, are equal to 43.5% of the ties now in Santa Fe tracks. The average renewals between 1935 and 1948 were 1,817,595 ties per annum. That represents 3.35% of the system total which is equivalent to replacement on a 30-year life cycle. This is well within the normal life expectancy of ties used in Santa Fe territory; much of which is an area of scanty or below average rainfall. The Santa Fe is benefitting from having been one of the first railways to make it a standard practice to use treated timber exclusively. New rail is laid only on primary main lines. The necessities of secondary lines, branch lines and yard tracks and sidings are provided by rail taken out of primary main lines and replaced by new steel. Since the transcontinental main lines between Chicago and California terminals represent 5,000 track miles, it is apparent that there is little or no rail in these principal routes that has not been laid new within the period of the improvement program being considered in this report. Its satisfactory rail condition permitted the Santa Fe to make the moderate reductions in renewals reported in the year 1948. The superior standards of Santa Fe track construction and maintenance constitute a fine physical reserve that could be translated into a reserve of earning power in the unhappy event that a prolonged business recession might overtake this country as some fear is a near future possibility.

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TABLE VIII

MAIN LINE RAIL RENEWAL IN MILES

DIVISION	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	TOTALS
Illinois	12	16	65	38	9			14	38	5		7	25	53	282
Missouri	12	42	31			16	22	16	60	35	6	46	75	75	436
* Eastern		2		3		16	21	15	53	41	77	12	12		252
* Middle	7	7	15		11	35	9	20	7	35	23		27	85	281
Panhandle						2					14		11	28	55
Plains						18			20	33	70	30	72	22	265
Pecos		39	50	24		7	3	10	20	41	14	30	6		244
Albuquerque	11		23	15	106	6	36		61	122	111	172	116	1	780
* Arizona	29	180	64		47	1			67	139	103	48	4	33	715
* Los Angeles	11	27	3		30	35	58	109	35	6	2	48	22		386
TOTALS OF ABOVE DIVISIONS	82	313	251	80	203	136	149	184	361	457	420	393	370	297	3696
SYSTEM TOTALS	111	451	443	142	343	325	252	244	413	498	551	447	571	381	5172

S. F. Standards 1935 - 1948

112# AREA Adopted 1934 for main line service
115# AREA Adopted 1947 for certain main lines
131# AREA Adopted 1934 for main line service on mountain grades
132# AREA Adopted 1947 for main line servide
131# AREA Adopted 1940 for main line service
6 hole angle bar adopted as standard in 1947, although some were in experimental use before that

* These divisions include main line mileage in addition to that on the Chicago - Los Angeles route via Ottawa Cutoff, Eldorado, Kans., Augusta, Kans., Amarillo, Tex., Belen, N.M. and Fullerton, Calif. analyzed in this report.

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TABLE IX

MAIN LINE TIE INSERTAIONS PER MILE OF TRACK

DIVISION	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948
Chicago Terminal	130	194	309	212	9	44	39	98	60	42	83	69	54	64
Illinois	220	270	228	65	124	71	86	93	48	61	78	74	125	177
Missouri	281	286	227	102	109	165	183	162	75	74	120	74	56	93
Kansas City	150	344	83	25	112	128	141	82	39	151	91	150	162	42
* Eastern	265	320	251	49	58	129	158	140	85	70	107	114	122	123
* Middle	157	192	226	109	177	132	131	99	45	109	84	104	114	124
Panhandle	97	262	153	63	72	63	98	71	82	117	304	112	106	385
Plains, AT&SF	45	65	99	83	47	115	43	95	90	126	414	284)	108	189
Plains, P&SF	24	12	34	35	29	69	78	128	23	96	80	100)		
Pecos	54	70	102	92	57	102	140	178	136	73	165	193	153	179
Albuquerque	112	108	116	60	84	76	72	102	44	53	91	76	117	81
* Arizona	95	135	110	94	111	126	205	186	169	170	213	85	189	145
* Los Angeles	117	98	74	68	50	50	85	156	39	121	106	78	130	151

* -- These divisions include main line mileage in addition to that on Chicago - Los Angeles route via Ottawa Cutoff, Eldorado, Kans. Augusta, Kans., Amarillo, Tex., Belen, N.M. and Fullerton, Calif., analyzed in this report.

TABLE X

SYSTEM TIE INSERTIONS AND RAIL RENEWALS SINCE 1935

(Excluding materials used in construction of additional main and other tracks)

	Tie Insertions	Miles of Rail Renewals Wgt. Per Yard of Rail Sec. 112#-115#-	130# - 132#	Total	Standards Adopted
1935	2 072 936	105*	-	111	8'6" tie adopted for use on principal lines
1936	2 296 409	429**	-	451	
1937	2 429 334	410***	6	443	
1938	1 641 873	127	15	142	
1939	1 947 802	327	16	343	9' tie adopted (See Note A)
1940	1 775 435	231	94	325	131# AREA rail adopted for main line service
1941	1 940 177	186	66	252	
1942	1 984 907	97	147	244	
1943	1 512 672	83	330	413	
1944	1 476 269	81	417	498	
1945	1 921 865	99	452	551	
1946	1 540 131	41	406	447	
1947	1 699 430	157	414	571	115#-132# AREA rail adopted for main line service in place of 112# and 131#
1948	1 707 094	80	306	386	
TOTAL	25 946 334	2 453	2 669	5 177	

* In addition 5 miles of 110# rail - 1 mile of 90# rail
** In addition 22 miles of 90# rail was laid.
*** In addition 27 miles of 90# rail was laid.

Note A: 9' tie adopted in 1939 for high speed and heavy traffic main lines on tangents and curves and on curves of one degree or over on other main lines. When 9' standard went into effect these ties were readily available. Due to tie shortages during the war many 8'6" softwood ties were inserted in lines on which 9' ties are the authorized standard. Oak and gum (hardwood) ties of 9' length, which are used on curves only, have generally been available in the desired quantities.

While frogs and switches and track fastenings are also a part of the discussion of track conditions, it must suffice here to state that all of these details on Santa Fe lines conform to the high standards found in the basic specifications of its ties, rail and ballast. Due candor, however, requires mention of the fact that the gravel ballast used on the Missouri and the Illinois Divisions does not appear to be a satisfactory material for present high speed track and might advantageously be replaced by stone as part of the development program of near future years.

Sidings will be discussed in a later chapter given over to consideration of them from the standpoint of adequacy of length and spacing to permit flexibility and frequency of train movement over single and double track divisions. In this chapter, however, it may well be noted that while sidings are properly built to standards inferior to those of high speed main tracks, Santa Fe sidings are well constructed and maintained within the limits of the restricted speeds at which trains necessarily move through them.*** The same observations apply to yard tracks, industrial side tracks and related facilities.

The 1935 - 1948 improvement program has produced exceptionally fine track on the Santa Fe. Its transcontinental main tracks are built and maintained to standards of structural excellence and detail of line* and surface** to permit high locomotive and train speeds except where restrictions

* "Line" of the track is established by the accuracy of the gage of the rail in relation to the theoretically correct position of the center line on tangents and curves.

** "Surface" of the track is determined by the accuracy of the elevation of the top of the rail in relation to its theoretical position in the vertical plane, with due allowance for superelevation of outer rail on curves. If there are track irregularities in the horizontal plane, it is "out of line"; if the irregularities are in the vertical plane it is "out of surface."

*** Sidings on new cTc installations constitute partial exceptions to this statement as outlined in the chapters on those subjects.

are imposed which represent the limitations of curves and grades and other physical conditions unrelated to standards of track construction and maintenance.

Present maximum authorized speeds for passenger trains are as follows:

Chicago - Newton, Kansas	90 MPH
Newton, Kans. - Los Angeles, via La Junta	100 MPH
Newton, Kans. - Wellington	85 MPH
Wellington - Amarillo - Dalies	80 MPH

Prevalence of gravel ballast and also the train control system installed on Illinois Division between Pequot and Fort Madison for 90 MPH maximum speeds, together impose this 10 MPH lower limit than on lines west of Newton (via La Junta). Since streamliners do not run from Newton via Amarillo to Dalies, schedules do not require higher authorized limits than 80 MPH on Southern District.

Chapter VI

BRIDGES

Bridges carry railroad tracks over depressions in the land surface where support cannot be provided by earthen fills, either because of the extreme differences in elevation or because water courses, highways, railways or other obstacles prevent. Frequent openings must be provided through the base of the earthen embankments which support railway tracks in order to provide minor requirements of drainage and other purposes that do not necessitate the construction of a bridge. These passageways which provide for the flow of water and other necessities, yet do not break the continuity of the fill supporting the track, are called culverts. These can be provided by a pipe of metal or concrete or an open ended box of rectangular cross section constructed of wood, steel or stone. The dimensions of the culvert are determined by the run off that follows maximum rainfall. Their capacity may be augmented by placing several in parallel positions.

The structural distinction between a bridge and a culvert is found in the fact that the track rests on the bridge and the latter supports both its own weight and that of the track and the passing trains. A culvert doesnot sustain these loads; it merely provides an opening in the embankment. The earth pressures resultant from the fill which covers the culvert and the track on top of the fill and the train running over the track, pass around the culvert rather than through its walls. A culvert therefore requires only sufficient structural strength to sustain the overburden until it solidifies and the forces of the surmounting dead and live loads can then pass through the fill and into the supporting ground without disturbing the material of which it is composed. It might be noted in passing that an open pipe or box used to conduct water under a track that is laid in a cut instead of on the top of the fill is a drain and not a culvert even though the same pipe or box under an earthen fill would be designated by the latter term.

A bridge is a composite structure erected to hold in equilibrium the forces produced by the various dead and live loads which it must support. The term, however, not only includes the superstructure which crosses the depression bridged, but also the substructure which supports the span or spans of the bridge. The substructure in turn consists of masonry or concrete piers or abutments or may be steel towers or piling of timber or steel or concrete. The superstructure can be formed of "I" beams or "T" rails supported at the ends directly on masonry or be long spans provided by girders, trusses, arches or cantilevers. Spans may also be hung from the cables of a suspension bridge.

Deck bridges are those in which the floor of the bridge rests on the top of the superstructure as in the simple "I" beam or "T" rail form of bridge. Through-girder bridges have some part of the (girder) superstructure above the floor level but this is of insufficient heighth to permit the use of overhead bracing. Through truss bridges are those in which the greater part of the superstructure is sufficiently high above the floor level to provide the clearances necessary to permit overhead bracing to be used between the trusses to obtain lateral stability and rigidity.

Bridges include a variety of engineering materials and designs used in the spans and their supports, viz.

MATERIALS	TYPE OF SPAN	TYPE OF SUPPORTS
A. Steel	1. "I" beam or "T" rail 2. Plate girder 3. Truss 4. Cantilever 5. Arch 6. Suspension	1. Columns 2. Piling 3. Towers
B. Masonry (Stone and concrete)	1. Arch 2. Concrete Slab	1. Piers 2. Abutments 3. Concrete Piling
C. Timber	1. Stringers (Wooden beams laid longitudinally)	1. Pile Bents 2. Framed Bents

Many bridges are multiple structures embracing various types of spans, using different materials of construction. Trestles are bridges which consist of a series of short spans of steel concrete or timber construction, supported on columns, piling or bents.

While most bridges are fixed in position, movable bridges are of common occurrence to provide for the passageway of boats on navigable channels for which the main span does not provide adequate clearance. Movable bridges are of various types, such as swing bridges, lift bridges and bascule bridges.

In the construction of bridges, there are two basic elements of cost; i.e. the superstructure and the substructure. The cost of spans increases rapidly with their length. Similarly the cost of pier and abutments increases with their number. If the spans are very short, and hence relatively inexpensive to fabricate and erect, there will be a corresponding increase in the number of piers and abutments. On the other hand, if there are relatively few piers and abutments, the length of the spans will be increased with substantial additions to the cost of the superstructure. Practice has indicated that it is a reliable rule of thumb of bridge construction that the lowest total cost will be obtained when the separate expenditures on the superstructure and on the substructure are about equal.

The type of the bridge to be used is determined by the relevant engineering, economic and operating factors. Span lengths will generally determine the type of construction of steel bridges, viz.

Usual limits of Length of Span	Type of Construction
Up to 6'	"T" Rail
6' to 25'	"I" Beams
25' to 125'	Plate Girders
125' to 600'	Trusses
300' to 1650'	Steel Arch
600' to 1800'	Cantilever with suspended truss span on longer bridges.

*Longest truss span in the world is 732' in length included in the Ohio River Bridge at Metropolis, Illinois, near Paducah, Kentucky, owned by the Chicago, Burlington & Quincy, Illinois Central and Nashville, Chattanooga & St. Louis railroads.

Suspension bridges provide maximum length spans but no structures of this type have the rigidity required for the heavy locomotives and trains used on the railways of North America. Subaquous tunnels are invariably used where suspension bridges would have otherwise been necessary for railroad service.

The longest bridge ever built was the $49,000,000 Key West extension constructed in 1905-1912 by the late Henry M. Flagler for his Florida East Coast Railway. The route covered about 110 miles of virtually open sea but the comparatively shallow water (10-20' with 26' maximum) made the project possible. This viaduct was badly damaged by a hurricane in 1935 and was subsequently sold to the State of Florida for highway use. The 103-mile Lucin Cut-off of the Southern Pacific, opened in 1903, includes a causeway across Great Salt Lake which has 31 miles of railway through or over the shallow water; 19 miles of line on rock fills and 12 miles on timber trestles. The foregoing achievements were spectacular and difficult engineering feats but the greatest honors in bridge building are rightfully awarded to those who have designed and erected the structures which cross bodies of deep, fast flowing rivers or tides on unusually long and high spans that must be supported on massive foundations sunk far below the water level. Estuaries,bays and rivers of great width and depth provide the heroic tasks to test the bridge builders art and skill and mettle. This observation is confirmed by the great bridges over the several arms of San Francisco Bay, the Hell Gate between the East River and Long Island Sound and across the lower Mississippi and the St. Lawrence Rivers.

The 4.4 miles Huey P. Long Bridge over the Mississippi River at New Orleans, used by the Southern Pacific, Missouri Pacific and Texas & Pacific Railways, is the longest steel railway structure in the world. Most of its length is represented by the land approaches but there are eight river spans, totaling 3,524 feet in length. The main channel span is a cantilever 790 ft. long.

The San Francisco Bay Bridge, 4.3 miles long, between San Francisco and Oakland includes twin suspension spans 2300 ft. in length * so it cannot be used by standard railway trains but it is crossed by interurban electric cars. The busses of the Santa Fe Railway are among the many motor carriers which use it. The Oakland, or eastern part of this causeway, has a cantilever span 1400 ft. in length.

The Canadian National Railways owns two monumental structures over the St. Lawrence River, one, the Victoria Jubilee Bridge at Montreal is comprised of 25 truss spans aggregating 10,284 ft. in length, while the

* -- Main span of the Golden Gate (highway) Bridge, of the suspension type, at San Francisco is 4200 ft; the longest in the world. The second longest span, also a highway viaduct of that type, is the George Washington Bridge at New York, which is 3500 ft. between its supporting towers.

3,238 ft. bridge at Quebec has an 1800 ft. cantilever channel span, the longest in the world, exceeding even that of Scotland's world famous Firth of Forth Bridge by 50 ft.

The nine-mile long New York Connecting Railroad, joining the Pennsylvania in Long Island City with the New York, New Haven and Hartford Railroad in the Bronx, includes three continuous miles of four-track bridges and viaducts, culminating in the Hell Gate Bridge. Its main span, 1017 feet in length, is supported by the second longest steel arch that has yet been incorporated into a railway bridge. First rank is held in far-away Australia, where a1650 ft. arch carries a 4-track railway and 6-lane highway across Sydney Harbor. Its great span is within 2 feet of the record-holding length of the Bayonne-Staten Island arch but this carries vehicular traffic only.

The greatest railway bridge in the west is the Southern Pacific Company's double track structure over Suisun Bay, a tributary of the San Francisco Bay, at the Straits of Carquinez, which was completed in 1930 at a cost of $12,000,000. It is rated for E-60 loading. Its aggregate length of 5,603'6" extends almost wholly over water and is obtained by seven pin connected through truss spans, each of approximately 530 feet in length, one 336 ft lift span and 2 deck truss spans; one near the south end being 266'6" long and the other at the north end being 506'6" in length. A viaduct 560 ft long at the south end and 220 ft at the north end is included in the bridge. It is worthy of note that this bridge was designed and built by Mr. Carroll R. Harding, then Consulting Engineer of the Southern Pacific Company, and now President of The Pullman Company.

Before the days of railroads, bridges carried only the small loads represented by horse drawn vehicles and pedestrians. Moreover, roads could be built up and down steep grades and pass around sharp turns to reach the site where a bridge could most easily and cheaply span the river. Carpenters and masons built the structure of such strength and dimensions as experience indicated necessary but they lacked the scientific knowledge of the stresses which it would sustain. This usually resulted either in excessive quantities of materials being used or the reverse. The former entailed unnecessary additional cost; the latter sometimes led to collapse and possible disaster.

Railroads introduced a completely new set of problems in bridge design and bridge building. The weight of locomotives far exceeded any highway vehicle both in total amount and in concentration of weight carried by each axle. The latter was increased in effect by the "hammer blow" or "dynamic augment" of counterbalanced driving wheels. The speed of trains also causes "impact" which creates stresses and strains in excess of those caused by static or slow moving loads of equal dead weight. Railways required bridges to be built much stronger than ever before. Moreover, approaches to railway bridges could not contain the sharp grades and curves used in reaching highway spans. In order to keep the profile and alignment of the former within the standards used elsewhere on the line, whole valleys might have to be bridged rather than just the stream at the bottom.

The first locomotive built 120 years ago weighed less than ten tons. By 1850 locomotive weights(including the tender) had advanced to 25 tons and in the next decade this doubled. Santa Fe #1 of the familiar American, or 4-4-0 type, was acquired second hand from the Ohio and Mississippi Railroad (now B&O) in 1869. Data on its weight is not available but it was probably less than 50 tons. Hundred ton locomotives first appeared in the 1890's and ones of 200 tons total weight were built soon after the turn of the century. An additional 100 tons of weight was added by the growth of each subsequent 10 year period, ultimately producing the 500 ton articulated steam giants which are now operated on a few railroads.* Increasing speed and dynamic augment, as well as an increase in weight, added greatly to the bridge loading capacity needed to carry modern motive power until Diesels suddenly eased these requirements.

Bridges can now be built to such strength and carrying capacity for double as well as for single track, as may be required to avoid restricting the speed of trains below that permitted on adjacent sections of track. This is particularly true if the structure is of the "ballast deck" rather than the "open deck" type, i.e. the bridge is constructed with a solid floor system which carries a standard depth of ballast. The track is then laid in ballast just as it is on ordinary roadway. In the case of an "open deck bridge" the ties rest directly on the top of stringers or girders and the inter-tie spaces are open. The ballast deck type of bridge is heavier and more expensive to construct but permits better maintenance of track to perfect line and surface and the diffusion of the live load of passing trains cushions the impact of them. All of these factors together generally permit faster and smoother operation of trains over ballast deck bridges than across ones with open decks.

Ballast deck bridges are among the distinguishing characteristics of superior standards of railway development, although on the very longest spans, the ballast type of deck construction may not be used in order to avoid the heavy additional dead load per linear foot which it entails. Likewise, in the case of long bridges, the dead weight of the span is so much greater than the live load of the train that while a ballast deck is always advantageous, the benefits of it are reduced due to the lower impact which follows from the greater proportional length of the structure and the lesser live stresses in relation to the ones produced by the dead loads.

*The types of modern steam freight and passenger locomotives in common use today weigh between 300-400 tons; including the tender. Diesel locomotive weights vary between 115 and 165 tons per cab depending upon type and horsepower but are usually comprised of two or more cabs.

The system of rating the carrying capacity of bridges was developed by a civil engineer names Theodore Cooper and is based on the axle loads of steam locomotives. Its basic postulate is that two maximum size locomotives are coupled together for double-header operation and are hauling a train of freight cars representing a live load of a stated amount per linear foot that varies somewhat with the weight of the locomotive axle loads. A bridge having Cooper's E-65 rating indicates that it can safely support a train hauled by double-header steam locomotives with 65,000 lb. axle loads. This limit is exceeded by only a few of the heaviest engines in America.

Probably the largest and heaviest type of steam locomotive that has ever been built is the 4-8-8-4 articulated class built for the Union Pacific by American Locomotive Company in 1941. The engine alone weighs 772,000 pounds. Its weight is distributed over eight driving axles; a four wheel lead or pilot truck and a four wheel trailer truck; a total of twelve axles. The axle loads carried by the drivers are 68,100 pounds; while the axle loads on the front truck are 50,000 lbs. and on the trailing truck 63,000 lbs. The tender, when loaded with coal and water to two-thirds capacity, weighs 348,000, producing 50,000 lb. loads on its seven axles. The engine wheel base is 85 feet in length which represents a concentration of 9,000 lbs. of load per track foot. The total weight of the locomotive (assuming the tender is two-thirds loaded) is 1,120,000 lbs. or 560 tons. The short wheel base of the tender produces a concentration of 9,500 lbs. per track foot.

In contract to this the single unit of a General Motors 2,000 horsepower Diesel electric passenger locomotive weighs only 315,000 lbs. The load on the two driving axles in the six wheel trucks at either end of the cab is 53,000 lbs. and the load carried by the idler axle supporting the middle pair of wheels is 51,000 lbs. The cab being approximately 70 feet in length reduces the weight to 4,875 lbs. per track foot. The 1500 horsepower type F-3 freight locomotive weighs 115 tons fully loaded, is 50 feet long, and is carried by four axles. This has an axle load of 57,500 lbs. and its weight is 4,600 lbs. per track foot.

The Union Pacific 4-8-8-4 locomotive cited as an example of the largest class of steam power is 117 feet long. It produces approximately 6,000 horsepower and hence is the equivalent of a four unit Diesel which would be 200 feet long. This increased length of the Diesel does entail some disadvantages but these are not related to the effects on track because that relative factor diffuses the comparative load as indicated. Moreover, there is the even greater advantage of the elimination of dynamic augment where the torque of an electric motor turns the driving wheels. These physical details of maximum size of steam and Diesel locomotives are recounted in order to indicate the weight carrying capacity for which bridges must be built.

In addition to the weight of the locomotive and cars which a bridge must carry there is the dynamic augment which creates a hammer blow that makes the effective weight of counter balanced driving wheels in certain angular positions of their rotating movement much greater than the actual load itself. There is also impact to be considered, for it is proven in mechanics that a load when instantaneously applied to a structure produces a stress exactly double that caused by the same load at rest. In the ordinary structure the maximum load cannot be applied instantaneously, although in bridges the length of time required for the locomotive and train to reach positions on the bridge which produce maximum bending momemtn or shear is very small. Sudden application alone is never sufficient to double the live stresses as computed for quiescent loads but many engineers use a coefficient equal to unity for short spans. This assumes that the effect of vibration, centrifugal force and friction and other uncertainties is balanced by the difference between the stress due to instantaneous application and that due to the very rapid but not instantaneous application caused by a fast railroad train. For longer spans the coefficient of impact is generally reduced. The two following formulas represent two different methods of computing impact:

$$I = S \frac{300}{L + 300}$$

$$I = S \frac{S}{S + D}$$

In these formulas

I = Impact
L = Length in feet of distance which must be loaded to produce maximum live stress in member
S = That maximum live stress
D = The dead stress

The live load on bridges produced by even the most heavily loaded freight cars is considerably below that caused by steam locomotives but may be higher than that caused by Diesels. Cars of 70-ton load carrying capacity are the maximum ones in normal use. Coal carrying hoppers of this size are at least 40 feet in length. When loaded to full axle carrying limit the dead weight of the car together with the load weight of the contents is permitted to go as high as 210,000 lbs. This represents 52,500 pounds on each of the four axles and as the car is 40 feet in length, is equivalent to a lineal weight of 5,250 lbs. per foot.

The heaviest concentration of weight per lineal foot of track is produced by the specially designed 75-ton capacity cars used to haul iron ore from the Minnesota and Wisconsin and Michigan ranges to the ore ports on Lake Superior and Lake Michigan. These cars are approximately 20 feet long and accordingly produce loads of 10,000 lbs. per track foot. Six of these ore cars would approximate the length of the Union Pacific 4-8-8-4 locomotive referred to previously but would weigh 1,260,000 lbs. compared to its weight of 1,120,000 lbs., an excess of 140,000 lbs. or 70 tons. However, 75-ton ore cars are special types of equipment which are confined to use on limited mileage of lines specially equipped to handle them and are mentioned in this report only to inform the reader of what type of equipment produces the maximum requirements for structural strength in track and bridges. Present axle loads of from 50,000 to 70,000 lbs. and track loads of from 5,000 to 10,000 lbs. per lineal foot represent 120 years of development of locomotives and cars and in the track and bridges necessary to carry them.

Axle loads and total loads per lineal foot produced by freight cars and locomotives far exceed those of passenger equipment, even the heaviest old style Pullman cars, so the latter presents no problem to the bridge builder that has not been fully satisfied when structures are adapted to the necessities of motive power and freight traffic. Very few passenger cars aggregate 200,000 lb. total weight, including load, and any total passenger car weights above 160,000 lbs. and many lesser ones, too, are carried on two six-wheel trucks. These represent maximum axle loads of 33,000 lbs. The 80 ft. length of passenger cars reduces the linear equivalent of weight to 2,500 lbs. per track foot. Modern light weight and semi-light weight passenger train cars use 4-wheel trucks. These give even lesser loading per track foot throughout the length of the car but their 4-wheel trucks increase axle loads to 40,000 lbs.; but this is still a moderate figure in relation to those of locomotives and freight cars.

The short wheel bases of passenger car trucks, compared to those of steam locomotives, and the superior type of frame and spring construction gives better riding qualities to passenger equipment, particularly those units recently designed for high speed movement. This characteristic greatly reduces the destructive action of passenger trains on tracks and bridges.

Few of the structures erected in this country more than 40 years ago can now sustain high speed operation of modern steam motive power except monolithic arches of stone and concrete. These seldom have load or speed limits, irrespective of their date of original construction and moreover they seem to be as resistant to the ravages of time as the Pyramids of Egypt. Unfortunately there are all too few structures of this character on the American railroad but where they exist in the proper locations they are great legacies from the past to the present generation of railway men. The Carrollton Viaduct of the Baltimore & Ohio Railroad near its original station of Mt. Clare was built in 1829 and is the world's oldest continuously used railroad bridge. That same company's Thomas Viaduct over the Patapsco River at Relay, Md., is another famous old stone bridge. The Erie's Starucca Viaduct across the West Brandh of the Susquehanna River near Susquehanna, Pennsylvania, is probably the best known bridge of this type in the country. The Pennsylvania Railroad is carried over the Susquehanna River near Harrisburg and over the Schuykill at Philadelphia and the Raritan at New Brunswick, New Jersey, on great multiple track stone arch viaducts built early in the present century. Soon after that concrete succeeded granite as the more economical material to use in such structures. The Lackawanna took the initial leadership in building great bridges of this type before World War I. The largest concrete structure in the world, other than dams, is the well known Tunkhannock Viaduct over the creek of the same name near Nicholson, Pennsylvania, northwest of Scranton. The Lackawanna crosses the

Delaware River at Martins Creek, New Jersey, on another great concrete bridge.

Old railroad bridges usually restrict speed particularly with the heavier classes of steam power. This is just as objectionable on a high speed line as limitations imposed by sharp curves and steep grades. Often bridges remain the last gap of single track in an otherwise double tracked line, forming bottle necks which further handicap capacity for movement of trains. Prior to the days when power switches could be remotely controlled, gauntlet tracks were used where lateral clearances permitted to avoid the expense of interlockers to throw the switches at either ends of double track lines which were single tracked through tunnels and over bridges.

A gauntlet is used to compress the two tracks of a double track line into the approximate ground area occupied by a single track, in order to run through a tunnel or over a bridge or pass some other restricting condition, which would require expensive enlargement, to accommodate two parallel main tracks built to standard spacing of track centers which is now 14 feet on the Santa Fe. Instead of installing switches to pass from double to single track and return a gauntlet uses frogs alone to enclose the center lines of the two tracks within each and their individual rails are spiked to the same ties. This obviates the use of switches at either end of the gauntlet. Automatic signals are required to protect opposing trains against collisions.

Gauntlet tracks antedate the remote control power thrown switch which is of comparatively recent development; i.e. the last 20 years. Prior to that time it was necessary to locate an interlocking plant in close proximity to any switches operated from a central point which were used to divert trains moving faster than at restricted speeds. While trains can make facing point movements over hand thrown switches at high speed so long as the switch is in normal position, it is necessary to reduce speed to moderate limits, i.e. 10, 15 or 20 miles per hour, to move over hand thrown switches when these are open or reversed. This is necessary for safety since hand thrown switches are held in position by a latch and not by mechanical or electrical locks. Moreover, these require assignment of switch tenders, if diverting movements are to be made without stopping trains to permit their crews to open and close the switches.

The introduction of a single track section of line occasioned the various technical restrictions which safety of train operation under the Standard Code of Rules requires trains to observe when passing from double to single track. Development of the track circuit for automatic signal systems provided the means of avoiding the switches at the end of the short stretches of double track through tunnels and over bridges and other similar obstructions to a second track by permitting the gauntlet arrangement of rails, provided clearance permitted. The gauntlet saved the expense of interlockers and operators or switchmen and observance of rules relating to single track operation. However, it entailed the extra cost of a double set of rails where one would be sufficient except for these other engineering and operating factors. Therefore, with the development of the remote control switch, which is in reality an unattended or remotely controlled interlocking plant, the recent practice has been to avoid construction of gauntlets and run the double track into a single track line over bridges and through tunnels of restricted lateral dimensions. Movement over the single track section is then directed by signal indication only, usually from the nearest interlocking plant, although an automatic interlocker at both ends of the double track can be installed which will clear the switches and signals for the approaching train if there are no interfering movements and the track ahead is unoccupied.

The Santa Fe's Transcontinental Lines, until recently had three important gauntlet bridges; viz. (1) over the Missouri River at Sibley, Mo., (2) across Canyon Diablo, Ariz., and (3) over the Colorado River at Topock, Ariz. New double track bridges have replaced the gauntlet structures over Cañyon Diablo and the Colorado River but the one over the Missouri River remains.

Single track bridges in otherwise completely double tracked lines are restrictions similiar to gauntlets. Only two such handicaps remain on the Santa Fe and both are on the 3rd District of the Los Angeles Division. One is over the Santa Ana River between San Bernardino and Colton and the other crosses the San Gabriel River at the station of Rivera, five miles east of Hobart Yard, Los Angeles. cTc minimizes but cannot eliminate the occasional train detentions which such conditions introduce in double track operation.

Maximum size cars and allowance for excessive dimensions of open loads on flat cars and gondolas establish the clearances which should be provided in bridges except the deck type which have all of the structural members below the track. "Half through" girders and "through" truss bridges introduce clearance problems and these are increased when any part of the structure must carry tracks on curved alignment, especially if sharp radii are required on approach spans. The standard 14-foot spacing of double tracks is used on Santa Fe bridges. Generous bridge clearances contribute to facility and safety of operation everywhere and prove especially useful whenever unusually high and wide open loads must be moved over them.

So much attention is given to bridges of monumental proportions and appearance that it may be overlooked that there are relatively few of these in the world. However, each railroad in proportion to its mileage and the nature of the territory traversed, has many structures of lesser length but which in the aggregate represent an appreciable component of railway mileage and investment. The most important factor to consider about railway bridges is that they shall always be so adequate structurally, for the service required of them and that they shall not restrict speed, load, or clearance of the sustained normal movement of all of the services operated over the route of which they are a component part. Obviously, main line necessities are much more exacting than those of branch lines and bridges must be economically adjusted to the traffic and operating requirements of the tracks which it carries.

The Santa Fe is fortunate in respect to bridge requirements. While there are thousands of openings under the track, from small culverts up to bridges of imposing length, nevertheless, it is at first surprising to realize there are but four structures of notable size on the Santa Fe. (1) Mississippi River Bridge at Fort Madison, Iowa. (2) Missouri River Bridge at Sibley, Mo. (3) The steel arch over Canyon Diablo west of Winslow, Ariz. (4) Colorado River Bridge at Topock, Ariz. near Needles, Calif. Only the last two were constructed since 1935 so will be discussed in this report.

There are, of course, hundreds of bridges of moderate and minor size over the streams which drain the vast area served by the Santa Fe. None of these structures, however, have any special engineering or operating significance beyond the general observation that those on high speed main lines have been brought up to standards that interpose no restriction on the train loads or train speeds. This, however, represents a major achievement because even on other large systems, many bridges are usually weak points in the line which are constant impediments to the movement of maximum capacity motive power at maximum speeds.

The Santa Fe system crosses 67,221 equivalent single track bridge spans of all types of structure and materials of construction, i.e. steel, concrete and timber stringer bridges. The latter are more familiarly known as trestles. One single bridge span carrying three tracks, for example, represents three equivalent single track spans. A bridge comprised of five double track spans would produce 10 equivalent single track spans; etc. Hence every double track bridge is the equivalent, in that table, of two single track bridges multiplied by the total number of spans in the bridge. It should be noted that a bridge for a double (or multiple) track line may use a common span to support the two or more tracks or these may be carried by parallel single track bridges. The stringers between each pair of bents of a timber trestle represents a span for purposes of that computation.

These 67,221 bridge spans carry 1,142,573 lineal feet, or 216.4 miles of track. This is equivalent to more than 1% of the Santa Fe's total track ownership.

These data are shown in the basic structural and territorial classifications in Table 11 on page 118.
The aggregate number of culverts is included.

B.E.S. 75

A.T. & S.F. RAILWAY SYSTEM

RAILWAY BRIDGES

SUMMARY BY GENERAL MANAGERS TERRITORIES

RECORD AS OF DECEMBER 31, 1947
OFFICE OF BRIDGE ENGINEER SYSTEM
CHICAGO, ILLINOIS

NUMBER OF EQUIVALENT SINGLE TRACK SPANS AND EQUIVALENT LINEAL FEET OF SINGLE TRACK IN STRUCTURAL STEEL, T-RAIL AND REINFORCED CONCRETE BRIDGES.

STRUCTURAL STEEL BRIDGES

TERRITORIES		COOPERS E65, E70 & E72 LOADINGS						HEAVY GRADE LOADING					
		TRUSS SPANS		GIRDER SPANS		I-BEAM SPANS		TRUSS SPANS		GIRDER SPANS		I-BEAM SPANS	
		OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK
EASTERN LINES	NUMBER OF SPANS	3	38	11	257	36	758						68
	LINEAL FEET	1199	8768	873	18770	1138	17161						1287
WESTERN LINES	NUMBER OF SPANS	6	6	45	140	27	186	1	3	7	63		14
	LINEAL FEET	873	1174	3970	9262	1302	6271	210	454	369	3797		288
COAST LINES	NUMBER OF SPANS	4	16	8	315		91				1		2
	LINEAL FEET	331	4009	732	24161		3009				32		57
GULF LINES	NUMBER OF SPANS		1	1	42	3	90						
	LINEAL FEET		149	90	1729	66	3201						
TOTALS	NUMBER OF SPANS	13	61	65	754	66	1125	1	3	7	64		84
	LINEAL FEET	2403	14100	5665	53922	2506	29642	210	454	369	3829		1632
LINEAL FEET		16503		59587		32148		664		4198		1632	
CLASSIFICATION TOTALS		108238						6494					
GRAND TOTALS		322,337											

TERRITORIES		BETWEEN E65 & OLD STANDARD LOADING						OLD STANDARD LOADING					
		TRUSS SPANS		GIRDER SPANS		I-BEAM SPANS		TRUSS SPANS		GIRDER SPANS		I-BEAM SPANS	
		OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK
EASTERN LINES	NUMBER OF SPANS	7	6	16	115	1	96	43	50	258	680	91	203
	LINEAL FEET	766	1780	747	6005	17	1800	7706	7813	15176	37193	2100	4833
WESTERN LINES	NUMBER OF SPANS				3	6	2	15	10	71	366	19	270
	LINEAL FEET				254	146	37	2193	1946	3877	21714	454	6006
COAST LINES	NUMBER OF SPANS			1	16	1		8	13	35	327	10	218
	LINEAL FEET			100	552	28		1898	2219	1836	22251	252	5236
GULF LINES	NUMBER OF SPANS	1	2	7		5		25	12	36	207	31	224
	LINEAL FEET	206	150	444		132		4484	2349	2229	12595	761	5295
TOTALS	NUMBER OF SPANS	8	8	24	134	13	98	91	85	400	1580	151	915
	LINEAL FEET	972	1930	1291	6811	323	1837	16281	14327	23118	93753	3567	21370
LINEAL FEET		2902		8102		2160		30608		116871		24937	
CLASSIFICATION TOTALS		13164						172416					

TERRITORIES		LESS THAN OLD STANDARD LOADING						STEEL STRINGER & CAP E65		T-RAIL BRIDGES		REINFORCED CONCRETE BRIDGES
		TRUSS SPANS		GIRDER SPANS		I-BEAM SPANS						
		OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	OPEN DECK	BALLAST DECK	
EASTERN LINES	NUMBER OF SPANS	4		11	13	2	14	6	260	417	430	68
	LINEAL FEET	614		532	752	39	389	84	3640	3964	3989	1331
WESTERN LINES	NUMBER OF SPANS	5	1	54	27				248	1115	1448	168
	LINEAL FEET	761	180	2431	1270				3472	10386	13208	2671
COAST LINES	NUMBER OF SPANS	1			23	1	3		264	265	2196	284
	LINEAL FEET	180			1437	22	120		3696	2508	19858	3978
GULF LINES	NUMBER OF SPANS	10		1	4				46	98	70	
	LINEAL FEET	1400		50	312				644	895	633	
TOTALS	NUMBER OF SPANS	20	1	66	67	3	17	6	818	1895	4144	520
	LINEAL FEET	2955	180	3013	3771	61	509	84	11452	17753	37688	7980
LINEAL FEET		3135		6784		570		11536		55441		7980
CLASSIFICATION TOTALS		10489						11536		55441		7980

NUMBER OF EQUIVALENT SINGLE TRACK SPANS AND EQUIVALENT LINEAL FEET OF SINGLE TRACK IN TIMBER STRINGER BRIDGES.

TERRITORIES		TIMBER STRINGER BRIDGES			
		OPEN DECK			BALLAST DECK
		3-PLY	4-PLY	5-PLY	
EASTERN LINES	NUMBER OF SPANS	1072	4475	1445	4523
	LINEAL FEET	15040	62950	20329	64498
WESTERN LINES	NUMBER OF SPANS	599	10663	272	7164
	LINEAL FEET	8245	148195	3790	99876
COAST LINES	NUMBER OF SPANS	124	2302	608	6508
	LINEAL FEET	1696	32701	8385	92342
GULF LINES	NUMBER OF SPANS	2049	6187	739	5238
	LINEAL FEET	29032	86777	10439	72520
TOTALS	NUMBER OF SPANS	3844	23627	3064	23433
	LINEAL FEET	54013	330623	42943	329236

SUMMARY OF STEEL, REINFORCED CONCRETE AND TIMBER STRINGER BRIDGES.

CLASSIFICATIONS		TERRITORIES				TOTALS
		EASTERN LINES	WESTERN LINES	COAST LINES	GULF LINES	
STRUCTURAL STEEL	NUMBER OF SPANS	3047	1595	1358	748	6748
	LINEAL FEET	141182	72711	72158	36286	322337
T-RAIL	NUMBER OF SPANS	847	2563	2461	168	6039
	LINEAL FEET	7953	23594	22366	1528	55441
REINFORCED CONCRETE	NUMBER OF SPANS	68	168	284		520
	LINEAL FEET	1331	2671	3978		7980
OPEN DECK STRINGERS	NUMBER OF SPANS	6992	11534	3034	8975	30535
	LINEAL FEET	98319	160230	42782	126248	427579
BALLAST DECK STRINGERS	NUMBER OF SPANS	4523	7164	6508	5238	23433
	LINEAL FEET	64498	99876	92342	72520	329236
TOTALS	NUMBER OF SPANS	15423	23024	13645	15129	67221
	LINEAL FEET	313283	359082	233626	236582	1142573

NUMBER OF ARCH, BOX AND PIPE CULVERT OPENINGS.

TERRITORIES	ARCH	BOX			PIPE					TOTALS
	STONE OR CONCRETE	STONE	REIN. CONCRETE	TIMBER	CAST IRON	CORR. CAST IRON	CORR. SH. METAL	REIN. CONCRETE	TILE	
EASTERN LINES	333	331	501	1666	2321		186	298	210	6046
WESTERN LINES	295	21	316	4041	1385	419	273	554	200	7504
COAST LINES	278	4	289	1786	647	242	56	1652	156	5110
GULF LINES	264	120	168	1694	996	71	14	190	253	3770
TOTALS	1170	476	1274	9387	5349	732	529	2694	819	22430

GENERAL NOTES

1. Data shown on the six sheets of this record have been compiled from the Division Bridge Lists, and from the Steel Bridge List made up by the Office of Bridge Engineer System. All types of bridges on all track classifications are included.

2. Structural steel bridges are classified as to their live load designs. T-rail bridges have been built to various live load designs, altho since 1935 the construction has been to Coopers E65. Reinforced concrete bridges have been built to Heavy Grade Loading and to Coopers E65 designs.

3. A culvert opening includes one or multiple lines of arches, boxes or pipes at the one bridge location.

Since 1935, 28 major bridge renewals (all made to Coopers E 65 and E 72 rating) have replaced nearly every structure that restricted maximum speed and load on the main transcontinental lines between Chicago and California. Only eight bridges remain which introduce such handicaps. Three each are on the Illinois and the Los Angeles Divisions and there is one each on the Missouri and the Plains Divisions. Other than over these eight bridges, Santa Fe main line trains can run over every bridge on the transcontinental line at the maximum speeds authorized on the adjacent sections of track. The bridge renewals and the bridge restrictions referred to herein are shown in Table 12, respectively.

The two most important bridge replacements made by the Santa Fe in its recent improvement program deserving further consideration are those of Bridge 313-A at Canyon Diablo, Arizona, and of Bridge A-567 over the Colorado River at Topock, Arizona.

The Santa Fe main line from Belen to Barstow crosses the Colorado River at Topock, Arizona, 12 miles east of Needles. Here the line is but 480 feet above sea level having descended westward in three steps from the summit of the Arizona divide at 7310 feet within a distance of little more than 200 miles. The line climbs westward from Needles up the Sacramento Wash to Goffs at 2584 feet. Located at the base of long eastbound and westbound ascents, the old gauntlet bridge over the Colorado at Topock formed a bottle neck in the movement of war traffic. It had been built in 1890 as a 990 foot through truss cantilever span with a 120 foot viaduct approach on the east end. Because the bridge soon became too light for the loads of locomotives which Mr. E. P. Ripley's improvement program provided, it was strengthened in 1901 and again in 1910 a pier was constructed in the center of the cantilever to provide additional reinforcing. It had been originally built as a single track structure but its clearances permitted a gauntlet track to be laid in 1923 in conjunction with the program for double tracking the coast lines. Inadequate physical capacity for modern trains necessitated speeds over this structure be limited to 15 MPH for passenger and freight trains.

Construction of a new bridge was begun in September 1942. This new structure was placed in service on March 7, 1945. It is located upstream from the old structure and consists of three 350 foot double track deck truss spans across the main channel, one 50 ft. wide flange I-beam span and one 100 ft. double track deck girder span on the east approach and three 100 ft. double track deck girder spans on the west approach. The abutments and the 7 piers are supported on reinforced concrete cylinders carried down to solid rock, a maximum depth of 123 feet below water level. The new bridge, of course, has no speed restrictions. A small line change was made on the east approach in conjunction with the Topock bridge renewals and a rather extensive one along the west bank of the river which lifted the track above record flood stage. This was particularly important since the Santa Fe suffered $1,500,000 damages in this vicinity from the 1939 floods. In order to prevent a repetition of this interruption to service, protection and line changes were made that cost $1,600,000. Five curves were reduced to longer radii and four curves eliminated which together cut out 327° 41' of central angle in each track.

Twenty-seven miles west of Winslow, Arizona, the Santa Fe main lines cross Canyon Diablo (Spanish: Devil Canyon) a 225 foot gorge which has been cut into the massive Kaibab limestone by the age-long erosive action of sand and water. The old bridge across the canyon was a steel trestle built in 1881 and renewed in 1920. A gauntlet track was placed across the new bridge during the double tracking of the adjacent mileage in 1923. The Canyon Diablo viaduct carried a permanent slow order of 10 MPH.

The new bridge at Canyon Diablo, located a few yards north of the old one, is a 544 ft. double track structure made up of two 120 ft. deck truss spans and one 300 ft. arch span. It carries no speed restriction for even the heaviest steam power and was completed in 1947.

A third important bridge, No. 348-A - Plains Division, is now under construction. It is being built in conjunction with a major line change along the west bank of the shallow Cimarron River crossed beyond Waynoka, Oklahoma. It seems paradoxical to find the Santa Fe using materials other than steel, stone or concrete in main line bridges but this one is a creosoted pile bridge carrying the single track on its ballast deck. The management states that this structure will have a life of at least 60 years; be rated for E 65 loading and impose no speed restrictions on trains; yet can be constructed for $300,000 less than a steel structure of like capacity.

All of the 28 bridges listed in Table 13 have fixed spans. None are moveable bridges. Probably the next important bridge replacements which may be made on the Santa Fe will be the substitution of new lift spans for the present swing bridges which the line uses in crossing the Chicago Drainage Canal first between Nerska and McCook and again between Willow Springs and Lemont.

Bridge conditions on the Santa Fe have been brought up to such a high standard that no work of this special character remains to be done at this time. Future bridge construction on the Santa Fe will therefore probably be limited to structures required for future line revisions and relocations and double tracking. Observation of Santa Fe and Union Pacific trains waiting to cross the single track bridge over the Santa Ana River betwen San Bernardino and Colton suggests that this is a bottle neck in an otherwise double track line which requires relief through a second single track bridge. This is a stream which has a water course of moderate proportions and could be built at moderate expense.

The readers attention is invited to the column of expenditures for bridges, trestles and culverts included in the table of capital Additions and Betterments to Railway property appearing as Table 1. Page 4-A

The bridges listed in Table XII suggest the probable replacements of the next decade except of the Missouri River Bridge at Sibley, Missouri, and the Mississippi River Bridge at Fort Madison, Iowa. The speed restrictions imposed upon those two are not due to the structural limitations of the bridges but to other unrelated factors.

TABLE XII

Existing Speed Restrictions on Bridges on Transcontinental Routes which imposes limits below those allowed by adjacent road conditions

Division	Bridge	Stream Crossed	Tracks	Maximum Speed Passenger	Maximum Speed Freight
Illinois	9-C	Chicago Drainage Canal***	2	30	25
Illinois	24-B	Chicago Drainage Canal***	2	40	30
Illinois	231-A	Mississippi River***	2	40 *	30 *
Missouri	425-A	Missouri River	Gauntlet	25 **	15 **
Plains	453-A	Canadian River	1	35	35
Los Angeles	A-35	Mojave River near Victorville W. B. Span only	1	35	35
Los Angeles	C-1	Lytle Creek at San Bernardino	1	20	20
Los Angeles	A-144	Los Angeles River at Los Angeles	2	20	20

* Bridge rating E 70. Restriction due to swing span and curves on approaches. All movable bridges, except of the lift span type, interpose speed restrictions due to impossibility of providing rail locks at end of swing spans adequate to protect maximum speeds across these unconnected points.

** Not due to restrictions in physical capacity of bridge which has an E-65 rating but is required by $8^\circ 45'$ curves on west approach and $7^\circ 14'$ curves and 0.55 % grades on east approach and also to gauntlet tracks.

*** Movable bridge of swing type; i.e. turns in horizontal plane.

TABLE XIII

MAJOR BRIDGE RENEWALS MADE ON AT&SF BETWEEN
CHICAGO AND LOS ANGELES (VIA SOUTHERN DISTRICT) SINCE 1935

Div.	Dist.	Bridge No.	River or Obstruction Crossed	Length of Bridge	No. of Spans	Length of Spans	Type of Span	Tracks	Year Built
Chgo	Term.	4A	Western Ave	191	3	37'	Wide Flange I Beam	6	1940
					2	32	" " " "	2	
					1	16	" " " "	1	
Ill.	1	36A	Illinois River	200	1	200	Thru truss on right skew	2	1935
Ill.	1	121A	Crow Creek	200	4	50	Wide flange I Beam	2	1948
Mo.	1	298B	Stream	48	1	48	Wide flange I Beam	2	1946
Mo.	2	378B	Big Creek	320	1	30	Wide Flange I Beam	2	1946
					5	50	" " " "	2	
					1	40	" " " "	2	
Plains	2	498B	Street	64	2	32	Wide Flange I Beam	3	1941
Pecos	1	663A	Street	24	1	24	Wide Flange I Beam	1	1943
Pecos	1	665A	Drainage	24	1	24	Wide Flange I Beam	1	1943
Pecos	1	670A	Drainage	48	2	24	Wide Flange I Beam	1	1943
Pecos	1	671A	Drainage	48	2	24	Wide Flange I Beam	1	1943
Pecos	1	676A	Drainage	48	2	24	Wide Flange I Beam	1	1943
Pecos	1	678A	Drainage	24	1	24	Wide Flange I Beam	1	1943
Pecos	1	711B	Street	125	1	29	Thru Girder Span	1	1941
					1	53	" " "	1	
					1	43	" " "	1	
Pecos	1	760A	Drainage	24	1	24	Wide Flange I Beam	1	1943
Pecos	1	776A	Drainage	72	2	36	Wide Flange I Beam	1	1943
Alburq.	2	A 195	Rio Puerco	371.5	2	100	Deck Girder	2	1947
					1	94	" "	2	
					1	77.5	" "	2	
Alburq.	3	A 313	Canon Diablo	540	2	120	Deck Truss	2	1947
					1	300	Two-hinged Arch	2	

TABLE XIII (Page 2)
MAJOR BRIDGE RENEWALS MADE ON AT&SF BETWEEN CHICAGO AND LOS ANGELES (VIA SOUTHERN DISTRICT) SINCE 1935 (Cont)

Div.	Dist.	Bridge No.*	River or Obstruction Crossed	Length of Bridge	No. of Spans	Length of Spans	Type of Span	Tracks	Year Built
Alburq.	3	A318	Canon Padre	300	1	29'	Wide Flange I Beam	2	1947
					1	111	Deck Girder	2	
					1	80	" "	2	
Ariz.	1	A567	Colorado River	1500	1	50	Wide Flange I Beam	2	1945
					4	100	Deck Girder	2	
					3	350	Deck Truss	2	
Ariz.	1	F568	Highway 66	60	1	60	Deck Girder	2	1944
L. Angeles	2	B124	Huntington Avenue Arcadia	130	1	130	Thru girder	1	1942
L.Angeles	2	DA127	Rosemead Avenue Chapman	146	2	28	Wide Flange I Beam	1	1939
					2	45	" " " "		
L.Angeles	2	CA134	Arroyo Seco Parkway, Pasadena	142	1	142	Continuous Thru Girder	1***	1940
L.Angeles	2	A139	Arroyo Seco	260	1	260	Continuous Thru Girder	2***	1941
L.Angeles	2	A-140	Los Angeles River	290	1	200	Thru Truss	1	1941
					1	90	Thru Girder	1	
L.Angeles	3	A31	Santa Ana River	650	2	70	Deck Girder	1	1939
					5	100		1	
L.Angeles	3	C152	San Gabriel River	350	2	49.5	Wide Flange I Beam	1	1947
					2	50.5	" " " "	1	
					3	50	" " " "	1	
L.Angeles	3	B151	Rio Hondo	250	5	50	Wide Flange I Beam	1	1946

* Santa Fe bridges are designated by the number of the mile post immediately to the east of north of the structure. The first bridge west or south of the mile post index is designated by the letter "A" following the number of the mile post, a second bridge, if any, is designated "B" the third "C" etc. A double letter combination such as "CA" indicates that a bridge was erected between Bridges C. and A. after these were constructed.

** A double track line may be carried on a double track bridge, or on two parallel single track bridges, etc. However, all of the new double and multiple track bridges tabulated here carry the double (or multiple) tracks on the common spans which is the more modern practice.

*** Bridge spans are normally supported only at both ends. If a single span is supported at more than two points, it becomes a continuous span. A continuous girder, therefore, is one which while a single unit structurally, has three or more points of support.

Chapter VII

TUNNELS

The chapter on physical characteristics of railroads outlined the problem of providing a roadway adapted to the efficient utilization of the mechanical forces produced by the locomotive which are converted first into service and then into revenues through the hauling capacities of the cars attached to it. While the greater proportion of railway track rests on earthen subgrade in open country, railways must cross rivers and valleys on viaducts and bridges and occasionally dig tunnels under hills and mountains and even under rivers, too.

Such structures and facilities are spectacular from the standpoint of the passenger and the general public but add to the cost and difficulties of railway construction and operation and maintenance. They are, of course, essential wherever required but on the other hand railways are fortunate to the extent that their use can be minimized without sacrificing desireable physical characteristics.

Tunnels represent the only branch of engineering in which the achievements of the railways of the United States do not bring first rank to this country. There are 39 railway tunnels in the world which are more than 3 miles in length, geographically distributed as follows:

Europe	27	tunnels	(mostly in the Alps of Switzerland, Italy, France and Austria).
England	4	"	
United States	3	"	
Canada	2	"	
Japan	2	"	
New Zealand	1	"	
Total	39	tunnels	

Ten of the foregoing 39 tunnels exceed 6 miles in length.

These are listed below:

Number	Tunnel	Date of Opening	Length Miles	Yds.	Railway
1	Simplon No. II	Oct. 16, 1922	12	559	Swiss Federal & Italian State
2	Simplon No. I	June 1, 1906	12	537	Swiss Federal & Italian State
3	Apennine	April 22, 1934	11	892	Italian State
4	St.Gotthard	Jan. 1, 1882	9	562	Swiss Federal
5	Lotschberg	July 15, 1913	9	140	Bern-Lotschberg-Simplon
6	Mont Cenis	Sept. 17, 1871	8	868	Italian State
7	Cascade	Jan. 12, 1929	7	1397	Great Northern
8	Arlberg	Sept. 20, 1884	6	939	Austrian State
10	Shimizu	1930	6	75	Japanese Government

There are five railway tunnels in North America which are more than 3 miles in length; viz.

Rank Among World's Longest Tunnels	Tunnel	Date of Opening	Length Miles	Yds.	Railway
7	Cascade	Jan. 12, 1929	7	1397	Great Northern
9	Moffat	Feb. 27, 1928	6	373	Denver & Salt Lake
18	Connaught	Dec. 6, 1916	5	39	Canadian Pacific
22	Hoosac	Feb. 9, 1875	4	1320	Boston & Maine
37	Mount Royal	Oct. 21, 1918	3	268	Canadian National

The foregoing data is abstracted from the 1947 edition of "The Railway Handbook" (Railway Publishing Co., Ltd., London) which has the following significant comments to make on North American railway tunnels.

"In relation to its size, and the great extent of its railway system, the North American continent is not prolific in railway tunnels. This results from the relatively undeveloped state of large parts of the countries in the era of railway construction, making it easier and cheaper in most cases to avoid hills that proved obstacles than to tunnel them. Nevertheless, today there are 1,539 railway tunnels in the U. S. A. alone, totalling about 320 miles and ranging in length from the 30 ft. Bee Rock Tunnel (on the Cumberland Division of the Louisville & Nashville Railroad) to the great Cascade Tunnel (on the Great Northern Railway) which is some 7-3/4 miles long, and is the sixth longest in the world and the longest in the Western Hemisphere.

"More than 400 of these U. S. A. tunnels exceed 1,000 ft. in length, but only forty are electrified. The Southern Pacific Railroad is responsible for the maintenance of the greatest number of 1,000 ft. and over tunnels, namely 50, of a total length of about 23 miles. The following are next in order:-

Railway	Number	Total Length
Baltimore & Ohio Railroad	37	81,324 ft.
Pennsylvania Railroad	30	97,246 "
Louisville & Nashville Railroad	25	48,512 "
Norfolk & Western Railway	21	43,801 "

"Four other systems in North America have large aggregates of such tunnels, but with materially fewer individual units, namely, the Great Northern Railway, 78,286 ft.; the Canadian Pacific Railway, 52,494 ft.; the New York Central System, 49,359 ft.; and the Chesapeake & Ohio Railway, 48,242 ft.

"There are 32 North American working railway tunnels more than a mile in length, 28 in the U. S. A. and 4 in Canada. Two others are given in the list which were abandoned in 1940. What is believed to be the world's longest tramway tunnel is the Twin Peaks Tunnel, Municipal Railway, San Francisco, which carries two tracks well over two miles (the precise distance is not known to us) under the hill at the head of Market Street. It has a station in the middle reached by a lift, which was the largest in the world at the time of its construction.

"The first railway tunnel in the Western Hemisphere appears to have been that through Staple Bend, 4 miles east of Johnstown, Pennsylvania, which was built in 1833 for the Allegheny Portage Railroad. It is 901 ft. long and has red sandstone portals; the archways are now partly bricked-in. A tunnel in New York City was built in 1837 for the New York & Harlem Railroad at 91st Street and Park Avenue.

"The Hoosac Tunnel, on the Boston & Maine Railroad between Troy and Springfield, under Hoosac Mountain, Massachusetts, took 25 years to build, but there were several suspensions of work. It was begun in 1851 by the State of Massachusetts, which formed the Troy & Greenfield Railroad. The art of tunnel construction in America was then in its infancy, and many accidents occurred. Work was begun from each end, and drilling at first was by hand. Despite improvements in technique, based on the experience of the Mont Cenis Tunnel, the State project continued to progress but slowly, and in 1869 a private Montreal contractor was given the job. The headings met on Nov. 27, 1873, and the railway through the tunnel was completed for traffic on Reb. 9, 1875. It was opened on Oct. 13, 1875, for Boston-Troy passenger trains, and for all business on July 1, 1876. With its length of exactly 4-3/4 miles, it remained for more than forty years the longest American tunnel. Ventilating difficulties were never solved until electric traction was inaugurated in May, 1911.

"The first North American tunnel to exceed the Hoosas in length was the Connaught Tunnel, 5 miles 39 yd. long, on the Canadian Pacific Railway in British Columbia, under Mount MacDonald, upon which work was begun in 1913. It was opened on December 6, 1916; avoided the hazardous Rogers Pass; reduced the transcontinental mileage by 4-1/2 miles; eliminated much curvature; and reduced the summit elevation 552 ft. The next longest tunnel in Canada (and the only other one in that country to exceed 3 or even 2 miles in length) is the Mount Royal Tunnel at Montreal, 3 miles 258 yd. long. This was formerly the property of the old Canadian Northern Railway and gave access to the terminal Tunnel Station of that company. Its importance has been enhanced enormously as the station has been made the basis of the new through Central Station of the Canadian National Railways (opened on July 15, 1943) and linked with the Victoria Bridge by a new approach line.

"What is now the second longest railway tunnel in the Western Hemisphere is the Moffat Tunnel under James Peak in Colorado, on the Denver & Salt Lake Railway. Snow conditions greatly hampered operations through the Rollins Pass every winter, and David Moffat promoted a tunnel to overcome the difficulty and also to make a better graded railway more suited to heavy traffic. The highest point in the tunnel is 9,257 ft. above sea level. The city of Denver, the principal potential beneficiary, secured powers to raise funds by a guaranteed bond issue, and built the property for lease to the railway. The Moffat Tunnel was opened on February 27, 1928, and shortened the rail distance between Denver and Salt Lake City via the route of the Denver & Rio Grande Western by 173 miles.

"During the same period the Great Northern Railway was engaged on driving an even longer tunnel through the Cascade Range in replacement at a lower level of its earlier Cascade Tunnel (opened in 1893 and electrified in 1909). This was built as part of the transcontinental railway that was the ideal of James J. Hill, which reached Puget Sound in 1893; the golden spike was driven on Jan. 7, 1893. The original Cascade Tunnel was 13,873 ft. (2 miles 1,104 yd.) long and reached an elevation of 3,383 ft. The approach lines had many miles of 1 in 45 gradient. The new tunnel was begun on November 27, 1925, the headings met on May 1, 1928, and it was opened on Jan. 12, 1929; it is also electrified. On the same date the old alignment was abandoned. This tunnel, which is 41,152 ft. (7 miles 1,397 yd.) long, was built as part of a betterment program which involved crossing the mountains at a summit elevation of 2,881 ft. or 502 ft. lower than the old line. Furthermore, the new line avoids entirely the avalanche zone through which the Great Northern Railway has been compelled to construct and maintain lengthy snow sheds.

"The first subaqueous tunnel in America was the Sarnia or St. Clair Tunnel of the Grand Trunk Railway (now part of the Canadian National Railways) and linking Sarnia in Ontario, Canada, with Port Huron in Michigan, U.S.S., in replacement of a ferry. Construction was begun on January 1, 1889; the two ends were linked on August 24, 1890; the first train passed through on April 9, 1891; and the tunnel was opened on Sept. 19, 1891. It runs under the River St. Clair, which here forms the boundary between the two countries, and is a single-line tube 21 ft. in diameter, driven by shield from each end through blue clay, lined with cast-iron segments, and faced inside with masonry. The actual tunnel is 6,026 ft. (1 mile 249 yd.) long, and the total length including approaches is 11,668 ft. After nearly seventeen years of steam operation, electric traction was introduced on May 17, 1908.

