Tank shipment of industrial chemicals.

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THESIS

Tank Shipment of Industrial Chemicals

by

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I. INTRODUCTION

A. Problem

The chemical and container industries have made great strides in the last two decades in developing containers for various types of liquid chemicals. However, the chemical manufacturer must be ever on the alert for safer and more efficient methods of transporting his products if he is to meet competition. This thesis will point out the advantages in tank shipments over others and present cost comparisons based on other methods of shipment.

B. Importance

Quite often it is possible for a manufacturer to effect reductions in production costs; however, this may require considerable time and effort before any noticeable savings are effected. A field often overlooked by both the producer and customer is the use of tank shipments of numerous chemicals. In many instances the savings realized by the use of tank cars and tank trucks in place of drums and carboys have greatly outweighed those resulting from process changes.

C. Work Already Accomplished

Numerous articles have been written for periodicals stating the advantages of tank shipment of liquid chemicals. Both the American Trucking Institute and the
American Association of Railroads have prepared articles on this form of shipping. The Bureau of Explosives and the Manufacturing Chemists Association have published material which is available to members stating the developments which have been made in this field.

These reports and articles show the ever increasing uses to which this form of transportation lends itself, and what its advantages are to the manufacturer as well as the consumer.

D. Method of Approach

The approach to the problem will be as follows:

1. Review the equipment that is available at present and show how it may be utilized.

2. Present what the author considers to be the proper techniques of loading and unloading various chemicals from tanks.

3. Discuss the savings that may be effected by adopting tank shipments when possible.

4. Show how the chemical industry can adopt distribution methods which other industries have used.
II. DEVELOPMENT OF CHEMICAL CONTAINERS

A. Small Containers

1. Nature

To the average person, chemicals and allied products are dangerous articles and are to be avoided as much as possible. However, to the chemical industry and their customers they are essential raw materials or finished products which must be handled safely and economically. To the railroad employee who has to transport them, chemicals and allied materials are products which require special handling, packaging, and labeling.

The safe transportation of such articles as corrosive liquids, poisons, explosives, and inflammables by the millions of tons annually over the congested rails and highways of our country has come about as the result of years of diligent effort, research, and cooperation on the part of both carriers and shippers. They have been aided by helpful rules and regulations prescribed by the Federal Government, Interstate Commerce Commission, Manufacturing Chemists Association, Bureau of Explosives, and various other organizations. The phenomenal development of American industry in the past fifty years could not have taken place without the proper packaging and the safe transportation of the products of the chemical, explosive and pet-
roleum industries."

The need for emphasis on container construction is vastly more important in the chemical industry than in many others because of the very nature of the products. For this reason the chemical industry, with the cooperation of the container industry, has been instrumental in the development of safe, efficient, and economical shipping containers in the past three decades.

2. History of Development

It was not until the latter part of the nineteenth century that the sciences of packaging and transporting dangerous articles were correlated. This was brought about by the many disastrous explosions which resulted from attempts to transport nitro-glycerine. On July 3, 1866, Congress passed an act forbidding the shipment of nitro-glycerine and allied products. However, it was not long before this statute was being violated and no serious effort was made to enforce it.

With the development of dynamite there resulted a number of serious railroad disasters, climaxcd by an accident on May 11, 1905, in which 20 persons were killed, 80 seriously injured, and a $600,000 property loss. Short-
ly thereafter, a nine man conference committee appointed by the explosive manufacturers submitted a report which was to provide the basis for future shipping regulations.

The success of the conference committees recommendations prompted it to study jointly with the Manufacturing Chemists Association the problem encountered in the safe shipment of such chemicals as phosphorous, sodium, nitrocellulose and the following acids: sulfuric, hydrochloric, nitric, hydrofluoric and mixed acid. This led them in 1910 into the field of the most common liquid container in the chemical industry, the carboy.

3. Carboys

The early carboy bottles were of the balloon type and varied in size from 5 to 13 gallons capacity. They were usually manufactured by being blown with the aid of clay molds; however, quite frequently they were blown without the use of any mold whatsoever. As a result of this unsystematic method of production, the sidewalls were of varying thickness and in most cases were

# Mixed Acid is a combination of nitric and sulfuric acids used in nitrating such chemicals as cellulose to form nitric cellulose or gun cotton. In contact with certain metals, toxic fumes are released. In contact with wood or other combustible material, fire may occur.

* 7, p. 17.
improperly annealed. Furthermore, the shape of the bottle was fundamentally incorrect in as much as shocks transmitted through the walls and packing of the box were concentrated on the extreme circumferential diameter of the bottle which is the weakest point and the one least protected by packing.

The Manufacturing Chemists Association, with the aid of the carboy manufacturers, shippers, and carriers, set out to determine the proper design of a glass carboy, with manufacturers specifications, packaging and labeling procedures, and the proper method of handling and testing the carboys.

Prior to the formation of the Bureau of Explosives, the larger chemical companies had taken steps to discourage the use of the balloon type carboy. Eventually, through a program of education, they prevailed upon the other shippers to discard the older and more dangerous type.

After a series of experiments a number of improved carboys were developed (see Figure 1.). However, it was not until 1914 that the present Manufacturing Chemists Association standard I.C.G. 1A carboy was developed (see Figure 2), which specified the minimum glass weight, annealing temperature, cooling time, and tapping test for wall thickness.
STANDARD CARBOY BOTTLE-GLASS

13 Gallon, Cylindrical, Straight Side

ADOPTED, 1936 - REVISED, 1943.

FINISH FLAT & SMOOTH

2 7/8" O.D. + 1/2" 2 D

32" R. Max.

1 1/16" Min. at any point

2 1/2" 2 1/2" 10 1/4"

25 1/8 - 1/16"

15 11/32" 1 1/32"

Fig. 2

Min. push up: 1/4"

7-28-43

Side Elevation

Scale: 1/4" = 1"
In spite of the progress made, there was still a serious deficiency, that of a proper method of testing the carboys for shocks which would occur when railroad cars were coupled and uncoupled. Although the previous work had been successful, (see Table 1) accidents continued in substantial numbers with excessive losses to both the shippers and carriers. It was obvious that the committee must study the practices employed and from these develop a satisfactory package which would withstand the shocks encountered in normal shipment.

It is apparent that a glass container of any size cannot be considered a pressure vessel and at its best is a relatively weak container when compared with a heavy-duty metal package. Hence, with a carboy bottle of substantial size, the chances for breakage incident to the shocks of ordinary railroad transportation are relatively large, unless its walls are of uniform thickness, all strains removed and unless it is properly suspended in the outer wooden box with adequate cushions to protect against shocks.

Bottle cushioning materials used at this time were inadequate protection for the bottles. Diatomaceous earth absorbed water and caked, mineral wool gradually packed down and lost its resiliency, hay was satisfactory for non-


### TABLE I

**PRINCIPAL CAUSES OF PROPERTY LOSS DUE TO TRANSPORTATION OF EXPLOSIVES AND CHEMICALS IN 1935**

<table>
<thead>
<tr>
<th>Cause</th>
<th>Loss in Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derailment or collision</td>
<td>$494,318</td>
</tr>
<tr>
<td>Improper loading or defective container</td>
<td>$8,524</td>
</tr>
<tr>
<td>Miscellaneous and unknown</td>
<td>$6,062</td>
</tr>
<tr>
<td>Spontaneous heating or excessive sensitivity, etc.</td>
<td>$5,460</td>
</tr>
<tr>
<td>Rough handling by carrier</td>
<td>$1,943</td>
</tr>
<tr>
<td>Negligence of employee (carrier or shipper)</td>
<td>$2,698</td>
</tr>
</tbody>
</table>

Source: *Chemical and Engineering News* - Cross, M.F., Jr.

"Development of Safe Transportation for Dangerous Articles", Volume 23, January 10, 1945, page 16.
oxidizing acids only when freshly packed and soon lost its cushioning efficiency. A block-type packing, employing corrugated wood strips, was extensively used for nitric acid shipments, but would not adequately protect the bottle against severe shocks. Bowed steel strips, split wooden springs, and even rubber hose were employed at various times as cushioning materials without particular success.

Beginning in 1919, the Manufacturing Chemists Association appointed a Carboy Committee which produced the following developments; (1) Substituting special types of cushioning materials such as natural cork, ground pressed cork blocks and rubber blocks, (2) Wire tied vented closures which prevented the building up of excessive pressures, (3) Plastic and asbestos gaskets and (4) Lip surfacing machines which eliminated losses due to the Federal regulations which forbid the use of chipped-lip carboys.

With the aid of carboy manufacturers, the committee spent nearly two years in developing a satisfactory testing machine. In approaching the problem, earnest consideration to what constituted a reasonable shock in transit had to be determined. Having settled upon a collision

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° 7; p. 23.
°°8, p. 23.
shock speed of 8 miles per hour, a swing testing machine was developed (see Figure 3). Briefly, the test consists of bringing the carboy back to a distance of 75 inches and allowing it to crash into the test stand. If the carboy survives this test, it is considered satisfactory for industrial use.

As a result of the efforts of these various groups to improve a basic chemical container, the frequency of breakage has been substantially reduced in the past 30 years (see Table 2). However, the use of carboys resulted in very high unit filling costs per pound of chemical shipped. In as much as a considerable saving could be effected by increasing the volume shipped per container, increased interest was developed in the use of both wood and steel drums.

4. Drums

Doubtlessly the development of the steel drum in its early stages owes much to the progress of the petroleum industry in the late 1800's and the production genius of one Mrs. Elizabeth Cochrane Seaman, of the Iron Clad Manufacturing Company.

Prior to 1900 the wooden barrel was the only large container available for transporting petroleum and other inflammable chemicals. It was not considered un-
usual to lose one-fifth to one-third of the contents of a barrel due to spillage or leakage. Many of the fires occurring on carriers property were caused by leaky wooden barrels containing highly inflammable materials. In as much as there were few steel drums available and many were of foreign manufacture, it was difficult to pass legislation forbidding the use of wooden barrels, especially since it had been a practice for many years. A number of large oil corporations had experimented extensively to develop a drum more suitable than the foreign types available, but on the whole were unsuccessful. It was not until Mrs. Seaman, the legendary Nellie Bly, returned from Europe in 1900 with the necessary patents and production know-how that a commercial steel drum was available to the chemical and petroleum industry.

