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GRAPHS AS A MANAGERIAL TOOL: A CASE STUDY OF DU PONT's USE OF GRAPHS, 1904-1949

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Today graphs are an accepted feature of the managerial world. They appear in reports, memos, presentations to colleagues or clients, annual reports, sales brochures, and the pages of business magazines and newspapers. They are even part of the popular image of business; the executives pictured in cartoons frequently sit in front of large wall charts of sales or profits. Moreover, microcomputers with graphics software promise to make graphs even more common by making graphs in minutes that an art room would have taken hours to produce. As powerful tools for communicating, analyzing, and monitoring the massive amounts of data managers deal with daily, graphs are here to stay.

Although we take them for granted now, graphs and charts appeared on the managerial scene relatively recently. They have served as managerial tools only since the very end of the nineteenth century and the beginning of the twentieth. As businesses grew and evolved structurally during those years, the managers who came to manage the enterprises needed better ways of handling larger quantities of data. At the same time, the capabilities of graphics were just beginning to be understood beyond circles of statisticians. In combination, these two factors led businesses to adopt graphical tools for managerial uses.

The evolving use of graphs at Du Pont[2] is an interesting example of this trend. In 1904 the executive committee considered

but rejected the notion of using graphs to aid them in handling newly increased amounts of data resulting from their consolidation of much of the American explosives industry. By the early 1920s they had developed a particularly interesting and comprehensive system of graphs and a novel display mechanism -- the chart room -- for presenting return on investment data used to monitor and control the newly diversified corporation. Thus the committee went from rejecting graphs as an executive tool to embracing them wholeheartedly. This change in attitude resulted, as the following analysis will show, both from an evolving understanding throughout Du Pont of the power and uses of graphics and from changing needs in the executive committee as the company developed from a functional hierarchy to a multidivisional, product-based structure.

This paper, then, will explore the evolution of graphs and charts as managerial tools of communication, analysis, and monitoring at Du Pont during the early twentieth century. To set that development in context, I will begin by briefly sketching the development of business graphics in America and establishing a framework for viewing their use. That background will set the stage for a discussion of the early use of technical and managerial charts at Du Pont as tools of communication and analysis. Finally, I will explore the origin of the chart room around 1920, and the important role it took on as a presentational mechanism closely allied to the executive control system at Du Pont.

Early Business Graphics in America

The visual display of numerical data was well over 100 years old at the time Du Pont started to use graphs, but the visual display of business data on the level of the firm was in its infancy. In his "Historical Development of the Graphical Representation of Statistical Data," Howard Gray Funkhouser asserts that William Playfair first introduced graphic methods for presenting empirical data (as opposed to Cartesian abstractions) in 1786, in his Commercial and Political Atlas. Most early graphs and charts of empirical data were used to represent aggregate statistical data such as census figures, international trade balances, and mortality statistics. Graphics in America continued to be used primarily in this way until the turn of the twentieth century.[3]

In the late years of the nineteenth century and the early years of the twentieth century, however, American engineers and then managers learned to use graphs to facilitate analysis and communication of engineering and managerial data in business. In 1914 Willard C. Brinton, the mechanical engineer who headed the recently formed Joint Committee on Standards for Graphic Presentation, published the first American text or how-to book on graphics aimed at non-technical readers in business and government.[4] He emphasized the value of graphs and charts in communicating information quickly, effectively, and persuasively, as well as their value as an analytic tool to help executives

interprete large quantities of data quickly. Within a few years his book was followed by others, for graphs caught on rapidly in the business world.[5]

The sudden interest in graphs as a tool for management is not surprising in light of two main factors: the growing size and complexity of businesses and the growing interest in systematic and scientific management. The late nineteenth and early twentieth centuries saw a period of growth and structural evolution in American business, as the traditional firm developed into the larger, departmentalized firm.[6] In the growing companies, the minimal amount of data necessary to manage the finances and operations multiplied extraordinarily. The fact that most of Brinton's examples are from railroads and public utilities, the first industries in which large and complex corporations grew up, supports this link. Graphs were one way to compress large amounts of data to make them handleable. The movement to make management systematic and even scientific[7] also seems to have encouraged the use of graphs. In their attempts to increase efficiency, advocates of the new modes of management collected and analyzed types of data never examined before. Here again, charts could help. The first graph of managerial data in the Transactions of the American Association of Mechanical Engineers (the ASME was one of the first professional societies to deal with managerial issues) was in an article by Henry R. Towne, an early proponent of systematic management. In it, after arguing that the ASME should systematically address questions of

management, as well as engineering issues, he addressed the management issue of labor costs. He used a graph to portray the reduction of labor costs under a special system of contract and piece-work.[8] We see this link between systematic management and graphic tools in Brinton's work, as well. For example Gantt charts, Brinton points out, were specifically designed by H. L. Gantt to gauge "progress made in training employees under scientific management."[9] In this period of growth and systematization, then, the time was ripe for graphics to emerge as a business tool.

As Brinton's pioneering book illustrates, graphs in management quickly came to be used in many of the ways we use them today. As managerial tools then and now, graphs can function in at least two different (but not always distinct) ways: as tools of communication and as tools of analysis. We can break down these categories even farther. As tools of communication, graphs can serve mainly to compile, compress, and present data, or they can play a more active role in persuading the viewer. As tools of analysis, they can serve to discover problems, or to solve them. In a combination role, they can serve as tools of monitoring and control, tracing some quantity or relationship over time in order to highlight problems or successes when they occur. A single graph, of course, could serve any or all of these functions depending on the context and the purpose for which it was used. All of these uses are illustrated (though not distinguished or labeled in this way) in Brinton's book. Let us look briefly,

then, at the state of the art of graphics in 1914, using the framework I have just sketched out. This framework will then be useful in viewing the ways in which Du Pont used graphs in the early years of the twentieth century.

In their most basic use as tools of communication, graphs serve to compile and present large quantities of data in a compressed, clear, and readily accessible form -- a capability particularly valued by the busy executive. Brinton suggested their usefulness in this role, although, as we will see, he considered their role as tools of persuasive communication even more important. In his opening chapter, he noted that "In many cases, the graphic method requires less space than is required for words and there is, besides, the great advantage that with graphic methods facts are presented so that the reader may make deductions of his own, while when words are used the reader must usually accept the ready-made conclusions handed to him."[10] Thus he saw the value of graphs to convey data compactly and without prejudice, as well as to save the reader time.

Brinton also discussed some extensive and elaborate systems of graphs to compile and present data, systems that partially prefigure Du Pont's use of graphs in the chart room some six years later. In a chapter entitled "Records for the Executive," he described a system of "curve cards," graphs on small index cards, covering every conceivable statistic, operating or financial, in the company. He suggested organizing the cards, perhaps as many as 4,000 or more for a large company, by department and indexing

them by function. They were supposed to enable a busy executive or board member to master all the important data on that company in a matter of hours.[11] He also pointed out that "It is sometimes desirable to have the chief facts relating to a business plotted on wall charts which are instantly visible in a conference room." Since they were limited by wall space, however, "Wall charts are suitable chiefly to furnish summarized information to directors or other men whose time is limited or who come to an office only at rare intervals."[12] In both curve card systems and wall chart systems of the type Brinton described, the charts served principally as tools of clear and concise communication of data. As the final section of this paper will illustrate, the Du Pont chart room shared many traits with these systems, but went beyond them to make charts the presentational mechanism for monitoring and analyzing the key financial and operational data for the firm.

Although graphs are useful for compressing and conveying information, Brinton viewed their role as tools of persuasive communication as even more valuable: "In many presentations it is not a question of saving time to the reader but a question of placing the arguments in such form that the results may surely be obtained."[13] Today this persuasive use is perhaps the most frequent; consultants, sales managers, and of course politicians have mastered the art of using graphs not simply to convey data, but to persuade the viewer to a particular point of view by highlighting and sometimes distorting information. In the early

twentieth century the value of graphs as a persuasive tool was just becoming apparent. Brinton began his book by pointing out this value:

> After a person has collected data and studied a proposition with great care so that his own mind is made up as to the best solution for the problem, he is apt to feel that his work is about completed. Usually, however, when his own mind is made up, his task is only half done. The larger and more difficult part of the work is to convince the minds of others that the proposed solution is the best one -- that all the recommendations are really necessary. Time after time it happens that some ignorant or presumptuous member of a committee or a board of directors will upset the carefully-thought-out plan of a man who knows the facts, simply because the man with the facts cannot present his facts readily enough to overcome the opposition. It is often with impotent exasperation that a person having the knowledge sees some fallacious conclusion accepted, or some wrong policy adopted, just because known facts cannot be marshalled and presented in such manner as to be effective.

Graphs, he went on to say, are frequently the most effective way to present an idea to a reluctant audience.

Brinton saw that, in addition to these communicative functions, graphs also had analytic functions. They could help find an answer, or at least identify a problem, as well as communicate that answer. In their analytic capacity, graphs could replace sophisticated mathematics, which few businessmen of the period could use, as a way of approaching a problem. Brinton illustrated, for example, a graphic method of analyzing the costs a company incurred in handling orders of various sizes. He commented that this technique was "an application of the cumulative frequency curve to a class of work which would be extremely difficult to understand if the graphic method were not used."[14]

While graphs did not always solve an otherwise intractable problem, they often highlighted relationships and trends in a more convenient and accessible manner than tabular data:

> "It is in just such problems as these, where a number of different sets of data must be compared, that curves have tremendous advantage over presentation by columns of figures. A man must be almost a genius to grasp quickly the facts contained in several parallel columns of figures, yet anyone of average intelligence can interpret correctly a chart which has been properly made for the presentation of curves."[15]

Carefully constructed graphs could also identify problems or successes by visually highlighting patterns or changes in a trend. This function, he noted, could sometimes be enhanced by using graph paper with a logarithmic scale on the vertical axis, or by plotting cumulative curves. He illustrated, for example, a cumulative curve of the scheduled production of a plant, with actual output plotted onto it at regular intervals.[16] (See Figure 1.) The graph highlighted deviations from schedule. In this use, graphs helped identify relationships or problems without actually revealing the cause of the relationship or the answer to the problem. They served as a spur to further analysis, which might or might not be graphic.