The longest and most famous under-river tunnels in the U. S. A. (excluding urban rapid-transit lines) are those serving the Pennsylvania Station in New York City. This station was established on Manhattan Island as a through station (despite the frequent American use for it of the word "terminal") approached by the Pennsylvania Railroad itself from New Jersey by twin single-track tubular tunnels under the Hudson (or North) River, and by the associated Long Island Railroad by four similar and only slightly shorter single-track tubular tunnels laid in two pairs under the East River. The entire length of line between the Bergen Hill (Hoboken, New Jersey) and the Long Island portals is 5.3 miles, all of which is below the surface, but differences in interpretation as to what precisely is tunnel and what covered way in Manhattan itself have resulted in various tunnel lengths being quoted. It appears that the net tunnel length of the Hudson River tunnel is 13,685 ft. and the gross covered length 15,600 ft. (2 miles 1,680 yd.) Similarly, the East River tunnel is 12,995 ft. net and 14,172 ft. (2 miles 1,204 yd.) gross. The franchise for the work was secured on October 9, 1902, and construction work on the tunnels was begun on June 10, 1903. The Hudson River tunnels were joined on October 9, 1906, and the East River tunnels on March 18, 1908. The station was begun on May 1, 1904, and the tunnels and station opened for public traffic on November 27, 1910."

x x x x x x x

The Santa Fe has just one mile long tunnel, the 5596 ft. bore which takes the San Joaquin Valley Division through the Coast Range at Glen Frazier, 23 miles east of Oakland to reach the shores of San Francisco Bay.

There are no tunnels on the Santa Fe except in New Mexico, Arizona and California and only a few in those states, as shown in Table 14.

Table XIV

TUNNELS ON SANTA FE RAILWAY LINES

State	Division	Tunnel Location	No. of Tracks Through Tunnel	Direction of Movement through single track tunnel on double track line	Length	Grade %
Transcontinental Main Lines						
New Mexico	New Mexico	Raton No. 1	1	East	2041	- 1.90
New Mexico	New Mexico	Raton No. 2	1	West	2789	+ 0.52
Arizona	Arizona	Johnson Canyon	1	West	397	- 2.10
Arizona	Arizona	Nelson Canyon	2		414	+ 1.22 East
California	Los Angeles	Cajon No. 1	1	East	379	+ 2.2
California	Los Angeles	Cajon No. 2	1	East	468	+ 2.2
California	Valley	Muir #1	1		1230	+ 1.0 West
California	Valley	Muir #2	1		300	+ 1.0 West
California	Valley	Glen Frazier	1		5596	+ 0.80 West
						+ 0.20 East
California	Valley	Richmond	2		860	+ 0.20 West
						+ 0.20 East
				Total	9644 ft.	
Branch Lines						
Arizona	Albuquerque	Sycamore (A)	1		568	+ 1.20 East
Arizona	Albuquerque	Harcuvar (B)	1		241	+ 1.25 East
				Total	809	
				Grand Total	10,453 ft.	

(A) On Clarkdale Branch
(B) On Parker Branch

Ten single track tunnels with an aggregate of 9,179 feet and two double track tunnels totalling 1,274 feet in length are a relatively small total for the 13,100 mile Santa Fe, especially in view of the mountainous terrain which much of its mileage crosses.

There are, however, 16 short tunnels, totalling 6,993 feet in aggregate length on the north slope of the Tehachapi Mountain which are embraced within the 67 miles of Southern Pacific trackage used by the Santa Fe between Mojave and Kern Junction, Bakersfield, California.

No tunnels were included in the Santa Fe improvement and development program which is the subject of this thesis. It might therefore appear inconsistent to include a chapter of such length on this topic but it has been discussed in detail to inform the reader why this surprising fact is true.

Unless a major relocation of the Santa Fe's route over Cajon Pass and the Arizona Divide may be made some day, there will be no important future additions or revisions to this short list of Santa Fe tunnels.

Chapter VIII

SECOND TRACK

It was pointed out in Chapter II that Wellington's classic "Economic Theory of Railway Location" divided grades and curves into two groups ; (1) those grades, and occasionally curves, are of primary significance, or effect, which establish the maximum weight or length, that a locomotive can haul. Such grades, which are not necessarily the maximum ones, are called ruling grades. (2) Grades or curves which do not limit train load have a secondary effect on cost and influence it through adding to the expense of operation of each train but do not determine the number run. Grades which are less than ruling grades increase costs by the additional rise and fall which results from them, measured in feet of elevation through which the train must be raised and lowered. Curves interpose additional resistances that are equivalent to grades.

It is significant that the work done in raising a ton of train weight one foot in elevation is equal to that required to move it through many (i.e. up to 667') feet of horizontal distance. A heavily loaded freight car interposes frictional resistance of three pounds per ton of its gross weight to movement on a level tangent track. It follows then that moving a ton of train weight through a distance of one mile (5,280 x 3 lbx.) requires 15,840 foot pounds of word to be done. When a ton of train weight is lifted one foot in elevation (irrespective of rate of grade) 2,000-foot lbs. of work is performed. Dividing 15,840-foot lbs. of work (representing the work of hauling a ton of freight one mile on level tangent track) by 2,000-foot lbs. (representing the work done in raising a ton of train weight one foot along a frade of any rate) establishes the fact that lifting a ton of train weight 7.98 feet in elevation requires as much work to be done as in hauling it one mile on level tangent track. Stated in other terms, raising a ton of train weight one foot represents the work done in moving it 667 feet on level tangent track (i.e. 2000 ft. lbs. ÷ 3 ft. lbs.). A continues one percent grade raises a ton of train weight 52.8 feet in one mile. The work done is 52.8 x 2,000 of 105,600 foot lbs. This represents the equivalent of 6.7 miles of haulage on level tangent tracks.

Since the frictional resistance of movement must be added to the work done in overcoming changes in elevation, the total work requirement to move a train up a mile of 1% grade is therefore 105,600 foot lbs. plus 15,840 per lb. or a total of 121,440 foot lbs. A ton of train weight could be moved 40,480 feet (121,440 ÷ 3) or 7.7 miles by the expenditure of the same force on straight level track. This operating relationship indicates the magnitude of costs which arise out of grades.

Hauling freight trains up grades gives them "velocity height" or "potential energy" that can be utilized on the descending grade to produce velocity which can be used to relieve the engine in pulling the train up a succeeding ascending grade, after the familiar principle of the roller coaster. However, unless the descending grades are of moderate length and rate (note this is a prime factor on ascent and descent alike) and are free of speed restricting curves, it will be necessary to dissipate the kinetic energy, or velocity height, of the train through application of the brakes. The importance of keeping ruling grades and total rise and fall (measured in feet) to minimum proportions consistent with the physical terrain crossed is obviously a matter of prime importance.

The basic grade characteristics of the Santa Fe have been discussed at length in Chapter III and are summarized in Table IV.

Reference to the present ruling grades in Table IV in Chapter III will facilitate the reading of the remainder of this chapter.

These were established by work performed during the Ripley administration (1896-1919) through the construction of the Belen Cutoff, or Transcontinental Short Line, and the addition of the second track on all mileage between Dalies and San Bernardino where the original line was laid on an ascending grade that exceeded the new standards. These were 0.60% over the 1,600 miles between Chicago and Winslow, Arizona (with the noted exception of 0.8% on Missouri Division.)

Ruling grades west of Winslow were established as 1.42% east and west across Arizona with the 1.8% helper ascent for 22.9 miles from Ash Fork to Supai. The ruling grades across southern California are 1% in both directions with helper grades as outlined in subsequent paragraphs.

Nothing short of complete reconstruction of the 613 miles of very expensive railroad between Winslow and Needles, which of course is a fantastic suggestion even to contemplate, can modify the present grade characteristics of that line due to the extremely high elevations which must be surmounted and which extend continuously for long distances. These are definitely fixed and unchangeable. This will long, possibly permanently, remain one of the two most difficult operations in America, measured from volume of tonnage to be raised and aggregate elevation to be overcome. The other instance of like proportions is the eastward climb of Southern Pacific's "Overland Route" over the Sierras from Roseville, California, to Norden and subsequent descent down to Sparks, Nevada.

It is worthy of special note that it is this tremendous concentration of rise and fall between Needles and Winslow, rather than the rate of grade itself, which makes the Santa Fe crossing of the Arizona plateau such an extremely difficult operation, measured in terms of the locomotive forces which must be expended on each ton of train weight.

The physical characteristics of the main line across southern California, at a superficial glance, appears to be an equally, if not more difficult, line by reason of the 2.2% eastward and 1.6% westward grade over Cajon Pass and the 1.42% westward ascents from Needles to Barstow. Actually this is a much more satisfactory set of operating conditions than the crossing of the Arizona divide. Eastward freight trains surmount only 17.3 miles of grades in excess of 1% crossing southern California. This distance, of course, represents the 2.2% helper grade from San Bernardino to Summit.

The westward grades from Needles to Barstow are actually 1.42% but their concentration permits them to be operated as helper grades from Needles to Goffs, 31.1 miles, and Cadiz to Ash Hill, 38.6 miles. The westward ascent of Cajon Mountain entails only 19.2 miles of 1.6% grade from Victorville to Summit. A helper is attached at the former station. The grade is virtually a continuously descending one from Summit to Los Angeles.

The second track construction accomplished on the Santa Fe since 1920 has not effected any improvement in ruling grades, for reasons stated. It has however, eliminated a considerable amount of rise and fall which is not only objectionable for the physical reasons indicated but also pitches and sags in the profile which causes the slack in freight cars alternately to run in and out in a manner that is objectionable to train crews and can cause damage to lading and occasionally breaks couplers and draw-bars. If this occurs, it always entails a delay to train movement while the damaged car is set out on the nearest siding and occasionally such an occurrence results in an accident. It is the pitches and sags in the profile which cause the conditions which labor union lobbyists try to capitalize fpr train limit and excess crew laws. The best way to correct slack action in freight trains is to improve profiles. This cannot be done by legislation - but requires engineering and management to plan and capitalize to pay for the cost of the work.

* * * * * *

As traffic increases over any line, certain betterments that increase capacity will provide operating economies in excess of interest on the investment which the improvement will require. Double tracking a single track railroad (or providing its present equivalent, cTc) should begin when train density reaches a point at which more than 10% of the total train hours on any engine district represent delays to inferior trains on sidings waiting to be met or passed by superior trains.

L. F. Loree, in "Railroad Freight Transportation," (written in 1922 before cTc was known) concludes that while a single track may handle 60 trains daily, whenever density exceeds 40 trains per day, double tracking should begin on those sections of track where any considerable number of trains regularly meet and pass each day. The second track should be built to protect approaches to terminals, long maximum grades and other natural points of congestion and portions of the line where the time table creates many meeting and passing points. A double track line, with sufficient passing sidings and properly signalled, has at least four times the capacity of a single track railroad. Double track routes are gradually expanded into three or four track systems after daily movement exceeds 75 trains. As in the case of initial double tracking, experience indicates points of congestion where the third and fourth tracks are most needed; usually approaching principal terminals but there is very little multiple track mileage, i.e. 3rd and 4th track, on western lines.

In 1925, a method of dispatching trains on single track lines was devised which increases their capacity about 80 per cent compared with the maximum train movement otherwise possible. Centralized Traffic Control, or cTc as it is more commonly known, provides an efficient and flexible method of directing train movement over an engine district or superintendent's division entirely by signal indications controlled from a central machine in the dispatcher's office. On lines equipped in this manner, trains enter and leave sidings by signal indications rather than by time table and train orders. The movement of the switches is usually, although not invariably, actuated by electric power, remotely controlled from the same machine as that which operates the signals. Since the investment required to equip a line with cTc is from but 10 to 25 per cent of the cost of double tracking and it produces immediate important operating economies and service improvements even on single track lines which are not overcrowded with trains, its use is becoming more widespread each year. Whenever train movements average 1 per hour, or 24 per day, it is advisable to install cTc with power thrown switches. The Wabash and Rock Island have made economically advantageous installationsof modified cTc (i.e. with hand thrown spring switches in lieu of power switches) on lines with a train density of only 12 per day. cTc is reviewed in considerable detail in the subsequent chapter on Signals and Interlockers.

The Santa Fe emerged from reorganization on Jan. 1, 1896. Edward P. Ripley, one of America's outstanding railway men was called from the Burlington (like his great successor, F. G. Gurley) to become the first President of the new company and served until 1920. He found the Santa Fe an inadequately developed and poorly maintained railroad but quickly laid broad and strong foundations for its present greatness by the comprehensive and courageous programs of betterments which followed year after year throughout his administration. Chief among these was the extensive progress made in double tracking the main line and the equivalent work of providing the Transcontinental Short Line by new construction from Amarillo to Belen and Dalies, N. M.

When Ripley became President the Santa Fe had only 16 miles of double track. When he retired at the end of 1919, it had 1,129 miles of second track, 29 miles of third track and 7 miles of fourth track.

The increases in mileage of second track and multiple track between 1920 and 1948 are summarized in Table XV below:

Table XV

CHANGES IN ADDITIONAL MAIN TRACK MILEAGE

As of End of Year	MILES OF 2nd track	3rd track	4th track	Total
1920	1129	29	7	1165
1925	1596	39	6	1641
1930	1824	46	10	1880
1935	1828	46	10	1884
1940	1851	46	10	1907
1942	1856	44	10	1910
1948	1945	49	15	2009

Reference is also made to Table XVI-A on Page 144 for location of second track on transcontinental lines.

It should be noted that all Santa Fe second track has been built to 14' minimum track centers on tangents except the first construction of this character on the north (or east) slope of Raton Pass where 13' 6" spacing was used. Clearances between tracks must be increased on curves to allow for the overhang of equipment. The necessary increase in spacing is determined by the maximum length of passenger cars and locomotives and the degree of the curve. Proper adjustment for these conditions have been added by the Santa Fe to procure adequate clearances between trains passing on curves.

The progress made in double tracking the Santa Fe may be summarized as follows to outline the route miles equipped with second track at the end of the Ripley administration.

There was continuous double track for 643 miles from Chicago to Mission, Kansas, 7 miles west of Newton. The line between Mission, Kansas and Dalies, N. M. contained five short stretches of second track totalling 30.6 miles and in addition had been double tracked over Raton Pass from Trinidad, Colo., to Raton, N. M., 23.7 miles. The Belen Cutoff from Amarillo to Dalies, 354 miles, had provided the equivalent of a second track by this alternate route for more than 700 miles between Florence, Kansas, or Newton and Dalies but only ten miles of second track had actually been built on it between Eldorado and Augusta, Kan. From Dalies on west for 800 miles to San Bernardino, beyond which alternative routes provided two tracks for the railway into Los Angeles, seven stretches of double track were in service between the following stations:

	Miles of Double Track Line
Rio Puerco, N. M. to Suwanee, N. M.	15
McCarthy's N. M. to Horace, N. M.	10
Baca, N. M. to Perea, N. M.	29
Winslow, Ariz. to Yampai, Ariz.	166
Topock, Ariz. to Bagdad, Cal.	103
Daggett, Cal. to Hicks, Cal.	21
Summitt, Cal. to San Bernardino, Cal.	28
TOTAL	372 miles

The foregoing data may be recapitulated by pointing out that the 2225 mile route from Chicago to Los Angeles via the Northern District through La Junta and over the Raton Pass included 1068 miles of double track. The route via the Southern District had 10 miles and there was only about 60 miles of double track on all of the other system lines.

W. B. Storey served as President from 1920 until June 1, 1933.

The construction of double track proceeded rapidly during the prosperous decade of the '20s which fell within the Storey administration (1920-1933). Seven hundred miles of second track was constructed principally on the transcontinental lines to raise the system's total to 1826 miles.

In 1920 there was 435 miles of single track and 372 miles of double track line in the 802 route miles between Dalies, N. M. and San Bernardino, Calif. By the end of 1929 the single track section had been reduced to short gap of 23.4 miles between Joseph City and D. T. Junction; Carrizo, Ariz. Except for this short distance, the Santa Fe was equipped with double track or two alternate lines over the entire 2225 miles of distance between Chicago and Los Angeles.

Intense activity between 1926 and 1929 in the bonanza oil and wheat country centering around Amarillo had increased train density on the Transcontinental Short Line within that section of the Plains Division to such an extent that 76 miles of double track had been provided between Pampa and Canyon, Texas. The continuous double track westward from Chicago, which in 1920 ended at Mission, Kansas, 7 miles west of Newton, had been extended 27 miles further to Hutchinson. A number of scattered minor double tracking projects were also authorized to avoid delays where train congestion occurred such as the 5 miles of 2nd track provided for this purpose on the east slope of the Glorietta Mountains between Fox and Rowe. No important additional second track mileage was added to the Santa Fe between 1930 and 1935.

The second track operated by the Santa Fe on December 31, 1948, is summarized below:

Wholly owned - main line		1726.81 miles
	branch line	0.99 "
	Total	1727.80 miles
Owned jointly		5.87 miles
Used under trackage rights		210.59 miles*
	Grand Total	1944.26 miles

TABLE XVI-A

The location of main line wholly owned 2nd track reported above is as follows:

		Miles
1.	Chicago to Plaines, Illinois	38.54
2.	Pequot to Carrollton, Illinois	330.56
3.	Hardin, Mo. to Kansas City	39.57
4.	Kansas City to Hutchinson, Kansas	218.12
5.	At Kinsley, Kansas	1.84
6.	Wright to Sears, Kansas	13.01
7.	Casa to La Junta, Colorado	4.57
8.	Trinidad, Colorado to Raton, New Mexico	23.79
9.	Fox to Glorieta, New Mexico	4.98
10.	Hahn to Albuquerque, New Mexico	5.11
11.	At Ottawa Jct. (S.K. Main) Kansas	1.11
12.	El Dorado to Augusta, Kansas	15.26
13.	Winfield to Newkirk, Kansas	26.41
14.	Ponca City to White Eagle, Oklahoma	6.76
15.	Cicero to Wellington, Kansas	5.48
16.	At Waynoka, Oklahoma	4.40
17.	Pampa to Canyon, Texas	74.93
18.	Farwell to Melrose, New Mexico	35.21
19.	Joffre to Vaughn, New Mexico	14.93
20.	Belen, New Mexico to Barstow, California	731.44
21.	At Bakersfield, California	3.02
22.	At Calwa, California	3.23
23.	Barstow to San Bernardino, California	83.12
24.	San Bernardino to Riverside, California	9.39
25.	Fullerton to Mission Tower, Los Angeles, California	23.08**
26.	At Los Angeles, 2nd District, Ave 33	0.73
27.	At Orange, California	4.49
28.	At Galveston, Texas	3.73
	Total	1,726.81

The 2nd track built by the Santa Fe between 1935-1948, totals 102.3 miles and is listed in Table XVI-B on the next page.

* Includes paired track as follows:

Plaines - Pequot, Illinois with GM&O	15.67 miles
Carrollton - Camden, Missouri with Wabash	15.10 "
Bragdon - South Denver, Colorado with D&RGW	104.99 "
Total	135.76 miles

**Excluding 2.2 miles of cTc equipped single track between D.T. Jct. and Bandini.

TABLE XVI -B

SECOND TRACK CONSTRUCTION
1935 - 1948

	Length	Placed In Service	Remarks
Texico, Tex., Farwell, N. M. - Clovis, N. M.	9.4 mi.	1944	Connects the important junction of Texico with the yard and engine terminal at Clovis, N.M.
Clovis, N.M. - Melrose, N. M.	24.1	1944	Continues second track from Farwell on west from terminal at Clovis
Joffre, N. M. - Vaughn, N. M.	14.9	1944	Entrance to crew terminal at Vaughn.
Through Belen	1.1	1945	Through congested yard district
Belen, N.M. - Dalies, N. M.	10.0	1943	On Helper grade and also completes 2nd track on main stem of Coast Lines
D.T.Jct. Carrizo, Ariz. - Joseph City, Ariz.	23.4	1940	Close single track gap in two track system between Dalies and San Bernardino
Colton, Calif.-Highgrove, Calif.	2.9	1944	To relieve congestion on single track line also used by Union Pacific
Fullerton, Calif. - D.T.Jct. * (Rivera, Calif.)	13.2	1943	(To provide second track, except (over the river* between (Los Angeles and Fullerton. (Used by both the trains to (San Diego and those (to San Bernardino via 3rd (district, (i.e. "freight (line.")
Bandini * - Hobart, Calif.	3.3		
Total	102.3 Miles		

* 2.2 miles from D. T. Junction, Near Rivera, California, to Bandini was not double-tracked in order to avoid construction of a bridge to carry the additional line over the San Gabriel River. However, the movement over this single track gap is directed by CTC.

These additions brought the total second track up to 1945 miles as of the end of 1948. The Santa Fe also operated 49 miles of 3rd track and 15 miles of 4th track but most of this was built prior to 1930 and this multiple track mileage, i.e. more than 2 tracks, is located largely within the Kansas City Terminal District except for 12 miles of 3rd track which provides additional capacity between the important Emporia Junction of the Ottawa Cutoff and the old main line via Topeka, east of the passenger station in Emporia and Ellinor, Kansas, where the Transcontinental Short Line going to Dalies, N. Mex. leaves the main line which extends on west to that same junction via Dodge City and La Junta.

A second track is built to provide additional line capacity, when the delays of single track operation are unduly burdensome in terms of time and cost. A complete double track gives at least four times as much line capacity as single track. Double tracking usually proceeds gradually and progressively and the transition from a completely single tracked line to a completely double track line covers a long period of years. The capacity of a single track, with adequate assignment of telegraph operators to deliver train orders at intermediate stations and sidings spaced five miles apart is 25 to 40 trains per day. Automatic block signals provide a great additional factor of safety in single track train dispatching but have minor effect upon line capacity which is largely determined by the number of operators and sidings. On the other hand, from 100 to 150 trains a day can be moved over a double track line, unless its capacity is handicapped by physical or terminal characteristics or the trains operate at different rates of speeds which frequently delay following movements.

There is a wide spread between the train density which congests an ordinary single track line and the capacity which a double track provides.

As previously stated in this chapter, cTc permits the capacity of a single track to be increased at least 80% beyond the maximum train density that is possible without it and train detention on sidings greatly decreases following installation of this improved method of train dispatching by signal installation only. The cost of cTc ranges from 10% to 25% of that incurred in building a second track yet, in most cases, will give all of the additional train movement capacity which would otherwise require a double track line to provide.

The outstanding importance of cTc makes it a separate topic in itself within the general chapter on "Signals and Interlocking" which will follow. The subject is mentioned here in order to explain why the Ripley administration built 1100 miles of double track and the Storey administration 700 miles while the exceptionally dynamic present regime has added only 100 miles of double track to the Santa Fe total. The answer lies in the single track mileage which has been equipped with cTc. This same improvement on the double track between Holliday and Olathe, 12.5 miles, has obviated the probable continuation of the third track west of the former point which marks the junction of the old main line via Topeka with the Ottawa cut-off and is within 6 miles of Argentine Yard, Kansas City. cTc is likely to obviate any considerable further construction of 2nd track on the Santa Fe until the future growth of Texas and California raises main line densities above 50 trains per day on the single track lines.

Unless present public expectations for the future growth of these two great Santa Fe states prove unfounded, it is reasonable to believe that all of the Transcontinental Short Line and also the long extension from Arkansas City, Kansas, into central and south Texas and from Riverside to Fullerton, California will be double tracked by 1960. Meanwhile, cTc will suffice for requirements of the immediate future, with consequent savings in capital and maintenance charges and property taxes. cTc is usually associated with single track operation but it greatly improves double track operation also, so as a second track is built in cTc territory, the effectiveness of both is increased. It is therefore especially sound policy to install cTc on single track lines which it is hoped will soon have a train density requiring the construction of a second track.

The description of physical characteristics of Santa Fe lines which preceded this chapter referred to the several sections of non-parallel locations of second track made to reduce ruling gradients when this improvement was made. Non-parallel locations also result from paired track operation of adjoining single track lines of diverse ownership which are pooled for joint use as double tracks. These non-parallel sections of second track are listed in Table 2 on Pages 49-50. It will be observed that the two longest non-parallel locations of double track are the ones of the latter classification, i.e. between Plaines and Pequot, Ill., with the Gulf, Mobile and Ohio, and between Camden and Hardin, Mo. with the Wabash.

While not on its transcontinental lines, it should nevertheless be pointed out that the longest section of paired double track operated by the Santa Fe is that with the Denver and Rio Grande Western between South Denver and Bragdon, near Pueblo, Colo., a distance of 105 miles. This takes second rank in length among the various sections of paired double track in the country; first place being held by the Southern Pacific - Western Pacific arrangement between Alazon, near Wells, Nev. and Weso, east of Winnemucca, Nev., a distance of 173 miles.

The preceding pages in this report have outlined the progress and location of second track on the Santa Fe. A total of 1,727.8 miles of second track is wholly owned by the System. All but 42.5 miles or 2.5%, are incorporated into the transcontinental main lines. It may also be of interest to record consecutively the location and length of sections of double track on the latter. These follow in Table XVI-C and include paired double track and double track owned by terminal companies at Chicago, Kansas City, Wichita and Los Angeles and also 34.2 miles of second track included in the Southern Pacific trackage used in the crossing of the Tehachapi Mountains between Mojave and Kern Junction, Bakersfield, California.

TABLE XVI-C

SECOND TRACK ON TRANSCONTINENTAL LINES

A. Chicago-Los Angeles via "Ottawa Cut-Off," Northern District-Newton-LaJunta-Pasadena.

Chicago-Hutchinson Junction, Kansas	670.3 miles
Kinsley, Kansas	1.8
Wright-Dodge City-Sears, Kansas	13.1
Casa-LaJunta, Colorado	4.6
Trinidad, Colorado-Raton, New Mexico	23.8
Fox-Glorieta, New Mexico	5.0
Hahn-Albuquerque-Abajo, New Mexico	5.1
Dalies-New Mexico-San Bernardino, California	802.7
Los Angeles	1.4
Total Second Track (Measured on Eastward Track)	1,527.8 miles
Total Distance Measured on Westward Track	2,224.3
Single Track	696.5 (*)
Proportion of Single Track Mileage - .	31.2%

(*) CTC equipped between Kinsley and Dodge City, 33.7 miles of which 26.3 miles is single track and 7.4 miles double track.

B. Ellinor via Eldorado-Milvane to Dalies via Amarillo.

Eldorado-Augusta, Kansas	15.3 miles
Cicero-Wellington, Kansas	5.5
Waynoka, Oklahoma	4.4
Pampa-Amarillo-Canyon, Texas	74.9
Texico-Clovis-Melrose, New Mexico	35.2
Joffre-Vaughn, New Mexico	14.9
Belen-Dalies	11.4
Total Second Track (Measured on Eastward Track)	161.6 miles
Total Distance Measured on Westward Track	765.1
Total Single Track Mileage on Route	603.5 (*)
Proportion of Single Track Mileage	79.0%

(*) Fully equipped with CTC.

C. Between Barstow and Oakland, California.

On S. P. Trackage	
Mojave-Tehachapi-Bena-Kern Jct.	34.2 miles (*)
Bakersfield	3.0
Calwa	3.2
Total	40.4 miles
Single Track	413.4
Total Distance	453.8 miles
Proportion of Single Track Mileage	91.1%

(*) Single track on S. P. between Bena and Tehachapi, 33.2 miles equipped with CTC.

D. Newton to Mulvane (via route used by passenger trains).

Total Distance	42.8 miles
Double Track at Wichita	4.1
Single Track	38.7 miles (*)
Proportion of Single Track Mileage	91.5%

(*) Fully equipped with CTC.

E. San Bernardino to Los Angeles over "Third District" of Los Angeles Division via Fullerton.

San Bernardino-Riverside Jct.	9.4 miles
Fullerton-Los Angeles (except 2.2 miles of S.T. between D. T. Jct. and Bandini)	23.4
Total	32.8 miles
Total Distance	72.2
Single Track	39.4 miles (*)
Proportion of Single Track Mileage	54.6%

(*) Fully equipped with CTC.

F. Holliday to Emporia via Topeka - 114.2 Miles (all single track). Not equipped with CTC.

Recapitulation

Proportion of Single & Double Track on Various Routes Between Chicago & Los Angeles.

Route	Total Distance via Eastward Track	Single Track Miles	Single Track %	Double Track Miles	Double Track %
"Ottawa Cut-Off"-LaJunta-Pasadena	2,224.3	696.5	31.2	1,527.8	68.8
Topeka-LaJunta-Pasadena	2,241.9	807.3	36.0	1,434.6	64.0
Ellinor-Augusta-Amarillo-Fullerton	2,213.9	603.5	27.2	1,610.4	72.8
Topeka-Newton-Wichita-Amarillo-Pasadena	2,238.6	637.4	28.4	1,601.2	71.6

CHAPTER IX

REVISION OF GRADES AND CURVES

An introduction to this subject necessitates reference to the outline of physical characteristics of railways included in Chapter II. It pointed out the factors which necessitate the use of curves in railway construction and the handicaps which they impose upon railway operation. Any deviation of the train from a straight line introduces elements of friction which require work to be done to overcome them. Moreover, the centrifugal force produced by trains rounding curves not only can cause minor discomfort and annoyance to passengers on fast trains and occasional damage to contents of freight cars but these same conditions increase wear and tear on equipment and track and cause derailments if permissable speeds are exceeded.

The objections to curves are minimized if they are held to such standards of minimum radius, expressed in degrees of circular measure, as will be safe for the same speeds on the curve, as are authorized on the adjacent tangent track. A train can safely run around a 6° curve at 40 MPH if the outer rail is superelevated 5". Since a 40 MPH speed restriction represented no handicap to train operation at the time railroads were built, 6° curves were commonly used except where ones of longer radius could be introduced without adding appreciably to construction costs. As railway construction and operating standards advanced in the last two decades of the Nineteenth Century, and lines were double tracked or otherwise improved, the 3° curve, i.e. 1910' radius, was considered to be a desirable standard. A curve of this radius permitted 65 mile operation with 6" of superelevation. Since 70 miles per hour was the general maximum authorized speed on even the principal railroads until 10 or 15 years ago, a 3° curve was not then considered a handicap to railway operation. The superiority of the longer radius was recognized, but there was no urgent necessity to revise railway alignments to obtain easier curvature until streamliners were built which could maintain sustained runs of 70 to 100 MPH. The continuing improvement in rail and track structures, as well as competitive transportation conditions, then spurred the railroads to incorporating these rates of speed into passenger train schedules.

The formulae for measuring Kinetic Energy is $\frac{WV^2}{2G}$; where W equals the weight of the train; V, its velocity; and G, the rate of acceleration impressed by the force of gravity or 32.2 feet per second. It is clearly apparent that great energy losses occur when trains must slow down around speed restricting curves and then reaccelerate after they have been traversed.

Since the Kinetic Energy of a train moving 100 MPH is four times that which it possesses at 50 MPH (i.e. 100 squared equals 4 times 50 squared, for 10,000 = 4 x 2500), a speed reduction from 100 MPH to round a 50 MPH curve entails a dissipation of 75% of the Kinetic Energy of the train. Similarly to reduce speed from 70 MPH to 50 MPH means a dissipation of nearly half of the Kinetic energy, i.e. as 70^2 is to 50^2 (or 4900 is to 2500). Accordingly, reduction of speed restricting curvature in high speed territory is not only essential to the sustained operation at maximum velocities, and hence fulfillment of minimum schedules, but becomes an important factor in the conservation of forces which are produced at heavy cost to move long trains at high speeds. The effective utilization of Diesel power requires that its capacity for high speed operation shall be continuously maintained over the longest possible distances with minimum interruptions by speed restricting curvature and other avoidable handicaps.

The Santa Fe like most railroads was originally built to 6° standards of curvature except where easier ones were conveniently and economically obtainable or sharper ones were introduced to reduce construction costs. The program of second tracking and line revision accomplished during the Ripley and Storey administrations (1896-1933) was done when 3° curves (on which 65 MPH velocity is safe and comfortable with 5" or 6" superelevation) were considered the best standard necessary for this radius did not handicap the conventional passenger train speeds of those periods.

The introduction of the Diesel locomotive on the Santa Fe in 1935 and '36 promptly proved that curves of this radii were unsuitable for the operating speeds which the Santa Fe would need to use immediately and these could be expected to increase progressively over future years. Accordingly, when Santa Fe's continuing program of improvements were resumed during the Bledsoe administration, the 3° standard for curves was raised to 1°30' or 4300' radius. Trains can run around these at 90 MPH.

This was established as the objective to which the curvature on Santa Fe main lines would be revised as rapidly as economic conditions permitted but always giving due recognition to the fact that in certain mountain areas construction costs might indefinitely postpone any major improvements of this nature. However, since improved alignment is intended to permit high speed operation it is not necessary to reduce curvature on steep grades to longer radii than may be necessary to conform to the rate at which the fastest trains can ascend them or may represent the limit of safe braking speed on the down grade. The crossing of Raton, Glorietta and Cajon Passes fell within the latter classification; but elsewhere on the Santa Fe, including the lines on 1.42% grades over the Arizona Divide and in California, the speed potentialities of Dieselized trains indicate the pressing desirability of curve reductions wherever the radii are in excess of $1^{\circ} 30'$.

When alignment is to be improved it is not the practice to start at one end of the railroad and proceed in geographical progression to lengthen the radii of the curves one by one, or to make the necessary revisions which will both do that and eliminate some curvature altogether. It is the better and hence the accepted practice, to study the physical characteristics of the line and ascertain those curves which will permit the maximum benefits to be gained in removing speed restricting alignment within the budget available for that purpose. Children are taught as a rule of conduct to tackle the hardest jobs first and leave the easier ones until the last but in the improvement of alignment of railroad tracks, it is considered good practice to reverse this order and do the simplest tasks first and leave the most difficult and more expensive revisions until the last. By spreading a given sum of money in this way over a larger number of easier projects, more benefits can be obtained in schedule improvements than would be possible if the expenditures were concentrated in a much fewer number of more difficult places. Likewise, where long and otherwise continuous stretches of high speed track are broken only by a short section of speed restricting curvature it is much better to eliminate it than to do equivalent work in other locations where a much lesser additional extent of continuous high speed track can be obtained through the resultant improvement.

Line revision entails work train and other construction service, which interferes with high speed operation. It is often desirable to limit the number of such projects on one division or subdivision in order that the train movement over it will not be unduly handicapped. Rather than have a number of such improvements under way at one time within a limited section of the road, it is better practice to diffuse these improvements and the related expenditures over the entire length of the line. For this reason, improvements in alignment are evident through all of the Santa Fe's primary main line mileage and have not been concentrated within limited portions of it.

Important progress has been made in eliminating curvature on the Santa Fe which restricts continuous maximum speed operation of trains. Notwithstanding the extent of the work already done, a considerable mileage of speed restricting curvature remains that should be corrected in future years. This statement is made with full recognition of the fact that the Santa Fe is in an unusually favored position in respect to standards of alignment in relation to railroads in general and its competitors in particular.

If the Santa Fe continues to press this feature of its improvement program vigorously for another decade, few if any curves will remain on it that will restrict the maximum speed of trains otherwise possible on that section of track. Due recognition, however, must be taken of the fact that terminal zones and ascents and descents of mountain grades (i.e. in excess of 1.50%) impose speed restrictions which make it unnecessary to reduce curvature below the rates equivalent to the maxima at which trains can run on tangent track in those places.

When the revision of alignment was begun in 1935-36 to adopt the Santa Fe for Diesel locomotive operation,,1°30' was first designated as the new standard of curvature. It permits 90 M.P.H. operating speeds and continued to set the pattern for line revisions until 1941. Messrs. Engel and Gurley then decided that curved alignment on high speed tracks should not exceed 1° if practicable of attainment. That radius was designated as the objective of future line revisions and curves of lesser degree are used if possible of attainment without uneconomic increases to construction cost.

Five inches of superelevation will permit trains to run 100 MPH on 1° curves but this heighth of the outer rail is unsatisfactory for the slower moving freight trains which bear heavily against the inside, or low rail. To meet the conflicting requirements of streamliners and heavy freight trains $0^\circ 50'$; $0^\circ 40'$ and $0^\circ 30'$ curves are being used whenever possible. These will allow 100 MPH operating speeds and higher with 3", $2\frac{1}{2}$" and 2" of superelevation respectively which minimizes rail wear of freight trains. However, a 30' curve has a radius of 11,459 ft. or more than 2 miles. The $0^\circ 40'$ curve has a radius of 8,594 and the $0^\circ 50'$ curve, 6,876 ft. Obviously, these curves are not susceptible of general use except over favorable terrain.

In no field of railway engineering or operation has the leadership of the Santa Fe been more conspicuously evidenced than in the elimination of speed restricting curvature. Such projects require the higher degree of courageous imagination because their principal benefits cannot be immediately gained but must await the cumulative effect of the complete program which will inevitably require a long period of time to accomplish. Individual line changes frequently appear unimportant or of minor advantage in relation to their cost but when the final objectives of sustained high speed operations are achieved, outstanding operating and competitive advantages are gained which multiply the benefits of the component projects.

Santa Fe line changes have advisedly been made where maximum benefits are obtainable immediately. While much of this improvement of alignment has been done along the mountain divisions of the west, nevertheless even here these construction projects have seldom required unusual quantities of grading measured in cubic yards of cuts and fills. Generally, the line changes made have been short relocations to reduce both the sharpness of curvature and the total angular deviation of the main track from a straight line.

While the aggregate length of relocated lines have been very considerable and the total quantities of excavation and fill have been large, individual line relocations have generally been short. Probably the longest line changes have been ones of approximately 5 miles aggregate length at Cardy Hill in Missouri, through Querino Canyon between Cheto and Houck, Ariz. (10 miles west of Lupton on the New Mexico boundary) the relocation west of the new bridge constructed over the Colorado River at Topock, Ariz. in 1942, and the several relocations of similar length made along the treacherous Sacramento Wash from Topock east through Powell and Franconia towards Haviland. The distance from Topock to Haviland is 19.7 miles and in this zone the larger part of the present line represents new locations in respect to both profile and alignment which reduced the curvature and raised the track level substantially above known flood water levels.

Table 17 appearing on page 167 summarizes essential factors pertaining to alignment. It is to be regretted that time did not permit refinement of this data to show the number of curves and aggregate length within 1° intervals of increase in radius up to the maximum. An adequate understanding of the alignment characteristics of any railroad can only be determined by ascertaining both the number of curves and the aggregate length of those which lie in the higher ranges of sharpness and consequently have greatest speed restricting effects. While the curvature of the component divisions of the route are shown in two classifications of $0^{\circ} - 8^{\circ}$ and 8° and over, it must be pointed out that the aggregate length of the higher ranges of curvatures in the $0^{\circ} - 8^{\circ}$ grouping are usually comparatively short and this designation of the 8° maximum does not imply any considerable number, or aggregate length, of 8° curves; or those of anything like that rate.

The miles of curved track per mile of line indicates the percent of the main line mileage on curved alignment. For example, on the Albuquerque Division, 17% of the mileage is on curved alignment. The maximum proportion of curvature is found on the Los Angeles Division with 23° and the minimum, as might be expected, is on the Panhandle Division which has only 8% of the mileage on the curved track. Consequently 92% of the line is on tangent track.

As has been mentioned in the chapter on physical characteristics of line, angular measure in degrees are used to indicate both radius, hence the relative sharpness of the curve, and its deviation from a straight line. The latter represents the central angle through which the line is turned by the curve. Line changes which reduce curvature can have either or both of these effects; to wit. It can reduce the radius, or sharpness, of the curve as would be the case when a 3° curve is eased to a 1° curve and no change in the central results. A 3° curve might be of such length that it would produce an angular deviation, or central angle of 30°, in the movement of the train. The reduction of the degree of the curve from 3° to 1° might only have the effect of increasing the radius from 1910 feet to 5730 feet and still leave the central angle at 30°.

This would place the curve on a new location inside of the former one, i.e. with the new line passing between the old line and the theoretical center of both the old and the new curves but the central angle subtended by these two curves of different radii would be the same, i.e. 30° in each case.

The primary purpose of improved alignment, i.e. reduction or easing of curves is to reduce their sharpness, i.e. lengthen the radius. However, reduction in central angle is also highly desirable where it can be obtained and thus usually permits some shortening of the total length of the line; another factor of improvement, although it does not always follow. Improved alignment occasionally requires some moderate lengthening of line and grade reductions may have this effect too. Table VI on Page 87 indicates the reduction in distances via component divisions and routes which have resulted from line changes between 1935 - 1938, totalled in Table XVII.

Where a series of curves follow one another in rapid or continuous succession, it is usually possible, and always desirable, to relocate the line in order to reduce the total amount of angular deviation as well as to ease the radius of curvature. This contraction of the total central angle of curvature will probably be obtained by the complete elimination of some curves as well as by the reduction of the angular deviation produced by others.

Table XVIII summarizes those salient engineering features of the Santa Fe's work in reducing and eliminating curvature which are readily susceptible of statistical presentation in tabular form. It is a matter of regret that that there was insufficient time to prepare this data in more detailed form. While no feature of this report required more time to prepare than table XVIII, nevertheless it has recognized inadequacies. Unfortunately the more elaborate presentation that both the reader and the author would desire to summarize this subject would have required an additional allotment of time that simply was not available without neglecting the other equally important parts of this thesis.

Such factors, moreover, restricted this compilation to the Transcontinental route via the Southern District between Emporia and Dalies and over the third district between San Bernardino and Los Angeles. A great deal of work on line changes was done on the Northern District of the Western Lines via La Junta and Albuquerque, much more so in fact that on the corresponding route via Amarillo which traversed much more favorable country for railway construction and contained much the lesser mileage of line on speed restricting curves. However, since the Santa Fe's Transcontinental freight traffic moves via the Southern District and many of its most important recent improvements have been made on the Southern District and moreover because it is likely over future years to absorb more and more of Santa Fe's Transcontinental passenger services, this table considers only the Transcontinental Route via the Southern District.

The aggregate number of curve eliminations and reductions and the central angle which these represent are an impressive total and were the similar improvements on the Northern District included, it would add materially to this cumulative result.

The work of improvement of alignment is one aspect of the Santa Fe progress which it might deservedly regard with pride and satisfaction but this will not dull its realization of all that remains to be done in the future in order to achieve the maximum potentials of its great route; particularly via the Southern District, for sustained maximum speed operation from start to stop between the principal stations along that line.

In this discussion of curves and in the general remarks about them which were included in Chapter II, occasional reference has been made to super elevation which is the excess height given the outer rail over the inner one of a curve in order to produce an offseting force from gravity to equalize the centrifugal forces of the train moving around a curve at high speed.

If a 3° curve is required and the curve of this degree and radius were to be joined directly to the tangent track, the railway engineer would be confronted with the conflicting necessities of having the track at the point where the curve meets the tangent super elevated 5" or 6" on one side of this point and level at the other. Obviously this is impossible. In the early days of railroad construction and operation a compromise was sought by having the ascent of the outer rail, from the point at which it is level with the inner one up to the point of maximum super elevation, begin as far down the tangent track as was necessary to divide the transition in super elevation in the outer rail half over the tangent track and half over the curve.

However, this was distinctly unsatisfactory because the super elevation on the tangent track caused a bad lurch as the force of gravity unopposed by any centrifugal force threw the cars inwardly. This condition was reversed when the curve was reached and the centrifugal force momentarily exceeded the force of gravity on the inadequately super elevated section. This produced a double jolt; first in one direction inwardly and then outwardly in entering a curve. The effect was repeated in reverse order upon leaving the curve. The problem was soon solved by introducing a spiral (also called a transition curve) between the end of the tangent track and curve.

A spiral, of course, is a curve having a variable radius which starts at infinity, i.e., is a straight line, and decreases progressively in relation to its length until finally it narrows to a point and the radius becomes zero. Spirals may have any desired geometrical relationship between the decrease in the radius as the length of the spiral increases. The spiral in most common use is the cubic spiral. It is so designated because its radius decreases inversely with the cube of the length of the spiral. All main track curves should be spiralled and the length of the spiral must be adjusted to the maximum speed of train operation.

The purpose of the spiral is to increase the super elevation of the outer rail at an even rate of ascent from zero at the point of tangency to the maximum required by the operating speed desired around the curve. Since the spiral is a curve of varying radii, the super elevation along it will be equivalent to that which is required by a simple curve of the actual radius at any point. At the end of the spiral, its radius will have contracted to that of the simple curve which continues on from there as the required super elevation will have been attained. The length of a spiral is determined by the number of inches of super elevation which it must attain and the maximum speed at which the train will run and so ascend to this super elevation.

It is found in practice that a train will be jolted by a spiral if its length is so short in relation to the speed of the train moving around it that the outer wheels are super elevated faster than 1¼" or 1½" per second of movement. If a spiral is longer than necessary to meet the requirements of maximum speed operation, it has no adverse effect upon the riding quality of the track for trains at that or lesser speeds; in fact, it is further improved. However, if spirals are shorter than desirable for the authorized speed they will cause trains to lurch and jolt.

Spirals are more expensive to install and maintain than simple curves so it is in the interests of economy to keep the former to whatever minimum lengths are needed. Atrain running 100 MPH traverses

147 feet per second; 88 feet per foot per second is equivalent to 60 MPH, etc. It follows that if a curve is being spiralled for 100 MPH speeds and requires 5" of superelevation that it must be 588 ft. in length (5" divided by $1\frac{1}{4}$" x 147 ft.) If $1\frac{1}{2}$" of increased super elevation is permissible per second of train travel a 488 ft. spiral would be sufficient (5" divided by $1\frac{1}{2}$" x 147) but the longer spiral will produce the smoother train movement.

The rate of increment in the degree of curvature developing along the length of the spiral must be such that it will have been reduced from a radius of infinity at its beginning, or PTS (point of tangent to spiral) to that of the curve at the PSC (point of spiral to curve). Spirals must be located at both ends of the curve. If the curve which extends beyond the spiral is not a simple one, that is to say, does not have a constant radius but is a compound curve, i.e. formed, or compounded, of two or more curves of different radii, but which do not change the direction of angular deviation (and thereby become a reverse curve), a spiral is the best means of effecting the transition from one curve to the other.

High speeds necessitate longer spirals as well as easier curves. It follows that wherever alignment has been revised, spirals of the required length were incorporated as an important feature of the plans for the new work. However, where existing curves were not revised, for any one of many reasons, the Santa Fe has nevertheless lengthened spirals on all of these where this was necessary to make transition curves consistent with the operating speeds authorized around the curves which they connect to adjacent tangents.

Curves $1^{\circ} 30'$ and less, of course, were built into railroad alignment where economically practicable long before the days of 100 MPH streamliners. However, when maximum operating speeds were lower, these curves did not require either the length of spiral or the super elevation necessary for present requirements. It has accordingly been necessary to increase super elevation and spiral lengths on many existing curves of this rate in order to adapt them to present maximum speeds. Likewise, curves of radii sharper than $1^\circ 30'$, while interposing restrictions to present maximum operations, nevertheless can be traversed at higher speeds with lengthened spirals and increased super elevation than would otherwise have been possible and so these improvements have been made to obtain the most effective utilization of the line.

The revision of spirals and super elevations is not a feature of an improvement program which attracts public notice but when carried out on the very extensive scale involved in the betterment of the Santa Fe main lines, it represents an important and expensive task. For that reason, this feature of the correction of SantaFe alignment has been given such detailed explanation in the chapter on "curves."

Maximum train speeds are achieved by the accumulative effect of improvement in the physical characteristics of lines and the engineering standards of construction and maintenance of tracks, bridges and signals. All of these factors play their part in determining the rates at which trains can run. Just as a chain is no stronger than its weakest link, so any one of these can nullify the benefits obtained by development of the other components of the railway plant.

The standards of Santa Fe main line track, bridges and signals are being developed to permit the full utilization of the maximum speed potentialities of its fastest locomotives. Where speed restrictions occur they are almost invariably due to physical characteristics of the line, i.e. the grades and the curves; rather than to limitations of track, bridges or signals.

The Santa Fe's Diesel powered streamlined passenger trains can run 100 mph. Those on the three daily transcontinental runs are routed over the "Northern District" through La Junta. The maximum authorized speed over the main lines of the Illinois, Missouri, Eastern and Middle Divisions between Chicago and Newton, Kansas, is 90 mph. All component main line districts of the divisions between Newton and Los Angeles via the Northern District allow 100 mph operating speeds for streamlined trains. The route from Newton to Wellington and thence via the Southern District, which is not traversed by these services, is restricted to 80 mph maximum authorized speeds, except 85 mph is authorized on the Middle Division between Wellington and Wichita and Newton.

These maxima, however, are not continuous but are interrupted by numerous speed restrictions where grades, curves and other operating handicaps interpose them. The working time table of each division and the standard signs along the roadway designate the lengths of track over which speed must be restricted below the established divisional maximum. The extent of the detailed restrictions imposed on continuous operation at the maximum speed authorized on each division are tabulated in Exhibit IV. Most of these limitations, outside of terminal zones, are required by curvature. The aggregate number encountered on the 2,200 mile transcontinental runs still appears high but nevertheless do not prevent the punctual operation of 39-3/4 hour streamliners between these distant terminals.

Speed restrictions can be most effectively presented by a chart which plots the authorized speed as the ordinate against distance along the line as the abscissae. This will show the extent of the route which can be traversed at maximum speed and indicates the location and length of all that are imposed by external conditions and the extent to which speed must be reduced in each case. A chart of this nature for the Santa Fe main line would be a very interesting study in itself but unfortunately time does not permit preparing one.

It could be made much more informative if the similar speed data for representative past years should also be plotted on it. This would show the increased speeds and reduced numbers and aggregate length of speed restricting conditions which have followed the Santa Fe's very extensive program of improvement of its alignment. It would also indicate what remains to be done to correct remaining conditions which interfere with continuous maximum speed operation.

The work already accomplished, when reflected against that which remains to be done only indicates what a gigantic task is involved in adapting any railroad, particularly one traversing mountainous country, to the requirements of high speed operation. It would thereby prove the foresight, courage and ability displayed by the Santa Fe in undertaking a program of such gigantic scope and dimension. What has already been done in reducing and eliminating curvature is the best proof which can be offered of the probability that the speed restricting curves which remain in Santa Fe high speed tracks will be revised to the desired standards at a progressively rapid rate. One may expect that in another decade, few if any speed restricting curves will remain in Santa Fe main tracks except where these lie in terminal zones and cross the most rugged mountainous terrain.

At the present time the principal work of this character now in progress is being done on the twelve miles of line between Holliday (13 miles west of Kansas City) and Olathe where the line follows the tortuous valley of Mill Creek, for 12½ miles to climb, 260 feet from the banks of the Kaw River to the plains which comprise the higher ground lying to the south and west.

Curvature in the 7-mile Canyon of the Mora River between Shoemaker, Valmora and Watrous, N. Mex., now imposes 45 MPH speed restrictions there. This is one of the most serious handicaps to speed that remain except on lines located on heavy mountain grades. This would suggest that this might be the scene of a major line revision except for the probability that the ultimate re-routing of streamliners over the Southern District probably will lead the Santa Fe to withhold important future capital expenditures on the alternative route via the Raton Pass.

Santa Fe leadership has been shown as forcefully and effectively in the line changes which it has made since 1935 in order to permit increased operating speeds by its new locomotives, steam as well as Diesel, as in its foresight in being among the first to utilize Diesel motive power. In fact, the two go hand in hand.

The Santa Fe has achieved great progress in both respects; but much remains to be done before the program for each can be considered as fulfilled.

Railroad tracks not only have curves located in the horizontal plane but also those in the vertical plane. Vertical curves are used to avoid bringing the profiles to an abrupt intersection at grade changes. This is done by smoothing out the change of direction of movement in the vertical plane by introducing a curved profile.

This serves as a transition curve just as a spiral does for a curve in the horizontal plane.

Faster speeds necessitate lengthened vertical curves as well as spirals and so work of this nature also has been necessary at many hundreds of points where grades change.

Likewise, where curves in the horizontal plane are of 4° to 6° of sharpness or greater, it is customary to protect the gage side of the rail, which will have inside position, i.e. be the low rail around the curve, with a flange oiler located a short distance in advance of the entrance to the curve. This flange oiler will be mechanically actuated by the wheels of passing trains and squirt a few drops of heavy oil on their flanges. This will reduce the friction of slow moving freight trains which bear heavily against the low rail and wear out the low rail rapidly under heavy traffic unless flange oilers are provided. These materially prolong the length of life of rail in this position on sharp curves and therefore are properly considered in connection with the program adopted by the Santa Fe to minimize the adverse effects of curvature upon operation.

IMPROVEMENT IN ALIGNMENT - TRANSCONTINENTAL ROUTE CHICAGO - LOS ANGELES — Table XVII

VIA FREIGHT LINE THROUGH ELDORADO AND BELEN

1935 - 1947

DIVISION	PRESENT TOTAL NUMBER OF CURVES (*) EB	WB	MAX. CURVE OUTSIDE OF TERMINALS	NUMBER OF CURVES REDUCED EB	REDUCED WB	ELIMINATED (**) EB	ELIMINATED (**) WB	REDUCTION OF CENTRAL ANGLE (**)
Illinois	158	158	6° 00	30	30	2	2	14° 46
Missouri	199	199	10° 00	58	58	13	13	471°00
Eastern	91	91	4° 00	11	11	2	2	-
Middle	91	91	5° 30	15	15	0	0	-
Panhandle	35	35	3° 00	8	ST	2	ST	25° 22'
Plains	130	130	4° 00	25	ST	18	ST	575° 31'
Pecos	113	113	4° 00	8	ST	0	ST	-
Albuquerque	405	422	10° 00	83	90	30	30	474° 53'
Arizona	288	278	8° 00	59	57	18	18	397° 53'
Los Angeles	186	195	10° 00	14	14	3	3	86° 17'
Total	1696	1712		281	245	88	68	2045° 42' (***)

Add Curves Revised or eliminated on single track lines	41	20
Total	281	88

(*) Curves Eastbound are total of those on eastward track of double track lines plus all curves on single track lines. Curves westward are counted similarly.

(**) In order to avoid duplication in count of curves reduced or eliminated, data for single track lines is shown in column for eastward track only. When both curves of parallel double tracks were reduced or eliminated, this is reported in column for each direction but reduction in central angle is for the line without a duplicate count for second track.

(***) Equal to 5-2/3 complete circles.

Chapter X.

SIDINGS

The capacity of railroad lines is a complex subject. It cannot be stated with precision in number of trains or cars per hour or per day and there are no mathematical equations to combine and weight the component factors which establish line capacity. Physical characteristics of grades and curves and the tractive effort and horsepower of maximum size locomotives are important determinants of the speeds at which trains can run and the loads which can be hauled. The available number of locomotives bears an obvious relation to line capacity and so do the engineering standards of track and bridge construction and maintenance, and the adequacy of signals and sidings and other important auxiliaries.

The dense population of England and of Europe and the short distances between cities led to the original construction of many of their railroads as double track lines. In contrast, the population in the United States was sparse and the distances great, so most of the original construction, even of the railways serving the principal eastern cities started as single track lines. Train movement practices, i.e. train dispatching, therefore developed around the conditions and necessities of single track operation in this country while, abroad, the methods of train operation grew out of double track operations. Only one-seventh of the total railway mileage of the United States has a second main track and this national proportion coincides with that of the Santa Fe.

If all trains ran at uniform speed on double track and did not stop between terminals there would be no need for sidings or block signals and the lines would have immense capacity for car movement. However, such ideal conditions cannot exist and both of these facilities must be provided to meet actual conditions. Double track routes used largely or exclusively for the movement of through freight trains can accommodate from 2,000 to 5,000 cars per day in each direction. When heavy passenger traffic is superimposed upon heavy freight traffic, i.e. in excess of 2,000 cars per day in each direction, three and four track lines may be required to avoid a frequent succession of passing sidings and delays to the trains that would have to use them.*

* The reader who may be particularly interested in the general subject of line capacity of the American railroads and of foreign ones, too, is referred to an article on this subject entitled the "Railway Pattern of the United States" by Edward L. Ullman, Assistant Professor of regional planning of Harvard University appearing on pages 242 - 256 in the April 1949 issue of "Geographical Review," published by American Geographical Society of New York. A supplementary item on page 324 and 325 of the same issue should also be noted. Page 243 is authority for the following interesting statement:

"The principal long stretches of four-track lines are the Pennsylvania Railroad from Pittsburgh to New York and the New York Central from Cleveland to Albany. Three-track lines add some mileage, mostly in the same area but extending out slightly farther. The westernmost extension of triple track is Aurora, Ill., the southernmost Washington, D. C., and even these points are not connected continuously with the other three- and four-track lines. Small in extent though the multiple-track sections are, they are almost unique, few other regions have any three- and four-track sections except a few short lines (one of the longer stretches is a 72-mile segment from London to Kettering, England; another about 40 miles, from Brussels to Antwerp). Their presence in the United States reflects the concentration of enormous streams of traffic produced by the world's most highly developed continental region enjoying free trade. In other words, this is the railroad facility corresponding to American mass production for a large home market. Specifically, the three- and four-track sections are related also to topography, as will be explained later.

"The inclusion of two-track lines adds tracks particularly in the Northeast but also brings in two transcontinental lines, the Union Pacific and the Santa Fe, and main lines to the south — the Atlantic Coast Line, the Southern and the Illinois Central, and the coal-carrying roads of the Pocahontas region. Note the almost complete absence in Texas, probably explained by a combination of (1) movement through pipe lines of the principal commodity, oil; (2) the level terrain, which permits many alternative routes; and (3) the relatively recent development of the area at a time when competing transportation and improved methods of operating single-track lines were available.

"In contrast with three- and four-track lines, the United States has a much smaller percentage of double track than most European countries. In France about half the lines are two track or more in comparison with about one-seventh in the United States. In northwestern Europe double track is the rule. In the United States it is still the exception in most areas, for the following reasons:

1. Many sections are less intensively developed than northwestern Europe.

2. The number of trains is smaller on many important railroads because of the relatively lighter passenger traffic and the much greater capacity of freight trains.

3. More alternative routes are available in most sections, mainly because of competition between privately owned roads, in contrast with state or regional monopolies in Europe.

2. Because of the preponderance of single track, operating methods have been adjusted to this condition, and single-track capacity has been increased, spectacularly so in recent years as a result of the improvement of signaling.

"Between the single-track railroads of the United States differences are great, though quantitative measures of these differences are difficult to obtain. Type of ballast, roadbed, or weight of rail might be used, but the government does not report such figures, and it would be impracticable to obtain them from the individual roads. One possibility remains — signaling data. On this basis single-track roads can be divided into three categories, from highest to lowest capacity: lines with centralized traffic control (cTc), lines with automatic signals, and lines without automatic signals."

Length of sidings is determined by the maximum length of trains which in turn is a function of motive power capacity and physical characteristics of the line. The spacing, or frequency, of siding location is indicated by experience to establish the number which is necessary on the one hand to minimize delay to train movement that occurs if sidings are too far apart and to avoid unnecessary investment and maintenance costs when more of them are provided than are required.

The number of meets which occur between any number of opposing trains are primarily determined by the aggregate number of train hours required for the movement of the traffic. If it might be possible to control the dispatching of trains in one direction so that the day's movement followed each other as a "fleet" operating more as a number of sections running on one schedule than as an equal number of individual schedules or extra trains and when this movement cleared, trains used the track in the opposite direction, the greatest possible capacity of a single track line could be obtained and likewise a minimum number of sidings would be required. However, schedules are not arranged primarily to meet the preferences of the Engineering and Operating Departments of railroads but for the accommodation of the public. Trains usually run at established intervals in each direction throughout the 24 hours based upon the frequency justified by available traffic. The schedules are necessarily related to convenient departure times from initial terminals and arrival times at destinations. These general observations apply to the freight as well as to the passenger service.

In practice it is generally found that on single track lines the number of trains running in each direction are fairly uniform over the different periods of the day. On the multiple track lines approaching large cities there is an unbalance of movement into these centers in the morning and away from them in the afternoon and evening but traffic of this pattern is operated on double or multiple track lines so does not materially alter the discussion of single track siding necessities.

American railroad operating practices developed around freight train engine districts service that were approximately 100 miles long. Modern Diesel freight and passenger locomotives can easily run 500 miles without stopping for fuel or water for train heating boilers and can make two transcontinental runs totalling 4,500 miles before being taken into a shop for inspection and servicing. However, beyond that which can be done during stops at stations or in yards the railroads are still being operated in accordance with many of the practices that were established to meet the conditions of a half century and more ago when a 100 mile run represented the maximum physical endurance of the crew and the engine alike. For that reason, freight yards and engine terminals follow in succession along railway lines at intervals of every 75 to 150 miles; with the actual location depending on whatever point within that range of distances was a logical place for the purpose from the various considerations of geography, population, traffic or train operation.

The dual basis of pay applied to compute the wages of road transportation employes uses a piece rate (miles) or a time rate (hours); whichever produces the maximum compensation for the employe. One hundred miles was originally considered as the piece rate equivalent of a10-hour working day. This represents a speed basis of 10 m.p.h. for equating service miles into service time for computing pay. "The Adamson Act," passed by Congress in 1916, under duress of the threat of a nationwide railroad strike, made eight hours the basic pay period for a day's work and correspondingly raised the mileage equivalent of an hour's work from 10 to 12½ service miles.

Total train hours achieved by running trains faster will do just as much to eliminate the number of meets as will follow an equal reduction in the number of train hours resulting from a reduced volume of business or the consolidation of trains into a lesser number through raising the tonnage rating either by increasing the size of motive power or reducing the grades or both. Some railroad men seem to believe that running trains faster will create more frequent meeting points enroute. Those who hold this erroneous view overlook the fact that the number of meeting points between opposing trains on single track are determined by the aggregate number of train hours required to move the traffic over any division and not by the speed at which trains run.

