THE INSTITUTE OF MARINE ENGINEERS

TRANSACTIONS

1978, Vol. 90

Paper read at the Institute on Tuesday, 25 October 1977

METALLURGY OF INERT GAS SYSTEMS

Dr M. Levens, B.Sc., C.Eng., M.I.Mar.E.
Shell International Marine Ltd.

SUMMARY

Large modern crude-oil tankers use salt water towers to scrub boiler flue gas free of corrosive sulphur oxides for use in cargo tanks to give an 'inert', non-corrosive atmosphere. This paper describes the metallurgical problems discovered in the operation of four different types of shipboard Inert Gas generating equipment and offers solutions to them. The problems are partly concerned with materials used in lines supplying sea water to the scrubbing tower, those used for discharging the acidic salt water from the tower, with the materials of the scrubbing tower itself, with the equipment used to pass the moist, slightly acidic gas to the tanks and with the deck safety equipment. It was found that materials of construction were often not adequate for their job, but solutions, sometimes modification in design, exist to all the problems observed and these are put forward. It is considered that a long-life unit could be designed along the lines suggested at the end of this paper.

INTRODUCTION

It has been recommended by IMCO since 1973 that all new crude-oil carriers of 100,000 tons or more should be fitted with an Inert Gas System to provide a non-flammable atmosphere in the tank spaces above the oil. This atmosphere, in the case of large crude-carriers, is generated by processing normal boiler flue gas. This gas comes from the combustion of heavy bunker fuel which contains a considerable amount of sulphur and thus generates quantities of sulphur trioxide and dioxide, the ratio depending on the combustion control. The gas also contains a fair amount of soot, nitrogen oxides and carbon dioxide. The machinery dealt with in this report is that which removes the majority of corrosive gases and soot from this gas and passes it to the tanks via a number of safety devices. At the time of introduction of the IMCO recommendations the most experience with such systems lay with B.P. As a result of this experience acceptable levels of sulphur oxides and soot burden were chosen and our specification can largely be said to be that found by experience not to give 'in-tank' corrosion problems. However, the market demand for the units used to process the boiler flue gas to give this acceptable 'inert' gas was great at the time and a number of manufacturers offered designs which, although all producing gas of the specified quality, achieved this in slightly different ways and in equipment of varying metallurgy.

In total, five different systems are fitted to Shell vessels and during the past years, several inspections of this machinery have been carried out. Information from these inspections has been combined with reports of defects from operating vessels to produce the present paper. The number of failures are presented in histogram form for two types of unit and these figures are broken down to detail causes of failure. The histogram shows details only from Frederikstadd Mekaniske Verkstad (F.M.V.) and F.A. Hughes units as the greatest operational experience has been gained with these types. Inspections of operating Howden and Peabody units have also been carried out. The results of all these inspections indicate that most problems can be overcome with care in design and good choice of materials. Remember too that criticism of any particular design is not necessarily a reflection on the manufacturers of the equipment for some associated equipment is supplied by the shipyard and original materials may also have been specified by Shell Companies and not the manufacturers. This report deals with four different systems separately; hence, some repetition occurs but,

