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CAUSES AND WAYS OF FIGHTING CORROSION INSIDE TANKERS

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Abstract: *The problem of corrosion is generally dealt with throughout the life of a vessel since the phenomenon of corrosion is the result of a combination of many factors. Despite the increased significance given to corrosion prevention and detection, decisions still have to be made concerning when to replace plating and upgrade coating or anodes. The present paper identifies the causes of corrosion and tackles ways of fighting corrosion inside cargo tankers by presenting and explaining corrosion as a process, due to varying levels of bacteria or sulphides released by various transported products such as gases or oil.*
Keywords: *corrosion, cargo tankers, oil, coating, chemicals*

Corrosion of cargo tank structure is an extremely important factor when operating oil tankers at sea. The internal structure of the cargo tanks, often un-coated or not so properly being taken care of, is exposed to sea water, corrosive gases, crude oil and oil products. Over a period of years the effect of this corrosion is to reduce the material thickness and therefore the strength of the entire structure after only two years in service.

One can already discuss about such an accelerated corrosion rate, which is approximately 2 to 3 times of a normal anticipation, and which is sometimes accompanied by accelerated general corrosion of the vapour space steelwork. In addition to accelerated general corrosion, there has also been an increase in the incidence and severity of pitting corrosion in cargo tank bottom plating. In one specific instance a 150,000 dwt tanker is reported as having an average pit depth of between 2.0 mm and 3.0 mm with a maximum pit depth of 4.0 mm.

In addition to the more conventional corrosion mechanisms, another possible contributory ***cause*** of accelerated corrosion has been microbial attack from bacteria in the cargo oil. It appears that, as crude oil is often loaded at temperatures higher than ambient air and sea temperatures, during the loaded passage the temperature of the cargo tank structure is being maintained at higher levels than normal due to the insulating effect of the double hull spaces.

The factors mentioned above are only some of the multitude situated at the base of corrosion. Therefore one can mention several ***types*** of corrosion; for example, the *general type*. This type of corrosion generally appears in tanks that are un-coated as a crumbly scale that is evident over large areas and which, when it is dislodged, exposes fresh steel to the corrosion cycle. General corrosion is allowed for in the design and construction of the oil tanker and an average value of in-service wastage is generally accepted as being around 0.1mm/year or less.

Highly stressed structural components tend to "work" during alternate compression and tension cycles when the ship is in service. Surface rust or scale on these components becomes dislodged during this flexing process, exposing bare steel to further insidious corrosive attack. To further exacerbate the situation, as the material thickness diminishes, the stress on the component is gradually raised and the corrosion continues at an accelerated rate. *Local corrosion*, in grooving form, occurs at structural intersections where water collects or flows. Grooving corrosion can also occur on the vertical structural members at the water flow path or on the flush sides of bulkheads in way of flexing of plating.

Pitting corrosion is a kind of localised corrosion that is more commonly found in the bottom plating of tanks and horizontal surfaces or structural detail where water tends to accumulate. Bare steel plates in cargo tanks are often coated with black rust and a residual waxy oil coating from previous cargoes which tends to protect the metal surface from heavy corrosion. Localised breakdown of these natural tank coatings, particularly in way of cargo bellmouths, or cleaning medium impingement areas, can quickly cause very severe pitting where sea water collects and electrolytic and/or microbial induced corrosion can occur. Severe pitting corrosion creates a tendency for the pits to merge to form long grooves or wide scabby patches with an appearance resembling that of general corrosion. Extreme pitting corrosion in addition to causing loss of structural strength necessitating extensive and costly steel renewals can, if not adequately repaired, lead to hull penetration and a serious pollution incident.

However, a variety of causes of accelerated corrosion have been examined and several factors identified as possible contributors to this process were included. For instance, when no protective coating is applied, general corrosion occurs across the full extent of the tank. However it is not un-common to identify particular areas within the tank where an increased corrosion rate can be found. This phenomenon is usually attributable to readily identified localised conditions, for example a cleaning medium direct impingement site or an area where mill scale has become detached.