If a streamliner runs over a 100 mile sub-division in approximately one hour, fewer opposing trains will have to take the siding than if its running time should be lengthened. Increasing the maximum and average speeds reduces the number of train hours and it follows that the number of meeting points, with opposing trains on single track, will be reduced in approximately direct proportion thereto. Differentials in the rates of speed between individual trains have no effect on the number of meeting points because of that particular variation itself, except through its effect upon train hours of main track occupancy. However, differential rates of speed are the primary factor in requiring trains to take the siding to be passed by following faster trains moving in the same direction. In this instance, the number of passing points will be increased as the speed differentials widen proportionately between the faster and the slower trains. It is, however, the relative speeds and not the absolute, or maximum, speeds which determine the number of passing points for a given volume and pattern of train movement. There will be the same number of passing points for a stated number of 45 m.p.h. freight trains and 90 m.p.h. passenger trains with given departure times from the initial terminal as for like number of 25 m.p.h. freight trains and 50 m.p.h. passenger trains.

The two factors of prime import in a consideration of sidings are their length and their spacing. The first is resolved by the very simple factor of what size trains must be accommodated and it is desirable to have the actual length of sidings a little longer than the theoretical requirements. Where this condition obtains, trains can move into sidings faster than is possible if it has minimum length to accommodate a full tonnage train. This has the advantage of permitting trains to clear the main line more expeditiously and therefore adds a material factor of safety as well as of line and siding capacity. Furthermore, this extra length can often be utilized to permit two short trains to occupy the same siding or one long freight train and a passenger train or work train and light engine or two to do so simultaneously. Extra siding capacity also provides for the growth in the size of trains as large motive power is added from time to time and this additional length obviates the necessity of extending sidings at that time. However, it is obvious that as trains grow to the full length of sidings, the advantages of the excess size originally procured gradually disappears.

The spacing of sidings is a subject about which there are wide opportunities for difference of opinion between railway men. For any one particular schedule or pattern of train movement, a plan of siding locations could be designed that would accommodate the service with a minimum number of sidings and possibly these might also be located at points where they could be constructed most economically and conveniently. However, the patterns of train movement change from time to time. Experience shows that where there is any considerable number of train movements per day, i.e. from eight to twelve or more in each direction which produces a total of from 16 to 24, or an average of from one every hour and 30 minutes to one every hour throughout the day, it has been advisable in the past to space full train length sidings about five miles apart. If these sidings are nearly a mile long as they should be for modern operating conditions there will be 15 sidings on a 100-mile division with an aggregate length of 15 miles and there will be sixteen $5\frac{1}{4}$ mile stretches of track between the initial and final terminal and these 15 intermediate sidings. (Actually the aggregate number of these 15 cases of one mile of line being paralleled by a siding of that length and the 16 x $5\frac{1}{4}$ miles of line without sidings alongside, or 84 miles, produces a grand total of 99 miles.)

On divisions where traffic density necessitates siding spacing less than five miles apart, obviously the additional sidings represent an inefficient method of obtaining track capacity and cTc or double track should be provided. One of several considerations to be noted in studying these alternatives is to recognize that double tracking proceeds gradually by reconstructing adjoining sidings to main track standards and by building the main track connection between them. This process may proceed slowly over a period of years. If cTc is installed, it may likewise be done on a limited basis over a small part of a division but usually it is extended at one time over the entire single track portions of the engine district between crew terminals.

As frequency of train movement decreases from the numbers of 16 to 24 trains per day or more requiring five mile siding spacing as indicated down to minimum service, the necessity of sidings obviously decreases to the point on these lightest traffic branch lines where no meets or passes regularly occur because a single engine and crew provides all of the service, possibly only on alternate days. Sidings might be abandoned altogether on such lines except for the contingency of occasional movements of an extra train in the crop moving season from an agricultural branch, etc. However, such necessities arise and a line will seldom be found that does not have one siding at least every 15 miles of sufficient length to accommodate whatever length train can be hauled by the maximum type of power permitted over its track and bridges.

Between these two extremes of five mile minimum siding spacing and 15-mile maximum, the various gradations of traffic density and other operating factors such as speed and cTc installations will determine the number of siding locations. It is worthy of special note, however, that the effect of high speed operation with cTc has suddenly reversed the practice on some lines to provide minimum siding spacing on a mileage basis and instead to establish sidings on a speed or time interval basis between these points. Recent cTc installations on some lines are using siding spacing that averages between 7 and 10 and even 15 miles apart. The increased speed of freight and passenger trains operation obtainable with Diesel power and the present control of train movement by cTc permits 10 - 15 mile siding spacing without incurring consequential delays to trains if movement averages less than one train per hour throughout the day.

For reasons which will be outlined later and which were due to political factors outside of the control of railway management, 70 cars became the established maximum length of freight trains run by the Santa Fe over the "Coast Lines" between the Rio Grande River terminals at Albuquerque and Belen and the western base of the California mountains crossed to reach its Pacific Coast terminals. This restriction was swept aside in 1942 by the necessities of meeting the transportation requirements of World War II but these prior restrictions had frozen siding lengths to a 70-car train operating maximum. Motive power had also been adjusted to this artificial car limit on operations.

This handicap was removed, in 1942, coincidentally with the arrival of the 5400 h.p. freight Diesel locomotive which hauled trains much in excess of the length of the sidings on the Albuquerque, Arizona and Los Angeles Divisions. When these new units of motive power were delivered in 1942 and '43, every transcontinental railroad was being offered all of the traffic which it could carry. The new Santa Fe freight Diesels necessarily had to haul full tonnage but whenever they departed with a train of that length, there was hardly a siding on the division that would accommodate it and it also exceeded the length of the longest tracks in the yards at either end of the run. The war also required running the maximum number of passenger trains for which the Santa Fe could provide equipment. The extra-fare streamliners, the "Super Chief" operating twice a week in each direction and the daily "Chief" were comprised of lightweight streamlined equipment. Cars of this type were not available to provide extra sections for these trains but all other transcontinental passenger schedules were run in two or more sections and there were many extra passenger trains each day; principally the so-called "main trains" for troop movements.

The problem of train dispatching to weave the many passenger trains through the fleets of freight trains moving in the same direction on the double track lines between San Bernardino and Belen was the more difficult because the lines were not equipped with facilities to direct trains to enter and leave sidings by signal indication. Instead, it was necessary to rely on timetables, train orders and messages to perform this function. Main line train movement was badly complicated and became congested during the conversion from steam to Diesel power on the "Coast Lines" by the unavoidably necessary operation of freight trains of greater length than the sidings would accommodate. Two expedients were open in this dilemma and both were unsatisfactory. The freight trains could keep out of the sidings but in that case the passenger trains must follow along behind them at reduced speed, accumulating delay. When a freight train entered a siding too short to hold it, the locomotive moved down through it and reentered the main track, pulling down enough to permit the rear end of the freight train to be in on the siding clear of the main track. This permitted the following passenger train to proceed down to the head block signal at the departure end of the siding which would be in the stop position, since the main track beyond it was fouled by the excess length of the freight train. After the passenger train had come to a full stop, the freight train would then back up on the siding far enough to permit its locomotive to clear the main track. Its rear end would trail back on the main track beyond the entering end of the siding. This kind of a movement which is colloqually known in railroad terms as "sawing by" on a siding requires that the back up movement be made under flag protection in order to avoid collision with a following train. After that awkward movement had been completed the passenger train could then proceed and the freight train would then follow it.

The delays which this type of operation produced can be readily appreciated so lengthening sidings in the Diesel operated territory west of Belen, N. M., was given a high priority in the war budget introduced by Mr. Gurley at that memorable meeting of its Board of Directors held in November 1942 to which reference was made in the opening chapter of this thesis. This type of work, however, is not spectacular so it did not attract public attention but it was all important to the Santa Fe improvement program. The previous spacing of sidings had been adequate but very few were long enough.

East of Belen there had been no laws restricting train length except a short time before the war one was passed in Oklahoma but fortunately too late to have interfered with original siding length. The war introduced no new motive power on these lines which increased train length beyond the prevailing capacity of its sidings. Additional train movement capacity was, of course, needed on the long single track lines of the component divisions, the Pecos, Plains, Panhandle and Middle through to Newton and Ellinor where a double track line extended to Chicago, but it was provided by cTc. Sidings were lengthened and increased in number, however, but for reasons other than to accommodate maximum train length which the existing ones would do.

In all of the new cTc territory, continuously from Belen to Ellinor, sidings were built or revised to standards that extended far beyond any previous practice of providing, at the most, train length ones with an additional 25% or 50% of trackage to permit so-called "non stop meets." It became the new practice to build or extend these sidings in cTc territory to two to three miles in length. In addition, these so called sidings were built, not to the usual secondary standards of such tracks, but generally to the same ones as the main track alongside. Finally to speed trains through them as will bepointed out again in the chapter on signaling, the block signal circuits were carried continuously through all sidings and subdivided into intermediate blocks with wayside signals. In all other cTc installations except these new ones on the Santa Fe, sidings have never been equipped with block signal protection through their length. Trains enter sidings under signal indication but, except on the new Santa Fe installations, these convey no information of track conditions beyond the clearance point. Trains are normally required to operate under full control prepared to stop within half the range of vision in case the track is found to be occupied.

It will be pointed out in the chapter on signals and cTc, that Santa Fe trains moving in either direction on a siding in this new cTc territory have complete block signal protection. As if this triple improvement in Santa Fe's cTc practices of providing (1) exceptionally long sidings and (2) two way block signal protection through them and (3) construction and maintenance to main track standards was insufficient, a fourth novel and original feature was introduced. Two parallel sidings on either side of the main track were usually built to these standards and proportions so that while a train in the opposite direction was being met, an inferior train in the same direction could be passed; or two trains in the same direction could be met or passed. It will be seen from these factors that the recent Santa Fe cTc installations embrace something more than the utilization of sidings under signal indications. The sidings on the single track main lines of the Pecos, Panhandle, Plains and Middle Division may, in reality, be considered more in the nature of short stretches of second and third track.

The increase in the length of Santa Fe sidings both on the double track lines west of Belen and in the cTc territory and the construction of new sidings where these had been placed has been one of the major components of the Santa Fe improvement program. Since work of this nature was performed at a large number of points, the principal individual projects have been necessarily compressed into statistical form in table 18 .

The summary of siding extensions made from Clovis, N. M., through Belen to Los Angeles are tabulated on its nine pages. While other siding extensions were made between Clovis and Kansas City, and between Barstow and Mojave and one siding, at Atherton, Mo., was lengthened on the Chicago-Kansas City line, details of this work are omitted from the statistical summary of siding extensions. It is regrettable that work of such immense importance and large aggregate cost is so inadequately reflected in these simple and inconspicuous data. Nothing short of a guided trip over the line, such as I was privileged to make in September 1948, and again in January 1949, is adequate to give a proper impression of the extent and aggregate magnitude of this work.

There are two distinct patterns of siding location found on double track lines. The conventional one is to provide separate sidings for trains in each direction and place them outside of the two high speed main tracks. Another pattern utilized by the Union Pacific, Southern Pacific and Illinois Central during the period of their reconstruction and double tracking under the regime of the late E. H. Harriman, in the first decade of the present century, placed a single siding in the center between the two main tracks, with connections permitting its use in both directions.

The advantages of the latter are that it reduces the total length of trackage required for equal siding spacing but whenever the connection between the center siding and the main track is located on a tangent, which is the prevailing condition, one of the main tracks must be moved over to one side. This introduces a "dog leg" in the track with curvature in alternating directions that is undesirable even though it cannot be classified as objectionable. The use of the central siding also entails the possibility that two full-length trains in opposite directions may find it necessary to use it at the same time. In this event delays will result to one of the two trains with consequent possible detentions to the train which will pass it. While the experience of the lines using the central sidings for double track lines is entirely satisfactory, nevertheless it appears that the plan of outside spacing of sidings, which the Santa Fe follows as standard practice, is the preferable one to use.

The frequency of siding spacing on double track lines over which any considerable number of passenger trains run will average close to five miles apart. However, if passenger movement is infrequent sidings spaced at greater distances will be found entirely adequate.

The movement of trains in and out of sidings is greatly accelerated if it can be directed by signal indication instead of leaving the important determination of where and when trains shall take sidings to time tables and train orders and messages. Likewise, power thrown switches at entering ends of sidings and spring switches at leaving ends, minimize the delays which occur wherever trains take sidings.

Sidings give single and double track railway lines flexibility and capacity for train movement. Signals and communication facilities are likewise of great importance in these respects, too. Discussion of these related topics are necessarily reserved for another chapter which is closely related to the subject outlined in this one.

INCREASES MADE IN SIDING CAPACITY 1935 - 1948

Table XVIII
1.

Pecos Division

Clovis to Belen

Station	MP	1935 in 44' Cars	1935 in 50' Cars	1948 in 50' Cars	Increase in 50' Cars	Single track except as noted.
Gallaher	662.6	112	99	127	28	2 Tracks
Grier	667.4	130	114	110	-4	"
St. Vrain	672.9	130	114	110	-4	"
Melrose	680.8	130	114	109	-5	"
Cantara	687.6	130	114	216	102	
Krider	693.4	130	114	220	106	
Tolar	699.0	138	121	161	40	
Taiban	702.8	69	59	260	201	
La Lande	710.1	110	97	201	104	
Ft. Sumner	716.8	130	114	112	-2	
Agudo	723.6	110	97	231	134	
Ricardo	729.3	110	97	216	119	
Evanola	736.6	110	97	216	119	
Yeso	743.9	130	114	216	102	
Largo	749.6	130	114	216	102	
Buchanan	756.1	127	112	216	104	
Cardenas	761.4	110	97	217	120	
Duoro	769.0	110	97	237	130	
Joffre	775.0	110	97	125	28	2 Tracks
Iden *	782.3	130	114	-	-	"
Tejon	792.0	110	97	214	117	
Carnero	798.8	110	97	181	84	
Encino	803.8	130	114	120	6	
Negra	808.7	110	97	239	142	
Padernal	815.5	130	114	229	115	
Dunmoor	819.5	130	114	116	2	
Culebra	824.1	90	79	191	112	
Lucy	828.8	110	97	213	116	
Silio	835.6	120	114	159	45	
Willard	842.1	110	97	128	31	
Broncho	848.6	130	114	246	132	
Mountainair	855.7	235	207	336	129	
Abo	863.0	130	114	270	156	
Scholle	868.9	130	114	301	187	
Sais	875.9	130	114	166	52	
Becker	881.6	130	114	186	72	
Bodega	886.6	130	114	186	72	
Madrone	892.3	130	114	187	73	

* Absorbed in
double track.

INCREASES MADE IN SIDING CAPACITY 1935 - 1948 Table XVIII 2.

Albuquerque Division - 1st District

Belen to Gallup

		WESTBOUND				EASTBOUND			
		1935		1948	Increase	1935		1948	Increase
Station	MP	in 44' Cars	in 50' Cars	in 50' Cars	in 50' Cars	in 44' Cars	in 50' Cars	in 50' Cars	in 50' Cars
Felipe	—	100	91	91	3				
Dalies	27.4	133	117	110	7	68	58	103	45
Rio Puerco	33.9	103	91	91	0	105	92	118	26
South Garcia	43.3	93	82	120	38	71	62	—	- 62
Suwanee	47.3	103	91	118	27	103	91	118	27
Armijo	53.4	103	91	—	- 91				
Marmon	58.0	115	101	125	24	103	91	118	27
Quirck	63.3	103	91	83	- 8				
Laguna	68.7	103	91	118	27	103	91	110	19
Acomita	77.6	103	91	118	27	103	91	118	27
McCartys	82.3	103	91	—	- 91				
Anzac	86.0	103	91	118	27	103	91	132	41
Grants	95.5	132	116	134	18	102	90	118	28
Reid	101.1	103	91	91	0				
Bluewater	107.2	103	91	118	27	103	91	118	27
Baca	114.9	103	91	91	0	103	91	91	0
South Chaves	121.7	103	91	118	27				
North Chaves	121.8					106	93	118	25
Thoreau	125.6	90	79	118	39				
Gonzales	129.3	84	74	-	- 74	103	91	118	27
North Guam	136.7					104	91	131	40
South Guam	136.2	103	91	118	27				
Ciniza	141.0					92	81	104	23
Perea	141.5	103	91	118	27				
Wingate	146.1					103	91	117	26
McCune	149.3			105	105				
Zuni	151.6	103	91	118	27	103	91	118	27

The line from Belen to Gallup is completely double tracked and so are succeeding subdivisions westward to San Bernardino.

INCREASES MADE IN SIDING CAPACITY
1935 - 1948

TABLE XVIII
3.

Albuquerque Division - 2nd Dist.

Gallup - Winslow

Station	MP	WESTBOUND 1935 in 44' Cars	WESTBOUND 1935 in 50' Cars	WESTBOUND 1948 in 50' Cars	WESTBOUND Increase in 50' Cars	EASTBOUND 1935 in 44' Cars	EASTBOUND 1935 in 50' Cars	EASTBOUND 1948 in 50' Cars	EASTBOUND Increase in 50' Cars
Defiance	166.9	80	70	114	44	80	70	104	34
Manuelito	174.2	78	69	-	- 69	80	70	84	14
Lupton	180.4	89	79	79	0	80	70	104	34
Allantown	187.3	87	78	-	- 78	80	70	0	- 70
Houck	191.2	80	70	114	44	100	88	100	12
Cheto	199.7	92	81	88	7	80	70	44	- 26
Chambers	205.7	83	73	85	12	80	70	74	4
Navajo	213.0	80	70	114	44	80	70	116	46
Pinta	219.2	84	75	75	0	80	70	130	60
Bibo	225.9	92	81	-	- 81	82			
Adamana	232.3	89	79	114	35	106	93	115	22
Carrizo	238.3	92	82	82	0	81	71	-	- 71
D.T.Junction	239.8	93	82	-	- 82				
Arntz	245.5	92	81	81	0	92	81	83	2
Holbrook	253.0	185	163	114	- 49	185	163	116	47
Penzance	258.6	165	145	152	7	103	91	-	91
Joseph City	263.5	80	70	72	2	84	74	74	0
Hibbard	274.8	80	70	114	44	92	81	104	25
Hobson	279.9					92	81		- 81

INCREASES MADE IN SIDING CAPACITY 1935 - 1948 TABLE XVIII 4.

Albuquerque Division
3rd District

Winslow - Seligman

		WESTBOUND				EASTBOUND			
		1935		1948	Increase	1935		1948	Increase
Station	MP	in 44' Cars	in 50' Cars	in 50' Cars	in 50' Cars	in 44' Cars	in 50' Cars	in 50' Cars	in 50' Cars
Moqui	293.0	69	59	-	- 59				
Dennison	298.3	68	58	104	46	69	60	96	36
Sunshine	305.9	81	72	72	0				
Canyon Diablo	312.1	60	52	115	63	68	59	109	50
Hibbard	317.3	66	58	-	- 58				
Angell	322.7	82	72	96	24	80	70	96	26
Winona	328.6	83	73	-	- 73				
Cosnino	333.2	81	71	96	25	95	83	98	15
Cliffs	339.1	81	72	72	0				
Flagstaff	344.2			105	105			96	96
Riordan	350.8	81	71	96	25				
Bellemont	356.3	81	71	99	28	81	71	87	16
Maine	362.5					64	56	108	52
Chalender	368.0	66	58	108	50	66	58	119	61
Williams	378.2			99	99			118	118
Supai	381.6					29	27	27	0
Sereno	383.1					80	70	108	38
McLellan	386.3	81	71	112	41				
Corva	390.3					80	70	131	61
Welch	391.7								
Daze	393.7	86	75	112	37	94	82	108	26
Ash Fork	401.2			308	308			120	120
Pineveta	408.8	80	70	108	38				
Gleed	414.7	91	82	82	0				
Crookton	419.1	69	60	110	50	81	71	109	38
Pan						81	71	-	- 71

INCREASES MADE IN SIDING CAPACITY 1935 - 1948 TABLE XVIII 5.

Arizona Division - 1st District

Seligman - Needles

		WESTBOUND				EASTBOUND			
		1935		1948	Increase	1935		1948	Increase
Station	M.P.	in 44' Cars	in 50' Cars	in 50' Cars	in 50' Cars	in 44' Cars	in 50' Cars	in 50' Cars	in 50' Cars
Chino	432.7	69	60	-	-60				
Audley	439.8	79	69	107	38	78	68	107	39
Pica	446.4	78	68	107	39			107	107
Yampai	451.9	78	68	107	39	78	68	107	39
Fields	454.8					78	68	-	-68
Nelson	460.2	115	111	92	-19	67	58	113	55
Shipley						78	68	-	-68
Peach Springs	576.8	78	68	107	39	78	68	107	39
Cherokee						68	59	-	-59
Truxton	477.3	78	68	107	39	78	68	110	42
Valentine	484.0					68	61	61	0
Hackberry	489.0	86	75	95	20	89	78	105	27
Antares	495.1	78	68	72	4	66	58	107	49
Walapai	501.3	78	71	71	0	78	68	72	4
Berry	509.4	78	68	107	39	78	68	107	39
Louise	513.9					41	36	30	-6
Kingman	516.4	Yard		118	118	Yard		107	107
McConnico	520.7	34	29	51	22				
Harris	521.4					68	59	68	9
Griffith	526.8	78	68	107	39	78	68	107	39
Kaster	531.2					70	61	-	-61
Athos	535.2	78	68	-	-68	78	71	71	0
Yucca	540.2	78	68	107	39	81	71	105	34
Haviland	546.2	78	68	-	-68	67	58	72	14
Franconia	552.7	78	68	95	27	79	69	105	36
Powell	558.8	78	71	71	0	78	71	71	0
Topock	565.9	78	68	107	39	78	68	107	39
Beal	571.4	77	67	-	-67	64	56	-	-56

INCREASES MADE IN SIDING CAPACITY 1935 - 1948 — TABLE XVIII 6.

Arizona Division - 2nd District

Needles - Barstow

Station	M.P.	WESTBOUND 1935 in 44' Cars	WESTBOUND 1935 in 50' Cars	WESTBOUND 1948 in 50' Cars	WESTBOUND Increase in 50' Cars	EASTBOUND 1935 in 44' Cars	EASTBOUND 1935 in 50' Cars	EASTBOUND 1948 in 50' Cars	EASTBOUND Increase in 50' Cars
Hartoum		67	58	-	-58				
Java	585.6	101	88	107	19	100	88	107	19
Ibis	592.4	97	85	107	22				
Bannock	597.0	66	58	107	49	78	68	107	39
Homer	601.5	104	91	97	6				
Goffs	609.1	82	72	107	35	100	88	107	19
Pinta						78	68	-	-68
Fenner	618.7	70	61	111	50	78	68	107	39
Essex	626.2	71	64	64	0	101	88	107	19
Arimo	630.2					78	68	-	0
Danby	634.7	101	88	107	19	103	90	114	24
Siam	641.8					78	68	72	4
Cadiz	648.1	78	68	107	19	78	68	107	39
Bolo	655.0					78	68	71	3
Saltus	658.4							51	51
Amboy	661.5	79	69	107	38	78	68	107	39
Bagdad	669.3	92	80	107	27	111	100	100	0
Trojan	673.4	95	83	-	-83				
Siberia	676.7	89	78	107	29	89	78	107	29
Klondike	682.0	78	68	72	16				
Ash Hill	686.7	103	90	107	17	78	68	107	39
Ludlow	693.4	78	68	117	49	88	77	101	24
Argos	698.5	77	67	71	4	79	72	72	0
Pisgah	706.6	102	89	107	18	101	88	107	19
Hector	712.8	79	69	73	4	79	69	73	4
Troy	719.5	78	68	72	4	78	68	72	4
Newberry	725.6	101	88	107	19	101	88	107	19
Minneola	731.7	78	68	107	19	78	68	72	4
Gale	735.3					71	62	67	5
Daggett	737.6	101	88	107	19	84	73	104	31
Nebo	741.6	74	68	68	0	77	67	71	4

INCREASES MADE IN SIDING CAPACITY 1935 - 1948 TABLE XVIII 7.

Los Angeles Division - 1st District

Barstow - San Bernardino

		WESTBOUND				EASTBOUND			
		1935		1948	Increase	1935		1948	Increase
Station	M.P.	in 44' Cars	in 50' Cars	in 50' Cars	in 50' Cars	in 44' Cars	in 50' Cars	in 50' Cars	in 50' Cars
Lenwood	6.2	80	70	92	22	80	70	104	34
Hodge	11.8	73	64	120	56	82	72	106	34
Helendale	21.1	70	61	98	37	80	80	108	28
Bryman	26.1	70	61	98	37				
Oro Grande	31.5	70	61	90	29	89	78	108	30
Leon	35.2					79	69	-	-69
Victorville	36.7	80	70	100	30	80	70	98	28
Thorn	41.1					82	72	105	33
Hesperia	45.1	70	61	99	38	80	70	106	36
Lugo	50.3	66	58	98	40				
Summit	55.9	70	61	122	61	76	66	126	60
Dell	58.5	26	22	-	-22				
Gish	59.6	68	59	71	12				
Alray	59.7					86	75	118	43
Cajon	62.4	72	63	95	42	80	70	70	0
Keenbrook	66.3					80	70	115	45
Devore	71.0	80	70	126	56	80	70	128	58
Ono	76.0	80	70	96	26	80	70	106	36

INCREASES MADE IN SIDING CAPACITY 1935 - 1948 TABLE XVIII 8.

Los Angeles Division - 2nd District

San Bernardino-Los Angeles

Single Track

Station	M.P.	1935 in 44' Cars	1935 in 50' Cars	1948 in 50' Cars	Increase in 50' Cars
Rialto	84.9	60	52	123	71
Fontana	88.8	63	55	94	39
Kaiser	91.4	27	23	105	82
Etiwanda	93.7	29	25	54	29
Cucamonga	97.7	88	77	50	-27
Upland	100.9	55	47	47	0
Claremont	104.8	66	56	56	0
Pomona	106.7	71	64	64	0
La Verne	107.9	48	40	40	0
San Dimas	110.2	49	42	42	0
Glendora	114.4	69	59	59	0
Azusa	116.9	43	37	-	-37
Kincaid	118.0	46	41	41	0
Butler	120.2	60	50	50	0
Monrovia	122.4	79	72	72	0
Arcadia	124.4	30	26	11	-15
Santa Anita	125.8	45	39	39	0
Chapman	127.3	71	62	62	0
Lamanda Park	128.0	31	25	25	0
Wilton	129.1	23	20	-	-20
Pasadena	131.7	41	34	34	0
Usado	132.2	22	19	-	-19
South Pasadena	133.7	5	4	-	- 4
Olga	134.2	40	34	34	0
Highland Park	135.9	26	20	20	0
Water Street	138.7	71	62	71	9
Mission Tower	146.1				

INCREASES MADE IN SIDING CAPACITY 1935 - 1948

TABLE XVIII
9.

Los Angeles Division - 3rd District

San Bernardino - Los Angeles

Station	M.P.	Westbound 1935 in 44' Cars	Westbound 1935 in 50' Cars	Westbound 1948 in 50' Cars	Westbound Increase in 50' Cars	Eastbound 1935 in 44' Cars	Eastbound 1935 in 50' Cars	Eastbound 1948 in 50' Cars	Eastbound Increase in 50' Cars
Double Track									
Coilton	2.9	-	-	49	49	-	-	112	112
Highgrove	6.7	74	65	114	49				
Riverside	9.8	59	51	-	-51	-	-	42	42
Single Track									
Pachappa		30	26	-	-26				
Casa Blanca	14.0	52	45	99	44				
Arlington	16.4	71	62	62	0				
May	19.7	71	62	94	32				
Porphyry	22.8	Yard	-	100	100				
Corona	24.1	90	79	167	88				
Prado Dam	29.2	70	61	94	33				
Gypsum	32.3	71	62	95	33				
Esperanza	36.4	28	24	129	105				
Yorba	40.8	37	32	-	-32				
Atwood	40.7	74	65	179	114				
Placentia	43.0	76	69	69	0				
Double Track									
Fullerton	47.4	81	71	94	23	-	-	74	74
Basta	50.1	38	31	31	0				
Buena Park	51.8	60	52	74	22				
La Mirada	53.6	70	61	-	-61	-	-	96	96
Santa Fe Springs	58.0	90	79	86	7				
Los Nietos	59.2	30	26	-	-26				
Single Track									
Rivera	61.2	71	62	95	33				
Bandini	63.7	60	52	-	-52				

CHAPTER XI

YARDS AND TERMINALS

As a letter to any address may be dropped into the most convenient mail box and the postal service will carry it to destination and there make delivery, so the freight houses and indistrual side tracks of the railway systems are receiving points for shipments in every direction. Continuing the analogy of the letter and the movement of freight, the former passes successively through a post office where it is sorted and re-sorted, then is placed in a pouch for movement in railway mail service and after possibly a number of repetitions of such handling, will reach the post office at the point of address where a final sorting by carrier routes will be made and delivery effected. This brief resume of the workings of the postal system is a familiar story to all and it may be helpful to understand that a railroad yard is a "post office" for freight cars.

Freight is loaded into cars placed at industries, freight houses and on team tracks. At the close of the business day, shifting engines performing work comparable to that of a collector of mail, move the cars to a yard, the "railroad's post office." There they are sorted by forwarding routes or destinations, as with letters, but onto tracks instead of into the pigeon-holes of a cabinet, and are made up into trains, whereas mail goes into a pouch. At destination, or at an intermediate classification point, further sorting will be necessary and finally a shifting engine will deliver the car to the consignee.

Instead of letters and packages, railways handle heavy cars, in good repair and bad, with lading often broken and generally breakable. The work continues through darkness of night, endures severest weather and must, at all times, be performed with safety, economy and dispatch.

Admittedly this is exacting work, requiring a high degree of cooperation between those who plan and direct and those who perform it.

A freight yard is an assemblage of tracks for classifying cars and making up trains. It often includes special facilities for auxiliary operations such as storage and transfer of grain, coal, ore, or other commodities and the accommodation of boats for the trans-shipment of rail-and-water traffic. The fundamental work of the yard is the classification of cars and the assembly of trains. The secondary functions are the collection and placement of loaded and empty cars at industry and freight house tracks. Yards are also required to relay through freight trains at the points where crews are changed and possibly locomotives, too, if steam power is operated.

The tracks in a freight yard must serve three primary functions:

1. Receive inbound trains, or switching runs from local industries or transfer runs from other railroads.
2. Sort or classify the cars.
3. Make up trains for outbound movement of the cars or delivery of the cars by switching and transfer runs.

Trains run through a relay yard without classification of cars so functions #2 and #3 are omitted and its physical requirements are limited to an adequate number of train length tracks to accommodate arriving trains that will stop only for the minimum time requirements of inspection and change of crews and power if the latter is necessary, and then move on to the next terminal.

The term "yard" is applied at once to a single set of a few short connected trains used for sorting or storing cars at minor points up to the largest freight terminals in the country. Some have 10,000 - 12,000 cars standing capacity. The operation of a large classification yard will be briefly described.

Inbound trains pull into a receiving track where locomotive and caboose are cut off. Car inspectors take charge of the train and under the protection of a blue flag (*) or light, inspect all cars, making minor repairs and adjustments and carding defective equipment with "SHOP" tags. Meanwhile, yard clerks prepare lists showing the proper classification of each car in the train for use of yard trainmen in classifying cars.

Distribution of the cars is accomplished by one of two methods, viz.:

1. Flat switching
2. Gravity, or hump classification.

Flat switching is the usual method of classifying cars but the term is not known outside of railway circles so the practice to which it relates should be described. As an engine rapidly pushes a draft of up to 15 or 20 cars forward, a brakeman uncouples the forward car and signals for a stop or reduction in speed. The uncoupled car coasts onto a body track as the locomotive reverses direction of movement and pulls the remaining cars back far enough to allow it sufficient run to "kick" the next car onto a classification track. This method is slow and can damage cars and lading and wear out motive power rapidly. However, it is adapted to use at any point without special arrangements in yard design and, is the most economical method for use at points classifying less than

Note: (*) A blue flag by day and a blue light by night, displayed at one or both ends of an engine, car or train, indicates that workmen are under or about it; when thus protected it must not be coupled or moved. Workmen will display the blue signals and the same workmen are alone authorized to remove them. Other cars must not be placed on the same track so as to intercept the view of the blue signals, without first notifying the workmen. Book of Rules - Rule No. 26

1,000 cars per day.

The principles of gravity classification are utilized in the sorting of cars over an artifically constructed summit, or "hump" save in the exceptional cases where the natural slope of the classification tracks obviates the use of a "hump." The hump is located at the throat between the receiving and classification sections of the terminal. As each car passes over the summit of the hump, it is uncoupled by a "car cutter" and in moving down the inclined plane, gains sufficient momentum to be carried onto the proper classification track. Switches may be thrown manually by a switchtender or be power operated and controlled from a convenient central point. In the past, the car was manned by a car rider (brakeman) to control the speed by use of hand brakes to prevent damaging collisions with equipment standing ahead on the classification track but modern practice mechanizes this operation by car retarders.

The purpose of the car retarder is to place in the track the brakeing force needed to control movement of cars passing off the hump and down into the classification yard, thereby obviating the necessity of assigning a brakeman to ride the cars. The car retarder includes a set of brake shoes laid in a long straight movable frame placed along each side of and parallel with each of the two rails of the track. These pairs of brake shoes can be simultaneously moved by electric or pneumatic devices toward each rail to clamp the sides of passing car wheels thus retarding their movement. Retarders are manipulated from central towers by operators who control the car retarders and the power thrown switches which direct the descending cars onto the proper tracks, as designated by the train classification lists that set forth the proper disposition of each car.

When several adjacent (i.d. a cut of) cars are to be placed on the same track, their disposition is accomplished in one operation. Special tracks are set aside to receive, respectively, cars shopped on account of defects, cars to be held awaiting disposition instructions, cars of stock to be unloaded for feed, water and rest in accordance with Federal regulations and cars to be re-iced as per request of shippers. Defective equipment, especially that containing perishable freight, is repaired immediately to prevent delay thereto or lading will be transferred if necessary.

Cars are advanced only a few miles at the most in moving through terminals yet expenses for work of this nature, especially on eastern lines, will be found to represent from one-half of the total of the road movement costs to a sum equal to them. It is not unusual for the cost of a car movement through a single yard to equal the expense of several hundred miles of road transportation. This will explain the special efforts which railway management have continually exerted to improve this condition. The operation of car retarder equipped hump yards at points having sufficient volume of traffic to justify the extensive facilities and costly investment required will permit the most expeditious and economical handling of cars.

Car retarders permit almost continuous classification of cars and greatly increase hump yard capacities over that obtainable with the use of brakemen as car riders. The saving in labor costs run to a substantial percentage of total yard expense and as the riding of cars off humps has been the most dangerous single feature of railway employment, substitution of mechanical methods for human labor in this operation is an important factor in reducing casualties to employes.

Prior to about 1920, it was the responsibility of each terminal merely to classify trains for movement to the terminal at the end of the engine runs operated from it and at this point the cars would be resorted for movement beyond. The scheme of classification at each terminal was relatively simple but all cars were handled again and again at the end of each successive engine district and the aggregate of terminal work and costs and delays was extremely high. "Prior classification" is the very carefully studied and arranged classification of cars at specified terminals, usually the one at or nearest the point of origin or receipt of the shipment. This permits movement of cars either in solid trains that need not be switched at intermediate yards or in "blocks" of cars which, while each not aggregating full train length, can be assembled with other "blocks" to give standard train loadings to intermediate terminals. There these "blocks" can be directly redistributed to outbound trains and the reclassification of individual cars is completely avoided. The development of methods of prior classifications has brought about very large proportional reductions in the aggregate volume of yard switching. This has contributed materially to economy in railway operation, to improvement in the dispatch and reliability of railway freight schedules, to the reduction of damage which is so often caused by rough handling in yard shifting and to prevention of accidents to employes.

Where space permits, tracks of maximum train length are located beyond the classification yard and are connected by the requisite ladders for the purpose of making up and dispatching trains without interfering with classification. Such yards are variously designated by the terms "Advance," "Departure," or "Make-up."

When sufficient cars of one or more classifications are assembled or the leaving time of an arranged service freight train approaches, the blocks of cars of the various classifications which will comprise it are assembled, inspected and the air brakes tested. Meanwhile, the road power and crew will have been assigned and at the proper time, the locomotive and caboose will be attached and the train dispatched.

Sufficient information about the car consist of each freight train is telegraphed to the yard in advance which will receive it to enable the Yardmaster there to make advance arrangements for its prompt handling. This work may entail variously the classification of blocks of cars to be set out, the assembly of blocks of cars to be moved out on it or the train may be relayed intact. Other information will be sent on in advance of the arrival of a freight train that relate to feeding and resting of live stock, icing of cars of perishable freight and other special attentions required for particular cars. The yard at the end of any freight run must also know the time the members of the train crew reported for duty in order to prevent violation of the "hours of service" law. This statute prohibits a railroad from keeping train service employes on duty for more than sixteen consecutive hours save in emergencies. Severe penalties are named for infractions of this Congressional enactment. A yard may be required to provide relief crews to bring in trains which, on account of delays, are unable to reach the terminal within the prescribed 16-hour time limit.

Important cities and junctions invariably require large freight yards. Others must be provided to relay through freight trains over individual crew districts which usually correspond to the main line subdivisions of a Superintendent's Division and so range from slightly under 100 miles up to 150 miles normal maximum. Occasionally crew districts are longer. Such instances have usually resulted from the shorter freight crew districts having been combined at the request of the management, with the consent of the transportation brotherhoods. The freight crew subdivisions between Chicago and California via the Southern District are tabulated on the next page to show the approximate mileage of these representative ones.

TERMINAL	DISTANCE FROM TERMINAL ON EAST	WEST
Chicago	-	130.1
Chillicothe, Ill.	130.1	104.5
Shopton, Ia.	104.5	112.7
Marceline, Mo.	112.7	103.8
Kansas City, Mo.	103.8	114.2
Emporia, Kan.	114.2	113.2
Wellington, Kan.	113.2	106.2
Waynoka, Okla.	106.2	107.6
Canadian, Tex.	107.6	97.9
Amarillo, Tex.	97.9	103.7
Clovis, N. M.	103.7	130.8
Vaughn, N. M.	130.8	109.0
Belen, N. M.	109.0	143.2 *
Gallup, N. M.	143.6 *	127.2
Winslow, Ariz.	127.2	142.7 *
Seligman, Ariz.	143.6 *	148.6 *
Needles, Calif.	149.3 *	167.6 *
Barstow, Calif.	165.8 *	80.8 *
San Bernardino, Calif.	82.8 *	59.7
Los Angeles	59.7	-
Bakersfield, Calif.	141.3	110.0
Calwa (Fresno) Calif.	110.0	100.4
Riverbank, Calif.	100.4	94.4
Richmond, Calif.	94.4	-
San Diego, Calif.	141.3	-

Note: * Difference in eastward and westward mileages between common terminals results from measurements being taken over eastward or westward tracks which are not of exactly the same length.

Some of the intermediate terminals; viz. Chillicothe, Shopton, Marceline, Waynoka, Canadian, Vaughn, Gallup, Winslow, Seligman, Needles, perform no classification of cars other than those which originate or terminate in the vicinity.

Similarly while important numbers of cars are switched at Wellington, Amarillo, Clovis and Needles and these cars are added to and taken off transcontinental trains in blocks, nevertheless the transcontinental cars pass through these points in unbroken units. Accordingly from the standpoint of transcontinental movement the yards at these points may be regarded more as serving the functions of relaying rather than classifying trains.

A yard used to relay trains serves just the purpose which its name indicates. An arriving train is held there for the minimum length of time required to service and inspect the cars. Cars found in bad order, if any, are cut out; a block of cars to be set out at that point are at the head end or the rear end of the train and a switch engine removes them. Another yard locomotive will add a block representing "fill-out" up to the limit of the rated tonnage for outward movement. Meanwhile, the road locomotive is being inspected and serviced as is the usual case with Diesels, or is changed if required in the case of a steam engine. Cabooses being assigned to individual crews are changed at these points.

The principal characteristic required of a freight yard used for relaying trains is to have its tracks of ample length to accommodate the maximum length train that can be hauled over the division without having to set over any part of the train on an adjoining track. The latter work takes additional time and the movement blocks other yard operation while it is being done. Moreover, the delay and interference is doubled because the same procedure has to be reversed when the train moves out. All freight yards should have a sufficient number of maximum length tracks so that they can conveniently and currently handle all trains arriving in both directions and never be forced to hold trains on the main track or sidings short of the yard awaiting yard tracks to be cleared to accommodate them. Trains can be relayed through yards in as little as ten or fifteen minutes if a sufficient number of car inspectors are available to distribute this work so that every car can be inspected on both sides within that time. Cabooses can be changed and engines serviced, too, within that time limit provided all of the work is systematically organized and carefully supervised. However, it will be found in practice that from thirty minutes to an hour is usually lost by each train stopping at a relay point, particularly when blocks of cars must be cut out and added to trains and allowance is made for minor repairs that frequently must be made to cars. Those which require it must be cut out to be sent to the shops and this adds detention, particularly if located in the middle of a long train.

If trains could always be dispatched as soon as they are ready to move it would probably be sufficient to have the number of tracks in a relay yard equivalent to the requirements needed to hold whatever number of trains can be expected to follow one another within three hours of maximum movement in both directions. Relay yards usually serve trains moving both ways and frequently their respective period of peak operations coincide. However, from time to time engines are not available to move trains when they are ready and accidents or other conditions ahead require that trains be held in terminals. For that reason relay yards should have more actual track capacity than that theoretically necessary. This provides a "margin of safety" to prevent yard congestion and holding inbound trains out of the yard.

A yard should always be able to accommodate 12 hours maximum movement in both directions without danger of congestion and be able to receive the trains on train length tracks. This, it will be observed, is equivalent to 24 hours capacity in one direction only and provides that amount of reserve trackage in the event of an accident, wash out, etc. on either side of the yard which would block movement there. It will be observed that an emergency which will prevent the dispatching of trains over one part of the line will probably delay the arrival of inbound trains from it. Therefore, the yard tracks normally used by the delayed trains can be assigned temporarily to trains arriving from the opposite direction that must be held in the terminal until traffic begins to move out again.

Well equipped yards will have all tracks used for making up outbound trains provided with compressed air lines throughout their entire length in order that air brakes can be tested without attaching locomotives to the cars to pump up the air pressure in the train lines. Santa Fe yards meet this test. Nothing is more wasteful than to make locomotives and their crews stand idle in freight yards while the engine performs the work of a compressed air pump.

The circumstances which held Santa Fe trains to 70-car operating lengths on the Albuquerque, Arizona and Los Angeles Divisions and confined their sidings to such limits were naturally integrated into the length of yard tracks, too. The onrush of war traffic with its increasing number and length of trains found the yards at many places, but more particularly from Belen on west, inadequate in all respects of length and numbers of tracks to provide for the growing size and frequencies of trains and to meet the needs of making a greater number of classifications at each point. The location of great camps and training bases and depots for the various branches of the armed services throughout the west and the construction of war industries at isolated points produced transportation requirements at local stations which had never before existed. This introduced the necessity of performing a considerable amount of yard service at stations where such functions were required for the first time. Additional trackage as well as switch engines had to be provided for this work, too. It followed that Santa Fe yards required enlargement, particularly from Belen west. Prompt and adequate attention was given to this work and the results are summarized in table XIX, on the next page.

Like the data on siding extensions, it cannot adequately represent the work which it tabulates by increased car capacities and track numbers and lengths in the yards listed therein.

The most important difficult piece of wartime yard expansion was done at Barstow. The magnitude of that construction was much greater than indicated by the increase in yard capacity alone. The location of the town, on the south, the railway station and the Mojave River on the north and the junction between the lines to Los Angeles and to San Francisco at the west end of the yard, required that the additional length be provided at the east, and the additional width on the south. Extraordinarily heavy excavation was required to tear down encroaching hillsides to provide room for the railroad tracks.

Yards make the best places for trains to meet and pass. Both schedules and dispatchers endeavor to direct train movement so that this will occur in as great a number of instances as practicable. However, to avoid detention or congestion in yards, it is advisable, where the construction costs can be justified by the saving in delay to trains, to provide running tracks for freight trains several miles in both directions outside of freight yards. This facilitates inbound freight trains clearing the main track ahead of following passenger trains. Similarly outbound trains do not have to be held in the yard awaiting departure of passenger trains from the station but can proceed down to the end of these running tracks to the

CAR (STANDING) CAPACITY OF FREIGHT YARDS AND OF LONGEST TRACK — TABLE XIX

Chicago - Los Angeles (Via Southern District) and Including Newton and Sand Creek on Northern District

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YARD	CAR STANDING CAPACITY: PREVIOUS (Note A)	CAR STANDING CAPACITY: PRESENT	PRESENT NUMBER OF TRACKS (Note B)	LONGEST TRACK (50 FT. CARS)	COMPLETION DATE OF RECENT IMPROVEMENTS
Corwith		2745		63	
Chillicothe		2375		234	
Shopton		1870		151	
Marceline		965		100	
Argentine *	6050	9088	100	127	1949
Emporia		4750		440	
Wellington		1680		152	
Waynoka		2310		184	
Canadian		785		128	
Amarillo		1965		99	
Clovis	1420	2140	22	120	1944
Vaughn	765	1240	7	136	1944
Belen	1755	2689	28	179	1944
Gallup	1005	1685	14	131	1945
Winslow	1021	2460	14	125	1945
Seligman	825	1040	10	118	1945
Needles	1270	1970	19	198	1945
Barstow	1735	2590	30	115	1945
San Bernardino	3220	3400	29	90	1945
Hobart	1885	2775	36	104	1945
Los Angeles		2185		104	
San Diego, 22nd St. Yard		375		49	
Bakersfield		1570		108	
Calwa		1710		76	
Riverbank		990		106	
Richmond		1300		104	
Newton		585		87	
Sand Creek		1005		104	

* Includes "Elevator Yard" at Turner.

Note A — Previous capacity is shown only for yards to which important additions have been made since 1935.

Note B — Present number ~~of tracks~~ of receiving, classification and dispatching tracks of yards at which important improvements have been made in recent years.

Reference

AT&SF Track Charts No. 1, 2, 8, 9 and
"Car Capacity of Terminal Freight Yards," 1944.

considerable advantage of both the movement of the freight train and the switching in the yard. Santa Fe's yard improvements included this desirable feature, of additional freight running tracks in and out of the yards on the east end of Barstow for 2.6 miles and also on either side of the yard at Needles.

Reference to freight yards in any study of transportation presumably calls for more detailed reference to the work performed in them than to the engineering and physical factors. The basic principle of yard operation necessary both for economy of operation and dispatch of movement requires the assembly of cars into blocks that can be run between points of origin and destination with resultant classification of each car at a minimum number of places. In order to accomplish this, blocks of cars are assembled in accordance with a pre-arranged plan of classification which is closely coordinated to road train movement and to the work of the yards through which these cars will pass in the movement towards distribution. These blocks are assembled at or close to point of origin or initial junction and are moved in unbroken units, if possible, to the final terminals where the cars are reswitched for delivery to industries, freight stations, connecting lines or for outward movement over the line of the inward road haul carrier if it extends on further.

Cars are made up into blocks usually at the yard where they are first assembled for road movement after loading by the shipper or being received from a delivering connection. Hobart Yard, in Los Angeles, San Bernardino, Richmond, Bakersfield and San Diego are all principal yards at which eastward freight from California is initially blocked for movement on through to destination. The blocks for Kansas City and Chicago are the principal ones and these classifications may frequently contain so many cars that they represent full train movements in themselves. Separate blocks are made for perishable produce moving under refrigeration on minimum schedules of 130½ hours from Bakersfield or San Bernardino to Chicago and for ordinary or dead freight which doesnot require equal expedition and attention en route. Blocks are also made for principal intermediate junctions and terminals along the route. The eastern terminals classify the westward cars in similar manner and the empties are also separately grouped for movement to the point where they are being sent for reloading or return to or towards the owner.

Eastward cars for Santa Fe destinations and junctions beyond Belen are normally blocked at Los Angeles, San Bernardino and Bakersfield in order to pass through Barstow without being switched there. However, during periods of peak movement Barstow must classify eastward cars when necessary in order to relieve the yards to the west of part of this work. Wartime traffic exceeded the capacity of other Santa Fe California terminals, even after enlargement, to classify traffic routing through them so Barstow was used increasingly to make prior classifications for freight moving both westward into and eastward from San Bernardino, Hobart, Bakersfield, Fresno and Richmond. In this way Barstow took over some of the work normally done at those points and thereby avoided congestion. By providing continuous assistance to all other California terminals, Barstow became the most important classification yard on the Santa Fe Coast Lines. This fact is significant in considering the relative importance of the yard improvements.

Freight yards of the railways of the United States include a few fine and well designed facilities but most are legacies of the past which have been outgrown by modern motive power and methods of moving traffic. The extensions and revisions of them which have been made from time to time have usually been temporary expedients that have added additional track capacity but a good many operating difficulties along with them. Railroad freight yards are consuming increasing proportions of transportation and maintenance expense - so their improvement and modernization is becoming a factor that is receiving increased attention from railroad management.

The problem of yard operations has been more acute in the east than in the west. In fact, it was never a serious problem on western railroads until confronted with the conditions of the last war. Until about ten years ago there was only one hump yard west of the Mississippi River; Lancaster Yard, on the Texas & Pacific at Fort Worth. It was built in 1928 and was equipped with car retarders; the first installation in the west. Taylor Yard of the Southern Pacific at Los Angeles has utilized gravity in classification but it could hardly be termed a hump yard in the sense in which that term is generally applied. Hump yards with car retarders were installed a few years before the war by the Burlington at its Galesburg, Ill. and Lincoln, Nebr. yard and by the Chicago & Northwestern at Proviso. The Santa Fe has just completed the transformation of its great Argentine yard at Kansas City, Kansas, into a car retarder equipped hump yard to permit concentration of a large proportion of the systems freight classification in this one place. Cars, loaded or empty, that are en route between any two points that require movement through Argentine, and this will represent a substantial part of the system total, will be blocked at the initial terminal for road movement to Argentine. That yard in turn will classify all inbound cars for further movement to every principal terminal on the system without subsequent rehandling. This, of course, will be in addition to performing all the classification required for delivery of cars to industries and connections in Kansas City. Movement will be expedited and system total yard and terminal expense reduced by this great new yard. The resulting economies will represent a substantial return on the $9,000,000 investment just made in the Argentine Yard improvements.

It may be of interest, in passing, to note other recent installations of car retarders on western lines. The Union Pacific built a car retarder equipped hump yard at Pocatello, Idaho, in 1947 and one at North Platte, Nebraska, in 1948. The Denver and Rio Grande Western is providing one at its Roper Yard, Salt Lake City, Utah; the Rock Island has one under construction at Armourdale, Kansas City, Kansas, and the Southern Pacific is equipping its Taylor Yard, Los Angeles with this device.

The most important single improvement in freight terminals ever made by the Santa Fe is the recent conversion of its former 6,000 car capacity flat switching freight classification yard at Argentine, Kansas, into a car retarder equipped hump yard with 9,000 car capacity; including the storage tracks at the huge grain elevator located there. Following a practice that is being increasingly used to effect economies in the great expense entailed in building car retarder yards and also to obtain the volume of car movement over the hump necessary for their efficient operation, both eastward and westward cars will be classified, moving westwardly over a single hump.

An immense classification yard, containing 56 tracks, and having 2300 cars aggregate standing capacity is being provided. The tracks on the north side of the classification yard will be used for eastward classifications and those on the south side for westward cars. Eastward and westward departure yards with 7 or 8 train length tracks each will extend westward beyond the classification yard. The north group of tracks will be used to make up the eastward trains.

Existing trackage will be utilized for the eastward and westward receiving yards. The westward receiving yard will lie immediately to the east of the new classification yard so westward cars will move progressively in the westward direction from the receiving yard over the hump and into the classification yard and on to the departure yard. The eastward receiving yard, however, is located alongside of but at an angle to the classification yard. This will necessitate trains first being pulled eastward on past the hump and down tracks from which the cars can later be shoved back over the hump in the westward direction of movement necessary for classification. Yard running tracks are carried under the hump in order to permit flexible and expeditious movement of road power between the engine terminal and inbound and outbound trains.

The cars passing through it will comprise a high proportion of the Santa Fe total movement which will be classified and blocked there according to plans which will greatly reduce the amount of classification necessary at other points.

Chapter XII

SIGNALS

A train is usually in charge of a crew of five men, unless more are required by the excess crew laws in effect in some states. An engineer and fireman are assigned to each locomotive, although the Diesel is rapidly making the latter term archaic. The train crew includes a conductor and two trainmen. One of the latter rides in a forward car on passenger trains and on the locomotive of freight trains in order to be available to couple and uncouple the locomotives and cars, open and close hand switches, and pass hand signals. The second trainman serves as the flagman and rides in the last car, which on freight trains is the caboose.

While the conductor is technically in charge of the train and its entire crew, the engineer is in actual control of the locomotive and hence of train movement. This makes his work of paramount importance to the safe, efficient and punctual operation of the train. Many trains run at high speed over the same track, in the opposing as well as in the same direction. It is therefore necessary that each member of the crew of every train shall be thoroughly conversant with and strictly conform to the standard practices which are embodied in the "Book of Rules" governing the Transportation Department, observe the schedules and special instructions in the time tables and obey all train orders and hand and fixed signals. These taken together determine the right of any train to enter or leave the main track at stations, yards and sidings, to proceed on it, and also establish maximum permissible running speeds at various places and under different circumstances.

The methods and facilities required for the safe and expeditious movement of trains over the railroad are described in this chapter in order to provide a background against which the recent development of Santa Fe signal installations may be recorded. This general subject centers in train dispatching. Train movements are variously directed by time table, train orders and signal indications or any two or three of these. Train dispatching requires the continuous use of communication facilities, except where CTC concentrates exclusive authority over train movements in signal indications directed from a single control station, but even in this case the telephone and telegraph are essential for auxiliary purposes continuously and in emergencies occasionally. The function of signals and interlockers in modern railway operation can best be understood through an outline of the historic conditions out of which these devices were developed to facilitate and protect train movement.

The original railroad consisted merely of a single track with a few sidings and it had no signals or communication facilities because railroads antedated both. At the outset trains operated at very slow speeds and it was the usual practice for each one to proceed until it met another in the opposing direction. One of the trains then backed up to the nearest passing siding. It is of record that this frequently led to disputes between the crews, each claiming that the other should take the siding. Railroad legend states that fights were a common means of settling disagreements on this important point and the conductors possessing the greatest skill with their fists were able to get their trains over the road more rapidly than their less pugnacious associates.

In order to overcome the disadvantages of this always uncertain and at times dangerous method of operation, it was necessary to develop a flexible technique which would, on the other hand, insure absolute safety of operation, if the rules were observed and, on the other, permit trains to be operated with a minimum of total delays and have some flexibility in respect to number of train movements per day. This was done through gradual development of ingenious rules and related time table practices which had as their fundamental purpose definite assurance that no two opposing trains could ever have authority to occupy the same track at the same time.

The principles of train operation which will be described herein were developed before signals were devised to prevent collisions or to direct movement. Signal systems were later superimposed upon the basic methods of train dispatching summarized in following paragraphs, but the reader must visualize the early conditions when these present aids to safe and efficient operation were not available, and in fact, not even the telegraph was used. The fundamental principles and practices still apply but have been enlarged, protected and amplified by modern signal and communication facilities.

The time table was the foundation of train operation. All train movements were represented by time table schedules. These showed the sidings at which opposing trains would meet or following ones would pass and run ahead of slower movements in the same direction. Trains were given superiority by class, i.e. first class (passenger trains) second class, (through freight trains,) third class, (local freight trains), etc. Trains of the first class were superior to those of the second, and so on. A train of an inferior class was required to take the siding at the designated meeting or passing point and wait until the superior train came, irrespective of whether the latter was on time or late. On the other hand, if the inferior train was late, it entered whatever siding short of the schedules meeting or passing point might be necessary to permit it to clear the main track before the superior train, moving in either the same or the opposite direction, was due, as shown by the time table.

Superiority by direction, e.g., making northbound trains superior to southbound ones of the same class, or eastward ones to westward, was universally used on railroads throughout the United States except on the New England roads, which required a "positive meet" between trains of the same class. There being no directional superiority, a train of the same class that was on time waited at the time table meeting point for the late train running in the opposite direction. The time table would indicate the direction of the trains which would take the siding for opposing schedules of the same class but this did not authorize the train moving in the direction allowed to hold the main track to proceed to the next siding, or on beyond that, if the other train was late.

No train had the right of main track occupancy at any station shown on the time table until the time designated therefor. This right was further subject to all overdue superior trains having arrived or departed.

In order to provide for the contingency of additional trains being required to move the day's business, two or more might use the same schedule as sections of it by displaying the proper classification signals, i.e., green flags by day and in addition, green lights by night, in the place designated therefor on the front of the locomotive. These classification signals, carried by all sections except the last, indicated to inferior trains that a following section was using the same schedule. The inferior train could not consider that a meet or pass with a superior train had been fulfilled until a train without signals had been identified (unless, of course, the inferior train possessed train order authority to proceed without waiting for the following section(s)). Trains identify one another met or passed on the line but it is equally important for each one to know of overdue trains that have not yet arrived at or left from the initial station or junction of any line. A book known as a "Train Register" is provided at such places for crews of trains to record the latter's arrival or departure. This will also show whether trains carried signals for following sections. While extra trains have not yet been mentioned in this discussion, they also are reported in the Train Register.

So long as trains moved in strict conformance with the time table, the possibility of accident was eliminated. However, late trains introduced the contingency of collision, both of the "head end" and the "rear end" type. The former occurs when two opposing trains strike and the latter happens when the engine of a following train crashes into the rear end of the preceding one. "Head on" collisions are the more spectacular and when they occur they usually take the more disastrous toll of life and property but prevention of these was the more readily possible than of the rear end type, until automatic signals were developed which are equally effective in preventing both. The crew of any train knows of all opposing regular, i.e., scheduled trains, which are superior to it, and the inferior one's right to hold the main track automatically terminates when the other one is due. However, in the absence of a block signal system, there is no definite way of continuously informing a following train of one immediately ahead moving in the same direction. Every train which stopped or moved at such reduced speed that it might be overtaken by a following train (except in specifically excepted locations such as "Yard Limits") was required to protect itself against rear-end collisions by a flagman using hand signals, fusees and torpedoes in the manner prescribed by the Book of Rules.

An inferior train must take the siding and await the superior train in the same or opposite direction when it is due. Since the superior train is not required to wait at the meeting point, (in the absence of the positive meet between trains of the same class) the inferior train can expect it to be on the main track whenever the former's schedule permits. Therefore, if the inferior train should be unable, from any cause, to get off the main track at the scheduled meeting point or a siding short of it, at the time required by the prescribed clearance of a superior train, the former is obliged to protect itself. If the superior train is running in the opposing direction the head brakeman or fireman, if necessary, must go forward with hand signals to stop the oncoming train.

When opposing trains occupy the same section of the main track at the same time, the superior train will not know it but the inferior one will. It is therefore the latter's responsibility to avoid collision through flag protection. However, a flagman need not be sent ahead of a delayed train standing on a single track line unless the time table, or train orders held (and the subject of train orders will be mentioned later) indicate that at that time an opposing train has the right to move over the occupied part of the main track. Even when a train is delayed on a single track line, flag protection is not necessary ahead of it so long as the train has a right to proceed under its schedule orders.

Most head end collisions occur because the inferior train overlooks, or otherwise disregards, the meeting point established in accordance with the time table, and related operating practices. It proceeds in disregard of the fact that the time table or other right to occupy the main track does not begin until an opposing train has been met. The opposing superior train, with the right of track occupancy, up to the established, but over-run, meeting point, obviously (in the absence of block signals) has no information of this disastrous mistake made by the inferior train and a collision between the two moving in opposite directions will result.

It is apparent that so long as a train can run over any section of the main track without the protection of flagmen it can stand on the same line without a flagman to protect its head end. Therefore flag protection of the head end of a train is required only when its right to main track occupancy ends. This occurs when an opposing superior train becomes due at the next siding or station in advance as established by its time table or train orders relating thereto. Rules for the operations of trains together with the time tables will, if properly observed, always prevent opposing trains occupying the same track simultaneously.

On May 24,1844, Samuel F. B. Morse sent his historic message "What hath God wrought" over the wires of his "magnetic telegraph" that had been strung on unbarked poles erected along the Baltimore & Ohio right of way from its Pratt Street Station in Baltimore to Washington and thence continued into the Supreme Court Chamber in the National Capitol. The telegraph proved an immediate commercial success and the construction of telegraph lines proceeded rapidly between the principal cities of the United States. These utilized railway rights of way for the pole lines so it was inevitable that this important new means of instantaneous communication should soon become incorporated into railway operation, particularly for the direction of train movement.

The use of the train order originated in 1851 when Charles Minot, General Superintendent of the (New York &) Erie Railroad, issued instructions by telegraph from the station that is now Harriman, New York, to the operator at the nearby town of Goshen to hold a train there for further orders while he thereupon wired immediate authorization to an inferior train to proceed to Goshen, regardless of the schedule of the opposing superior train. The art of train dispatching developed out of that simple beginning and soon train dispatchers, usually located in the offices of the Division Superintendent, were directing train movement on railroads through train orders which, issued pursuant to standard rules and procedures, modified schedules and rights of train in order to minimize the affect of delayed trains upon the movement of others. This method of train operation also permitted running extra trains, which had no time table schedule. Their status was indicated by classification signals; white flags by day, and by night, white lights, in addition, displayed on the front of the engine. Extra trains were inferior to all regular trains, i.e., scheduled ones, irrespective of the latter's numerical class and had to clear the main track for all of them unless otherwise directed by train order. Since extra trains could only know of other extra trains by train order, meeting and passing points between them had to be arranged in that manner at the time they were authorized to run.

