Corrosion on Tankers

First of a series of articles by William B. Jupp, Manager Construction and Repair Division, Marine Transporation Department, Socony-Vacuum Oil Company, Inc., on the serious problem of corroding tanks aboard tankers. It is published in The Compass to provide tankermen everywhere with information vital to their profits or loss.

PART I—Tanker Corrosion

The corrosion in the cargo spaces of tankers shows a wide variation, dependent upon the trade route, the type of cargo carried, and the frequency of ballasting and cleaning tanks. Vessels operating exclusively in fresh water show a low rate of corrosion regardless of the type of cargo. Some river barges and tankers on the Great Lakes, with which I am familiar, have required no repairs to the cargo spaces after 14 years in service, regardless of predominately clean trade during this period. On the other hand, vessels operating in salt water have developed serious bulkhead failures in six to eight years of clean trade when frequent cleaning has been required.

A study of tankers operating in the ocean and coastwise trade should furnish the best data on the cost rate and nature of corrosion, as well as points of the greatest wastage. The data and comments herein are based primarily on the analysis of corrosion gathered from some twenty ships, some riveted, some welded, all operating in the Gulf East coast trade alternating between clean and dirty cargoes. If a tanker is to make its anticipated twenty-year life, in the above trade, half in the clean service and half in the dirty service, the data would indicate that it will be necessary to renew completely all internal structure in this period, with partial renewal of deck and bottom plating and also with some renewals of framing.

A recent estimate for the complete renewal of internal structure of cargo space indicated that this would cost a minimum of $750,000. Work on the partial renewal of deck, shell and bottom plating, including some longitudinals, could not be covered for less than $250,000. In round figures the expenditure for steel work to maintain a twenty-year life (one half in dirty and one half in clean trade) would be in the neighborhood of $1,000,000 for 500 cargoes between Gulf/North of Hatteras. I will assume for the moment that corrosion is three times as rapid in the clean trade as in the dirty trade. It therefore follows that if the 500 cargoes are operated as 250 clean and 250 dirty, the corrosion cost of the clean cargoes is $750,000, or $3,000 each, and the cost of the dirty cargoes is $250,000, or $1,000 each. Looking at it another way, the 250 dirty cargoes at one-third the corrosion rate would be equal to one-third this number of clean cargoes, or 83 cargoes. These 83 equivalent clean cargoes added to the 250 clean cargoes would make an equivalent of 333 clean cargoes in the 20-year life of the ship. Most of this expenditure is, of course, in the second half of the ship's life. It can be expended on a year-to-year basis or in one or two major overhauls.

To place this figure in another light, in a fleet of 20 ships in this service, the cost would be $1,000,000 per year or $50,000 per year per ship, $75,000 per year for the clean trade and $25,000 per year for the dirty trade. This expenditure does not include the cost of cargo pipes, valves, reach rods, etc.

In the early thirties, the ships of the summer-tank type built during and immediately after World War I were carefully drilled to determine the necessary steel renewals to extend their life. These data were analyzed in an effort to determine the rate of corrosion. An effort to plot the amount of wastage against time or number of cargoes gave a very good plot when a time scale was adopted using time in the dirty service evaluated at a corrosion rate of one-third that of clean service. (See Fig. 1).