In order to insure that the steel drums would provide satisfactory container service in transport, a series of conferences were held between the Bureau of Explosives, shippers, and drum manufacturers. As a result of these meetings, a set of specifications for a 55 gallon

![Image](20)

# Mrs. Elizabeth C. Seaman, nee Elizabeth Cochrane, while a reporter for the New York World, made her famous trip around the world in 1899 and used the nom de plume of Nellie Bly.
TABLE II

BREAKAGES OF BOXED CARBOYS OF ACID DURING RAIL TRANSPORTATION 1920-1943

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Instances</th>
<th>Property Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>913</td>
<td>$38,455</td>
</tr>
<tr>
<td>1921</td>
<td>744</td>
<td>22,635</td>
</tr>
<tr>
<td>1922</td>
<td>613</td>
<td>21,493</td>
</tr>
<tr>
<td>1923</td>
<td>536</td>
<td>10,943</td>
</tr>
<tr>
<td>1924</td>
<td>359</td>
<td>8,356</td>
</tr>
<tr>
<td>1925</td>
<td>376</td>
<td>11,203</td>
</tr>
<tr>
<td>1926</td>
<td>277</td>
<td>13,444</td>
</tr>
<tr>
<td>1927</td>
<td>290</td>
<td>8,259</td>
</tr>
<tr>
<td>1928</td>
<td>237</td>
<td>3,870</td>
</tr>
<tr>
<td>1929</td>
<td>235</td>
<td>6,630</td>
</tr>
<tr>
<td>1930</td>
<td>202</td>
<td>16,068</td>
</tr>
<tr>
<td>1931</td>
<td>119</td>
<td>1,829</td>
</tr>
<tr>
<td>1932</td>
<td>79</td>
<td>1,949</td>
</tr>
<tr>
<td>1933</td>
<td>54</td>
<td>2,587</td>
</tr>
<tr>
<td>1934</td>
<td>59</td>
<td>2,309</td>
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<tr>
<td>1935</td>
<td>70</td>
<td>1,550</td>
</tr>
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<td>1936</td>
<td>69</td>
<td>2,956</td>
</tr>
<tr>
<td>1937</td>
<td>66</td>
<td>1,135</td>
</tr>
<tr>
<td>1938</td>
<td>48</td>
<td>566</td>
</tr>
<tr>
<td>1939</td>
<td>47</td>
<td>3,416</td>
</tr>
<tr>
<td>1940</td>
<td>50</td>
<td>696</td>
</tr>
<tr>
<td>1941</td>
<td>40</td>
<td>1,530</td>
</tr>
<tr>
<td>1942</td>
<td>62</td>
<td>7,699</td>
</tr>
<tr>
<td>1943</td>
<td>70</td>
<td>8,549</td>
</tr>
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steel drum were developed. They were sufficiently complete so as to serve as a model for subsequent specifications. Briefly, they included the following details:

1. Minimum weight, 70 pounds
2. Minimum gage 16 (U.S. Standard)
3. Tests required:
   a. A 2 minute air pressure test at 15 pounds per square inch gage.
   b. A 5 minute hydraulic test at 45 pounds per square inch gage.
   c. A 4 foot "drop test" on chime or side on concrete, filled to 98% of capacity with water.

In addition, the specifications prescribed "secure closing devices, preferably threaded metal plugs with gaskets", but permitted wooden plugs, provided such plugs were "covered with a suitable coating and must have a driving fit into a tapered hole." "Leaks must not be repaired by soldering, but by the method used in constructing the barrel."

5. Single Trip Containers

Prior to 1923 the heavy duty steel drum was the only container used for inflammable liquids and acids, but its weight of approximately 110 pounds was a serious draw-

* 7, p.25.
back from both a material handling point of view and from a shipping aspect. As a result of numerous inquiries from customers, the steel barrel fabricators set about to develop a light weight, safe, and economical drum which would suffice for a single trip. In 1923 the Manufacturing Chemists Association began a series of tests on various types of drums and as a result, developed a container which weighed 50 pounds. This resulted in a direct saving on shipping weight of 60 pounds for every barrel filled. While the original idea was to develop a "single tripper", it was found that many of the containers could be reused as often as four and five times. The success of the barrel as an industrial container is witnessed by the record construction of 8 million such drums in 1937 and in increasing amounts ever since.  

6. Alloy Drums

The development of the heavy duty and single trip drums did not in themselves satisfy the container demands of the chemical industry. With the increased demand for such acids as sulfuric and nitric, the industry endeavored to increase the volume of the containers from the 13 gallon glass carboy to one of larger volume. However, there was little or no information available upon which to base the design of these much needed items.

* 7, p.25.*
Thus the Metal Barrels and Drums Committee of the Manufacturing Chemists Association in the late 1920's began to develop alloy drums which would be resistant to the chemical action of the various acids. As a result of their work, the chemical industry now had available drums made of stainless steel, aluminum, chrome-nickel, monel metal, and a 14gage all-nickel drum.

The value of the metal drum as a container in aiding the progress of the chemical industry cannot be overstated. Because of the careful attention of the various parties concerned, the chemical and associated industries have been provided with an efficient, economical and safe means of transporting increasing volumes of dangerous liquids. The thoroughness with which the drums were designed and tested is attested to by the fact that containers constructed according to Interstate Commerce Commission regulations have withstood severe abuse and have not ruptured. A typical example of such sturdiness of construction is shown in Figure 4. Originally, all three drums were identical; however, the drums on the left and right were involved in a fire during transport. Although subjected to intense heat and hydrostatic pressure they did not burst, but merely distorted without leaking. Needless to say, if the drums had been of in-
ferior construction and design they would have burst and caused serious injury or death to those fighting the fires. It is an occasion such as this which demonstrates the value of close cooperation between Federal regulatory commissions, shippers, manufacturers, and carriers in designing, producing and using the best possible containers for the shipment of industrial chemicals and their allied products.
1. **History**

Although it is impossible to ascertain the nature of the first bulk liquid shipment by tank car, it was in all probability a petroleum product. For from the time Colonel Drake drilled the first successful oil well in 1859 until the tank car was developed there was an acute shortage of shipping containers. As it was previously stated, first wooden barrels and then steel drums were used to bring the crude petroleum to market. However, it was impossible to expect this type of container to cope with the tremendous demands that the petroleum and allied industries were to make in the next few years. It was imperative that a method of handling bulk cargos of liquids be developed and to this end the first tank cars were constructed.

a. **Wooden Tanks**

The first tank car was to make its appearance in 1865. It consisted simply of a railroad flat car with two iron hooped wooden tanks, each tank having a capacity of about 500 gallons. Crude as it may seem, it was a great improvement over the old equipment and was very popular for several years.°

° 1, p. 445.
The next important improvement was the forerunner of the modern tank car, one large wooden tank, cylindrical and horizontal, with a capacity of approximately 5000 gallons. In the early models, the present day tank car dome was non-existent, but was later instituted to allow for expansion of the contents without damage to the tank.

A familiar sight in a chemical plant in the mid 1800's was that of several wooden tanks perched on a railroad flat car (see Figure 5). However, the use of such cars was limited to chemicals which would not effect the wooden tanks. As a result of this, the majority of liquid chemical shipments by railroad were made in the old balloon-type carboys.

To overcome the limited use of wooden tank cars for chemicals a number of the cars were lined with lead or coated with tar. While this increased the effectiveness of the car as a means of shipping liquid chemicals, it was not until the development of improved steel tank fabricating facilities that the tank shipment of industrial chemicals was to assume any magnitude.

b. Steel Tanks

To provide a safer and more flexible bulk container for the movement of liquids over the American railroads, the first steel tank car was constructed in 1871. For the
FIGURE 6

TANK CARS IN FRANCE.

This congested freight yard at Lyons, France, pictures the tank cars in evolution. Over there wood tank cars still are used, especially in the transportation of wine. Here we see them on the same trains with steel tank cars.
most part, these tank cars were crude affairs consisting of a steel tank on a wooden supporting frame.

The modern steel tank cars, owned and operated by chemical manufacturers, are the outgrowth of a development which began in 1907. In June of that year, the matter of safe transportation of explosives and other dangerous articles was placed in the hands of the Bureau of Explosives. Up to this time, the movement of dangerous commodities in tank cars was relatively small, being confined chiefly to shipments of sulfuric acid, liquid caustic soda, crude petroleum oils, and napthas. The tank cars consisted essentially of wooden flat cars with cradles upon which the tank was set. The earlier tank cars' had very little steel in their construction because long heavy freight trains were not used. Therefore, wood center sills, wood truck bolsters, and wood end blocks were the rule. Furthermore, these earlier tank cars lacked air brakes and even the minimum number of appliances considered necessary in modern day safety practices. This doubtlessly was due to the fact that no definite specifications existed. If the running gear of the car was in operating condition, then the entire car was considered to be satisfactory for service.

1, p. 445.
2, p. 3.
2. **Present Tank Equipment**

Much of the growth of rail transportation has been possible because of the willingness of car builders and lesors to offer specially designed cars for different commodities. They have kept abreast of the advances of the chemical industry by developing units made of a variety of materials of construction.

The modern tank car consists principally of a horizontal metallic tank on a wheeled carriage. Numerous refinements and variations have been used to broaden the usefulness of this versatile transportation unit (see Figure 6). Such cars usually carry liquid commodities, but in many instances they have been used for slurries, greases, sludges, gases, high melting point chemicals, and free flowing solids. As a rule, these cars usually fall into a classification called "general service cars". This designation means that after carrying one commodity and then being thoroughly cleaned, they may be placed in service hauling some other material. Cars of this type ordinarily have a capacity of 8000 or 10,000 gallons and there may be several compartments in the tank.

a. **Lined Cars**

With the possible exception of the maintenance

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and repair of mechanical parts, the most important problem in bulk transportation is corrosion. Adequate protection of the shipment and the car is a continuing problem. To combat this, a number of investigations of corrosion conditions have been undertaken by various groups and many successful linings have been developed;

1. Rubber Linings

In spite of the increased use of steel cars, there were still many high sales volume chemicals which could not be shipped in the conventional cars. Chemicals such as hydrochloric, phosphoric, and acetic acids either attacked the material of construction of available cars, or were contaminated. To overcome this deficiency, rubber linings for tank cars were developed and applied by either cementing rubber sheets to the surface, or by painting rubber compounds and allowing them to set. However, caution must be exercised in the loading and unloading of such cars as the rubber lining may be damaged.

The application of a rubber lining is the most expensive form of protective lining and usually costs between $2000 and $2800 per car. The life of the interior linings varies considerably with the type of chemical carried, but under proper conditions, the coating should give
2. **Resin Linings**

The use of linings of a phenolic or vinyl type resin to provide resistant coatings to protect the lading and the car has become a common practice in the transportation of chemicals by tank car. The development of the use of such materials was brought about by the extremely high cost of cars with stainless steel clad linings and those of rubber.

When synthetic resin paints are used, the general practice has been to apply five to seven coats on the interior of the car. It has been found that this number generally is necessary to provide sufficient protection. A modified high voltage tester can be used to determine the minimum coat of thickness. In some cases of mild service, such as in the transportation of glucose, only two coats of aluminum paint need be applied. The number of coats required obviously depends upon severity of conditions and in the case of caustic soda, it may be necessary to apply 22 or more coats of a suitable material.

In order to insure proper performance of some of the coatings and linings it may be necessary to cure or bake them. If the user should find it necessary to perform this operation it may be accomplished by introducing °9, p. 2032.
forced hot air or superheated dry steam into the car. The inlet air temperature for this procedure may be as high as 800 degrees Fahrenheit. Naturally the control of the baking schedule of a tank car is not as refined as with smaller objects. This is due primarily to the large heat capacity and heat losses through radiation. However, very good results can nevertheless be obtained provided the coating does not have a critical time-temperature relationship.