Train dispatching, which was first made possible through telegraphic communication, was greatly improved when the telephone came into general use on the railroads. Now a train dispatcher controls, by telephoned orders or directions, a district or division of a railroad which may include hundreds of miles of line, if the traffic is light, or only 30 to 50 miles if train density is extremely heavy as it is over the busiest zones of the eastern carriers. He is in continuous communication with every signal tower and local station along the line from which train orders are issued by the agent or operator or signals and switches are controlled by towermen. These outposts along the line report the arrival, departure and passing of trains and directions relating to any movements thereof not provided by the time table may be made by the dispatcher through them. Now, CTC can obviate all of these intermediaries and bring the complete control of signals and switches used in train movement into the office of the dispatcher.

The introduction of train dispatching led to installing telegraph operators at stations along the line to receive train orders for delivery to trains at such times of the day as an agent or operator was on duty.

The Book of Rules prescribes a standard method for the transmission and handling of train orders to insure their complete accuracy and uniformity and certainty of delivery. Train order signals are displayed at offices having orders for trains. Before automatic block signals were in general use, form "31" orders were extensively used to restrict the rights of trains. These required written receipts from the engineman and conductor of the train to which addressed and so necessitated stopping the train to effect delivery. The presently universal use of the form "19" order permits delivery without stopping the train, except of course when the instructions which it conveys restrict the right to proceed from the station at which received.

The use of these train order signals soon led to the introduction of the time interval method of spacing trains to prevent rear end collisions.

It became a fixed rule that each operator was to hold the signal at his office in the "stop" position for a stated number of minutes, usually 10 or 15, after a train had passed before permitting a following one to proceed. The time interval method added a factor of safety, but obviously would afford little protection against a rear end collision if the train ahead was delayed so as to be overtaken when not properly protected by its flagman. Also, of course, the time interval system of spacing trains afforded absolutely no protection against head-on collisions. Experience disclosed the inadequacy of the time interval system, and this, together with the delays which the method interposed, led to efforts to correct it by substituting the space interval (i.e. "block") method on lines carrying a number of trains and hence having train order offices at close intervals of probably five miles as a minimum, to ten as a maximum.

The manual block system considered that the track between each two train order offices, or block stations as they now became known, was one block. Only one train might be in a block at any time, and the telegraph operators at either end of it, by keeping proper written block records and communicating between themselves by telegraph, permitted a train to enter a block only when the block was entirely clear. Sidings were located adjacent to block stations in order that operators could report trains clear of the main track. They would then permit another train to use the main track through the block. With the later development of the telephone, one was usually located in a booth at either or both ends of sidings. Train crews could report when their trains had cleared the main track and likewise could ask for permission to reenter the block when the train to be met or passed had gone by.

The manual block system was equally applicable to single and to double track and constituted only an additional element of protection to the observance of time schedules and the directions conveyed by train orders, which were supplemented and reinforced by the signals but not superseded by them. Trains continued to have their time table schedules which they fulfilled and all deviations from scheduled movements were made by train orders delivered as in the past, but the block system provided a much more effective method of preventing collisions on busy lines and also expedited train movement by the greater precision of control it assured the dispatcher.

To give increased track capacity, modifications were soon introduced to permit freight trains to follow other freight trains through a block, but in no case would any train ever be allowed to enter a block occupied by an opposing train. In order to afford special protection for passenger trains, they were never permitted to enter any but a clear block and no following train might ever be allowed to enter a block occupied by a passenger train. As traffic density increased and greater train movement capacity was needed either in the operation of single or of double track lines, further increases in track capacity were sought by decreasing the length of the blocks. However, each block of a manual block system required operators for 24 hours a day if maintained at standard length continuously. Operators could be dispensed with at non-rush periods of the day by closing a block station between stated hours, in which event its signals were fixed at proceed and the block length was increased to the aggregate of the blocks on either side.

When the volume of traffic on important lines reached a point at which it became necessary to establish the block stations at average intervals of five miles or less the cost of block operators became burdensome, particularly when the number of block stations began to exceed the number of wayside freight and passenger stations, for in the beginning most agents also served as the block operators. At the same time this disadvantage was being felt, some of the human fallibility in the manual block system itself became increasingly apparent. While the manual block or space interval method was a great improvement over the time interval method of protection of following trains (and the latter was not applicable to the protection of opposing trains on single track), collisions due to man failure were not uncommon, on routes so protected. This followed both disregard of signals and the practical necessity of permitting freight trains to follow other freight trains through occupied blocks under so-called "distinctive permissive" (i.e., caution) signals. These could be accepted only by a "train, other than a passenger train" and indicated that it was proceeding into a block occupied by a "train other than a passenger train." There was a growing necessity both for reasons of safety, economy and expedition of movement to have signals actuated by the trains themselves rather than by operators at wayside points. This led to the utilization of automatic block signals controlled entirely by electric circuits carried in the tracks, which, in turn, were actuated by trains moving over the line.

In the automatic block signal system, any given length of track might become a block. The signal protecting it was located at the entering end, considered from the standpoint of the direction of traffic. In the simplest form of such an installation, an electric battery is located at the forward or leaving end of the block; the positive pole is connected to one rail and the negative one to the other. All rail joints are bonded to insure an uninterrupted flow of current except at either end of the block where insulated joints are used to prevent the passage of current from one block into another. When the block is not occupied by a train and there are no broken rails or open switches or other conditions interrupting the passage of the electric current, it flows constantly down through the rail to the other end of the block where the signal guarding its entering is located. There the electricity passes through a relay, which in turn actuates the device controlling the position of the signal. When the track ahead is clear and a train passes the signal and enters the block which it protects the wheels and axles short circuit the current which no longer energizes the relay.

The signal relay is then de-energized, causing the signal to indicate STOP.

The signals just described are of the very simple two-position automatic type indicating stop, the block is occupied or there is a broken rail or open switch ahead, or proceed. In present practice, signals convey not only information relating to the block immediately ahead but also to the condition of succeeding blocks and indications respecting diverging movements to be made through turnouts and cross-overs at interlockers with required speed restrictions. These various signal aspects are controlled through interconnected electric circuits which can only be satisfactorily explained in detail by reference to wiring diagrams, which is beyond the scope of this study. Signals may be entirely automatic in their actuation or their protective features may be of that nature yet still be subject to the control of the towerman, in order that he may hold, advance or divert trains in accordance with the directions of the train dispatcher or on his own initiative if this authority has been delegated to him.

At interlockers the switches and signals are so interconnected that their operation must be made in pre-determined order and are so interlocked with signals that conflicting train movements cannot be made; hence the significance of their name. These usually serve as train order offices and block stations and are in continuous communication with the dispatchers at division headquarters, thereby permitting the manipulation of trains to be brought entirely under the control of the dispatchers.

On lines equipped with two or more main tracks and automatic block and interlocking signals, train orders are seldom used except when it is necessary to run trains against the current of traffic on a track on which the automatic block signals protect trains running only in the opposite direction. Double track lines normally are not signalled both ways, but only in the direction of the established current of traffic. Single tracks may be equipped with automatic signals and in this event are of course signalled in both directions. Automatic signal systems for one way traffic on double track lines are not so complex as those for two way movement on single track lines so the former preceded the latter which are usually of the "Absolute Permissive Block" type, commonly referred to as "APB." "Absolute", i.e. "stop and stay," signals protect the entire extent of single main track between sidings against opposing movements but establish the ordinary type of protection afforded by the three indication block signal (i.e., stop, approach, proceed) for following movements which are facilitated by intermediate signals at standard spacing.

Block signal protection on single track lines, whether of the manual or of the automatic type did not permit the operation of trains by signal indication, without the use of the time table or train orders, unless the protective features of "controlled manual block" or of "the lock and block system" were superimposed on those respective facilities. The "controlled manual block" system was designed before the days of automatic block signal protection to permit trains to run by signal indication only. This device and its related practices were principally used on the Pennsylvania many years ago. It was never extensively utilized and is mentioned more because it represents a significant step in the history of signal development than because it was very widely used. In a controlled manual block system, the manually operated signals protecting either end of a block were interlocked by an electric locking device which prevented the manually operated signal at one end of the block being cleared except by the coordinated action of the operator at the opposite end who thereby locked the signal governing the opposing movement there in the stop position.

Controlled manual block was primarily utilized in the days of the manual block system to permit two directional operation of trains on double track or on the middle track of three track lines. When automatic signals supplanted the manual block system on double track lines, the middle track of three track lines at first usually remained under controlled manual block. This was an unsatisfactory hybrid arrangement which was eventually corrected by the development of the so-called "lock and block" or "traffic direction block" system for movement of trains by signal indication, only, over tracks automatically signalled in both directions. "The lock and block system" established the traffic direction of the automatic signals for the track equipped for this type of movement through the coordinated action of the block operators at adjoining interlocking towers. The operator at one end of the block must electrically lock all signals in the stop position for opposing trains before the towerman at the other end can clear the signals for the train movement to be made.

Installation of the "lock and block" system of two directional signalling for train movement by signal indication only was limited to a relatively few installations on very busy two and three track lines approaching terminals where there was heavy alternating directions of traffic at different hours of the day. The "lock and block" system, like the controlled manual block system which preceded it, depended upon operators at adjacent interlocking stations to manipulate electric locks which established the direction of movement under the telephoned or telegraphed instructions of the dispatcher at division headquarters.

CTC now achieves fully the objective of train movement by signal indication only which was obtained over limited sections of track first by controlled manual block and later by the "lock and block" system for automatic block territory. CTC permits all switches and signals over an extended distance, now as much as 100 miles or more to be handled directly by the dispatcher himself from a single control panel. Switches and signals are so interlocked that the dispatcher cannot clear signals to permit opposing trains to occupy a block between two main track turn-outs at the same time, or mishandle switches or commit other errors. The dispatcher has an illuminated diagram before him of all tracks, switches, and signals. Indicators show the position of signals and switches, and lights report whether tracks are occupied or clear. By the manipulation of small levers and control buttons, he is able to place switches and signals in the position required to hold or to advance trains or move them on and off of sidings. Trains can be run, however, only if tracks are clear of opposing ones and the movements which the dispatcher arranges can be made with safety. An interesting auxiliary to this equipment is a train dispatcher's register which records automatically the time each train passes designated "reporting points;" that is, turn-outs to passing sidings, junctions, etc.

The principal advantages of these CTC installations are that they dispense entirely with wayside block and interlocker operators and also permit the dispatcher to select the siding at which trains will take sidings to meet, or be passed by, other trains at the latest possible moment before such movements occur. Very little time is required to place CTC switches and signals in proper position to advance a train on the main track or to move it to and from sidings but many minutes of time are consumed to accomplish the same results through train orders or instructions issued to block or interlocking stations. The latter leads to inevitable delays in train movements which CTC eliminates; along with the costs of many operators who are no longer needed.

CTC invariably enables the dispatcher to advance the inferior train to the most distant siding which it can reach without delay to the superior train. Many of the "meets" and "passes" of trains established in CTC territory are so closely timed, yet all with complete safety, that the train which takes the siding is never stopped. While it cleared the main track in time to avoid any detention to the superior train, by the time the former has run through the siding, the latter has gone by. The train on the siding continues moving; the outlet switches and signals are promptly cleared and a "non-stop meet" (or pass) has been made.

The foregoing represents only a brief summary of the practices relating to the operation of trains which are set forth in detail in the Book of Rules for conducting transportation on modern railroads. Safety of employees, the public, and of property of great value, depends upon a complete understanding and unquestioning obedience of these rules by those who execute them. Faithful performance, not once or twice but upon every occasion is essential in the most minute detail. For this reason discipline is inflexible and the penalties for violation of rules must be severe. Thousands of trains run daily in the United States and serious accidents seldom occur. This is eloquent testimony to the personal efficiency of the management and employees of American railroads.

While the fundamental principles of train movement embracing the art of train dispatching are deeply grounded in experience and practices of the past, actual train movement, particularly on heavy density lines, whether of single, double or multiple track, is being governed more and more by signal indications, only, and less and less by time table and train orders.

In railway practice, the term "signal" has many meanings. There are fixed signals, hand signals, whistle signals, communicating signals and devices such as torpedoes, fusees, switch targets, signs at mile posts, tunnels, bridges, crossings, points of speed restrictions, etc., used to convey information affecting the movement of trains and engines. However, in this chapter on "signals" that word will be used solely to refer to signals of fixed location which are used to indicate whether a track is clear or occupied and whether a train is required to stop or is authorized to proceed, either at the maximum permissible rate or under the restrictions indicated. Signals are of two types: (1) those which govern movement through an interlocking plant and (2) those which govern movement through the consecutive blocks of a block system. The same signal may do both.

The definition of an interlocking is an "arrangement of signals and signal appliances so interconnected that their movement must proceed each other in proper sequence . . . . . It may be operated manually or automatically." Switches and crossings and drawbridges as well as signals are controlled by interlocking stations. Trains can make diverting movements through interlocked facing point turnouts at higher speeds than would be possible over hand thrown switches. Diverting movement through all switches, whether interlocked or not, must be made at restricted speeds, although it is now permissible to run 40-45 m.p.h. through interlocked #20 turnouts and crossovers, with their long switch points, small frog angles and comparatively easy radius of curvature between the heel of the switch and the point of the frog. The curvature through the turnout cannot be superelevated because of the necessity of bringing the gauge lines of the rails together at a crossing in a frog. Crossovers* to parallel tracks or convergence of parallel tracks introduce reversed curves.

Note: *A turnout is the technically correct term for the device popularly known as a switch. The number of a turnout is established by the number of the frog which is the ratio between the distance from the point to the heel of the frog and the spread between the gage lines there. Trigonometrically expressed, the number is half the cotangent of half the frog angle or $N = 1/2 \cot. 1/2 F$. The shortest turnout commonly used in main track practice is a No. 10. No. 20 is the longest. The intermediate numbers of 12, 14, 15 and 16 are standard practice for various roads under predetermined conditions. A crossover is comprised of two turnouts in adjacent parallel tracks so arranged with connecting rails as to permit trains to pass from one track to another. Turnouts which are so located in relation to the direction of movement of a train that it can be diverted from the normal route if the switch is "reversed" are called a facing point turnout or switch. In this case, the train passes over the switch point before reaching the frog. If the train movement is in the opposite direction in relation to the switch, it is said to be a trailing point movement.

The speed of the train through a diverging route must be restricted to that which is safe for operation around a curve of that radius without superelevation. The curve used in the diverging route may have a long radius or a relatively short one. The longer the radius, the greater the distance between the switch point and the frog, i.e. the "lead" of the switch; hence the smaller the angle at the frog.**

Railway signal systems first developed around interlocking plants. Since visual signals of fixed location are of paramount importance to train operation, brief reference to their historical background may be appropriate. The semaphore method of hand signalling was developed by armies and navies before the time of the Napoleonic wars. Railway signals of the semaphore arm type were first used in England and were connected with switches in such a manner as to show the latter's position. The use of semaphores was soon extended by bringing their control into conveniently accessible cabins or stations. Both switches and signals were operated from those points to direct train movement.

Before 1860 interlocking plants were being installed on the British railways on a considerable scale to control the manipulation of switches and signals at junctions and crossings and to direct the operation of trains through and beyond them. Interlocking towers were located at all of these points, and at many intermediate ones where crossovers were needed on multiple track routes, so the principal British routes became lined with these cabins. The concurrent development of manually controlled switches and signals and the interconnection of the control stations by the telegraph formed the basis for the natural evolution of the system by which

Foot Note: **Flanges bear against the gage, or inner side of the rail and are necessary to prevent car wheels from running off the track. Where turnouts and crossings must be placed in railroad tracks, a device known as a frog is necessary to provide a flangeway for the wheels through the gage of another rail and also to afford adequate protection to prevent derailments at those points where the gage is not continuously provided by a rail or other supporting and guiding surface.

trains were moved from tower to tower under manual block signal indications on the double and multiple track lines of Great Britain. This could be done without the overriding supervision of a train dispatcher to arrange meeting points with opposing trains through train orders sent by a telegraph operator, who in this country was usually also a station agent or otherwise the operator of the signals and switches controlled from an interlocking tower. Train dispatching is a peculiarly American development designed to meet the economic necessities of the light traffic single track lines of this country, in contrast to the double track lines abroad.

The manual block signal system which is the practical application of the space interval system between train movements was first established on a large scale in the United States on the main line of the New York Central & Hudson River Railroad between New York and Buffalo in 1882. This was then a double track line and the block system merely spaced following trains. The first manual block system on single track on the North American continent was installed on the Canadian Pacific Railway in 1885, while its transcontinental line was still under construction. Manual block signals were installed solely in the interest of safety to prevent collisions and did not authorize any movement not provided by time table and train orders. In England, however, the manual block system signal provided the means to move trains.

The development of the electric track circuit provided the foundation of the automatic block signal systems. The first successful installation was made in 1879 on the Fitchburg Railroad, now part of the Boston & Maine. There was a gradual development of automatic block signals in the '80's. At the outset, these were used only to prevent rear end collisions on double track lines where there was a one-way movement of traffic on each track. The commercial application of electricity was then in its infancy and reliable small motors were not yet available to actuate the signals so clockwork and compressed air provided the power to do so. The first successful installation of automatic block signals on any considerable length of single track was made by the Cincinnati, New Orleans and Texas Pacific Railroad (now Southern Railway System) in 1891, and the second was completed by the Chicago & Alton Railroad in 1899. It was in the first decade of the present century that the Union Pacific and the Southern Pacific, under the direction of E. H. Harriman, installed the first automatic block signal protection on important aggregate lengths of single and double track mileage.

The desirability of non-stop operation of trains over junctions, railway grade crossings, drawbridges and through crossovers created the original necessity for interlockers which controlled movement within their fixed limits but at first the interlockers did not enter into line operation of trains beyond the trackage directly included within the scope of the plant. It was, however, a logical development to substitute the operators at interlockers for station agents, wherever available, for transmission of train orders and as the manual block system developed, interlocking stations naturally became block stations, too.

The first mechanical interlockers were confined to the limits within which a strong man could move the switches and locks manually by levers connected to them by pipe leadouts. The maximum range was around 600-700 feet on either side of the tower. Separate levers were necessary for the facing point locks and for each switch point and movable point frog where the latter devices were used in slip-switch installations. The inevitably slow speed of manipulation of these levers and the length of the mechanical interlocking machine needed to accommodate any considerable number of switches and signals required the services of several men at the larger plants. It may be of interest to mention that the largest electro-mechanical interlocker (i.e., signals controlled electrically but switches and other track functions operated manually) in the United States is the one at State Line, Illinois, near Hammond, Indiana, owned and operated by the Chicago & Western Indiana Railroad. Most of the large manually controlled plants were replaced long ago by newer ones using power operated switches.

The range of trackage covered by a single interlocker was greatly extended and the operation accelerated when it became possible to operate switches first by pneumatic and later by electric motors and control these, as well as the signals, electrically. This permitted a natural integration of interlockers into the automatic signal system which protected all of the tracks within its limits. Interlocking and block indications could then be given by the same signal.

When the electric all-relay type of interlocking was perfected as an improved substitute for the mechanical interlocking previously used in power as well as manually operated plants coincidentally with the low voltage remote controlled power thrown switch it became possible to provide in effect (1) a small interlocker at every switch, (2) establish a "lock and block" system of traffic directional control of signals between all sidings, and (3) consolidate at one point all of the controls for both switches and signals over a long extent of line. When fully perfected this became centralized traffic control, or CTC. The original installation was one of about 40 miles made in 1925 on the "Ohio Central Line" of the New York Central System between Toledo and Berwick, Ohio, and was reported as follows in "The Railway Age" of October 2, 1926:

"The arrangement of switches and signals to provide for the convenient movement of trains on single track without the use of written orders is to be established by the New York Central on a line about 40 miles long, putting the movement of trains on the whole of this section as completely in the hands of the man in the cabin as is the case in a large passenger terminal. Single-track arrangements of this kind and the terminal arrangements at such places as the Grand Central, New York City, are alike, in that the man who controls the levers is constantly giving proceed signals for trains where both the train and the signal are entirely out of his sight.

"This section extends from Stanley, Ohio, on the Ohio Central Lines, about five miles from Toledo, southward to Berwick, Ohio. It is on the line from Toledo to Bucyrus and Thurston. A statement printed in the New York Central Lines Magazine for September, page 11, says that in this territory the man in control will operate 30 switches--the equivalent of 30 small interlocking plants, and interspersed with these are 31 automatic block signals with 31 block signals interspersed."

The length and completeness and complexity of CTC installations has greatly increased over the subsequent years. Now there are more than 10,000 miles of CTC equipped lines in the United States.

On both single and double track, CTC permits the inferior train to be advanced to the most distant siding it can reach without delay to superior trains. The automatic block signals which are an integral part of the system afford absolute protection against the hazard of collision and obviate the time losses of long clearances otherwise required.

Time tables are used on CTC equipped lines only to indicate the train service to be provided and the running time to be observed. Signals alone establish the right of any train to occupy and move on the main track or direct it to enter sidings or yards. Watches and time tables and train orders are not necessary for train dispatching on CTC equipped lines.

The operator of a CTC machine must have complete control over the entire railroad within his jurisdiction. No locomotive or train may enter a CTC equipped line except upon the specific authority of the operator. Each power thrown switch and its protective signals is actually a small remote controlled interlocking plant and it would add excessively to the cost of an installation to use this type of switch and signal control mechanisms at the turnouts to industrial sidings and auxiliary tracks. However, an accident can be as readily caused by a switch engine entering the main track from an industry track without appropriate authority, as though it were to proceed to move off of a siding without a signal to do so. It is essential to give the CTC operator absolute control over trains entering or leaving the main track at every point. In order to avoid the expense of providing power controlled switches and signals when these are not used by road trains (i.e. at industry tracks, etc.) electric locks are provided that prevent main track hand switch connections of industrial tracks, etc., being reversed to allow engines and cars to leave or enter the main track until the CTC operator authorizes the movement by unlocking the proper switch. This in turn can be done only when the protective circuits indicate that the line control on the CTC machine is clear of any train movements that would make it unsafe to do so. Telephones located adjacent to the switches provide the means of communication between train crews and CTC operators relating to the use of electrically locked switches.

CTC is usually associated with single track operation but it is equally applicable to double track or multiple track for it permits complete flexibility of train movement by signal indication in both directions on each track. When this is done and sets of crossovers are installed at intervals of 5 to 10 miles for facing point movement in either direction on both tracks, to facilitate the meeting and passing trains, the line will have maximum capacity for expeditious movement of trains. Sidings are integrated into double track CTC installations but these are used as little as possible because the primary purpose of two-way operation on two tracks is to keep trains moving continually and hence off of sidings.

CTC will increase the capacity of single track at least 80% over that which is possible without it and give a double track line virtually the same capacity as a 3-track route having the two outside tracks automatically signalled in the current of traffic and the middle track signalled both ways with traffic directional locking of the "lock and block" type between interlocking stations. It should, however, be pointed out that the 80% estimated increase added to single track capacity by CTC does not give the line so equipped 80% of the capacity of a double track. A double track, with automatic block signals in the direction of current of traffic only, has at least 400% of the capacity of a single track. A CTC installation on single track has 180% of the capacity of a line not so equipped. Therefore, the installation of CTC on single track gives that line no more than 45% of the capacity of a double track without CTC but this is sufficient to substitute CTC for double track in most cases.

CTC is not yet extensively used on long stretches of double track, although there are some notable exceptions to this statement (but small in proportion to the total installations), such as the Rock Island's CTC equipped two track main line across Illinois. The Santa Fe has installed CTC on its busy double track main line between Holliday and Olathe, Kansas, 12.5 miles where train density is the heaviest on the system and capacity is handicapped by a continuous 0.6% westward ruling grade out of the Kaw River Valley. Sharp curvature has been an additional handicap there in the past but this is now being reduced so that it will no longer restrict speed in this section where it is important to provide maximum capacity.

There are, of course, short stretches of double track, usually protecting terminal approaches, on some of the Santa Fe's CTC equipped routes which are predominantly single track lines but even the new installations later tabulated in this chapter were not extended over much, if any, of the double track mileage of the routes equipped.

The completion of the Wellington-Waynoke installation will bring the Santa Fe total up to 862.3 road miles and 909.8 track miles of CTC. This indicates 57.5 miles of double track lines included in the routes so equipped. The one between Holliday and Olathe, Kansas, is 12.5 miles in length. The remaining 45 miles of CTC equipped two-track lines are in scattered locations on predominantly single track installations, the longest being 7.4 miles between Dodge City and Wright, Kansas.

Outside of CTC territory the following double track lines are equipped through traffic directional locking of two-way signalling on each track to permit two-way operation of trains on each track by signal indication only:

Division	Limits of Operation	Miles
Illinois	Willow Springs (17.4 mi. w. of Chicago)-Joliet	20.0 mi.
Illinois	Pequot, Ill.-East Fort Madison, Ill. except for 14.1 miles between GI Tower through Galesburg to Appleton *	159.7
Missouri	Gauntlet over Missouri River Bridge at Sibley **	1.0
New Mexico	Wootton, Colo.- Lynn, N. Mex. (through Raton tunnels)	1.0
Los Angeles	San Bernardino-Rana (three tracks)	2.1
Los Angeles	Rana-Bridge B5 over Santa Ana River between Colton and Highgrove	3.8
Los Angeles	Mission Tower-Broadway, Los Angeles	0.7
	Total	188.3 mi.

Note: * Equipped with Union Switch & Signal Co.'s continuous induction automatic speed control with three speeds and three indication cab signal. Wayside signals omitted except at interlockers.

** Automatically interlocked signal protection against opposing movements.

While listing the sections of Santa Fe track, outside of CTC territory, which can be used by trains running in both directions under signal indication only without time table or train order authority, it may be well to mention that there is one single track section of this classification - between Sheffield (Kansas City) and Congo, Missouri, 2.2 miles. The track layout and operation there is described in Section D of Chapter III.

The problem of passing faster trains around slower ones on double track lines must be considered from the standpoint of prevailing conditions rather than the ideal ones which are provided by equipping each track with two-way automatic signals and through centralized traffic control or traffic direction locking run trains in both ways on each by signal indication only without the use of train orders.

The normal pattern of operation of double track lines is to assign one track to the current of traffic in one direction and the other one for the opposite movement. Automatic signals on double track lines protect trains moving with the current of traffic only. Trains moving against the current of traffic have no automatic block signal protection and so can proceed only under the authority of train orders as though operating on a single track under like conditions. This restricts such movements to emergencies. However, trains operating with the current of traffic on double track lines equipped with automatic block signals do not require train orders, either to leave the initial terminal or move en route, including the necessity of entering a siding to clear the main track for a following train or trains, or to return to the main track after the latter have passed. Therefore, whenever a slower train must be passed by a faster one following on the main line the former must take the siding for the latter.

The slower trains to be passed are usually freight trains, both through and local. On all Santa Fe main line train districts which include all important double track mileage, every freight train runs as an extra train, i.e., it has no time table schedule. It is the passenger trains which require the freight trains to take the siding. Passenger trains run on time table schedules. This enables a freight train to determine the siding at which it must clear the main line for each passenger train that will pass it. If the passenger train is late, the dispatcher must avoid delay to the freight train through a message informing it of details of this fact.

Some eastern railroads have equipped certain double track lines with distinctive "take siding" indicators, or signals, controlled from stations and interlockers along the line under the direction of the dispatcher.* Freight trains are permitted to run over these routes without regard to the schedules of following trains until directed to take the next siding in this manner. Such facilities are uncommon but every interlocker located along a line of railroad to protect crossings and junctions and perform other functions can in effect give a "take siding" or "proceed" indication through the information it can relay from the dispatcher to the train by a signal or a message. The interlocker should also control the facing point turnouts to sidings; if need be through remote controlled switches. The trailing point turnouts at the leaving end of sidings can be equipped with spring switches to permit trains to enter the main track without stopping to throw hand switches.

Interlockers, while provided for other purposes, greatly facilitate train movement (in the absence of CTC) not only through the avoidance of delay to trains entering sidings by operating the switches leading to

*In accordance with Rules Nos. 280, 296 and 508, Santa Fe uses a "take siding sign" to instruct trains to enter certain sidings. To secure an additional measure of control at these or other points, it also makes limited use of a "leave siding signal". Signals for both purposes are limited to use on automatically signaled double track lines in non-cTc territory and are under the control of an operator at an interlocker or train order office.

them, but of even greater importance is their control of the movement of the inferior train at that point through the coordinated action of the dispatcher and the tower operator. Train order offices also provide points of communication with inferior trains permitting the dispatcher to inform them of later superior trains, and, if desirable, specify the places at which they shall take the siding.

Approximately one third of the mileage between Chicago and Los Angeles over any of the combination of routes over which Santa Fe trains run are single track lines. Wherever these exist an alternate main line provides a second track because its transcontinental train density is much too heavy to be carried on one. However, even though another is available on a different location, the single track lines impose their individual operating problems and requirements and these influence the facilities and details of train operation reviewed in this chapter.

All of the first and second main tracks included in the component routes of the Santa Fe's transcontinental lines between Chicago and Los Angeles, San Diego and San Francisco are completely equipped with automatic block signals. These also have been installed between La Junta and Pueblo and Denver, between Mulvane and Winfield, Kansas, and on south to Houston and Galveston; between Ottawa Junction, Kansas, and Tulsa; and between Fort Worth and Dallas. The line between Temple, Texas, and Texico, New Mexico, is partially equipped.

Significant data on the extent of the Santa Fe's present signal system and recent extensions and improvements of it are summarized in the tables which will follow. The one listing the CTC installations includes the mileage between Waynoka and Wellington which is still under construction. As a matter of comparative interest, similar data for the fifteen railroads having the largest aggregate mileages of CTC in service as shown on Table XXIII. It shows that the CTC equipped mileage of Santa Fe's neighbor and competitor, the Union Pacific, now gives it first rank in this important respect. That position has been achieved by its rapid extension of this type of signalling over all single track sections of its system extending from Los Angeles through Salt Lake City and thence northwest from Ogden to the Columbia River. The Santa Fe, however, now has continuous CTC or double track from Chicago via the Southern District to Los Angeles and this gives it all of the line capacity which it presently needs.

Since the principal purpose of cTc is to control the movement of trains in and out of sidings and between them, these tracks should be carefully studied from the standpoint of proper location, spacing and length before an installation of this nature is made. It will invariably be found necessary to lengthen a considerable number, if not all, of those retained for use, particularly if it is desired to take advantage of the frequent opportunities which cTc provides for so called "non-stop meets" or passes.

Train densities justifying cTc will usually have necessitated sidings at minimum intervals, i.e., five miles apart, for operation under time tables and train orders, with or without automatic signal protection. Unless train movements average at least one per hour or 24 per day, equally close spacing of sidings will not be required to move the same number of trains expeditiously with cTc as without it. Therefore cTc has frequently permitted a reduction in the number of sidings on a division, but this general observation does not apply to the recent Santa Fe installations, which have been designed to permit peak movements of from 40 to 70 trains per day.

TABLE XX

INSTALLATIONS OF AUTOMATIC SIGNALS
December 31, 1948

Miles of Road			Miles of Track			No. of Block Sections		
Single Track	Double Track	Total	Single Track	Double Track	Total	Single Track	Double Track	Total
3124	1877	5001	3124	3660	6784	2602	2646	5248

Santa Fe's manual block signalled mileage was small; i.e., 9 miles of single track and 40 track miles of third and fourth track on multiple track lines where the first and second track is equipped with automatic signals.

The foregoing data includes the automatic block signalling embraced in cTc and continuous induction speed control installations as follows:

	Miles of Road	Miles of Track
Centralized Traffic Control	754.0*	798.8
Continuous induction speed control with cab signals	175.4**	355.0
Total	929.4	1153.8

*See Table XXII for details of cTc installations. cTc mileages reported in this table exclude Wellington-Waynoka project, with 108.3 miles of road and 111.0 miles of track. This was under construction but not in service on January 1, 1949.

**From East Fort Madison, Illinois, to Plaines, Illinois.

TABLE XXI

AUTOMATIC BLOCK SIGNAL INSTALLATIONS

A. T. & S. F.
ALL DIVISIONS
1935 - 1948

DIVISION	LOCATION FROM	TO	MILES S.T.	D.T.	YEAR
Missouri	Congo, Mo.	Sheffield, Mo.	2.2****		1939
Middle	Newton	N. Wichita, Kan.	24.0**		1948
	S.Jct.Wichita	Mulvane, Kan.	14.7**		1948
	Ellinor	Bazar, Kan.	10.7**		1945
	Bazar	Eldorado, Kan.	36.7**		1947
	Augusta	East Jct. Mulvane	15.0**		1945
	Mulvane	Cicero, Kan.	11.0**		1945
Colorado	Bragdon	So. Denver, Colo.	103.9**		1947
Plains	Waynoka, Okla.	Pampa, Tex.	150.4**		1945-47
	Canyon	Texico, N. M.	73.8**	6.2	1948
	Texico	Clovis, N. M.		9.3	1944
Pecos	Clovis	Melrose, N. M.		24.1	1944
	Melrose	Joffee, N. M.	94.2**		1944-45
	Joffee	Vaughn, N. M.	[illegible]	12.5	1944
	Vaughn	Negra, N. M.	21.2**		1944
	Negra	Belen, N. M.	87.8**	1.1	1943-4-5-6
Albuquerque	Belen	Dalies, N. M.		10.3	1943
	Joseph City	D.T.Jct.Carrizo,Ariz.		23.5	1940
Arizona	Topock	Needles, Calif.***		11.6	1945
Los Angeles	Colton	San Bernardino, Cal.		3.5	1944
	Arcadia	Pasadena, Cal.	7.5		1946
	Pasadena	Olga	2.5		1941
	Broadway	Mission Tower, Los Angeles		0.7	1939
	Colton	High Grove		3.8	1944
	Riverside	Fullerton	36.2*		1945
	Atwood	Orange	5.8**		1945
	Fullerton	D. T. Jct.		12.9	1943
	D. T. Jct.	Bandini	2.2**		1943
	Bandini	Hobart		3.2	1943
	Fullerton	San Diego	99.1**	3.3	1943-44
	Redondo Jct.	Mission Tower		3.0	1939
Valley	Richmond	Malott, Cal.	4.0		1940
Gulf	Algoa, Tex.	Houston, Tex.	23.5**		1944-45
Northern	Paul's Valley	Purcell, Okla.	22.0		1945
Southern	Brownwood	Sweetwater, Tex.	112.1		1946-7-8
		Total	960.5	129.0	

* Incorporated into cTc installation.

** Installed on paired track; hence while listed under single track since AT&SF owns only one track and D&RGW has the other, these signals protect trains running with current of traffic only and are not the conventional APB type, used on all other single track installations reported herein.

*** On new bridge and related line change. **** Equipped with traffic direction locking.

CENTRALIZED TRAFFIC CONTROL INSTALLATIONS

Division	Between	Miles of Road	Miles of Track	Location of control Machine	Mis.from control point to most distant controlled home signal	No. Passing Sidings	No. Switches Controlled	No. Signals Controlled Semph.	No. Signals Controlled Light	No. Auto.Signals Semph.	No. Auto.Signals Light
Eastern	Holliday-Olathe, Kans.	12.5	25.0	Holliday, Kans.	12.5	1	6	-	13	-	28
Middle	Ellinor-Eldorado(Twr.B)Kans.	47.4	47.4	Newton, Kans.	107.1	8	14	-	42	-	22
Middle	Augusta(EndDT)-EastJct.,Kans.	12.7	12.7	Mulvane, Kans.	18.9	2	5	-	17	-	16
Middle	WestJct.-Cicero(End DT)Kans.	8.3	8.3	Mulvane, Kans.	9.6	1	4	14	-	5	-
Middle	Newton-N. Wichita, Kans.	24.0	24.0	Newton,Kans.	24.0	4	11	-	38	-	10
Middle	S.Jct.Wichita-Mulvane,Kans.	14.7	14.7	Newton,Kans.	42.8	3	12	-	21	-	7
Western	Kinsley-Dodge City, Kans.	33.7	41.1	Dodge City, Kans.	34.1	6	22	-	46	-	24
Panhandle	Wellington (S.K.Jct.)Kans. Waynoka, Okla.	108.3	111.0	Wellington, Kans.	102.0	17	70	-	143	-	82
Plains	Waynoka,Okla.Pampa,Tex.	150.1	151.8	Amarillo, Tex.	205.8	26	91	-	205	-	123
Plains	Canyon,Tex.-Texico,N.Mex.	80.0	86.2	Amarillo, Tex.	96.1	12	43	-	99	-	51
Pecos	Melrose-Joffre, N.Mex.	96.7	101.0	Clovis,N. Mex.	119.5	16	38	-	106	-	68
Pecos	Vaughn-Belen, N. Mex.	107.2	107.2	Clovis, N. Mex.	238.9	20	44	-	126	-	82
Los Angeles	Riverside-Fullerton, Cal.	42.0	42.0	Fullerton, Cal.	36.2	14	32	-	79	-	34
Los Angeles	Bandini-DT Jct., Cal.	2.2	2.2	Fullerton, Cal.	15.1	1	2	-	6	-	2
Los Angeles	Fullerton-El Toro, Cal.	23.0	27.0	Fullerton, Cal.	23.0	5	16	-	37	-	14
Los Angeles	El Toro-Old Town, Cal.	76.0	80.5	Oceanside, Cal.	38.0	20	43	-	113	-	64
GC&SF-Gulf	Houston (T&NO Xing)-Algoa, Tex.	23.5	27.7	Alvin, Tex.	19.3	6	26	-	47	-	13
		862.3	909.8			152	479	14	1610	5	640

Reference: Centralized Traffic Control Installations Report to I.C.C.
I.C.C. Signal Report - Form 5 - January 1, 1948. (Corrected to January 1, 1949.)

TABLE XXIII

CENTRALIZED TRAFFIC CONTROL

On the Principal Users of This Facility
Ranked in Order of Track Mileage in Service
at end of 1948

		Track Miles In Service Jan. 1, 1948	Track Miles Installed During 1948	Total
1.	U. P.	673.4	320.5	993.9
2.	A. T. & S. F.	693.6	124.9	818.5*
3.	M. P.	692.4	76.2	768.6
4.	C. B. & Q.	719.4	25.5	744.9
5.	C. R. I. & P.	648.8	64.0	712.8
6.	C. & O. (Incl. P.M.)	491.7	135.3	627.0
7.	L. & N.	533.1	76.0	609.1
8.	D. & R. G. W.	483.6	12.7	496.3
9.	N. & W.	449.3	44.6	493.9
10.	C. M. St. P. & P.	469.3	--	469.3
11.	S. P. (Pacific System)	364.4	50.4	414.4
12.	P. R. R.	412.0	--	412.0
13.	S. A. L.	354.9	36.4	391.3
14.	B. & M.	254.5	27.1	281.6
15.	N. Y. C. & St. L.	210.3	68.5	278.8

Notes:

A - Data with respect to track miles in service January 1, 1948 is taken from Table No. 8, I. C. C. Tabulation of Signal Statistics.

B - Data with respect to track miles placed in service during 1948 is taken from Railway Age Annual Statistical Number, January 8, 1949.

* Subsequently increased to 909.8 miles when entire installation on Pan Handle Division between Wellington and Waynoka was placed in service.

The preceding table, No. XXII, which summarizes the Santa Fe's 862 miles of cTc shows the number of sidings included in each installation. The total of 152 is equivalent to one for each 5.7 miles of cTc equipped line. However, the actual spacing between them is reduced by the length of the siding itself and Santa Fe sidings in cTc territory average much in excess of one mile long. There are 47.5 miles of double track included in cTc line mileage and reduced siding spacing is properly allowable there. Average siding spacing is increased whenever two parallel sidings are located on either side of the single or double track main line. After adjusting for these factors, it is reasonable to state that the distance between the ends of sidings on single track in cTc territory averages around four miles.

Long sidings built and equipped in the manner that will be described in a following paragraph and integrated into cTc permit maximum capacity for moving trains on single track over high speed lines of favorable physical characteristics. The probable capacity of such a route is close to 100 Diesel-powered trains per day before congestion and delay will appear but double tracking would undoubtedly begin by connecting the principally used sidings when average daily train movement approaches 72, or three trains per hour, and would be completed by the time it had grown to 96, or four trains per hour; two in each direction within that period.

The Santa Fe endeavored to carry the development of single track cTc installation to its maximum potentialities for providing line capacity, short of actual construction of double-track, by (1) building sidings of extraordinary length; i.e. from $1\frac{1}{2}$ to 3 miles and (2) by building many of these sidings, virtually to main track standards; (3) carrying the installation of automatic block signals in both directions entirely through these tracks and providing intermediate block signals, to give continuous block protection in both directions through their entire length. In addition to all of these unique features, at some points within cTc territory, not just one long siding was built at the conventional intervals but two were installed; one on either side of the track. This in effect provides short stretches of three track railroad at these points.

The unusually large cTc office in the headquarters of the Plains Division at Amarillo, Texas, is notable because it includes three cTc machines, one for each district. One of the three is not in a fixed location but is on rollers in order that it can be moved for consolidated operation by one man handling two districts, or seperately when traffic is so heavy as to necessitate individual operators for both the First and the Second Districts east of Amarillo and for the Third District which is west of that city.

Another unusual feature of the newer Santa Fe installations is that the pens on the automatic train record chart in the control panel not only indicate the time trains pass the siding switches, which are "OS", or recording, points but they also designate by distinctive marks, the time when the signals governing movement over those sections of track are cleared. This is of assistance in obviating, or settling differences, of opinion which occasionally arise when trains lose time and their crews insist that the delay was caused by the signals not being cleared sufficiently in advance to permit running under a continuous succession of proceed signals.

In the days of manual block signals, the latter displayed two indications. Those of the home signal protecting the entrance to a block were either stop or proceed. In order to warn an oncoming train when the next signal ahead was in the stop position, a distant signal, distinctively indicated by its fish tail horizontal blade by day and its yellow light by night was located sufficiently in advance of the home signal to relay that fact to an engineer.

The first automatic signals also provided only two indications; stop and proceed. By day these were displayed by the semaphore blade being in the horizontal and the vertical position, respectively. At night a light was projected through the red or green lense of the spectacle forming the rear portion of the semaphore blade to convey the same instructions as the equivalent day indication. Automatic signals, like the ones in manual block territory, required distant signals to relay advance information of stop indications to engineers of approaching trains. The distant signal, in some instances, was located apart from a block signal and in other places was attached to the mast of the block signal in the rear, as a second aspect of it. In any case, it had to provide braking distance sufficient to permit the train to stop before overrunning the home signal. The upper blade of the two arm, or two aspect, semaphore gave the indication relating to the block immediately ahead and therefore was the home signal. The lower blade served as the distant signal providing an advance indication of the next home signal. In the course of the development of the automatic block signal, the semaphore blade giving the home block indication was also utilized to serve the function of the distant signal by assigning the diagonal position for that purpose and providing an equivalent yellow light for it by night.

The earlier observations relating to the basic principles of protecting trains against collision pointed out that this was first done by providing a time interval between following trains. Later space intervals were imposed by block signal systems. Manual block was used first, and automatic block signal systems followed. The track length between signals obviously has a considerable bearing on line capacity as well as safety. As the length of blocks is shortened, trains can follow one another at closer intervals. This increases line capacity. However, as the blocks are shortened, more signals are required so the expense of their installation and operation is increased accordingly.

Table XX on Page 239 indicated that automatic block lengths average 1.2 miles on single track and 1.38 miles on double track lines. The proper length of blocks is determined by the various considerations of line movement capacity and safety of braking distance. Minimum block lengths are established by the braking distances necessary to enable trains running at the maximum permissable speed at that point to be stopped within the limits of the block between the signal giving the distant, or approach, indication and the home block signal protecting an occupied block.

Where physical characteristics of grades and curves or other operating factors restrict speeds, this can be safely given effect in blocks of reduced length. In terminals it is also desirable to have the blocks very short in order to permit trains to follow one another closely. Since speeds are low this entails no risk. On heavy grades ascending or descending where high speeds are impossible or prohibited, line capacity is increased by giving effect to this operating condition in reduced signal spacing. Conversely, on high speed main lines signal spacing must be lengthened either by extending the blocks or providing an additional block indication to protect the rear end of trains.

Just as the operation of high speed trains introduces problems of providing the power necessary to attain these increased maximum velocities, so braking systems had to be improved to overcome them in minimum time and distance for service as well as for emergency stops. While efficiency and effectiveness of braking systems has advanced along with the other features of equipment design, nevertheless the present maximum speed trains cannot be stopped within the same space limits of safe braking distance that were formerly adequate for the lower operating speeds of past decades. Signal systems that were originally built when passenger and freight trains were run at materially slower speeds must have the signal spacing revised when speed is increased in order to provide an adequate braking distance between any signal that will display a "caution" or approach, indication and the one which will give the stop indication. Where the distance between an approach (i.e. caution) and a home signal is insufficient to permit a train to come to a stop at the latter from the maximum authorized speed, the necessary protection can be given without lengthening the block, by providing a third distinctive indication in advance of the occupied block. It will warn a train one full block in advance of an approach signal that it is displayed in that aspect. This permits the warning of a stop signal ahead to be given not one but two full blocks in advance. A signal system designed to do this is called a "three block system" because three block signals protect a train against a following one by (1) stop, (2) approach or caution, (3) advance indications, before the latter can receive a clear signal to proceed at maximum authorized speed. The conventional two block signal system omits the advance indication. The three block signal system will provide adequate spacing to permit even the fastest train to stop, under the most difficult conditions, before reaching a block signal in that position.

In the familiar two block signal system a train is protected by two full blocks between a stop indication behind a train and the nearest proceed signal which can be displayed to a following train. This may be summarized as follows:

Indication of Block Signal as Stated in Rule No.	Condition of Block	Directions Conveyed to Trains
Clear - Rule No. 281	Clear	Proceed
Stop - Rules Nos. 291 or 292	Block Occupied	Stop, (also stop and proceed under Rule 509.)
Approach - Rule No. 285	Block clear, second block occupied.	Reduce speed and be prepared to stop at next signal.
Clear - Rule No. 281	Clear	Proceed

Unless blocks are longer than the 6,000-foot average, greater stopping distance is generally required for 90 - 100 M.P.H. trains than can be provided by a single approach signal.

The three block signal system carried the advance indication of a stop signal back through a second block in the rear which will afford an approach indication notifying the engineer that two blocks ahead are clear but the third is occupied. This is a command to reduce speed prepared to pass the next signal at medium speed, i.e., 40 M.P.H. for passenger trains; 30 M.P.H. for freight trains. The three block signal system will insure that trains running 100 M.P.H. or faster can come to a full stop before reaching the stop signal protecting an occupied block. The advance signal enables speed to be reduced from 90 - 100 M.P.H. to 40 M.P.H. within the limits of the first block and so permits the train to pass the approach, or caution, signal at the latter reduced rate. This assures an easy stop safely within the limits of the block ahead. The indications are:

Indication of Block Signal as stated in Rule No.	Condition of Block	Directions Conveyed to Trains
Clear (281)	Clear	Clear
Stop (291 or 292)	Block occupied	Stop (also stop and proceed under Rule 509)
Approach (285)	Block occupied, second block occupied.	Reduce speed and be prepared to stop at next signal.
Advance (282)	Two blocks ahead clear, third block occupied.	Reduce speed in order to pass next signal at medium speed.
Clear (281)	Three or more blocks ahead clear.	Proceed

A three block signal system requires four distinctive signal indications as outlined in the preceding paragraph. Three indications are as many as can be provided by one single semaphore blade in its basic positions, horizontal, diagonal and vertical and their equivalent meanings of stop, approach or caution, and proceed. On semaphore type signals the equivalent night indications shown by the colored lens in the spectacle of the blade are red, yellow and green. When a fourth or fifth indication is required, a second aspect is supplied by using another semaphore blade or its color light equivalent below the primary one to show the approach (caution) indication is displayed by the next block signal in advance. This is done by repeating the yellow light or diagonal semaphore blade on the approach signal as a part of the advance signal to it and having the second or lower aspect also show yellow. The semaphore equivalent of a yellow light is a signal blade in the diagonal position. Thus the advance signal is displayed by two semaphore blades in the diagonal position or by two yellow lights or by a combination of them; i.e. diagonal blade above and yellow light below.

It is significant to observe that one yellow light or semaphore blade in the diagonal position indicates that the block ahead is clear but the one beyond is occupied. An engineman receiving that signal must be prepared to stop at the next signal. Two identical signals of that indication, displayed one above the other; i.e., two semaphore blades in the diagonal position or two similarly placed yellow lights, or one diagonal blade above and a yellow light below, comprise the standard indication of the advance signal, reporting the block ahead in the approach or caution position. The advance signal is less restrictive than the approach signal. It will be observed that two light or semaphore blades are used for the former advance indication. If either light or blade fails, the indications appear to be more restrictive than conditions require. This is a notable safety feature of this and other details of signal aspects and instructions which automatically transfer failures or imperfectly displayed indications into more restrictive ones than would be shown if the signal were properly operative.

The advance indication (282) is frequently referred to as a "medium speed" signal or unit. The ordinary two block system was sufficient for most railway requirements until the era of high speed trains began 15 years ago. The inauguration of high speed passenger and freight service necessitated the addition of these "medium speed" signals wherever braking distance between adjoining block signals was found to be insufficient to permit trains operating at maximum authorized speed to stop.

It was, of course, not necessary to equip all block signals even in maximum speed territory with these medium speed units. In many cases braking distances between signals were of sufficient length to afford full protection without an advance indication, particularly on ascending grades, where gravity assists braking forces in stopping trains. On the other hand, the medium speed units would be required in the opposite direction with its descending grades. Where speed restrictions exist due to curves or other limitations, this factor obviates the need for advance indications of approach signals.

The number of signals equipped with "medium speed" aspects over the component divisions of the transcontinental line, via Ellinor, Eldorado, Mulvane, Wellington, Belen and the Third District of the Los Angeles Division through Fullerton (this being in part the route of the through freight rather than the high speed streamliners) between 1935-1948 was as follows:

TABLE XXIV

MEDIUM SPEED UNITS ADDED
By Divisions
From Chicago to Los Angeles via Eldorado,
Belen and Fullerton, 1935 to 1948

Division	Number of Signals
Illinois	9
Missouri	9
Eastern	42
Middle	39
Pecos	46
Plains	162
Albuquerque	198
Arizona	120
Los Angeles	138
Total	763

No data is available to show the number of blocks lengthened, due to line changes or otherwise, except on A.T.C. territory shown in Table XVII.

The foregoing table does not include a considerable length of transcontinental high speed mileage so the system total of medium speed units installed would certainly exceed 1,000 and might approach 1,500. It will be observed that only 9 were installed on the Illinois Division and a like number of the Missouri Division. The Illinois Division is equipped with the continuous induction three speed train control system with three indication cab signals, and no wayside signals, except at interlockers. It too has undergone changes to adapt its block length to higher speeds, which are authorized at 90 M.P.H. between Newton, Kansas City and Chicago.

This additional approach aspect has been added to many semaphore type block signals having the single blade required for the usual three position indications. Since a color light signal is both more effective and more economical to install and operate than a semaphore signal, this second aspect is provided by a color light (yellow) which converts the three block signal system into the four block type and so permits maximum speed trains to be operated safely without physically respacing signals. This also retains the benefits of the increased line capacity permitted by the shorter distances between block signals.

References have variously been made to semaphore and to color light signals. Until less than 20 years ago, it was necessary to use semaphore blades to convey signal indications by day. Lights reflected through the colored spectacles of the semaphore blades provided the night indications but these did not have adequate visibility in daylight to be dependable until the constant improvement of the electric lights used in signals and the optical principals incorporated into them and the lenses permitted the use of lights to give day as well as night indications. Since this was accomplished, all new signal installations on every road have been of the color light type, except on the Pennsylvania. Many years ago it sought to eliminate the use of the semaphore blade in connection with signal improvements made during the course of its electrification of its suburban service between Philadelphia and Paoli, completed in 1915, and developed the so-called position light type of signals for use there. These provided the aspects of semaphore blades by rows of brilliant amber tinged white lights. The success of this installation lead the Pennsylvania to adopt the position light type of signal as its system standard.

When color light signals were first introduced, seperate lights were necessary for each color so three were necessary for display of the seperate indications of each signal aspect. These were closely grouped together either in a vertical row or a triangular pattern within a circular shield and so were termed the "unit type" of color light signal. This arrangement was not entirely satisfactory because of the number of lights required. The modern searchlight type of color light signal was soon developed to use a single light and obtain the different colored signals by projecting its beam through the selected lens of a small spectacle containing red, yellow and green glasses, no more than two inches in diameter. The one positioned in front of the light bulb is selected by the electrical control circuits of the signal.

Semaphore signals were superseded by the unit-type colorlight signals a little more than 20 years ago, but before many of these were installed, they were in turn succeeded by the searchlight type of color light signal. It was adopted as standard on the Santa Fe about 1931 and since that time has been used for all new work except at a few locations where old unit-type color light signals were used.

The relative proportions of track mileage equipped with the several types of signals are as follows:

TABLE XXV

	Track Miles	Percent of Present Mileage	
		of wayside signals	of all signals
Type of wayside signals:			
Semaphore	3803	59	56
Color Light	2626	41	39
Total	6429	100	95
Wayside signals not used except at interlockers:*	355	-	5
Grand Total	6784	100	100

* Installed on Illinois Divisions between Pequot, Illinois, and East Fort Madison, Illinois.

Having the medium speed or advance indication given by two yellow lights, one over the other, representing the equivalent of two semaphore blades in the diagonal position, embodies an important feature of safety. The failure of one of those signals will automatically transform the indication into the approach or caution signal registered by one yellow light or a single blade in the diagonal position. This principal was used to provide an additional measure of protection on single track, to give two warnings of stop signals on two consecutive blocks in advance, not by an advance signal (Rule 282) and then by an approach (caution signal) (Rule 285) but by two approach (caution) signals. The track circuits required for this indication two blocks in advance of a stop signal were the same as those required by the medium speed or advance indication (Rule 282) but the ommission of the second arm provided a more restrictive, and also a more economical installation. The installations made of this nature are as follows:

TABLE XXVI

Additional Restrictive Indications Added to Permit Increased Operating Speeds on Single Track, 1935 to 1948.

Year	Territory	Track Miles
1938	D. T. Junction - Joseph City, Arizona	23.0*
1939	Atwood - Fullerton, California	5.3
1939	Fullerton - Redondo Junction, California	21.8
1941	Clovis - Vaughn, New Mexico	130.8
1942	Vaughn - Belen, New Mexico	109.0
	Total	199.9

* Before second track built in 1939-1940.

It will be observed that all of the foregoing installations of this character were subsequently either double tracked or equipped with cTc and these additional restrictive indications on single track provided by the repitition or overlap, of the approach (caution) signal (Rule 285) were changed to provide the advance indication in the standard manner through a distinctive indication (Rule 282.) This expedient is mentioned, however, as a matter of general interest in the narrative of the development of the present signal system.

In the original Automatic Train Control installation, each automatic train control block had been 4,000 feet in length, plus or minus 200 feet. In order to provide adequate stopping distance for higher speeds, the entire system from Pequot to East Fort Madison was changed to provide ATC blocks 6,000 feet long, plus or minus 200 feet. This was done by removing 51 block locations, moving 76 block locations and converting 16 block locations to cut-section locations. With few exceptions each location controls both tracks to provide parallel blocks that are now uniformly of 6,000 feet lengths (approximately). In general, there are approximately twice the number of blocks on the two tracks that there are block locations along the double track line. The locations of the interlockings were not changed by this rearrangement of ATC block lengths. Consequently the space between each two interlockers did not necessarily divide up evenly into suitable block lengths and some "block locations" had to be converted to "cut sections" in order to obtain track circuits which were not too long to operate successfully.

It has been explained that the current for the track circuit is supplied by a track battery at one end of the block. It must flow through the rails to the opposite end in order to energize the relays there which actuate the signal mechanisms permitting a proceed indication to be displayed there. The voltage must be low or the current will leak across between the rails when rain or other conditions impair the insulation, normally provided by the roadbed itself. The resultant short circuit of the current in the track will cause the signal to display a false restrictive indication.

Long blocks require high voltage to drive the current from the track battery to the signal, but high voltage increases the risk of short circuits which cause signal failures. In order to keep track voltage low, as required for successful operation of the signal system, yet cover unusual block lengths, the latter is cut into several sections, hence the term "cut section." Each is electrically complete but the two or more seperate circuits within a single block are interconnected by relays in order that a train in the block, or other conditions affecting the signal system, will interrupt the flow of the current through all cut sections. This will actuate the signal in the same manner as though a single track battery and set of relays covered the entire block.

The work to which previous mention has been made that was required to adapt the automatic train control system to 90 M.P.H. speeds may be summarized as follows:

TABLE XXVII

Blocks lengthened in automatic train control territory between Pequot, Illinois, and East Fort Madison, Illinois 1935 to 1948

Year	Blocks Removed	Blocks Relocated	Blocks Converted
1941	23	34	1
1943	14	19	2
1944	5	6	1
1946	9	17	12
Total	51	76	16

The improvements to the Santa Fe's signal system outlined in this chapter will now permit any train to run safely at the maximum authorized speed and receive (a) warning indication(s) a sufficient distance in advance of a fixed signal displaying stop to be able to obey its command even under the most difficult braking conditions; i.e., descending maximum grades at maximum speed under bad weather conditions, i.e. in drizzling rain or snow and ice, and a strong tail wind. Together these will handicap making stops within distances ordinarily possible on a dry rail and ordinary wind conditions. The latter normally produces a retarding effect upon the train at high speeds. Improvements in signal spacing and signal facilities have been an essential feature of line changes so that the new tracks represent the highest standards of signal equipment and arrangements as well as of construction.

The Standard Signal Indications of Santa Fe's Signal System Number Two are shown as an Exhibit of this report. System No. 1 is not included as an exhibit since System No. Two adopts all of the former's indication, except two, representing the signals displayed by Rules #273 and #274 and substitutes improved aspects for their functions in the manner which will be explained.

Signal System No. 1 utilizes the same basic aspect of a diagonal semaphore blade or its equivalent yellow light variously to provide:

1. the conventional approach or caution signal in automatic block territory,
2. the signal to proceed at restricted speed through a turnout or crossover at an interlocker.
3. authority to enter occupied interlocked or manual block territory.

Automatic signals displaying the stop and proceed (in accordance with Rule 509*) indication in contrast to an absolute stop bear a number plate to indicate this distinction. The numbers of automatic signals relate to the numbers of tenths of a mile from the base point of zero for measurements along the line. Letter prefixes are sometimes given to distinguish between the signals of different lines, while suffixes such as "X" relate to signals

*When a train or engine is stopped by a "stop and proceed" signal it may: (a) On single track, send flagman ahead immediately, wait five minutes and follow at restricted speed, except that when next governing signal in advance can be seen displaying other than "stop" indication and track is clear, train or engine may proceed at once at restricted speed. Flagman need precede train or engine only to a point where next governing signal in advance can be seen displaying other than "stop" indication and track seen to be clear. (b) On single track, where facing point switch is located immediately beyond signal and switch is lined for turnout, train may, without stopping, pass such signal at restricted speed to enter turnout, provided main track is clear to fouling point. (c) On two or more tracks, proceed at once at restricted speed.

on the second track built on non-parallel locations in respect to an original main line continued in service. The nearest even numbered tenth of a mile is assigned to the signal for the eastward or northward direction of traffic on single or double track lines. Westward or southward signals take their number from the nearest odd numbered tenth of a mile from the base point. Thus signals 4985 and 4986 would be located 498.5 miles (plus or minus) from the base point of 0.00 for measurements along that line. The opposite signal for the westward direction would bear the number 4986 or possibly 4984.

The only distinguishing mark to indicate which of the three very different instructions are being given by the yellow light or diagonal semaphore blade used by signals displayed in accordance with Rules #273 and #274 of Signal System No. One is provided by the number plate on those automatic signals which display it in order to authorize trains to proceed in accordance with Rule 509 when the stop signal is displayed.

The single yellow light or diagonal semaphore displayed by a signal bearing a number plate in territory where Signal System No. One is operative constitutes an "approach" or caution indication to a stop signal. Without the number plate, it can apply either to a diverting movement or constitute the authority necessary to permit a train to enter occupied or otherwise restricted manual block or interlocking territory.

The indications of signals displayed in conformance with Rules #273 and #274 are not related with sufficient definiteness to the exact movement with which each is associated to be entirely satisfactory for present day requirements on the Santa Fe. Signal System No. Two, and the engineering application of it, was therefore devised to give distinctively different indications for the three seperate uses of this one single aspect by Signal System No. One. The fundamental aspect, a single yellow light, remains the approach indication. It follows that the signal for Rule 274 (System One) and #285 (System Two) are identical but the number plate loses its significance on an approach signal in System Two. Indication No. 285, approach, means the same whether the signal displaying it bears a number plate or not. The number plate has no operating significance in relation to a signal indication under System No. 2, except if displayed on a stop signal, where its presence signifies the applicability of Rule 509; stop and proceed.

The signal displayed at an interlocker to authorize movement over a diverging route, that is clear, is shown by the one displayed under Rule 283. It consists of a green light below a red light.

The important indication authorizing trains to proceed at restricted speed into interlocked, or other territory which is occupied by another train or may be affected by some other potential hazard, is given by the specific restricting indication, Rule 290, which displays a yellow light under a red one.