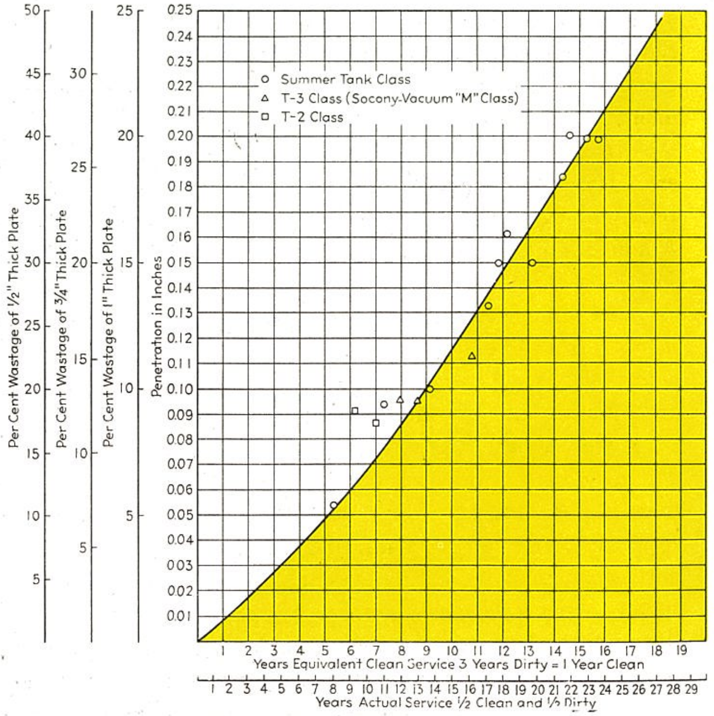

Fig. 1—Tanker Corrosion Curve
Based on Average Corrosion of Internal and External Cargo Tank Surfaces, Aug. '52

It will be noted that at the end of nine years of service, where three years of dirty trade equals one year of clean trade, that the average corrosion was 0.10 in. or a rate of 0.011 in. per year, on a clean trade basis. In the next six years, however, the corrosion had accelerated to an average of 0.015 in. per year, an increased of 35% in the rate of corrosion. The external or shell plating corrosion average is very close to that of the internal members, although they are exposed to the cargo on one side only. This is due to the very high rate of wastage under deck. When the deck wastage is averaged with the shell wastage the result as stated above is very close to average wastage of the internal members.

The general wastage is shown in percent of the original thickness for various thicknesses of plate, as well as actual loss, as renewals usually are required when the general wastage exceeds 25% of required scantlings, particularly in the shell. Rebuilding becomes absolutely essential in any part of the structure before it reaches 40% because of the much higher rate of wastage when the material is so far below the designed scantlings.

The wastage data on ships built after the mid-thirties also have been plotted on this same curve. They show the same rate of corrosion as the older ships when plotted on this scale. Their higher speed, however, represents 25% more cargoes carried in the same period. These new ships have had some treatment of inhibitors after tank cleaning which may be a factor in the increase in cargoes carried.

Several of the new ships had about 0.04 in. extra thickness added to the upper structure and therefore the percentage loss below the required scantlings in this case must be replotted when consideration is given to renewals. The increased scantlings in plates under one-half inch in thickness required about 60 to 80 tons of metal. It has given an increase in life of about four years before requiring replacement.

In Fig. 2 the wastage data used to determine the general corrosion rate were analyzed again to determine the relative loss of metal in the various parts of the structure. A number of modern tankers were used for this purpose. The data correspond closely to that of a previous study of the old summer tank ships. The average wastage of the shell is not far different from the bulkheads although only one side is exposed to the cargo. The greatest wastage is in the deck plating and framing—even greater than the bulkheads.

The bulkheads and their framing show a difference in corrosion rate of only about 10% more in the upper spaces than at the bottom. This is roughly in inverse proportion to the thickness of the plates and also is true of the general corrosion curve indicating that fatigue corrosion may be a factor. When these wastages are put on a percentage basis, the picture changes, showing a much higher percentage in the lighter upper cargo structure and deck plates and frames. It also is of interest to note that the corrosion is greater where the steel is exposed to moisture and sweating from change of temperature by heating in the sun, cooling at night, etc.