By 1914, then, graphs were not widely used, but the most prominent expert on them saw many possible functions for them. Graphs could function as tools of communication, to present or persuade, or as tools of analysis, to solve or identify problems. These categories were not, of course, mutually exclusive, though Brinton did not fully present the possible combinations of uses. Graphs can both present facts and reveal relationships or trends,

for example. When graphs serve these two purposes and are regularly maintained and extended over time, they function as a monitoring system. A few years later, the Du Pont chart room would provide a brilliant example of this dual function, one that exceeded in power and extent any use of graphs demonstrated by Brinton. Before Brinton's book even appeared, however, Du Pont had begun experimenting with more limited uses of graphs.

Early Use of Charts and Graphs at Du Pont

In the early years of the twentieth century, Du Pont began to use graphs to communicate and analyze data. The earliest extant graphs were used to convey technical and operational data and to serve as the basis for simple analysis. Gradually graphs came to be used for persuasion, problem solving, and monitoring; moreover, financial data joined technical and operational data in being subjected to graphic treatment. By 1919, the year in which the chart room was probably conceived, the company had developed a considerable set of graphic tools.

Although the earliest graphs remaining in the Du Pont archival collection at Eleutherian Mills Historical Library[17] are from 1907, graphs were first proposed but rejected as a managerial tool in 1904. In 1902 the company underwent massive organizational changes when members of the older generation of du Ponts then running the company died or retired and a younger generation, the cousins Pierre, Alfred, and Thomas Coleman du Pont took over the company.[18] They immediately went about

consolidating the majority of the nation's powder industry (previously interconnected financially but fragmented operationally) into a new, much larger operating company. In 1904, Alfred Chandler and Stephen Salsbury tell us, graphs were suggested but rejected as a method of compiling and displaying the massive amounts of data, especially sales data, then flooding in on the company's new Executive Committee.[19]

At that time the suggestion would have been very innovative indeed, given the fledgling state of business graphics in America. Unfortunately, no graphs remain from this period, nor has the Executive Committee's discussion of the issue survived. We know only that the suggestion was rejected as likely to oversimplify data. At this point the Committee felt they must deal with the figures themselves, not with any visual representation, however much more quickly such a representation might be grasped. Over the next decade and a half, as their needs changed and as they came to understand the power of graphs, they were to reverse themselves completely.

The earliest surviving graphs, dated a few years later, come from two major sources: the Experimental Station and the High Explosives Operating Department.[20] The Experimental Station was an early research and development facility, set up shortly after the 1902 reconstitution of the company. Its first graphs were, predictably, visual representations of technical data from experiments, rather than operational or financial data. Nevertheless, they illustrate the use of graphs for analysis and

communication at Du Pont. In a 1907 report on the consumption of fuels at a charcoal plant, for example, we find two large, blueprinted graphs with two curves (charted lines) each.[21] The graphs, analytic in purpose, reveal clearly the relationship between the three variables -- fuel, temperature, and time -- in the experiment. The double sets of curves bypass sophisticated mathematics to arrive at and demonstrate that relationship. The blueprint format, while large and unwieldy, allowed the charts to be reproduced for inclusion in several copies of the report. Thus the charts communicated the analysis to others, as well.

This graphic technique of analyzing and communicating the results of experiments was relatively unusual to the Experimental Station at that point; only two years later Irenee du Pont, Director of the Development Department, recommended increased use of graphs to the next head of the Experimental Station:

> "This is to suggest a wider use of plotting paper for indicating the results of sundry experiments. For instance, in the black powder investigation, if a plot be made, showing the time of wheeling or the total number of revolutions as abcissae, and velocity as ordinates, the results are shown much clearer than by a simple tabulation. This method of quickly arriving at generalization has been found to be advantageous."[22]

Thus graphs must still be used relatively rarely to warrant such an injunction from upper management.

Irenee's recommendation is also interesting in revealing his reasons for advocating the use of charts. First, he says, they compile and present the results in a clearer form than a tabulation does. Equally importantly, he points out that the graph is a means of "quickly arriving at generalization" -- that

is, a method of analysis. By plotting the data the experimenters themselves could analyze it for its meaning; they could also use the graphs to communicate that meaning more clearly to others.

Irenee's thoughts on the subject of graphs are interesting for a third reason, as well: Irenee would be president of the company over 10 years later when the chart room was established. This passage reveals that he had long been enthusiastic about graphs and their possibilities as tools of analysis and comunication.

Even more evidence remains on the evolving use of graphs by superintendents in the High Explosives Operating Department (HEOD). The HEOD, which produced high explosives such as dynamite, was the largest of the three explosives departments during peace time. It grew out of the Repauno Chemical Company, a company started by a member of the du Pont family and partially owned by the pre-1902 Du Pont company. In the 1902 restructuring of Du Pont and the explosives industry, Repauno became the nucleus of Du Pont's new HEOD. Its director, Hamilton Barksdale, was devoted to systematic management and aggressive in his pursuit of efficiency.[23] Here graphs were used chiefly to chart operational, rather than technical, data. This department may have started the practice of using graphs as the basis for group (rather than individual) analysis at Du Pont, a practice that was to become an integral part of the chart room's operation.

HEOD started using graphs at least as early as the

Experimental Station, but from the beginning used them for more operational, less technical, purposes. During that period of consolidation, Thomas Johnson has demonstrated, the HEOD and the other production departments, in conjunction with the corporate office, adopted managerial accounting systems to collect and report information both to the Executive Committee above and the the mill superintendents below.[24] At first only occasionally, but eventually more frequently, financial and operating information reached the superintendents in graphic form.

The earliest reference to graphs that I have found in HEOD records is an August 12, 1907 circular letter from the HEOD main office to all HEOD superintendents: "We hand you herewith graphic statement of Labor Cost per 100 shells for quarterly periods July 1904 to July 1907, which is interesting particularly because showing a very marked improvement for nearly all works."[25] Clearly this chart had a different purpose than those first used at the Experimental Station. The figures visually represented are cost accounting figures, not experimental results. They center on the issue of cutting labor costs. The chart (which unfortunately did not survive with the circular) was used to present some operational data, but was indirectly persuasive, as well. The encouraging results were, no doubt, intended to urge the superintendents on to even better efforts.

The chart was also, however, intended to be the basis for more intensive analysis and discussion. The circular goes on to say, "Those Superintendents who attend the Superintendents'

Meeting will please bring their copy of this statement with them." These superintendents' meetings were used to bring together the superintendents of the many high explosives plants, both those absorbed in the 1902 reorganization of the industry and those constructed since then, to discuss methods of plant management throughout the expanded Du Pont organization. Barksdale hoped these meeting would produce more efficient and consistent management practices. The main office sent the chart and accompanying materials home with the superintendents before the meeting to allow them to study it more carefully. The details emerging from this study would be discussed at the meeting.

Other graphs were likewise occasionally mentioned in the circular letters and bulletins[26] or in the skeletal minutes of the HEOD superintendents' meetings before 1909, but the references do not tell us very much without the graphs themselves. From 1909 to 1914, however, the HEOD printed or duplicated complete minutes for each superintendent at the meetings. They included papers presented at the meeting, charts accompanying papers, and transcriptions of all discussions.[27] These minutes show a trend toward increasing use of graphs to analyze, communicate, and monitor operational factors. The four meetings from 1909 to 1911 (with two meeting in 1909) had three, zero, one, and two graphs, respectively. In the 1912 meeting, however, the total jumped to ten, and it doubled to twenty in 1913. In 1914, before the war interrupted the series, the total leveled off at nineteen. This growth reveals their increasing fascination with graphic

techniques.

The graphs themselves varied in subject from quasi-technical to purely operational. Figure 2, from the 1913 meeting, for example, plotted average monthly nitroglycerine yield for the five plants with the highest yield, the five with the lowest yield, and the average at all the plants.[28] Although nitroglycerine yield had to do with the technical process of dynamite making, the graph portrays operational, not experimental, data. It had clear implications for control of materials costs. Figure 3, from the 1910 meeting, was even more directly focused on cost control.[29] It compared labor costs in dynamite box packing for the various company plants. Both of these graphs revealed the types of management accounting data Johnson discusses. Both served as the basis for discussion aimed, ultimately, at reducing cost and increasing efficiency at all of the plants.

Both the graphs themselves and their use in the meetings as revealed by the transcribed discussions point to a main purpose more as an analytic tool than a persuasive one, though they certainly functioned as both. The graphs represented data clearly in such a way as to highlight points for constructive discussion, rather than just to convey the information or to prove a specific point. In this matter, the use of these charts anticipated the Executive Committee's later use of the Chart Room. The discussions that followed the presentation of the graphically illustrated HEOD papers generally centered around reasons for trends, or comparisons of technical methods and of operating procedures at

the various plants. Figure 2, for example, highlights a similarity in the three curves, particularly the dip in July. The discussion focused on the technical reasons for that operational fact. The superintendents debated the possible technical causes of the slump in nitroglycerine yield and possible ways to combat the slump and thus improve operating statistics.

The discussion transcribed in the minutes reveals one more interesting detail about HEOD's use of graphs as analytic tools. In response to speculation about the role of the July heat in the decreasing yield, F. B. Holmes said, "I did one other thing -- I plotted average temperatures by months for about 22 years, and they show that the monthly temperatures increased from January to July, so that the curve for temperature starts and goes up all the way to July. The yields go up as far as June and drop off in July in spite of the slight increase in temperature, so it can't be temperature alone, and probably not humidity." In his own work on the issue, Holmes clearly used graphs to analyze, not just to present data.