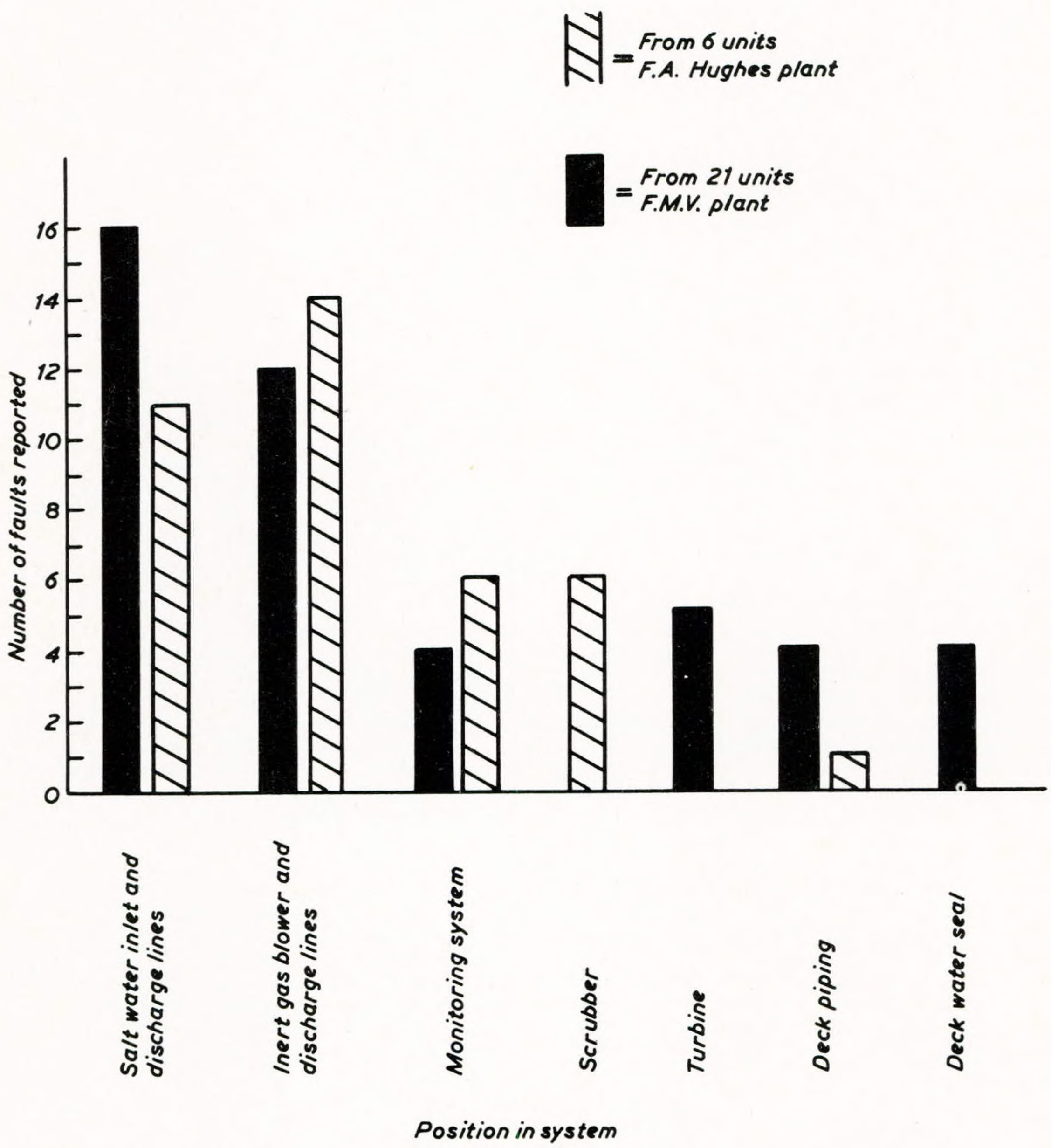


Fig.1 – Histogram to show the position and number of failures in F.M.V. and F.A. Hughes inert gas systems on Shell vessels

hopefully, less confusion than if each part of four types was treated as a unit. The fifth type of unit is expected to give some problems within its first years of operation but, as yet, no inspections have been possible.

F.M.V.

These units were retrofitted to all "M" Class vessels (200,000 tons approx.). They have been in operation the longest and are the most numerous of a single design within the fleet. They take flue gas from the uptake well above the economiser and lead the gas through a butterfly valve and metal expansion bellows via Corten steel piping, of heavy gauge, into the base of the scrubber unit. This piping becomes heavily encrusted with acidic soot which can lead to three different problems. Ingress of flue gas to the gas uptake piping can occur during the shut-down condition if the flue gas valves leak either through corrosion of the valve seats or through a buildup of soot and salts sufficient to prevent the valve from closing. The cast iron valves of the F.M.V. system do not seem to give problems in this respect as the soot tends to be soft in nature and, although undoubtedly corrosive, the valves seem to be kept free of major corrosion problems through the installation of an air sealing device and a soot blowing facility. The second area in which problems can, and have arisen, is in the bellows downstream of the gas valves. These bellows tend to accumulate damp, acidic soot which causes severe pitting and leads to leakage in comparatively short times. These bellows as fitted were made of A.I.S.I. 316L type stainless steel and will always give corrosion problems unless a very efficient soot-blowing or washing facility is installed and the bellows are fitted in the vertical position. The fitting of either of these systems downstream of the flue gas valve will of course cause other problems and it seems that a change of materials might be the only answer. Any of the higher molybdenum-chrome-nickel alloys should be suitable e.g. Hastelloy C276 or Inconel 625. Incoloy 825 is not recommended for this application in which the acid is stationary. The third problem is that of corrosion of the flue gas line itself. This corrosion tends to be general in nature and has been observed to be quite light in F.M.V. systems. These contain quite dry soot and have valves which give good seating and, therefore, do not allow flue gas to percolate into the line during the shut-down condition. It must be stated, however, that it is not possible to inspect the whole length of these lines and more serious corrosion may be occurring in other parts.

