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T H E S I S

THE IMPROVEMENT OF THE ACID FILLING PROCESS

FOR

THE MERRIMAC CHEMICAL COMPANY

BY

Guy H. Davis
and
Richard P. Windisch
Course XV_3

Massachusetts Institute of Technology
1921

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June 1,1921

Professor A.L.Merrill,
Secretary of the Faculty,
Massachusetts Institute of Technology.

Dear Sir:-

In accordance with the requirements for graduation we herewith present a thesis entitled "The Improvement of the Acid Filling Process for the Merrimac Chemical Company."

We wish to express our appreciation to Messrs. Wilder, Lund and Curtis of the Merrimac Chemical Co., Boston, Mass., who materially aided us by helpful suggestions and advice in the solution of our problem.

Respectfully submitted,

METHOD OF PROCEDURE

In order to become familiar with the problem in view several days were spent in merely exploring the plant and studying, both from literature and visualization ~~of~~ the actual operation of those processes with which we were to be directly concerned. With this preliminary investigation as a background an actual plan of procedure was then adopted. The problem seemed to fall naturally into three parts; first, an analysis of the faults of the present filling system; second, the improvement of this system; and third, the design and operation of an improved system.

In attacking the first part it was necessary to study the present method of filling. We were materially aided in this by talks with plant superintendents, foremen and workmen. After all possible data was gathered together, the principal defects were segregated and we proceeded to the second step. This consisted of an attempt to remedy the defects discovered. Much valuable information was obtained by consulting various equipment houses in Boston, by actual experiment and by references to the library.

Under this head also, came the problem of the selection of a suitable site for the central filling station. Before undertaking this, a list of all factors influencing the choice of such a location was prepared. Then the entire field was thoroughly studied and some six or seven possible sites were selected, from which the proposed site was chosen.

Finally, when all defects were either eliminated or improved to the best of our ability the proposed filling station was designed for the site chosen.

SUBJECT OF INVESTIGATION

Description of Plant

The Merrimac Chemical Company operates two separate plants, one located at Everett, Mass., a suburb of Boston, and another at South Wilmington, Mass., which is a railroad stop about twenty miles north of Boston. Both plants are engaged in the manufacture of commercial heavy chemicals. The same chemicals are made by approximately the same processes in both plants. The South Wilmington plant occupies about 80 acres of land the Everett plant about 20 acres. The former plant at which most of the data for this investigation was obtained consists of about 75 disconnected buildings ranging in size from 200 feet square to ten feet square (see Appendix I for Ground Plan). The construction of the buildings varies from all wood to iron clad steel and brick. (see Appendix II for general views of plant).

The Products and Methods of Manufacture

The products with which this thesis is concerned are the commercial grades of sulphuric and muriatic acids and "carbonizer." The latter consists of a rather impure solution of aluminum chloride in hydrochloric acid.

Sulphuric Acid

Three grades of this acid are manufactured for sale. So-called 60-degree acid which is collected from the lead chambers in the chamber process and which runs 60 degrees Beaume or 1.75 specific gravity. This acid attacks most all metals and must be handled in either glass or lead. It is used mainly in automobile batteries. 66 degree acid is also sold commercially and is that acid collected from the bottom of the Glover tower in the chamber process. It may also be made by concentrating chamber acid by passing sulphur trioxide, which has been made by the contact process, through it. This acid is handled mainly in lead although it has such slight effect on the other metals that iron valves may be used in the pipe lines. Both of these acids are marketed in glass carboys. The third grade of acid made is oleum which

runs above 100% sulphuric acid. It is made by concentrating the chamber acid using the contact process. This acid does not corrode any of the common metals so that large orders are usually shipped in tank cars.

Muriatic Acid.

This is the commercial name for hydrochloric acid and it is made by treating common salt with sulphuric acid in brick furnaces. The fumes of hydrogen chloride coming from the furnaces are passed through absorption towers where they are taken up by various proportions of water to form the different concentrations of muriatic acid. Three stock concentrations are sold by this company, viz. 18, 20 and 22 degree Beaume acids. These acids are very corrosive and can be handled only in glass, rubber or stoneware. Around the plant it is transported in hard rubber pipes and stored in large stoneware urns. The concentrated acid gives off hydrogen chloride fumes which corrodes any metal with which it comes in contact. Nearly all of this acid is shipped in carboys to textile works, dyers, and bleachers.

Carbonizer.

This consists of a commercial solution of aluminum chloride in hydrochloric acid and is made specifically for use in woolen mills as it will dissolve out cotton and other vegetable fibres from wool shoddy, without attacking the latter. It is manufactured by treating aluminum oxide with hydrochloric acid solution in wooden tanks. The resulting solution, because of the large amount of impurities contained, is allowed to settle three or four days in wooden tanks. This solution must also be kept out of contact with metals and is handled in either wood or rubber. It is shipped entirely in carboys.

The Preparation of Acids for Shipping.

At present each type of acid is put into carboys at their respective bulk storage point, viz. Carbonizer at the south end of building 5, Hydrochloric Acid in building 57, and Sulphuric Acid in building 69 (see Appendix I). The carboys which have been filled and are awaiting railroad cars are stored in the open yards adjoining these points.