Many charts in papers for the Superintendents' meetings served as tools for monitoring as well as analyzing operations, that is, for compiling and analyzing data over time, without focusing on a specific problem at a specific time. Although no evidence suggests the existence of any extensive system of card charts such as that recommended by Brinton, evidence does suggest that some individual charts were kept up over a period of time to monitor operational performance in

certain areas. In the 1914 Operating Reports of the Chemical Department, for example, almost all of the graphs repeated exact chart formats from the 1913 Operating Reports, but with more recent data.[30] That is, certain operating facts such as the efficiency and cost of important raw materials were graphically monitored from year to year, regardless of whether major changes had occurred. Such monitoring charts would, of course, highlight changes when they occurred, and prompt close analysis of potential problems.

Charts were used at Du Pont for monitoring performance on the level of the individual plant, as well. In the minutes of meetings at the Carney's Point plant, we find references to maintaining certain curves and starting new curves. These curves were apparently updated weekly. Sometimes the curves showed little, as in the June 14, 1917 report, in which the minutes commenting on the curves record that, "Taking the plant as a whole, there is practically no change from the results as given in last week." At other times, the graphic reports are more interesting, as in this November 8, 1917 discussion of the "Safety Curve": "Curve is not quite as good as it was during the first nine months of the year. This should be borne in mind and efforts made to keep it at a low point."[31] This use of charts to monitor performance, rather than simply to study unusual developments, reflected the goals of the evolving managerial accounting system and prefigured the chart room's similar function.

The HEOD's fledgling Safety Division, under L. A. de Blois, introduced a strong persuasive element into the use of charts at HEOD Superintendents' meetings, while using them for analytic purposes as well.[32] A graph of the "Annual Number and Cost of Injuries," for example, was certainly intended to persuade the superintendents of the importance of de Blois's work and to lobby for increased attention to safety. Elsewhere in the accompanying paper he referred to average statistics for 1907-11: "Surely the avoidance of 16 deaths, 255 non-fatal injuries and an attendant loss of $17,000 a year is worthy of study and preventive measures, if the success of such efforts proves in proportion to their expense."[33] He was clearly still selling his program to the superintendents and higher management. Other charts, however, seem analytic as well as persuasive. In the same report he presented a graph plotting a curve of the number of non-fatal and fatal injuries on the same chart with curves of the number of payroll employees and pounds of powder packed, all over five years. This graph served as both an analytic tool and a communicative one. He could discover and communicate to the meeting the relationship -- or, in this case, the surprising lack of relationship -- in order to provoke further discussion of causes and effects. He refined his graphic analysis the following year by plotting injuries against time of year, day of week, and time of day. He seemed to prefer graphic analysis to numerical analysis and certainly preferred to communicate his information that way.

The Safety Division apparently led the way in using graphs to communicate with the payroll employees, as well. In a 1914 circular letter, H. H. Haskell, then head of HEOD, mentioned that someone (surely de Blois) had suggested plotting injury figures on a large scale and posting the graph on employee bulletin boards to draw attention to it.[34] By then, graphs must have been common enough to warrant the assumption that the workers could understand them. The graph was obviously intended to motivate the employees to improve their safety record. Du Pont continued to use graphs in publicizing the safety issue throughout the first half of the twentieth century. A 1940-41 photograph of a Du Pont plant pictures a huge graph of injury statistics mounted on the roof.[35]

Thus far I have concentrated on the technical and operational charts of the Experimental Station and the HEOD. During World War I, the Treasurer's Department used graphic techniques to compile and analyze financial data. For example, the office used a series of layered charts to present the ongoing and complicated financial relations between Du Pont Engineering Company (a financially separate entity created by splitting off the company's Engineering Department for the duration of the war) and the U. S. government in building new plants for wartime production of needed gunpowder and explosives.[36] Most of the charts discussed so far have been operational; these are purely financial. The photostats of the charts show that at least by April 1918, and probably earlier, they charted week by week statements of government balances. In a

complex layered chart they graphed, as percentage of normal cash advance, such categories as U. S. government accounts receivable, paid vouchers in Engineering Department's hands, and cash in banks. Thus the graphs, prepared by the Du Pont Treasurer's Office for executives of the two Du Pont companies, made visual and clear the complex and changing financial relationships that would have been hard to follow when seen in numerical form.

By this period, the Treasurer's Department was using graphs extensively. A set of large graphs (about 18" by 12") marked "Treasurer's Book Diagrams" were used to display information on many different aspects of finances and raw materials purchasing.[37] These charts, reminiscent of Brinton's graph of scheduled versus actual production, show forecast, actual, and revised forecast figures for each quantity, usually in both monthly and cumulative forms. The financial charts concern such quantities as total receipts, advances to subsidiary companies, undistributed expenses, net working capital, and so on. Other charts show the values, purchases, consumption, and supply on hand of six important raw materials, information likely to be used in purchasing. Thus these graphs allowed the Treasurer's Department to monitor certain quantities and observe their deviations from forecast. How the graphs were used (whether displayed for a group or passed around to individuals one at a time) is not clear. In their scope and comprehensiveness, as well as their use of forecasted and actual figures, these charts may be the closest graphic precursors of the chart system soon to be established in

the chart room.

Du Pont, then, used graphs increasingly during the pre-war and war periods. In fact, graphs had become common enough that the General Chemical Division had investigated various sizes and grades of cross-section paper, "in an attempt to find a suitable size to be used with letters and weekly reports."[38] These graphs were used for a variety of managerial purposes related to the efficient and safe operation and financial management of the company. As tools of compilation and presentation, graphs presented data clearly and concisely. Charts were used to communicate persuasively with the superintendents, as in talks aimed at convincing them of the importance of safety, and with the employees, as in the public charts on plant safety records. As tools of analysis, graphs helped managers analyze relationships critical to operations. When used for group analysis and monitoring, graphs communicated data to an audience in a form intended to highlight information and provoke analysis, whether of operational or financial data. The subject matter could be a deviation that deserved close analysis, or simply routine data that served as the basis for monitoring and discussion. This monitoring function was most clearly related to the use of graphs in the chart room that was soon to be established.

The Evolution and Use of the Chart Room

Although it was established in the years immediately following World War I, the chart room was shielded from public view for almost three decades. At the 1949 annual meeting of the American Management Association's Financial Management section, T. C. Davis, Treasurer of Du Pont, described both their executive control system and its presentational mechanism, the chart room. Within a year of Davis's presentation to the AMA finance committee, Fortune magazine revealed the existence of the chart room to a much larger public, as well. After 30 years of relative secrecy, the chart room, in which graphs played a key role in presenting and monitoring vital control statistics, was finally public knowledge.[39]

What was the chart room? It was an unusual room on the 9th floor of the Du Pont Wilmington office complex, the floor housing the executive offices. (See photograph.) The ceiling of half of this room was covered with a complex system of tracks and switches adapted from equipment designed to move heavy bails of hay in barns. From these tracks hung metal frames holding large (30" x 40") charts that represented each department's contribution to the elements of a complex return on investment (ROI) formula. The tracks allowed any of the 350 such charts in the room to be brought up to the center front position where it could be viewed by the semi-circle of Du Pont executives making up the Executive Committee (or, less frequently, other groups such as the Finance

Committee and the Board of Directors). At least once a month and sometimes as often as once a week the Executive Committee met in the chart room to view the charts for one or more divisions of the multidivisional corporation.[40]

The chart room, which Fortune called "uniquely Du Pont," provided the presentational mechanism with which the Executive Committee monitored the financial and operational health of the company. As others have clearly demonstrated, the ROI system on which the charts were based played a critical role in Du Pont's control and development of the vast resources amassed during the first world war and was well suited to the decentralized divisional form that the company adopted in 1921.[41] Graphs, so successful in other uses at Du Pont, were a particularly appropriate presentational mechanism for this control system. Moreover, the particular way in which the charts were used in the chart room enhanced their effectiveness. The origin of the chart room serves as an appropriate starting place for examining the role it came to play.

In the decades since its establishment, Angus Echols, then Assistant Treasurer, has more than once told his story of the chart room's origin, a story that is revealing even if colored by the intervening years.[42] At the time, he was responsible for supplying a great deal of information to the Executive Committee for its weekly meetings. Recognizing that the committee members were not reading all of the documents provided to them, he set out to demonstrate that fact. He pasted together several pages in

each committee member's set of papers passed out in advance of a meeting, and waited through the meeting a few days later to see if anyone would comment on the glued pages. When no one did, he used this demonstration of the committee members' inability or unwillingness to handle the large amounts of economic data to argue that that data must be presented visually at each meeting, rather than in lengthy documents before the meetings. Experience with graphs at Du Pont was extensive enough at that point that such a suggestion no longer seemed shocking, as it had in 1904. Out of that incident (according to Echols's story) grew the chart room.

The precise dates of this incident and of the subsequent creation of the chart room are unclear. When T. C. Davis revealed the chart room's existence to the AMA Financial Management Group in 1949, he stated that the chart system was conceived and inaugurated in 1919.[43] While a chart series centering on the ROI formula was clearly established in 1919, evidence seems to suggest that the chart room itself, with its overhead track system, was probably not set up for another two or three years. Internal documents from 1919 and 1920 reveal that charts were maintained, but were distributed to committee members rather than displayed in a permanent location. The Treasurer's Office, for example, set guidelines for circulation to prevent the confidential data from getting out.[44] Meanwhile, the "General Statistical Committee" was formed (with Angus Echols representing the Treasurer's Department) to standardize the "forms and reports,

used in the provision of data for our Forecasts and our executive series of diagrams."[45]

The earliest unequivocal evidence of the chart room's existence as a permanent fixture dates from early 1922, soon after Du Pont's transformation from a centralized structure into a decentralized, multidivisional structure in 1921. By 1922 the chart room clearly existed and was functioning in Room 9004 of the Du Pont office complex -- the floor with all of the executive offices. On March 22, 1922, W. S. Carpenter, the new Treasurer, announced an access policy for the room to guard the confidentiality of the information.[46] By at least September, 1922, the system was so routinized that the Treasurer's office had begun sending out a mimeographed form (with dates filled in by hand) to announce that the data from the preceding month was plotted and on display in the chart room.[47] Since the form requested advance notice of Executive Committee meetings to be held in the chart room, we know that use had not yet settled into the once a month pre-scheduled viewing adopted sometime before 1949. Nevertheless, the chart room had become a part of the executive routine at Du Pont.