Protective linings are being used in an ever increasing number of applications in bulk transportation and it is to be expected that their use will be still greater as further improvements are made in the field of synthetic resin base protective paints.

3. **Alloy and Aluminum Cars**

Boiler plate steel of flange quality is the most common construction material for tank cars carrying liquids in bulk. The balance of the tank car and other bulk railroad cars are built of ordinary open-hearth steel. As the severity of service conditions increases, the number and variety of specifications are enlarged.

To help establish the proper material of construction for the transportation of a chemical, numerous laboratory corrosion tests are conducted. A corrosion rate in

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inches penetration per year is determined with a totally and partially immersed specimen. The maximum corrosion rate should be less than 0.0052 to 0.0062 inches penetration per year.

Other materials of construction for tank cars are stainless steel, stainless clad, nickel-clad, chromium-nickel alloys, and aluminum. In the hauling of weak (65%) nitric acid for example, the material of construction of the tank car would be of chromium bearing stainless steel containing 15 to 18% chromium. However, in the case of strong nitric acid (95% or better) aluminum has been found to be the most satisfactory material. In the case of a commodity such as phenol, which must be protected from picking up small amounts of iron, it is essential that a nickel-clad tank car be used. While Table 3 provides a list of materials of construction for selected chemicals, a complete list may be obtained by consulting either the Interstate Commerce Commission regulations or "Specification for Tank Cars" by the Association of American Railroads.

4. Steam Heated Cars

To meet the demands for special cars for their customers, the tank car manufacturers developed the steam jacketed and/or steam coil equipped car. Through the use of such a car the chemical industry is able to ship high viscosity chemicals and lading which are normally solids
### TABLE III

**MATERIALS OF CONSTRUCTION FOR TANKS FOR SELECTED CHEMICALS**

<table>
<thead>
<tr>
<th>PRODUCTS</th>
<th>TANK MATERIAL</th>
<th>TANK LINING MATERIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACETIC ACID 56% to GLACIAL</td>
<td>Steel 1/4 in. thick for 3000 gal. 3/8 in. thick for 15000 gal.</td>
<td>Rubber 3/16 in. thick</td>
</tr>
<tr>
<td>HYDROCHLORIC ACID (MURATIC ACID) AND (SULFURIC) BATTERY ACID</td>
<td>Steel 1/4 in. thick for 3000 gal. 3/8 in. thick for 15000 gal.</td>
<td>Rubber 3/16 in. thick or Saran lined</td>
</tr>
<tr>
<td>SULFURIC ACID 66°Be to 100% ALSO OLEUM</td>
<td>Steel 3/8 in. thick for 3000 gal. 1/2 in. thick for 15000 gal.</td>
<td>None</td>
</tr>
<tr>
<td>MIXED SULFURIC &amp; NITRIC ACIDS</td>
<td>Steel 3/8 in. thick for 3000 gal. 1/2 in. thick for 15000 gal.</td>
<td>None</td>
</tr>
<tr>
<td>NITRIC ACID</td>
<td>No. 347 stainless steel 1/4 in. for 3000 gal. 5/16 in. for 16000 gal.</td>
<td>None</td>
</tr>
<tr>
<td>PHOSPHORIC ACID (Up to 85%)</td>
<td>1/4 in. steel for 3000 gal. 3/8 in. for 15000 gal.</td>
<td>Rubber 3/16 in. thick</td>
</tr>
<tr>
<td>FORMALDEHYDE</td>
<td>Steel 1/4 in. thick for 3000 gal. 3/8 in. thick for 15000 gal.</td>
<td>Americoat 55</td>
</tr>
<tr>
<td>LACQUERS</td>
<td>Steel 1/4 in. thick for 3000 gal. 3/8 in. thick for 15000 gal.</td>
<td>Stainless steel clad if necessary</td>
</tr>
</tbody>
</table>

Source: *Bulk Handling of Chemicals*, Boston, Monsanto Chemical Company, 1950
at atmospheric temperatures. Once the car has been loaded, the source of heat is disconnected and not reapplied until the car reaches its destination. A steam heated car is usually insulated and the chemicals will retain a substantial amount of the heat input while in transit thus decreasing the amount of heat required to bring the contents to the proper unloading temperature.

5. **Insulated Cars**

As an additional service to industry, the tank car manufacturers have provided cars with varying degrees of insulating material to suit the needs of the shippers. While it may be thought that the principle reason for having an insulated car would be to save heat, such is not the case. Quite the contrary in many instances. In the shipment of compressed gases and certain petroleum products it is imperative that the absorption of heat be prevented as extreme pressures might build up in the tank. Such an increase might result in an explosion or in the discharge of dangerous fumes if the safety valve were opened.

The insulation may consist of Fiberglas or cork and is applied to the shell of the tank. To protect the insulation from the weather and possible damage, an outer cover of 3/8 inch steel is placed over the material. The thickness of the insulation on a tank car generally varies from two to six inches and in some cases applications of
as much as 10 inches have been made. The Interstate Commerce Commissions specifications for thickness of lagging depends upon the type of car to be used and the commodity to be transported.

An interesting and practical formula is used to determine either the amount of insulation required to keep the lading in liquid form during transit or to calculate the expected temperature drop with a known thickness of insulation. The cooling curves resulting from the graphic representation of the results are based on the flow of heat through the compound, wall of the tank, insulation, jacket, exposed metal anchor, manhole and jacket supports (see Figure 7). The formula used is:

\[ V G p C dt = (U_1 A_1 U_2 A_2 \ldots Un An) T H \]

where:

\[ Un = \frac{La Ka Lb Kb}{L} \]

- \( L \) = Tank Capacity in gallons
- \( G \) = Specific gravity of commodity
- \( p \) = Weight of water in pounds per gallon
- \( C \) = Specific heat of commodity B.T.U./lb/°F.
- \( dt \) = The increment of temperature drop for which time is being calculated
- \( T \) = Mean temperature difference between the upper and lower temperature of an increment and the

\(^9\) 9, p. 2030.
FIGURE 7
Cooling curves for Fiber-glass insulated tank car containing 73% caustic soda. 4" and 6" insulation.

Source: Chemical Engineering News
May, 1951   Page 2032
ambient outside temperature

\[ H = \text{Time in hours} \]

\[ U_n = \text{Over-all heat transfer coefficient for section } "n" \text{ in B.T.U./hr./sq.ft./°F.} \]

\[ A_n = \text{Area of section } "n" \text{ in square feet} \]

\[ la = \text{Thickness of insulating material in inches} \]

\[ K_a = \text{Thermal conductivity of insulating material} \]

While this equation does not include such factors as the surface coefficients of heat transfer, the velocity of the train or heat lost through certain exposed areas, it has been found to produce results which agree fairly accurately with actual experience.

A typical example of a commodity shipped in a car is 73% caustic soda which is loaded at 266 degrees Fahrenheit and solidifies at 144 degrees Fahrenheit. Using the above formula, graphs are shown in Figure 7 that indicate that the caustic soda will remain liquid for approximately 20 to 25 days, depending upon the thickness of the insulation and the outside temperature.

The shipment of molten sulfur is an interesting example of the use of insulated cars. Formerly, the sulfur mined by the Frasch process was allowed to cool and solidify and the lumps of sulfur were shipped in hopper or gondola cars. In order to conserve the heat in the liquid sulfur a method has been developed to load the liquid
sulfur immediately into an insulated tank car equipped with steam coils. The tank car of sulfur is shipped to the customer, the steam coils reconnected, and the car unloaded when the contents reach the proper temperature. The unloading procedure to use in the case of a normally solid material is given in the chapter on unloading of high melting point chemicals.
IV. LOADING AND UNLOADING HIGH MELTING POINT SOLIDS

A. General Description

With the advent of steam heated and insulated tank cars, the chemical industry had available a means by which many chemicals that were viscous or solid at ordinary temperatures could be shipped in tank cars. The method consisted of loading the chemicals in a molten state, permitting it to cool while in transit, and then reheating it at its destination. After having reached the proper temperature, the chemical could then be pumped, blown or permitted to flow by gravity to storage tanks. The savings to both the customer and the manufacturer has led to an ever increasing number of high melting point chemicals being shipped in tank cars. Table 4 supplies a partial list of chemicals shipped in such a manner.

B. Equipment

While the method of loading and unloading of high melting point chemicals might be considered in some instances as no different from ordinary liquids, there are a number of procedures and operations which vary from the regular methods.

1. Material of Construction

In the matter of material of construction of the equipment to handle the chemical, a number of important
TABLE IV

HIGH MELTING POINT SOLIDS SHIPPED BY TANK CAR AND TANK TRUCKS

<table>
<thead>
<tr>
<th>Material</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt</td>
<td>Para-Nitrochlorobenzene</td>
</tr>
<tr>
<td>Carbolic Acid</td>
<td>Paraffin</td>
</tr>
<tr>
<td>Caustic Soda</td>
<td>Phosphorous</td>
</tr>
<tr>
<td>Dinitrobenzol</td>
<td>Phthalic Anhydride</td>
</tr>
<tr>
<td>Fatty Acids</td>
<td>Potassium Arsenate</td>
</tr>
<tr>
<td>Lard</td>
<td>Sulfur</td>
</tr>
<tr>
<td>Meta-Nitrochlorobenzene</td>
<td>Tallow</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>Wax</td>
</tr>
</tbody>
</table>

factors come into consideration:

a. Corrosive chemicals

Is the chemical corrosive when liquid? If so, then the problem of handling is increased because of the necessity of obtaining the proper material of construction for the tank car, pumps, unloading lines and storage tanks. As regards corrosion, it is well to keep in mind that the temperature of the material will have to be controlled carefully as an increase in temperature ordinarily accelerates the rate of chemical reaction. Thus a metal which is normally inactive when placed in contact with a chemical may react quite violently when the reaction temperature is increased.

b. Heat sensitivity

Having obtained the proper material of construction, it is wise to determine whether or not the chemical is heat sensitive. That is, will the heating of the chemical damage it in any way? Such properties as the color of the molten material may be affected by exposure to excessive temperatures. This being the case, care must be exercised to see that the temperature of the tank car is controlled within the proper limits.

c. Effect of moisture

What is the effect of steam condensate upon the
chemical? Because of the importance of avoiding contact of many chemicals with water, the design of the heating system is very important. Even under ordinary circumstances the equipment should be designed so as to avoid leakage of steam or water into the loading lines or tank cars. In as much as the steam coils in the tank car will be subjected to great shock when the tank car is bumped, it would be advisable to have the heating system consist of a jacketed section. The loading and unloading lines should be jacketed in addition to jacketed storage tanks. While the use of steam jackets might be considered the best method of heating, it may not be the most practical from the standpoint of initial costs; therefore, the individual has to determine to what extent he will use jacketed equipment in place of coils and tracing. In either event it is desirable that all heated areas be carefully and thoroughly insulated to limit heat loss and prevent freezing of the chemical in the tank and lines.