The present carboys in use are in no way standardized. They consist of a large glass bottle holding anywhere from 11 to 14 gallons of liquid, and which is enclosed in a wooden box so that about 8 inches of the bottle neck protrudes. The space between the round bottle and the rectangular box is packed with small pieces of cork so as to minimize the shocks transmitted to the bottle in shipping and to prevent the liquid running out too rapidly in case a bottle should be broken. Most of the carboy boxes are one of three sizes; one having an 18" square base and about 24" height; another having an 18" square base and 28" in height and the third consisting of a 24" cube. The latter type is considered old fashioned and contains the so-called balloon type of bottle but many are still in use. The empty carboys weigh from 55 to 100 pounds ordinarily, but in the winter time due to the water and ice collecting in the packing, the weight often increases 20 to 30 pounds. The carboys are filled with from 110 to 200 pounds of acid giving them gross weight of from 175 to 300 pounds. There are three different methods in use for moving the carboys as they are too heavy for one man to carry. The first consists of a modified wheel-

barrow permitting one man to carry a carboy. The second method is that of two men carrying the carboy between two boards in stretcher fashion (see photograph in Appendix II). In the Everett plant an industrial railroad is used in which the cars holding eight full or thirty-six empty carboys are pushed about by two men each. To simplify handling of the carboys by the first two methods two parallel cleats are nailed on each side of the carboys.

Four thousand carboys per month of each kind of acid is the average capacity of the plant but provision must be maintained for double this capacity.

The operation of filling is usually performed by three men although one man is often used to perform the complete operation when business is slack. When a gang of three men is used they are usually transferred about the plant first filling all of the days production of one kind of acid and then moving on to fill the days production of the next kind. In filling the carbonizer solution all of the empty carboys must first be washed out due to the large amount of sludge which remains in the carboy. In filling the acid carboys only about one out of about every twenty carboys returns in such a dirty condition as to require washing. In the operation

of filling an ordinary beam scale is used having a double arm graduated into half pounds and each arm reading up to one hundred pounds. By using the double arm the tare weight is first counterbalanced and the net weight is then obtained by direct reading upon the other arm. This eliminates the necessicty of the workman subtracting the tare weight from the gross and minimizes the danger of error. At present two scales are used at once, both being placed side by side within reachof the hose connecting the acid storage reservoirs. This arrangement enables much time saving in that while the carboy on one scale is filling, the men obtain the net of the carboy on the second scale, remove it and replace it with another empty and obtain its tare. By the time this is accomplished the other carboy is filled and the hose is free to be used in filling the second carboy. Theoretically this method allows the hose to be used the maximum of time. While two men are thus engaged the third is washing those carboys which require it or he may be capping and luting the filled carboy. The third man or either of the other two, while not engaged in the above mentioned operation,

will scrape the old stencilling from the carboy boxes and stencil on the name and grade of acid with which the carboy has been filled and also the net weight.

The empty carboy boxes are usually stored by piling them on their sides, three high, although they may be if necessary piled eight high. The expense of piling to the latter height has been found to be excessive unless they are to be allowed to remain there for a very long time. The weight of the boxes prevents an ordinary man from lifting one much above the height of his waist without assistance. The filled carboys may be stored three high if necessary with the aid of stretchers and a plank. The carboys are usually stored on the ground level and are loaded into the railroad cars by the use of a plank.

Faults with the Present Methods.

Mixed Orders.

When acid is sold in less than carload lots it often is necessary to load a car with two or three kinds of acid. With the present system it is then necessary to move the car around to each of the three filling points. If a central storage or shipping platform was built much of the switching and delay so caused would be eliminated.

Loading and Unloading of Railroad Cars.

The absence of a shipping platform at the storage points makes it necessary for the loading gangs to carry the carboys up a plank to the car level. This obviously increases the time and labor of loading a car. The use of two men to carry every carboy from storage into the car seems a very extravagant use of labor. The industrial railway in use at the Everett plant seems to be only very useful in cases where a large number of carboys are to be moved a comparatively long distance. They are not used in loading the freight cars.

Transporting Carboys.

The stretcher and the wheelbarrow methods of moving the carboys are objectionable in that they can not be used unless the carboy is clear on all four sides. This is seldom the case, however, as the carboys are, of course, stored as close together as possible to save space. This necessitates the movement of each carboy by hand before it can be picked up by either of the devices.

Weighing.

An ordinary beam scale is used to weigh the full and empty carboys. Great difficulty has been experienced in protecting the scales from the corrosive action of the acids. The knife edges and bearing points rust rapidly and thus increase the friction and reduce the sensitiveness of the scale. Experiments were performed to see how accurately the scales in use would balance. Few of them were found on which weighings more accurately than within one and one-half pounds could be made, and none within less than one pound. That is, a certain carboy which would balance the scale arm at 120# would give an equally good balance if the poise were moved out to the point reading 121½". This is evidently due to friction at the bearing points. It also appears

that the scale arm is two short or the graduations upon it are too fine to allow very accurate weighing unless the workman gives more time to this operation. The graduations on the scales in use occupy about 5# to the inch. This means that the workman must be willing to move the poise a distance of at least 1/5 of an inch to weigh the carboy within one pound of its true weight. It seems that few workman would go to all of this trouble, especially if they were working on piece rates as is the case at the Everett Plant. A series of the carboys were checked up as to weight in order to determine how accurately the work was being done. The data obtained is as follows:

Weight Full	Weight Empty	Net Weight	Pounds Marked	Difference
220-221½#	79-80#	141#	136#	5
183½-185#	63-64½#	120-121½	119	1-2½
	59½-61½	116½	117	½
176-178 #	88-89½#	120½	123	2½
209-211#	86½-88#	123	124½	1½
209½-211½#				

The above results were obtained at the Hydrochloric acid filling department at the South Wilmington works where the workmen were paid by day rates. The average discrepancy between the weights

marked on the carboys and that which it was found that they contained was $2\frac{1}{2}$#.