The latter general aspect is also utilized as a signal for a diverging route, at an interlocker, combined with an approach indication for the signal beyond by causing the lower yellow light (which is fixed in the restricting indication) to flash when used for that other purpose. The flashing yellow light below the red one modifies the more restrictive indication conveyed by the same color light combination and permits a train to proceed at medium speed, i.e., not exceeding 40 M.P.H. for passenger trains or 30 M.P.H. for freight. The advance indication of Rule 282 is used, under Signal System Two, for the approach to an interlocked high speed turnout governed by the home signal indicating Diverging-Clear, in accordance with Rule 283, and also the Diverging-Approach Signal (Rule 286) just described with its flashing yellow light below a red one.

Under Signal System No. 1 the same diverting movement would have to be made under an approach restricting signal governing movement through the interlocker. The same signal aspect would also constitute authority to enter an occupied track or block, and except when the approach indication has been carried back to a preceeding block through an overlap, or "additional restrictive indication", an oncoming train would receive no advance information of an approach restricting signal displayed at interlocker for any one of the several purposes for which it is used.

Signal System No. Two was developed to provide the additional distinctive indications needed now but which were not required under the operating conditions existing when Signal System No. One was devised. Examination of current Santa Fe working time tables indicates that Signal System Number One is still effective on all of its automatically signalled lines and at all interlockers except those indicated below where Signal System No. Two is the designated standard:

Willow Springs, Illinois, interlocker.

Morris, Kansas, interlocker, at west end of Argentine Yard.

cTc installation between Newton and Mulvane, except on double track line of AT&SF and Wichita Union Terminal through Wichita.

cTc installation between Ellinor and Eldorado.

Mulvane, Kansas, interlocker.

Dodge City through La Junta to C&S interlocked crossing north of Trinidad, Colorado.

Raton, New Mexico, - Albuquerque, New Mexico.

Wellington-Waynoka-Clovis, except at interlockers at Wellington, Harper, and Attica and on 2.8 miles of double track east of Waynoka station.

Interlocker at West End of Clovis, New Mexico, Yard.

Winslow - Seligman.

Eastward track ascending Cajon Pass from a point near Highland Junction, San Bernardino, to a point near Summit.

Bragdon (near Pueblo, Colorado) - South Denver.

While it is apparent that Signal System No. One is used on the much greater extent of automatically signalled mileage, nevertheless since System Two is the present standard to which the development of the signal indications at all interlockings and the related approach signals is being directed, attention was therefore focused on it rather than on the one in greater use, but which is being superseded. The rapidity of future signal improvements on the Santa Fe may well be measured by the increments in mileage operated under Signal System No. Two over successive future years.

It will be recalled that in the historical summary with which this chapter opened it was pointed out that signals were first used to govern movement through junctions and crossings and were controlled from towers or cabins that eventually became interlocking plants. Now signals are more commonly associated with automatic block signal systems than with the other purposes for which they can be used. However, interlockers are as vital to the successful operation of a modern railway as the automatic block signals and both are equally important components of its entire signal system.

Interlockers have undergone constant improvement in design and construction from the simple mechanical plants of previous generations with their cumbersome detector bars and facing point locks to modern all-electric and electro-pneumatic interlockers which include the latest electrical and mechanical appliances.for controlling and actuating switches and signals and properly interlocking their manipulation to afford complete protection against every conceivable contingency that might cause an accident.

A large number of interlockers are located along the component lines of the Santa Fe System in order to control the movement of its trains in and out of yards and terminals, at junctions, drawbridges, railroad crossings, at the ends of double track, at places where crossovers are required, or other circumstances dictate their location. Most of these are owned and operated by the railroad itself but some are jointly owned with other companies, both affiliated terminals and foreign lines; the tracks of which the Santa Fe uses or crosses. Some new interlocking plants have been added in recent years while others have been rebuilt and modernized. A tabular summary of present Santa Fe interlocking facilities follows in Tables XXVIII and XXIX.

TABLE XXVIII

Summary of Interlockers used by Santa Fe.

Wholly owned by AT&SF	101
Owned jointly with other railroad and terminal companies	119
No ownership interest by Santa Fe	5
Total	225

Types of Interlockers maintained and/or operated by AT&SF

Automatic	20
Electric	96
Electro-Mechanical	1
Mechanical	46
Electro-pneumatic	1
Total	170*

* Includes 101 wholly owned and 69 jointly owned interlockers.

TABLE XXIX

Summary of Improvements made to Interlockers 1935-1948

	No.
New	24
Rebuilt	26
Improved	29
Total	79

The detailed list of individual interlockers improved follows:

TABLE XXIX (Cont.)

IMPROVEMENTS OF INTERLOCKINGS
1935 to 1948

Year	Location	Type of Interlocking	New, Rebuilt Or Improved
1936	Canyon Diablo, Arizona	Automatic*	New
1936	Topock, Arizona	Automatic*	New
1937	Argonia, Kansas	(Not Stated)	New
1937	Valley Center, Kansas	Automatic	New
1939	Mission Tower, Los Angeles	Electric	Rebuilt
1940	Pequot, Illinois	Mechanical	Improved
1940	C. A. Junction, (Camden) Mo.	Electric	Improved
1940	H. U. Tower (Ottawa), Kansas	Electro-Mech.	Improved
1940	Mulvane, Kansas	Electric	Improved
1941	Plaines, Illinois	Electric	New
1941	Streator, Illinois	Mechanical	Improved
1941	Monica, Illinois	Mechanical	Improved
1941	Medill, Missouri	Mechanical	Improved
1941	Henrietta, Missouri	Electric	Improved
1941	Eton, Missouri	Electro-Mech.	Improved
1941	Congo, Missouri	Mechanical	Improved
1941	Turner, Kansas	Electric	Improved
1941	H. U. Tower (Ottawa), Kansas	Electro-Mech.	Improved
1941	Emporia Jct., Kansas	Mechanical	Improved
1941	Harper, Kansas	Electric	Improved
1942	Miss. River Bridge	Electric	Improved
1942	Medill, Missouri	Mechanical	Improved
1942	Atherton, Missouri	Electric	New
1942	Florence, Kansas	Electric	New

* Removed following subsequent construction of new bridges at both places, which replaced gauntlet type structures with double track ones.

TABLE XXIX (Cont.)

IMPROVEMENTS OF INTERLOCKINGS
1935 to 1948

Year	Location	Type of Interlocking	New, Rebuilt Or Improved
1942	Belen, New Mexico	Electric	Rebuilt
1942	San Bernardino, California	Electric	Rebuilt
1943	Toluca, Illinois	Mechanical	Improved
1943	Shopton, Iowa	Mechanical	Improved
1943	Baring, Missouri	Electro-Mech.	Improved
1943	Edgerton, Kansas	Mechanical	Improved
1943	Texico, New Mexico	Electric	Rebuilt
1943	Clovis, New Mexico	Electric	New
1943	Fullerton, California	Electric	Rebuilt
1944	Lebo, Kansas	Electric	Rebuilt
1944	Vaughn, New Mexico	Electric	Rebuilt
1944	Dalies, New Mexico	Electric	Rebuilt
1944	Daggett, California	Electric	Rebuilt
1944	Barstow, West Yards, California	Electric	Rebuilt
1944	San Bernardino, W. Yards, Calif.	Electric	Rebuilt
1945	Joliet, Illinois	Electric	Improved
1945	Streator, Illinois	Electric	New
1945	Quenemo, Kansas	Electric	Rebuilt
1945	Ridgeton, Kansas	Electric	New
1945	Gladstone, Kansas	Electric	New
1945	Jaques, Kansas	Electric	New
1945	Chelsea, Kansas	Electric	New
1945	Salter, Kansas	Electric	New
1945	Rose Hill, Kansas	Electric	New
1945	East Junction, Kansas	Electric	New

TABLE XXIX (Cont.)

IMPROVEMENTS OF INTERLOCKINGS
1935 to 1948

Year	Location	Type of Interlocking	New, Rebuilt Or Improved
1945	Clovis, New Mexico, East End	Electric	Rebuilt
1945	Clovis, New Mexico, West End	Electric	New
1945	Gallup, New Mexico	Electric	New
1945	Needles, Calif., East Yards	Electric	New
1945	Needles, Calif., West Yards	Electric	New
1945	Barstow, Calif., West End	Electric	Rebuilt
1945	Colton, California	Electric	New
1946	Edelstein, Illinois	Electric	Rebuilt
1946	W. B. Junction, Missouri	Electric	Rebuilt
1946	C. A. Junction, Missouri	Electric	Rebuilt
1946	Florence, Kansas	Electric	Improved
1946	Waynoka, Oklahoma	Electric	Rebuilt
1946	Belen, New Mexico	Electric	Rebuilt
1946	Ash Fork, Arizona	Electric	New
1947	Ancona, Illinois	Electric	Rebuilt
1947	Baring, Missouri	Electro-Mech.	Improved
1947	Holliday, Kansas	Electric	Improved
1947	Morris, Kansas	Electric	Rebuilt
1947	Melvern, Kansas	Electric	Rebuilt
1947	Ellinor, Kansas	Electric	Improved
1947	Eldorado, Kansas	Electric	Rebuilt
1947	Amarillo, Texas, East End	Electric	Improved
1947	Winslow, Ariz., W. Frt. Jct.	(Not Stated)	New
1947	Basta, California	Electric	Rebuilt

TABLE XXIX (Cont.)

IMPROVEMENTS OF INTERLOCKINGS
1935 to 1948

Year	Location	Type of Interlocking	New, Rebuilt Or Improved
1947	Fullerton, California	Electric	Improved
1947	Mission Tower, Los Angeles	Electric	Improved
1948	Ormonde, Illinois	Electric	Rebuilt
1948	Marceline, Missouri	Electric	Rebuilt
1948	Amarillo, Texas, West Yard	Electric	New
1948	San Bernardino, California	Electric	Improved.

The provision of interlockers to connect the yard and the main tracks at the ends of freight terminals will greatly facilitate movement through these natural points of congestion and delay. The characteristically adequate foresight and planning of the Santa Fe is evident at these places. All of the principal yards, at which interlocked connections are needed, have been equipped in this manner. Additional flexibility has been obtained by continuing one or more running tracks for freight trains several miles beyond the ends of certain yards and establishing the main track connections at that point through remotely controlled switches and signals operated from the interlocker at the adjacent end of the nearby yard. Examples of this type of improvement are found in the eastward and westward freight running tracks between the east end of Barstow Yard and Nebo, four miles distant, and also at either end of the yard at Needles, as well as at other points.

When commenting on the general subject of interlockers, it should be pointed out that that movement of transcontinental trains on any of the

Sante Fe's routes are handicapped by a safety stop at but a single non-interlocked railway grade crossing. That occurs where the Santa Fe crosses the parallel double track lines of three railroads, which reading from east to west are the Chicago River & Indiana, a switching line of the New York Central System, The Baltimore & Ohio Chicago Terminal Railroad Company, and the Pan Handle Route of the Pennsylvania. This intersection lies 4.4 miles west of Dearborn Station, Chicago. One may well hope that the installation of an interlocker at this point has high priority on the list of Santa Fe improvements for near future years. Possibly it only awaits the cooperation of the three eastern lines to install protection at this point now where it would obviate delay to Santa Fe passenger trains moving in and out of Chicago and all of its switching and transfer runs between Corwith Yard and points east of it.

High speed movement over Santa Fe tracks has necessitated the progressive elimination of the potential hazards of hand thrown switches at industry and other auxiliary tracks. All which connect with cTc equipped tracks are electrically locked and the use of electric locks outside of cTc territory is growing. A list of the electric locks installed during the period of the Santa Fe improvement program is included as Table XXX.

TABLE XXX

ELECTRIC SWITCH LOCKS INSTALLED
1935 to 1948

Year	Location or Territory	No. of Locks
1938	Los Angeles, California, Mission Tower	7
1942	Gardner, Kansas	2
1943	Texico, New Mexico	6
1943	Mountainair - Belen, New Mexico	7
1943	Hobart - Fullerton, California	4

TABLE XXX (Cont.)

ELECTRIC SWITCH LOCKS INSTALLED
1935 to 1948

Year	Location or Territory	No. of Locks
1944	Vaughn - Mountainair, New Mexico	9
1944	Melrose - Joffre, New Mexico	10
1945	Chicago, Illinois	1
1945	Romeo, Illinois	1
1945	Pequot, Illinois	2
1945	Gladstone, Kansas	4
1945	Rose Hill, Kansas	2
1945	Waynoka - Curtis, Oklahoma	8
1945	Canadian, Texas	2
1945	Vaughn - Mountainair, New Mexico	2
1945	Melrose - Joffre, New Mexico	15
1945	Riverside - Fullerton, California	42
1946	Curtis, Oklahoma - Canadian, Texas	54
1946	Canadian, Texas	1
1946	Belen, New Mexico	4
1946	Ash Fork, Arizona	3
1946	Ash Hill, California	2
1946	Riverside Junction, California	1
1947	Bazar - Eldorado, Kansas	8
1947	Canadian - Pampa, Texas	11
1947	Pampa, Texas	1
1948	McCook, Illinois	2
1948	Canyon, Texas - Texico, New Mexico	41
	Total	252

While spring switches may appear to be a more logical subject for inclusion in the chapter on track structure or on sidings, these devices are so closely integrated, functionally, into train dispatching and signal systems that they may nevertheless be appropriately mentioned in this section of the report.

These devices have been of great importance in facilitating the speedy movement of trains out of sidings. If the switch must be opened and closed by hand, long trains will be delayed as the engineer necessarily runs very slowly while the rear end of the train is pulling down past the hand thrown turnout from the siding to the main track. It must be restored to normal by the flagman who then has to overtake the caboose. If the train pulls out too far or does not pull out far enough, delays ensue.

Spring switches avoid the necessity to open a switch for the train to leave a siding or to close it after the last car has passed on to the main track. It follows that spring switches are of great service in reducing delays to trains on sidings and they facilitate movement of short freight trains and passenger trains, as well as long freight trains, even though to a lesser degree.

The first requirement of a spring switch is that it must be very strong and resilient and be under constant high pressure to return the switch rail to its closed or normal position but yet not be so quickly activating that the switch point is constantly closing against each passing wheel as a long freight train goes through it. The varying combinations of pressures needed both to keep the switch open under passing trains moving out in the trailing point direction and to restore it to normal after the movement has ceased is afforded by powerful springs actuating a piston which has minute perforations to permit a viscous oil to pass through it. This oil buffer in conjunction with the springs gives the required precision of control of these functions.

It is standard practice on the Santa Fe to provide dwarf signals to facilitate the movement of trains off sidings equipped with spring switches and to locate switch point indicators to protect the movement over spring switches against the current of traffic on double track.

The spring switch installations on the Santa Fe, as reported to the Interstate Commerce Commission on its Signal Report Form 8, as of January 1, 1948 were as follows:

TABLE XXXI

LIST OF SPRING SWITCHES BY DIVISIONS

Division	Number
Illinois	9
Missouri	16
Eastern	19
Middle	8
Oklahoma	34
Western	23
Colorado	88
New Mexico	66
Pan Handle	32
Plains	24
Pecos	3
Slaton	18
Northern	51
Southern	84
Gulf	13
Albuquerque	62
Arizona	53
Los Angeles	41
Valley	82
Total	686

Signals are obviously but a means of communication. Some of the messages which signals give are automatically conveyed by trains ahead; others are directions specifically given by operators in interlocking towers, block stations and at the control boards of cTc machines. Other communications respecting train movements are conveyed by train orders although modern railroad practice is using these to a continually decreasing degree. When the telegraph was the single means of fast communication beyond the range of the human voice, messages could only be conveyed between trains and dispatchers and others controlling movement through the services of telegraph operators at the stations where the latter were located. The telephone broadened the range of communication and it was a natural development that railroad signal and dispatching systems should include the location of telephones at sidings and at most, if not all, of the automatic block signals between them. These telephones enable the crews of trains to communicate with neighboring stations and the dispatcher to report breakdowns of equipment and other conditions affecting train movement and to inquire respecting circumstances in holding trains on sidings and elsewhere. This enables the dispatcher, operator and train crews to take the proper steps to minimize the resulting delay. Information of this type not only assists the train which is delayed but prevents its detention from spreading to other trains more than to the minimum extent avoidable by resourceful train dispatching.

The telephone has added greatly to the development of modern railroading. No other industrial activity is scattered over such a far flung territory and in no other activity are so many people working independently and so far removed from direct supervision. The work of coordinating and directing all phases of railway operation are immeasurably facilitated by the telephone. Every great railroad has its own telephone and telegraph communication facilities which in the case of great railroads, such as the Santa Fe, embody the finest technical standards and developments available for integration into them. The extent of the Santa Fe telephone and telegraph lines may be briefly summarized as follows:

TABLE XXXII

Mileage of Santa Fe Telegraph and Telephone Lines

	Miles of Pole Line	Miles of Telegraph Wire	Miles of Telephone Wire
Fully owned and operated	14,063.12	31,942.65	53,371.68
Used by Santa Fe but owned by other companies	359.57		
Total used by Santa Fe	14,422.69	31,942.65	53,371.68
Owned by Santa Fe but used by other companies		70.34	
Long-distance message or conversation telephone lines			16,775.62

These connect all stations and offices of the entire railroad by its own telephone system which is coextensive with the track mileage and so permits sidings and signals to be equipped with telephones that are in constant use in the conduct of transportation and the direction of traffic. The Santa Fe has been particularly progressive in this respect. Its telephone system follows its railroad everywhere and like the commercial telephone system, utilizes mechanized exchanges to the greatest possible extent. There is one very important distinction between a railroad and commercial telephone system. The former has a much higher proportion of its total calls in the long distance classification than the latter and accordingly an unusual large number of long distance circuits are necessary in proportion to the aggregate size of the communication system. Modern communication engineering, however, permits these to be obtained through methods which greatly reduce the wire mileage in relation to the many message circuits which are available simultaneously for the telegraph and telephone lines. These are coordinated into a single system providing maximum message capacity by voice and by teletype and by manually operated telegraph instruments far beyond the numbers of the physical circuits between the component points.

Dependable two-way radio communication between moving trains and wayside offices and dispatchers offer vast possibility to expedite train operation and reduce the contingencies of accidents. It has equal opportunity for improving yard and terminal services. The Santa Fe began using two-way radio more than five years ago and has gained substantial experience with this new facility. However, it has not yet been fully perfected to meet the requirements of railway service and remains an incidental rather than a primary factor in the operation of trains and of yards. For that reason it has not been specifically included in the topics studied for the preparation of this report and only this brief mention can be made of it here.

The annual report of the Santa Fe for the year ended December 31, 1947, states on Page 19 under the heading "Signaling Requirements":

"On June 17, 1947, the Interstate Commerce Commission in its Docket 29543 titled "Appliances, Methods and Systems Intended to Promote Safety of Railroad Operation," issued an order requiring --

1. Installation of (a) automatic train control, (b) automatic stop, or (c) cab signal systems on lines over which any train is operated at a speed of 80 M.P.H. or more;
2. Installation of automatic block or manual block systems on lines over which any passenger train is operated at 60 M.P.H. or more or any freight train is operated at 50 M.P.H. or more.
3. These installations to be made progressively over a period of years with completion by December 31, 1952.

"Provisions of this order affect operations on almost half of the System mileage and on the basis of retaining present maximum speeds, it was estimated that full compliance with the order would cost from $17,435,000 to $41,200,000, depending upon whether automatic train stop systems or automatic train control is used where maximum speeds are 80 M.P.H. or more. Santa Fe has spent millions of dollars for signal protection and other types of improvements which have a direct bearing on safety of train operation. Programs of centralized traffic control, automatic block signal systems, etc., are continuing as reflected by the preceding section of this report. Due to the large amount of capital money required to carry out the Commission's proposed program in its entirety, and the effect this would have on providing money for other desirable improvements, the Company worked out a modified program which it believes would meet the purpose and spirit of the Commission's order without seriously disturbing train operations and other planned improvements and at the same time not adversely affecting the safety factor. The modified program provides for:

> Installation of 2,622 miles of automatic train stop system; equipping 219 passenger locomotives with train stop devices; installation of 173.1 miles of automatic block signals, and reduction of maximum authorized speeds of secondary lines where that can be done without substantial harm to efficiency of train operation. Estimated cost of the modified program is approximately $4,000,000.

"Hearing on the Company's petition seeking relief from certain provisions of the order was held in October 1947, and the Commission's decision is awaited."

The Interstate Commerce Commission recently authorized the Santa Fe to continue its present train speeds without the signal equipment required for operation in excess of 80 M.P.H. and deferred the requirement of major new work of this character for a year, or until further orders. However, it refused to authorize the continued operation of maximum speed passenger trains within the state of California without one of the three specified systems of (1) automatic train control, i.e. speed control; (2) automatic stop; or (3) cab signals between Barstow and Bakersfield and Santa Ana and Sorrento on the San Diego line.where Santa Fe had requested the right to run passenger trains at 85 M.P.H. without changes in the present signal system since automatic block protection is provided and in addition cTc has been installed on the latter of these two routes.

The Santa Fe has agreed to install automatic train stops outside of present automatic train control territory, i.e. Fort Madison, Iowa, to Pequot, Illinois, wherever passenger trains now or in the future will operate in excess of 80 M.P.H. between Chicago and Los Angeles and between Newton, Kansas, and Houston, Texas. However, since freight locomotives do not yet operate in excess of 60 M.P.H. these units will not have to be equipped with automatic train stop devices until further orders of the Interstate Commerce Commission. It remains to be seen whether the Santa Fe will later decide to equip the high speed mileage between Sorrento and Santa Ana and between Barstow and Bakersfield and the locomotives hauling passenger trains over those routes with train stop devices or reduce its maximum passenger train speeds on those districts to 79 M.P.H.

In the original order of the Commission in Docket 29543 on Appliances, Methods and Systems Intended to Promote Safety of Railroad Operation, the definition of medium speed is stated to be 30 M.P.H. and low speed 15 M.P.H. or less. The automatic train control installation on the Santa Fe's line between Fort Madison and Pequot, Illinois, has the locomotive governors set for a medium speed of 40 M.P.H. for passenger trains and 30 M.P.H. for freight trains and for a low speed of 20 M.P.H. for all trains. The Interstate Commerce Commission has authorized the Santa Fe to use its own definitions of low and medium speed rather than the ones which this federal body has otherwise prescribed in Docket 29543.

Supplementary data will follow on subsequent pages to amplify certain of the tables included in this chapter. The indulgence of the reader is requested for the omission of these statistics in the tables of which they should be a part when they were typed.

The data which has been presented by no means encompasses all of the signal improvements made on the Santa Fe within the past fifteen years, particularly those many betterments made coincidentally with line changes and the conversion of semaphore to color light signals. The Signal Department of the Santa Fe has very considerately prepared a summary for inclusion in this report. It will follow as an epitome of the development and extension of the Signal System of the Santa Fe.

TABLE XX - Page 239

	Road	Track
Line #1--Total operated miles less trackage rights	12,739	14,508
Line #2--Total operated miles less trackage rights and branch lines used exclusively for freight service	8,963	10,674
Line #3--Total operated miles less trackage rights and lines either used exclusively for freight service or over which only 1 engine operates	8,506	10,217
Lines equipped with automatic signals	5,001	6,784
Ratio of mileage equipped with automatic blocks to Line #3 above	59.0%	66.8%

180 locomotives and 3 motor cars are equipped for operation over the continuous induction automatic speed control main tracks between Fort Madison, Iowa, and Pequot, Illinois.

TABLE XXIII - Page 242

Total of cTc Installations in Service in the United States January 1, 1949, Compared with that of AT&SF

	Miles of Road	Miles of Track	No. of Passing Sidings	No. of Switches Controlled	No. of Signals Controlled Sem.	No. of Signals Controlled Lite	No. of Auto Signals Sem.	No. of Auto Signals Lite
Total of 407 installations on 55 Railroads	10,163	11,310	1,739	5,204	504	13,799	301	6,907
A. T. & S. F.*	754	798.8	135	409	-	1,467	-	558
AT&SF percentage of national total	7.4%	7.1%	7.8%	7.9%	-	10.6%	-	6.1%

* Excluding Wellington - Waynoka installation not complete on January 1, 1949.

TABLE XXV - Page 253

(Restated)

	Miles of Road	Miles of Track	Percentage of Total Signalled Mileage: Road, Incl. ATC	Road, Excl. ATC	Track, Incl. ATC	Track, Excl. ATC
Semaphore Signals	2912	3803	60	58	59	56
Light Signals	1914	2626	40	38	41	39
Total	4826	6429	100	96	100	95
Automatic Train Control without wayside signals except at interlockings	175	355	-	4	-	5
	5001	6784	100	100	100	100
Total Block Section					5248	

TABLE XXXI - Page 270

Spring Switches in Service on AT&SF, January 1, 1949

Reference: I.C.C. Signal Statistics.

Classification as to territory:

In automatic block territory	870
In non-block territory	10
At interlockings	20
In Yards	13
Total	913

Classification as to application:

At ends of sidings	806
At end of double track	15
At junctions	16
On yard tracks	37
On other tracks	39
Total	913

Equipped with:	facing point locks	6
	electric locks	2
Total		8

TABLE XXXI (Cont.)

Number of signals protecting spring switches:

Low signals	518
High Signals	1,548
Total	2,066

The Interstate Commerce Commission Report of Signal Statistics states that there are 6,621 spring switches in service on the railroads of the United States. Santa Fe has first rank with 913 in service; the Southern is second with 633 and the Louisville & Nashville third with 452. The Santa Fe's installation of spring switches represents 14 per cent of the national total.

TABLE XXXII - Page 272

Use of Telephone and Telegraph in Train Dispatching on AT&SF, January 1, 1949

Dispatched by	Miles of Road
Telegraph	1,532
Telephone	10,542
Total	12,074

Radio Train Communication Systems of AT&SF, January 1, 1949
As Reported to I.C.C. Signal Statistics

Road Service: 2 locomotives and 2 cabooses equipped for service between Kansas City and Chicago.

25 locomotives and 11 cabooses equipped for service between Barstow and Bakersfield.

Yard Service	No. of Wayside Stations	No. of Locomotives Equipped	No. of Portable Pack Sets
Chicago - Corwith Yard	2	19	0
Kansas City-Argentine Yard	4*	30	6*
Belen, New Mexico	3*	4	6*
Los Angeles	1	32	0
San Francisco	1	2	0
Total	11	87	12

* Portable pack sets and two of the wayside stations are used for car checking service and operate on separate frequencies from that used for communication with yard locomotives.

Page 234 lists double track mileage over which trains operate by signal indication only. Table 8 of Interstate Commerce Commission Signal Statistics of January 1, 1949, reports that outside of cTc territory the Santa Fe operates the following mileage by signal indication only; (i.e. by traffic direction locking and automatic block signals between interlockings.)

	Miles of Road	Miles of Track
Single track	30 miles	30 miles
Double track	198 "	396 "
Total	228 miles	426 miles

The double track lines listed on page 234 total 188.3 line miles and 376.6 track miles.

There are also short lengths of double track operated by signal indication only at Newton and Hutchinson, Kansas, and at Pampa, Texas, and 4.4 miles between Fox and Rowe, New Mexico, on the east slope of the Glorieta Mountains, east of Lamy which together total 10 miles of line; bringing the aggregate of double track lines, equipped in this manner as listed on Page 234, up to a total of 198 miles. The single track mileage equipped for two way operation by signal indication only, but by traffic direction locking rather than cTc, is as follows:

On Oklahoma Division of AT&SF and GC&SF	27.7 miles
On Missouri Division between Congo and Sheffield	2.2 "
Total	29.9 miles

Brief History of Signaling on the Santa Fe

Prepared by Signal Department - AT&SF Ry.
February 3, 1949

"Previous to 1900 there was very little signaling on the Santa Fe. About that time the first automatic block signals were installed installed between West Yard Emporia and Plymouth, Kansas, a distance of about six miles of double track with electric semaphore signals; and double track between Kansas City and Holliday, Kansas, a distance of 13 miles with Hall disc signals commonly known as banjo type. About the same time an extensive program of manual block signaling was started, and also many interlockings were installed at railroad crossings, junctions, crossovers, etc. By 1910 there were on the Santa Fe system 1,450 miles of manual block, 110 miles of automatic block, and 138 interlockings. Most of the automatic block was on double track with current-of-traffic operation which does not involve the complications encountered on single track.

"In 1913 automatic block signals were installed on 18 miles of single track between Ardmore and Arbuckle, Oklahoma. This was followed by 43 miles between San Bernardino and Arcadia, California in 1916-17, but the Santa Fe standard system of single-track automatic block signaling was not completely developed until 1918 in connection with installation of almost 200 miles between Fresno and Ferry Point, California.

"In 1918 a spring switch was installed at San Bernardino, California. This device was developed and improved chiefly on the Santa Fe, which now has a total of 920 spring switches in service, resulting in considerable saving of train time, especially in connection with the meeting of trains on single track. This was chiefly a signal development.

"During the period 1920 to 1930 an accelerated program of automatic block signaling was placed in effect, and for a number of years about 500 miles of automatic block signaling was constructed annually. This was on both single and double track, and the installations were carried on simultaneously at various locations on all four grand divisions of the Santa Fe system; much of it superseding the manual block previously in use on the same territory.

"During the period 1923 to 1927 automatic train control was installed in Illinois between Fort Madison and Pequot, a distance of 175 miles, in compliance with an order of the Interstate Commerce Commission. This is three-speed continuous automatic train control with cab signals, but without wayside signals except the home signals at interlockings, and it is arranged for operation in either direction on each of the two tracks by signal indication under the control of interlocking stations spaced six to twenty miles apart. Previous to the installation of this system, manual block was in use in Illinois with the exception of a few short stretches of automatic block signaling.

"Previous to 1929 practically all interlockings were controlled manually with either mechanical or electric operation. Starting in 1929 automatic interlockings were developed and installed at many railroad crossings where trains were previously required to stop before proceeding over the crossing. The Santa Fe now has twenty-three of these automatic interlockings which function without any manual control.

"In 1930-31 centralized traffic control was installed on 13 miles of double track between Holliday and Olathe, Kansas; and 33 miles, chiefly single track, between Kinsley and Dodge City, Kansas. This system places the operation of switches and signals throughout a considerable territory directly in the hands of the dispatcher or operator at a central office. It is a combination of remote interlockings and automatic block signaling which makes use of practically all previous developments in the signaling art and makes it possible to operate by signal indications superseding the superiority of trains for both opposing and following movements, thus eliminating the delays which are inherent in the train order system.

"By 1935 the Santa Fe had 4,674 road miles of automatic block signaling, including automatic train control and centralized traffic control; only 116 miles of manual block was left, and most of this has been replaced since by automatic block signals.

"In 1935 the Santa Fe received delivery of its first Diesel locomotive, and the era of high speed began. An extensive program of curve reduction was placed into effect, and signals were respaced and rearranged on the entire railroad so as to provide ample stopping distances for higher speeds. This is a progressive program and is still under way. As each curve reduction, change of line, or other improvement involving speed is made, the signal spacing is again checked and signals respaced where necessary, in order to facilitate and safeguard train movements.

"In 1942 when traffic increased greatly under war conditions, it became apparent that something had to be done to increase the capacity of single-track lines. It was not possible to obtain necessary materials and manpower for double track, and the management turned to centralized traffic control in order to solve the problem. The Santa Fe system of CTC was developed first in connection with 102 miles installed between Los Angeles and San Diego. This was followed by further installations at various points in New Mexico, Texas, Oklahoma, California, and Kansas, the most extensive systems being on the Southern District of the Western Lines where the final section is now under construction Wellington to Waynoka, which will complete

CTC on the freight route all the way from Emporia, Kansas to Belen, New Mexico, except on the few stretches of multiple track within that territory. All of these CTC installations supersede automatic block which was previously in use on the same territory.

"The system of signal aspects and indications used on the Santa Fe is very simple, and previous to 1935 it made use of only one semaphore arm or red, yellow, or green light on each mast. The advent of higher speeds required additional indications to safely take advantage of improved facilities. Four composite aspects were added, and the system now consists of eight indications which provide more information for the engineman as to conditions in advance of the train, thus permitting him to operate at the highest permissible speeds consistent with safety.

"As of January 1, 1949 the Santa Fe has 6,784.4 track miles of automatic block signaling, including 798.8 miles of CTC, and 355.0 miles of ATC, and only 40.1 track miles of manual block. There are 225 separate interlockings (exclusive of 160 similar layouts which form part of CTC), of which 23 are purely automatic, 920 spring switches, and 1692 highway crossings protected by flashing light signals or other devices for automatically indicating the approach of trains.

"Automatic block signaling is continuous all the way from Chicago to the Pacific coast and the Gulf of Mexico, as well as Denver, Colorado. When presently authorized CTC is completed between Wellington, Kansas and Waynoka, Oklahoma, the Santa Fe will have either double track or CTC all the way from Chicago to Los Angeles and San Diego via the southern route through Texas."

CHAPTER XIII

LOCOMOTIVES

Tractive power is the basis of railway service and is therefore the product which railways manufacture and the source of railway revenue. This factor establishes locomotive operation as the fundamental element in rail transportation. It follows that the nature and detail of railway plant is determined by the limitations and requirements and capabilities of the locomotives which use it. Improvements in standards of service and efficiency stem largely from management's unrelenting demands for continued development of locomotive capacity in order to haul longer trains faster and at lower unit costs measured in hours of labor and quantities of fuel required to run them.

The entire railroad is developed around the locomotive. Track, cars, bridges, signals and all of the most important facilities and appliances are intended to permit locomotives to do their work most efficiently and effectively. None of these secondary factors should be permitted to handicap the full utilization of the potentialities of the locomotive, but it would be wasteful to have track, bridges, cars, etc. designed for weights, speeds and other factors of capacity in excess of the requirements of the locomotives running over them.

The locomotive is the principal actor in the drama of railroading. It enters so intimately into every feature of the design and use of track, structure and facilities that much necessarily has been said about it in the preceding chapters. Those remarks are properly a part of this section of the report but will be incorporated by this reference and not by repetition.

The locomotive is a British invention but American ingenuity contributed most to its subsequent development. The first self-propelled vehicle ever to run on a railed road was built by Richard Trevithick in 1804 but the locomotive continued in an experimental stage without much practical significance until October, 1829, when George Stephenson's "Rocket" proved to be commercially successful. Meanwhile, the "Stourbridge Lion" had been imported from England by the Delaware & Hudson Canal Company and on August 8, 1829, gained the distinction of being the first steam locomotive to run on the western hemisphere. However, it remained for "The Best Friend of Charleston" in January 1831, to be the first to produce revenues in regular service for an American owner of a locomotive.

The story of locomotive development is the essence of railroad history which must trace the growth of locomotive size and weight, the increase in allowable steam pressure in the boiler and the advance in hauling capacity measured by tractive effort and horsepower. Progress over the years must record all significant changes in wheel arrangement and in the many auxiliary devices which have contributed to improvement in economy and efficiency and safety of operation and added to output of work.

The Chicago Railroad Fair of 1948-49 presents the story of locomotive development in one continuous and colorful parade. The historic early locomotives are there; the British "Rocket," Delaware & Hudson's "Stourbridge Lion," Southern Railway's "Best Friend of Charleston," Baltimore & Ohio's "Tom Thumb," "Atlantic," "Lafayette," and "William Mason," Pennsylvania's "John Bull" and many others covering the intervening decades, down to Union Pacific's "Big Boy" the largest steam locomotive in the world today. The latest and largest all-electric and Diesel-electric locomotives are also on display.

In the earliest locomotives, the vertical rather than the horizontal boiler predominated and when the latter was used, it was very short in length. The piston was invariably coupled to a single pair of drivers; the cylinders were located inside the frame and their axis was inclined rather than horizontal. None of these characteristics are found in the present steam locomotives, all of which represent a natural evolution from the 4-4-0 type of wheel arrangement; i.e., a locomotive with a four wheel pilot truck, four coupled driving wheels and no trailing wheels. It was most appropriately termed the American type.

Three basic improvements were necessary to produce the American type (4-4-0) locomotive from the original primitive engines. In May, 1835, Matthias Baldwin, the founder of the Baldwin Locomotive Works, delivered his eleventh locomotive, the "Black Hawk" to the Philadelphia & Trenton Railroad (later to become part of the Pennsylvania Railroad System.) Its cylinders, steam shests, and driving rods were placed outside the frame of the locomotive and so it became the first "outside connected" engine. The superiority of the long horizontal fire-tube boiler was meanwhile being proved over the vertical type and it remained only to couple two pair of drivers together and the steam locomotive would assume its permanent basic form.

On February 5, 1836, Henry R. Campbell of Philadelphia, Chief Engineer of the Philadelphia, Germantown and Norristown Railroad (later acquired by the Reading) was granted a patent covering the design of the 4-4-0 locomotive, which later became known as the American type. Campbell arranged with a local builder, James Brooks, to construct an engine from his plans for the railroad with which he was associated. It was completed in May, 1837, but still used inside connections between the cylinders and the forward pair of driving wheels.

The successful use of two or more pairs of connected driving wheels necessitated a system of continuous equal distribution of weight on the driving axles permitting sufficient vertical flexibility in their attachment to the frame to allow the wheels to follow the imperfections in the surface of the track and changes in the rate of grade. The locomotive that James Brooks had built to the Campbell patents proved too rigid to do this until Joseph Harrison, Jr., of Philadelphia, who had been employed as a machinist in the Norris Locomotive Works in that city, developed the present system of equalizing levers. These permit locomotive driving wheels to alter their vertical position, with respect to one another and the locomotive frame, without unbalancing the equal distribution of the load on each driving axle. This made it possible to utilize two or more pairs of connected drivers. The American type, 4-4-0, of locomotive was established and the foundations were laid for a century of progress for the steam locomotive.

The final development of the American type of locomotive was made by William Mason at his locomotive works in Taunton, Massachusetts. The locomotive bearing his great name, which was built for the Baltimore & Ohio Railroad in 1856 and which appeared in the Monon Centennial of 1947 and hauled the Lincoln funeral train in the pageant "Wheels-A-Rollin" at the Chicago Railroad Fair (of 1948-49) may well be considered to mark the transition from the primitive types of locomotives to a mature, albeit relatively small, machine which provided the permanent foundation on which subsequent advances were developed. The locomotive, "William Mason," was the first to use the horizontal cylinder with its axis in line with the center of the drivers. That same locomotive embodied important improvements in design of driving and front truck wheels, and in counter-balances and staybolts. This ingenious builder subsequently standardized parts for his various designs of locomotives to an extent not previously attempted by others. Edward Hungerford has written that "William Mason might possibly be called the father of the American (steam) locomotive of today. For he was among the first to give serious attention to the fine features of its design. He worked with an inherent belief that both strength and beauty could be combined to advantages in the construction of a locomotive. He studied symmetry as well as simplicity. The improvements that William Mason wrought upon American locomotives remain in use until today."

The later development of the steam locomotive evolved from the 4-4-0 wheel arrangement of this American type of Locomotive. At first it was used as an all purpose locomotive but other types of engines that will be mentioned in subsequent paragraphs largely superseded it in freight service. The 4-4-0 remained the standard passenger locomotive until the 1890's and many units of this type were used on branch line and suburban service until around 1925.

Necessity to secure greater hauling capacity lead to successive increases in the number of driving wheels and to the addition of front wheels and trailing wheels for functional purposes. A third pair of drivers were added to a locomotive built for the Reading in 1847 and the 4-6-0 patters was produced. Many years later this became a very popular engine for passenger service and was then known as the "10-wheeled" type.

In order to obtain a greater concentration of the locomotive weight on drivers, one of the pairs of front or pilot wheels was ommitted in the design of a locomotive, having six driving wheels, built in 1863 for the New Jersey Railroad and Transportation Company (now the Pennsylvania Railroad between New Brunswick and Jersey City) and the familiar "Mogul" (2-6-0) was produced. In 1867 a fourth pair of drivers was added to the 2-6-0 or "Mogul" class to make a 2-8-0 class of locomotive. It was initially used by the Lehigh Valley Railroad and became known as the "Consolidation" type. This was standard heavy freight power for nearly half a century. These two designs established the sound precedent of using only two wheel front trucks under freight locomotives but four wheel ones are required to give the better guiding qualities needed for high speed passenger service.

As greater steaming capacity for fast passenger locomotives required increases in the size of the fire box, the 4-4-0 type was improved by the Atlantic Coast Line Railroad to provide the 4-4-2 wheel arrangement, first built in 1885. The name "Atlantic" type was a logical name for it and immediately became a popular design. The "Pacific" type, 4-6-2, followed soon after the turn of the century. The Missouri Pacific Railroad was identified with this development; hence the appropriate and widely recognized name.

In 1897, a pair of trailing wheels was added to the "Consolidation" design, 2-8-0, to produce a 2-8-2 locomotive for use on the Japanese Railways. The familiar "Mikado" type locomotive resulted which gradually superseded the "Consolidation" as the most popular type of freight motive power. World War II caused a change in the name to "MacArthur" type but the old one lingers on.

In 1903 the Santa Fe extended and enlarged the "Mikado" type locomotive by adding a fifth pair of drivers to produce a 2-10-2 or Santa Fe type of locomotive. In 1919, Baldwin Locomotive Works built Santa Fe locomotive #3829 which had a 2-10-4 wheel arrangement; the forerunner of the many locomotives that would be constructed with 4 wheel trailing trucks after 1926. Santa Fe #3829 is still in service. The 4-8-2 "Mountain" type was first designed for use in 1912 on the Chesapeake & Ohio Railway by adding another pair of drivers to the "Pacific" type locomotive to provide greater tractive effect needed on mountain grades.

The 100th anniversary of the birth of the steam locomotive in

1904 was marked by the first Mallet articulated Compound locomotive built in America for the Baltimore & Ohio. It was constructed by the American Locomotive Company and was sponsored by the well known L. F. Loree when serving briefly as the President of that railroad. This first mallet had the 0-6-6-0 design. Various developments and variations of wheel arrangement followed in logical steps to produce the 550-ton Union Pacific "Big Boy" of 4-8-8-4 design and other engines built during the intervening years that had lesser power but greater numbers of driving wheels.

The growing demands upon the boiler necessitated having fire boxes which required greater support. An experimental locomotive of the 2-8-4 design was built by Lima Locomotive Works in 1925 which soon went into service extensively on the New York Central's Boston & Albany Railroad and so became known as the "Berkshire" type. A four wheel trailing truck was used by New York Central to produce a Hudson type locomotive, 4-6-4, in 1926, in place of a Pacific. The most important "general service" locomotives in use at the present time has the 4-8-4 wheel arrangement. It was first built in 1926 by the Northern Pacific but the principal immediate utilization of this class of motive power was made by the Canadian National.

The Santa Fe has long been a leader of motive power development as in other phases of railroad operation. Its difficult profile over the mountains of Colorado, New Mexico, Arizona and California necessitated utilizing maximum capacity locomotives. Proof positive of this is found in its development of the Santa Fe type locomotive in 1903 which is the heaviest type of non-articulated power found in general use. In 1926, the Union Pacific designed a 4-12-2 locomotive powered by 3 cylinders, but while a considerable number of them was built at that time, the expense and difficulties of maintenance prevented their obtaining any permanent favor on that road or elsewhere. The 12-driver locomotive has only been successful by using it in the 4-cylinder articulated designs developed over the past 15 years.

The idea of making steam work twice in two types of cylinders was used in locomotives built by Anatole Mallet in 1867. Samuel Vauclain of the Baldwin Locomotive Works adapted this idea in the United States in his design of a cross compound locomotive in 1889. Probably no railroad in America has had in service as many locomotives with compound cylinders as the Santa Fe. Over the history of the railroad these reached the impressive total of 948 but not one is in service today, all having been dismantled or rebuilt with single expansion cylinders.

Most of these, however, were two cylinder locomotives rather than the 4-cylinder articulated engines with which compound cylinders are usually associated. The first Mallet articulated compound locomotive appeared on the Santa Fe in 1909 and between 40 and 50 of them were built in 1909, '10 and '11. However, it is quite apparent that these were not successful because the construction records indicate that these represented but a brief interlude in Santa Fe locomotive policy which thereafter developed around increasing use of the 2-8-2 and 2-10-2 classes of freight and of Pacific and Mountain types of passenger power. The Lima Locomotive Works in 1927 and 1928, which was associated with producing a Berkshire (2-8-4) design of locomotive out of the driving wheel arrangement of the Mikado (2-8-2) followed by adding a second pair of trailing wheels under the fire box of a Santa Fe type locomotive to produce a 2-10-4. This power had been ordered by the Texas and Pacific Railway so it became known as the Texas type but Santa Fe now owns 38 of this class, including the very first 4 wheel trailing truck locomotive, its own Baldwin built #3829, a 2-10-4 constructed in 1919, as previously mentioned but well worth noting a second time.

The Santa Fe acquired no new locomotives during the depression years of '31, '32, '33 and '34, which carries this summary of that company's locomotive development down to the opening date of years to which the special events of this study if directed. By that time the Diesel engine was first beginning to attract attention as the possible superior source of future motive power.

The steam locomotive has nearly a century and a quarter of magnificent service behind it and has made railroads supreme as mass producers of land transportation, but it never proved adaptable to highway vehicles. Fulfillment of the latter's needs for mechanical propulsion awaited the comparatively recent and concurrent development of the internal combustion engines and the world's petroleum resources. These touched off a miraculous demand for individual transportation which created two great industries. Progress feeds upon its own momentum, and the resultant vast expansion in the utilization of internal combustion engines and production of liquid fuel for consumption in them inevitably provided railways with a new source of motive power, too.

Substitution of rail motor cars for profitless branch line passenger trains, composed of the oldest and smallest equipment, provided the place for the internal combustion engine to start "workin' on the railroad." From this humble beginning, it climbed the ladder of success, in the time-honored tradition, up to the most difficult and responsible assignments. In the course of this achievement, the spark-ignition gasoline engine was completely superseded by the compression-ignition distillate burning one familiarly designated as the Diesel, in order to pay conscious and richly merited respect to the genius of its inventor.

The continued development of the Diesel engine permitted a reduction in its size and weight in relation to its power output which provided units suitable as the prime mover of a portable generating station that could produce low cost power in quantities adequate for road train operation. This current is available for turning traction motors that will convert the portable power plant, that is, power car, into a self-contained electric locomotive. The term "self-contained locomotive" is of course redundant for purposes of emphasis because, as previously observed, the syllable "loco" - implies that the "motive" (power) carries its own source of energy with it.

Diesel has now replaced steam power in those locomotive services where some one or more of the component factors of traffic, transportation, fuel and maintenance conditions bring service improvements or cost reductions, or both, in the wake of this change. Proof positive of the success which has attended installation of Diesel motive power is found in the significant fact that it has completely pre-empted the field of orders for new locomotives from all except lines that are wholly dependent upon coal traffic for their existence and even Chesapeake & Ohio is now purchasing Diesel switchers in large numbers. This transformation is the more remarkable because the general introduction of the Diesel on long distance passenger trains dates back only to 1935 and in freight service to 1940. While Diesel electric switchers were first built in 1925, that is only 24 years ago, and their numbers increased very slowly until 1937. Only the present widespread use and success of Diesel motive power makes us overlook how new this type of equipment is.

The development of the locomotive is the gauge of railroad progress, but the reverse side of the coin is the fact that any inadequacies in service or excesses in unit costs suggest deficiencies in motive power standards or efficiency of utilization. The same forces which spur progress in steam locomotive design and construction also produce attempts to short circuit it and seek completely new sources of motive power. The revolutionary progress of the electrical industry, in the early decades of this century, stimulated immediate interest in the possibilities which this type of energy might possess to release the railroads from some of the familiar handicaps of the steam locomotive.

Electric traction permits the highest possible standards of locomotive operations. The barrier to its immediate universal use was the high capital cost which restricted installation of the originally required electric power distributing system to super density lines or ones with tunnel or terminal or suburban passenger problems, and these entail but a tiny fraction of the railway network. Until the progress of science permits electric power to be transmitted from central stations without wires and cables, the only means of providing electric railway traction without costly overhead or third rail transmission systems, is to have the source of electric power made an integral part of the electric locomotive, just as the boiler is of the steam type. This not only dispenses with the need of electric power distributing facilities but makes the electric locomotive as flexible as its steam component.

Experience had defined the upper and lower limits of size and effectiveness of steam locomotive operation and it was inevitable that those two extremes offered the logical point for substitution of other types of motive power, that is, electrically driven units, which possessed broader range of capacity and could provide power in either larger or smaller quantities than steam locomotives could do. The all-electric locomotive initially appeared to offer the solution for the higher ranges of total and individual unit power requirements and the self-contained electric locomotive seemed to possess possibilities of meeting the lesser service ranges successfully. The latter were represented by branch line passenger trains and the lighter classes of freight yard and terminal switching in both of which cases the minimum size of steam locomotive was larger than necessary for much of the work. Standby fuel losses and slow acceleration added to the disadvantages of the steam locomotive in services characterized by maximum numbers of stops and starts. Traction motors driven by diesel generated power offered a possible release from these handicaps, and this new type of motive power gradually began to appear in branch line passenger train service and for switching freight cars. The continuous torque of the electric motor permits maximum utilization of the weight carried by the driving wheels to produce tractive effort at starting with current produced by the constant speed Diesel, carried in the body above the trucks, which is able at all times to turn its full rated mechanical power output into the electric generator which it drives.

Horsepower is fixed by Diesel engine capacity, but tractive effort and speed are variables. When generator output is fed into traction motors at starting, this power is represented by maximum component of current with correspondingly reduced voltage. These are the electrical characteristics necessary for maximum starting torque of motors. As these speed up the current drops and the voltage builds up proportionately to the former's decline.

The switcher provided the Diesel engine with its first introduction to freight service and the rail car to passenger work. Most switching requires low horsepower but high tractive power and ability to accelerate rapidly at low speeds. The Diesel engine, with the direct current generator and motor, are ideal characteristics to meet these requirements. Moreover, many switching assignments are "around the clock" on a 24-hour continuous basis. Steam switchers usually lose the equivalent of one shift of the three for servicing, and are forced to take time out during the other two for refilling the water tank. Diesel switchers can run continually with only about one day lost per month for routine servicing and repairs. An average of 7 gallons of fuel oil will be consumed per hour by a 1000 H.P. switcher, in ordinary work. This totals 168 gallons per day. Several days' supply is carried in the fuel storage tanks under the locomotive and these can be filled, if necessary, from tank trucks sent out from the engine house to meet the switcher on the job. This high availability, and low fuel consumption in comparison with steam, due to elimination of standby losses and reduced servicing and repair costs, give the Diesel a great advantage in ordinary terminal and yard work. One Diesel can perform the work of two or more steam switchers and unit costs per hour represent a substantial saving over that possible with steam service. For a time these had the additional benefit resulting from one man operation of the Diesel which needs no helper, but the railroads later agreed to assign a second man on switchers weighing 90,000 lbs. or more, hence the popularity of the 44 ton unit for light work.

The Diesel started in passenger service propelling small rail motor cars and provided surplus power sufficient to haul no more than one or, at the most, two light trailers. Trains of this character were very useful on light traffic branch lines. In 1934-35 the Burlington and the Union Pacific designed trains which were planned to utilize the highest available capacity of Diesel engine, suitable for transportation purposes, to propel trains that would be of specially designed cars built of high tensile alloy metals. The Diesel engines were placed in a power car which became an integral part of the train. These new trains were sensationally successful and within a very few years created a widespread demand for a service of that character. The resultant development of Diesel motive power led to the manufacture of Diesel locomotives which were no longer a mere power car portion of an articulated train, but were completely flexible units that could be used wherever desired. Power limitations of the early rail transportation Diesel engines limited the output of the first power cars to moderate quantities of electricity and hence restricted their use to specially built trains. The rapid development of this type of power soon permitted locomotives of 1800 H.P. capacity to be built which utilized two 900 H.P. engines in a single cab. Two or more of these units could be coupled for multiple operation controlled from the forward one.

It is significant to observe that the first Diesel electric road locomotive was Canadian National's "9000" built in 1928. It comprised two cabs each equipped with 1330 H.P. Beardmore Diesels which gave 2660 H.P. for the complete locomotive. The progenitor of CN 9000, which is "The Daddy" of all road Diesels, was the late Sir Henry Thornton, and Diesel motive power on the National, during his regime, could well be pointed to as proof of the general outline of the foregoing remarks about the early history of this type of locomotive. Undoubtedly Sir Henry's previous associations with electrified lines in the United States and England, stimulated his interest in developing means of providing electric traction through self contained electric locomotives. I saw one of the two cabs of this locomotive in operation between Quebec and Edmunston, New Brunswick, in November, 1945. The other was then assigned to service at the opposite end of the continent, Prince Rupert. They were finally retired and salvaged in 1947 after 20 years of service, a notable record which proved the stamina of this first Diesel road locomotive.

Diesel locomotive development has followed that of the steam locomotive and can be gauged by horsepower output. As fast as it progressed to higher ranges, new and more important assignments opened up for it. Diesel motive power is now available in such a variety of types and capacities that a Diesel locomotive can now be secured which will fulfill any assignment better and more economically than steam power.

The spectacular progress of Diesel locomotive development and its economic superiority over the reciprocating steam locomotive should not however make anyone indifferent or complaisant towards those of its characteristics which are not wholly satisfactory or are underdeveloped. The great manufacturers of these machines are striving for improvement of their products and are aided in their efforts by the experience and cooperation of the railroads. It is reasonable to expect that the rate of progress of Diesel locomotive development over the next decade will equal or surpass that of the last one.

At the present time 6,000 H.P. Diesel locomotives are approximately 200 feet long and require the support of 16 axles, all motor driven if the consist is four 1500 H.P. cabs, or 18 axles, of which 12 are motorized and 6 idlers, if the pattern is three 2000 H.P. cabs. The trend of future development of the Diesel locomotives will provide equivalent, or greater, power in substantially reduced length. The present small diameter driving wheels, directly geared to a single traction motor mounted in swivel trucks, are more akin to car than to locomotive design. In a Diesel locomotive of the anticipated dimensions, two large motors will probably be used to turn each set of driving wheels and their torque will be transmitted through the quill form of spring cushioned drive to the spokes of the large diameter wheels, journaled in the locomotive frame, thereby following the present practice of all electric locomotives.

Steam locomotives now transmit as high as 1000-1250 H.P. per axle. Diesel locomotives do not transmit more than 400 H.P. per axle. While recognizing that this difference underlies the high initial starting tractive effort of the Diesel, this in itself becomes of no practical value when it exceeds the capacity of the drawbars of the cars in the train to transmit it. Diesels have such an inherently large starting tractive effort that some of it can be sacrificed if need be to reduce locomotive length and remove all time limitation on slow speed operation with high drawbar pull. As the length of the Diesels is compressed and their overall weight per horsepower reduced, the power transmission per axle will approximate that of steam locomotives.

Every four years the railroads spend the equivalent of their original investment in steam locomotives in repairs to them and the gross annual expenses of owning and operating steam locomotives represent about 75% of the original cost of these machines. It is obvious from such basic considerations that an important capital investment is justified to obtain the economies that follow Dieselization.

The Santa Fe was never identified with the development or use of the little articulated streamliners having a power car built into the train as an integral part of it; the original form in which both the Diesel engine and lightweight cars appeared in railway service. The Santa Fe's interest in the Diesel locomotive was, from the outset, completely centered in obtaining a Diesel locomotive which would provide a form of motive power superior to the steam engine for the most exacting tasks of railway work and would not have to be restricted to assignments using specialized equipment.

It is especially significant, in the light of the foregoing statement, that while the Santa Fe owns a large fleet of lightweight streamlined passenger cars, none are articulated and it has never owned a train of this type. Moreover, it has never obtained Diesel produced tractive power from an engine carried in a power car but only from a standard locomotive. The Santa Fe was therefore one of the very first railroads to employ the Diesel road locomotive, using that term to distinguish it from a power car. Its first one was delivered by the

Electro-Motive Division of the General Motors Corporation in the late summer of 1935. It was comprised of two multiple-unit cabs each containing two 900 H.P. Diesel engines to provide a rating of 3,600 H.P.

This important new unit was promptly tested on transcontinental runs and proved that it could reduce the 55-hour schedule of "The Chief" to 39 3/4 hours. On November 20, 1935, this original Santa Fe Diesel locomotive was badly damaged near Gallup, New Mexico, while in service on a transcontinental run with a special party, by a fire resulting from a leaky oil line. However, this epoch making locomotive enabled the Santa Fe to inaugurate the trains 17-18 "The Super Chief" on a weekly basis between Chicago and Los Angeles on May 12, 1936, using standard heavyweight equipment until the following year.

The power output of the individual Diesel engines used in the cabs of road locomotives soon advanced from the 900 H.P. used in 1935 to 1,000 H.P. to raise the cab capacity to 2,000 H.P. with two engines and thereby provide 6,000 H.P. locomotives to fulfill the difficult schedules of the transcontinental streamliners. The Diesel freight locomotives, first introduced in 1940-41, were comprised of three or four units each containing a single 1,350 H.P. Diesel engine to provide 4,050 or 5,400 H.P. locomotives. 1,500 H.P. and 2,000 H.P. Diesel engines became available in 1945 permitting 6,000 H.P. locomotives to be obtained with four cabs of the former capacity or three of the latter.

The record of the dieselization of the Santa Fe is summarized in the tables of locomotive acquisition which follow at the end of this chapter. Steam and Diesel purchases must be considered together because they are both part of a common program to provide improved service, capacity and economy. In considering the relative acquisitions of steam and Diesel power since 1935, it must be remembered that the latter was in an experimental status until 1938 and was not used at all on any railroad for freight service until 1940. Moreover, during the war years, 1942-45, greater restrictions were imposed on Diesel than on steam motive power purchases. The Santa Fe therefore reluctantly bought both new and used steam locomotives during that period, notwithstanding its decided preference for new Diesel power which had definitely proved its economic and service superiorities by that time.

Locomotives are provided to produce transportation; the product which the railroads have to sell. Therefore the assignment of new locomotives to particular districts and services is almost as significant as the number of them that have been procured.

The Santa Fe owned the largest fleet of Diesel locomotives, measured by aggregate horsepower, until within the past few months when the giant systems of the east, the New York Central and Pennsylvania, which have been dieselizing their important through freight and passenger services with great rapidity in order to obtain urgently needed economies, passed the former in this respect. However, the Santa Fe will always be remembered in railway history as the principal exponent of Diesel motive power during the important period of its early development in freight and passenger service, when many great systems were skeptical of its ultimate practicability.

It is significant to observe that the first Santa Fe Diesel locomotive is still running satisfactorily and is producing its rated horsepower within reasonable limits of operating and maintenance expense. While the details of design and construction of Diesels show a tremendous range of improvement when the newest and the oldest Santa Fe Diesel units are compared, nevertheless the ones first acquired are still very useful members of its motive power fleet and show no greater degree of obsolescence than steam power of comparable age and hold their superiority to it in operating performance. The Santa Fe is therefore rapidly turning the beloved "Iron Horse" out to pasture in order to perform increasing proportions of its work with Diesel locomotives.

TABLE XXXIII

STEAM LOCOMOTIVE PURCHASES
1935 - 1948

NUMBER PURCHASED	CLASS	YEAR	TYPE WHEEL	TYPE NAME	CYLINDER DIMENSIONS	DIAMETER DRIVERS	MAXIMUM STEAM PRESSURE	STARTING TRACTIVE EFFORT PER LOCOMOTIVE	TOTAL TRACTIVE EFFORT (000)
5	3460	1937	4-6-4	Hudson	23½ x 29½	84	300	43,050	215.3
1	3460	1938	4-6-4	Hudson	23½ x 29½	84	300	43,050	43.0
11	3765	1938	4-8-4	Northern	28 x 32	80	300	66,000	726.0
10	5001	1938	2-10-4	Texas	30 x 34	74	310	93,000	930.0
10	3776	1941	4-8-4	Northern	28 x 32	80	300	66,000	660.0
10	2900	1943	4-8-4	Northern	28 x 32	80	300	66,000	660.0
20	2900	1944	4-8-4	Northern	28 x 32	80	300	66,000	1320.0
25	5011	1944	2-10-4	Texas	30 x 34	74	310	93,000	2325.0
92 - Total					Total Tractive Effort				6779.3

SECOND HAND LOCOMOTIVE PURCHASES

PURCHASED FROM & NO.									
B&M 7	4193-4199	1945	2-8-4	Berkshire	27½ x 30	63	240	60,900	426.3
PRR 3	882-884	1945	2-8-2	Mikado	27 x 30	62	205	61,465	184.4
N&W 6	1792-1797	1943	2-8-8-2	Mallet	25 x 32 39 x 32	57	270	114,154	684.9
N&W 2	1790-1791	1944	2-8-8-2	Mallet	25 x 32 39 x 32	57	270	114,154	228.3
18 - Total					Total Tractive Effort				1523.9
110 - Grand Total					Grand Total Tractive Effort				8302.2

All of the foregoing second hand locomotives have been sold or scrapped except the seven B&M 2-8-4.

TABLE XXXIV

DIESEL HORSEPOWER ACQUIRED EACH YEAR

Year	Passenger	Freight	Switch	Total
1935	1,800		2,400	4,200
1936			600	600
1937	3,600		5,700	9,300
1938	16,200			16,200
1939	4,000		28,000	32,000
1940	8,000	2,700	2,000	12,700
1941	10,000	24,300	1,720	36,020
1942		59,400	6,760	66,160
1943	1,350*	90,450	36,900	128,700
1944	22,950*	128,250	30,080	181,280
1945	18,900	83,700	21,000	123,600
1946	48,000			48,000
1947	42,000		4,000	46,000
1948	112,000	12,000	26,000	150,000
Total 1-1-49	288,800	400,800	165,160	854,760

*Eleven 5400 H.P. Electro-Motive Division Diesels purchased 1943, 1944 and 1945, were converted from freight service to passenger service in 1946. Three have since been converted back to freight service, leaving eight in passenger service. These have an aggregate of 43,200 H.P. designated (*) which has been subtracted from the column of freight locomotives.