The scrubbing tower itself consists of a series of Incoloy 825 trays, containing quartz chips, which are sprayed with sea water from bronze jets. The base of the tower is lined with Incoloy 825 and the upper part with high build coal tar epoxy paint (H.B.C.T.). A facility for fresh water washing is provided and control of the water level during operation is achieved with stainless steel float switches. Sea water is fed into the unit by aluminium brass lines and out of it by stainless steel A.I.S.I. 316 lines. The scrubbed gas passes through a polypropylene demister supported in A.I.S.I. 316 baskets via H.B.C.T. epoxy coated steel lines to the fans. The latter are of nickel aluminium bronze and their casings are lined with coal tar epoxy. The gas is fed to a deck water seal, again coated with epoxy, through one or two non-return valves and hence to the tanks via epoxy coated steel lines.

Figure I is a histogram showing problems recorded with these units. From this it is apparent that most problems have been experienced with failures affecting the sea water inlet and discharge lines. In the inlet these problems have been mainly concerned with failures of the piping at welded joints and a few problems have recently come to light in regard to the valves in these lines. Aluminium brass is a good choice of materials for these lines but care must be taken to avoid poor internal weld profiles and sharp bends. If problems continue then one solution is to upgrade the erosion resistance of these lines by fitting 90/10 copper nickel piping which is not only more erosion resistant but also readily welded to give a good profile.

Valves for sea water service are, of course, often a troublesome area but manufacturers have recently been made more aware of our problems concerning sea water valves in general and we specify "Disc of nickel aluminium bronze to BS.1400 AB2C pinned to an A.I.S.I. 316L stainless steel shaft by Monel or A.I.S.I. 316L pins. The valves shall be rubber lined and have 'O' ring seals to prevent leakage of water past the shaft". Several European firms now supply valves to meet this specification and our troubles now seem to be limited to the removal of the rubber linings.

The overboard sea water discharge lines from the scrubber have a U bend in them and a small drain line is fitted at the lowest point of the bend. The drain is, however, small and liable to blockage (or perhaps is not opened). Thus the bend tends to remain full of static water which causes pitting of the steel, particularly at welds. As these lines cannot always be drained this problem will remain and must be solved by a change to, say, mild steel lined with epoxy bound glass fibre or a more expensive alloy, not subject to pitting attack in stagnant sea water, such as Incoloy 825. The latter is probably a better choice as it is not prone to impact damage as is a brittle fibreglass coating. A fibreglass-lined unit has however given good service for two years. The classification societies are softening their attitude in regard to these discharge lines and now allow un-supported, non-metallic piping to be used. As to other internal coatings, it has been found that certain rubbers have a tendency to crack in this application on these units (which were retrofitted and are thus on deck and exposed to the sun) but stoved epoxy coating or glass coating (a paint system containing glass flakes) can also give long life here, providing the coating is done on clean, shot blasted steel in a clean environment.