In the present method of filling each carboy is weighed twice. This seems very inefficient and the possibilities of avoiding this by the adoption of a standardized carboy or of standardizing the amount to be put into each carboy is discussed under "Improvement of the Filling Process".

Filling.

It seems as though the present method of filling the carboys with the use of a flexible hose can not be improved upon.

Storing.

At present there are no provisions at the filling stations for storing either filled or empty carboys. They are merely piled up in the open wherever it is convenient. The filled carboys are stacked three high on end while the empties are laid on their sides and are often piled eight high. Storing in the open allows the carboys to fill with dust and with water. The latter on freezing in the winter time is liable to crack them. Storing in the open also allows the packing to absorb water which might be some influence in decreasing the life of the box

due to rotting. The increase of weight so caused also makes them more difficult to handle. The storing in high piles introduces high labor costs as at present it is not being done with the assistance of a portable elevator.

Repairing.

The reparing is now all done in buildings 3A, 4A (see plan in Appendix I) which are not very centrally located. A central filling station would save the time now consumed in transporting the damaged carboys from each of the sub-filling stations.

Stencilling.

The question arises as to whether or not it would be better to send a man around to remove all of the old stencilling from the empty carboys when they are put into storage instead of having one of the men who is filling it pick up the scraper and remove it from each one separately as he is filling it.

SELECTION OF THE SITE.

Contemplated Sites.

After a preliminary survey of the available ground suitable for the location of the Central Filling Station, it was decided that there were only six sites which could be considered as possibilities. For the sake of brevity these sites will be lettered and will hereafter be referred to by their respective letters. All locations are referred to the "Ground Plan of Works". (See App.I). The space allotments to each are approximations taken from the Ground Plan, but are sufficiently accurate for the purpose in view.

SITE A.

This location lies between the Phenol Building (106) and the Glauber Building (8) on the East and West and between the Nitre Storage (105) and the Oleum (70) buildings on the North and South respectively (440' x 220').

SITE B.

This involves the use of the Phenol Building itself with the land adjoining to the south of

the same. The maximum space available, excluding the building itself, is 120' x 70'.

SITE C.

This location includes the present site of the Muriatic Acid Building (8A) and the land to the South and East of it. It is "L" shaped in character and covers a total space of 30,500 square feet.

SITE D.

This site adjoins the Sulphur Ore Shed (67) on the South and would include an unlimited amount of sapce to the South and East of same.

SITE E.

This location lies directly outside the fence bounding the southern limits of the Plant and is immediately adjoining the main line R.R.tracks. There is unlimited land available.

SITE F.

This location is the only one considered on the West side of the main line tracks. It adjoins the Lumber Yard (44) on the South and has a maximum available space of about 55,000 square feet.

Factors Involving Selection.

After all possible locations had been considered and tabulated it was found necessary to formulate some common ground upon which each site could be judged. Accordingly the following list of factors was compiled in order of their relative importance. These points of course apply only to the problem in view.

SRACE REQUIREMENTS.

This is obviously one of the first points to be considered. The building itself, due to its character, has, necessarily a minimum space requirement and any location without this requirement is immediately to be rejected.

SHAPE.

This factor, like the previous one involves the peculiarities of the building itself. In order to gain maximum efficiency from internal transportation and storage facilities the sahpe of the building should conform to the lines of a freight shed or other structures of a long,narrow type.

FIRE HAZARDS.

As is true of all manufactures of heavy chemicals, the fire hazard is of greatest importance due to the quantity of frame structures comprising their plants. This is further increased by the inflammable nature of certain of their products. Prohibitive rates of insurance are charged on chemical plants of this nature.

PROFILE.

In order to eliminate too great an expense from grading, draining or other difficulties caused by irregular profile, this factor has been places among those of prime importance.

ACCESSIBILITY TO TRANSPORTATION.

As the proposed building is to be a shipping platform as well as a filling station it is important that it be readily accessible to both railroad and truck transportation.

INTERFERENCE WITH EXPANSION OF PLANT.

Since processes are constantly changing and output will supposedly increase it is necessary to take into account the question of the space surrounding the various department buildings, and if

possible not to encroach upon their land.

SUBSEQUENT ENLARGEMENT OF FILLING STATION.

If possible it is necessary that space be allowed for further growth of the Filling Station. Due to the changing requirements of the industries for raw materials, the possible expansion of the acid departments must be considered.

PIPING DIFFICULTIES.

These are relatively unimportant, as only in an extreme case would the cost of piping be prohibitive. The only difficulty of any importance would be encountered in attempting to cross the main line of the R.R.

CENTRALITY.

While this factor plays an important part in the selection of the average site, it is also relatively unimportant in the present case due to the eass of piping from the various acid departments.

BUILDINGS TO BE RAZED.

Since only buildings of small value would even be considered this item is comparatively unimportant.

USE OF EXISTING STRUCTURES.

This item is worthy of consideration only because of the fact that in the present case there are several buildings used during the war which are not in use at the present time.

REVISION OF PLANT TRACKAGE.

This detail is of minor importance and is only considered because of the inconvenience and small expense to which the Company would be put in rerouting their present transportation system.

Consideration of the Individual Sites.

SITE A.

SPACE: As it has been previously estimated That 30,000 square feet will be ample space for the proposed Filling Station this site offers all that could be desired in this respect as the estimated land available approximates 90,000 square feet.