2. Fabrication of Pipe Lines

The material of construction for the pipe lines will be dependent upon the chemical to be handled; however, the method of fabrication and installation will be quite similar regardless of the nature of the chemical.

The following is a brief description of the highlights to be observed in the construction of the pipe lines:
The steam jacketed sections are made up from standard pipe of a size one inch in diameter larger than that used for the line. Jackets should be extended very close to the ends of each section and welded. The various sections may be joined either by welding or with flanges. The use of pipe sections butt-welded is to be preferred over the usual flanged joints for it eliminates the likelihood of leakage, especially where temperature changes occur in the line. Flanges will very likely be sprung when heat is applied if the line is full of solid material for enormous pressures are generated if the material melts and is not properly vented.

The steam outlet of each jacket must be at the lowest point in the section to assure proper drainage of the condensate. A typical method of connecting steam jackets in a horizontal line is shown in Figure 8. It is possible to connect these jacketed lines in series of sections of pipe line up to two hundred and fifty feet long; however, proper allowance should be made for expansion of the line. The pipe line and pipe joints should be covered with a suitable insulation and if the installation is out of doors, the insulation should be weatherproofed.

Lines should be constructed without pockets and with a slight slope in the direction of the storage tank.
SLOTTED FLANGE

PLAN

FREE SWINGING SUPPORT

SLOTTED FLANGE

MAY NOT BE NECESSARY HERE

FIXED SUPPORT

VENT

VENT

END ELEVATION

FLANGE DETAIL

FLANGE O.D. TO BE LARGER THAN STANDARD

FIG.

TANK CAR

FLOAT CONTROL

SEE FIGURE 8

MEASURING TANK

ELEVATION

FIG.

PUMP

STORAGE TANK

SUBMERGED PUMP

SEE FIGURE 4

LAIRUT FOR UNLOADING TANK CARS

FIG.

WELDED JOINT

FLANGED JOINT

FIG.

FIGURE 8
Such drainage of lines reduces the possibility of material solidifying in the lines. In addition, it minimizes time of contact of large surface areas on small volumes of material. This is of advantage in preventing damage to the chemical by overheating.

3. Pumps

While it is permissible to use air pressure to load or unload tank cars it is not recommended that they be handled in this manner as a regular practice. There are numerous cases on record in which the air pressure was improperly controlled with the result that too much pressure was applied and the tank car exploded. Consequently, it is recommended that an externally submerged pump be installed. It should be jacketed and self priming, the latter feature being most desirable as it is preferable to pump out of the top of a storage or tank car.

For the submerged type of pump a special mounting has been developed and is illustrated in Figure 9. The shaft is not sealed tightly in the lower bearing and lubrication is supplied by liquid being forced upward from the impeller. There are holes in the shaft housing to allow drainage of the liquid.

If a positive displacement pump is used, the installation must be equipped with a pressure relief valve
to prevent rupturing the lines. If possible, the relief valve should be integral with the pump.

To facilitate servicing the pump, such as repacking and repairing, there should be valves at the suction and discharge ends. Provision for draining the pump should also be included.

4. **Storage Tanks**

The storage tanks should be jacketed, but it is not necessary for the jacket to cover the entire surface of the tank. A jacket of about the area shown in Figure 10 will be more than ample when carrying steam at 100 pounds per square inch gauge. It is obvious that if lower steam pressures are to be used, then the jacket area might be proportionally larger.

With this partial jacket, provision must be made for expansion of the material on the bottom of the tank when the contents are being melted. For, when the solid material melts it expands and if the liquid is not allowed to rise to the surface of the tank, tremendous pressures can be generated which will cause the tank to explode. Therefore, the surface of the mass in the tank should not be permitted to remain solid while material below is being melted.

The pressure that will be generated may be re-
lieved by melting an outlet to the surface for the liquid layer next to the steam jacket or coils. In the case of a storage tank, this is accomplished by fitting the jacket tank with channels extending down the side of the tank through which steam is admitted to the jacket. Venting of the liquid in tank cars is accomplished by means of a bayonet of sufficient length to reach to the bottom of the car. It is imperative that this bayonet be installed and have gone to the bottom of the tank car before turning the steam on the tank car coils. In addition, the steam must be left on the bayonet during the entire melting operation to insure against the plugging up of the liquid vent. Failure to comply with both of these requirements may result in a disastrous accident to both equipment and personnel.

The vapor space in both the storage tank and tank car should be steam jacketed to prevent blockage with sublimed material. The steam jacket should extend a few inches into the tank since the upper walls will at times be covered with a layer of sublimate. To improve the "housekeeping" of the tank area, the jacketed vent pipe can be extended to discharge into a large diameter unjacketed stack such as is shown in Figure 10. The bottom flange of the stack can be removed occasionally to clean out the sublimed material.

The outlet line from a storage tank or tank car
should be steam jacketed on the section extending inside the tank. This will serve to clear the line more quickly when the contents are being melted as well as provide a positive vent for the pressure which may develop in the bottom part of the tank below a solid crust.

C. Unloading Procedure

It is recommended that tank cars and trucks be unloaded by pumping out through a stand-pipe. Unloading from a bottom outlet is hazardous because of the possibility that leakage at the bottom connection might cause injury to workmen as well as loss of material. However, due to the construction of many of the cars and the material therein, it is only possible to unload from a bottom outlet. In which event, a steam jacketed flexible hose is attached to the connection and every possible precaution is taken to see that the tank is not bumped while unloading.

It is important that all parts of the line between the stand-pipe and the pump are well heated. This section of line is under pump suction only and is most subject to freezing. Therefore, in as much as swivel or swing joints are difficult to heat and insulate adequately they are not recommended. To overcome this inflexibility Figure 11 shows a line of the recommended type which allows adjustment to the position of the stand-pipe
without the necessity of extremely precise spotting of the tank car. A reasonable length of pipe should be provided between the last fixed point of the unloading line and the stand-pipe to provide a small amount of flexibility. When melting the contents of a tank car, care must be taken to insure that the pressure generated by the expansion of the material melting in the bottom of the car is relieved. A steam jacketed car should have steam inlets near the top of the car and channels down the sides so that the vertical passages are melted when steam is first turned on. The steam jacketed stand-pipe will also accomplish this purpose. If the car does not have steam inlets at the top and is not equipped with a steam jacketed stand-pipe, it will then be necessary to melt a free passage to the bottom of the car with a steam heated pipe or "bayonet" before melting the contents.

Care should be exercised so that the vapor space of the car is vented during melting. To insure this it is recommended that the vent be steam jacketed to avoid plugging with sublimed material. In the case of a tank car, it may be vented directly to the atmosphere or connected to a stack as in the case of a storage tank.

The dome opening should be protected from rain, snow, and steam condensate, and the manhole covers should
be left on except when inspecting the tank or sampling. if it is necessary to use compressed air to start unloading the tank car, the air should be filtered and dried. However, when unloading inflammable material the use of an inert gas such as carbon dioxide is recommended.

To facilitate the unloading operation and lend a uniformity of performance it is wise to publish and distribute to all personnel concerned an unloading procedure similar to the following:

1. Spot car, set brakes at either end of car.
2. Place derails at either end of car.
3. When unloading inflammable materials attach grounding connections. Figure 11 provides an illustration of the grounding connections.
4. Open vent. Be certain that it is not blocked with sublimed material. If vent line to stack is to be used, connect vent line.
5. Make steam connections to car and to jacket of unloading stand-pipe.
6. Turn steam on stand-pipe jacket or use "bayonet" heater" to melt a vent hole for molten material to rise to top of car. Check the jacket of the pipe for any evidence of a steam leak.
7. Apply steam to jacket or coil of car, starting with low pressure for the first hour, then
increase it to appointed maximum pressure.

8. Place thermometer or thermocouple in proper opening.

9. Check the level in the car occasionally. If the liquid level rises near the top of the dome, it may be necessary to shut off the steam and pump out some material to prevent overflowing the car.

10. Turn steam on discharge lines and pump.

11. When the contents of the tank car reach the appointed temperature, check the vent on the tank car and then connect the stand-pipe to the discharge line.

12. Open discharge valves to storage tank and start pump.

13. Check level of storage tank occasionally.

14. When the tank car is empty, shut off pump, close valves and disconnect piping.
V. UNLOADING INFLAMMABLE LIQUIDS FROM TANK CARS

A. General Description

1. Introduction

The directions outlined in this chapter are intended for use in the unloading of tank cars of inflammable products which are liquid under ordinary atmospheric conditions. Interstate Commerce Commission Regulations for the Transportation of Explosives and Other Dangerous Articles (Sec. 100) define an INFLAMMABLE LIQUID as any liquid which gives off inflammable vapors (as determined by flash point from Tagliabue's open-cup tester, as used for test of burning oils) at or below a temperature of 80 degrees Fahrenheit.

2. State and Municipal Regulations

Many states and some municipalities have stringent regulations governing the possession, storage, use, handling and sale of inflammable liquids. Insurance companies have similar regulations which, in some cases, are more stringent than state and municipal regulations. At least six states prohibit the unloading of inflammable liquids from tank cars through the bottom outlets. Some states prohibit syphoning. Other states require official approval of unloading sites and installation or relocation of piping, storage tanks, pumps, and other equipment used...
in the unloading, storage or handling of these liquids. Consignees should thoroughly familiarize themselves with all such requirements pertinent to the locality in which their plants are situated. They should also locate and design their unloading and storage facilities in conformity with such requirements.

3. **Placement of Tank Car for Unloading**

To insure the proper placement of tank cars all personnel should be instructed as follows:

- **a.** See that train or engine crew accurately spots the car at the unloading line. Unloading track should be level.

- **b.** Brakes must be set and wheels blocked on all cars being unloaded.

- **c.** Caution signs must be so placed on the track or car as to give necessary warning to persons approaching the car from the open end or ends of the siding and must remain posted until after the car is unloaded and disconnected from discharge connection. Signs must be of metal, at least 12x15 inches in size, and bear the words "STOP-Tank Car Connected", or "STOP-Men at Work", the word "STOP" being in letters at least 4 inches high and the other words in letters at least 2 inches high. The letters must be
white on a blue background.

d. It is recommended that derrails be placed at open end or ends of siding approximately one car-length from the car being unloaded, unless the car is protected by a closed and locked switch or gate.

B. Safety

1. Safety Rules to be Observed by Unloaders

As a safeguard to personnel and property all employees should be thoroughly familiar with the following safety rules:

a. Unloading operations should be performed only by reliable persons properly instructed and made responsible for careful compliance with these regulations.

b. Except where approved electric lights are available, the loading or unloading of tank cars must not be permitted except during daylight when artificial light is not required.

c. A tank car must not be allowed to stand with unloading connections attached after unloading is completed. Throughout the entire period of unloading, or while the car is connected to an unloading device, the car must be attended by the unloader.

d. If it is necessary to discontinue unloading a
tank car for any reason, all unloading connections must be disconnected. All valves must first be tightly closed, and the closures of all other openings securely applied.

e. Make sure the permanent storage tank is vented before connecting the unloading line.

f. Car numbers should be compared with that on shipping papers or an invoice to determine contents of car and avoid mixing of products.

g. All tools used in unloading car should be of the non-sparking type. Avoid striking car fittings with tools or other hard objects.

h. All tools and implements used in connection with unloading should be kept free from oil, dirt and grit.

i. To open or close dome covers or other fixtures on top of the dome, and to make connections to dome fittings, wrenches or bars should be pushed (not pulled) so that if tool slips the possibility of the workman falling off the car platform is greatly reduced.

j. No naked flame of any kind should be permitted for any purpose whatever, near the car or within the vapor area surrounding the car. Smoking is strictly forbidden within this area.