Figure I shows that no damage to the scrubber tower itself has been reported within the F.M.V. unit. The units are, however, deteriorating slowly and three areas of concern are manifest. Firstly, damage to the paint in the upper half of the scrubber often occurs at the joint with the lower half of the scrubber and leads to corrosion of the underlying mild steel. This is possibly due to mechanical damage during fitting or the fact that corners are, generally, more difficult to protect successfully with paint. Secondly, pipework associated with the scrubber is often not protected to the same standard as the scrubber itself and thus gives corrosion problems. Thirdly the control float switches suffer some corrosion which may lead to problems in the future but has not done so yet after four years operation. The Incoloy 825 of the scrubber trays and the gas inlet section have been found to be in excellent condition on six different vessels inspected. The splash zone of the gas inlet piping, where the Incoloy is wetted intermittently by the cooling salt water, has not been inspected. This is the most likely area in which corrosion could be occurring. It cannot be seen from any inspection ports but it is suspected that after four years, considerable deterioration may have occurred in this area. The gas inlet space is fitted with fresh water sprays for flushing down at the end of an inerting operation. These are made of copper piping and corrode internally through condensation of flue gas. Some erosion of the salt water spray nozzles has occurred within the scrubber. These are made of nickel aluminium bronze and should be replaced by nozzles of the same material if they become eroded. Some very slight corrosion of the stainless steel demister supports has been observed in the top of the tower but this is not considered harmful.

The gas is led via H.B.C.T. epoxy coated steel piping to two blowers, one steam and one electrically driven. The histogram (Figure I) shows that this is the second major problem area. Most of the problems lie with the gears and the bearings of the turbine rather than within the gas system. Within the gas space the problem is the removal of the epoxy paint; this is particularly severe within the blowers themselves, and corrosion and blockage of the stainless steel fan drains also occurs through soot deposition which leads to penetration of the piping around and above the blockage. The paint within the pipework and impellers is subject to corrosion by damp acidic soot. Green and white salts can often be seen in the soot. These are ferrous sulphates and indicate the presence of corrosive acids downstream of the scrubber. The impeller housings suffer most and not one of the eighteen inspected had retained its coating of paint. Clearly this type of paint cannot withstand the duties imposed upon it within the fans, in particular, or the pipework, in general. To overcome these problems, internal surfaces could be either rubber-lined, stove coated or fibreglassed. A stoved epoxy lined impeller casing and a glass fibre painted one have been tried. After one year in service these were in good condition but showed some pinhole corrosion from entrained shot blast. Less large blisters were produced with the latter coating which showed no tendency to flaking.

A few problems have been experienced with the deck water seal and the deck distribution lines. In general, epoxy painted mild steel pipes have lasted well on the deck and only occasional patchy breakdown has been recorded. Similarly, a little blistering of paint within the deck seal itself has occasionally been noticed. It is however, always the case that the wall of the deck piping is covered in small soot particles and quite heavy build-up can occur. More serious is the corrosion of the Monel level floats, which spend most of their time half immersed in salt water. Several cases of corrosion of these floats have now been reported and coated or glass fibre floats should be used. The F.M.V. unit has quite a complicated deck water seal. This is a dry seal and a loss of pressure in the line activates a drop valve that lets fall a volume of water into the seal itself. On occasion the valve actuation can fail; but there has been only one reported case and this seems to have been caused through internal icing of the supposed dry pneumatic actuation pipes. A far more serious problem is that concerning the internal coating of the gas inlet piping to the deck seal. It is known that the epoxy paints blister in these units. Usually this occurs on edges but large blisters have been observed on flat surfaces. The latter may well be the result of insufficient venting during initial painting. Thus it is reasonable to assume that some corrosion may be taking place internally within the inlet piping (which cannot be inspected easily). Should this piping become holed then the water seal is no longer acting as such in the shut-down condition. It is therefore imperative that this piping's coating be upgraded or that regular inspection and touching-up be carried out.

Non-return valves in the deck distribution line also deteriorate. The conical drop valve is sealed by a large 'O' ring which becomes displaced and the cone itself becomes quite deeply pitted in a very short time. This valve could be improved by a redesign of the seating arrangement (removing the 'O' ring and making a larger rubber to rubber seat, perhaps) and making the cone from, say nickel aluminium bronze although this would increase its weight. Early systems were fitted with an extra non-return valve; a split butterfly-type which gave the same corrosion problems as have been appearing in sea water systems for a number of years. These valves should, of course, be fast acting and gas tight. The latter is not true of the present design and this has safety implications, especially in the majority of cases in which a conical, non-return valve only is fitted, as gas can readily leak back to the deck water seal.