SHAPE: The shape of this site is such that if necessary, a building of 440' x 220' could be erected which would easily permit the erection of the proposed shape i.e. 360' x 90'.

FIRE HAZARD: The close proximity of the Nitre Storage, Glauber, Acetic Acid and Glauber Stor-

(* pg. 22 doesn't exist.)
mis-numbered count

age Building, all of which are of frame construction, would be a great fire risk were another large frame building erected on this site.

PROFILE: The land is level except on the eastern corner where a small amount of grading would be necessary. There is a small pond located on this site, but this would in no way interfere with the construction of a building as it could be built over the pond.

TRANSPORTATION: Relatively speaking this site is inacessible to transportation facilities as it is off the main line and would necessitate the construction of a new spur in order to make the loading and unloading of carboys most efficient.

PLANT EXPANSION: The interference with further expansion of the plant is exceedingly great. Were a building erected upon this site it would leave no room for the logical expansion of the Glauber, Nitric Acid or Acetic Acid Departments.

ENLARGEMENT: Since 30,000 square feet of land are needed and 90,000 square feet are available it is obvious that there is ample foom for subsequent enlargement. This is true provided it does not become necessary to expand the adjacent departments. On the whole, however, this location would tend to cramp and

crowd the buildings in this vicinity, were it selected.

PIPING: There would be little or no difficulty with piping as the departments making the acids to be filled are in close proximity to this site. The O.V.filling station immediately adjoins and the other two - the Muriatic and Carbonizer Departments - but a short distance away.

CENTRALITY: This is one of the outstanding features of this site as it is central to all three departments as well as to the rest of the works.

RAZING: Were this location used it would necessitate the razing of the employees service building which is an item worthy of serious consideration. This is an all brick building, 45' x 65', containing a quantity of plumbing fixtures that would involve considerable expense to replace. Also the Fire Pump House and Tar buildings would have to be razed. As these are very small buildings the expense would be neglible. Also the matter of moving seven large horizontal fuel oil tanks must be given attention. A large pile of stored sulphur would also have to be removed.

EXISTING STRUCTURES: No advantage could be taken of an existing structure.

TRACKAGE: A radical revision of the present plant trackage would be necessary in order to reach the Glauber and Glauber Storage Buildings.

SITE B.

SPACE: The space requirements are adequate, as the total floor space available, including the Phenol Building is about 35,000 square feet. This space would be further increased by the use of the upper stories of this building.

SHAPE: The shape of the ground plan is entirely satisfactory but the shape of the Phenol building is not such that it could be readily adapted to the most efficient form of Filling Station.

FIRE HAZARD: As the Phenol Building is entirely of brick construction the fire risk of this site would be relatively small. The only building adjoining is the Nitre Storage.

PROFIE: The profile of the land is excellent as it is all level.

TRANSPORTATION: The transportation facilities are excellent as it would be unnecessary to lay any additional trackage. The spur tracks adjoining the Acetic Acid and Glauber buildings can be utilised as they stand.

PLANT EXPANSION: As in the previous site interference with expansion is one of the main objections. However, in this case it would not be as great as the difficulty would lie only with the Nitric Acid and the Glauber Departments.

PIPING: The question of piping is identical with that of Site A.

CENTRALITY: As with Site A this is one of the outstanding features.

RAZING: The only building necessary to tear down is the Fire Pump House which is at pressent abandoned.

EXISTING STRUCTURES: The use of the Phenol Building is the outstanding feature of this location. This building is about 80' x 80' and is all brick. It could be remodeled into three separate floors which might be used as storage space. The chief objections are that the shape of the building is not satisfactory, the expense of remodelling would be great and there is the question as to whether or not it would be advisable to use such an expensive structure for a Filling Station.

TRACKAGE: The same applies with regard to revision of the plant trackage as in the case of Site A.

SITE C.

SPACE: The space requirements are just sufficient as the ground space is slightly over 30,000 squre feet.

SHAPE: In order to utilize all the available space of this site, it would be necessary to build an #L" shaped structure and fix the lay-out accordingly. A building of this nature would lessen the efficiency of the entire system.

FIRE HAZARD: The fire risk would be greatly increased by the erection of a building at this point as the site directly adjoins the Gluaber and Litharge buildings as well as the Sulphur Ore shed.

PROFILE: The ground is level with the exception of a sludge pond which could be built over with no difficulty.

TRANSPORTATION: As this site adjoins the main line track the transportation facilities are excellent.

PLANT EXPANSION: The further extension of the Muriatic, Glauber and Litharge Departments would be cut off.

ENLARGEMENT: Further expansion of the Filling Station beyond the present requirements of the plant would be impossible in this location.

PIPING: Little or no piping difficulties would be encountered as the site is centrally located to all departments from which acids would be piped.

CENTRALITY: This is another of the outstanding features of this location.

RAZING: The only building to be razed would be the small frame filling station (57) as the Muriatic Acid building (#2) has already been torn down.

EXISTING STRUCTURES: No use of present buildings could be made whatsoever.

TRACKAGE: As one of the main switches would have to be removed it would cause some revision of plant trackage.

SITE E.

SPACE: The space available on this site is almost unlimited as there is no impeding structures whatever. All of the land to the south of the fence is owned by the company, although it is not indicated on the Plan.

SHAPE: Any shape of building desired could be erected on this site.

FIRE HAZARD: As it is a matter of over 200 feet to the nearest existing structure, there would be little or no fire risk at this point.