Failure to observe these precautions may result in ignition of the contents of the car, a serious explosion,
and personal injury.

2. Protection of Property and Workmen

Before any connection or contact is made between the tank car and unloading line or other unloading equipment, the tank car must be grounded in an effective manner (see Figure 11 for suggested details). Permanent electrical connections of not less than one No. 4 or less than two No. 6 AWG stranded copper, bronze or copper-covered steel wire should be made between the rails on which the tank car stands and the piping to the storage tank. This connection may be made in either of two ways:

(1) The rails may be bonded by means of standard rail bonds and connected to the permanent piping system with not less than one No. 4 or less than two No. 6 AWG standard copper, bronze or copper-covered steel wire connections at each end of the unloading section.

(2) A similar connection may be made between each rail on which the cars stand and the permanent piping system.

All electric lights, plugs, motors, wiring and controls at the unloading dock and within the vapor area should be explosion-proof, conforming in design and in-
Figure 11  Grounding of Tank Cars.
stallation with Article 500, and supplements and reissues thereof, of the National Electrical Code for Class 1 Hazardous Locations, or to the regulations of the insurance company for the particular location.

Approved chemical fire extinguishers, foam generators, or other approved extinguishing agents should be immediately available. All employees working at or near the unloading dock should thoroughly understand how to use such equipment. In addition, safety fire blankets should be available and easily accessible at the unloading dock, in close proximity to fire extinguishers but at a sufficient distance to permit access to either in all emergencies.

"NO SMOKING" signs should be prominently displayed, both at the loading dock and at strategic points surrounding the vapor area. The property around the unloading docks should be kept free from weeds, high grass and litter of all kinds, and should be maintained in a neat and clean condition.

C. Tank Fittings

1. Safety Valves

All tank cars containing inflammable liquids are equipped with one or more safety valves. On cars with domes, the valves are located either on the top or
side of the dome and are set to release at a pressure of 25 pounds per square inch. On cars of the ICC 104A type with protective housings, the safety valves are located within the housing on the manhole cover plate and are set to release at a pressure of not more than 75 pounds per square inch. At no time should any safety valve be adjusted in the field except upon specific authority and instructions from the shipper of the loaded car.

2. **Manhole Cover**

Some cars are equipped with a discharge pipe extending into a fitting on top of the dome, which is used for top unloading. On cars equipped with both a discharge pipe and a vacuum relief valve, and where top unloading by pump or syphon is contemplated, it is not necessary to remove the manhole cover before unloading. On cars not so equipped, and regardless of the unloading method contemplated, opening or removal of manhole cover must be accomplished in accordance with the following directions:

a. **Screw Type.** The cover must be loosened by placing a bar (non-sparking metal) between the manhole cover lug and the knob. After
two complete turns, so that vent openings are exposed, the operation must be stopped, and if there is any sound of escaping vapor, the cover must be again screwed down tightly and interior pressure relieved before again attempting to remove the cover. During unloading, the manhole cover must be put in place, but not entirely screwed down, in order that air may enter the tank through vent holes in the threaded flange of the cover.

b. Hinged and Bolted Type. All nuts must be unscrewed one complete turn, after which the same precautions as prescribed for screw type cover must be observed. During unloading, a small wooden block may be placed under one edge of cover to provide venting.

c. Interior Type. All dirt and cinders must be carefully removed from around the cover before the yoke is unscrewed. During unloading, the yoke screw may be tightened up so that the cover will be brought up within $\frac{1}{2}$ inch of the closed position.

d. Protective Housing Type. Remove one housing cover pin in order to lift cover on protec-
tive housing. This will expose all the valves and fittings by means of which unloading, sampling, etc., are accomplished. Do not disturb any studs or bolts on the manhole cover plate or within the housing.

When unloading through bottom outlet of cars equipped with interior manhole type of covers, and in all cases where unloading is done through the dome (unless special covers are used, provided with safety-vent opening and tight connection for discharge outlet), the manhole must be protected against entrance of sparks and other sources of ignition of vapor to the inflammable contents by asbestos or metal covers, or by covering and surrounding with wet burlap or cloth treated with fire retardants. Burlap must be kept damp by replacement or by the application of additional water as needed. Do not scrape or drop the manhole cover as friction sparks may result!

D. Unloading Techniques

1. General Method

Some states, and many companies, prohibit the unloading of inflammable liquids from the bottom outlets of tank cars. Since many tank cars are equipped only for bottom unloading, consignees in such states, or who have such restrictions at their plants located in other states,
use a special device for top unloading. This consists of a special cover which is placed over the opened manhole and through which a pipe is inserted so that overhead unloading may be accomplished. Particulars on this device may be obtained from the Manufacturing Chemists' Association (see Figure 12).

It is recommended that tank cars be unloaded through the dome connection rather than through the bottom outlet. Air pressure must never be used for this purpose. Use of a pump is the recommended method. Consignees desiring to unload cars through the dome by water displacement method or with the aid of a standard system employing an inert gas such as carbon dioxide or nitrogen as a pressure-generating medium, should contact the shipper for details on unloading procedures. Tank cars must be unloaded into storage tanks of adequate empty capacity to take the entire contents of the car.

Before a manhole cover or outlet valve cap is removed, a tank car must be relieved of all interior pressure by cooling the tank with water or venting the tank by raising the safety valve or opening a vent on the dome at short intervals. If venting to relieve pressure will cause a dangerous amount of vapor to collect outside the car, venting and unloading must be deferred until pressure is re-
UNLOADING INFLAMMABLE LIQUIDS FROM TANK CARS

- Protect openings against sparks with sheet steel, asbestos, fire retardant cloth or wet burlap.
- 2 to 3 pipe safety valves.
- For cars with ejection pipe.
- For cars not equipped.
- Recommended methods.
- Heater coils.

Unloading through bottom outlet not recommended.

MANUAL SHEET TC-4
duced by allowing the car to stand over-night or otherwise
cooling the contents. These precautions are not necessary
when the car is equipped with a manhole cover which hinges
inward or with an inner manhole cover which does not have
to be removed to unload the car, and when pressure is re-
lieved by piping vapor into a condenser or storage tank.

a. Cars With Domes. Before connecting the un-
loading line or removing the manhole cover, the tank car
must be relieved of internal pressure as described above.

b. Cars With Protective Housings. Internal
pressure should not be relieved prior to starting the un-
loading operation. These cars may be unloaded only from
the top of the car.

2. Sampling

a. Screw, Bolted or Interior Type Manhole Covers.
Before attempting to secure a sample from these types of
cars, the internal pressure must be released. If it is
desired to sample contents of car before unloading, the
manhole cover must be opened and a sample taken through
the manhole.

b. Protective Housing Type Cars. These cars
are provided with a sampling valve which is located on
the manhole cover plate inside the protective housing.

c. Alternate Method - All Cars. A tee and
valve may be installed at any point in the unloading line between the tank car and storage tank, from which a sample may be taken during unloading.

3. **Unloading Through Top Connection With Pump**

All protective housing type cars and certain other types are equipped with eduction pipes. For cars not so equipped, it will be necessary to open or remove the manhole cover and insert a 2-inch pipe (non-sparking metal) of sufficient length, provided with a bracket on the lower end to keep it approximately one inch from the bottom of the car (see Figure12). Be sure tank cars are grounded and internal pressure relieved on cars with domes before any connection is made with the unloading system.

Begin the unloading operation as follows:

a. Remove closure from valve through which car is to be unloaded.

b. Connect eduction pipe unloading valve to the pump suction line and open valve.

c. In the absence of a vacuum relief valve on dome, open the manhole cover.

d. Start pump.

e. After all liquid has been removed, shut off pump, close valve, disconnect plant unloading line from the tank car, replace valve outlet plug and housing cover. All other closures
should then be made tight.

f. If it is necessary to inspect the interior of the car, use only an approved flashlight (Underwriters Laboratories or Bureau of Mines approved). Do not enter tank.

4. Unloading Through Dome With Syphon

This method of unloading may be used only in cases where the top of the storage tank is below the bottom of the tank car. Such being the case and having "spotted" the car correctly, the unloading operation should be carried out as follows:

a. Remove closure from valve through which car is to be unloaded.

b. Connect the eduction pipe unloading valve to the syphon unloading system.

c. Fill syphon tank with a liquid similar to that in the tank car. As this liquid may be dangerously inflammable, care should be exercised to avoid creating a spark.

d. Open unloading valve on tank car.

e. Open valve on syphon tank to start syphon.

f. After tank car has been emptied, close tank car unloading valve, disconnect unloading line and syphon system, replace valve outlet plug and housing cover.
5. **Unloading Through Bottom By Gravity**

Many cars cannot be unloaded by this method since regulations prohibit equipping certain cars with bottom unloading devices. The discharge of tank cars containing volatile inflammable liquids through the bottom outlet is dangerous and should not be attempted even in localities where such unloading is not prohibited by statute or by ordinance. If such a method must be used, extreme care is necessary. Protect the car from being struck or moved from either end while it is being unloaded. If the bottom connection is torn loose, it is probable that the entire contents of the tank car will be lost.

To accomplish bottom unloading safely use the following procedure:

a. Open the manhole cover and leave it in the recommended position while the car is being unloaded. This is done to provide venting and to keep out sources of ignition.

b. The outlet leg cap or reducer must be removed

# If upon removal of the outlet cap the outlet chamber is found to be blocked with frozen liquid or any other matter, replace the cap immediately and make a careful examination to determine that the outlet casting has not been cracked. If the obstruction is not frozen liquid, the car must be unloaded through the dome. If the obstruction is frozen liquid and no crack has been found in the outlet casting, the car may be unloaded from the bottom as follows: Remove cap and attach unloading connections immediately. Then, before opening the valve inside the tank car, apply steam to the outside of the outlet casting or wrap the casting with burlap or any other rags and apply hot water to melt the frozen liquid. In any event, top unloading is safer than bottom unloading.
with a suitable wrench after the set screws are loosened, and a pail placed in position to catch any liquid that may be in the outlet chamber. If the valve cap or reducer does not unscrew easily, it must be tapped lightly with a mallet or wooden block in an upward direction. If leakage shows when starting the removal, the cap or reducer must not be entirely unscrewed, but sufficient threads must be left engaged and sufficient time allowed to permit escape of any accumulation of liquid in the outlet chamber. If leakage stops or the initial rate of leakage diminishes materially, the cap or reducer may be entirely removed. If the initial rate of leakage continues, the valve rod handle or control in dome must be operated a few times to see that the outlet valve in the bottom of the tank is on its seat. If this fails, the cap or reducer must be screwed up tight and tank must be unloaded through the dome.

c. Attach unloading line to the proper connection on the outlet leg.

d. Return to dome and open bottom outlet valve by turning the valve rod handle. This handle
may be inside the dome or located on top of the dome. In the latter case the handle is in the form of a hood which covers the protruding valve rod. Remove this hood, invert it, and fit it to the top of the valve rod, in which position it is used to open the valve.

e. Open valve on outlet leg cap on cars so equipped, to permit tank car contents to flow to storage tank.