A slower-acting, butterfly, shut-off valve is fitted in the deck piping and a sound seawater type design was used.

F.A. HUGHES

These units, of which four have been inspected, take gas directly from the upper bank of the economiser and lead it into the scrubber through heavy gauge Corten piping. The flue gas valve is located in the uptake very close to the economiser. This valve is metal-seated and when one valve was inspected, after water washing of the economiser, a layer of hard salts was observed to be preventing the valve from closing fully. Corrosive gases could therefore penetrate from the gas uptake to the inert gas piping during the shut-down condition and cause corrosion. The inert gas piping itself accumulates moist sooty deposits with bright, active metal beneath them. No areas of local pitting have however been observed and corrosion is fairly general. It will therefore take some years to penetrate this thick piping. However, any branch lines in which pockets of soot can accumulate are in danger and one such failure has occurred after three years, allowing flue gas to escape into the engine room. The rate of corrosion could be slowed by ensuring positive seating of the uptake valve.

Gas from the inlet piping is cooled by a spray of sea water from Monel pipe, housed in an Incoloy 825 clad, mild steel, quench section. The gas is then bubbled into a mass of sea water in an ebonite lined scrubbing tower. The Monel spray pipes are a continual source of trouble. Hot, acidic gases quench out on the upper surface of these, because of the cooling sea water being carried by them, causing severe acid attack. The pipe then ceases to function as a controlled spray and sea water is thrown all over inlet piping and quench section, causing dew point corrosion to occur above the normal water line. Corrosion in this quench section of the Incoloy 825 can lead to penetration within a year. For instance on one vessel, after only three inerting operations, the plug welds holding the Incoloy 825 in place had corroded right through. This was a direct result of local weld dilution from the mild steel support, however, pits over the remainder of the undiluted Incoloy indicated that penetration would not take longer than a couple of years. The spray pipe and cladding must therefore be upgraded to fulfil their design function. Inconel 625, EPE 53 or Hastelloy C 276 would seem to be good choices for both spray pipe and quench section. Experimental quench sections in EPE and Hastelloy C276 are at present under test. The quench section might not suffer such rapid attack, except perhaps around the water line, if the spray pipe remained intact. A more satisfactory way of attaching the cladding to the mild steel support must be used to prevent weld dilution at the holding plugs.

The scrubber unit consists of polypropylene trays over which sea water flows. Figure 1 shows that a number of faults have been reported with this part of the F.A. Hughes System, (the spray and quench section mentioned above are included in this). Other problems are corrosion of the mild steel, epoxy painted submerged baffle plate and fretting corrosion of the bronze bolts for the scrubber internals. The submerged baffle plate ought to be made from a nickel alloy but it is difficult to suggest a non fretting replacement for the bolts, though Hastelloy C276 bolts are presently on test. Very close inspection of this scrubber unit is not possible as it cannot be entered as easily as can the F.M.V. units.

The gas lines and fan casings are mild steel H.B. C.T. epoxy painted and suffer similar problems to the F.M.V. units. The lines are full of soft, acidic salts and paint removal is common. The fan blading is aluminium bronze and has suffered some dealuminification in service. It is suggested that the blading should be made of the same material as the fan hub, nickel aluminium bronze. The impeller is of the single stage, overhung type and some balance problems were encountered at the outset but these have been overcome.

Few problems have occurred with deck water seals in these units, other than those with sea water piping and some internal paint blistering. No non-return valves in the deck distribution piping have been inspected. The deck lines are internally unpainted steel and these are subject to quite heavy corrosion, though an estimate of the anticipated life of these lines is difficult to make. They should, however, last for several years unless water is allowed to lie stagnant in them in which case penetration could occur very rapidly. If, for example, the line is moist and the ship is trimmed by the stern, then penetration just forward of the deck seal is likely to occur very quickly.

A flame screen is placed in the main inert gas line just before the mast riser. This screen tears at almost every inerting and should not be left in place when a rapid through-put of gas is occurring. For this reason its usefulness is questionable and, in the event of an inert gas plant failure, it is doubtful whether the screen would arrest a flame. To do this either its position would have to be altered, i.e. to the top of the mast riser, or a proper retractable arrester would have to be put in which would give a large pressure drop when in place.