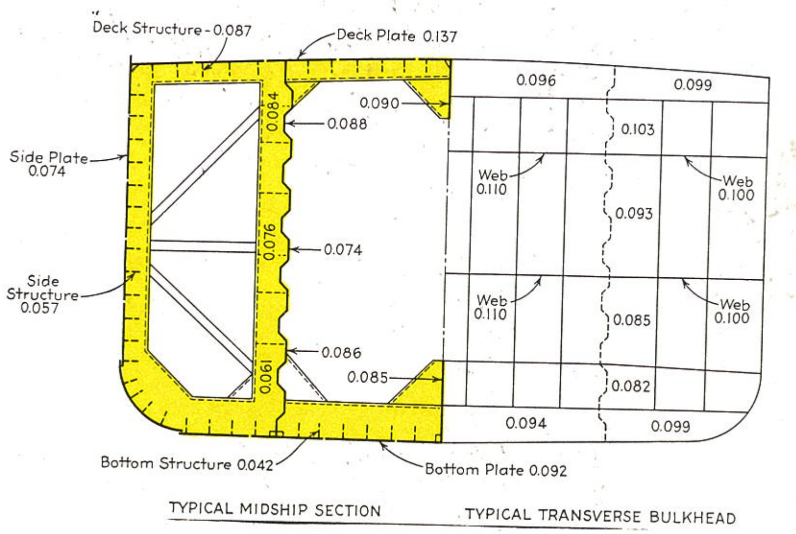

Fig. 2—Average Penetration in Inches for 8 Years of Clean Service
Note: Above Average Penetration in Inches is the Average of Seven T3 and T2 Tankers. Penetration is the Average for Both Sides

It was impossible to find excessive corrosion in the tanks normally used for ballast. If corrosion due to sweating is a predominating factor, as indicated by these figures, one would anticipate the greater corrosion on the empty side of a ballasted tank where both moisture and oxygen are present. It is well known that both are required in normal corrosion and the rate of corrosion is much greater with a high oxygen content than when the amount of oxygen is restricted as in a ballasted tank. It has been pointed out very clearly that there is need of maintaining a pH value of the moisture film in contact with the steel of at least 10 to lower the corrosion rate in the presence of oxygen.

Data from two ships operating on the West Coast, where less cleaning and gas freeing are required with a consequent lowering of the moisture in the tank, show a decidedly lower rate of corrosion. No difference was found in the corrosion rate of ballasted tanks as compared with the tanks normally empty on the ballast run.

The local corrosion shown in Fig. 3 unfortunately is not of equal intensity throughout each of the various panels between stiffeners making up the bulkheads, but is as much as three times as rapid at the points of maximum working or hard points in the general structure. These points cause failures in cargo segregation long before the general corrosion gives difficulty.

The maximum local corrosion occurs at hard points or the points of maximum flexure or strain; that is, at the points of working of the structure or the points of high cyclic stress not necessarily at the parts of the structure under the heaviest load or stress. In other words, a distinction must be drawn between uniformly distributed stresses and local hard points where cyclic stress or fatigue play an important part.

Sketch A of Fig. 3 shows the grooving of the bulkhead plate above a web or horizontal stiffener. This locol corrosion is particularly aggravated at the limber hole in the horizontal web. The web itself is grooved in the same manner. These grooves may run toward a lightening hole. This condition is not found on the bulkhead under a web stiffener.

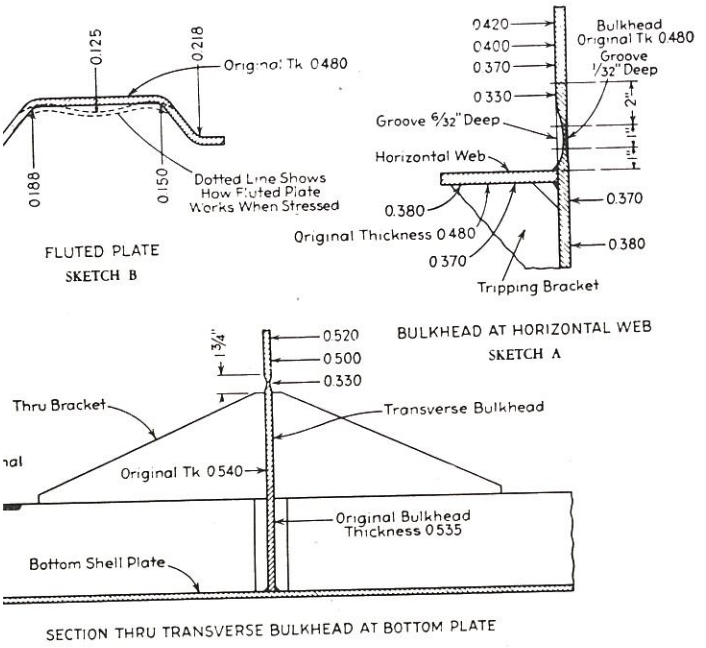

Fig. 3—Local Corrosion
Note: Sketches A, B, and C are for Vessels with Eight Years Equivalent Clean Service

The usual shallow pits, however, are present as in other parts of the structure.