Why, we may ask, did the Executive Committee turn so wholeheartedly to graphs at this time, after rejecting them in 1904? Echols's story suggests one reason: the Executive Committee members were suffering from what we now might call "information overload." This explanation seems particularly plausible in light of the huge quantities of information flowing in at this time.

Even before the enormous growth of the war years, the quantity of information flowing up through the system was overwhelming. To take just one example, the 1911 annual report of the Experimental Station was 147 pages long -- and had no executive summary. This problem got so severe well before the war that at one point a Reports Committee was set up essentially to abstract the reports sent to the Executive Committee. Later, in 1914, T. C. du Pont was forced to establish a new form of departmental reports which included a "synopsis in brief" (what today would be called an executive summary).[48] Moreover, the management accounting system used at this period, as Thomas Johnson has demonstrated, still left many operating decisions in the hands of upper management, rather than delegating them to lower levels.[49]

Thus the Executive Committee had long suffered from information overload. The huge growth of the war years, added to the diversification that began during the war and gained momentum at the end of the war, must have made that overload unbearable. Charts could improve the situation by compiling and condensing into a single visual display data that took pages of text and tables to convey, and at the same time making the implications of the data clearer. This concept of information overload, then, helps explain the need to turn to a graphic medium during this general time period.

But the critical role in the executive control system that the chart room took on so quickly and kept so long takes on additional meaning in light of the shift to a multidivisional

structure in 1921. The chart room became such an important mechanism to Du Pont not just because it used graphs, but because the graphs were carefully constructed around the return on investment control system to permit the Executive Committee to monitor and evaluate the activities of each of the company's newly created product divisions, without becoming involved in the operation of them. To understand the connection between the chart room, the ROI system, and the multidivisional structure, we must look at developments in the company as a whole and in the Treasurer's Department in particular during the war years.

The Treasurer's Department had been developing more and more sophisticated data-gathering and statistical procedures for monitoring present financial conditions and forecasting future ones.[50] In particular, they sought ways to coordinate the allocation of funds, a task that became more challenging as the business grew. During the war years F. Donaldson Brown developed an effective way of carrying out this task -- a formula for figuring return on investment. This formula (see Figure 4)[51] became the centerpiece of the chart system. It related rate of return to its component parts: turnover and earnings (or profit on sales). These, in turn, were broken down into further components, as the chart illustrates. Thus he established the relationship of each major financial and operating statistic to the all-important final measure, return on investment. "The significance of Brown's formula," Chandler tells us, "was that it provided executives at both central and departmental headquarters with an accurate

standard with which to appraise each operating unit's performance, to locate the sources of deficiencies and inadequacies, and to change and adjust present plans and policies." It provided a way of linking unit operating data to the financial performance of the company.

This financial tool became even more crucial in the period of post-war diversification. As Thomas Johnson has pointed out, "[D]iversification by centralized companies entailed burdening top management with a voluminous and complex flow of internal communications."[52] The additional communication and information demands that diversification created undoubtedly contributed to the information overload Echols noted. Du Pont struggled with this problem for two years, and finally, in September of 1921, devised a multidivisional organizational structure to decentralize responsibility for operations along product lines.[53] In this structure, each product line formed an autonomous profit center or division (still called a department at that time) under a general manager. That general manager was responsible to the Executive Committee for the performance of the division. Donaldson Brown's ROI system was particularly well suited to this new structure; with it the Executive Committee could evaluate the performance of each division over time and in comparison to other divisions. Moreover, they could do so without ever becoming involved in its operations. The ROI control system "reinforced top management's centralized control while freeing it from having to consider details pertaining to a division's

decentralized operations."[54]

Thus when Angus Echols reportedly demonstrated the need for a different medium for presenting data to the Executive Committee, these developments were underway. When combined, the graphic mode of presentation and the ROI control system provided both a convenient tool for compiling and presenting data and a complete and consistent system of analysis providing an overview of the vital operations of the multidivisional company. The new role of the Executive Committee helps explain why that group would embrace the graphic medium at this time, after rejecting it in 1904. Under the new system, the Committee was explicitly enjoined from meddling in operating details of the divisions, and restricted to evaluating the general managers and setting strategy and policy. For this sort of work, the level of detail provided by the chart room and its 350 charts was appropriate. The 1904 Executive Committee rejected charts for fear they would obscure detail. The 1921 Executive Committee wanted, in fact needed, to have details obscured beyond a point. They needed to see the business in its broad outlines, not in its minor details. Graphs seemed to provide the perfect medium for tracking ROI data for all the new product-based divisions without burying the committee in details.[55]

By examining how the charts were set up, we can see how well the medium matched Du Pont's needs. In the 1949 AMA presentation T. C. Davis along with Howard L. Hessler, Chart Room Supervisor, described the chart room's operation. For each department, a

series of charts covered each of the boxes in the ROI diagram. Figures 5, 6, and 7 are hypothetical examples that Hessler showed at the AMA presentation to illustrate how the system worked.[56] Based on the left end of the ROI diagram, Figure 5 brings together turnover and earnings as percent of sales to arrive at the ultimate goal: return on investment. Figure 6 is based on the lower right hand boxes of the ROI diagram. It examines cost of sales, breaking it down, as the diagram does, into mill cost, selling expense, freight and delivery, and administrative expenses. Figure 7, from the upper right corner of the ROI diagram, shows working capital broken down into inventories, accounts receivable, and cash.

Each chart, in fact, includes a great deal of information. Figures 5 and 6, we can see, presented actual figures and average figures over several years, then examine the current year in detail. In the current year's chart we get forecasts and actual figures to date, based on different time periods. Figure 7 uses a different type of chart, with cross hatching, to illustrate deviation from standard. Hessler pointed out, also, that tabulated data was frequently shown beside or above the graph in the chart room, in case more detail was needed.

The chart system, then, was an ideal medium for presenting ROI data to the Executive Committee. Conversely, in its compactness and comprehensiveness, the ROI formula provided the ideal analytic framework for the charts. This use of monitoring charts was undoubtedly more effective than the 4,000 card chart

system Brinton mentioned in his 1914 text. Given the ROI measurement used, the Executive Committee could analyze each component, knowing that they were ignoring nothing.

The analytic and presentational purposes of graphs united in the chart room's monitoring system. As T. C. Davis put it, "the primary purpose of reviewing data presented on the charts is to point up the places where further analysis, review and attention may be desirable or necessary."[57] Group analysis of monitoring charts had already served such a function in the H.E.O.D. Superintendents' meetings. That the chart room served that function for the Executive Committee we know from indirect and direct evidence. In the early years of the system, monthly sessions in the chart room were frequently followed by a memo from the Treasurer's Office to the Executive Committee.[58] These memos, based on discussions with the relevant department manager, elucidated questions and issues raised by the Executive Committee. In later years, according to the Fortune article and the AMA presentation, the department's general manager was present to explain any anomalies and to receive orders for any further analysis needed.[59]

This indirect evidence for the chart room's effectiveness as a monitoring mechanism is supported by Davis's own statements, as well. Of the five points Davis listed in favor of this chart system, the first four related directly to graphs as a medium of communication and analysis:[60]

> First, you will note the complete absence of narrative. There is no opportunity for one reviewing the

> figures to bog down under the weight of particular words or phrases which may be chosen by an individual to explain a given variation in operating results.

He saw the charts as a clearer and less confusing (or less prejudicing) method of presenting the data.

> Second, note the comparative ease with which the attention of an entire group can be held to one item at a time.

As anyone who makes frequent business presentations knows, a single, large visual using an overhead transparency, slide, flip chart, or blackboard focuses the attention of a group much more easily than individual papers, charts, or tables handed out to each participant. Thus the large charts were an effective mode of presentation.

> Third, more or less rigid rules govern the assembly of data for the presentation. To the maximum extent possible the data for all periods shown on the charts are on a uniform basis and afford common measurement of performance for all investment lines. If we find that changing conditions require a new approach to presenting any one or more of the chart series, then all the data for the current year and the preceding years are re-set on the new basis.
> . . . . . .
> Fourth, strict adherence to format is observed until such time as it becomes clear that a change would substantially improve the presentation. Then a new format is brought into use, complete at one time, including a re-set for the entire 10-year period.

These two items highlight one of the key elements of the chart system -- its rejection of any overtly persuasive function in charts. In his treatment of management accounting in the early multidivisional firm, Johnson points out that such firms could only be run effectively when the management accounting system "convey[ed] unbiased information about each division to the central office."[61] As Davis's statement suggests, the charts

were set up to eliminate bias that might creep into a written account. The charts could not be manipulated to prove a point. Their form was kept consistent so they truly monitored certain vital signs. This insistence on using graphs to compile and spur the analysis of data, rather than using them to persuade someone to do something, was one of the most important elements in the chart room's success as a mode of presentation. The long-term credibility of the ROI monitoring system depended on insulating it from misuse through incompetence or unscrupulousness. The rules of chart format worked with the rules of data analysis to provide that insulation.