HOWDEN

Although a number of Howden units are now operational within Shell Fleets, only two opportunities have arisen to inspect this type of unit. One was however, a three year old unit and as such is a good example.

Gas is taken from high up the uptake of the boiler and so the shut-off valves were not inspected for corrosion or tightness. Gas is led under the water in the scrubbing tower by an inlet foot of epoxy coated mild steel. This foot needs replacing annually and should be made of acid resisting alloy, such as Hastelloy C, if its life expectancy is to be increased. The glass fibre internal lining within the tower bottom is good. However, this coating blisters and detaches in large quantities on that part of the internal surface where gas impingement can take place as a result of the wastage of the foot. The lining within the top-most part of the scrubber surface remains in excellent condition but some of the painted steel internal fittings in the middle section corrode. The main contact area between water and gas is in a series of slates of fibreglass over which water is sprayed from cast iron nozzles in copper nickel piping. The manufacturers claim that the sprays themselves are not very critical which is probably a good thing as the cast iron will not long retain its original dimensions. Replacement should be in nickel aluminium bronze or 70/30 copper/nickel when required. The use of fibreglass slates is, however, a good idea. The uptake lines themselves could not be inspected in the three year old unit nor could the gas lines to deck or to the fans. The fan housings are H.B.C.T. epoxy coated mild steel and these become covered in soot and iron salts and, as is usual, the paint coating peels away. In view of the good service given by the internal coating of the scrubber it would seem sensible to line the impeller glass fibre reinforced coating. This is now done on later units and gives an excellent corrosion resistance coating for this application. The impellers are of nickel aluminium bronze and have given no problems in service. The gas lines themselves were not inspected but previous experience with other units and the condition of the impeller casing leads us to believe that these too will have suffered paint breakdown and some attack of the underlying steel by the acidic burden of the moist soot deposited in them, although this had not occurred after 1 year on the other unit inspected. The deck lines are epoxy painted and had penetrated in one place by corrosion through salty, slightly acidic water lying towards the after part of the piping.

The deck water seal on these units is a wet seal, that is to say that the pressure of gas going through the seal maintains a head of water pressure which falls back to form the seal in the event of a loss of gas pressure. Thus, there are no moving parts to the fail safe system. Some of these units are H.B.C.T. epoxy coated mild steel and suffer the expected internal corrosion problems, others are glass fibre lined and are expected to last much longer, barring mechanical damage. Two glass windows are fitted to the seal itself so that water levels can readily be observed. The only problem with this type of seal is that at low gas pressure water pulses tend to be passed into the deck line thus worsening conditions inside it.

Two valves are fitted to the deck line to prevent the back-flow of gases to the water seal in the shut-down condition. These are a rubber-lined butterfly valve and a metal-seated, flap valve, the former conforming to our salt-water specification. Both become coated in soot and ferrous sulphates though the butterfly valve remains in good condition underneath the deposits and may be expected to give a reasonable seal.

PEABODY

Two units, each of one year old, of this type have been inspected.

The unit draws flue gas from some fifteen feet above the top bank of the economiser and gas passes via a cast iron valve and line to an Incoloy 825 foot, that extends below the water line, in the scrubber house. This gas uptake line could not be inspected nor could the internal part of the foot. The outer part of the foot was, however, in excellent condition and showed no signs of corrosion. The condition of the F.A. Hughes quench section does, however, indicate that corrosion may be occurring internally in this inlet foot particularly at the splash zone. A periodic, say four year, inspection is thought necessary. This cannot however be done without dismantling the foot. Similarly the poly propylene and Incoloy water sprays were free of corrosion and wastage. The scrubber unit itself was ebonite rubber lined and this was in good condition apart from two tears associated with the low level alarm system. The tears followed the path of two welds and were revealed by the copious amount of rust associated with them from corrosion of the underlying mild steel. The floats of the level switches had suffered no corrosion, though the retaining device, of aluminium brass, was verdigrised and might jam at some later date. The demisters in the top of the scrubber tower consist of polypropylene mesh in an H.B.C.T epoxy painted mild steel retaining basket. A similar device is used as a demister in the deck seal and, in both cases, the paint on this complicated structure was failing and corrosion of the underlying metal was occurring. A more corrosion resistant material, such as stainless steel A.I.S.I. 316L should be used for these retaining baskets to prevent attack. The gas pipework associated with the system is the traditional H.B.C.T. epoxy coated mild steel. In the region of the scrubber, especially the gas recirculation line, some paint breakdown had occurred. In areas in which corrosive liquid could be retained i.e. the recirculation line, this could lead to penetration in a comparatively short time. The impeller casings were also epoxy painted and this material should be upgraded along the lines suggested earlier.