Sketch B is interesting as it shows the same effect on a fluted bulkhead where the shape of the sides of the flute allow this flexuring to take place in the middle of the panel. Here a section in the middle of the panel is reduced to about one-half that at the knuckle of the flute. This type of corrosion requires expensive patching before the structure as a whole has failed to a point requiring renewal.

Sketch C shows the same situation at the bracket through bulkheads for shell longitudinals. This condition does not occur at brackets adjacent to a cargo pipe through the bulkhead which helps stiffen the plate at the nearby brackets and thereby restricts the working of the plate.

Cyclic stresses or fatigue alone may account for these very rapid failures. In each case the scale was broken (presumably due to flexure or working of the plate). The condition in each case was more marked on an upper surface of a horizontal stiffener than on the underside, or on a vertical stiffener. This holds true on brackets with their points up rather than on deck longitudinal brackets with their points down. At first this appeared to be due to an accumulation of loose scale and the consequent moisture. Recently, in scaling a section of a bulkhead, it was noted that a considerable amount of moisture drained from the scale immediately above. This moisture could contain concentrated brine or other material to make it a strong electrolyte. If this is so, it would help explain these local failures.

Pitting plays its part in corrosion. The pits do not tend to progress on the vertical surfaces, as the scale breaks free before deep penetration occurs. This is not equally true on the bottom plating where this condition can become very troublesome, particularly when carrying sour crudes. As sour crude pitting is not considered a major corrosion deterioration problem on the majority of tankers now in operation, pitting penetration was not considered in Fig. 1, which indicates the overall corrosion penetration plotted on an adjusted time basis.

It would be helpful to know when the corrosion is most active. Does gasoline alone cause corrosion? Is ballast the worst offender? There are considerable data indicating that moisture with a low pH value and high oxygen content will produce the most rapid corrosion unless the residual cargo protects the steel.

Table 1 summarizes these conditions.

Corrosion Rates

	Condition of tanks			
Type of Cargo	*Loaded*	*Ballast*	*Empty*	*Cleaned*
White products	Minor	Moderate	Major	Maximum
Light Fuels	Minimum	Minor	Moderate	Maximum
Crude & heavy fuels	Minimum	Minor	Minor	Maximum
Sour crudes	Moderate	Major *(bottom plate)*	Major	Maximum

The cargo, whether clean or dirty, is an excellent insulator and it inhibits corrosion where the tank is loaded with cargo. The heavier petroleum leaves a coating on the steel which gives protection in an empty tank. Gasoline, however, cleans the steel and exposes it to corrosion when moisture is present. Cleaning with sea water adds moisture and accelerates the rate of corrosion.

The above data, in conjunction with the well-known theories of corrosion, indicate that the assumptions reached appear to be logical. Here are indicated, I believe, some of the points where research and controlled tests aboard ship could help in giving precise answers to such questions as:

1. What percentage of the over-all corrosion occurs under the various conditions of cargo-ballast-clean, etc.?
2. What is the difference in corrosion between the plate not under strain or not working and that of one subject to high strains or flexing under load?
3. Does the rough surface of an already corroded plate increase its rate because of the increase in surface, or is the increasing rate of corrosion due to its greater unit stress?
4. Does the breaking away of scale at the points of flexure in itself affect the rate of corrosion?
5. What percentage of the corrosion occurs on the side of the plate carrying ballast and in the empty tank due to sweating from differences of temperature of the ballast and the empty tanks?
6. Would the removal of scale reduce or accelerate the general corrosion?
7. What effect would an occasional fresh water wash of the rusted bulkheads have on removing brine and how would this affect the corrosion rate?
8. What is the chemical analysis of the water retained in heavy scale under varying operating conditions?
9. What is the corrosion rate of steel in a hot salt saturated atmosphere, in comparison to a steam saturated atmosphere?

Methods and types of corrosion control will be covered in the next issue of *The Compass*—Editor.