The final measure of the success of this chart system, Davis pointed out in 1949, was the fact that it had lasted substantially unchanged for 30 years (and was to last even longer before its demise at the end of the 1960s[62]). Du Pont continued to use charts in various other ways throughout this period. As Davis said in the question and answer period following his AMA presentation, "We use charts extensively. We use them for every conceivable thing. We employ every device that we can lay our hands on to draw the interest and the attention of the persons whose judgement and decision we desire and need to the focal point."[63] In 1938, for example, they first introduced graphs into the annual report -- clearly a more persuasive use of charts than that of the chart room, but one that had its place, too. But in terms of its importance to the administration of Du Pont as a whole, the chart room with its graphic ROI monitoring system was

certainly the most critical use of graphs. In the chart room, graphs came of age as managerial tools at Du Pont.

NOTES

[1]The research on Du Pont's use of graphs was supported in part by an Eleutherian Mills Historical Library Grant-in-Aid. I am indebted to Dr. Richmond D. Williams, Director of the Eleutherian Mills Historical Library for his suggestions and encouragement, as well as to others at the Library, especially Mrs. Betty-Bright Low and her reference staff, for their help in using the Du Pont collections.

[2]I use the term Du Pont to refer to both E.I. du Pont de Nemours and Company, the parent corporation and, during much of the period treated here, a holding company, and the E. I. du Pont de Nemours Powder Company, the company set up to consolidate most of the American explosives industry beginning in 1904. For an explanation of the relationship between the two companies, see Alfred D. Chandler and Stephen Salsbury, Pierre S. du Pont and the Making of the Modern Corporation (NY: Harper and Row, 1971), pp. 85-93.

[3]Osiris 3 (Nov. 1937), p. 181.

[4]Funkhouser, pp. 323 and 358. Brinton himself also claims that his book is the first such book: Graphic Methods for Presenting Facts (NY: The Engineering Magazine Company, 1914), p. vii.

[5]See, for example, Allan C. Haskell, How to Make and Use Graphic Charts (NY: Codex, 1919); and Karl G. Karsten, Charts and Graphs (NY: Prentice-Hall, 1923).

[6]This trend is explored in detail in Alfred Chandler's works, particularly The Visible Hand: The Managerial Revolution in American Business (Cambridge, MA: The Belknap Press of Harvard University Press, 1977).

[7]Frederick Taylor is the best known figure in the scientific management movement, but the trend towards systematizing management had begun much earlier. For a useful discussion of the early stages of this movement, see Joseph a Litterer, "Systematic Management: The Search for Order and Integration," Business History Review 35 (Winter 1961), pp. 461-476.

[8]Henry R. Towne, "The Engineer as an Economist," ASME Transactions 7 (1885-86), pp. 428-432.

[9]Brinton, p. 54.

[10]Brinton, p. 2.

[11]Brinton, pp. 289-295.

[12]Brinton, p. 306. The example given here and pictured on p. 305 is of swinging-leaf charts on public-service corporations at Day and Zimmerman, Philadelphia consultants. There is an interesting possible influence here. In 1921 and possibly earlier Pierre du Pont, chairman of the board of directors at Du Pont, was in professional contact with Day and Zimmerman over problems at General Motors (Chandler and Salsbury, P. S. du Pont, p. 515), where he was at that point president. He would probably have learned about the Day and Zimmerman wall charts, and may have been influenced by their form, though probably not their content.

[13]Brinton, p. 2. The extended quote that follows is from pp. 1-2.

[14]Brinton, p. 184.

[15]Brinton, p. 107.

[16]Figure 1 is from Brinton, p. 150. See pp. 132-137 for logarithmic curves and pp. 149-163 for cumulative curves.

[17]The archives of the Du Pont Company are housed at Eleutherian Mills Historical Library (EMHL), and all quotations and reproduced graphs are courtesy of EMHL.

[18]Chandler and Salsbury, P. S. du Pont, Chapter 3.

[19]Chandler and Salsbury, p. 133 Unfortunately, the Du Pont Company has since retired or destroyed the Executive Committee minutes referenced in this passage, so no further details of this incident are available.

[20]The collections from the Experimental Station and the High Explosives Operating Department are among the most extensive of the post-1902 collections at EMHL. Graphs may have been used in other departments, the Sales Record Division, for example, at the same time or even earlier, but they do not form part of the collection in EMHL.

[21]EMHL, Accession 500 (Papers of the E. I. du Pont de Nemours & Company), Series II, Part 2, Box #133, file ES-196. Unless otherwise stated, all references to Du Pont Company materials are to EMHL, Acc. 500, II, 2. Box numbers, file numbers, and dates, only, will be listed in succeeding references.

[22]Box #205, file XES-4.

[23]For discussion of the HEOD and Barksdale, see Chandler, Strategy and Structure, pp. 56-57; Chandler and Salsbury, p. 131; and Ernest Dale and Charles Meloy, "Hamilton MacFarland Barksdale and the Du Pont Contributions to Systematic Management," Business History Review, 36 (Summer 1962), pp. 127-152.

[24]H. Thomas Johnson, "Management Accounting in an Early Integrated Industrial: E. I. du Pont de Nemours Powder Company, 1903-1912," Business History Review 49 (Summer 1975), pp. 184-204.

[25]Box #550.

[26]The more technically oriented Bulletin series includes one blueprinted curve of the freezing point of sulpheric acid, but it is from HEOD's Chemical Division: Box #553, Jan.25, 1910.

[27]Boxes #566, #570, #573, #577, #581, #585, and #589.

[28]Box #585, HEOD Supts' Meeting #35, 1913, p. 213. The discussion of this graph mentioned in the next two paragraphs is on pp. 237-240+. The quotation is from p. 239.

[29]Box #573, HEOD Supts' Meeting #32, 1910, p. 197.

[30]Boxes #585 and #589, HEOD Supts' meeting #35 (1913) and #36 (1914).

[31]Box #134, File 196.

[32]See especially Boxes #581 and 585, HEOD meetings #34 (1912) and #35 (1913).

[33]Box #581, HEOD Supts' meeting #34 (1912), pp. 306 and 313. The next example is from p. 307.

[34]Box #551, Book 7, Circular #1151, Aug. 13, 1914.

[35]Box #111, 1940-41 edition of the Engineering Department's Standard Practice Book, Charleston (Indiana) Plant.

[36]EMHL, Longwood Manuscripts Group 10 (Pierre S. du Pont's personal files), file 418, box 4.

[37]Acc. 500, II, 3, box #181, Treasurer's Book Diagrams.

[38]EMHL, Acc. 500,II,2, box #118, file ES-57-B; circular letter dated July 30, 1919.

[39]"How the DuPont Organization Appraises Its Performance," by T. C. Davis, reprinted in Financial Management Series #94 (NY: AMA, 1950), pp. 3-23. See also Lawrence P. Lessing, "The Story of the Greatest Chemical Aggregation in the World: Du Pont,"

Fortune 42:4 (October 1950), pp. 86-118+. The AMA paper is actually in three parts: an opening discussion by T. C. Davis under the title just mentioned; a middle section by Howard L. Hessler, Chart Room Supervisor, entitled "Presentation of the DuPont Chart System Adapted to a Hypothetical Department," starting on p. 8; and "Concluding Remarks" by T. C. Davis, starting on p. 20 and including a transcription of questions and answers following the presentation. In his unpublished doctoral thesis, "Return on Investment as a Measure of Performance" (Harvard Business School, 1958), for which he interviewed several Du Pont executives, William Rotch comments on the secrecy maintained until that presentation.

[40]This description of the Chart Room comes from Davis's AMA presentation; Lessing, p. 169; Rotch's recollections from 1958 interviews; pictures courtesy of the Eleutherian Mills Historical Library; and a Mar. 28, 1983 interview with L. T. Alexander, who from 1931-34 was a clerk in the Secretary's office at Du Pont and helped prepare materials for the Executive Committee and other committees.

[41]Alfred D. Chandler, Strategy and Structure: Chapters in the History of the Industrial Enterprise (Cambridge: MIT Press, 1962), pp. 66-67. Rotch also deals with the ROI formula in his dissertation.

[42]I learned this story from Richmond D. Williams, Director of EMHL, in a memorandum dated February 17, 1983. In this memorandum he explains that the story came from an "interview which I held with Angus Echols, either in the late spring of 1961 or 1962. The purpose of the interviews was to help Professor Alfred D. Chandler gain background for his biography of P. S. du Pont." Prof. Chandler reports having heard Echols tell this story many times, as well.

[43]Davis, p. 4, 21.

[44]EMHL, Acc. 1662, box #18, circular letter from Brown to a list of executives, Oct. 18, 1920

[45]EMHL, Acc. 1662, box #78, communication from F. D. Brown to heads of departments, Aug. 23, 1919.

[46]EMHL, Acc. 500, II, 2, box #8, memo from W. S. Carpenter, Jr., to a list of other executives, March 22, 1922.

[47]EMHL, Longwood Manuscripts Group 10, file 418-18. A Sept. 20, 1922 form announces that figures for August 1922 are plotted and ready to be viewed.

[48]For examples of the committee's work, 1911-1914, see EMHL, Acc. 500, II, 3, box #131, file "Executive Committee." T.

C. du Pont's memo to Heads of Departments, dated Feb. 21, 1914, may be found in EMHL, Acc. 500, II, 3, box # 131, file "Reorganizations."

[49]Johnson, "Management Accounting in an Early Integrated Industrial," p. 196.

[50]Chandler, Strategy and Structure, pp. 66-67. This paragraph draws mainly on Chandler's account. The quotation is from p. 67.

[51]The chart as shown comes from Davis's AMA paper, p. 7. Another version of the chart with minor changes in how the components are designated appears in a company ruling book dated 1907-1928, in EMHL, Acc. 500, II, 2, box #8. The version of the chart that Brown used when he moved to General Motors is shown in Thomas Johnson, "Management Accounting in an Early Multidivisional Organization: General Motors in the 1920s," Business History Review 52 (Winter, 1978), p. 509.