TABLE XXXV

ROSTER OF DIESEL ROAD LOCOMOTIVES

Passenger

Class	Locos.	Units	H.P. Per Loco	H.P. Per Unit	Total H.P.	Builder
1	1	1	1800	1800	1,800	EMD
2 - 9	8	11	Various	1800	19,800	EMD
11	5	9	Various	2000	18,000	EMD
16	18	72	6000	1500	108,000	EMD
50	1	2	4000	2000	4,000	Alco
51	12	36	6000	2000	48,000	Alco
70	4	8	4000	2000	16,000	Alco
90	1	3	6000	2000	6,000	F-M
158	8	32	5400	1350	43,200	EMD
	58	174			288,800	

Freight

Class	Locos.	Units	H.P. Per Loco	H.P. Per Unit	Total H.P.	Builder
100	79	288		1350	388,800	EMD
200	2	8		1500	12,000	EMD
	81	296*			400,800	

* Recapitulation:

52 four-unit Locos	208 units
29 three-unit Locos	87 "
1 spare 1350 H.P. unit	1 "
81 Locomotives	296 units

* Designated by the lowest serial number of locomotives in the class.

TABLE XXXVI

ROSTER OF DIESEL SWITCHING LOCOMOTIVES

Engine Nos.	Locos.	Horsepower Per Unit	Total Horsepower	Builder
400,450	2	360	720	Whitcomb
460 - 468	9	380	3420	G. E.
500 - 502	3	1000	3000	F. M.
2150 - 2153	4	600	2400	E.M.D.
2201 - 2278	78	1000	78000	Baldwin
2300 - 2302	3	600	1800	Alco
2303 - 2304	2	660	1320	Alco
2310 - 2358 2385 - 2388	53	1000	53000	Alco
2400 - 2402	3	900	2700	E.M.D.
2403 - 2417	15	1000	15000	E.M.D.
2600	1	2000	2000	Baldwin
2611	1	1800	1800	E.M.D.
Total	174		165,160	

TABLE XXXVII

ASSIGNMENT OF STEAM FREIGHT LOCOMOTIVES OF HEAVIEST TYPE COMMONLY USED

Class	Terminals
2-8-2	Chicago to Clovis
2-10-4	Clovis to Belen
2-10-2	Belen to Barstow*
2-10-2	Barstow to Los Angeles, San Diego*
2-10-2	Barstow to Bakersfield*

ASSIGNMENT OF STEAM LOCOMOTIVES PURCHASED SINCE 1935

Class of Locomotive				
Wheel Arrangement	Type	Total No. Purchased	Class of Service	Terminals
4-6-4	Hudson	6	Passenger	Chicago - LaJunta
4-8-4	Northern	51	Passenger	LaJunta - Los Angeles
2-10-4	Texas	35	Freight	Clovis - Belen
	Total	92		

* Freight service of Coast Lines now completely dieselized between Belen - Bakersfield - San Bernardino. Diesels also used to extent available for service between San Bernardino and Los Angeles.

TABLE XXXVIII

ASSIGNMENT OF DIESEL PASSENGER LOCOMOTIVES

Assignment	Serviced At	No. of Locomotives	Horsepower Per Loco.	Diesel Operated Passenger Trains	Limits Of Diesel Service
Transcontinental	Barstow	30	6000	7-8, 17-18, 19-20, 21-22, 23-24	Chicago-Los Angeles
Pool		8	5400	3-4	Newton-Los Angeles
				2nd Section of 7-8	LaJunta-Los Angeles
				2nd Section of 23-24	Belen-Los Angeles
				1-2	Clovis-Los Angeles
				23-24	Barstow-Bakersfield
Los Angeles San Diego	Los Angeles	2	3600	71-72, 73-74, 76-77, 78-79	Los Angeles-San Diego
Bakersfield Oakland	Bakersfield Richmond	2	3600	60-61, 62-63	Bakersfield-Oakland
Chicago Galveston Pool (Via Newton)	Chicago	4 Pool made up of:* 8 - 2000 HP 2 - 1800 HP 1 - Spare 1800 HP		1-2	Chicago-Galveston Locomotives operate 3 units Chicago to Newton where third unit is cut out and sent back to Chicago on first eastward train of this pool. Giving 5400-5800 HP Chicago to Newton, 3800-4000 Newton to Galveston.
Chicago Galveston	Chicago	3	4000	15-16	Chicago-Galveston
Chicago Purcell	Chicago	2	4000	12-12 (111-112)	Chicago-Purcell
Kansas City Tulsa	Tulsa	1	1800	211-212	Kansas City-Tulsa

* The variations in horsepower per unit (2000 to 1800) and the units per locomotive east and west of Newton (8 and 2 respectively) produce various power combinations of locomotives from 3600 to 6000 H.P.

TABLE XXXIX

ASSIGNMENT OF DIESEL LOCOMOTIVES IN FREIGHT SERVICE

Assignment	Service Base	Number of Locomotives	Horsepower per Locomotive	Limits of Operation
Coast Lines	Barstow, Cal.	50	5400	Belen - Barstow
		2	6000	Barstow - Los Angeles
				Barstow - Bakersfield
Chicago Colorado Texas	Cleburne, Tex.	29	4050	Chicago - Argentine
				Argentine - Pueblo
				Argentine - Bellville, Tex.
	Total	81		

Reference

S. F. 116 Report

SWITCH ENGINE ASSIG~mNT
TO YARDS ON TRANSCONTINENTAL MAIN LINE
BETVffiEN CHICAGO AND LOS ANGELES (VIA SOUTHERN DISTRIGr)

Yard	Diesel No.	Diesel Tricks	Steam No.	Steam Tricks	Remarks
Chicago					
Corwith	13	31	4		steam necessary for protection.
Produce Term.	2	5			6 d~s per wk. 3 tricks on Sun.
18th Street	5	14	2	2	Steam necessary for protection.
Joliet	2	6			
Streater			1	3	
Chillicothe			3	5	
Galesburg	1	1			2-3 hours, 5 days per wk. overtime.
Shop ton	2	6	4	6	
Marceline			1	3	
Argentine	31	74	9	5	Steam necessary for protection.
Emporia	4	12	2	3	
Ottawa			1	2	
Eldorado			2	3	
Agusta			1	1	
Wellington	2	6	2	3	
Waynoka	2	6			
Amarillo	4	"12	2		Steam necessary for protection.
Clovis	4	12	1		Steam necessary for protection.
Belen	4	10	1		Steam necessary for protection.
Gallup			3	4	
Wins IoV{			4	8	
Ash Fork			1	2	
Seligman			1	2	
Needles	1	3	1	2	
Barstow	6	15	2		Steam for protection and relief.
San Bernardino	7	21	2	3	
Los Angeles	31	71	o		
Total	121	305	50	57	

The Santa Fe owns 174 yard switching Diesel locomotives.
Remaining 53 units are assigned to yards and terminals not on the Chicago-Los Angeles Transcontinental main line (via Southern District.)

CHAPTER XIV

CARS

The business of a railroad is to move cars. The details of car construction, their adaptation to varied service requirements, while always retaining complete flexibility for movement over all lines of railway and the continued availability of required supply at all points as needed, constitute one of the major functions of railway operation. Cars must be designed of structural strength capable of transmitting the thrust and pull of locomotives, absorbing the shock of high-speed movement over switches, crossings and imperfect track while sustaining loads of maximum capacity. Modern freight equipment varies in carrying capacity from 35 to 45 tons in refrigerator cars, 50 to 60 tons for box cars, to as high as 80 tons for open top equipment designed to carry the products of mines and heavy structural material. Some coal cars in the lake and tidewater trades will carry 90 to 100 ton loads of coal. In passenger service the heavyweight Pullman cars, built prior to introduction of lighter weight materials in the middle 30's, weigh in excess of 80 tons.

All cars must be designed to the minimum clearances permissible on the road by which the cars are owned. Standard minimum clearances have been adopted by the American railroads through their joint agency, now the Association of American Railroads. Box and other closed types of cars which do not exceed these established limits, must be accepted in interchange with the alternative of the receiving line, of restricted clearances, being required to bear the cost of transferring or detouring. Such cars exceeding these minimum measurements need not be accepted in interchange or if this is done the cost of transferring the contents must be borne by the road on which the load originated, which it should be noted may not be the owning line.

Open top cars, themselves, do not exceed even the minimum clearance limits of any railroad, but their loads often do. It is the responsibility of shippers, and originating railways to hold open loads within all clearance limits with the resulting expense of transfer or other special hauling falling on the latter if offered in interchange.

In freight cars the important structural features are (1) trucks, wheels and axles; (2) couplers, and attachment of drawbars to the underframe of the car; (3) the floor system and underframe; (4) side frames and roofs; (5) brakes.

The freight cars are supported at either end by a four-wheel truck. Wheels are rigidly attached to axles with external (i.e., outside of the gage of the rails) journals revolving in journal boxes. These journal boxes are held in place by truck side frames which, in turn, are connected by a very strong structural member termed a "truck bolster." The weight of the car is transmitted through the floor system into the center sill and then on through a body bolster which is a strong supporting member under the car and which, when it is on a straight track, is parallel to and directly above the truck bolster. The latter member is not rigidly attached to the side frames but is joined by side bearing rollers to permit vertical but not horizontal motion and rests on heavy coil springs which, in turn, are supported and held in place by a spring nest resting on and connecting the bottom of the truck side frames. This method of assemblage dampens vertical motion of the trucks against direct transmission of shock into the car body. The truck is attached to the car body by a center pin which passes through the center of both the body bolster and the truck bolster, allowing the truck to revolve when the car moves over curved track. The coil springs and vertical movement of the car body occasionally have harmonic periods of oscillation which reinforce the intensity of each causing vibration of such amplitude and force as to damage contents of cars and occasionally cause derailments. Accordingly, non-harmonic springs are in process of development to utilize both eliptic and coil springs in order to take advantage of the different rates of oscillation of the two separate devices and the snubbing action of the leaves of the eliptical springs' oscillation. The truck frames in the past had been assembled from various parts framed on an arch bar which is essentially a steel strap suspended from the top and bottom of the journal boxes and supporting the truck bolster and also the spring nest and the springs on which the truck bolster rests. The arch bar proved to be a member of insufficient strength to meet the needs of modern freight transportation and frequent breaking of arch bars in transit was a prolific cause of derailments so the use of arch bar type of trucks was prohibited on cars offered in interchange after January 1, 1938.

The coupler is a device for attaching cars to one another so that trains may be assembled. The rigid attachment of the coupler to a car underframe would result in damaging shocks in starting and stopping trains, which might seriously overstrain the car if it did not actually wreck it in transit. The transmission of the "thrust" and "pull" of the coupler must be cushioned through spring or friction devices in the attachment of the coupler to the underframe. This is the function of the draft gear.

The wheels used under the older freight cars are of cast iron, although solid steel wheels have been supplanting these on the new cars built over the past 10 or 20 years, except during the war. Only steel wheels are used under passenger equipment and under locomotives and tenders.

All axles are, of course, of steel, their surfaces outside the area of attachment to the hub of the wheels are carefully turned to a smooth and perfectly true cylindrical face which normally rests against a bearing made of anti-friction metal inserted into the top of journal box which is packed with oil-soaked waste, that is kept continually oiled by lubrication at terminal points. The friction bearing is gradually being supplanted in passenger service by roller bearings but these are too expensive for use on freight cars.

The backbone of the car, the center sill, an I-beam of heavy construction, extends for its entire length, is connected with the side sills by a number of cross members, and the side sills are connected by end sills at each end of the car. This assemblage of steel members comprises what is known as the underframe of the car. All of the dead or live load of a car and the thrust of train movement, as well as much of the shock transmitted by trucks moving over frogs and switches and rough track, are concentrated on the center sill.

The design of the underframe and the steel members rising from it to support the roof are subject to the same principles as govern structural design of bridges and buildings, although the stresses of members of movable structures are never as susceptible of exact determination as is possible in the case of fixed structures and, therefore, the factors of safety in the movable structure must be greater. The closed type of car, such as the box, refrigerator or stock car, having high sides and a roof, lends itself more readily to sturdy construction by reason of the depth of the truss structure. The truss structure, of course, can be built to meet any necessary standard of strength required for any allowable lading.

Open top cars do not lend themselves as readily to securing maximum structural strength with the most economical use of material, because the lower sides correspondingly reduce the depth of the trusses and, hence, require material of increased cross sectional dimension to secure equivalent strength. Because of their design, open top cars lack the strengthening influence of top bracing available in the construction of a closed car type. In this connection, too, open top cars usually carry the heaviest loads, i.e. coal, ore or structural steel, heavy material, blocks, building stone, et al, and the lighter freight commodities are carried in closed type cars in which structural strength can be most economically obtained at lowest cost. However, in spite of the greater structural problems of open top cars, these are now being built to meet every service requirement. From what has been previously said, it is obvious that flat cars present the greatest difficulties in securing structural strength, and no type of equipment is called upon to bear as heavy concentrated loads as are these units, which are so frequently utilized for the lading of the most ponderous machinery and other heavy commodities. The design of cars which meet these service requirements is probably sufficiently familiar to all so that detailed mention of them need not be embodied in a thesis of this character.

At the beginning, cars of every type were built entirely of wood, practically no metal parts being used except for trucks, wheels and axles, the running gear on the air brake system and truss rods and auxiliary devices. Gradually over the years increasingly severe physical requirements of railway transportation on its equipment forced the substitution of steel for wood in an increasing number of parts of the car and for the last twenty years, most freight cars built have been of all steel construction.

Passenger cars vary in length from 65 to 90 feet, in extreme length and are about 15 feet in extreme height from the rail. The heaviest Pullman sleeping cars weigh in excess of 85 tons but the availability of aluminum, stainless steel and low alloy steel at prices that permit its use in car construction have led to all passenger equipment built over the past 10 or 12 years to be made of these materials rather than the ordinary carbon steel with a consequent reduction in car weights to 60 - 70 tons. Much of the weight saving of improved metals has been offset by the weight of air conditioning apparatus and improved lighting and heating facilities.

General structural principles utilized in passenger car design are similar to those of freight car construction. The side frames are trussed but a more complex design is necessary to provide for windows and doors. The ends are given maximum strength to resist telescoping in collisions and spring buffers are placed in the ends of the cars over the couplers to cushion shocks of starting, stopping and coupling. Six wheel trucks were utilized on the heavier passenger cars built in past decades but the modern lightweight or semi-light weight cars permit a return to 4-wheel trucks. The requirements of greater safety, improved riding qualities, and higher speed have made many other important modifications necessary, in passenger car truck design.

The American railways have frequently been criticized for the alleged excessive weight of cars and critical comparisons have occasionaly been made with the railways of other countries using lighter cars. The point has been completely overlooked that the car is light or heavy, less by reason of its actual weight than in relation to the load which it carries and to its structural strength. The problem is one of keeping the ratio of the car weight to the pay load at a minimum. In practice, it is found that the larger the size of the cars, the more favorable this ratio and if a given number of hundreds or thousands of cars of freight are to be moved or a stated number of people to be carried they can be handled with a reduced dead weight of cars if these are relatively smaller number of larger units. Long experience in car design proves that often minor increments in car weight give very large increased loading potentialities. Detailed analysis will show that if a freight or passenger car is loaded to capacity only a few times a year, the excess revenue will pay the added interest of maintenance and operating cost resulting from the larger capacity and hence weight. If the maximum load can be maintained even but a few times a year, it is much more economical to have built the large car than a smaller one. Moreover, the first essential of railway operation is safety and durability, and larger and stronger cars possess these virtues in the highest degree.

The same qualities of leadership which the Santa Fe has shown in other features of railway management are equally manifest in its progressive policies in relation to car design, maintenance and operation. Proof of this is seen in its fleets of modern streamlined trains and in the high proportion of its freight and passenger cars which are of recent construction.

While freight is the mainstay of railroad revenues, the competitive necessities of the passenger service usually provide the initial impetus to major technical advances and usually is the first service to reflect them. The Diesel locomotive is a case in point. This whole narrative of Santa Fe development since 1935 relates to improvements within that great system which sprang from the Diesel locomotive that was developed to haul better passenger trains faster. The Diesel was extensively utilized in passenger service several years before it was seriously considered for freight trains.

The arrival of the Diesel locomotive coincided with the availability of new alloys of metals and improvements of all component parts and features of passenger cars which led to marked advances in the construction and design. These produced moderately lighter cars but ones which provided much greater riding comfort at all operating speeds and also many conveniences and attractions and features of interior design and furnishing heretofore unknown.

New passenger equipment is so widely known and generally acclaimed that any detailed description of modern cars is unnecessary. Attention may therefore be confined to recording statistically the numbers and types of Santa Fe passenger cars acquired since light weight ones were introduced in 1936-37 following three depression years, 1933-34-35 when no new passenger train cars were acquired.

The resumption of the aggresive development of the Santa Fe began early in 1935 when its management decided to reduce the schedule of trans-continental passenger trains between Chicago and Los Angeles by the equivalent of a day. The "Chief" was then the fastest long distance train in the west and made its run in 55 hours but the conventional time between Chicago and the Pacific coast, on all routes, represented a 3-night and 2-day schedule, approximating 60 hours of travel time. Early in 1935 the Santa Fe began the coordinated program of improving standards of track construction and maintenance, reducing curvature and improving signal facilities which have been outlined in this report. The goal of this work was to run passenger and freight trains faster.

The immediate objective was a new train to be known as the "Super Chief". The Santa Fe's first Diesel locomotive, a 2-unit, 3600 H.P. machine, has been ordered. Initially there would be but a single locomotive and train. The locomotive for the "Super Chief" was received in the fall of 1935 and made a memorable test run on the proposed 39-3/4 hour Chicago to Los Angeles schedule in October of that year. Streamlined light weight equipment was not yet available, so the train was composed of standard heavy weight Pullman cars. The service was inaugurated for the use of the public on May 12, 1936, and the train ran once a week in each direction.

Light weight streamlined cars having stainless steel exterior and car body construction were ordered from E. G. Budd Company and substituted for the standard heavy weight cars in 1937. Five light weight sleeping cars were obtained for that service; one providing an observation-lounge type car for rear end. All additional light weight sleeping cars used on Santa Fe trains up until the segregation of Pullman's manufacturing and operating corporations in 1945, '46 and '47, were Pullman built, owned and operated.

Other Santa Fe streamlined trains were developed around the Diesel locomotives and the light weight passenger cars acquired in 1938 and subsequent years. A second "Super Chief" was added in February 1938 in order to permit twice a week service. "El Capitan," the transcontinental coach train was added at the same time, also on twice a week basis between Chicago and Los Angeles. The "San Diegans," between Los Angeles and San Diego; the "Kansas Citian" and the "Chicagoan" between Chicago, Kansas City and Oklahoma City, and the "Golden State" streamliners in the San Joaquin Valley between Bakersfield and Oakland were inaugurated in 1938.

The story of Santa Fe passenger car acquisition closely parallels the record of its new trains and its service improvements. The statistical record appears on a following page. All cars listed thereon represent new ones built for Santa Fe and delivered in the designated year except the acquisition of 83 sleeping cars reported in 1945. These were light weight units obtained between 1938 and 1942 which were built, owned and operated by Pullman but were assigned to Santa Fe. The latter exercised an option to buy these in anticipation of the segregation of the Pullman Company from its prior owner and subsequent purchase by the user railroads.

No heavy weight equipment has been built new for the Santa Fe since the last car of this type was delivered to it in 1932. However, in order to obtain some much needed additional passenger car capacity it purchased 15 heavy weight coaches second hand in December, 1944. One car was subsequently destroyed in an accident and the remaining 14 were sold in October, 1947.

During 1948 the Santa Fe purchased 71 heavy weight Pullman sleeping cars assigned to its lines. These were obtained at the depreciated book value of this equipment pursuant to the contract provision relating to railroad acquisition of the sleeping car business.

A railroad earns most of its revenues through hauling freight which moves in freight cars. The necessity of operating the American railroads as a unified and coordinated system from the standpoint of moving freight between any combination of points in the United States requires complete flexibility in the interchange of cars from one line to the other. It follows, as every traveler knows, that the cars of any one railroad may be seen on the tracks of all others and it is a fortunate railroad indeed which has more than a small proportion of the freight equipment which it owns on its own rails at any one time. They have, however, the cars of other railroads to use in partial exchange for the ones which are off line at the time. This complete interchangeability of freight cars, and passenger cars, too, requires a high degree of standardization in the basic elements of design and dimensions.

Freight cars, like all railroad equipment, must be of sturdy construction for safely handling under load in long freight trains. Such construction which is necessary for safety also insures a long life.

Freight cars, if continuously maintained in good condition, can last thirty to forty years or even more. However, obsolescence is apparent in most cars after they have been in service more than 20 years and cars that are more than 10 years old usually are beginning to evidence inferiorities of design and equipment in relation to those of recent construction.

The Santa Fe owned 79,526 freight cars on December 31, 1948. It is therefore significant to observe its purchases of new freight cars of various classes, beginning with 1935, that are summarized in the following table. Data on age and total ownership of freight equipment is also included.

ACQUISITION OF LIGHT WEIGHT STREAMLINED PASSENGER TRAIN EQUIPMENT
1935-1948

	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	TOTAL
Baggage		1				1	21					17		40
Baggage & Chair			2		2									4
Baggage Dormitory			2		1							3		6
Baggage & Mail		1	2			1				5				9
Chair	2	30	17		-1*	15				2	14	54		133
Chair & Club			2		4	-2*						1		5
Chair & Observation			2		3	2						3		10
Club		6	2			4					5			17
Dining		11	3		1		10							25
Lounge		7	1		1									9
Lunch Counter			5		1	2						3	16	27
Mail					2									2
Parlor & Observation			5		-2*	-1*								2
Sleeping		4								83**		31	21	139
Sleeping & Observation		1												1
Net Additions	2	61	43	0	12	22	31	0	0	90	19	119	37	436
Cumulative Additions	2	63	106	106	118	140	171	171	171	261	280	399	436	436

No cars purchased in 1935.
* Cars have been destroyed or reclassified.
** Net after deducting one car destroyed.

Reference: Statement by sub-classes of equipment owned and changes, SF Form 585.

FREIGHT CARS ACQUIRED NEW OR REBUILT - 1935-1948

TABLE XLII

	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Total	Total Ownership January 1, 1949
Revenue Service																
Automobile		705	1000		400	250	754	308			492	8		500	4,417	5,577
Box		500	2200		235	3110	4102	1375		1000	101	1149	350	1650	15,772	29,922
Open Top*		60	325			327	700	75	900	600		250		653	3,890	14,388
Concentrate																25
Flat						142	50		3	200					395	2,412
Logging																56
Refrigerator	17	337	1351	752	937	1701	1323				2	1	350		6,771	14,584
Stock																7,134
Tank								200							200	3,395
Total	17	1602	4876	752	1572	5530	6929	1958	903	1800	595	1408	700	2803	31,445	77,493
Company Service																
Ballast						200	300								500	205
Caboose								8	92	100				100	300	1,152
Drover	8														8	9
Ice																276
Tie																391
Total	8					200	300	8	92	100				100	808	2,033
Grand Total	25	1602	4876	752	1572	5730	7229	1966	995	1900	595	1408	700	2903	32,253	79,526

Reference: Statement by sub-classes of equipment owned and changes, S.F. Form 585.

* Except "Flat" and concentrate cars but including covered hoppers.

While the above table lists 32,253 cars acquired new or rebuilt, 1935-1948, and 29,350 cars between 1935-1947, Table XLIII on Page 319 reports 18,601 cars as being in the 0-15 year age group on January 1, 1948, i.e. acquired after January 1, 1933. Those purchased new in 1933-34 are not listed above but were of small totals indicating that something in excess of 10,000 of the above cars are rebuilt units, while more than 20,000 new cars were acquired in that period or between 25% and 30% of present ownership.

TABLE XLIII

AGE OF FREIGHT CARRYING CARS
ATCHISON, TOPEKA & SANTA FE RAILWAY COMPANY
JANUARY 1, 1948
BASED ON DATE ORIGINALLY BUILT

Age	Box	Flat	Stock	Gondola	Hopper	Tank	Refr.	Other	Total	Per Cent To Owned
1 to 5 Yrs	3,193	200		399	1,350		350		5,492	6.95
6 to 10 "	7,179	191		725	824	200	446		9,565	12.11
11 to 15 "	2,475			324	60		695		3,554	4.50
16 to 20 "	8,088	665	1,784	1,881	350	100	1,565	5	14,438	18.28
21 to 25 "	7,067	613	3,041	3,088	199	20	9,115	16	23,159	29.32
26 to 30 "	2,608			1,931		524	2,445	18	7,526	9.53
Over 30 "	4,002	674	3,252	3,844		2,646	1	832	15,251	19.31
Total Owned	34,612	2,343	8,077	12,192	2,783	3,490	14,617	871	78,985	100.00

CHAPTER XV

LOCOHOTIVE AND CAR SHOPS, STATIONS AND MISCELLANEOUS FACILITIES, TOOLS AI\TD APPLIAHCES

While a number of important topics have been reviewed in this analysis of Santa Fe improvements, it by no "means covers all of the work done. Car and locomotive shops, engine houses, office buildings, stations} .locomotive fuel and water and other auxiliary facilities of every sort together vdth tools, appliances and devices ranging from the largest power driven machines to small hand operated ones have been continuously improved~over the years. In addition to the facilities which Santa Fe directly ovms i.t has necessarily contributed its prorata or wheelage proportion to the development of the various terminal and other con~anies wIllch mvn facilities that it uses.

The !:lost important new mechanical facilities built in recent years have been those provided for the efficient and expeditious servicing and repair of Diesel locomotives. In 1945 the Santa Fe completed the largest and finest Diesel locomotive servicing station in the country at Barstow, California. The building is 138 ft. vnde and 250 ft. long and contains six tracks of length sufficient to hold a four unit locomotive • ~ shop extension 75 ft. by 225 ft. was added in 1948 and contains three additional tracks.

Servicing of Diesel locomotives requires work being performed at various levels from ".inspection of the trucks, wheels and motors below the track level to access to machinery and apparatus high within the inside of the cab. Pits and platfonls are therefore necessary to provide convenient access and working space at these different places. Adequate, shadowless lighting everywhere and at all angles is a paramount necessity and this requirement has been well fulfilled at Barstow Shop. It likewise is completely equipped with systems for dispensing fuel, lubricating oil, compressed air and water and other supplies conveniently to the locomotives at all of the servicing platforms.

Shop facilities and store rooms are of adequate size and accessible location. An elaborately complete set of coordinated facilities is located alongside the shops for filling locomotives with fuel, train heating boiler water and sand and also for washing them mechanically.

Barstow is essentially a "service station" where passenger locomotives are cut in and out of trains after a complete transcontinental round trip of 4,500 miles between Chicago and Los Angeles. Similarly freight locomotives are cut out of road service only after established mileage has been run on the various freight train assignments between Belen, Barstow, Bakersfield and San Bernardino with possibly an occasional run into Los Angeles. No heavy repairs are made at Barstow; work of this type being done at the San Bernardino Shop which has been converted to perform such functions, in addition to providing for all of the requirements of the steam power which remains on the Coast Lines.

San Bernardino is one of the three important locomotive shops built by the Santa Fe shortly before World War I. The other two are at Albuquerque and Cleburne, Texas. The fourth Santa Fe locomotive repair shop is at Topeka, Kansas, and is the oldest one on the system. All of the four, however, have been kept abreast of modern shop practice by the continuous replacement of obsolete tools by modern ones and by making such additions to crane capacity and other facilities as have been required to handle motive power of continuously increasing size and weight.

Passenger Diesels have transcontinental assignments so can be serviced at Barstow along with the Diesel freight locomotives which now haul all of the freight trains between Belen, San Bernardino and Bakersfield and also operate into Los Angeles whenever available for runs on the "Third District" (of the Los Angeles Division.) Through freight service is completely dieselized between Chicago and Kansas City and substantially so between Kansas City - La Junta and Pueblo and between Kansas City and Belleville, Texas, a freight engine terminal 80 miles north of Houston. Since none of these freight locomotives touch Barstow, their assignments are planned to concentrate heavy repairs at Cleburne, Texas, and routine servicing at Argentine, Kansas. Santa Fe also has a large and modern repair and servicing facility for Diesel locomotives adjacent to its Chicago Coach Yards but the latter's functions are auxiliary to those of Cleburne and Barstow. A complete Diesel "service station" is being erected at Corwith Yard, Chicago, to care for road freight and switching power at that terminal.

A plan of development for a modern railroad must cover innumerable details. New office machinery and equipment, redecoration and reconstruction of stations and of office buildings, minor shops and enginehouses, provision of fuel and water dispensing apparatus, ad infinitum, have as definite a place as the more spectacular features outlined herein. It is obviously impossible to do more than mention these adjuncts but they must not be overlooked when one is considering the breadth and extent of the accomplishments which the Santa Fe has made over the last 15 years to keep its railroad in the forefront of progress.

Through the years, the Santa Fe has been very generously provided with handsome and spacious stations at most of the intermediate points on its line; the larger cities being invariably served by Union or other jointly owned and operated facilities.

Therefore comparatively little remained to be done to add to the list of attractive stations built prior to 1930 except in Newton, Kansas, and paradoxically enough, in the Santa Fe's home city of Topeka. The former was constructed during the middle 30's and an unusually attractive and completely equipped passenger station was opened to public use in the capital city of Kansas early this year. It very appropriately contains a bronze plaque, dedicated by the present President, to honor his predecessor, the Santa Fe's founder, Cyrus K. Holliday.

CHAPTER XVI

CAPITAL COST OF THE IMPROVEMENT PROGRAM AND FINANCIAL AND STATISTICAL RESULTS OF OPERATION

Improvements can be counted both by the cost and by the numbers and size of physical units added and can also be measured by the increased efficiency and capacity which follows their completion. The Santa Fe improvement program should be viewed from all three of these important points of view.

The capital component of it is summarized in a comprehensive Table, No. I, Page 4-A, to which reference was made in the opening chapter of this report. It is requested that the reader turn to Page 4-A again. The information given in the subsequent chapters of this thesis provide the descriptive background of the additions and betterments which are consolidated therein in terms of cost. It is hoped that the narrative will give greater meaning and significance to this data than it could have had when necessarily introduced without explanation at such an early point in this study.

Table I totals the gross capital charges made for each class of improvement listed but that is not the whole cost of much of the type of work. In all cases where improvements are made to "non-depreciable" roadway property, application of Interstate Commerce Commission accounting practices result in a substantial part of the outlay being charged to operating expense rather than to capital accounts. Consideration of this table, therefore, falls short of reporting the total expenditures made by the Santa Fe to finance the improvement program. The data shown represents only the aggregate number of dollars spent which are capital charges and does not include the substantial component charged to operating expenses.

Improvements are of two classifications:

1. Additions - which represent new work, i.e., a second track; block signals, or cTc on a line not previously equipped, a new car or locomotive, etc.

2. Betterments - replacing a timber bridge by a steel or concrete one; relaying light rail with heavy rail, providing a better boiler on a steam locomotive, replacing a manual interlocker by an electric one; etc.

All of the cost of improvements classed as additions are capitalized but there are two different accounting procedures in the case of replacements and betterments relating (1) to all cars, locomotives and other rolling stock and all fixed property on which depreciation charges are continuously accrued to operating expenses and accumulated in depreciation reserves stated in the balance sheet of the owner company, and (2) to property which is non-depreciable.

Right-of-way, grading, tunnels, the component parts of track, i.e. rail, ties, ballast, turnouts, crossings and other material, which is undergoing regular cycles of replacement continuously throughout the railroad, also minor items such as hand tools, office appliances, furniture and fixtures, etc. is considered non-depreciable property. No depreciation reserves are established for these things which are continuously wearing out and being simultaneously replaced in relatively constant numbers and proportions from year to year.

When any one of these non-depreciable items is replaced in kind, no betterment results and the entire cost of the replacement is an operating expense. If the replacement represents a betterment, the excess cost of it as actually made, over the cost of replacement in kind, represents the capitalizable improvement. Also improvements made without involving a replacement are a betterment and so are fully capitalized. The addition, for example, of air conditioning to an existing passenger car is a betterment. Its cost is a capital charge. Some examples may be given. If a track which is laid with old 90# rail is relayed with new 90# rail, the entire cost is an operating expense. On the other hand, if 90# rail is replaced with 115# rail, that proportion of the total cost which is the estimated equivalent of doing the work in kind (i.e. replacing with 90# rail) is chargeable to operating expense but the remainder, which represents the cost of the betterment, goes into the capital accounts. If a boiler is replaced on a steam locomotive with a new one which permits increased steam pressure and has other characteristics of being a "betterment" the cost of replacement in kind is an operating expense; the excess cost beyond that represents the capitalizable betterment.

Non-depreciable road property removed or abandoned and not replaced in kind is credited to the appropriate investment account and this amount, less salvage, is charged to retirements as a maintenance expense. The latter practice must be followed in the accounting for line changes. The cost of the new line is fully capitalized but the investment in the old line abandoned, and track on it must be written out of the property investment accounts through a retirement charge to operating expenses equal to its book value less credits for property salvaged.

Depreciable road property such as a car or bridge that is replaced by a new and better one is written out of the property accounts in the balance sheet through credits thereto and offsetting charges (less salvage credits) are made to the appropriate depreciation reserves. The entire cost of the betterment is then capitalized. New items of equipment are capitalized and units of equipment retired is written out of the accounts through the depreciation reserves for them.

It may be noted that the capital improvements made on the Santa Fe from 1896 through 1930 comprised a very high proportion of additions; i.e. double track, block signals and many other things going in for the first time. The period from 1935 to date contains a substantial proportion of betterments to non-depreciable roadway property hence entailed a considerable component of operating expense in addition to the capital charges aggregated in Table I.

It would require an interesting but very extended audit to develop the grand total of the improvement program embracing both classifications of capital and operating expenditures. The same observations would apply to an analysis of the source of funds for Santa Fe's capital improvements which variously come from:

1. Sale of securities; now only Equipment Trust Certificates since the Santa Fe has sold no stock or bonds within the period covered by this report; i.e. since 1935.
2. Depreciation charges to operating expenses.
3. Salvage of retired property.
4. Earnings (net income) reinvested in the property.

The total investment of $829,656,000 of new capital in a period of 27 years, or more than $30,000,000 per year, represents nearly 60 per cent of the book value of $1,389,671,000 of road property and equipment before accrued depreciation and amortization of $400,533,000 reported on December 31, 1948. Such data constitutes an eloquent statement of the high proportion of the total plant and investment which is represented by the additions and betterments of the past thirty years.

The Santa Fe improvement program was made to provide additional transportation capacity and to enable the railroad to operate more economically and efficiently. Railroads keep their accounts according to prescribed methods and instructions of the Interstate Commerce Commission and make very complete information public periodically through the year on the results of their operation in terms of money, traffic units and measurements of operating efficiency. Their annual reports are models of breadth and completeness of coporate and financial information.

A financial and statistical analysis of the Santa Fe Railway made to confirm the extent and adequacy of the improvement program and the success with which it achieved its purpose would be a comprehensive separate study in itself. An impressive array of financial, traffic, transportation and maintenance statistics could be marshalled in it. Some representative tables are presented as Appendix D but no attempt will be made to discuss and explain these data which covers a period beginning in 1921. It is hoped that they will prove to be self-explanatory. Wide changes in economic, political and transportation conditions occurred within that 28-year period. The component tables of Appendix D show principal sources of revenue and income and nature of expenses. The magnitude of operations is reflected in conventional units of traffic and transportation as well as dollar amounts. A few significant ratios have been computed to indicate trends and relationships.

If Appendix D were extended to include the usual measures of operating efficiency and earning power and project the salient factors of Santa Fe performance against the record of other large systems, it would prove that this great railroad is being managed with outstanding foresight, skill and ability, and is utilizing the capital effectively. It has also established an impressive record of growth and development of traffic, even after making due allowance for the favorable natural factors which have aided it.

Most important from the standpoint of this study is the record of its earning power, especially before taxes. It proves that the funds which have been invested in the expansion and development of the Santa Fe over the past 15 years have been fully justified by the increase in capacity and revenue and improvement in operating efficiency. These results have also vitalized the investments made by the predecessors of the present generation of Santa Fe executives and have laid a firm and enduring foundation to sustain this great railway throughout future decades and even centuries. The work of the men who will run the Santa Fe in the years ahead will be made more effective and their ambitions and abilities will be stimulated by the achievements of the Engel-Gurley administration briefly described herein, that will be bequeathed as a great legacy to the future.

CHAPTER XVII

OPERATION OF THE SANTA FE

The preceding chapters have described the property of the Santa Fe but have said little of how it is used to perform the service for which it is provided. The details of railway operation would be another long study; summarizing the freight and passenger schedules offered to the public and the manner in which the work of running the trains, the yards and the stations is organized and supervised.

In its fundamental aspects, railway operation is largely a matter of the assignment of men and engines and cars to provide the services of the required standard with a minimum expenditure of labor and fuel and of materials, both for transportation and maintenance.

Efficiency may well be considered to be represented by the ratio between the number of man hours and engine hours and materials actually utilized to perform a railroad's work compared with the number which should be sufficient on the basis of most effective planning and administration.

This report cannot, at Page 330, begin a description of the operation of the Santa Fe in the manner involved in fulfilling the foregoing outline, so this chapter will center its attention on the physical factors which at the outbreak of the war handicapped the Santa Fe in providing instantaneously the large increase in transportation capacity which it was called upon to produce as its great contribution to the war effort. It will weave a number of the essential facts contained in the preceding ones into a brief narrative of the operation of the Santa Fe's transcontinental lines in a manner designed to show what these restrictions were, what historical or other fundamental facts had produced them, why action had not been taken prior to the war to relieve them and when and where and why corrective measures were applied and what has been the resultant improvement.

There will be some inevitable repetition of what has been stated before, but it is hoped that this will be helpful to the reader. At the outset he is requested to turn again to the traffic density chart, Exhibit 3, and is reminded that Santa Fe's average freight traffic density measured in revenue ton miles per mile of line has fluctuated over recent years to the extent indicated by the following table:

Year	Density in ton miles per mile of line	Percent of 1945 density	Percent of 1941 density
1941	1,398,425	46	100
1942	2,114,285	74	158
1943	2,429,698	84	181
1944	2,869,905	100	214
1945	2,871,608	100	214
1946	2,274,252	79	169
1947	2,502,959	87	187
1948	2,522,320	88	188

The proportional traffic increases on the Chicago-California main lines have been substantially greater than the system averages tabulated above. Population trends are a basic factor in determining the long term trend of traffic and significant data of this character relating to the Santa Fe's territory are set forth as Tables XLVI and XLVII.

Study of the traffic density chart, Exhibit #3, will show the uniformity of density along the 1400 miles of main line between Barstow, California, and Wellington, Kansas. These are very important junctions. The reader is urged to keep their location clearly in mind.

Two-thirds of Santa Fe's California traffic normally originates and terminates on the Los Angeles Division in southern California, and one-third moves to or from stations and junctions on the Valley and San Francisco Terminal Divisions. During the war, this relationship was modified by the extraordinary concentration of military traffic through the Port of San Francisco so the tonnage over the two routes became nearly equal; the Los Angeles Division remained the heavier, but the percentage relationships narrowed close to 50-50. It is now back to its pre-war ratios, two-thirds and one-third.

The First District of the Los Angeles Division which extends between Barstow and San Bernardino over Cajon Pass, however, has train, car and tonnage density somewhat heavier than the Santa Fe main line divisions east of Barstow, because the Union Pacific's important Los Angeles & Salt Lake Railroad between those two cities uses Santa Fe trackage for 100 miles between Daggett, which is 8.8 miles east of Barstow, and Riverside, 9.2 miles west of San Bernardino.

The Union Pacific's freight traffic in and out of Southern California fully balances the Santa Fe's traffic to northern California and Union Pacific runs four daily passenger trains each way in and out of Los Angeles. The increment of Union Pacific traffic raises the train and traffic density of the Santa Fe's line between Daggett and San Bernardino, the latter station being the junction of the former's two routes to Los Angeles, to the highest on the Santa Fe except the main lines of the Middle Division and the Eastern Division, both of which it will be recalled lie in eastern Kansas. The peak movement in the west, however, is on the 8.8 miles of line east of Barstow to Daggett which carries all of Santa Fe's California transcontinental traffic, both of the Los Angeles and the Valley Division and is used by the Union Pacific also. The physical characteristics and track facilities of the line between Daggett and Barstow are favorable for movement of a heavy train density; i.e. 100 or more per day without delay or congestion.

The lines into southern and northern California which diverge at Barstow may be summarized as follows:

SOUTHERN CALIFORNIA

Los Angeles Division

First District - Barstow over Cajon Pass to San Bernardino:

Double track	80.8 miles	westbound
Double track	82.8 "	eastbound
Average	81.8 miles	

Second District - San Bernardino - Los Angeles via Pasadena:

Single track	1.4 miles
Double track	58.0 "
Total	59.4 miles

Third District - San Bernardino to Los Angeles via Riverside and Fullerton:

	Eastward	Westward
Single track	39.4 miles	39.4 miles
Double track	32.1 "	32.8 "
Total	71.5 miles	72.2 miles

Fourth District - Fullerton to San Diego and National City; distance Fullerton to San Diego - 102.3 miles, equipped with cTc; 10.3 miles D.T., 92.3 miles S.T., 7.0 miles D.T. has no cTc.

"Olive District" - 5.8 miles of cTc equipped single track between Atwood, 5.3 miles east of Fullerton on Third District and Orange, 7.6 miles south of Fullerton on Fourth District, is used by through freight trains between San Bernardino and San Diego.

NORTHERN CALIFORNIA

Arizona Division - Barstow - Mojave	71.6 miles
Southern Pacific trackage, Mojave - Kern Junction	66.8 "
Valley Division and San Francisco Terminal Division	
Kern Junction - Oakland	315.4 "
Total	453.8 miles
Double track - On Southern Pacific trackage	36.5 miles
On Santa Fe	6.2
Total	42.7 miles
Single track equipped with cTc on Southern Pacific trackage	32.3 miles

East of Wellington the continued accession of main and branch lines builds up traffic so rapidly that between Emporia and Kansas City it is more than double that registered at any point between Barstow and Wellington. The traffic volume between Chicago and Kansas City is just a little more than half of the density between Emporia and Kansas City, and in fact is only from 10 - 25% heavier than on the lines between Barstow and Wellington in spite of the accretions provided by Texas lines and Kansas mileage and the important local and gateway tonnage of Kansas City. This underscores the fact that half of the traffic which Santa Fe brings into Kansas City goes east on other lines. Some of it is destined to or via Saint Louis, the Twin Cities and Memphis to which Santa Fe does not run but many cars also go via Santa Fe's rivals to Chicago, for Kansas City is an "open gateway" for competitive solicitation of business. The network of railway mileage which other railroads, such as the Burlington, Rock Island, Milwaukee, Gulf, Mobile & Ohio, and other railroads operate within the states in the populous area between the Missouri River and Lake Michigan and their direct access to many Chicago industries which are available to the Santa Fe only through reciprocal switching, constitute an additional factor leading to the diversion at Kansas City of tonnage originating on the Santa Fe west of that great middle western railway center.

Appendix D outlines the traffic fluctuations, year by year, from 1921 - 1948, inclusive. The effect of the decade of prosperity in the 20's and of the depression in the 30's is clearly manifest but this thesis is a study of capacity and so is related to maximum rather than minimum requirements.

In the peak years of 1926 - 1929, Santa Fe's daily average freight car movement, loaded and empty, between Barstow and Wellington averaged 500 to 750 cars per day each way. Several important branches, and indeed the main passenger route, too, (at Dalies) connected with this 1400 mile long section of the railway. Principal among these are the feeder lines through valleys productive of substantial agricultural and mineral traffic. These and their main line junctions may be summarized as follows:

1. Cadiz, California, with the line to the Palo Verde Valley, ending at Ripley.

2. Ash Fork, to the Salt River Valley and Phoenix.

3. Belen, through the Rio Grande Valley to El Paso on to the south and Albuquerque on the north.

4. Clovis with its Pecos River Valley line to Pecos, Texas. The principal Texas junctions, on the other hand, are with through routes at Texico, Canyon, Amarillo and Pampa. While the traffic of these branch and secondary lines is important, the cars and tonnages moving to and from them are relatively small in relation to the main line total and is moreover so divided between east and westward movement as to produce a balancing effect on the main line traffic density which seems to have more of a tendency to stabilize it than to produce any noticeable changes in it.

In 1929, the lines from Wellington to Belen and on 10 miles further to junction at Dalies with the passenger route via the Northern District, was a continuous single track with the exception of 62 miles of second track between Pampa, Amarillo and Canyon, built during 1926-27, when the Texas Panhandle experienced a great wave of economic development under the impetus of rapidly increasing production of oil and wheat. The long main lines of the Panhandle, Plains and Pecos Divisions, between Wellington and Belen had ample capacity to handle 500 to 750 cars in each direction daily moving in 10 to 12 trains each way and hauled by a 2-8-2 locomotive over the 0.6% maximum ruling grades and easy curves which characterized all of the route between the Rio Grande and the Missouri Rivers, except for helper districts shown in Table IV on Page 80 and Table XLIV. All of the latter are short and represent relatively minor ascents except the crossing of the Manzano Mountains at Mountainair, New Mexico, 40 miles east of Belen. Two through passenger trains in each direction daily running on easy schedules were conveniently accommodated on these three divisions of the Southern District. Local and intermediate traffic was unimportant except within the 62 miles between Pampa, Amarillo and Canyon where a second track had been provided in 1926 and '27.

Between Belen and San Bernardino the railroad crossed high mountainous country and there the through passenger trains routed via Dalies and La Junta over the Northern District were added to the daily fleet of freight trains. A double track line had been provided between Dalies and San Bernardino before 1930, except the 23.4 miles from D. T. Junction, Carrizo Junction to Joseph City. This gap in the second track was closed in 1940. The original line between Belen, Dalies and San Bernardino embodied adverse physical characteristics which required almost continual revision throughout. The second track was built to better standards of ruling gradient than the original one and so was used in the ascending direction. The first main track was assigned to the descending direction. In this manner the 0.6% eastward and westward ruling grades, which had been made the system main line standard during the Ripley administration, and so had been embodied in the Transcontinental Short Line, or present Pecos Division, were continued on west from the Rio Grande at Belen, New Mexico, and over the Continental Divide at Gonzales, N.M. and on to Winslow, Ariz., and required only 10.3 miles of helper grade west from Belen to Dalies.

The grade characteristics of the Santa Fe's transcontinental freight route between Chicago and Los Angeles are of such continuing importance in this study that they may well be again summarized at this point, notwithstanding that they have been frequently mentioned and tabulated in other parts of this report.

TABLE XLIV

The grade characteristics on the Atchison, Topeka & Santa Fe Railway's freight route between Chicago and Los Angeles are as follows:

A. East of Winslow, Arizona, via Dalies, New Mexico, Belen, New Mexico, Amarillo, Texas, Waynoka, Oklahoma, Wellington, Kansas, Augusta, Kansas, Ellinor, Kansas, and Ottawa Cut-off.

Ruling grade (Maximum; i.e., it is less on some engine districts.)

Eastward - 0.6% except 0.8% over First District of Missouri Division from Marceline to Shopton (Ft. Madison) Iowa, 112.7 miles.

Westward - 0.6% except 0.8% over First District of Missouri Division from Shopton (Ft. Madison) Iowa, to Marceline, Missouri, 112.7 miles.

Helper grades on engine districts included within the foregoing routes.

Division	District	Limits of Helper District	Length of Helper District	Maximum Ascending Grade
Eastward				
Pecos	2nd	Becker, N.M. - Mountainair, N.M.*	25.9 mi.	1.25%
Plains	1st	Canadian - Coburn, Texas**	17.8 mi.	0.6%
Missouri	2nd	Kansas City (on K.C.T. Ry.)***	4.0 mi.	9.95%
Missouri	2nd	Rothville - Marceline***	7.3 mi.	0.90%
Westward				
Illinois	1st	Chillicothe, Ill.-Edelstein, Ill.***	8.0 mi.	1.10%
Plains	1st	Heman, Okla.*** # - Curtis, Okla.***	16.4 mi.	1.0%
Albuquerque	Belen	Belen, N. M., - Dalies, N.M.***	10.3 mi.	1.25%

* Helper engines usually operate out of the engine terminal at Belen, 14.9 miles west of Becker.

** While 0.6% is ruling grade on Division, the terrain has a virtually continuous descent east except for this long eastward climb out of the Canadian River Valley. Since Canadian is an engine terminal, it is common practice to use a yard engine to help eastward steam powered freight trains to Coburn to permit faster ascent of the 360-foot climb.

*** Use helpers on Diesel powered trains only to obtain faster movement.

\# Helper engines usually operate out of the engine terminal at Waynoka, 5.2 miles east of Heman.

TABLE XLIV (Cont.)

B. West of Winslow, Arizona

Ruling Grade			Distance		Ruling Grade	
Division	District	Limits	E'wd Track	W'wd Track	E'wd Track	W'wd Track
Los Angeles	3rd	1st St. Yard, Los Angeles-San Bernardino via Fullerton (Route used by through freight trains)	70.5*	71.2*	1.0%	0.7%
Los Angeles	2nd	1st St. Yard, Los Angeles-San Bernardino via Pasadena (Principal passenger route)	59.7**	59.7**	2.2%	1.5%
Los Angeles	1st	San Bernardino, California,-Barstow, California	82.8	80.8	2.2%	1.6%
Arizona	2nd	Barstow, California-Needles, California	165.7	167.6	1.0%	1.0%
Arizona	1st	Needles, California-Seligman, Arizona	149.7	149.5	1.42%	1.0%
Albuquerque	3rd	Seligman, Arizona-Winslow, Arizona	143.6	142.7	1.42%	1.42%

All the foregoing lines are double track, except:

*Los Angeles Division - 3rd District: Single track - Riverside-Fullerton 36.8 mis.

**Los Angeles Division - 2nd District: All single track, except 1.7 mis. of double track between 1st St. Yard, Los Angeles, and Broadway.

It will be observed that the 2nd and 3rd Districts of the Los Angeles Division provide alternate routes between Los Angeles and San Bernardino.

Los Angeles Union Station is one mile west of Mission Tower and the latter is one mile east of 1st St. Yard on the Pasadena Line; viz.:

To San Bernardino via Second District through Pasadena Broadway - end of double track

0.7 mi.

Los Angeles Union Station — 1 mile — Mission Tower

1 mi.

1st St. Yard

To San Bernardino via Third District through Fullerton

TABLE A~IV'(Cont.)

Helper Grades on Main Line Engine Districts West of Winslow, Arizona

Division	District	Limits of Helper District	Length of Helper District	Maximum Ascending Gra.de
Eastward				
Los Angeles	1st	San Bernardino, California Smmnit, California		
Albuquerque	-3rd	Ashfor~, Arizona, Supai, Arizona		1.8%
Westward				
Arizona	1st	Seligman, Arizona - Yampai, Arizona	23.1 mi.	1.42%
Arizona	2nd	Needles, California - Goffs, California	31.1 mi.	
Arizona	2nd	Cadiz, California - Ash Hill, California	38.6 mi.	
Los Angeles	1st	Victorville, California,- Summit, California	19.2 mi.	1.6%

Crossing the Arizona Divide between Winslow and Needles, grades of 1.h2% are encountered in each direction Y'rith a helper grade of 1.8% eastward from Ash Fork to Supai. The Sl~'cbnd District of the Arizona Division between Needles and Barstow has 1% ruling grades east and west but there are 1.42% helper districts/'westbound from Needles to Goffs and from Cadiz to Ash Hill. The climb over Cajon Mountain is on 1.6% helper erades 'west and 2.2% east. Substantially in excess of 100,000 pounds of tractive effort is required to haul a 3,500-ton train, equivalent to 70 loaded cars averaging 50 tons each, up a 1.42% ascent. 'No single locomotive had been built, which would do this until about 20 years ago•. It is significant at this point to consider the horsepower required to haul a ton of train weight at varying rates of speed. A table of this nature, prepared by the American Locomotive Company, dated February 13, 1940 is repro'duced in Table XLV with expressions of thanks. Its data shows the relative effect (f which increase in grades and speeds have

DRAW BAR HORSE POWER REQUIRED PER TON (2000#)
40 TON (RAIL WT.) FREIGHT CARS
ON VARYING RATES OF GRADE AND AT
5 MILE INCREMENTS OF SPEED TO 60 M.P.H.

GRADE %	MILES PER HOUR											
	5	10	15	20	25	30	35	40	45	50	55	60
LEVEL	0.06	0.13	0.20	0.29	0.40	0.52	0.66	0.83	1.01	1.23	1.47	1.74
0.1	0.09	0.18	0.28	0.40	0.53	0.68	0.85	1.05	1.25	1.49	1.76	2.06
0.2	0.11	0.23	0.36	0.51	0.67	0.84	1.04	1.26	1.49	1.76	2.05	2.38
0.3	0.14	0.29	0.44	0.61	0.80	1.00	1.22	1.47	1.73	2.03	2.35	2.70
0.4	0.17	0.34	0.52	0.72	0.93	1.16	1.41	1.69	1.97	2.29	2.64	3.02
0.5	0.19	0.39	0.60	0.83	1.07	1.32	1.60	1.90	2.21	2.56	2.93	3.34
0.6	0.22	0.45	0.68	0.93	1.20	1.48	1.78	2.11	2.45	2.83	3.23	3.66
0.7	0.25	0.50	0.76	1.04	1.33	1.64	1.97	2.33	2.69	3.09	3.52	3.98
0.8	0.27	0.55	0.84	1.15	1.47	1.80	2.16	2.54	2.93	3.36	3.81	4.30
0.9	0.30	0.61	0.92	1.25	1.60	1.96	2.34	2.75	3.17	3.63	4.11	4.62
1.0	0.33	0.66	1.00	1.36	1.73	2.12	2.53	2.97	3.41	3.89	4.40	4.94
1.1	0.35	0.71	1.08	1.47	1.87	2.28	2.71	3.18	3.65	4.16	4.69	5.26
1.2	0.38	0.77	1.16	1.57	2.00	2.44	2.90	3.39	3.89	4.43	4.97	5.58
1.3	0.40	0.82	1.24	1.68	2.13	2.60	3.09	3.61	4.13	4.69	5.28	5.90
1.4	0.43	0.87	1.32	1.79	2.27	2.76	3.28	3.82	4.37	4.96	5.57	6.22
1.5	0.46	0.93	1.40	1.89	2.40	2.92	3.46	4.03	4.61	5.23	5.87	6.54
1.6	0.49	0.98	1.48	2.00	2.53	3.08	3.65	4.25	4.85	5.49	6.16	6.86
1.7	0.51	1.03	1.56	2.11	2.67	3.24	3.84	4.46	5.09	5.76	6.45	7.18
1.8	0.54	1.09	1.64	2.21	2.80	3.40	4.02	4.67	5.33	6.03	6.75	7.50
1.9	0.57	1.14	1.72	2.32	2.93	3.56	4.21	4.89	5.57	6.29	7.04	7.82
2.0	0.59	1.19	1.80	2.43	3.07	3.72	4.40	5.10	5.81	6.56	7.33	8.14
2.1	0.62	1.25	1.88	2.53	3.20	3.88	4.58	5.31	6.05	6.83	7.63	8.46
2.2	0.65	1.30	1.96	2.64	3.33	4.04	4.77	5.53	6.29	7.09	7.92	8.78

TABLE DOES NOT INCLUDE RESISTANCE DUE TO CURVES WHICH SHOULD BE EQUATED TO GRADE EQUIVALENT THEREOF AND ADDED TO ACTUAL RATE OF ASCENT, UNLESS RULING GRADES ARE COMPENSATED FOR CURVATURE. THIS, HOWEVER, IS SANTA FE PRACTICE.

CAR RESISTANCE PER DAVIS FORMULA FOR FREIGHT CARS, (2 AXLE TRUCKS.)

Table prepared by American Locomotive Co. February 13, 1940.

in consuming the power output of any locomotive. Since grades of 0.6% and 1.42% are ones most frequently mentioned in descriptions of Santa Fe operations, the horsepower requirements per ton of train weight in loaded cars are underscored for those ascents.

The use of two locomotives to "double head trains" over an entire engine district early gained a place among the fundamental principles of efficient railway operation to obtain a greater total of locomotive power than was produced by a single unit. It should, however, be pointed out that double heading over an entire engine district, on which heavy ruling grades prevail throughout its entire length, is a technically different practice than using one or more assisting locomotives on helper or pusher grades. The latter are grades of limited length; i.e., substantially less than a full engine district, on which the ascending gradient exceeds the ruling grade that establishes the tonnage rating of locomotives over the division.*

The Santa Fe, in common with all western railroads, (and one eastern one, the Monon, was required to accept the same restriction many years ago) was barred by contract with the Brotherhoods from using double headers to increase tonnage over the maximum rating of the largest locomotive on any division. The recognized helper districts on pusher grades were excepted and also a minor modification was made in respect to double header operation between Winslow and Needles. The background of the double header restrictions and their application have been very interestingly outlined in the memorandum that will be quoted on the following pages and for which appreciative acknowledgement is made to Mr. L. D. Comer, Director of

* The reader is reminded that the general subject of ruling grades and helper grades was discussed on pages 28 - 32 so it need not be amplified or repeated here.

Employment, Santa Fe Railway, Chicago;

"Prior to 1903 there were, generally speaking, no rules in the agreements between the railroads and their employees, covering the working conditions of the latter, which prohibited railroads from operating trains with mbre than one locomotive, if the pr~ctice seemed desirable. In that year, under strike threats, certain western railroads having their headquarters at St. Louis were forced by the train service organizations to agree to rules substantially similiar to the present western double-header rule, quoted below, except that the prohibition then agreed to covered the operation of double-headers vdth more than 30 cars, exclusive of cabooses. Similiar rule~ were agreed to by other western railroads about the same time and have continued in effect without substantial change 'except for 'an increase from 30 to 40 cars which took place in 1924 in conjunction with certain wage negotiations.

(The present western double-header rule generally reads as follows:

tI(a)First: With trains of over 40 cars, exclusive of cabooses, doubleheading is prohibited except as hereinafter stated:

ft 1•. Doubleheaders may be run on any district provided the rating of largest engine handling the train is not exceeded.

f1!12., In case of an accident to an engine, consolidation may be effec~ed \vith'another train and consolidated train brought into terminal as a doubleheader, if. practicable.

"("6) Second: Necessary helPers 'will be used between the following points to maintain the tonnage intact over grades:u

The points between which helpers may be used vary from road to.road.~nd were limited to established helper grades.)

UIn some doubleheader rules there are incorporated certain exceptions peculiar to individual railroads and on the Santa Fe Coast Lines, for example, the agreements provide that between Needles and Winslow, in either direction, doubleheaders may be run vnth not to exceed 2900 tons.

In this territory a helper may be used eastbound only from Ash Fork to Supai.

Following the 1924 negotiations, as a reult of which the 30-car limit was increased to 40 cars as above stated, the western carriers again sought an opportunity to renew their effort to obtain relaxation of the doubleheader prohibition. This occasion was provided by the demands of the conductors' and trainmen's brotherhoods for an increase of 7½% in the levels of their wage rates in western territory. The carriers proposed the elimination of all double-header rules as a condition to any increase, or in the alternative that the increase be not more than 6½% if the rules were retained. The 7½% had been demanded by the train service employees, in order to obtain in western territory substantially the same measure of increase as had been granted to these classes of employees in the eastern and southern districts where basic wage levels had been increased by 7½% in 1926. Failure of negotiations between the two organizations and the western carriers resulted in the issues being submitted to an Emergency Board at Chicago in October, 1928. That Board recommended, in effect, that the employees accept either a 7½% increase but submit to arbitration as to whether the double-header rule should be abrogated in any particular district or districts where the affected carrier might so propose, or a 6½% increase, and retain the double-header rules. The employees elected the latter alternative and the double-header rules of the western carriers were, therefore, continued in effect.

The double-header rules are contained only in the agreements with the conductors and trainmen.* There have been no material changes in the double-header rule since 1924, except that during World War II the Interstate Commerce Commission issued a service order abrogating

*"Double header operation" reduces the number of conductors and trainmen required but does not similarly affect engineers and firemen; hence the contract with the Brotherhoods representing the two latter groups of employees do not contain similar restrictions on operations of trains hauled by two or more locomotives over an entire engine district.

TABLE XLVI

GROWTH OF POPULATION OF STATES IN WHICH SANTA FE OWNS OR OPERATES RAILWAY MILEAGE*
(000 Omitted)

	Illinois	Iowa*	Missouri	Kansas	Nebraska*	Oklahoma	Texas	Louisiana*	Colorado	New Mexico	Arizona	California	Total
1860	1,712	675	1,182	107	29	-	604	708	34	94	-	380	5,431
1870	2,540	1,194	1,721	364	123	-	819	727	40	92	10	560	8,190
1880	3,078	1,625	2,168	996	452	-	1,592	940	194	120	40	865	12,070
1890	3,826	1,912	2,679	1,428	1,063	259	2,236	1,119	413	160	88	1,214	16,397
1900	4,824	2,232	3,107	1,470	1,066	790	3,049	1,382	540	195	123	1,485	20,260
1910	5,639	2,225	3,293	1,691	1,192	1,657	3,897	1,656	799	327	204	2,378	24,958
1920	6,485	2,404	3,404	1,769	1,296	2,028	4,663	1,799	940	360	334	3,427	28,909
1930	7,631	2,471	3,629	1,881	1,378	2,396	5,825	2,102	1,036	423	435	5,677	34,884
1940	7,897	2,538	3,785	1,801	1,316	2,336	6,415	2,364	1,123	532	499	6,907	37,513

*While Santa Fe lines actually enter Nebraska, Iowa and Louisiana, the mileage therein is unimportant; viz., Nebraska 1.27 miles, Iowa 19.9 miles, Louisiana 64.0 miles.