PROFILE: The profile of the ground is relatively poor. About half of the site is eight feet or so below the level of the main line tracks the other half being the plant dumping ground.

TRANSPORTATION: As the site borders on the main tracks it is readily accessible as regards shipping and receiving facilities.

EXPANSION OF PLANT: A building erected on this site would in no way interfere with further plant expansion.

ENLARGEMENT: Ample room is offered here for further expansion of the Filling Station.

PIPING: Compared to the previously discussed sites, the piping facilities are poor as it would require an installation of over 2000 feet of pipe line to bring the three different products to the Station, 1500 feet of this must be of hard rubber or some other expensive material.

CENTRALITY: This site being at some distance removed from the rest of the plant offers a very poor central location.

RAZING: None.

EXISTING STRUCTURES: None

TRACKAGE: Would involve no revision of routing through the plant.

SITE F.

SPACE: The space is adequate.

SHAPE: The site is suitable for a building of optional shape.

FIRE HAZARD: Very little fire risk would be offered the rest of the plant as the only structure adjoining is the Lumber Yard which is separated from the rest of the works by the main line right of way which is 80 feet wide.

TRANSPORTATION: Due to the fact that the plant locomotive is only allowed to cross the right of way once a day the transportation facilities are poor. In every other respect the site is readily accessible to transportation.

PLANT EXPANSION: A building erected on this site would in no way interfere with future expansion of the plant.

ENLARGEMENT: The subsequent enlargement of the Filling Station would be expensive due to swampy land adjoining on the south. There is, however,

ample room for expansion in this direction.

PIPING: Due to regulations made by the Railroad it would be impossible to pipe the acids directly over the main line. It would become necessary, therefore to utilize the present subway. This would call for over 2500 feet of pipe lines.

CENTRALITY: The site is, physically speaking, quite centrally located, but due to the intervention of the Railroad between the site and the Works, practically speaking, it is poorly located.

RAZING: None.

EXISTING STRUCTURES: None

TRACKAGE: No revision necessary.

SITE D.

The discussion of this site was purposely omitted from its logical order because it is so similar in all respects to Site E. The fire risk is a little greater but the land is more centrally located and has a better profile.

THE PROPOSED SITE

After considering the relative merits of each site and weighing them against each other (see chart of Sight Comparisons Appendix 3) Site E seems to offer the maximum advantages. It can be regarded as excellent in every respect except as to profile, piping, centrality and in the use of existing structures. The profile of this site is very irregular but as it is proposed to build the floor of the filling station 3 feet above the track level such irregularities as are there will be of minor consequence, after a small amount of grading has been done. The length of piping would be great compared to that necessary for some of the other sites but the difficulties encountered should not be great with a well designed gravity flow system and a small pump in each line. Since all of the material to be transported from the plant is in the liquid form and could be handled through pipes the item of centrality becomes of minor importance. We have therefore designed the proposed filling station to fit on this site.

Suggested Methods of Improving the Process of Filling.

Method 1.

It has been suggested that an official tare weight be stamped on each carboy box when it is first put into service. It would then only be necessary to weight the carboy after it had been filled and the amount of acid which it contained could be obtained by subtraction.

The advantage of this sytem would be that it would eliminate the operation of weighing 375 carboys per day at normal production.

The disadvantages of this system are that in obtaining the tare and total weights errors would be introduced by the differences of the settings of the two scales used. An unnoticed change in the tare might result from the carboy packing absorbing water on standing in the rain. A customer might find it necessary to repair a damaged carboy box before returning it and the resulting change in tare would be unnoticed by the company.

Method 2.

In order to eliminate weighing of carboys it is proposed to fill each carboy with a definite volume of acid. This could be most easily accomplished

by marking a filling line on the neck of each carboy and then stamping on the carboy box the weight of acid which the carboy will contain when filled up to the line. This would not only eliminate all weighing but also all stencilling.

One of the difficulties encountered with the use of this method would be the change of the specific gravity of the acids, due to change in temperature. It was found by calculations and laboratory experiemnts (for calculation and laboratory data see Appendix III) that thirteen gallons of hydrochloric would weight 1.95# more, and thirteen gallons of 66 degree Beaume sulphuric acid 3.44# more, at 30 degrees Fahrenheit than they would at 90 degrees. By marking the carboys for acids at 60 degrees the error at extreme temperatures could be reduced to 1# for hydrochloric and $1\frac{3}{4}$# for sulphuric acid or about .8 of 1% in both cases. It seems as though this small percent of error could be overlooked in view of the fact that at present the weights are obtained with an average of 2% error. The change in the volume of the bottle at extreme temperatures due to the expansion and contraction of the glass was calculated and found to be only .068# per 13 gallons, and therefore a negligible quantity. An incon-

venience arising from this method of filling would be the fact that each carboy could only be used for one kind of acid. With the present method, if an unusual demand arises for one kind of acid, carboys which have been filled with other acids may be used without much inconvenience. With this new system however the capacity by weight of the diverted carboys would first have to be calculated. It is even possible to use the carboys for two or three grades of acid by stencilling on the box the several weights which it will hold. By branding the weight into each box instead of stencilling it the danger of having this permanent weight number obliterated in shipping would be removed. The initial cost of calibrating the carboys and calculating the weight capacities would, we think, be a minor expense compared to the saving effected by the elimination of 750 weighings per day.

Method 3.