Crude oil cargoes can cause a waxy layer to form on the cargo tank steel structures and this layer helps to inhibit corrosion. However, washing mediums such as hot and cold sea water can remove this protective layer and thus allow the corrosion process to start. The integrity of the protective layer is also reduced by an increased frequency of crude oil washing.

Crude oils that contain high concentrations of sulphurous constituents can cause high levels of general and pitting corrosion when these components react with entrained or residual sea water to form acidic compounds. In addition, sulphur is cathodic by nature and can promote the formation of an active corrosion cell.

Inert gas should always have an oxygen content of less than 8% and at these concentrations the rate of corrosion of steel structure should be reduced. However, for corrosion rates to be significantly reduced, the oxygen content should be below 1%. Sulphurous compounds, and soot in the flue gas, if not sufficiently removed in the water washing process, can also cause accelerated corrosion due to relatively strong concentrations of acid compounds being introduced into the tank along with the inert gas. If the quality of the inert gas is allowed to deteriorate due to the lack of attention or poor maintenance, then the corrosion rate may increase, particularly on the overhead surfaces in the vapour space of the tank where moisture has the tendency to condense.

It is also important to mention the fact that where the cargo tanks have been protected by a coating, local breakdown of this coating can lead to accelerated pitting corrosion due to concentrated electrolytic action in the area of the breakdown. Furthermore, ineffective earthing/grounding of electrical equipment can lead to stray currents circulating in the steel work and these can increase the incidence and severity of pitting corrosion.

A wide range of bacteria can exist in all areas of oil production facilities including the production plant, pipelines, the water injection plant, the reservoir and, of course, in the cargo tanks on board the oil tanker used to transport the oil. Most microbes produce corrosive acidic compounds. Optimal microbial proliferation and subsequent corrosion inevitably relates to a population of differing but mutually inter-dependent bacterial species rather than individual species. The bacteria most frequently associated with corrosion of steel are those that generate sulphides and these are commonly called sulphate-reducing-bacteria (SRB). Under favourable conditions these bacteria can produce prodigious quantities of sulphides which can precipitate out as metal sulphides, dissolved sulphides or hydrogen sulphides. On board ship, when bacteria find a niche on a steel surface they can proliferate and a corrosion pit develop at the site. Evidence of microbial contamination is confirmed by the presence of bacteria in water samples taken from the bottom of the tank and the presence of active corrosion pits in the bottom plating. Generally, small lumps with a crust of scale over them are evident and underneath this crust, oily sludge and a few drops of water can usually be found. Temperatures above ambient suit most SRB and they are known to inhabit sea water and the produced water associated with crude oil from older reservoirs where the necessary nutrients for their growth may exist.

It is not unusual for significant quantities of sludge and/or scale to be found accumulating in the bottom of cargo tanks. This debris from previous cargoes or dislodged corrosion scale can create an ideal breeding ground for bacteria and which can hide subsequent pitting damage. Accumulated scale/sludge also inhibits proper draining of tanks by blocking drainage holes and creating an uneven surface.

Residual water in cargo tanks can originate from a number of sources and when it settles out from the cargo can cause electrolytic or microbial influenced corrosion of structural components, particularly on after end tank bottom plating around the suction bellmouths where water tends to accumulate due to the trim of the ship. The most common sources of water in cargo include the following: condensate leakage from heating coils, condensate water from inert gas, residual heavy weather ballast, residual wash water, retained water due to ineffective draining arrangements, water entrained in cargo, water from the slop tank and water leakage from adjacent ballast tanks.

Excessive residual water creates high humidity conditions in the vapour space when the tank is loaded and across the whole tank in the ballast voyage exacerbating both the general and pitting corrosion processes. The wing and double bottom spaces of a double hull tanker act as a thermal barrier which effectively insulates the cargo tanks from the cooling effect of the sea. Consequently, the cargo tank structure is less subject to temperature change reflecting changes in ambient sea temperature and tends to remain close to the cargo loading temperature. After cargo discharge, the steel structure remains at an elevated temperature for some time until such times as it is cooled by ambient air or adjacent ballast tanks being filled by water. The temperature differential between sea and cargo tanks during the ballast voyage has been reported as high as 150ºC. High temperatures lead to an increase in general corrosion. It has been reported that the corrosion rate doubles for every 100ºC increase in temperature. High temperatures can also lead to an increased bacterial growth rate and consequent increase in microbial influenced corrosion rates. Wing tanks of single hull tankers also provide an insulating thermal barrier for centre cargo tanks.