6. **Unloading Through Bottom With Pump**

The hazards of pumping from the bottom of a tank car are of the same order as with gravity unloading and this method is therefore not recommended. Where regulations prohibit the bottom unloading of tank cars, they usually apply to all methods of bottom unloading. If it is necessary to use this method, the same procedure should be followed as outlined in Section 5.

7. **Piping From Unloading Point to Storage Tank**

All piping should be standard full weight wrought iron or steel pipe with standard fittings. Short sections of approved flexible metal, flexible rubber-metal or synthetic rubber hose or equivalent may be used to facilitate connection to tank cars where rigid connections are impractical. All piping should be securely supported to prevent vibration and mechanical injury. Where necessary, pipe
should be protected against corrosion. Pipe joints and connections should be made tight in a workmanlike manner. Unions requiring gaskets or packing and right and left couplings should not be used. Proper allowance should be made for expansion, contraction, jarring and vibration.

Approved shut-off valves should be installed in the suction and discharge line at the pump and at a convenient location near the storage tank. Where the elevation of the top of the storage tank is higher than that of the pump, an approved check valve should be placed in the discharge line to prevent the liquid from backing up into the tank car.

Piping should be tested hydrostatically after installation, and at reasonable periods thereafter, at a pressure of not less than 150 pounds per square inch nor less than one-and-one-half times the working pressure. Tests should continue for at least thirty minutes without a noticeable drop in pressure.

8. Pumphouse

Pumps should be located in a separate building of fire-proof construction and at a safe distance from the storage tank and other buildings. The pumphouse should have adequate electric lighting and all lights, wiring and

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Pumps should be located in a separate building of fire-proof construction and at a safe distance from the storage tank and other buildings. The pumphouse should have adequate electric lighting and all lights, wiring and
controls should be explosion-proof.

If the pump is motor driven, the motor and its controls (entrance switch, starter and start-stop switches) should be explosion-proof. All electrical equipment in the building within the vapor area of the building should conform in design and installation with Article 500, and supplements of the National Electrical Code for Class I Hazardous Locations.

Pumps should be of an approved type. Positive pressure pumps should be avoided, but if used, they should be equipped with a relief valve in the discharge pipe. Outlet from relief valve should then be piped into suction side of pump, in order to prevent excessive pressures.

The pumphouse should be ventilated with a gravity type ventilator, the duct extending to within a few inches of the floor to be certain that all heavier-than-air vapors are removed.

9. Examination of Empty Car

Many fatal accidents have resulted from using lanterns or lighted matches to examine the interior of empty tank cars or in using hot rivets to repair unsteamed tank cars which may contain inflammable vapors even when the previous lading was not of a flash point below 80 degrees

° 6, p. 4.
Fahrenheit. An approved flashlight should be used for this examination. In addition, fumes in an empty tank car should be considered injurious to a person entering it and proper precautions must be taken to prevent the inhalation of these vapors.

In no case should an empty tank car be entered before it has been thoroughly cleaned by steaming or another approved method. A person entering the tank car should be provided with a hose mask and safety belt with rope attached, and another person should be stationed at the manhole. Metal is liable to create sparks; therefore, men entering tanks should be required to wear safety shoes without nails or metal eyelets.

10. Service

Tank car shippers endeavor, as far as is within their power, to have their tank cars reach their destination in good mechanical condition; therefore, the consignee should notify the shipper of any trouble encountered. This will insure proper repairs, as required, upon receipt of the tank car by the shipper.

° 6, p. 6.
VI. ECONOMIC ASPECTS OF TANK SHIPMENTS

A. General Aspects

In general it may be said that the tank shipment of industrial chemicals has numerous advantages, both to the shipper and the customer. Many industries are finding that they can save money, increase operating efficiency, and make their plant a cleaner, safer place to work in by buying and/or selling their chemicals in bulk. Many of the manufacturers of industrial chemicals own their own tank car and tank truck fleets and are ready to supply immediate delivery of many chemicals by this means of transportation. From the customers point of view, many chemical users are now specifying bulk chemical delivery because of the lower unit cost of the chemicals themselves and the reduced handling costs at their plants. Others favor bulk handling because of its greater safety to employees and the virtual push button control over the movement of materials at their plants. Still others use tank shipment because storage space is at a premium and also keeping records of carboys and drums and the deposits necessary requires excessive accounting.

B. Advantages

1. Lower Material Cost

Because of the decreased labor costs resulting from filling tank cars and tank trucks instead of carboys and drums,
the manufacturer is almost invariably willing to offer a customer a lower price per pound for a chemical. It is true that labor charges for filling drums and carboys are not the only packaging expense for the manufacturer; however, this is the item that frequently provides the greatest saving. If this saving is shared with the customer, then over a period of time, the cost of storage facilities is more than repaid.

2. Transportation Charges

By the use of tank shipments freight charges are reduced quite materially because they consist of delivery charges on the material only and not the material plus containers. There are no additional deposits as is the case with carboys and drums, further, there is the factor of a freight saving on returning empty containers. With bulk handling all parties concerned are able to sidestep the bookkeeping, storage costs, handling, breakage and loss of closures on stored empty containers. Damage and breakage can amount to a sizeable loss which can easily be prevented by bulk shipments.

3. Savings in Storage Space

Bulk handling of industrial chemicals increases the available warehouse space within a given plant. Raw materials can remain outside of the actual plant buildings
in bulk storage tanks, thus the space available may be utilized to store finished goods. Almost all of the labor costs of warehousing and rehandling are saved by the use of bulk storage. In addition, the closed piping systems keep the storage and working areas cleaner and the chemicals are always ready for use.

4. Increased Safety

By piping the chemicals to and from the storage area the dangers of leakage, spilling, breakage, and the handling dangers attendant upon emptying the containers are eliminated. Thus the safety aspect of the material handling problem is greatly reduced. It is not to be inferred however, that all dangers have been eliminated by merely changing to bulk handling. For a more detailed discussion of the safety aspect of the handling of tank loading and unloading, refer to the two sections on the subject in the previous chapters.

C. Adaptability

1. Unloading

In the event that a customers requirements for chemicals do not justify the installation of a bulk storage tank and the purchasing of pumping equipment, or if the layout of the plant is not adaptable to a single storage tank, the various chemical suppliers and carriers still
make it possible to obtain the savings inherent in bulk shipments. This is done by providing in many instances the necessary discharging equipment with the delivery of the chemicals. For example, it is possible to unload a tank car or truck by gravity, pump or air pressure, thus a number of carriers provide trucks equipped with power take-off pumps or in some instances, portable pumps. The contents may then be transferred either to bulk storage or emptied into bulk containers on the customers premises.

2. Combination Shipments

In view of the fact that there are available a number of compartmented tank cars and tank trucks, it is possible to make combination shipments of liquid chemicals in a single delivery. The quantity of chemicals to be delivered in such a manner are optional within certain limits and it is to be expected that the most economical costs will be on the larger loads. However, it appears to be the practice of the carriers to permit the lost to vary between 1000 and 4500 gallons. Thus the customer is given the opportunity to obtain bulk freight rates for two or more chemicals by receiving them in the same shipment. The savings in freight charges by the use of such a system can amount to an appreciable sum over a short period of time, depending upon the quantity of chemicals he uses.
3. **Storage Requirements**

For tank truck deliveries, the customer will require a bulk storage tank with a minimum capacity of 3,000 gallons. For tank car deliveries, the tank should have a minimum capacity of 15,000 gallons. The storage tank should be located in an easily accessible open area, mounted on an elevated structural steel support with a wooden operating platform and ladder. Foundations should be concrete of the spread footing type. A 3000 gallon tank requires 5 cubic yards of concrete for the footings; a 15,000 gallon tank requires 10 cubic yards of concrete.

Tank trucks are usually unloaded using air pressure generated by the truck. Flammable liquids are unloaded by a pump carried on the truck. If the lift is too high, a pump will be required for unloading any of the bulk chemicals. Tank cars require that compressed air for unloading be available from an existing supply or from an air compressor assigned to that operation. A 3 horse power, 2 cycle, 30 cubic feet per minute at 25 pounds per square inch (30 gallon receiver) compressor with an open 220-440 volt motor is satisfactory. For tank cars, a pump would be required for high lifts. All air piping should be steel pipe.

At the point of unloading, a supply of 220 or 440
volt 3 phase power must be available with a free circuit if pumps are installed.

Tank elevation is determined on the basis of local conditions, methods of operation, and chemicals to be stored. The maximum elevation (to the top of the tank) for tank car or tank truck unloading using air pressure will be limited by the specific gravity of the material to be unloaded and may be determined by the following formula:

\[
\text{Maximum elevation} = \frac{350}{\text{pound weight per gallon of liquid}}.
\]

D. Savings

1. Comparison - Tank Cars versus Tank Trucks

a. Benefits to Shipper:

As it has been previously stated, the major saving to the shipper of industrial chemicals by tank cars or tank trucks lies in the fact that his packaging costs are reduced. However, there are other items which, while it is difficult to attribute an actual dollars and cents value to, nevertheless do provide savings. In the matter of direct comparison of unit costs between tank cars and tank trucks, tank cars are in a somewhat more favorable position by virtue of load capacity. To ship a given number of pounds of material, fewer loadings are required in the case of a tank car than in a tank truck; however, the

* 5, p. 12.*
difference in unit cost is quite small when compared with small container shipments.

In view of the fact that there is little difference in unit cost between the use of tank cars and trucks what, if any, other benefits can the shipper expect from the use of one over the other? The advantages lie in the following:

1. The use of both methods insures the shipper and his customers that there is a dual delivery service available.

2. Either method is used as a dampening factor over the other as regards the price that the carrier will charge. Essentially the two carriers do not overlap as regards facilities and are thus competing for the shippers business.

3. The shipper can increase his competitive position by offering tank truck deliveries within certain areas at tank car prices.

b. Customer Benefits:

An effort has been made by the author to compare the break-even points of tank car and tank truck shipments in either a graphic or tabular form; however, I have not been successful for many reasons. The principal reason be-
ing the complexity of the various freight rate structures. To illustrate this, it is ordinarily assumed that the tank truck is the most economical means of transportation for short hauls, say within a radius of 150 to 200 miles; however, because of the rate structure, it is possible to ship a tank car a distance of 10 or 20 miles at a much cheaper price than by tank truck. This is possible for it is conceivable that the only freight charge will be that of the switching service provided by the railroad. While this might be considered an exceptional instance, it illustrates that the freight charges cannot be rationalized on the basis of distance. In addition, the factors of the price of the material and what freight rate classification it comes under determine which method of transportation is most advisable and make a general comparison impossible.