In order to eliminate the operation of lifting the carboy on and off of the scales which is probably the most difficult and fatiguing part of the process of filling to the workman, a method of measuring out or weighing the given quantity of acid to

go into each carboy a separate vessel has been worked upon. The working out of such a method involves the use of a "Master Carboy" in the form of a lead boot for sulphuric acid and a stoneware urn for hydrochloric to be placed under the main outlet from the acid reservoirs. A pipe and hose containing a valve leads from the bottom of the master carboy to the glass carboys which are to be filled. The bottom of the master carboy must be above the top of the regular carboys and the bottom of the supply reservoir must be higher than the top of the master carboy so that all feeding will be by gravity. If it is desired to weight out the amount of acid going into each carboy the master carboy is mounted on the platform of a scale and if it is desired to measure out by volume, the master carboy, may be built with a wide and open top would be equipped with a float valve mechanism. The float valve would be connected to the supply pipe coming from the reservoir and would shut off the supply valve when the master carboy contained sufficient acid to fill one carboy. The cut off point on the float valve could be reset for changes in the specific gravity due to changes in temperature. If the master carboy were mounted on a scale

the supply valve could be cut off by an automatic arrangement connected to the scale arm. When sufficient liquid had flown in to the master carboy to counterbalance the scale poises the arm would rise and by a system of lever connections shut off the supply valve. When the master carboy had filled the operative would open the discharge valve and allow the contents to flow into the shipping carboy. While the master carboy is refilling the operative would be stencilling and corking the recently filled carboy. By operating two master carboys simultaneously, allowing one to fill while the other is emptying much time could be saved. This system of filling should work best in conjunction with an industrial railway as the carboys would not have to be unloaded from the cars in order to fill. Possible disadvantages of this system may arise through failure of the valves to work properly. The variations in the sizes of the different carboys would cause many of them to go out incompletely filled. One more intelligent and hence more highly paid man would be required in the operation of the master carboy.

Method 4.

A study was made of the manufacture and operation of scales to determine if the present method of filling could be operated more rapidly and within a greater degree of accuracy. The Howe Scale Company informed us that they have been experimenting with an acid proof beam to be used on their 500# scales (see Appendix for letter from Priest, Page & Co.) As the same is not yet ready for shipment we are unable to determine just what they mean by acid proof, but believe that it involves the use of some acid resistant metal as Duriron. To facilitate more accurate weighing with the consummation of no graater time than at present we should recommend the construction of a scale having a beam at least 2 feet long, the same to be graduated into 25 one pound units. We see no reason for having the one pound graduations divided into half pounds as the scales will not weight within that degree of accuracy, even if the operator conscientiously tries to read it that carefully, which we have observed to be seldom the case. This is particularly so in the case of the men working on piece rates.

These extra half pound graduations it seems would even be a source of confusion to the eye when it is attempted to weight rapidly. The use of an automatic spring scale would greatly reduce both the time required for weighing and the chances of error due to incorrect balances and readings. Unless it is possible to completely seal up the delicate mechanism of this type of scale the acid fumes would prove much more injurious to it than to the more simple beam type. The initial cost of such a scale would be from two to three times greater than that of the beam scale.

The possibilities of sealing up the automatic mechanism with the use of marine pitch and by having levers at the base of the scale pass through an oil bath were discussed with the Boston representatives of the Howe Scale Company. The conclusions reached, however, were that the added friction, and difficulties of regulating the scale would make such measures impractical.

Method 5.

This method involves the use of a narrow gauge industrial railroad. In the process of filling it is proposed to push a car containing approximately eight empty carboys upon a railroad scale. The load of empty carboys would first be weighed. The carboys would then be filled one at a time without removing them from the car. By weighing the car after filling each carboy the content of acid in each carboy could be obtained by subtraction. To avoid mathematical subtraction which could not be entrusted to the type of workman now employed it is proposed to use a multiple beam scale, which would read directly the weight of acid put into each carboy. Such a multiple beam scale would be identical to the scale now in use except that it would have seven tare arms instead of one, arranged vertically one above the other. Scales of such type and of the capacity desired are not kept in stock by any of the scale companies having agencies in Boston. The Fairbanks Company, however, estimate that scales of the type and dimensions desired could be made at a cost of from $500 to $800 when business conditions improve. Scales of such type but of only 1000# capacity are now made by

them for use by dairy product merchants. Scales of 2000# capacity would be necessary for carboy weighing.

An outline of the process of filling which is deemed the best to be used in the proposed filling station is as follows:

1. Operator pushes car A filled with empty carboys to the right of filling platform.
2. Places empty car B in a parallel position on opposite track
3. Slides an empty carboy No.1 from car A onto scale No.1 and weights.
4. Places hose into carboy No.1 and allows it to fill with acid
5. While carboy No.1 is filling removes carboy No.2 from car A and places on scale No.2 and weighs tare.
6. By this time carboy No.1 being filled operator removes hose from same and places in No.2 and allows to fill.
7. Weighs carboy No.1net, gross and stencils same
8. Slides carboy No.1 onto car B.
9. Takes carboy No.3 from car A and places on scale No.1
10. Registers tare weight of carboy No.3 and removes hose from carboy No.2 which is now filled and places into 3
11. Takes net weight of carboy No.2 stencils,places on car B and returning takes carboy No.4 from car A and places on scale No.2
12. Etc.etc. until car A is empty and car B is filled with filled carboys.
13. Pushes car B onto loading platform and pushes up car C full of empty carboys in its place.
14. The filling of the next eight carboys takes place in the reverse direction when car A is filled with full carboys and is removed to loading platform.