[52]Johnson, "Management Accounting in an Early Multidivisional Organization," p. 491.

[53]Chandler, Strategy and Structure, pp. 104-113.

[54]Johnson, "Management Accounting in an Early Multidivisional Organization," 508. Here stated in relation to General Motors, but the statement applies to Du Pont, as well.

[55]James Garvin, a Du Pont employee, remembers a 1921 communication from Angus Echols to Donaldson Brown about presenting financial data graphically. Part of the reason cited was the need to track all the new product lines. (Personal communication from Richmond Williams, July 27, 1983.)

[56]Davis, pp. 9, 13, and 16.

[57]Davis, p. 20.

[58]EMHL, Acc. 1662, box #78, file C-12. See for example, Mar. 27, June 5, and July 7, 1923.

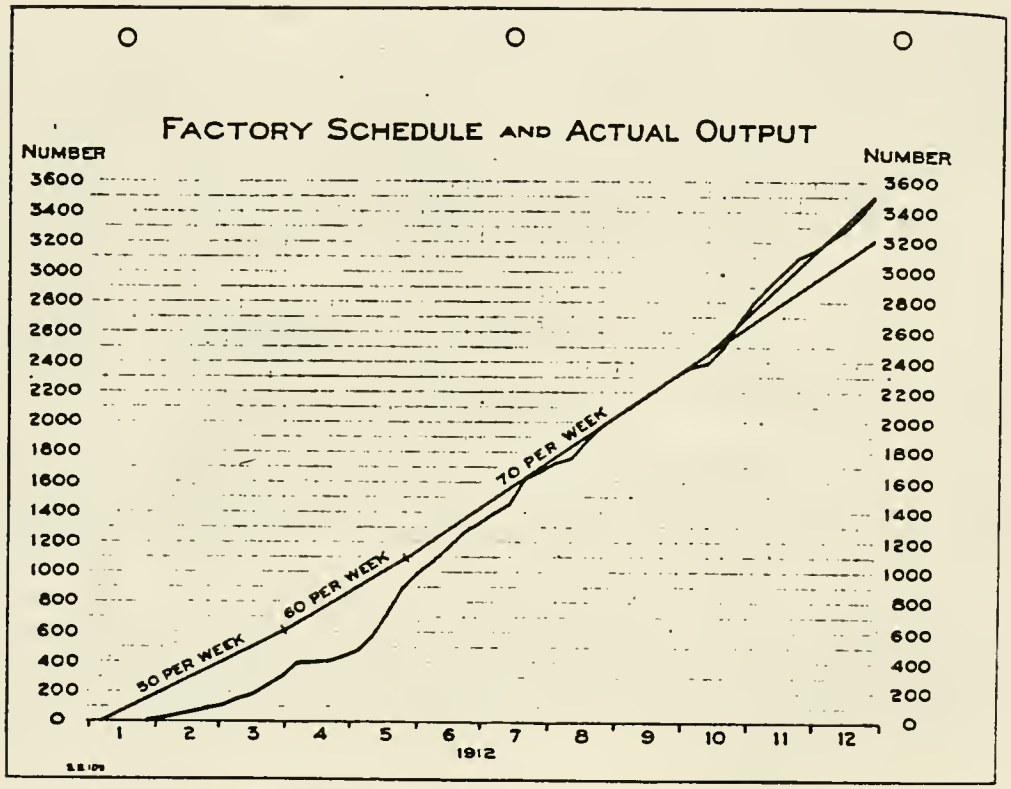
[59]Fortune, p. 169; Davis, p. 20.

[60]Davis pp. 20-21. The fifth point is that the Executive Committee that uses them, not the Treasurer's Office that prepares them, determines the rules for classifying financial data and dividing lines of business.

[61]Johnson, "Management Accounting in an Early Multidivisional Organization," p. 491.

[62]James Garvin dated the demise of the chart room to late 1969. (Personal communication from Williams.)

[63]Davis, p. 22.



Production Schedule and Actual Output of an Automobile Factory for One Year

Figure 1. Graph highlighting deviations from scheduled production. From Willard C. Brinton's Graphic Methods for Presenting Facts.

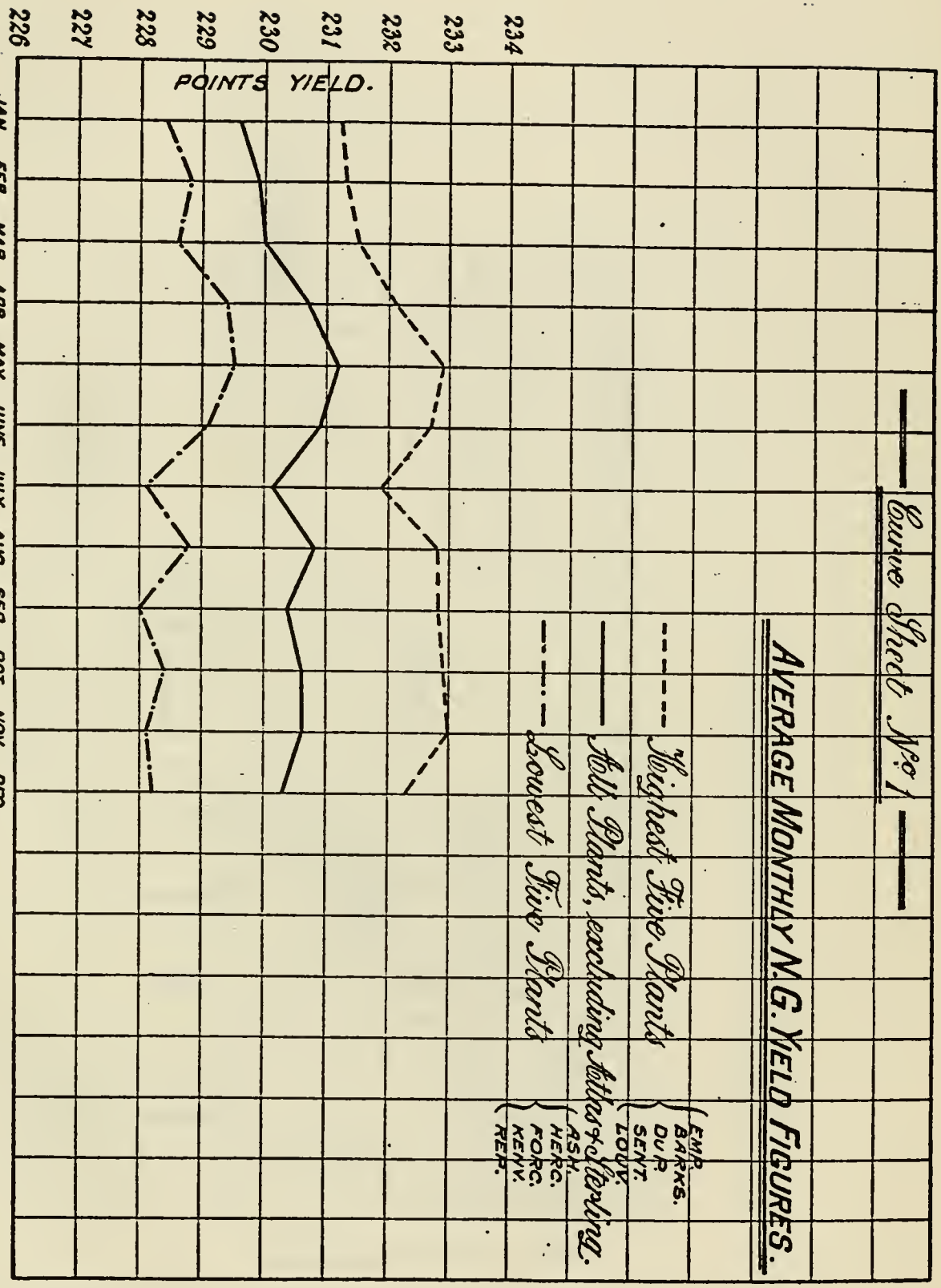


Figure 2. Operational/technical graph from the 1913 HEOD Superintendents' Meeting. Courtesy of Eleutherian Mills Historical Library.

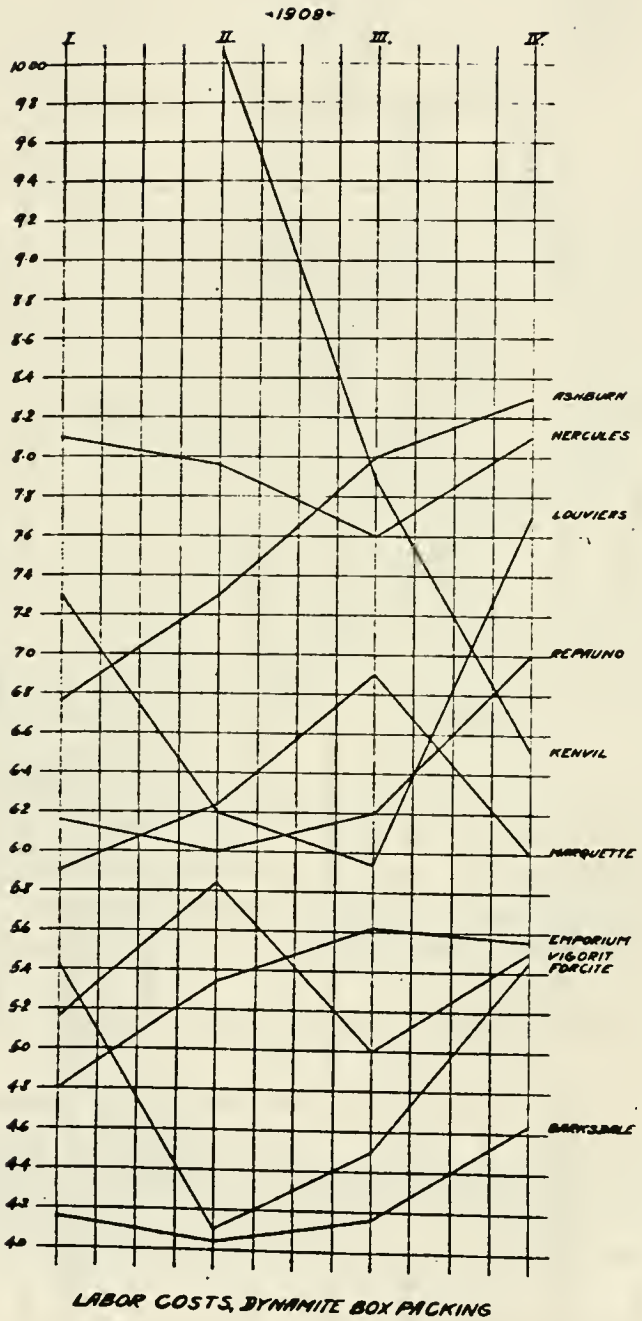


Figure 3. Graph on operational costs from the 1910 HEOD Superintendents' meeting. Courtesy of Eleutherian Mills Historical Library.