Thus it can be seen that in order to obtain the most favorable transportation charges on a bulk shipment, it is imperative that either the customers or the shippers traffic department consider each case carefully in order to obtain the most economic method of shipping the product.

2. Tank Cars versus Carboys or Drums
As an illustration of the savings that can be effected in freight costs, the author has worked out a comparison of tank car shipment of nitric acid versus carboys in box cars. The figures used are as close to actual conditions that existed as is possible with the data available.

The company examined purchased on the average 424 tons of 42 degree Baume nitric acid from a supplier some 1000 miles away. To deliver this material required 6060 carboys which were shipped via "carload rail freight" with the empty carboys being returned via "rail carload freight". This method of shipment based on prevailing rates results in the following cost of delivery to the customer:

\[
\begin{align*}
\text{Gross weight} & \times 0.9517 = 2.00 \text{ shipping cost per full carboy} \\
\text{Tare weight} & \times 1.3596 = 0.95 \text{ shipping cost per empty carboy} \\
\text{Net weight} & = 2.95 \text{ cost for shipping each carboy}
\end{align*}
\]

This results in a delivery cost of $2.11 per hundred pounds of acid, or $42.20 per ton.

If, during the year, the customer purchased an average of 424 tons of acid at $74.00 per ton F.O.B. it would cost $31,376.00. Add to this the cost of delivery of 424 tons at $42.20 per net ton, $17,892.00, and the total cost for 424 tons delivered becomes $49,268.00.
The same tonnage shipped via tank car would present the following charges:

Net tons 424 x $19.034 car rate per ton = $8,070.00  
Net tons 424 x $58.00  price per ton = $24,426.00  
Total cost for 424 tons delivered = $32,516.00

The savings to the customer could be as follows:

Cost of acid as purchased in carboys = $49,268  
Cost of acid if purchased in tank cars = $24,426  
Potential yearly saving to customer = $24,842

Needless to say, the annual savings that are to be realized would quickly pay for the installation of storage tanks at the customers plant as well as eliminate a great deal of carboy records. In addition, a substantial sum of money that would ordinarily be tied up in carboy deposits is made available for working capital.

3. Tank Truck versus Carboys or Drums

A study was made of the potential savings for a customer with a plant approximately 20 miles from the source of supply of Hydrochloric Acid on the basis of using tank trucks in place of carboys and drums.

The customer averages approximately 115 tons of acid per year in 1100 carboys. By the purchase of a small, 1000 gallon rubber lined tank so as to accomodate tank truck shipments, the following savings could be effected:

Via carboys - Cost of acid $45.00 per ton F.O.B.
Cost of delivery $6.00 per ton
Cost per net ton $51.00
Via tank truck - Cost of acid $27.00 per ton F.O.B.
Cost of delivery $3.00 per ton
Cost per net ton $30.00

Comparing these two figures, there is a net saving of $21.00 per ton which, on the basis of 115 tons per year, would amount to $2400.

It is obvious that the success of programs similar to those above depends upon the manufacturer sharing the savings in carboy and drum packaging with the customers and the ability of the customer to install the necessary storage facilities.

The shipper benefits greatly from bulk shipments of the above type for it then becomes possible to liquidate the large stocks of carboys and reinvest this capital in new chemical processes. The amount of capital invested in carboys can be quite substantial when it is considered that a moderately large company may possess 70,000 carboys valued at $20.00 each. In addition to the initial investment, there is the problem of maintenance, which may run as high as $5.00 per carboy per year.
E. Economic Basis for Leasing Tank Cars

In any study covering rail transportation of bulk liquid products it must first be understood that only one-fifteenth of the tank cars in the United States are owned by railroads (see Table V). The balance, approximately 140,000 tank cars, are privately owned by individual industries or by companies who lease cars to industry. The latter class, the leasing companies, account for ownership of over two-thirds of all tank cars. It is primarily to the leasing companies that industry must look for its tank car supply. The allocation or assignment of tank cars is not controlled by the railroads except where their own tank cars are concerned.

The fact that two-thirds of the privately owned cars are controlled by car lines would lead the reader to ask, "Why does the shipper today usually prefer to lease rather than own his cars?". The answer lies partly in the intermittent character of many shippers use of their equipment due to the following.

1. Seasonal Factor

Numerous commodities are seasonal in either their production or sale. Asphalt, for example, is used during the seasons when roads can be built in certain regions. Molasses is moved during only about six months of the year;
<table>
<thead>
<tr>
<th>Service Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum Service</td>
<td>94,825</td>
</tr>
<tr>
<td>Chemical Service</td>
<td>27,333</td>
</tr>
<tr>
<td>Miscellaneous Service</td>
<td>19,089</td>
</tr>
<tr>
<td><strong>Total Privately Owned Cars</strong></td>
<td><strong>141,247</strong></td>
</tr>
</tbody>
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B. Railroad Owned

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Miscellaneous Service</td>
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</tr>
<tr>
<td><strong>Total of all U.S. Tank Cars</strong></td>
<td><strong>149,973</strong></td>
</tr>
</tbody>
</table>

cottonseed oil likewise is transported in volume during certain months. A fleet of 100 standard tank cars, depending on the year in which manufactured, involves an investment of from $180,000 to $550,000. It is not economical for a shipper to make such an investment, tying up his capital continuously for eight, fifteen, or even twenty to thirty years, when the cars would be idle for a quarter, a third or a half of every year. Were he unable to lease equipment as he required it, there might be no alternative; but a car leasing line can rent to him during the months he needs the equipment and then put the same equipment to work for other shippers having different seasonal peaks during other months.

2. Effect of Business Cycle

From year to year, likewise, some shippers find it cheaper to rent, regardless of seasonal factors, because businesses vary greatly in their fluctuations during different phases of the business cycle. A staple food or tobacco manufacturer may be subject to little or no cyclical variation; his annual volume may not decline or increase by more than 2 per cent from good years to bad. On the other hand, a chemical, steel or machine tool manufacturer may experience a decline of 75 per cent or more from a peak year of prosperity to the trough of depression. Under a modern rental arrangement, it may be possible for such shippers to relieve them-

# The figures cited are for cars of 10,000 gallon capacity, not insulated or coiled.
**TABLE VI**

**AVERAGE TANK CAR TURN AROUND TIME**

(Days Employed for Round Trip)

<table>
<thead>
<tr>
<th>MONTH</th>
<th>1947</th>
<th>1948</th>
<th>1949</th>
<th>1950</th>
<th>1951</th>
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<td>14.55</td>
<td>16.03</td>
<td>17.52</td>
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<td>16.65</td>
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</tr>
<tr>
<td>March</td>
<td>15.07</td>
<td>14.43</td>
<td>17.01</td>
<td>17.49</td>
<td>16.99</td>
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<td>17.75</td>
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<td>17.82</td>
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<td>15.19</td>
<td>17.85</td>
<td>18.44</td>
<td>18.75</td>
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<td>18.95</td>
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<td>December</td>
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<td>15.00</td>
<td>17.71</td>
<td>17.71</td>
<td>18.01</td>
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</tbody>
</table>

(1st10 mo.)

selves of a portion of the financial burden which constant ownership would entail.

F. Availability of Tank Cars

1. Liquid Rail Traffic

Liquid movements by rail have not increased in proportion to the increases in production of both petroleum and non-petroleum products. This is definitely shown by the fact that daily tank car loadings of all tank cars are less than during the war period, although the transport of liquid commodities by all means of transport has increased as much as 32 per cent, with chemical shipments even higher.° The slowing down of expansion in liquid rail traffic, which is predominantly petroleum, is due not only to the completion of various new crude oil and products pipe lines, but to continued diversion of traffic from the rails to barges and tank trucks as a result of cost differentials and truck convenience for short hauls. Thus it would appear on the surface that there should be more than an ample supply of tank cars to supply the needs of the various industries. However, such is not the case because of the lack of new tank car construction and the emergency demands due to trucking strides and seasonal changes.

2. Shortage of Tank Cars

° 11, p. 3.
<table>
<thead>
<tr>
<th>MONTH</th>
<th>1943</th>
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<th>1948</th>
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<td>68.3</td>
<td>60.4</td>
<td>58.5</td>
<td>66.7</td>
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<tr>
<td>February</td>
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<td>56.6</td>
<td>72.1</td>
<td>62.2</td>
<td>60.1</td>
<td>59.8</td>
</tr>
<tr>
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<td>73.0</td>
<td>59.1</td>
<td>60.7</td>
<td>65.3</td>
</tr>
<tr>
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<td>69.5</td>
<td>54.6</td>
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<tr>
<td>May</td>
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<td>63.7</td>
<td>69.1</td>
<td>54.1</td>
<td>54.3</td>
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<tr>
<td>June</td>
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<td>December</td>
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<tr>
<td>Average</td>
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<td>64.3</td>
<td>67.4</td>
<td>57.0</td>
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<td></td>
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</tbody>
</table>

A private survey made recently covering all United States owned tank cars estimated that over 50 per cent of all tank cars in the country, approximately 75,000, would reach or exceed the age of 35 years, their life expectancy, within the next five years. Unless plans are made in the immediate future to guarantee the timely replacement of these cars, the effect on the economy of the country as a whole will be quite profound. The urgency of the situation is further heightened by the fact that steel has been made available for the expansion of existing plants or the construction of new plants much earlier than steel has been assigned for the transportation required to move the production of these plants.

In regard to pressure cars for chemical service, there will be shortages of chlorine cars, cars for anhydrous hydrofluoric acid, metallic sodium, vinyl chloride, ethyl chloride and other special chemicals whose production has been increased faster than cars for their transportation can be built. The lending of chemical cars whenever available has been going on for some time within the chemical industry and many shortages have been averted by this cooperative practice and maximum efficiency in the use of chemical tank cars.
The inability of car builders to obtain adequate allocations of steel has resulted in a tank car deficit in the first and second quarters of 1952. The tank cars required to meet essential new plant production and increased production from existing chemical plants will be at least 2,000 cars short overall. It is believed that future shortages of cars and any resulting cut-backs in chemical production will almost exactly correspond to the extent that the car building program is behind schedule. Even with this possibility and peak production by car builders there is no possible way of making up the tank car shortage until some time in 1953.
VII. POTENTIAL DEVELOPMENTS AND CONCLUSIONS

A. Expanding Use Under Present Conditions

The use of tank cars and tank trucks for the transportation of industrial chemicals is continually expanding. While the rate of increase in the volume of chemicals being moved may not be as rapid as in the past, the diversity of the products being moved is dynamic. Through the close cooperation of the tank manufacturers, shippers, carriers, and the various regulatory commissions and associations new methods of shipping chemicals in bulk quantities are being developed.