Operation of Central Filling Station

The operation of the central filling station may best be described by following the path of a carboy from the point at which it is received empty to the place where it is shipped full of acid.

Unloading.

The carboys when returned by rail are unloaded on both sides of the space marked "Empty Carboy Storage" shown in the "Proposed Design" (see App. II). They are here examined and those in need of repair are carried by industrial cars to the repair department. Those ready to be filled are either placed in storage or immediately taken by industrial cars to the next step.

Industrial Cars.

The platform of the industrial cars in use is 10' x $3\frac{1}{2}$' in surface area and is eighteen inches above the floor level. They are made of slats so arranged that the empty carboys may be placed on the car upside down with the neck protruding beneath. All cars are propelled by hand on a 24" gauge track.

Washing.

The loaded car of empty carboys is then taken to the washing pit. This consists of aperture (10' x 3½') in flooring over which the industrial track is laid. Underneath is a basin to drain off the waste water. A hose with a hooked shape metal nozzle and valve is installed at each of the three washing pits. The operator by merely inserting the upturned end of the nozzle into the neckof carboy and turning the valve allows the force of the water to play on the inside of the carboy without removing it from the car.

Filling.

The car containing the empty carboys next goes to the filling platform immediately adjoining the washing pits. This platform is raised to the level of the car floor with an intervening space of three inches. At each end two scales are placed flush with the platform. This platform is placed between two tracks with a switch at each end. The carload of empties is brough to the platform on one track and an empty car is placed opposite on the other track. The operator places an empty carboy on one scale, takes the tare weight, inserts the filling hose and turns the valve. While this carboy is filling he goes through

the same process with another empty on the second scale. When the first carboy is filled it is placed on the second car where it is stencilled, capped and luted, and another empty carboy is put in its place on the scale. This process is continued until the entire carload of empty carboys are transferred to the second car filled. The car of full carboys is then taken to the loading platform and a carload of empties takes its place. The same operation is repeated except it now takes place in the opposite direction.

The process of filling while requiring three men to operate it with greatest efficiency can readily be operated by two men and if necessary in periods of depression, may be operated by one man.

Loading.

From the filling platform the carload of full carboys goes directly to the loading platform. Here the carboys may either be stored or loaded directly into freight cars. Carboys which are to be shipped by truck are placed at the extreme end of this platform where facilities are provided for loading them in trucks. The handling of carboys by workmen has been reduced to a minimum as eighteen feet is the furthest distance they will be

transported in this manner.

Repair Department.

The repair department is placed directly adjoining the space alloted to empty carboy storage, obviously to reduce transportation distance. When broken carboys, unloaded and brought to this department, are repaired they are immediately placed in storage or if possible taken directly to the washing pits to prepare them for filling. On either side of the repair department immediately adjoining the main line spur, space is provided for the storage of repair materials. These consist of bottles, packing and boxes.

FEATURES OF THE PROPOSED FILLING STATION.

Minimization of Handling.

Due to the fact that the weight of a full carboy is very close to the limit of lifting power of the average laborer a certain degree of skill must be acquired on the part of the operator before his motions in handling the carboys can be called anything but awkward. For this reason the first requisite in the designing of an efficient filling station is the minimization of the moving of carboys by hand. This is effected in two ways. First, the horizontal movements are minimized by the use of an industrial railway. It thus becomes necessary to carry the carboys at only three points, and at any point the maximum carry would be 18 feet. At two of these points, viz. when carrying from the freight car onto the industrial car and when carrying from storage onto the freight car, roller conveyors could be used to advantage to reduce the length of carriage to 8 feet. Vertical lifting is reduced to a minimum by the use of a platform at the filling point and possibly on the loading platform, such platforms to be level with the industrial car level.

Straight Line Flow.

In order to prevent congestion of carboy traffic in the filling station the latter has been designed so that the path of the carboy from the emptying railroad car to the filling railroad car will be as straight as possible. In order to minimize the interference of the empty industrial carboys with the full cars passing through the station switches have been provided, and a one way system of tracks in the storage department.

Variation in Operating Capacity.

With the system outlined above the operation of filling can be carried out by using as many as five men without interferring in case the plant is rushed or the whole system may be operated by one man if necessary.

Provisions for Enlargement.

If in the future it should become necessary to enlarge the South Wilmington plant the location of the filling station is such that it would not interfere with the expansion of any other part of the plant. The filling station itself could be easily enlarged by shortening the east track and building on

that side another filling unit, converting the present east track into a blind siding and building another loading platform on the other side of it, thus building three loading platforms.

Ventilation.

In order to diminish the inconvenience now experienced at the Everett plant by the hydrochloric acid fumes collected under the covered filling station it is proposed to construct a large open ventilator in the roof of the filling stations and to place the hydrochloric acid reservoirs on a superstructure above the station so that such fumes arising from them will be carried away by the wind.

Storage.

As storage exposed to the weather is a big factor in deteriorating the carboy boxes it is suggested that low and inexpensive roofs be built over the storage and loading platforms. This is not however necessary if it is desired to make the initial cost of the improvement as small as possible.

CONCLUSION

After thorough investigation of the filling process at the Merrimac Chemical Company, South Wilmington, Mass., we conclude that the fundamental principle of weighing and filling cannot be improved upon. The entire process of receiving, storing, filling and shipping, however, can be materially improved as follows:

1. By centralization of the filling processes for the oil of vitriol, carbonizer and muriatic acid departments.

2. By providing a central receiving, and shipping point for all carboys used by the above departments.

3. By improvement of the Repair Department.

4. By combining the above three features into a single unit.

5. By installing an internal transportation system within this unit.

6. By placing this unit upon a site adjoining the main line railroad directly outside the southern boundary of the plant.