RANK OF STATES IN POPULATION (000 Omitted)

1.	New York	13,479
2.	Pennsylvania	9,900
3.	ILLINOIS	7,897
4.	Ohio	6,908
5.	CALIFORNIA	6,907
6.	TEXAS	6,415

Santa Fe states capitalized.

Source: Statistical Abstract of the United States 1947.

TABLE XLVII

GROWTH IN POPULATION OF SANTA FE CITIES
HAVING 50,000 INHABITANTS OR MORE IN 1940
(000 Omitted)

	Amarillo, Texas	Beaumont, Texas	Berkeley, California	Chicago, Illinois	Dallas, Texas
1890	-	3	5	1,100	38
1900	1	9	13	1,699	43
1910	10	21	40	2,185	92
1920	15	40	56	2,702	159
1930	43	58	82	3,376	260
1940	52	59	86	3,397	295

	Denver, Colorado	El Paso, Texas	Ft. Worth, Texas	Fresno, California	Galveston, Texas
1890	107	10	23	11	29
1900	134	16	27	12	38
1910	213	39	73	25	37
1920	256	78	106	45	44
1930	288	102	163	53	53
1940	322	97	178	61	61

	Houston, Texas	Kansas City, Kansas	Kansas City, Missouri	Long Beach, California	Los Angeles California
1890	28	38	133	1	50
1900	45	51	164	2	102
1910	79	82	248	18	319
1920	138	101	324	56	577
1930	292	122	400	142	1,238
1940	385	121	399	164	1,504

	Oakland, California	Oklahoma City, Oklahoma	Pasadena, California	Peoria, Illinois	Phoenix, Arizona
1890	49	4	5	41	3
1900	67	10	9	56	5
1910	150	64	30	67	11
1920	216	91	45	76	20
1930	284	185	76	105	48
1940	302	204	82	105	65

TABLE XLVII (Cont.)

GROWTH IN POPULATION OF SANTA FE CITIES
HAVING 50,000 INHABITANTS OR MORE IN 1940
(000 Omitted)

	Pueblo, Colorado	Sacramento, California	St. Joseph, Missouri	San Diego, California	Stockton, California
1890	25	26	52	16	14
1900	28	42	103	18	18
1910	42	51	77	40	23
1920	43	62	78	74	40
1930	50	81	81	148	48
1940	52	83	76	203	55

	Topeka, Kansas	Tulsa, Oklahoma	Wichita, Kansas	San Francisco, California
1890	31	-	24	299
1900	34	1	25	343
1910	44	18	52	417
1920	50	72	72	506
1930	64	141	111	634
1940	68	142	115	635

Source: Statistics Abstract of the United States 1947.

the 2900 double header limitation on the Santa Fe in the territory between Winslow and Needles. At that same time the Interstate Commerce Commission also issued a service order lifting the 50 loaded car limit from Summit to San Bernardino. (Reference to this will be made on a following page.) Following the issuance of these directions by the Interstate Commerce Commission, negotiations with the conductors and brakemen resulted in agreements being made with their organizations under which members of train crews operating double headers with more than 2900 tons in the territory, Winslow-Needles, would be granted a certain arbitrary allowance. Another agreement made at that time also provided that when trains with more than 50 loads or its equivalent number of empty cars are handled from Summit (of Cajon Mountain) to San Bernardino, the members of the train crew will also be paid a certain arbitrary in addition to the basic rates."

As a further handicap to operation, California had imposed the most burdensome excess crew law to be found in the statute books of any state. Since the subject of excess crew laws is under consideration, it must be pointed out that Arizona required an additional, i. e. third brakeman on all freight trains from 39 to 70 cars in length. The standard 2-8-2 heavy Mikado type locomotive had a drag or slow freight tonnage rating of 2900 tons on the long continuous 0.6% grades of the Albuquerque Division. This, however, was reduced to 2600 tons when hauling the fast through freight trains which comprised the principal type of traffic over the transcontinental lines. The 2900 ton double header exception on the 1.42% grades west of Winslow was related to the train rating of the same tonnage which was the maximum weight their standard motive power in use between Belen, Winslow and Gallup could haul between those points. Larger power was not made available there on account of the Arizona train limit law to which reference will be made in the next paragraph.

As a further handicap to the development of motive power and of operating practices necessary to handle long trains, particularly on heavy grades, the state of Arizona, in response to the political pressures of the railway transportation Brotherhoods, enacted a law in 1912 holding freight trains to 70 cars in length and passenger trains to 14 cars. This Statute, of course, had no legal effect beyond the boundaries of that state but the imposition of a 70-car train limit on 400 miles in the middle of Santa Fe's "Coast Lines" had the effect of establishing that pattern of train operation, and hence of motive power standards and all related facilities, upon all of the important mileage west of Belen.

The operation of Santa Fe's transcontinental main lines across Arizona is embodied in three districts; viz.

Division	District	Limits of District	Distance Via E.B. Track	Distance Via W.B. Track
Arizona	1st	Needles, California-Seligman, California	149.7 mi.	149.0 mi.
Albuquerque	3rd	Seligman, Arizona-Winslow, Arizona	143.6 mi.	142.7 mi.
Albuquerque	2nd	Winslow, Arizona-Gallup, New Mexico	127.7 mi.	127.7 mi.
		Total	421.0 mi.	419.4 mi.

The engine and crew terminals are not at the boundary at either end of the state but are at Gallup, New Mexico, 15 miles beyond it, and at

Needles, California, 11 miles west of the Colorado River which separates those two states. However, Barstow, California, and Belen, New Mexico, and not Needles and Gallup are the junctions of major routes and hence are the natural points where yards have been provided for classifying cars and assembling and rearranging the consist and tonnage of trains. The district terminal which marks the transition between 1.42% and 0.6% grade engine districts is not Gallup, New Mexico, but Winslow, Arizona, so the Arizona train limit law prevented capitalizing the lighter grades east of Winslow for long train operation in the state, just as the double header restrictions along with that law did west of it.

West of Barstow still another artificial restriction had been imposed on the size of trains. During 1901 when air brakes had not reached their later state of efficiency and effectiveness and the hauling capacity of locomotives was very small in relation to present standards, the Santa Fe entered into an agreement with its train and engine service employees limiting the length of freight trains to 50 loaded cars descending from Cajon Pass at Summit (station) to San Bernardino. Empty cars are equated to loads on a basis of 3 to 2, so a westward train of empty refrigerators, for example, was limited to 75 cars. The same requirements applied to Union Pacific operation over these jointly used tracks. The descending grade is 3% from 6.5 miles from Summit to Cajon on the present westward track which occupies the original line. The eastward track between those stations ascends at 2.2% on a line, 8.5 miles long, between those two points. Between Cajon and San Bernardino both tracks are parallel and on an eastward continuous maximum ascending grade of 2.2% for 17 miles from Highland Junction, 1.9 miles east of San Bernardino. While the foregoing loaded car limit related to westbound movement only, the eastward trains were necessarily adjusted to the number in the opposite direction on the First District of the Los Angeles Division.

The adverse effects of the double header restrictions imposed by the two train service Brotherhoods, which were only partially modified by the right to use more than one engine to operate a 2900 train between Needles and Winslow, together with the 70-car train limit inflicted by law across the whole state of Arizona, and the California extra crew law and the 50-loaded car (with adjustments for empties on a 3 to 2 basis) limit descending Cajon Pass were cumulative in handicapping the development of the railroad and its motive power.

The 2-10-2 type of locomotive to which the Santa Fe lent its great name when the first one was built for it in 1903, became the largest non-articulated engine in general use, until the Texas type of 2-10-4 wheel arrangement surpassed it only a little more than 20 years ago. In 1919, Baldwin Locomotive Works produced thirty of a new and more powerful design of 2-10-2 locomotives which became the Santa Fe's 3800 class. The last of this first lot, No. 3829, was modified by the installation of a four-wheel trailing truck and so became the original locomotive to use that arrangement which was destined to become so popular only a few years later. More of these new 3800 class 2-10-2 engines followed in each year through 1927 to provide a total of 141, including the one 2-10-4. These were numbered consecutively from No. 3800 to No. 3940. Each produced 85,360 pounds tractive effort through 63" driving wheels powered by 30" x 32" cylinders using steam of 220 pound boiler pressure.

These 3800 class engines were designed for and assigned to service on the heavy grade districts of the Coast Lines between Winslow and San Bernardino and Bakersfield. Its rating was 2200 tons eastward on the long continuous 1.42% grades encountered on the run from Needles to Winslow. One 3800 class engine could haul an eastward train of 58 cars of average weight. This was 12 cars short of the legal limit of 70 cars and was 700 tons under the double header exception permitted between these points.

The cost of a helper engine could not be justified by so small an increment in tonnage and cars which represented much less than the full capacity of a second locomotive. It was therefore not the usual practice to use a helper on 1.42% grades with 3800 class engines. However, helpers were required on the 1.8% ascending pusher grade from Ash Fork to Supai.

The Arizona 70-car limit law held freight trains to that length but the anti-double header rule, even with its 2900 ton exception, neither permitted the 70-car nor the 2900-ton train to be reached, because of circumstances just stated.

When locomotive boilers were first built about twenty years ago that had the capacity to supply the four large cylinders of a single expansion articulated locomotive, with its double sets of six coupled or eight coupled drivers, the tractive power of steam locomotives was raised to 95,000 pounds and on up to 140,000 pounds. Unfortunately, their use was in effect barred on the Santa Fe "Coast Lines" by the Arizona train limit law. Locomotives of that size could not be used efficiently when restricted to 70 car trains.

The Arizona train limit law and the 2900 ton double header limit therefore froze the physical development of the Santa Fe Coast Lines around the 3800 class, 2-10-2, locomotive and its 2200 train, although sidings and yard tracks were generally built to accommodate trains 70 cars in length. Roundhouse, turntables and other facilities were similarly fitted into that overall pattern.

The 1.42% ruling grades extended both ways across the First District of the Arizona Division between Needles and Seligman and the Third District of the Albuquerque Division between Seligman and Winslow. The remaining Arizona main line mileage is embraced within the Second District of the Albuquerque Division between Winslow and Gallup. As previously indicated the 3800 class of 2-10-2 locomotive was not assigned east of Winslow. The standard Mikado type or 2-8-2 locomotive with its 63,000 pounds of tractive effort* was used between Winslow and Chicago, where it had a rating of 2,900 tons or more on the 0.6% maximum ruling grades (with the exception of 0.8% on the First District of the Missouri Division between Marceline and Shopton, Iowa.) Therefore at Winslow, trains arriving from the west with less than 70 cars could be filled out to that limit if permissible within the 2600-2900 ton fast or slow freight tonnage rating of the engine. East of Gallup that tonnage rating and not car limit was the limiting factor, but to exceed 70 cars with a 2900 ton load limit, cars had to average less than only 41 tons gross weight.

A double track railroad has great capacity, even without many sidings of maximum train length, provided it is used in constant speed operation. This fact is evidenced by the daily train and car movement over coal and ore roads, the low grade exclusive freight lines of the eastern systems and certain passenger routes in the same area. However, to obtain high train density on a double track line used by different services of variable speeds, it is necessary to have an adequate number of maximum train length sidings and these should be equipped with such switch and signal facilities as may be required to permit faster trains to pass slower ones with a minimum of delay and interference.

On the Santa Fe main line west of Belen there were five "speed groups" of train services operating during the later war years, viz.

* The largest Santa Fe owned locomotives of this class are of the 4000 series and have 27" x 32" cylinders, 63" driving wheels and 200 pounds per square inch steam pressure.

Type of Train Service	Normal Maximum Operating Speed Where Not Restricted by Grades and Curves
1. Streamlined passenger trains	80 - 100 M.P.H.
2. Ordinary passenger trains	60 - 80 M.P.H.
3. Troop trains	45 - 60 M.P.H.
4. Freight trains hauled by Diesel locomotives and modern steam power	From 16 M.P.H. ascending heavy ruling grades; to 55 M.P.H. on descending or light ascending grades.
5. Freight trains hauled by older steam power	Up to 45 M.P.H. maximum depending upon grade conditions.

During the period of peak war movement, with the Santa Fe's heavy traffic density and the variable operating speeds of the different types of services previously listed, on the double track lines, many trains had to be passed around others. It was, therefore, urgently necessary that its main line sidings be adequate in respect to both length and frequency of spacing and methods of directing slower trains to enter and leave sidings. Train length yard tracks were equally essential.

The Santa Fe began to experience congestion and delay in 1942 whenever freight traffic on its Pecos Division and the Coast Lines averaged 750-900 cars per day in each direction. Both line and motive power capacity were needed for at least double that volume of freight traffic and to handle expeditiously up to 20 or more "main" or troop trains on days of maximum movement, in addition to regular passenger service. It required fleets of locomotives of greater capacity, hundreds of sidings and yard tracks of greater length and a thousand or more improved signals and power switches to direct train movement. The magnitude of the problem which confronted the Santa Fe in the expansion of capacity, particularly on the Coast Lines, is shown statistically in Table XLVIII on the next page.

With Santa Fe's background of operation of dieselized passenger service, it had been among the first to test the new 5,400 horsepower General Motors freight Diesel-electric locomotive in 1940. A small fleet

TABLE XLVIII

TRAFFIC DENSITY

BETWEEN
WINSLOW, ARIZONA, AND SELIGMAN, ARIZONA
MEASURED IN MILLIONS OF GROSS TON MILES
PER MILE OF LINE OF CARS, CONTENTS AND LOCOMOTIVES

Year ended Dec. 31st	Freight			Passenger			Total Passgr. and Freight
	West-bound	East-bound	Total	West bound	East-bound	Total	
1924	4.4	5.0	9.4	2.0	2.0	4.0	13.4
1925	4.6	5.3	9.9	2.0	2.1	4.1	14.0
1926	4.6	5.5	10.1	2.2	2.3	4.5	14.6
1927	5.2	6.2	11.4	2.5	2.5	5.0	16.4
1928	5.0	6.0	11.0	2.5	2.5	5.0	16.0
1929	5.4	6.1	11.5	2.7	2.7	5.4	16.9
1930	4.5	5.3	9.8	2.5	2.6	5.1	14.9
1931	3.8	4.6	8.4	2.3	2.3	4.6	13.0
1932	3.4	4.2	7.6	1.9	1.9	3.8	11.4
1933	3.3	4.0	7.3	1.8	1.9	3.7	11.0
1934	3.7	4.4	8.1	1.9	1.9	3.8	11.9
1935	4.5	5.1	9.6	2.1	2.1	4.2	13.8
1936	5.4	6.2	11.6	2.6	2.5	5.1	16.7
1937	5.7	6.5	12.2	2.8	2.8	5.6	17.8
1938	4.9	6.1	11.0	2.8	2.7	5.5	16.5
1939	5.3	6.5	11.8	2.9	2.9	5.8	17.6
1940	6.6	7.9	14.5	2.8	2.8	5.6	20.1
1941	9.7	10.7	20.4	3.1	3.1	6.2	26.6
1942	14.6	13.9	28.5	4.2	3.7	7.9	36.4
1943	16.9	13.8	30.7	5.7	5.3	11.0	41.7
1944	20.2	17.1	37.3	5.5	5.4	10.9	48.2

of these was soon ordered for assignment on the Santa Fe "Coast Lines," initially between Winslow and Barstow where the greatest service could be procured from them. Fortunately these arrived during 1941 and the success which followed their use led to immediate orders for more, but unfortunately maximum effectiveness of utilization was hampered by the 70-car train limit in Arizona and the related 70-car sidings in California.

Relief from all train tonnage and length restrictions had been ordered by the Interstate Commerce Commission in September, 1942, through service order No. 85 but the Santa Fe remained greatly handicapped by the sidings and yard tracks that had been built for trains legally or otherwise restricted to 70 cars or less. Moreover, the new Diesels were not yet available in sufficient number to move any considerable part of the total tonnage and the trains which they hauled invariably exceeded the capacity of all sidings. Delays and congestion resulted to both passenger and freight trains but even these difficulties did not prevent the new Diesel motive power from adding immediately and materially to transportation capacity. They did, however, underscore the urgent necessity of adapting the yards and sidings and signals to long train operation.

Santa Fe took prompt and adequate steps to break the bonds which years of operation under a 70-car limit law had placed on its operation. Unfortunately, the infection of this restriction in Arizona and related ones in California had inevitable repercussions in motive power standards which in the larger sense were of system wide effect. This form of feather-bedding had spread to Oklahoma which placed a 70-car freight train, 14-car passenger train limit law on its statute books in 1939. Fortunately, this was done so late in the progress of the Santa Fe that it did not arrest the earlier development as the Arizona act had done, and of course, the action of the Interstate Commerce Commission set it aside three years later, in 1942.

During the fall of 1942 Mr. Gurley developed the Santa Fe's major war plan to dieselize the Coast Lines as rapidly as possible. The service between Winslow and Barstow would be changed over the new basis before Diesel power was regularly run either east or west of those limits. Twenty-five new Baldwin built 2-10-4 steam locomotives were added in 1944 to eleven already in service on the Pecos Division between Belen and Clovis. Line capacity was needed on the Coast Lines and the Southern District of the Western Lines. It could be obtained by lengthening sidings and yard tracks, building some additional second track in selected locations and equipping all single track main lines between Ellinor and Newton, Kansas, and Belen, New Mexico, with cTc and providing the same facility on the Third and Fourth Districts of the Los Angeles Division.

The broad outline of this plan of wartime development was presented by Mr. Gurley, then Vice President-Executive Department, to the Board of Directors of the Santa Fe in November, 1942. This was the earliest opportunity to do so in detail after the "Gordian Knot" of artificial restrictions had been cut by the Interstate Commerce Commission in September. This plan of intensive development of transportation capacity for war was placed in action immediately and grew continuously in scope and dimension. Its details have been described in preceding chapters. New motive power, double track, longer sidings, yard enlargements, signals, bridges and cTc followed with kaleidescopic rapidity.

1943 was a year of transition from the old to the new on the "Coast Lines" and the Pecos Division. It was also a year of tremendous traffic, measured by all past standards, but would be exceeded in future ones. The Diesel fleet was growing steadily and these were necessarily assigned to haul long freight trains before the sidings and yard tracks had been extended to hold them. The problem of weaving fleets of passenger trains between an equal or even greater number of freight trains before either the sidings or the signal facilities had been developed for that purpose led to inevitable delays that temporarily curtailed the maximum effectiveness of the new power and briefly added to some of the difficulties of wartime transportation which the public, as well as the railroads, experienced.

The improvements progressed rapidly. During 1944, Santa Fe's expanding motive power capacity was kept reasonably abreast of the mounting traffic requirements made of it. Line capacity was of equal importance and by that time an adequate number of sidings and yard tracks were available to hold full length Diesel-powered trains. Daily movement rose to 1300 cars in each direction and congestion was infrequent and occurred only at the 1500 car level.

The improvement program continued on after the war ended, and indeed is still in progress. Every detail of the program developed in 1942, as well as the many subsequent additions to it, have been carried out except the plans for train operation by signal indication between Verdemont and Victorville. This had included a project to install cTc for two-way operation by signal indication on the double track between Verdemont (7.9 miles east of Barstow) and Cajon, 10.9 miles, and thence on the eastward track only for 8.5 miles to Summit, to permit the use of this 2.2% grade by descending trains when opportunity permitted. There is a 3.0% grade on the westward track which made it unsuitable for operation in the reverse or ascending direction. It had also been intended to equip all sidings between Summit and Victorville with power-thrown switches at the entering end, in the direction of the current of traffic, and with spring switches at the leaving end, and direct all movement to and from sidings in that area by signal indication. Delays in procuring material prevented starting that project before the war ended in August, 1945, and it has evidently been deferred or dropped. However, the extension of tracks at Summit which were part of that plan were completed. This gave additional much needed capacity for trains stopping there to test brakes and set up retainers before going down the 3% grade.westward.

Santa Fe's 5,400 H.P. Diesels acquired during the war years were comprised of four 1350 H.P. units each. These locomotives could haul a 3500-ton train at increased speeds between San Bernardino and Bakersfield and Winslow with helper service over the 2.2% grades on Cajon or Tehachapi Mountain and up the 1.80% ascent from Ash Fork to Supai. At Winslow trains would fill out to any convenient tonnage or length of from 110-125 cars for the run to Gallup and Belen.

A 2-10-4 locomotive of the #5000 class, assisted up the 1.25% grade from Becker to Mountainair, hauled a 6,000-ton train from Belen to Clovis at the eastern end of the Pecos Division. Heavy motive power released and rearranged by the dieselization of the "Coast Lines" permitted increasing the tonnage ratings between Clovis and Kansas City. Differences in assignment of classes of locomotives and variations in the actual physical characteristics of the line, together altered the tonnage ratings of steam locomotives between those terminals from the 3,500 tons minimum eastward between Clovis and Waynoka to 5,000 tons maximum from Waynoka to Argentine Yard. Westward ratings varied for these same classes of power between 3,750 to 6,000 tons except ascending out of the Kaw River Valley from Argentine Yard to Olathe where the unassisted limit is 3,150 tons. East of Kansas City trains were dieselized as fully as possible; now that this transition has been completed, the ratings for Diesel powered train is in excess of 6,000 tons.

The Santa Fe's great program of development which has been the central theme of this thesis was based upon a determination to establish system wide operation of maximum capacity locomotives. The Arizona train limit law had been suspended "for the duration" but it hung like a "sword of Damocles" to becloud the post war future of efficient operation of the Santa Fe's "Coast Lines." Fortunately for the nation as well as for the Santa Fe and its great Arizona neighbor, the Southern Pacific, this law was declared invalid, as an infringement of the Commerce Clause of the Federal Constitution by the United States Supreme Court, in its decision dated June 18, 1945, in Southern Pacific Company vs. Arizona, 325 U. S. 761. This action also nullified the Oklahoma Train Limit Law.

Further important relief was obtained in the general election in California on November 2, 1948, when its voters repealed the burdensome excess crew law which had long been in effect in that state.

The dieselization of the Santa Fe freight service over all of its difficult operating districts and on several other important component parts of the system has permitted use of this high capacity freight motive power where it can be most effectively assigned. The concentration of the fleet of 36 2-10-4 type steam locomotives on the Pecos Division has amply provided for the needs of the important district, which in the past had been a point of congestion when traffic rose above normal.

The significant allocations of the new steam and Diesel locomotives have conveniently permitted the rearrangement of the best of the older steam engines to divisions having physical characteristics that do not interfere with efficient hauling of freight traffic. Increased tonnage ratings over engine districts of the transcontinental lines have been a principal objective of the Santa Fe improvement program. This important objective has been achieved.

The purpose of the Santa Fe improvement program has from the outset been to develop additional transportation capacity. It is a three dimensional product requiring:

1. Line Capacity:

    a. Train length,
    b. Train frequency,
    c. Train speed.

2. Locomotive Capacity:

    a. Power of individual units,
    b. Aggregate number of units.

3. Car Capacity - Freight and Passenger:

    a. Size of individual units,
    b. Aggregate number of cars.

The reader is requested to reflect upon the discussion in this chapter in the light of observations made early in the report that every railway is developed around the requirements, necessities and capacities of its locomotives.

The projects which have been described in this thesis have together enabled the Santa Fe to raise the capacity of its transcontinental lines to permit fast and continuous movement of 1500 to 2000 freight cars in each direction daily. This represents a margin above wartime maximum requirements when it seldom exceded 1500 cars per day west of Augusta, Kansas. Giving effect to present locomotive ratings and assignments, this volume of freight traffic represents one train per hour in each direction throughout the day. The Santa Fe can also easily accommodate an equal number of main line passenger train movements. Its stock of locomotives is adequately balanced to its line capacity. This is the end product to date of the cumulative achievements of a half century of development which have culminated in the intensive program reported herein. It has made the Santa Fe the most adequately developed railroad in the United States in relation to the necessities and opportunities of its territory. The very factors and personalities which have produced these achievements will insure the attainment of still higher ones as the future years follow one another. The developments which they will bring will soon make this report out of date.

Ruskin observed: "When we build, let us think that we build forever. Let it not be for the present delight or the present use alone, but let it be such work as our descendants will thank us for."

Future generations of Americans will have reason to be grateful, whether they are conscious of their obligation or not, to the unusual combination of continuous courage, foresight, leadership and ability which has produced the Santa Fe of today and will bequeath a continuously finer one to posterity.

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Appendix "A"

AN OUTLINE OF THE DEVELOPMENT OF THE SANTA FE'S TRANSCONTINENTAL LINES

Part "A" - Lines across Kansas

1859 - Feb. 11: Atchison & Topeka Railroad Company chartered.

1860 - Sept 15/17: Atchison & Topeka Railroad Company organized. C. K. Holliday, first President.

1862 - July 1: Pacific Railroad bill passed by National Congress, establishing Federal railroad land grant policy.

1863 - March 3: Federal Congress appropriates lands in Kansas to be granted in assistance to railroad construction within that State. Provision made to include the Atchison & Topeka Railroad in the benefactions of this statute, which Company was promptly thereafter re-chartered as the Atchison, Topeka & Santa Fe Railroad Company.

1864 - Feb. 8: Kansas Legislature accepts Federal land grant and at same time authorizes counties to issue bonds to finance subscriptions to stock of railroads built therein.

1868 - Nov.: Construction of the Atchison, Topeka & Santa Fe Railroad Company started at Topeka to build southwest, 25 miles to Burlingame.

1869 - (End of) 28 miles of line built southwest from Topeka.

1870 - August: Line completed to Emporia (62 miles).

1871 - July: Line completed to Newton (63 miles from Emporia).

1872 - May 1: Construction started west from Newton.

1872 - May 16: Topeka-Atchison line completed (50 miles).

1872 - (Spring of) Newton-Wichita line completed (27 miles).

1872 - June 17: Line completed to Hutchison (33 miles).

1872 - Aug. 5: Line completed to Great Bend (51 miles).

1872 - Aug. 12: Line completed to Larned (23 miles).

1872 - Sept. 19: Line completed to Dodge City (47 miles).

1872 - Dec. 28: Line completed to Colorado State boundary, thereby completing line within time limit of land grant, March 1, 1873.

1875 - Oct. 1: The Atchison, Topeka and Santa Fe Railroad Company leases Kansas City, Topeka & Western Railroad Company and gains entrance to Kansas City, Missouri.

Part "B" - Extensions to Pueblo, Albuquerque and El Paso

1873 - May 10: Line opened from the Atchison, Topeka and Santa Fe Railroad Company connection at Colorado-Kansas Line to Grenada, Colorado (12 miles) built by Colorado & New Mexico Railroad (affiliated with AT&SF).

1875 - Mar. 24: Pueblo & Arkansas Valley Railroad incorporated in interests of The Atchison, Topeka and Santa Fe Railroad Company.

1875 - Sept. 13: Pueblo & Arkansas Valley completed line from Grenada to Las Animas (50 miles).

1875 - Oct. 1: Pueblo & Arkansas Valley absorbs Colorado & New Mexico Railroad and is leased to The Atchison, Topeka and Santa Fe Railroad Company for 30 years.

1876 - Mar. 1: Line opened to Pueblo.

1876 - Feb. 26: April 18: - Fight with Denver & Rio Grande for control of Raton Pass. The Atchison, Topeka and Santa Fe Railroad Company successful in retaining control of Pass but completion of line delayed until 1878. Denver & Rio Grande had been opened as a narrow gauge line from Denver to Pueblo (118 miles) in June, 1872 and branch from Pueblo to Canon City (37 miles) completed in October, 1872. Subsequently reached El Moro (near Trinidad) in 1876 and Alamosa in 1878. El Paso was original goal and Raton Pass controlled approach.

1876: Silver discovered near present site of Leadville, Colorado.

1877 - Feb: Canon City and San Juan Railroad organized to build westward from Canon City through Royal Gorge to Leadville.

1877 - July: City of Leadville founded and "Leadville Boom" commenced, immediately becoming goal of both Denver & Rio Grande and The Atchison, Topeka and Santa Fe Railroad Company which led in 1878 to a bitter struggle between the two companies.

1878 - April 19: The Atchison, Topeka and Santa Fe Railroad Company obtains control of Canon City & San Juan Railroad which on September 12, 1878 was merged with Pueblo & Arkansas Valley (AT&SF lessee). Latter, earlier in year, had commenced construction from Pueblo to Canon City (41 miles).

1878 - April 19/20: Contest begins as Denver & Rio Grande assembles construction forces.

1878 - Feb. 6: New Mexico & Southern Pacific incorporated to build from Colorado-New Mexico State Line near Raton Pass to Albuquerque (248 miles).

1878 - Sept. 1: Line completed from La Junta to Trinidad, having been started in June.

1878 - Oct. 19: After a hotly contested struggle, both legally and physically, in which advantage had alternately rested with either side, Denver & Rio Grande by September gained victories in Court which temporarily decided control of Royal Gorge line in its favor but on October 19, 1878, Denver & Rio Grande was leased to The Atchison, Topeka and Santa Fe Railroad Company for 30 years.

1878 - Dec. 7: "Switch-back" line over Raton Pass completed pending completion of Tunnel on September 7, 1879.

1879 - March: Strife over Royal Gorge renewed and action commenced by General Palmer, builder of Denver & Rio Grande, to break lease of latter to The Atchison, Topeka and Santa Fe Railroad Company.

1879 - April 21: Supreme Court confirmed prior right of Denver & Rio Grande to Royal Gorge line.

1879 - June 10: Injunction against operation of Denver & Rio Grande by The Atchison, Topeka and Santa Fe Railroad Company, lessee.

1879 - June 23: Injunction vacated.

1879 - July 24: Denver & Rio Grande placed in receivership pending cancellation of lease to The Atchison, Topeka and Santa Fe Railroad Company.

1879 - Sept. 29: Gould, who controlled Kansas Pacific (now U. P. line from Kansas City to Denver) acquired half interest in Denver & Rio Grande stock.

1880 - Jan 2: Court decides Denver & Rio Grande should hold Royal Gorge line but specifies compensation payable The Atchison, Topeka and Santa Fe Railroad Company for its rights and work done on part of route.

1880 - Feb. 2: Settlement out of Court of Denver & Rio Grande-The Atchison, Topeka and Santa Fe controversies. The Atchison, Topeka and Santa Fe Railroad Company relinquished Denver & Rio Grande lease and latter's receiver discharged: The Atchison, Topeka and Santa Fe paid $1,800,000 in settlement of Royal Gorge dispute. Gould (now interested in Denver & Rio Grande) agreed not to build his projected Pueblo & St. Louis Railroad from Pueblo to Great Bend, Kansas, where lines would diverge to connect with Kansas Pacific at Salina and Missouri Pacific at Wichita. The Atchison, Topeka and Santa Fe Railroad Company agreed not to build to Denver or Leadville or west of Denver & Rio Grande main line, except to Canon City. Also traffic agreement reached covering division of Denver & Rio Grande traffic moving East.

1879 - July 4: Line opened to Las Vegas - 110.6 miles from Colorado Boundary (built by New Mexico & Southern Pacific).

1879: The Atchison, Topeka and Santa Fe Railroad Company absorbs its two subsidiaries, viz., Pueblo & Arkansas Valley and New Mexico & Southern Pacific Railroad Companies.

1880 - Feb. 9: Santa Fe, New Mexico reached by 18.1 mile branch from Lamy, New Mexico.

1880 - April 15: Line completed to Albuquerque.

1880 - Oct. 1: Line completed to San Marcial, New Mexico and continued south from that point under new charter of Rio Grande, Mexico and Pacific Railroad Company.

1881 - Mar. 8: Connection established with Southern Pacific at Deming, New Mexico, 127.8 miles from San Marcial and 53.3 miles from Rincon from which station line continued south to El Paso (76.9 miles).

1881 - June 11: Rio Grande, Mexico and Pacific reaches El Paso.

1887 - March:	Denver & Santa Fe Railroad organized as subsidiary of The Atchison, Topeka and Santa Fe Railroad Company to build from Pueblo to Denver (119 miles).

Part "C" - Extensions into Old Mexico

1879:	Santa Fe interests acquire Sonora Railway in Mexico to build from American border at Nogales through the Mexican State of Sonora to Guaymas on the Gulf of California.
1880:	Work commences at Guaymas.
1881 - Mar. 8:	The Atchison, Topeka and Santa Fe Railroad Company completes line of Rio Grande, Mexico and Pacific into Deming, New Mexico, and obtains 2-year trackage rights over Southern Pacific from Deming to Benson, Arizona (176 miles).
1881 - Nov.:	Line completed 85 miles - Guaymas to Hermosille, Mexico.
1881 - Summer:	The Atchison, Topeka and Santa Fe Railroad Company incorporates and places under construction New Mexico and Arizona Railroad to connect Benson and Nogales, Mexico (90 miles).
1882 - Jan.:	Huntington acquires interest in St. Louis & San Francisco and threatens to block progress of Atlantic & Pacific (See Part D) into California.
1882 - March:	The Atchison, Topeka and Santa Fe Railroad Company retaliates by formally acquiring Sonora Railway and preparing to rush completion of entire line between Benson-Nogales-Guaymas, which was opened for service October 25, 1882, giving The Atchison, Topeka and Santa Fe Railroad Company a Pacific outlet.
1898 - July 15:	Southern Pacific Company takes over operation of New Mexico & Arizona Railroad and Sonora Railway, under reciprocal lease in exchange for Needles-Mojave Line of Southern Pacific previously acquired by The Atchison, Topeka and Santa Fe Railroad Company.

Part "D" - Extension from Albuquerque to the Needles and into California

1880 - Jan. 31:	The Atchison, Topeka and Santa Fe Railroad Company acquired, without cost to it, one-half interest in Atlantic & Pacific Railroad and enters into agreement with St. Louis & San Francisco for joint prosecution of enterprise.

1880 - Oct.: 50 miles of line completed, the work having started at Isleta, New Mexico, 12.6 miles south of Albuquerque, on The Atchison, Topeka and Santa Fe Railroad Company's main line.

1881 - Feb. 1: Track laid 100 miles west of Isleta.

1881 - June: Track laid to Ft. Wingate, New Mexico (about 160 miles).

1882 - Jan.: C.P. Huntington (S.P.) and Jay Gould (T&P etc.) acquire control of St. Louis & San Francisco, Huntington being bent on keeping The Atchison, Topeka and Santa Fe Railroad Company out of California and Gould desiring to restrain Frisco from building into territory in competition with his lines. This control was of less than two years' duration.

1882 - May: Line of Atlantic & Pacific complete to Canyon Diablo, Arizona.

1882 - Winter: The Atchison, Topeka and Santa Fe Railroad Company reaches compromise with Huntington whereby Atlantic & Pacific will build only to the Needles, California to which point Southern Pacific will be extended and through traffic arrangements made.

1883 - August: Connection established with Southern Pacific at the Needles.

1884 - July 29: Completion of permanent bridge over Colorado River at the Needles, permits inauguration of through passenger service.

1884 - Aug. 20: Southern Pacific Company makes following agreements with The Atchison, Topeka and Santa Fe Railroad Company, St. Louis & San Francisco and Atlantic & Pacific.

1. Sales of Mojave Division (Mojave-Needles) to Atlantic & Pacific (title not passing until 1905 owing to technicalities of mortgage - meanwhile line leased).

2. Atlantic & Pacific, or The Atchison, Topeka and Santa Fe and St. Louis & San Francisco to have trackage rights (upon 12 months' notice) over Southern Pacific from Mojave to San Francisco @ $1,200 per mile annual rental.

3. The Atchison, Topeka and Santa Fe Railroad Company to buy \$3,096,768 par value of Atlantic & Pacific securities from a Southern Pacific holding company at cost to latter of \$1,524,356.

1884:-	(After Southern Pacific transaction referred to above). The Atchison, Topeka and Santa Fe Railroad Company acquires half interest in California Southern Railroad chartered October 12, 1880, to build from San Diego to Colton and San Bernardino.
1885 - Nov. 9:	Extension completed of California Southern from San Bernardino to Barstow (on Mojave-Needles Line) giving The Atchison, Topeka and Santa Fe Railroad Company continuous line to a California port and it also gained an entrance into Los Angeles through trackage over Southern Pacific from Colton, authorized by agreement of September 24, 1885.
1886 - 1887:	The Atchison, Topeka and Santa Fe Railroad Company builds its own line from San Bernandino to Los Angeles via Pasadena.
1898 - July 15:	Southern Pacific takes over ownership and operation of New Mexico and Arizona Railroad and Sonora Railway in exchange for permanent lease of Mojave Division to The Atchison, Topeka and Santa Fe Railway Company.
1898 - Dec.:	The Atchison, Topeka and Santa Fe Railway Company acquires San Francisco & San Joaquin Valley which which had been incorporated in February 1895, and completed line from Stockton to Bakersfield in 1897.
1900 - May 1:	The Atchison, Topeka and Santa Fe Railway Company commences operation into San Francisco via San Francisco & San Joaquin Valley Railroad using Southern Pacific trackage over Tehachapi Mountains from Mojave to Bakersfield.

Part "E" - Extension from Kansas City to Chicago

1886 - Dec. 3:	Chicago, Santa Fe & California Railway Company incorporated which through construction and acquisition of intermediate lines extended The Atchison, Topeka and Santa Fe Railroad Company into Chicago.
1887 - Dec. 31:	Line Completed.
1888 - April 29:	Line placed in operation.

Part "F" - "Transcontinental Short Line" - sometimes referred to as "Belen Cut-Off"

This route of the Santa Fe System comprises the lines from Ellinor, Kansas, to Rio Puerco, New Mexico, via Eldorado, Augusta, Mulvane, Wellington, Harper, Attica and Kiowa, Kansas, Waynoka, Oklahoma, Amarillo, Texas and Clovis and Belen, New Mexico. In order to avoid heavy grades over Raton and Glorieta Passes, all through freight is moved over this route, which comprises lines built as follows:

Line			Completed	
From	To	Distance	or in Operation	Building Company
Ellinor*	Gladstone	4.4	1924	El Dorado & Santa Fe Railway Company
Gladstone	Bazar	6.3	1888	Started by Emporia & El Dorado Short Line R.R. Co.; completed by Chicago, Kansas & Western R.R. Co.
Bazar	El Dorado	38.2	1924	El Dorado & Santa Fe Railway Company.
El Dorado	Augusta*	11.3	Aug. 1, 1881	Florence, El Dorado & Walnut Valley R.R. Co.*
Augusta	Mulvane	21.2	Oct. 1, 1887	Chicago, Kansas & Western R.R. Co.
Mulvane	Wellington	18.5	1880	Cowley, Sumner & Ft. Smith R.R.
Wellington	Harper	34.9	1880	Southern Kansas & Western Railway Company.
Harper	Attica	11.8	Nov.10, 1884	Harper & Western R.R. Co.
Attica	State line near Kiowa	21.3	Aug. 6, 1885	Started by Harper & Western R.R. Co. and completed by Southern Kansas Railway Company.
State line near Kiowa	Texas State line near present station of Goodwin, Okla.	116.4	Sept.12,1887	Southern Kansas Railway Co.

Line From	Line To	Distance	Completed or in Operation	Building Company
Texas-Okla. State Line	Canadian, Texas	31.2	Sept. 12, 1887	The Southern Kansas Ry. Company of Texas.
Canadian, Texas	Panhandle City, Texas	70.9	Jan. 15, 1888	The Southern Kansas Ry. Company of Texas.
Panhandle City	Amarillo, Texas	27.0	Apr. 12, 1908	The Southern Kansas Ry. Company of Texas.
Amarillo	Texas-New Mexico State Line	94.4	Mar. 1, 1899	Pecos & North Texas Ry. Company - Pecos Ry. Construction & Land Co.
Texico, N.M.	Rio Puerco, N. M.	268.2	1908	Eastern Ry. Company of New Mexico

* Prior to 1924, connection with main line was made at Florence, Kansas, by using line originally built from Florence through El Dorado and Augusta to Winfield, by Florence, El Dorado & Walnut Valley Railroad Company.

Appendix B

THE LINE OF SUCCESSION

of

SANTA FE PRESIDENTS

THE ATCHISON, TOPEKA AND SANTA FE RAILROAD COMPANY

PRESIDENT	FROM	TO	DECEASED
Cyrus K. Holliday	Sept. 17, 1860	Jan. 13, 1864	Mar. 29, 1900
S. C. Pomeroy	Jan. 13, 1864	Sept. 2, 1868	Aug. 27, 1891
W. F. Nast	Sept. 2, 1868	Sept. 24, 1868	Apr. 7, 1893
H. C. Lord	Sept. 24, 1868	Feb. 17, 1869	Mar. 23, 1884
Henry Keyes	Feb. 17, 1869	Sept. 24, 1870	Sept. 24, 1870
Giney Twichell	Oct. 10, 1870	May 22, 1873	July 23, 1883
Henry Strong	May 22, 1873	May 28, 1874	Oct. 21, 1911
Thomas Nickerson	May 28, 1874	May 13, 1880	July 24, 1892
T. Jefferson Coolidge	May 13, 1880	Aug. 1, 1881	Nov. 17, 1920
Wm. B. Strong	Aug. 1, 1881	Sept. 6, 1889	Aug. 3, 1914
Allen Manvel	Sept. 6, 1889	Feb. 24, 1893	Feb. 24, 1893
J. W. Reinhart	Mar. 7, 1893	Sept. 1, 1894	Jan. 27, 1911
D. B. Robinson, Actg.	Sept. 1, 1894	July 1, 1896	May 31, 1901
Cyrus K. Holliday	July 1, 1896	Mar. 29, 1900	Mar. 29, 1900
Charles S. Gleed*	Nov. 14, 1900	July 25, 1920	July 25, 1920

* The properties of the original Atchison, Topeka and Santa Fe Railroad Company, which passed into receivership in 1895, were transferred to the Atchison, Topeka and Santa Fe Railway Company on January 1, 1896. The predecessor company, however, remained in existence, and had its own Board of Directors and President (although it owned no property and conducted no business) until the death of Charles S. Gleed in 1920.

THE ATCHISON, TOPEKA AND SANTA FE RAILWAY COMPANY

PRESIDENT	FROM	TO	DECEASED
Edward P. Ripley	Dec. 12, 1895	Jan. 1, 1920	Feb. 4, 1920
W. B. Storey	Jan. 1, 1920	May 2, 1933	Oct. 24, 1940
S. T. Bledsoe	May 2, 1933	March 8, 1939	Mar. 8, 1939
E. J. Engel	Mar. 28, 1939	Aug. 1, 1944	Mar. 30, 1947
F. G. Gurley	Aug. 1, 1944		

Appendix C

SPEED RESTRICTIONS IMPOSED ON PASSENGER TRAINS BY SPECIAL INSTRUCTIONS IN WORKING TIMETABLE

Chicago - Los Angeles
Via component divisions
over both
the Northern and Southern Districts

Note: Speed restrictions are principally due to curvature. Other factors are highway crossings in cities and towns, bridges, mountain grades, interlockers and operating conditions in terminals. The handicaps of the latter, however, are principally due to curvature and close clearances and interlockers.

While maximum authorized freight train operating speeds are shown on each division, individual restrictions for that service are omitted since the passenger limitations are the most significant indicators of the speed characteristics of the line. Restrictions on third and fourth track and other supplementary tracks such as Missouri Pacific from Congo to Rock Creek Junction, Missouri, are not included.

ILLINOIS DIVISION

Dearborn Station, Chicago - Shopton, Iowa - 234.6 miles, Double Track.

Maximum authorized speeds - Passenger trains - 90 M.P.H.
Freight trains - 60 M.P.H.

Maximum authorized speed reduced to	Number of Restrictions EB	Number of Restrictions WB	Total length of Restrictions EB	Total length of Restrictions WB
85 M.P.H.	1	-	0.1 miles	- miles
80	5	5	1.6 "	1.6 "
75	-	1	-	0.3 "
70	4	3	9.7 "	9.4 "
65	1	1	1.3 "	1.3 "
60	3	6	0.9 "	2.2 "
55	2	1	5.0 "	4.2 "
50	2	2	1.5 "	1.5 "
45	1	-	0.4 "	-
40	3	3	0.6 "	0.6 "
35	1	1	0.1 "	0.1 "
30	3	3	2.6 "	2.6 "
25	-	-	-	-
20	3	3	0.8 "	0.8 "
15	2	2	0.5 "	0.5 "
8	1	1	0.1 "	0.1 "
Total	32	32	25.2 miles	25.2 miles
Proportion of unrestricted mileage			89.0%	89.0%
Length of unrestricted mileage			209.4 miles	209.4 miles

Appendix C

MISSOURI DIVISION

Shopton, Iowa - Kansas City, Missouri, 216.5 miles, Double Track.

Maximum authorized speeds - Passenger trains - 90 M.P.H.
Freight trains - 60 M.P.H.

Maximum authorized speed reduced to	Number of Restrictions EB	Number of Restrictions WB	Total length of Restrictions EB	Total length of Restrictions WB
80 M.P.H.	5	5	2.8 miles	3.6 miles
75	4	3	2.5 "	2.3 "
70	3	3	1.8 "	1.8 "
65	6	6	5.1 "	5.1 "
60	1	3	4.1 "	5.1 "
55	4	4	4.2 "	4.2 "
50	3	3	3.6 "	3.6 "
45	3	3	1.8 "	1.8 "
40	4	5	1.0 "	1.2 "
35	1	-	0.1 "	-
30	1	1	0.3 "	0.3 "
25	1	1	1.3 "	1.3 "
	36	37	28.6 miles	30.3 miles
K. C. Terminal zone - west of Sheffield			4.7 "	4.7 "
Total restricted mileage			33.3 miles	35.0 miles
Unrestricted mileage			183.2 miles	181.5 miles
Total length of Division			216.5 miles	216.5 miles
Percent of unrestricted mileage			84.6%	83.8%

Appendix C

EASTERN DIVISION

Kansas City - Emporia via Ottawa Cut-off, 112.1 miles, Double Track.

Maximum authorized speed - Passenger trains - 90 M.P.H.
Freight trains - 60 M.P.H.

Maximum authorized speed reduced to	Number of Restrictions EB	Number of Restrictions WB	Total length of Restrictions EB	Total length of Restrictions WB
85 M.P.H.	5	5	3.3 miles	3.3 miles
80	2	2	1.1 "	1.1 "
75	4	4	2.0 "	3.5 "
70	1	2	0.4 "	1.0 "
65	5	5	5.0 "	5.2 "
60	3	3	4.1 "	4.1 "
55	5	4	1.0 "	0.8 "
50	3	3	2.0 "	2.3 "
45	1	1	0.7 "	0.7 "
40	2	2	4.0 "	4.0 "
35	1	1	1.2 "	1.2 "
20	1	1	1.3 "	1.3 "
15	1	1	0.1 "	0.1 "
	34	34	26.2 miles	28.6 miles
Unrestricted mileage			85.9 miles	83.5 miles
Length of Division			112.1 miles	112.1 miles
Proportion of unrestricted mileage			76.5%	76.0%

Appendix C

MIDDLE DIVISION

Emporia to Newton, 73.0 miles, Double Track.

Maximum authorized speed - Passenger trains - 90 M.P.H.
Freight trains - 60 M.P.H.

Maximum authorized speed reduced to	Number of Restrictions EB	Number of Restrictions WB	Total length of Restrictions EB	Total length of Restrictions WB
80 M.P.H.	5	5	2.3 miles	2.3 miles
75	1	1	0.4 "	0.4 "
70	1	1	0.4 "	0.4 "
10	1	1	0.3 "	0.3 "
	8	8	3.4 miles	3.4 miles
Total unrestricted mileage			69.6 miles	69.6 miles
Total mileage			73.0 miles	73.0 miles
Proportion of unrestricted mileage			95.5%	95.5%

Appendix C

MIDDLE DIVISION

Newton to Wellington, via Wichita, 61.3 miles, 9.9 miles Double Track, 51.4 miles of single track.

Maximum authorized speed - Passenger trains - 85 M.P.H.
Freight trains - 50 M.P.H.

Maximum authorized speed reduced to	Number of Restrictions	Length of Restrictions
80 M.P.H.	1	0.5 miles
65	1	2.1 "
60	2	1.5 "
45	1	0.1 "
40	1	0.2 "
30	2	1.5 "
15	1	1.5 "
10	1	0.4 "
	10	7.8 miles
Total mileage		53.5 miles
Percent of unrestricted mileage		87.4%

Appendix C

MIDDLE DIVISION

Ellinor via Eldorado to Mulvane, 81.4 miles; 66.1 single track, 15.3 double track.

Maximum authorized speed - Passenger trains - 60 M.P.H.
Freight trains - 50 M.P.H.

Route used by through freight trains but not by through passenger trains. Restrictions, however, are those applicable to latter trains; for comparative purposes.

Maximum authorized speed reduced to	Number of Restrictions EB	WB	Total length of Restrictions EB	WB
50 M.P.H.	1		0.3 miles	
45	1	1	0.4 "	0.4 miles
30	1	2	0.3 "	0.6 "
	3	3	1.0 miles	1.0 miles
Total unrestricted mileage			80.4 miles	80.4 miles
Total mileage			81.4 miles	81.4 miles
Proportion of unrestricted mileage			99.0%	99.0%

Appendix C

WESTERN DIVISION

Newton to Dodge City, 171.4 miles, 41.9 miles double track, 129.5 miles single track.

Maximum authorized speed - Passenger trains - 100 M.P.H.
Freight trains - 90 M.P.H.

Maximum authorized speed reduced to	Number of Restrictions EB	Number of Restrictions WB	Total length of Restrictions EB	Total length of Restrictions WB
95 M.P.H.	8	8	1.8 miles	1.8 miles
95*	2	2	1.0 "	1.0 "
90	1	1	0.5 "	0.5 "
85	3	3	0.6 "	0.6 "
85*	1	-	0.4 "	-
80	2	2	0.9 "	0.9 "
80*	1	1	1.8 "	1.8 "
75*	1	1	0.1 "	0.1 "
70*	1	-	0.3 "	-
60	1	1	0.1 "	0.1 "
60*	1	1	1.8 "	1.8 "
55	1	1	0.3 "	0.3 "
55*	1	1	0.2 "	0.6 "
40	2	2	0.2 "	0.2 "
25*	1	1	2.7 "	2.7 "
15*	2	2	0.4 "	0.4 "
	29	27	13.1 miles	12.8 miles
Total unrestricted mileage			158.3 miles	158.6 miles
Total mileage			171.4 miles	171.4 miles
Proportion of unrestricted mileage			92.5%	92.5%

* Restrictions on double track lines. Other restrictions are on single track lines.

Appendix C

COLORADO DIVISION

Dodge City to La Junta, 202.4 miles, 9.3 miles double track, 193.1 miles single track.

Maximum authorized speed - Passenger trains - 100 M.P.H.
Freight trains - 60 M.P.H.

Maximum authorized speed reduced to	Number of Restrictions EB	WB	Total length of Restrictions EB	WB
95 M.P.H.	15	15	9.2 miles	9.2 miles
95*	-	2	-	1.1 miles
90	8	8	2.6 "	2.6 "
90*	2	1	1.1 "	0.2 "
85	5	5	3.6 "	3.6 "
70	1	1	2.0 "	2.0 "
70*	-	1	-	0.6 "
65*	2	1	0.5 "	0.3 "
50*	1	-	0.6 "	-
50	2	2	0.2 "	0.2 "
40	1	1	0.1 "	0.1 "
30	1	1	0.1 "	0.1 "
	38	38	20.0 miles	20.0 miles
Total unrestricted mileage			182.4 miles	182.4 miles
Total mileage			202.4 miles	202.4 miles
Proportion of unrestricted mileage			90.0%	90.0%

* Restrictions on double track lines. Other restrictions are on single track lines.

Appendix C

NEW MEXICO DIVISION

La Junta - Albuquerque - Isleta 358.8 miles.

Maximum authorized speed - Passenger trains - 100 M.P.H.
Freight trains - 50 M.P.H.

Speed Restrictions below maximum	Number of Restrictions EB	WB	Total length of Restrictions EB	WB
95	22	22	16.0 miles	16.0 miles
95*	1	1	0.3 "	0.3 "
90	6	6	1.5 "	1.5 "
85	37	37	50.0 "	50.0 "
80	5	5	4.6 "	4.6 "
75	3	3	2.6 "	2.6 "
70	6	6	5.8 "	5.8 "
65	2	2	2.5 "	2.5 "
60	2	2	1.5 "	1.5 "
55	8	8	8.4 "	8.4 "
50	11	11	15.2 "	15.2 "
45	5	5	17.4 "	17.4 "
45*	1	1	0.4 "	0.4 "
40	3	3	8.6 "	8.6 "
40*	2	1	0.6 "	0.1 "
35	3	3	4.0 "	4.0 "
35*	1	1	0.1 "	0.1 "
30	1	1	1.4 "	1.4 "
30*	4	4	21.5 "	20.6 "
25	1	1	5.3 "	6.7 "
20*	2	2	1.0 "	1.5 "
15	3	3	1.7 "	1.7 "
	129	128	170.4 miles	170.9 miles
Total unrestricted mileage			188.4 miles	187.9 miles
Total mileage			358.8 miles	358.8 miles
Proportion of unrestricted mileage			52.5%	52.3%

* Restrictions on double track lines. Other restrictions are on single track lines.

Appendix C

PANHANDLE DIVISION

Length of Division, 106.6 miles, 3 miles double track, 103.6 miles single track.

Maximum authorized speed - Passenger trains - 80 M.P.H.
Freight trains - 50 M.P.H.

Maximum authorized speed reduced to	Number of Restrictions EB	WB	Total length of Restrictions EB	WB
85 M.P.H.	5	5	1.0 miles	1.0 miles
80	3	3	1.9 "	1.9 "
75	2	2	1.4 "	1.4 "
70	1	1	0.2 "	0.2 "
65	2	2	3.8 "	3.8 "
60	1	1	0.8 "	0.8 "
60*	1	1	0.6 "	0.6 "
55	1	1	2.2 "	2.2 "
50	2	2	1.9 "	1.9 "
45	2	2	2.5 "	2.5 "
45*	1	1	0.3 "	0.3 "
40	1	1	0.5 "	0.5 "
40*	1	1	0.2 "	0.2 "
	22	22	17.3 miles	17.3 miles
Total unrestricted mileage			89.3 miles	89.3 miles
Total mileage			106.6 miles	106.6 miles
Proportion of unrestricted mileage			83.9%	83.9%

* Restrictions on double track lines. Other restrictions are on single track lines.

Appendix C

PLAINS DIVISION

Length of Division, 309.2 miles, 87.0 double track, 222.2 miles single track.

Maximum authorized speed - Passenger trains - 80 M.P.H.
Freight trains - 50 M.P.H.

Maximum authorized speed reduced to	Number of Restrictions EB	WB	Total length of Restrictions EB	WB
85 M.P.H.	2	2	0.4 miles	0.4 miles
85*	2	2	0.4 "	0.4 "
80	9	9	16.6 "	16.6 "
80*	2	3	0.4 "	1.6 "
75	9	9	13.9 "	13.9 "
75*	3	-	0.6 "	-
70	4	4	5.3 "	5.3 "
70*	-	3	-	0.9 "
65	7	7	10.9 "	10.9 "
65*	3	1	1.0 "	0.1 "
60	2	2	1.8 "	1.8 "
55	-	-	-	-
50	1	1	0.4 "	0.4 "
45	1	1	5.1 "	5.1 "
40	2	2	0.6 "	0.6 "
40*	-	1	-	0.1 "
35	1	1	0.4 "	0.4 "
30*	6	6	0.9 "	0.9 "
25	1	1	0.1 "	0.1 "
	55	55	58.1 miles	59.6 miles
Total unrestricted mileage			250.4 miles	249.6 miles
Total mileage			309.2 miles	309.2 miles
Proportion of unrestricted mileage			81.1%	80.6%

* Restrictions on double track lines. Other restrictions are on single track lines.

Appendix C

PECOS DIVISION

Length of Division, 239.8 miles, 50.8 miles double track, 189.0 miles single track.

Maximum authorized speed - Passenger trains - 80 M.P.H.
Freight trains - 50 M.P.H.

Maximum authorized speed reduced to	Number of Restrictions EB	Number of Restrictions WB	Total length of Restrictions EB	Total length of Restrictions WB
85 M.P.H.	26	26	13.8 miles	13.8 miles
85*	3	3	1.7 "	1.7 "
80	7	7	9.1 "	9.1 "
75	6	6	4.8 "	4.8 "
70	5	5	3.0 "	3.0 "
70*	1	1	1.7 "	1.7 "
65	19	19	22.0 "	22.0 "
65*	-	2	-	1.3 "
50	1	1	0.6 "	0.6 "
40	3	3	1.7 "	1.7 "
30	5	5	4.0 "	4.0 "
15*	1	1	1.1 "	1.1 "
	77	79	63.5 miles	63.8 miles
Total unrestricted mileage			176.3 miles	176.0 miles
Total mileage			239.8 "	239.8 "
Proportion of unrestricted mileage			73.8%	73.7%

* Restrictions on double track lines. Other restrictions are on single track lines.

Appendix C

ALBUQUERQUE DIVISION

Isleta - Seligman - Distance via eastward track - 430.2 miles.
Distance via westward track - 431.5 miles.
Continuous double track except for 14.8 miles from Isleta to Dalies.

Maximum authorized speed - Passenger trains;
All lightweight cars - 100 M.P.H.
With one or more heavyweight cars - 90 MPH.
Freight trains - 55 M.P.H.

Speed Restrictions below maximum	Number of Restrictions EB	WB	Total length of Restrictions EB	WB
95 M.P.H.	7	7	15.5 miles	25.7 miles
90	3	3	7.9 "	7.9 "
85	15	14	38.7 "	36.6 "
80	3	4	11.4 "	7.9 "
75	4	5	4.0 "	12.0 "
70	3	3	6.7 "	5.3 "
65	5	4	8.8 "	9.3 "
60	4	5	5.8 "	7.4 "
55	4	3	11.2 "	10.4 "
50	11	8	27.8 "	26.9 "
45	1	2	1.5 "	1.6 "
40	9	4	22.1 "	18.3 "
35	4	3	8.6 "	4.4 "
30	5	7	1.6 "	12.8 "
25	2	6	2.2 "	14.8 "
20	-	1	-	0.1 "
15	1	1	0.6 "	0.3 "
	81	80	174.4 miles	201.7 miles
Total unrestricted mileage			255.8 miles	230.8 miles
Total mileage			430.2 miles	431.5 miles
Proportion of unrestricted mileage			59.4%	52.5%

Appendix C

ALBUQUERQUE DIVISION

BELEN DISTRICT

Belen - Dalies, 10.3 miles, double track.

Maximum authorized speed - Passenger trains - 85 M.P.H.
Freight trains - 55 M.P.H.

Speed Restrictions below maximum	Number of Restrictions EB	WB	Total length of Restrictions EB	WB
80 M.P.H.	1		3.3 miles	
70		1		1.7 miles
60		1		1.8 "
30	1		0.2 "	
15	1	1	0.3 "	0.3 "
	3	3	3.8 miles	3.8 miles
Total unrestricted mileage			6.5 miles	6.5 miles
Total mileage			10.3 miles	10.3 miles
Proportion of unrestricted mileage			63.0%	63.0%

Appendix C

ARIZONA DIVISION

Seligman - Barstow, continuous double track.
Distance via eastward track - 316.2 miles.
Distance via westward track - 316.9 miles.

Maximum authorized speed - Passenger trains -
All lightweight cars - 100 M.P.H.
With one or more heavyweight cars - 90 M.P.H.
Freight trains - 55 M.P.H.

Speed Restrictions below maximum	Number of Restrictions EB	Number of Restrictions WB	Total length of Restrictions EB	Total length of Restrictions WB
95	5	7	20.3 miles	33.0 miles
90	7	7	24.0 "	13.1 "
85	5	3	11.5 "	9.1 "
80	7	5	27.3 "	10.1 "
75	6	4	33.9 "	4.0 "
70	4	2	12.9 "	1.4 "
65	8	9	16.3 "	25.7 "
60	6	6	37.6* "	17.5 "
55	5	5	6.6 "	12.1 "
50	4	7	7.5 "	13.0 "
45	4	3	6.5 "	3.9 "
40	4	5	6.1 "	2.5 "
35	1	1	1.3 "	1.3 "
30	1	2	1.6 "	3.1 "
25	1	1	0.1 "	0.1 "
20	1	1	0.1 "	0.1 "
	69	68	213.6 miles	150.0 miles
Total unrestricted mileage			102.6 miles	166.9 miles
Total mileage			316.2 miles	316.9 miles
Proportion of unrestricted mileage			32.4%	52.7%

* Gives effect to reduction of maximum limit to 60 M.P.H. imposed on descending grades from Goffs to Needles 31.1 miles.

Appendix C

LOS ANGELES DIVISION

Maximum authorized speed - Passenger trains -
With lightweight cars only - 100 M.P.H.*
With one or more heavyweight cars - 90 M.P.H.*
Freight trains - 55 M.P.H.*

* Reduced to 75 M.P.H. maximum on crossing of Cajon Mountain, ascending and descending; westward between Oro Grande and San Bernardino; eastward between San Bernardino and Lugo. Elsewhere similar zone restrictions are in effect on Second District between Santa Anita and Los Angeles and on Third District between San Bernardino and Fullerton and between Hobart and Los Angeles. The effect of these requirements is included in the tables which follow.