Primarily, the problems encountered in developing a method of handling bulk shipments of chemicals must be solved by the chemical manufacturers. It is only rarely that the customer will enter into the development stage. Therefore, having once resolved the material handling problem, the chemical manufacturer is then faced with the further problem of convincing the customer that it is to his advantage to accept tank shipments. This is all the more difficult to do when the advantages are not as clear-cut as those stated in the previous chapter. In as much as the development of tank shipping methods for new chemical products is a rather lengthy proposition, the greatest potential for expanding tank shipments under
present conditions is for the manufacturer to conduct an "educational" program directed at his present and potential customers. By pointing out the savings that are to be realized when chemicals are purchased in bulk form, the alert producer can gain a great competitive advantage. As a means of awakening interest in a bulk shipment program, the manufacturer can prepare simple booklets or letters stating the savings that a customer can make and how rapidly the cost of a bulk receiving station can be amortized.

Each year more and more customers are being converted to bulk shipments and it is but a matter of time and salesmanship on the part of the chemical manufacturers before a great majority of the tonnage of liquid industrial chemicals will be moving by tank shipment.

B. Proposed Future Developments

1. Tank Truck - Flat Car Shipments

In view of the flexibility in operation that is afforded by tank trucks in being able to provide rapid delivery of chemicals, they have cut quite deeply into the tank car share of the market. This is particularly true when the radius of operation is within 200 miles. However, I feel that both the railroads and the trucking companies
can benefit from an arrangement similar to the following proposal.

A tank truck trailer containing a liquid material could be transported from the chemical plant to a railroad loading terminal and placed upon a flat car. The driver would then remove the tractor and the trailer tank could be shipped to the customers city by rail. Having reached the customers railroad terminal, the trailer tank could be removed from the flat car and delivered to the customers plant. Upon being emptied by the customer, the trailer is possibly reloaded with other materials for a return trip or is returned empty. Because of the variations in rate classifications this arrangement can be made to work satisfactorily for a number of chemicals to be moved limited distances. It is quite possible that through such an arrangement tank trucks could be shipped considerable distances economically to the mutual benefit of all parties concerned.

2. Distribution Centers

With the increasing number of tank truck deliveries that are made to large cities from outlying areas, there is a possibility of adopting a distribution method used by the petroleum companies. It consists of the chemical manufacturers establishing, by purchase or lease, bulk
storage tanks in various cities some distance from the manufacturing location. Chemicals are then shipped to these areas in tank cars or tank trucks and unloaded into the shippers tanks. Arrangements can then be made to reship the material to the customers via tank truck. This method permits sales to customers who are too distant for economical tank truck shipments and yet not accessible by rail. Thus the chemical manufacturers area of operations is increased by the use of first tank cars and then tank trucks, providing him with potential customers that were unavailable previously.

3. **Constant Temperature Tank Cars**

The shipment of certain materials via tank car has been impossible because of the existing practice of not providing heat to the tank cars in transit. In as much as loss of heat may spoil certain products, a system of providing heat to the tank car under a controlled system could be developed. The simplest approach would be to utilize steam generated in the locomotive. Failing to do this, a system could be provided whereby heat is supplied to the tank car coils or jacket by the carefully controlled burning of bottled gases carried on the car. Admittedly, the uses of such a car are limited, but the possibility is suggested by the successful operation of just
such a system on a tank truck used to transport molten chocolate from a chocolate firm in New England to a candy manufacturer in the Philadelphia area.

4. Seatrain - Ballast Tanks

The author has not discussed the use of sea going tankers as a means of transporting chemicals for it is felt that such a method of transport was quite restrictive. However, there is a system in operation which utilizes ocean going vessels in conjunction with tank cars, which is known as the "Seatrain".

The "Seatrain" is a relatively new type of vessel on which 100 loaded freight cars may be stowed. Upon arrival of the cars at the seatrain terminal, specially constructed cranes lift the entire car by its four corners and place it in the hold of the ship. The car is then switched along rails within the vessel to the desired place and the wheels are locked to prevent rolling. Not only is there a great advantage through the elimination of terminal delays, but through the cutting out of costly packing requirements as well.

The tarriff rates which prevail through the use of the seatrain are such that it is possible for the New England area to compete with concerns in the Middle West for the customers in the South and Southwest.
As a further refinement of this method of transportation, it is suggested that industry investigate a procedure used by the armed forces during World War II in which portable ballast tanks were utilized to carry fuels and supplies while serving as ballast. The tanks used vary in size, but it is suggested that tanks of the 25,000 gallon size be filled with chemicals and these in turn would be loaded upon a seatrain for shipment to the port nearest the manufacturers distribution center. Upon arrival, the ballast tanks would be removed from the vessel and placed in a suitable location so as to unload their contents into tank cars and tank trucks, or into terminal storage for reshipment to customers at a later date.

C. Conclusions

In following the evolution of chemical containers from the early carboys and drums through the modern tank cars and tank trucks the most important factor considered by the various federal commissions and trade associations was safety in handling and transportation. Through the cooperative effort of chemical manufacturers, carriers, the Bureau of Explosives, the Manufacturing Chemists Association and tank manufacturers, industry has been provided with equipment for transporting industrial chemicals which will not jeopardize either the public or the workers if it
is used intelligently. Therefore, as a constructive rec-
ommendation, it is suggested that the methods of handling
tank shipments of chemicals as set forth in this thesis
be considered the minimum standards of safe operation.

While the various phases of loading and unload-
ing of tank cars were covered quite extensively, there are
still numerous situations which were not discussed and are
encountered in the every day routine of a sizeable bulk
shipment station. Fortunately for industry, practically
every situation to be encountered is covered in the manuals
published by the Bureau of Explosives and the Manufacturing
Chemists Association. These manuals may be obtained for
a small fee by contacting the above agencies and stating the
information desired. The date published has been used
successfully by the author and provides an excellent source
of reference when preparing a program for instructing the
workers as to the proper material handling techniques.

The chemical industry can accomplish much towards
the increased use of tank shipments of industrial chemicals
by sponsoring continuous research into the field of chemi-
cal containers and their applications. In addition, it
would benefit the manufacturer as a seller and a customer
if he were to attempt to interest others in the possible
use of tank cars and trucks in place of drums and even bags
as a shipping container. The examples cited in the text showing the potential savings are wholly realistic and are based upon actual experience. While it is obvious that the savings to be effected in other situations might not be as dramatic, they can nevertheless be substantial, especially so with the return of the buyers market. Therefore, in order to maintain or better their position competitively, those connected with the use of industrial chemicals must be ever on the alert for safer, more efficient and more economical shipping techniques.
APPENDIX I

REPRESENTATIVE GROUP OF COMMODITIES TRANSPORTED IN TANK CARS

1. PETROLEUM PRODUCTS
   Alkylate
   Asphalt
   Benzine
   Bright Stock
   Butane
   Coal Spray Oil
   Codimer
   Crude Oil
   Cumene
   Cylinder Stock
   Flux Oil
   Fuel Oil
   Furnace Oil
   Gas Oil
   Gasoline
   Gilsonite
   Kerosene
   Lubricating Oil
   Naphtha
   Petrolatum
   Propane
   Propylene
   Rust Preventative
   Wax
   Trans-Oil

2. TAR & CREOSOTE
   Coal Tar
   Creosote
   Creosote Oil
   Crystile Acid
   Water Gas Tar

3. VEGETABLE OIL & PACKING HOUSE PRODUCTS, FISH OIL, ETC.
   Babassu Oil
   Castor Oil
   Chinawood Oil
   Citrus Oil
   Cocoanut Oil
   Core Oil
   Corn Oil
   Cottonseed Oil
   Fish Oil
   Glycerine
   Grease
   Inedible Oil
   Lard
   Linseed Oil
   Liquid Stick
   Margerine Oil
   Muru Muru
   Neats Foot Oil
   Oiticica Oil
   Olive Oil
   Palm Oil
   Peanut Oil
   Perilla Oil
   Rapeseed Oil
   Red Oil
   Soapstock
   Soya Bean Oil
   Stearine
   Tallow
   Tung Oil

4. ALCOHOLS - CHEMICALS
   Acetate
   Acetone
   Acetic Acid
   Acetic Anhydride
   Acid (other than sulphuric)
   Acrylonitrile
   Agrol Fluid
   Alcohol
   Alum
   Ammonical Liquor
   Ammonia Nitrate Solution
   Analine Oil
   Anglomol
   Anhydrous Ammonia
   Anti-Knock Compound
   Arsenic
   Benzene
   Benzine (Polyethyl)
   Benzol
4. ALCOHOLS - CHEMICALS (cont.)

Bisulphide
Black Liquor Skimmings
Brine
Butanol
Carbon Bisulphide
Carbon Fertilizer
Carbon Tetrachloride
Calcium Chloride
Calcium Magnesium Brine
Caustic Soda
Chloride
Chlorine
Chlorinated Kerosene
Chlorinated Paraffin
Chloroform
C. S. Chemical
Cresol
Cyclo Hexanol
Dibutyl Phthalate
Dodecyl Mercapatan
Drip Oil
Ether
Ethyl Oxide
Ethylene Glycol
Fatty Acid
Fermentation Slop
Formaldehyde
Furfural
Fusel Oil
Glauber Salt
Glycol
Insecticide
Lamblack Oil
Latex
Lime Sulphor Solution
Lignin Liquor
Light Acid
Liquid Potash
Lite Oil
Lorol
MP 189
Methanol
Monochlorobenzene
Muriatic Acid
Naphthalene
Naphthenic Acid
Neutral Liquor
Nitro. Fert.
Nylon Salt Solution
Oil of Coal Tar

Oil Additive
Oleum
Paper Mill Liq.
Peroxide
Petro. Reduction Compound
Perchloroethylene
Phenol Acid
Phenolate
Phosphorus
Piscalt Oil
Plasticizer
Rubber Inhibiter
Salt Solution
Santicizer #141
Silicate of Soda
Sludge Acid
Solvents
Sodium Sulphurate
Stalite
Styrene
Sulphate Skimmings
Sulphur - Molten
Sulphur Dioxide
Tall Oil
Tannic Acid
Tanning Liquor
Tar Acid Oil
Thinner
Toluol
Tollac
Vinolite
Vinyl Acetate
Weed Killer
Wet Flow
Wood Preservative
Xylol

5. MOLASSES & SYRUPS

Corn Sugar
Glucose
Hydrol
Liquid Starch Greens
Molasses
Steep Water
Syrup
6. NAVAL STORES

- Paper Size
- Pine Oil
- Pine Tar
- Pitch (Check Lessee)
- Resin Oil
- Rosin
- Turpentine

7. SULPHURIC ACID

8. WINE

9. MISCELLANEOUS

- Black Japan Varnish
- Brew Yeast

9. MISCELLANEOUS (cont.)

- Cordage Oil
- Dry Flow
- Fullers Earth
- Glue
- Glue Size
- Ink
- Lacquer
- Liquid Chalk
- Liquid Clay
- Magnesium Hydrox Slurry
- Paint
- Paint Reducing Oil
- Pickles
- Resin Glue
- Shellac
- Skimmed Milk
- Smokeless Powder
- Varnish
- Vinegar
- Water
- Whey
- White Oil
- Wire Enamel
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