Being aware of all these facts, scientists paid attention to all details and have come up with ***remedial methods*** which may be taken into consideration. When accelerated corrosion is suspected then an enhanced programme of tank inspection and corrosion data recording should be undertaken by a specialized team in order to determine how serious the situation is. In addition, biological samples should be taken during these inspections.

A common repair method for pitting is to thoroughly clean or blast the surrounding area and fill the pits either by welding or with epoxy filler or by welding and over-coating with an epoxy paint or filler. One should always bear in mind that localized damage to a coating can cause accelerated pitting corrosion to occur.

Experience has shown that grit blasting and epoxy coating of the upper and lower areas of cargo tanks is effective in controlling corrosion. Should this course of action be adopted, an epoxy coating with antibacterial properties should be employed. Surface sterilisation may also be necessary in the case of microbial induced corrosion. As with all coating systems it is imperative that this coating be regularly inspected and maintained as appropriate.

Accelerated corrosion requires the presence of water and for this reason the installation of pitguard anodes, i.e. anodes which are only a few millimeters from the tank bottom, may diminish the general and pitting corrosion process. It should be noted that anodes are only effective when immersed in water and may not be effective in inhibiting microbial influenced corrosion. Anodes should always be installed and maintained as per manufacturers' recommendations.

Crude oil washing can remove the protective waxy layer on steel surfaces thus exposing the steel to corrosion. However, effective crude oil washing may also serve to lessen the conditions that lead to corrosion. Consideration should be given to reducing the amount of tank side washing whilst instead focusing the washing medium on the tank bottom to facilitate the flow and discharge of liquids and entrained solids. Attention should also be placed on reaching shadow areas in order to remove 'dams' formed by sludge and scale.

Elevated temperatures of the cargo tank structure of oil tankers may be conducive to accelerating general corrosion and the proliferation of microbes influencing corrosion. The temperature of the steel could be reduced by changing out the relatively warm ballast loaded alongside with cooler deep sea ballast on the way to the load port. Another consideration could be the replacement of the relatively warm inert gas in the cargo tank whilst at sea when the scrubber plant sea temperature is lower.

A broad spectrum biocide may be added to the bottom water in the cargo tank on an on-going basis to ensure that bacteria do not have an environment which will allow proliferation. It is highly likely that these biocides would be harmful to humans and the environment although some less harmful products may be available. A narrow spectrum biocide may be added to the bottom water on an on-going basis to ensure that SRB do not have an environment which will allow proliferation.

A nitrate rich chemical may be introduced to the bottom water in a cargo tank to divert SRB from reducing sulphate to the less harmful reducing nitrate type. Most SRB actually prefer nitrate to sulphate and relatively harmless nitrogen gas and ammonia are the resultant products of reduction, not sulphate. Chemical additives (alkaline) may be as well introduced to the bottom water to modify the pH beyond the range which facilitates the proliferation of SRB and to offer some protection against acidic corrosion.

Careful consideration should be adopted at the early design stage to ensure that the "in tank" drainage is effective and capable of reducing retained water to an absolute minimum. Enlarged and/or additional well placed drain holes in the tank bottom structure will facilitate the removal of liquids from the tank, thereby lessening the amount of standing water remaining after cargo discharge. Enhanced flow rates resulting from improved drainage will also serve to reduce the deposition of solids entrained in the cargo.

Consideration should be given to coating the entire internal surface of the cargo tank. If a decision is made to apply a coating to only a portion of the cargo tank then priority should be given to the cargo tank vapour space, bottom plating and all associated structural members. Surfaces should be grit blasted and coated with an epoxy coating which is light in color. Cargo tank vapour space, bottom plating and bulkhead plating material thickness could be increased to accommodate increased corrosion rates. Consideration should be given to improvement in structural design such as reduced frame and longitudinal spacing to improve the stiffness of the structure and thereby reduce structural flexing.

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