The deck water seal of the Peabody units is ebonite lined, mild steel with an inlet foot, which is also ebonite lined, terminating in Incoloy 825 in the submerged region. The internal condition of this unit is much better than those which are epoxy painted and no dangers exist of unobserved corrosion taking place within the foot because it is both corrosion resistant and inspectable. The Incoloy has a welded seam but no corrosion has taken place along this either in the submerged or splashed zone. Access to the level switches is not easy from inside this unit as it is housed in a protective casing. Inspection can be carried out either by Introscope or by removing the external flange holding the float housing. The float is Monel and can be penetrated within one year. Removing the flange to replace the float can tear off all the ebonite around the flange. This is an interesting point when considering whether to use fibreglass or rubber lining. The salt water drain lines from these units are a sensible choice, 90/10 cupro nickel. Unfortunately on the units as fitted, this drain passes into the vessels slop tank where it is attached to a mild steel pipe. Needless to say, the steel corrodes rapidly away in salt water. This can, of course, allow hydrocarbon gases to pass fairly readily back to the deck water seal.

Two valves are again fitted to the deck lines; a weighted flap valve and a gate valve. Both these valves are metal-seated and become fouled with soot so that continual maintenance is needed to give reasonable, but still not gastight, sealing. The deck lines themselves are H.B.C.T. epoxy painted and on one unit it was difficult to tell, in the after part of the pipe, that the line had originally been painted so severe was the build up of rust. The deck lines are fitted with high pressure vent valves of two different designs. The vents themselves work well but need cleaning occasionally. The associated flame screens are also of two different types, a strong, crimped metal type or a more flimsy Monel gauze. The latter readily becomes blocked with rust and disintegrates when there is a high throughput of gas, and thus requires, to be renewed every ballasted voyage.

CONCLUSIONS

Several problems exist within the different types of inert gas units fitted to Shell vessels. However, the answers to most of these problems are fairly straightforward but often involve the purchase of more expensive materials of construction. These solutions have been put forward in the text whenever possible and several experiments aboard vessels are at present under way to assess alternatives. A further study is being undertaken to monitor the performance of these four types of unit in terms of their ability to scrub the gas of sulphur oxides and soot. Two types of unit have so far been investigated in this way. The results were interesting and showed that both these units were not able to efficiently remove sulphur trioxide and allowed considerable particulate matter through. The results of these tests will no doubt put the choice of inert gas systems on a firmer footing, as far as quality of gas is concerned, and then the results of the inspections reported here can be used to produce a longlasting and efficient unit. The ideal inert gas systems should however be built along the following general lines as far as its metallurgy is concerned.

1. Gas Uptake should be from well above the economiser to prevent the formation of hard soots which may prevent uptake valve closure.

2. Cast iron uptake valves should be fitted with an air sealing device and soot blowing facility.

3. If expansion bellows are considered necessary they should be of high grade nickel alloy.

4. Piping of heavy gauge steel should be used for the gas uptake and branch piping avoided if possible.

5. Sea-water sprays should be avoided in the gas stream prior to the inlet foot. These pipes are subject to excessive corrosion.

6. The inlet should be of Incoloy 825 or heavier duty nickel alloy and care should be taken in welding to avoid dilution of the weld with material of inferior corrosion resistance.

7. Incoloy 825 can be used to line the base of the tower and painted steel should be avoided in this area.

8. Gas scrubbing trays of the types at present fitted to F.M.V., Howden or Hughes units show little signs of corrosion and are, therefore, satisfactory.