A P P E N D I X

SPECIFICATIONS OF PROPOSED ACID FILLING STATION

Truck Loading Platform

80 feet long, 8 trucks can be loaded at one time

Loading and Storage Platform

Contains 12,000 sq.ft., 10,400 available for storage

Capacity for storing 5,000 full carboys staked in two layers.

Length of Loading Platform

450 ft.long. Can accommodate 15 freight cars at one time.

Acid Storage Capacity.

Carbonizer
Two days average filling
One vertical cylindrical tank 10 ft.diameter 12 ft. high.
Capacity 7,044 gal. or 580 carboys

Sulphuric Acid
Two days average filling, half for 60 degree and half for 66
640 cu.ft. or each tank 8 by 8 by 8 by 10

Hydrochloric Acid

One days average filling
10-1000 liter stoneware urns with 6 ft. diamter each.

Scales

Six required 500# beam scales having at least $2\frac{1}{2}$ x $2\frac{1}{2}$ ft. platforms.

Industrial Cars.

Estimated need when filling station is running at maximum capacity 20

Height of car platform above floor 18"

Load of each car 10 carboys or $1\frac{1}{2}$ tons

Dimensions of car - 10 feet long and 40" wide

Track gage $21\frac{1}{2}$"

Empty Carboy Storage

5,700 sq.ft. or 4,200 empty carboys stacked in three layers.

Storage available between filling stations in case of an emergency, 2000 sq.ft. or 1,400 carboys.

Length of unloading track

200 feet or accommodations for 6 cars.

Industrial Trackage Required

Estimated 1365 feet

14 switches and 3 turntables.

Area Under Roof.

1940 sq. ft. filling station and 360 sq.ft. repair shop.

Total 2300 square feet.

SITE COMPARISONS

Factors	SiteA	Site B	Site E	Site E	Site F
Space	Good	Fair	Fair	Ex.	Ex.
Shape	Good	Fair	Fair	Ex.	Ex.
Fire hazard	Poor	Fair	Poor	Ex.	Good
Profile	Good	Good	Good	Fair	Poor
Transportation	Fair	Good	Ex.	Ex.	Poor
Interference with Expansion	Poor	Fair	Poor	Ex.	Ex.
Enlargement	Fair	Fair	Poor	Ex.	Good
Piping	Ex.	Ex.	Ex.	Poor	Poor
Centrality	Ex.	Ex.	Ex.	Poor	Poor
Razing	Poor	Fair	Fair	Ex.	Ex.
Use of Existing Structures	Poor	Ex.	Poor	Poor	Poor
Trackage Revision	Poor	Fair	Fair	Ex.	Ex.

APPENDIX III

Change in weight of H_2SO_4 with change in temperature.

Experiment:-

Sample:- 1970 cc. 60° Be H_2SO_4

At 50°C. vol. 2006 cc.

" 21° C. " 1970 cc.

36 cc. change in vol./ 29°C/1970cc.

29° C. difference 52.5° F.

3785 cc. 1 gal. Carboy 13 gals.

$\frac{3785 \times 36 \times 13}{1970}$ 900 cc. change in vol./52.5F/13gal.

$\frac{900 \times 60}{52.5}$ 1028 cc. change in vol./60°F / 13 gal.

$\frac{1028 \times 1.71}{453}$ 3.8# change in wt./60°F./ carboy

Computation:-

Change in wt./1° F/cc .00053 g.

60 x .00053 .0318 g./cc/60° F.

$\frac{3785 \times .0318 \times 13}{453}$ 3.43#/ carboy

Change in of HW with change in temperature

Computation:-

Change in wt./1°F/cc. .0003 g.

60 x .003 .018 change in wt./60° F/cc.

$$\frac{3785 \times 13 \times .018}{453} \quad 1.95\#/\text{carboy}$$

Change in vol. of carboy with change in temp.

.00000451 coef.of expansion of glass /1° F.

x 81 255 sq.in cross section of carboy

.00000451 x 255 x 60 .069 sq.in. expansion of cross section /60° F.

.069 x 24 1.7 cu.in vol.expansion of carboy/68F

1.7 x 2.54^3 31 cc.or .0683# due to expansion of glass.

BIBLIOGRAPHY

The packing and Plant Handling of Hazardous Chemicals

N.A.Laury Chem.& Met.Eng. 17 (407-408) 1917

The Transportation of Corrosive Liquids

H.N.Morris Jour.Soc.Chem.Ind. 35 (1243-7) 1916

The Transportation and Storage of Liquids in Small Packages

L.R.Atkins Jour.Ind.Chem. 9 (979-80) 1917

The Handling and Transportation of Liquids

M.H.Eisenhart. Jour.Ind.Chem. 9 (980-2) 1917

Suspension Railways in the Chemical Industries

H.H.Dietrich Z.Angew. Chem. 29 I (201-5) 1016

Manual of Industry Chemistry

Allan Rogers Van Nostran Pub. 1915

Outlines of Industrial Chemistry

Frank Thorp. MacMillan Pub. 1910

Hunt Industrial Railway

C.W.~~Hobart~~ Hunt Co.Inc. Catalogue 20-1

Sweets Industrial Guides

Boston Public Library