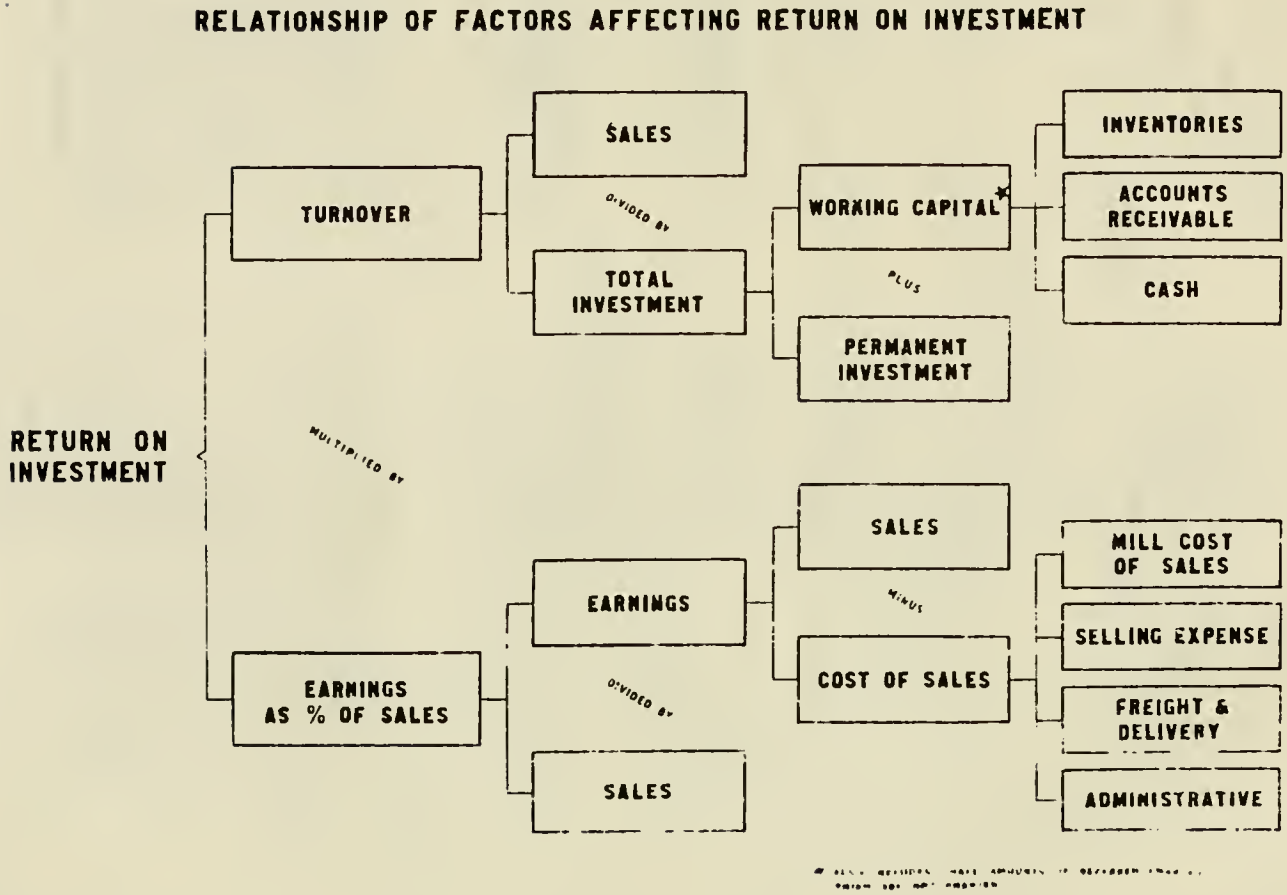


Figure 4. Diagram of F. Donaldson Brown's return on investment formula.

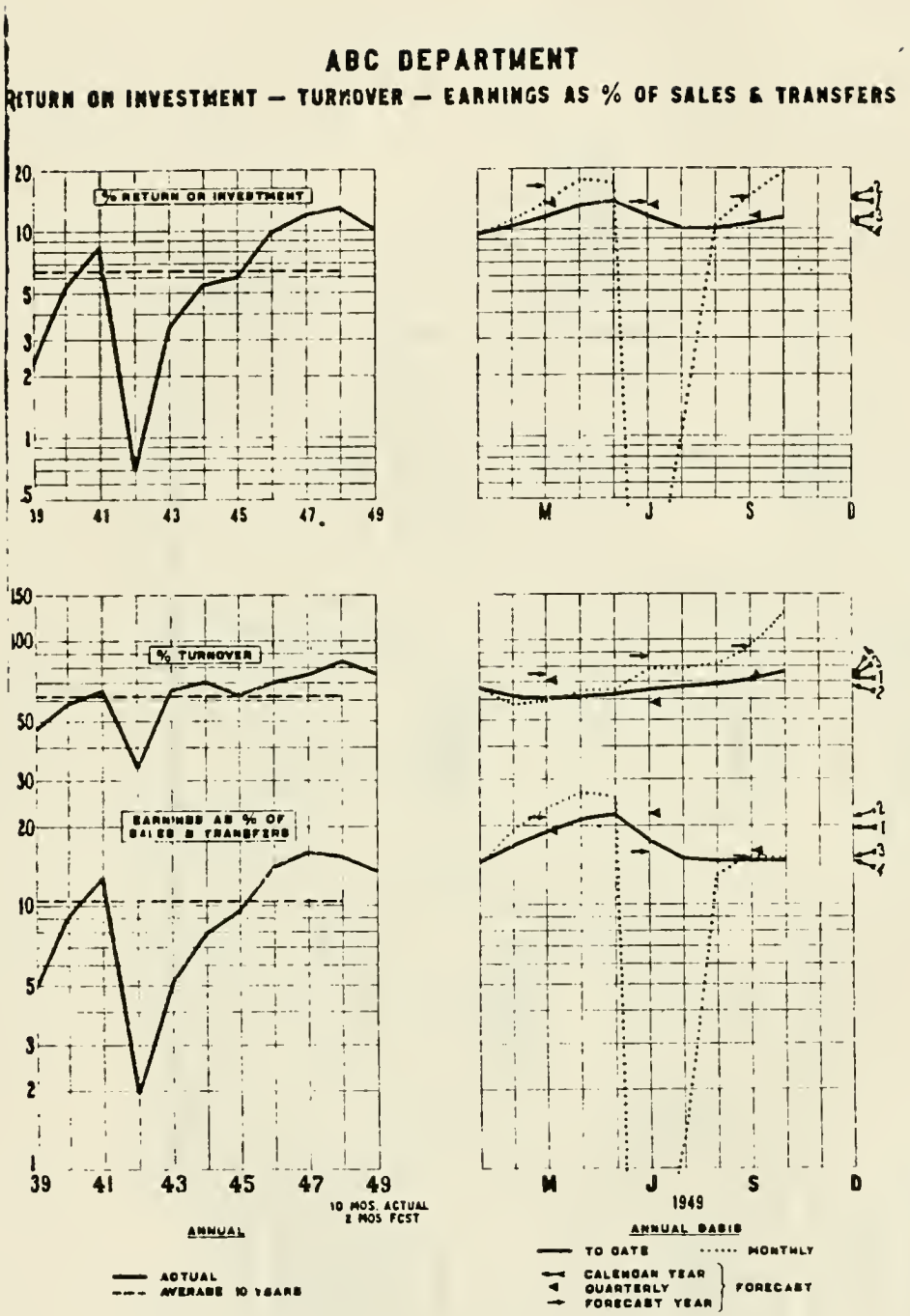


Figure 5. Fictitious Return on Investment Chart from Davis's AMA presentation.