FIRST DISTRICT

Barstow to San Bernardino. Distance via Eastward track 82.8 miles.
Continuous double track. Distance via Westward track 80.8 miles.

Speed Restrictions below maximum	Number of Restrictions EB	Number of Restrictions WB	Total length of Restrictions EB	Total length of Restrictions WB
90 M.P.H.	3	2	1.9 miles	1.0 miles
85	4	4	2.2 "	2.1 "
80	-	-	-	-
75	2	10	9.9 "	10.1 "
70	-	1	-	0.3 "
65	1	1	0.2 "	0.2 "
60	4	1	5.1 "	1.5 "
55	3	3	3.0 "	3.0 "
50	2	2	0.6 "	9.0 "
45	3	2	3.9 "	2.8 "
40	5	4	7.7 "	11.6 "
35	-	-	-	-
30	4	5	10.3 "	7.0 "
25	1	1	0.2 "	0.4 "
20	1	1	0.7 "	1.0 "
10	1	1	0.5 "	0.5 "
	34	38	45.7 miles	50.5 miles
Total unrestricted mileage			37.1 miles	30.3 miles
Total mileage			82.8 miles	80.8 miles
Proportion of unrestricted mileage			45.0%	37.4%

Appendix C

LOS ANGELES DIVISION-SECOND DISTRICT

San Bernardino - Los Angeles; 59.4 miles; 1.4 miles of double track, 58.0 miles of single track.

Speed Restrictions below maximum	Number of Restrictions	Total length of Restrictions
95 M.P.H.	1	0.1 miles
90	1	0.3 "
85	-	-
80	2	3.1 "
75	1	2.6 "
70	1	0.4 "
65	3	6.0 "
60	-	-
55	2	1.2 "
50	-	-
45	1	0.2 "
40	2	3.3 "
35	-	-
30	1	0.5 "
25	3	4.4 "
20	3	7.3 "
15	1	1.5 "
8	3	0.3 "
	25	31.2 miles

Total unrestricted mileage	28.2 miles
Total mileage	59.4
Proportion of unrestricted mileage	47.5%

Appendix C

LOS ANGELES DIVISION-THIRD DISTRICT

San Bernardino-Fullerton-Los Angeles

Masimum Authorized Speed:

Passenger trains;

San Bernardino - Fullerton	75 M.P.H.
Fullerton - Hobart;	
All Streamlined cars	100 M.P.H.
With one or more heavyweight cars	90 M.P.H.
Hobart - Los Angeles	75 M.P.H.
Freight Trains	55 M.P.H.

Speed Restriction Below Maximum (See Note)	Direction East No.	Aggregate Length	West No.	Aggregate Length
95 M.P.H.	1	0.4 miles	1	0.4 miles
90	-	-	-	-
85	1	1.6	1	1.6
80	4	4.0	3	1.6
75	8	6.8	7	6.5
70	1	0.9	2	1.3
65	4	4.0	4	3.5
60	3	1.8	2	1.6
55	2	1.7	2	1.7
50	1	0.6	1	0.6
45	-	-	1	0.4
40	5	1.8	4	1.4
35	2	1.0	2	1.0
30	4	3.7	3	2.0
25	-	-	-	-
20	1	0.5	1	0.5
15	2	1.5	2	1.5
Total	39	30.3 miles	36	25.6 miles
Unrestricted Mileage		41.2 miles		45.9 miles
Total Mileage		71.5 miles		71.5 miles
Percent of unrestricted mileage		57.6%		64.0%

Note: On mileage where the maximum authorization is 75 M.P.H. this speed is not considered a restriction.

Exhibit 1 Page 390

Exhibit II

(A)

MILES OF ROAD OPERATED BY A.T.&.S.F. AND DISTRIBUTION BY STATES

State	Line Owned: Main line	Line Owned: Branch lines	Line operated under lease	Line operated under trackage rights	Total mileage operated	Line Owned, Not Operated A.T.&.S.F.: Main line	Line Owned, Not Operated A.T.&.S.F.: Branch Lines
Illinois8	229.44	52.12		8.11	289.67		
Iowa	19.87				19.87		
Missouri	193.58	73.00		42.37	308.95		
Kansas	1,229.73	1,667.97		33.86	2,931.56		
Nebraska			1.27	1.26	2.53		
Oklahoma	615.43	843.86		17.66	1,476.95		
Texas	1,574.73	2,036.12		82.46	3,693.31	.48	5.28
Louisiana		63.97		.56	64.53		
Colorado	363.06	241.02		39.78	643.86		
New Mexico	964.77	372.26			1,337.03		
Arizona	385.30	430.98		.19	816.47		
California	888.34	493.72		113.80	1,495.86		11.26
Total Mileage (First track)	6,464.25	6,275.02	1.27	340.05	13,080.59	.48	16.54

(B)

MILES OF TRACK OPERATED BY A.T.&.S.F. CLASSIFIED BY TYPE OF SERVICE

	Running Tracks, Passing Tracks, Cross-overs, etc.: Miles of road	Miles of second main track	Miles of all other main track	Miles of passing tracks, cross-overs, and turn-outs	Miles of way switching tracks	Miles of yard switching tracks	Total
Main Line	6,546.94	1,916.20	64.94	1,621.54	887.26	2,231.49	13,268.37
Branch Lines	6,533.65	28.06		475.51	719.92	241.36	7,998.30
Total	13,080.59	1,944.26	64.94	2,097.05	1,606.98	2,472.85	21,266.67

Exhibit 2 Page 392

EXHIBIT IV

ATCHISON, TOPEKA & SANTA FE RAILWAY

FREIGHT TRAFFIC DISTRIBUTION

Year ended December 31, 1941

DENSITY	PER CENT CUMULATIVE TO DENSITY INDICATED		DENSITY	PER CENT CUMULATIVE TO DENSITY INDICATED	
	TOTAL MILES	TOTAL NET TON MILES		TOTAL MILES	TOTAL NET TON MILES
10,000	1.33	0.00	2,750,000	80.07	32.25
15,000	2.69	0.01	3,000,000	81.65	35.27
20,000	4.02	0.03	3,250,000	82.11	36.22
25,000	5.51	0.05	3,500,000	82.41	36.87
50,000	13.03	0.22	3,750,000	82.96	38.14
75,000	16.95	0.38	4,000,000	-	-
100,000	21.14	0.62	4,250,000	84.04	41.10
125,000	25.72	0.95	4,500,000	84.65	42.84
150,000	30.42	1.39	4,750,000	85.44	45.31
175,000	33.10	1.67	5,000,000	87.87	53.07
200,000	34.55	1.84	5,250,000	90.28	61.17
250,000	37.86	2.31	5,500,000	93.23	71.56
300,000	40.53	2.80	5,750,000	96.52	83.66
400,000	44.54	3.73	6,000,000	98.22	90.12
500,000	48.05	4.76	6,250,000	98.34	90.60
600,000	50.41	5.60	6,500,000	98.47	91.12
700,000	52.35	6.40	6,750,000	98.58	91.61
800,000	53.00	6.72	7,000,000	98.65	91.91
900,000	57.42	9.10	7,500,000	99.10	94.08
1,000,000	60.09	10.78	8,000,000	-	-
1,250,000	67.09	15.94	8,500,000	-	-
1,500,000	69.53	18.05	9,000,000	-	-
1,750,000	72.41	20.96	9,500,000	-	-
2,000,000	73.81	22.70	10,000,000	99.51	96.66
2,250,000	76.18	26.06	11,000,000	100.00	100.00
2,500,000	79.14	30.65			

Per cent of total mileage operated and of total net ton miles between any two densities indicated on scale may be obtained by calculation of the difference for each column:

Example - density between 100,000 and 1,000,000 accounts for 38.95% of total mileage operated and 10.16% of total net ton miles.

Where blank spaces in columns follow any density on the scale the difference applies only to the density next preceeding:

Example - density between 9,500,000 and 10,000,000 accounts for 0.41% of total mileage operated and 2.58% of total net ton miles.

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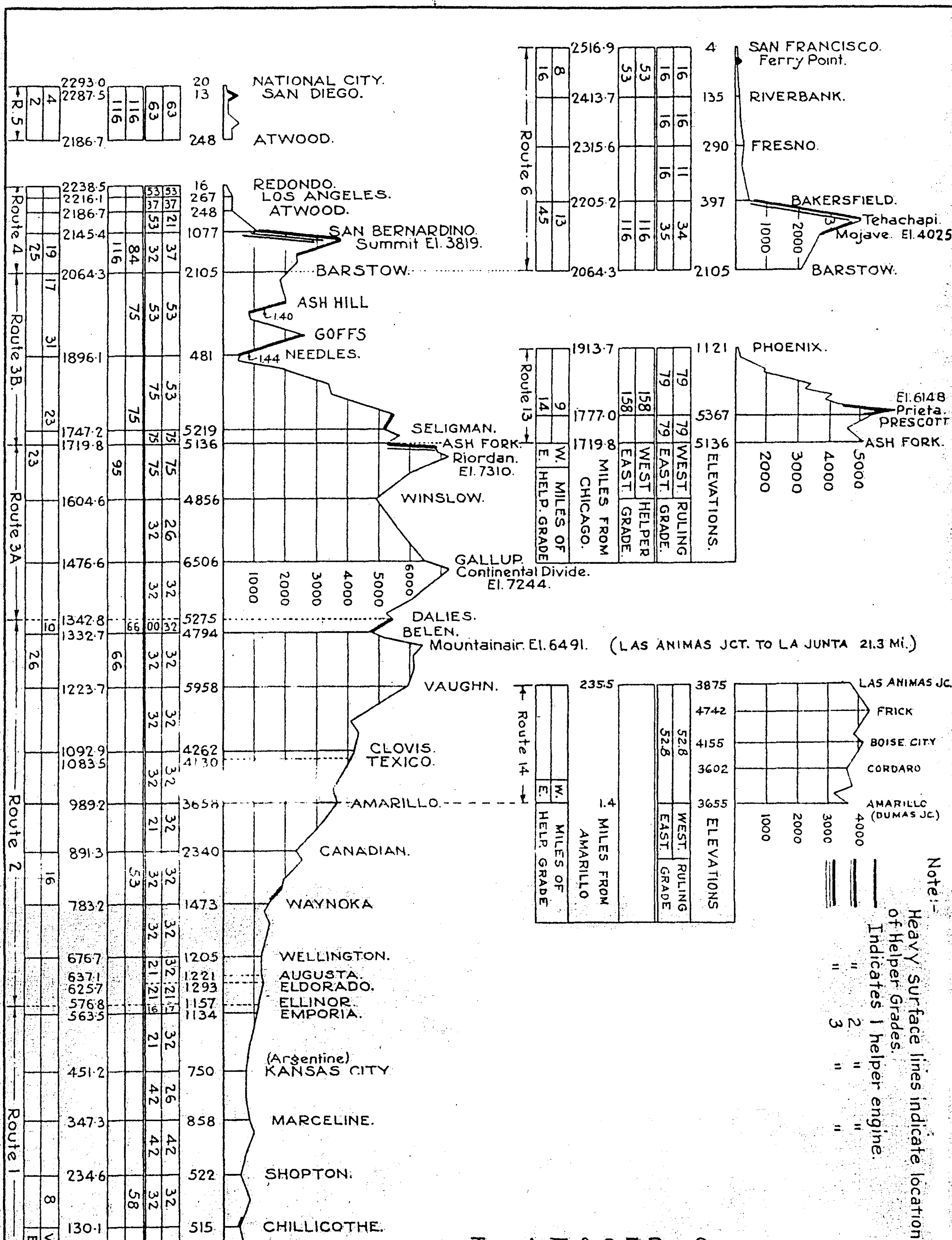


THE A.T. & S.F. RY. SYSTEM.

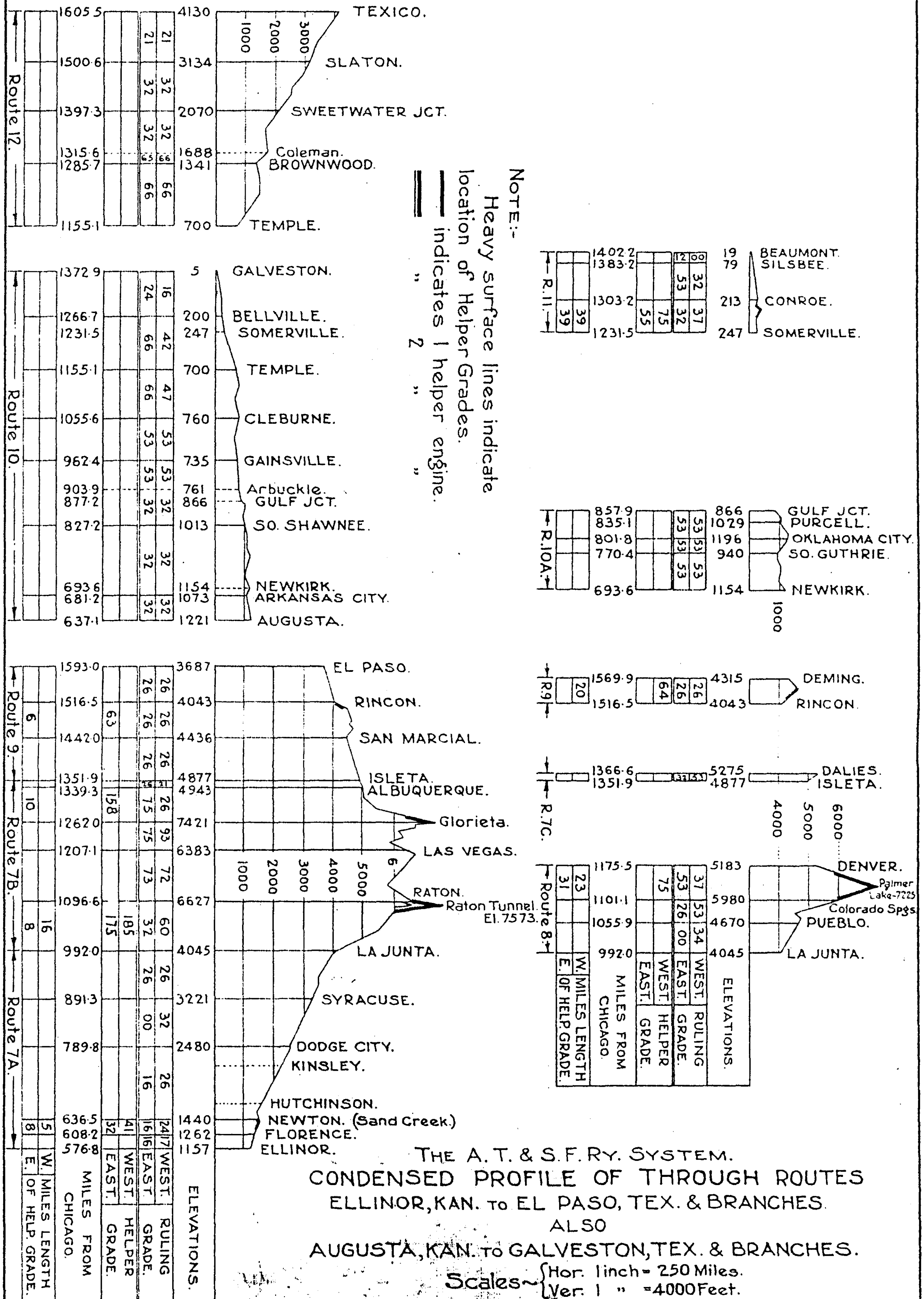
CONDENSED PROFILE OF THROUGH ROUTES
CHICAGO TO PACIFIC COAST POINTS
VIA AMARILLO.

Revised Dec. 1942

Scales~ {Hor. 1 inch = 250 Miles. Ver. 1 " = 4000 Feet.

C.E.S. No. 50088, Sheet 2. Chicago, June, 1926.

Superseding C.E.S. No. 50088, Sheet 2, dated Feb. 1923.



THE A. T. & S. F. RY. SYSTEM.

CONDENSED PROFILE OF THROUGH ROUTES
ELLINOR, KAN. TO EL PASO, TEX. & BRANCHES.
ALSO
AUGUSTA, KAN. TO GALVESTON, TEX. & BRANCHES.

Scales ~ {Hor. 1 inch = 250 Miles. Ver. 1 " = 4000 Feet.

C.E.S. No. 50088, Sheet 3. Chicago, June, 1926.

Superseding C.E.S. No. 50088, Sheet 3, dated Feb. 1923.

Exhibit 6
Page 2

[illegible], TOPEKA AND SANTA FE RAILWAY

OPERATING RESULTS
(000 Omitted)

Year	Total Operating Revenues	Total Operating Expenses	Net Rev. From Ry. Operations	Railway Tax Accruals	Uncoll. Railway Revenues	Railway Operating Income	Equipment Rents	Joint Facility Rents	Net Ry. Operating Income
1948	$ 526,734	$ 387,511	$ 139,223	$ 69,090	-	$ 70,133	Dr. $ 578	Dr. $ 839	$ 68,716
1947	462,699	339,218	123,481	68,082	-	55,399	Dr. 254	Dr. 843	54,302
1946	411,604	313,926	97,678	52,699	-	44,979	Cr. 1,383	Dr. 808	45,554
1945	528,703	404,460	124,243	81,612	-	42,631	Dr. 4,629	Dr. 918	37,084
1944	528,081	303,739	224,342	158,347	-	65,995	Dr. 4,335	Dr. 1,481	60,179
1943	471,119	256,456	214,663	144,870	-	69,793	Dr. 3,126	Dr. 827	65,840
1942	361,149	198,327	162,822	76,266	-	86,556	Dr. 2,213	Dr. 795	83,548
1941	225,044	156,911	68,133	27,626	-	40,507	Cr. 599	Dr. 558	40,548
1940	170,004	129,657	40,347	17,160	-	23,187	Cr. 1,493	Dr. 662	24,018
1939	160,040	125,335	34,705	15,485	-	19,220	Cr. 635	Dr. 685	19,170
1938	154,323	120,412	33,911	14,988	-	18,923	Dr. 242	Dr. 655	18,026
1937	170,670	139,902	30,768	12,966	-	17,802	Cr. 11	Dr. 736	17,077
1936	157,266	125,062	32,204	14,103	-	18,101	Cr. 1,123	Dr. 722	18,502
1935	135,686	109,423	26,263	10,476	48	15,739	Cr. 677	Dr. 713	15,703
1934	128,094	102,084	26,010	10,353	35	15,622	Cr. 330	Dr. 723	15,229
1933	119,826	93,803	26,023	11,399	49	14,575	Cr. 78	Dr. 691	13,962
1932	133,133	101,918	31,215	12,825	38	18,352	Cr. 44	Dr. 736	17,660
1931	181,181	132,813	48,368	15,038	53	33,277	Dr. 991	Dr. 837	31,449
1930	226,421	159,921	66,500	18,280	41	48,179	Dr. 2,504	Dr. 799	44,876
1929	270,618	177,799	92,819	20,065	57	72,697	Dr. 2,475	Dr. 597	69,625
1928	256,263	176,144	80,119	18,592	53	61,474	Dr. 2,182	Dr. 780	58,512
1927	265,753	187,577	78,577	19,998	51	58,528	Dr. 2,949	Dr. 722	54,857
1926	265,781	174,737	91,044	21,118	66	69,860	Dr. 2,843	Dr. 688	66,329
1925	242,543	168,447	74,096	17,725	74	56,297	Dr. 1,758	Dr. 783	53,756
1924	240,440	174,626	65,814	17,831	66	47,917	Cr. 91	Dr. 583	47,425
1923	241,459	176,073	65,386	20,225	115	45,046	Cr. 1,550	Dr. 579	46,017
1922	226,994	169,110	57,884	18,456	69	39,359	Cr. 751	Dr. 647	39,463
1921	231,951	163,589	68,362	14,973	77	53,312	Cr. 1,033	Dr. 698	53,647

Includes: Panhandle & Santa Fe. Ry.
Gulf, Colorado & Santa Fe. Ry.
Kansas City, Mexico & Orient Ry.
Kansas City, Mexico & Orient Ry. Co. of Texas

ATCHISON, TOPEKA AND SANTA FE RAIL...

Exhibit 6
Page 3

OPERATING REVENUES
(000 Omitted)

Year	Freight	Passenger	Mail	Express	All Other	Total Operating Revenues
1948	$ 427,135	$ 53,244	$ 17,118	$ 10,520	$ 18,717	$ 526,734
1947	370,487	50,236	13,857	10,610	17,509	462,699
1946	301,192	75,216	10,527	11,905	12,764	411,604
1945	380,294	112,832	10,516	13,554	11,507	528,703
1944	379,157	112,433	11,031	14,027	11,433	528,081
1943	333,838	103,804	10,555	11,021	11,901	471,119
1942	284,230	52,987	8,132	7,547	8,253	361,149
1941	185,127	22,786	7,253	3,615	6,263	225,044
1940	136,535	18,493	6,342	3,199	5,435	170,004
1939	127,531	18,278	6,092	3,122	5,017	160,040
1938	124,140	16,897	5,697	3,057	4,532	154,323
1937	138,985	17,527	5,727	3,205	5,226	170,670
1936	128,400	15,629	5,326	3,128	4,783	157,266
1935	109,686	13,447	5,062	2,567	4,924	135,686
1934	104,721	11,971	5,002	2,396	4,004	128,094
1933	97,427	12,202	4,968	2,101	3,129	119,826
1932	107,400	14,521	5,165	2,646	3,401	133,133
1931	143,624	22,557	5,929	4,223	4,848	181,181
1930	175,960	31,180	6,439	6,291	6,551	226,421
1929	207,662	38,045	9,101	7,950	7,860	270,618
1928	197,089	38,637	5,841	7,628	7,068	256,263
1927	202,725	43,011	5,375	8,102	6,540	265,753
1926	202,487	44,341	5,215	7,136	6,602	265,781
1925	179,977	44,396	5,147	6,693	6,330	242,543
1924	172,687	48,417	5,159	7,896	6,281	240,440
1923	169,543	52,575	4,701	8,430	6,210	241,459
1922	160,375	48,314	4,783	7,935	5,587	226,994
1921	163,429	52,508	4,558	6,399	5,057	231,951

Includes: Panhandle and Santa Fe Railway
Gulf, Colorado and Santa Fe Railway
Kansas City, Mexico and Orient
Kansas City, Mexico and Orient Railway Co. of Texas

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ATCHISON, TOPEKA AND SANTA FE RAILWAY

OPERATING EXPENSES
(000 Omitted)

Year	Maintenance of Way & Structures	Maintenance of Equipment	Total Maintenance Expenses	Traffic	Transportation	Misc.	General	Transportation for Invest.-Cr.	Total Operating Expenses
1948	$ 78,933	$ 92,114	$ 171,047	$ 11,377	$ 184,047	$ 10,682	$ 10,358	--	$ 387,511
1947	67,490	84,789	152,279	9,875	157,775	10,122	9,167	-	339,218
1946	61,784	79,838	141,622	8,981	149,405	5,164	8,754	-	313,926
1945	97,032	139,852	236,884	7,889	151,262	278	8,147	-	404,460
1944	64,304	81,778	146,082	7,427	142,318	256	7,656	-	303,739
1943	51,801	70,069	121,870	6,794	120,957	301	6,534	-	256,456
1942	35,326	53,916	89,242	5,986	97,700	183	5,216	-	198,327
1941	28,391	43,635	72,026	5,919	74,389	124	4,661	208	156,911
1940	24,349	35,842	60,191	5,741	59,509	92	4,434	310	129,657
1939	23,725	34,585	58,310	5,534	57,249	83	4,489	330	125,335
1938	19,755	33,481	53,236	5,264	57,471	79	4,558	196	120,412
1937	27,282	39,863	67,145	5,464	62,336	139	5,127	309	139,902
1936	24,320	35,846	60,166	5,104	54,677	117	5,466	468	125,062
1935	18,727	33,134	51,861	4,796	48,424	195	4,323	176	109,423
1934	16,538	30,843	47,381	4,468	43,817	118	6,397	97	102,084
1933	15,418	27,849	43,267	4,482	40,597	63	5,542	148	93,803
1932	15,342	31,536	46,878	4,921	43,997	79	5,963	Dr. 80	101,918
1931	23,825	39,822	63,647	5,686	57,048	207	6,522	297	132,813
1930	35,460	45,403	80,863	5,965	67,094	351	6,757	1,109	159,921
1929	43,217	49,040	92,257	5,942	73,829	258	6,705	1,192	177,799
1928	41,803	49,154	90,957	5,858	74,090	182	6,548	1,491	176,144
1927	45,752	52,352	98,104	5,801	78,766	125	6,121	1,741	187,176
1926	36,485	48,783	85,268	5,351	78,974	112	6,031	999	174,737
1925	35,363	48,281	83,644	4,908	74,739	184	5,795	823	168,447
1924	37,686	53,909	91,595	4,610	74,519	136	5,354	1,588	174,626
1923	34,232	58,315	92,547	4,336	75,022	77	5,162	1,071	176,073
1922	36,539	51,608	88,147	3,979	72,243	180	5,116	555	169,110
1921	23,833	48,826	72,659	3,846	81,897	63	5,632	508	163,589

Includes: Panhandle and Santa Fe Ry.
Gulf, Colorado and Santa Fe Ry.
Kansas City, Mexico & Orient R.R.
Kansas City, Mexico & Orient Ry. Co. of Texas

ATCHISON, TOPEKA AND SANTA FE RAILWAY

MAINTENANCE OF EQUIPMENT EXPENSES
(000 Omitted)

Year	Superintendence	Mach. (Shop Power Plant & Sub-Stations)	Equipment Repairs	Equipment Depreciation	Equipment Retirements	Amortization of Defense Projects	Casualty	Maintaining Joint Equipment Debit	Maintaining Joint Equipment Credit	All Other	Equalization Equip.	Total M. of E. Expenses
1948	$ 3,646	$ 2,869	$ 71,455	$ 12,776	Cr $ 219	$ 368	$ 633	$ 369	$ 152	$ 369	–	$ 92,114
1947	3,293	2,058	63,990	14,077	28	368	686	317	136	108	–	84,789
1946	3,150	1,774	60,110	13,604	37	316	528	304	138	153	–	79,838
1945	2,708	1,775	59,394	12,925	26	61,686	561	299	134	612	–	139,852
1944	2,508	1,530	51,805	12,652	68	12,485	467	240	133	84	–	81,778
1943	2,390	1,213	43,790	11,898	15	10,333	253	221	107	63	–	70,069
1942	1,964	988	35,065	12,566	70	2,955	153	194	106	67	–	53,916
1941	1,685	1,090	28,086	12,285	63	–	140	181	78	183	–	43,635
1940	1,580	847	21,178	11,847	94	–	108	157	8	39	–	35,842
1939	1,562	781	20,410	11,638	77	–	62	140	118	33	–	34,585
1938	1,562	663	19,353	11,704	58	–	97	131	117	30	–	33,481
1937	1,618	1,120	25,663	11,227	93	–	93	137	128	40	–	39,863
1936	1,520	840	22,282	11,069	30	–	72	126	122	29	–	35,846
1935	1,398	709	19,610	11,256	92	–	18	132	106	25	–	33,134
1934	1,353	505	17,287	11,178	402	–	79	109	95	25	–	30,843
1933	1,331	342	14,355	11,548	169	–	60	112	95	26	–	27,849
1932	1,490	374	17,174	12,219	125	–	70	129	76	32	–	31,537
1931	1,981	737	23,737	12,995	175	–	99	133	81	46	–	39,822
1930	2,197	970	28,728	13,030	237	–	110	158	99	72	–	45,403
1929	2,184	1,009	32,848	12,530	350	–	Cr. 20	157	106	88	–	49,040
1928	2,199	1,157	32,873	12,220	432	–	133	149	93	84	–	49,154
1927	2,179	1,280	36,343	11,599	530	–	271	164	112	98	–	52,352
1926	2,146	1,070	33,725	11,259	251	–	171	158	88	91	–	48,783
1925	2,148	972	33,614	11,030	162	–	207	142	81	87	–	48,281
1924	2,162	1,210	39,536	10,375	194	–	196	167	51	120	–	53,909
1923	2,214	1,237	45,202	9,067	53	–	268	134	53	193	–	58,315
1922	1,993	879	37,885	8,681	67	–	237	133	45	1,778	–	51,608
1921	1,849	1,134	41,901	8,276	Cr 75	–	230	115	43	103	Cr 4,664	48,828

ludes: Panhandle and Santa Fe Ry.
Gulf, Colorado and Santa Fe Ry.
Kansas City, Mexico & Orient R.R.
Kansas City, Mexico & Orient Ry. Co. of Texas

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ATCHISON, TOPEKA AND SANTA FE RAILWAY

TRANSPORTATION EXPENSES
(000 Omitted)

Year	Superintendence	Dispatching Trains	Station Service	Yard Service	Road Service	Protective Service	Oper. Float. Equip.	Casualty	Joint Yards, Termls. Tracks and Facilities Dr.	Joint Yards, Termls. Tracks and Facilities Dr.	All Other	Total Trans. Expenses
1948	$ 5,077	$ 1,374	$ 23,271	$ 26,885	$103,847	$ 3,385	$ 352	$ 11,179	$ 7,739	$ 2,766	$ 3,204	$ 184,047
1947	4,584	1,801	23,707	23,830	85,291	3,264	340	10,397	6,399	2,532	694	157,775
1946	4,419	1,830	23,507	21,950	79,524	3,152	343	10,688	6,000	2,642	634	149,405
1945	4,067	1,751	21,123	21,158	83,555	3,332	373	11,102	5,815	2,302	688	151,262
1944	3,864	1,835	19,785	20,502	81,418	2,830	313	8,182	5,376	2,429	642	142,318
1943	3,571	1,704	17,412	17,403	69,363	2,428	314	5,457	4,675	1,906	536	120,957
1942	2,756	1,141	13,700	14,701	56,386	2,210	295	4,067	3,651	1,680	473	97,700
1941	2,147	841	10,410	10,846	43,614	1,746	225	2,324	2,766	875	345	74,389
1940	1,933	748	9,290	8,645	33,846	1,540	158	1,671	2,442	1,070	306	59,509
1939	1,944	739	9,201	8,413	32,617	1,530	149	1,450	2,279	1,348	275	57,249
1938	1,999	741	9,516	8,657	32,496	1,557	161	1,305	2,059	1,293	273	57,471
1937	2,077	746	9,792	9,562	35,584	1,590	184	1,674	2,151	1,316	292	62,336
1936	1,970	694	9,027	8,417	30,797	1,536	173	1,334	1,962	1,207	244	54,677
1935	1,888	672	8,509	6,962	26,422	1,499	143	1,267	1,894	1,041	209	48,424
1934	1,733	611	7,925	6,392	23,483	1,391	130	1,126	1,794	979	211	43,817
1933	1,719	622	7,708	5,863	21,123	1,375	149	1,052	1,729	932	189	40,597
1932	1,895	725	8,531	6,492	22,573	1,398	205	1,134	1,858	1,015	201	43,997
1931	2,590	921	10,821	8,782	29,442	1,656	260	1,335	2,218	1,288	311	57,048
1930	2,866	1,022	12,432	10,532	34,558	1,758	297	2,185	2,531	1,530	443	67,094
1929	2,880	1,160	13,239	11,823	38,969	1,784	296	2,222	2,546	1,563	473	73,829
1928	2,926	1,220	13,491	11,586	39,642	1,719	322	2,051	2,186	1,484	431	74,090
1927	2,871	1,255	13,528	12,126	42,756	1,701	300	2,924	2,350	1,532	487	78,766
1926	2,719	1,160	13,100	12,011	44,127	1,639	362	2,941	2,284	1,880	511	78,974
1925	2,657	1,124	12,624	10,761	41,787	1,634	352	2,749	2,198	1,660	513	74,739
1924	2,622	1,175	12,716	10,883	41,346	1,541	383	2,661	2,201	1,526	517	74,519
1923	2,600	1,209	12,673	10,596	42,184	1,517	323	2,695	2,138	1,437	524	75,022
1922	2,414	1,149	12,267	9,826	40,629	1,463	313	3,041	2,028	1,393	506	72,243
1921	2,576	1,270	13,580	10,595	46,269	1,540	349	4,488	2,092	1,484	622	81,897

Includes: Panhandle and Santa Fe Railway; Gulf, Colorado and Santa Fe Railway; Kansas City, Mexico & Orient Railway; Kansas City, Mexico & Orient Railway Co. of Texas

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ATCHISON, TOPEKA AND SANTA FE RAILWAY

TONNAGE ORIGINATED, BY GROUPS OF COMMODITIES

Year	Products of Agriculture	Animals and Products	Products of Mines	Products of Forests	Manufactures & Misc.	All L.C.L. Freight	Total Tons
1948	13,439,222	1,271,321	13,136,113	1,607,314	16,262,792 **	447,883	46,164,645
1947	14,372,397	1,617,042	12,040,247	1,547,987	16,409,628 **	537,672	46,524,973
1946	12,237,133	1,604,975	9,552,706	1,410,075	14,441,310	587,150	39,833,349
1945	13,681,412	1,660,552	8,253,786	1,341,821	14,760,424	523,229	40,221,224
1944	11,838,640	1,605,185	8,484,838	1,189,371	13,351,748	483,077	38,519,305 *
1943	11,463,902	1,646,128	9,660,508	1,020,063	11,758,663	422,048	37,600,801 *
1942	9,026,735	1,372,816	9,528,778	1,056,838	12,111,339	379,324	34,678,438 *
1941	7,992,317	938,511	7,336,868	1,053,987	10,865,332	391,102	28,578,117
1940	6,640,350	895,770	5,397,810	876,192	8,537,033	356,383	22,703,538
1939	7,018,783	986,297	7,403,955	728,306	8,024,334	368,841	24,530,516
1938	7,390,780	958,356	6,475,471	730,659	7,979,931	400,788	23,935,985
1937	7,044,572	1,023,405	10,475,737	869,743	9,972,782	479,280	29,865,519
1936	5,971,036	848,783	6,801,664	928,033	9,277,958	476,541	24,304,015
1935	5,004,819	974,967	5,399,092	788,667	7,661,996	393,622	20,223,163
1934	5,742,500	1,300,322	6,176,313	636,361	7,363,428	408,303	21,627,227
1933	5,643,383	984,012	5,484,344	681,173	6,894,763	405,153	20,092,828
1932	7,755,878	1,012,322	5,401,319	538,420	7,071,295	438,622	22,217,856
1931	10,093,535	1,072,361	9,240,093	829,568	9,409,852	591,072	31,236,481
1930	8,741,550	1,254,466	12,378,606	1,348,096	11,490,306	811,195	36,024,219
1929	10,417,693	1,294,733	15,051,265	1,724,267	11,373,957	983,799	40,845,714
1928	9,030,235	1,491,317	14,868,024	1,842,262	11,027,988	1,059,141	39,318,967
1927	8,300,590	1,528,513	16,751,836	1,995,826	10,842,824	1,150,485	40,570,074
1926	8,800,543	1,372,046	16,591,454	1,950,474	9,570,764	1,152,694	39,437,975
1925	6,835,411	1,580,364	13,907,131	1,960,169	9,412,612	1,129,945	34,825,632
1924	8,304,771	1,558,175	11,915,061	2,100,002	8,216,565	1,128,466	33,223,040
1923	6,327,591	1,685,244	12,141,468	2,267,912	8,144,835	1,166,719	31,733,769
1922	6,420,314	1,665,617	8,521,907	1,608,544	7,237,358	1,152,525	26,606,265
1921	7,630,189	1,238,139	5,944,754	1,800,689	5,599,667	1,155;393	23,368,831

* - Certain commodities omitted in order to avoid revealing information concerning strategic and critical materials pursuant to the order of the I. C. C. dated April 27, 1942. However, they are included in "Total Tons."

** - Includes forwarder traffic.

Includes: Panhandle & Santa Fe. Ry. Gulf, Colorado & Santa Fe Ry. Kansas City, Mexico & Orient Ry. Kansas City, Mexico & Orient Ry. Co. of Texas

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ATCHISON, TOPEKA AND SANTA FE RAILWAY

REVENUE FREIGHT TONNAGE HANDLED
(Thousands)

Year	Products of Agriculture	Animals and Products	Products of Mines	Products of Forests	Manufactures and Products	Less Carload	Total Tons Handled
1948	15,160	1,682	18,073	3,181	24,749	643	63,528
1947	16,219	2,029	17,077	3,069	24,455	803	63,652
1946	14,187	2,086	13,706	2,908	22,017	892	55,796
1945	15,733	2,140	13,619	2,594	26,593	789	61,468
1944	13,850	2,066	13,763	2,564	26,579	743	59,565
1943	13,361	2,056	16,422	2,438	22,739	695	57,711
1942	10,477	1,731	14,824	3,037	20,351	616	51,036
1941	9,034	1,203	10,092	2,170	15,831	577	38,907
1940	7,622	1,130	7,093	1,728	11,957	500	30,030
1939	7,993	1,229	8,964	1,503	10,847	518	31,054
1938	8,371	1,167	7,783	1,469	10,456	555	29,801
1937	8,142	1,247	12,233	1,677	13,447	664	37,410
1936	7,016	1,039	8,372	1,672	12,255	646	31,000
1935	6,118	1,189	6,671	1,289	9,958	542	25,767
1934	6,821	1,548	7,678	1,049	9,334	564	26,994
1933	6,541	1,199	7,124	1,091	8,633	549	25,137
1932	8,699	1,220	6,856	908	8,674	590	26,947
1931	11,209	1,291	11,129	1,313	11,569	787	37,298
1930	9,907	1,519	15,026	2,135	14,918	1,079	44,584
1929	11,635	1,608	18,334	2,716	15,346	1,310	50,949
1928	9,942	1,759	17,070	2,833	13,896	1,347	46,847
1927	9,067	1,759	18,395	2,969	13,786	1,426	47,402
1926	9,658	1,573	18,828	3,078	13,107	1,431	47,675
1925	7,767	1,796	16,452	2,956	12,431	1,380	42,782
1924	9,321	1,752	14,138	3,016	11,085	1,383	40,695
1923	7,374	1,879	14,461	3,318	11,224	1,428	39,684
1922	7,496	1,892	10,560	2,453	10,018	1,394	33,813
1921	8,337	1,365	7,883	2,537	7,582	1,356	29,060

Includes Panhandle and Santa Fe. Ry. — Kansas City, Mexico and Orient Ry.
Gulf, Colorado and Santa Fe. Ry. — Kansas City, Mexico and Orient Ry. Co. of Texas

ATCHISON, TOPEKA AND SANTA FE RAILWAY

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OPERATING STATISTICS

ear	(000,000 Omitted) Revenue Ton Miles	Non Rev. Ton Miles	Net Ton Miles	(000 Omitted) Train Miles Freight	Train Miles Passenger	Locomotive Miles Freight	Locomotive Miles Passenger	(000,000 Omitted) Car Miles in Transportation Service Freight Loaded	Freight Empty	Total Freight	Passenger	(000 Omitted) Pass. Miles
948	32,994	2,164	35,158	35,032	24,927	38,859	23,615	1,302	647	1,949	259	2,263,822
947	32,805	2,190	34,995	35,760	23,690	39,827	22,417	1,324	633	1,957	242	2,373,540
946	29,758	2,118	31,876	33,637	28,105	37,581	28,355	1,229	557	1,786	307	4,023,889
945	37,658	2,469	40,127	40,862	29,840	45,449	31,922	1,472	769	2,241	342	6,367,753
944	37,604	2,271	39,875	40,673	27,221	45,941	29,038	1,472	754	2,226	312	6,250,295
943	31,952	2,037	33,989	36,693	26,653	42,333	28,129	1,212	665	1,877	301	5,827,179
942	28,111	2,020	30,131	36,735	23,026	42,715	22,678	1,133	709	1,842	223	3,014,073
941	18,780	1,684	20,464	30,053	20,278	34,975	19,156	896	537	1,433	175	1,327,691
940	13,083	1,399	14,482	23,681	19,648	26,835	18,333	681	435	1,116	162	1,056,357
939	11,700	1,191	12,891	21,544	20,583	24,091	18,894	607	378	985	162	1,033,310
938	11,172	925	12,097	20,941	19,975	23,495	18,238	578	369	947	158	912,203
937	12,938	1,438	14,376	23,718	20,617	26,857	19,813	669	405	1,074	163	980,243
936	11,513	1,338	12,851	21,883	19,859	24,756	18,453	616	357	973	151	872,942
935	9,719	1,041	10,760	20,094	18,685	22,132	16,558	539	320	859	144	748,116
934	9,352	956	10,308	19,179	18,176	20,777	15,668	511	311	822	139	639,025
933	8,712	770	9,482	17,815	18,152	19,648	15,496	461	276	737	136	555,020
932	9,070	835	9,905	18,435	18,623	20,310	15,897	482	301	783	140	573,645
931	12,350	1,107	13,457	20,967	21,177	23,341	19,362	602	360	962	167	799,218
930	14,527	1,772	16,299	23,317	23,536	26,284	22,807	730	426	1,156	192	1,050,545
929	16,797	1,981	18,778	26,090	24,271	29,562	24,846	831	490	1,321	202	1,243,938
928	15,791	1,978	17,769	25,120	24,437	28,500	25,165	799	450	1,249	197	1,238,137
927	16,917	2,175	19,092	27,657	24,530	31,135	25,632	837	507	1,344	200	1,349,808
926	16,668	1,733	18,401	26,845	23,345	30,186	24,368	802	471	1,273	188	1,396,572
925	14,192	1,647	15,839	24,601	23,286	27,600	24,340	730	403	1,133	181	1,417,352
924	13,427	1,860	15,287	24,939	23,006	27,674	24,274	699	375	1,074	181	1,517,466
923	12,567	1,949	14,516	25,739	22,969	28,354	24,572	681	361	1,042	176	1,612,802
922	11,335	1,813	13,148	23,450	21,961	25,595	23,320	612	300	912	169	1,472,131
921	10,557	1,630	12,187	23,059	22,332	25,204	23,715	552	335	887	167	1,550,443

cludes Panhandle and Santa Fe. Ry.
Gulf, Colorado and Santa Fe. Ry.
Kansas City, Mexico and Orient Ry.
Kansas City, Mexico and Orient Ry. Co. of Texas

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ATCHISON, TOPEKA AND SANTA FE RAILWAY

RATIO OF NET RAILWAY OPERATING INCOME TO TOTAL OPERATING REVENUES

Year	Total Operating Expenses	Net Rev. from Ry. Operations	Railway Tax Accruals	Uncoll. Railway Revenues	Railway Operating Income	Equipment Rents	Joint Facility Rents	Net Ry. Operating Income
1948	73.57	26.43	13.12	-	13.31	Dr. 0.11	Dr. 0.16	13.04
1947	73.31	26.69	14.72	-	11.97	Dr. 0.05	Dr. 0.18	11.74
1946	76.27	23.73	12.80	-	10.93	Cr. 0.34	Dr. 0.20	11.07
1945	76.50	23.50	15.44	-	8.06	Dr. 0.88	Dr. 0.17	7.01
1944	57.52	42.48	29.98	-	12.50	Dr. 0.82	Dr. 0.28	11.40
1943	54.44	45.56	30.75	-	14.81	Dr. 0.66	Dr. 0.17	13.98
1942	54.92	45.08	21.12	-	23.96	Dr. 0.61	Dr. 0.22	23.13
1941	69.72	30.28	12.28	-	18.00	Dr. 0.27	Dr. 0.25	18.02
1940	76.27	23.73	10.09	-	13.64	Cr. 0.88	Dr. 0.39	14.13
1939	78.31	21.69	9.68	-	12.01	Cr. 0.40	Dr. 0.43	11.98
1938	78.03	21.97	9.71	-	12.26	Dr. 0.16	Dr. 0.42	11.68
1937	81.97	18.03	7.60	-	10.43	Cr. 0.01	Dr. 0.43	10.01
1936	79.52	20.48	8.97	-	11.51	Cr. 0.71	Dr. 0.46	11.76
1935	80.64	19.36	7.72	0.04	11.60	Cr. 0.50	Dr. 0.53	11.57
1934	79.69	20.31	8.08	0.03	12.20	Cr. 0.26	Dr. 0.57	11.89
1933	78.28	21.72	9.51	0.04	12.17	Cr. 0.06	Dr. 0.58	11.65
1932	76.55	23.45	9.64	0.03	13.78	Cr. 0.03	Dr. 0.55	13.26
1931	73.30	26.70	8.30	0.03	18.37	Dr. 0.55	Dr. 0.46	17.36
1930	70.63	29.37	8.07	0.02	21.28	Dr. 1.11	Dr. 0.35	19.82
1929	65.70	34.30	7.42	0.02	26.86	Dr. 0.91	Dr. 0.22	25.73
1928	68.74	31.26	7.25	0.02	23.99	Dr. 0.86	Dr. 0.30	22.83
1927	70.43	29.57	7.53	0.02	22.02	Dr. 1.11	Dr. 0.27	20.64
1926	65.74	34.26	7.95	0.03	26.28	Dr. 1.07	Dr. 0.25	24.96
1925	69.45	30.55	7.31	0.03	23.21	Dr. 0.73	Dr. 0.32	22.16
1924	72.63	27.37	7.41	0.03	19.93	Cr. 0.03	Dr. 0.24	19.72
1923	72.92	27.08	8.37	0.05	18.66	Cr. 0.64	Dr. 0.24	19.06
1922	74.50	25.50	8.13	0.03	17.34	Cr. 0.33	Dr. 0.28	17.39
1921	70.53	29.47	6.46	0.03	22.98	Cr. 0.45	Dr. 0.30	23.13

Includes: Pan Handle & Santa Fe. Railway
Gulf, Colorado & Santa Fe. Railway
Kansas City, Mexico & Orient Railway
Kansas City, Mexico & Orient Railway of Texas

Exhibit 6
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ATCHISON, TOPEKA AND SANTA FE RAILWAY

RATIO OF REVENUE ACCOUNTS TO TOTAL OPERATING REVENUES

Year	Freight	Passenger	Mail	Express	All Other
1948	81.09	10.11	3.25	2.00	3.55
1947	80.07	10.86	2.99	2.29	3.79
1946	73.18	18.27	2.56	2.89	3.10
1945	71.93	21.34	1.99	2.56	2.18
1944	71.80	21.29	2.09	2.66	2.16
1943	70.86	22.03	2.24	2.34	2.53
1942	78.70	14.67	2.25	2.09	2.29
1941	82.26	10.13	3.22	1.61	2.78
1940	80.31	10.88	3.73	1.88	3.20
1939	79.69	11.42	3.81	1.95	3.13
1938	80.44	10.95	3.69	1.98	2.94
1037	81.43	10.27	3.36	1.88	3.06
1936	81.55	9.94	3.39	1.99	3.03
1935	80.84	9.91	3.73	1.89	3.63
1934	81.75	9.35	3.90	1.87	3.13
1933	81.31	10.18	4.15	1.75	2.61
1932	80.67	10.91	3.88	1.99	2.55
1931	79.27	12.45	3.27	2.33	2.68
1930	77.72	13.77	2.84	2.78	2.89
1929	76.74	14.06	3.36	2.94	2.90
1928	76.91	15.08	2.28	2.98	2.75
1927	76.28	16.19	2.02	3.05	2.46
1926	76.19	16.68	1.96	2.69	2.48
1925	74.21	18.30	2.12	2.76	2.61
1924	71.82	20.14	2.15	3.28	2.61
1923	70.22	21.77	1.95	3.49	2.57
1922	70.65	21.28	2.11	3.50	2.46
1921	70.46	22.64	1.96	2.76	2.18

Includes: Panhandle & Santa Fe Railway
Gulf, Colorado & Santa Fe Railway
Kansas City, Mexico & Orient Railway
Kansas City, Mexico & Orient Railway of Texas

Exhibit 6
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ATCHISON, TOPEKA AND SANTA FE RAILWAY

RATIO OF OPERATING EXPENSES, BY GENERAL ACCOUNTS, TO TOTAL OPERATING REVENUES

Year	Maintenance of Way & Structures	Maintenance of Equipment	Total Maintenance Expenses	Traffic	Transportation	Misc.	General	Transportation for Invest.-Cr.	Total Operating Expenses
1948	14.99	17.49	32.48	2.16	34.94	2.02	1.97	-	73.57
1947	14.59	18.32	32.91	2.13	34.10	2.19	1.98	-	73.31
1946	15.01	19.40	34.41	2.18	36.30	1.25	2.13	-	76.27
1945	18.35	26.45	44.80	1.49	28.61	0.05	1.55	-	76.50
1944	12.17	15.49	27.66	1.41	26.95	0.05	1.45	-	57.52
1943	11.00	14.87	25.87	1.44	25.68	0.06	1.39	-	54.44
1942	9.78	14.93	24.71	1.66	27.05	0.05	1.45	-	54.92
1941	12.62	19.39	32.01	2.62	33.06	0.06	2.06	0.09	69.72
1940	14.33	21.08	35.41	3.38	35.00	0.05	2.61	0.18	76.27
1939	14.82	21.61	36.43	3.47	35.77	0.05	2.80	0.21	78.31
1938	12.80	21.70	34.50	3.41	37.24	0.05	2.95	0.12	78.03
1937	11.57	19.62	31.19	3.08	33.67	0.05	2.67	0.11	70.55
1936	15.46	22.80	38.26	3.25	34.77	0.07	3.48	0.31	79.52
1935	13.80	26.42	38.22	3.53	35.69	0.14	3.19	0.13	80.64
1934	12.91	24.08	36.99	3.49	34.21	0.09	4.99	0.13	79.69
1933	12.87	23.24	36.11	3.74	33.88	0.05	4.63	0.13	78.28
1932	11.52	23.69	35.21	3.70	33.05	0.06	4.47	0.06	76.55
1931	13.15	21.98	35.13	3.14	31.49	0.11	3.60	0.17	73.30
1930	15.66	20.05	35.71	2.64	29.63	0.16	2.98	0.49	70.63
1929	15.97	18.12	34.09	2.19	27.28	0.10	2.48	0.44	65.70
1928	16.31	19.18	35.49	2.29	28.91	0.07	2.56	0.58	68.74
1927	17.22	19.70	36.92	2.18	29.64	0.05	2.30	0.66	70.43
1926	13.73	18.35	32.08	2.01	29.71	0.04	2.27	0.37	65.74
1925	14.58	19.91	34.49	2.02	30.81	0.08	2.39	0.34	69.45
1924	15.67	22.42	38.09	1.92	30.99	0.06	2.23	0.66	72.63
1923	14.18	24.15	38.33	1.79	31.07	0.03	2.14	0.44	72.92
1922	16.10	22.73	38.83	1.75	31.83	0.08	2.25	0.24	74.50
1921	10.27	21.06	31.33	1.66	35.31	0.03	2.42	0.22	70.53

Includes: Panhandle & Santa Fe Railway   Gulf, Colorado & Santa Fe Railway
Kansas City, Mexico & Orient Railway
Kansas City, Mexico & Orient Railway of Texas

ATCHISON, TOPEKA AND SANTA FE RAILWAY

RATIO OF MAINTENANCE OF EQUIPMENT EXPENSES TO TOTAL OPERATING REVENUES

Year	Superin-tendence	Mach. (Shop, Power, Plant Sub-Stations)	Equipment Repairs	Equipment Depreciation	Equipment Retirements	Amortization of Defense Projects	Casualty	Maintaining Joint Equipment Debit	Maintaining Joint Equipment Credit	All Other	Equalization Equip't	Total M. of E. Expenses
1948	0.69	0.54	13.57	2.43	Cr. 0.04	0.07	0.12	0.07	0.03	0.07	-	17.49
1947	0.71	0.44	13.83	3.04	0.01	0.08	0.15	0.07	0.03	0.02	-	18.32
1946	0.77	0.43	14.60	3.30	0.01	0.08	0.13	0.07	0.03	0.04	-	19.40
1945	0.51	0.34	11.23	2.44	0.01	11.67	0.11	0.05	0.03	0.12	-	26.45
1944	0.49	0.29	9.81	2.40	0.01	2.36	0.09	0.05	0.03	0.02	-	15.49
1943	0.51	0.26	9.29	2.53	-	2.19	0.05	0.05	0.02	0.01	-	14.87
1942	0.55	0.27	9.71	3.48	0.02	0.82	0.04	0.05	0.03	0.02	-	14.93
1941	0.75	0.48	12.48	5.46	0.03	-	0.06	0.08	0.03	0.08	-	19.39
1940	0.93	0.50	12.45	6.97	0.06	-	0.06	0.09	-	0.02	-	21.08
1939	0.98	0.49	12.74	7.27	0.05	-	0.04	0.09	0.07	0.02	-	21.61
1938	1.01	0.43	12.54	7.59	0.04	-	0.06	0.09	0.08	0.02	-	21.70
1937	0.95	0.66	12.04	6.58	0.05	-	0.05	0.08	0.07	0.02	-	23.36
1936	0.97	0.53	14.17	7.04	0.02	-	0.05	0.08	0.08	0.01	-	22.79
1935	1.03	0.52	14.45	8.30	0.07	-	0.01	0.10	0.08	0.02	-	24.42
1934	1.06	0.39	13.49	8.73	0.31	-	0.06	0.09	0.07	0.02	-	24.08
1933	1.11	0.29	11.98	9.64	0.14	-	0.05	0.09	0.08	0.02	-	23.24
1932	1.12	0.28	12.90	9.18	0.09	-	0.05	0.10	0.06	0.03	-	23.69
1931	1.09	0.41	13.10	7.17	0.10	-	0.05	0.07	0.04	0.03	-	21.98
1930	0.97	0.43	12.69	5.75	0.10	-	0.05	0.07	0.04	0.03	-	20.05
1929	0.81	0.37	12.14	4.63	0.13	-	Cr. 0.01	0.06	0.04	0.03	-	18.12
1928	0.86	0.45	12.83	4.77	0.17	-	0.05	0.06	0.04	0.03	-	19.18
1927	0.82	0.48	13.68	4.36	0.20	-	0.10	0.06	0.04	0.04	-	19.70
1926	0.81	0.40	12.69	4.24	0.09	-	0.06	0.06	0.03	0.03	-	18.35
1925	0.88	0.40	13.86	4.55	0.07	-	0.08	0.06	0.03	0.04	-	19.91
1924	0.90	0.50	16.44	4.32	0.08	-	0.08	0.07	0.02	0.05	-	22.42
1923	0.92	0.51	18.72	3.75	0.02	-	0.11	0.06	0.02	0.08	-	24.15
1922	0.88	0.39	16.69	3.82	0.03	-	0.10	0.06	0.02	0.78	-	22.73
1921	0.86	0.49	18.07	3.57	Cr. 0.03	-	0.10	0.05	0.02	0.05	Cr. 2.01	21.07

Includes: Panhandle & Santa Fe Railway
Gulf, Colorado & Santa Fe Railway
Kansas City, Mexico & Orient Railway
Kansas City, Mexico & Orient Railway of Texas

Exhibit 6
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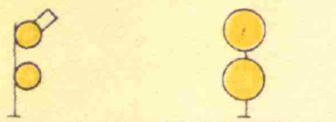
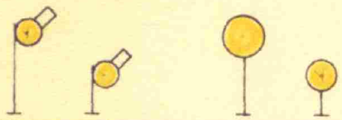
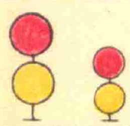
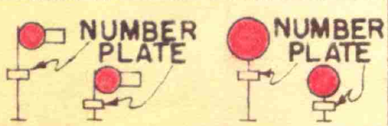
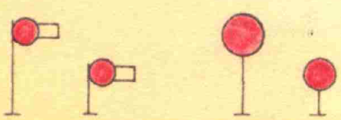
ATCHISON, TOPEKA AND SANTA FE RAILWAY

RATIO OF TRANSPORTATION EXPENSES TO TOTAL OPERATING REVENUES

Year	Superintendence	Dispatching Trains	Station Service	Yard Service	Road Service	Protective Service	Oper. Float. Equip.	Casualty	Joint Yards, Termls., Tracks and Facilities Dr.	Joint Yards, Termls., Tracks and Facilities Cr.	All Other	Total Trans. Expenses
1948	0.96	0.36	4.42	5.10	19.72	0.64	0.07	2.12	1.47	0.53	0.61	34.94
1947	0.99	0.39	5.12	5.15	18.44	0.71	0.07	2.25	1.38	0.55	0.15	34.10
1946	1.07	0.45	5.71	5.33	19.32	0.77	0.08	2.60	1.46	0.64	0.15	36.30
1945	0.77	0.33	4.00	4.12	15.80	0.63	0.07	2.10	1.10	0.44	0.13	28.61
1944	0.73	0.35	3.75	3.88	15.42	0.53	0.06	1.55	1.02	0.46	0.12	26.95
1943	0.76	0.36	3.70	3.69	14.72	0.52	0.07	1.16	0.99	0.41	0.11	25.67
1942	0.76	0.32	3.79	4.07	15.61	0.61	0.09	1.13	1.01	0.47	0.13	27.05
1941	0.95	0.37	4.63	4.82	19.38	0.79	0.10	1.03	1.23	0.39	0.15	33.06
1940	1.14	0.44	5.46	5.09	19.90	0.91	0.09	0.98	1.44	0.63	0.18	35.00
1939	1.21	0.47	5.75	5.26	20.37	0.96	0.09	0.91	1.42	0.84	0.17	35.77
1938	1.30	0.48	6.17	5.61	21.06	1.01	0.10	0.85	1.33	0.84	0.17	37.24
1937	1.17	0.43	5.58	5.07	19.04	0.91	0.09	0.76	1.21	0.76	0.17	33.67
1936	1.25	0.44	5.74	5.18	19.58	0.98	0.11	0.85	1.25	0.77	0.16	34.77
1935	1.39	0.50	6.27	5.13	19.47	1.11	0.11	0.93	1.40	0.77	0.15	35.69
1934	1.35	0.48	6.19	4.99	18.33	1.09	0.10	0.88	1.40	0.76	0.16	34.21
1933	1.43	0.52	6.43	4.89	17.63	1.15	0.12	0.88	1.45	0.78	0.16	33.88
1932	1.42	0.54	6.41	4.88	16.96	1.05	0.15	0.85	1.40	0.76	0.15	33.05
1931	1.43	0.51	5.97	4.85	16.25	0.92	0.14	0.74	1.22	0.71	0.17	31.49
1930	1.26	0.45	5.49	4.65	15.26	0.78	0.13	0.97	1.12	0.68	0.20	29.63
1929	1.07	0.43	4.89	4.37	14.40	0.66	0.11	0.82	0.94	0.58	0.17	27.28
1928	1.14	0.48	5.26	4.52	15.47	0.67	0.13	0.80	0.85	0.58	0.17	28.91
1927	1.08	0.47	5.09	4.56	16.09	0.64	0.11	1.10	0.89	0.58	0.19	29.64
1926	1.02	0.44	4.93	4.52	16.60	0.62	0.13	1.11	0.86	0.71	0.19	29.71
1925	1.10	0.46	5.20	4.44	17.23	0.67	0.14	1.13	0.91	0.68	0.21	30.81
1924	1.09	0.49	5.29	4.53	17.19	0.64	0.16	1.11	0.91	0.63	0.21	30.99
1923	1.08	0.50	5.25	4.39	17.47	0.63	0.13	1.12	0.88	0.60	0.22	31.07
1922	1.06	0.51	5.41	4.33	17.90	0.64	0.14	1.34	0.89	0.61	0.22	31.83
1921	1.11	0.55	5.85	4.57	19.95	0.66	0.15	1.94	0.90	0.64	0.27	35.31

Includes: Panhandle & Santa Fe Railway
Gulf, Colorado & Santa Fe Railway
Kansas City, Mexico & Orient Railway
Kansas City, Mexico & Orient Railway of Texas

SIGNAL SYSTEM TWO — ASPECTS AND

RULE	ASPECT	NAME
281		CLEAR
282		ADVANCE
283		DIVERGING-CLEAR
285		APPROACH
286		DIVERGING-APPROACH
290		RESTRICTING
291		STOP AND PROCEED
292		STOP

RESTRICTED SPEED - A SPEED THAT WILL PERMIT STOPPING SHORT OF ANOTHER TRAIN, OBSTRUCTION OR SWITCH NOT PROPERLY LINED, BUT NOT EXCEEDING 15 M.P.H.

INDICATIONS — SIGNAL SYSTEM TWO

INDICATION	RULE
PROCEED.	281
PROCEED; APPROACH NEXT SIGNAL NOT EXCEEDING 40 M. P. H. FOR PASSENGER OR 30 M. P. H FOR FREIGHT TRAINS.	282
PROCEED NOT EXCEEDING 40 M.P.H FOR PASSENGER OR 30 M.P.H. FOR FREIGHT TRAINS THROUGH TURNOUT	283
PROCEED PREPARING TO STOP AT NEXT SIGNAL; IF EXCEEDING MEDIUM SPEED, IMMEDIATELY REDUCE TO THAT SPEED.	285
PROCEED NOT EXCEEDING 40 M.P.H. FOR PASSENGER OR 30 M.P.H. FOR FREIGHT TRAINS THROUGH TURNOUT: APPROACH NEXT SIGNAL PREPARING TO STOP, IF EXCEEDING MEDIUM SPEED, IMMEDIATELY REDUCE TO THAT SPEED.	286
PROCEED AT RESTRICTED SPEED.	290
STOP; THEN PROCEED IN ACCORDANCE WITH RULE 509	291
STOP.	292

MEDIUM SPEED — A SPEED NOT EXCEEDING ONE-HALF AUTHORIZED SPEED BUT NOT EXCEEDING 30 M.P.H.

Exhibit 7 Pgs #16

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