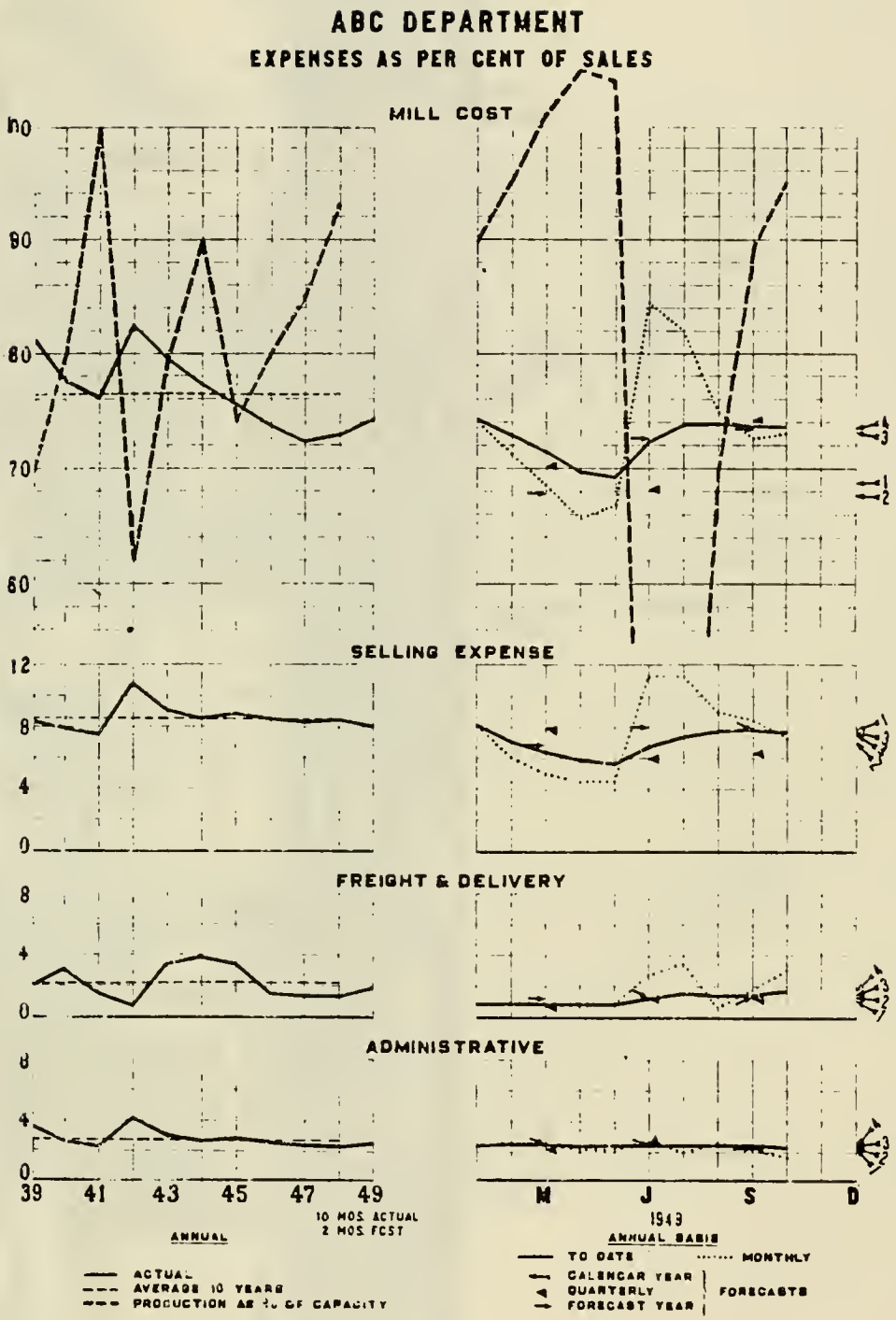


Figure 6. Fictitious chart of cost of sales from Davis's AMA presentation.

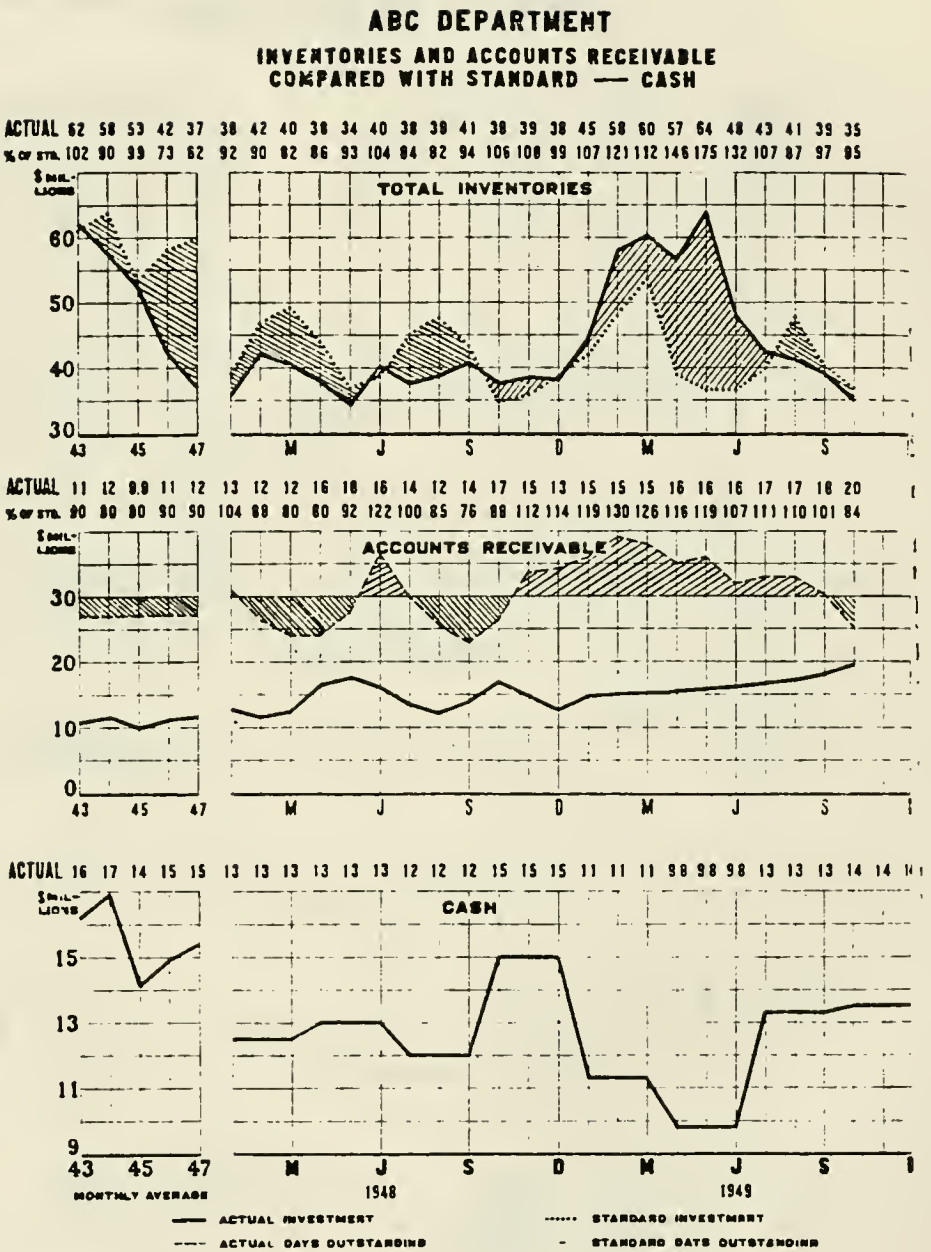
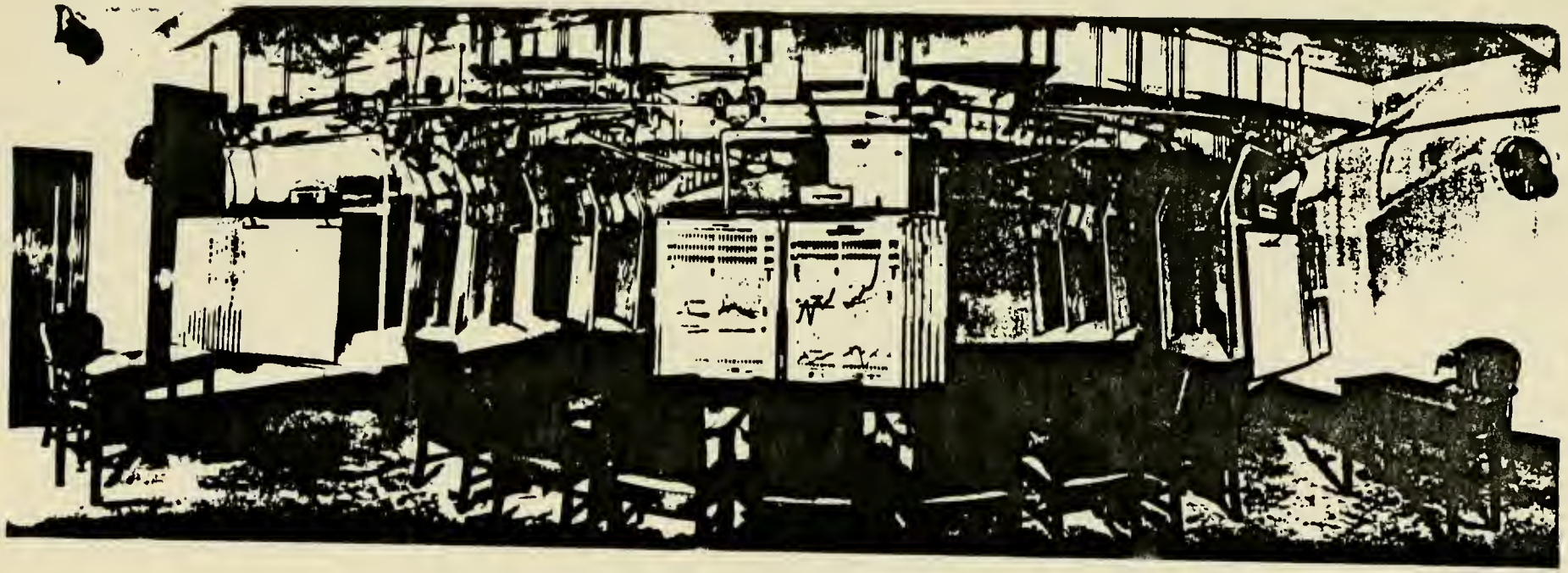


Figure 7. Fictitious chart of inventories, accounts receivable, and cash (the components of working capital) from Davis's AMA presentation.



Photograph of the Du Pont chart room, courtesy of the Eleutherian Mills Historical Library