9. Float switches should be plastic coated and associated fittings exposed to the salt water and gas should be made of nickel alloy.

10. Attention should be paid to ensure the internal lining of steel water inlets into the scrubber.

11. The main sea water inlet should be of 90/10 copper nickel or aluminium brass (the latter with good weld profiles internally), and butterfly valves should conform to the S.I.M. specification for salt water valves.

12. Upper sections of towers should be ebonite rubber lined or glassfibred and welding in way of this area should be avoided.

13. Sprays and salt water inlet lines should be of copper nickel alloy.

14. Demister nets of polypropylene are adequate but these should be supported on Incoloy 825 or A.I.S.I. 316L stainless steel trays.

15. Gas circulation lines should be ebonite lined, glass fibre weave/epoxy resin or stove epoxy coated.

16. Impellers should be of nickel aluminium bronze to the BS 1400 AB2C specification.

17. Impeller casings should be stove-coated, rubber lined or glassfibred.

18. Impeller drains should be of Incoloy 825 and should be large and readily accessible for cleaning internally.

19. Scrubber drains can be of stainless steel A.I.S.I. 316L but care should be taken to upgrade material in any area in which water is liable to lie.

20. Deck-water seals should follow the same principles as for scrubbing towers in so far as choice of material is concerned.

21. Deck lines should at least be high-build, coal-tar epoxy coated or, better still, coated with a stoved epoxy paint with a high chemical resistance to corrosion.

22. Attention should be paid to non-return valves fitted in deck lines. In essence these should follow the same principles laid down for salt water valves as far as their materials of construction are concerned i.e. rubber seated and non-ferrous discs.

23. High pressure vent valves and strong flame arrestors should be fitted to deck lines.

In looking to the future there are several areas which might be affected by either outside legislation or internal requirements. For example, certain port authorities dislike the discharging of scrubber effluent into harbour waters, despite the fact that any acidity in the effluent is soon neutralised by sea water to give water of normal pH within a few feet of the discharge. In the second place the corrosive gases being passed to the tanks have been occasionally blamed for increased in-tank corrosion. This has not yet been proven and the many years of B.P. experience would suggest that such was not the case. Thirdly this paper has dealt only with equipment used to process flue gas for crude oil carriers; units producing entirely particle and acid-free gas would necessitate much more careful design and attention to materials of construction than is the case at present aboard crude-oil vessels. If units were expected to be capable of removing all sulphur trioxide, all sulphur dioxide, all nitrogen oxides, all carbon dioxide and all soot and then not discharging the scrubbing media into the sea then it would be less difficult to take nitrogen from a shore installation.

DISCUSSION

MR. R.F. THOMAS, F.I.Mar.E., said that from a materials point of view the design of a boiler flue inerting system posed many challenges if problems similar to those illustrated by the author were to be avoided. The environment in which the materials were required to operate was hostile, under the influence, either singly or in combination, of solids, sulphur oxides, water, salt, elevated temperatures and water spray or splash. The choice of materials and coatings was clearly of paramount importance in such a system if material problems in service were to be avoided. In practice there seemed to be little substitute for experience in proving the suitability of the materials that had been selected.

The experience gained by BP Tanker Company over some three hundred ship years of operational service since 1961 has not been without problems - including some of those, or similar to those described by Dr. Levens. This had led to both careful initial selection and progressive evaluation to a selection of materials in which one could have confidence. To this one must add the physical design of system components, and the operational and maintenance practices to be adopted if a satisfactory operational system was to result.

Some of the problems encountered include for example the failure of Ni - resist cast iron for the scrubber trays in a products ship and also the galvanised steel water spray manifold. These particular problems and other corrosion problems had been overcome by a non-metallurgical solution - the use of Glass Reinforced Plastic. This had been used for over ten years on the scrubber effluent line with very good results. Also it had been used for the fan drains. In fact, such had been the success rate of this material that a GRP tower had been designed, and approved by the regulatory bodies, but not yet constructed and evaluated. The author's view on non-metallurgical solutions would be welcome.

Avoidance by design may be one solution to the problems encountered. This might particularly relate to expansion bellows and level control floats - both of which might be avoided by design.

Satisfactory results had been obtained with scrim reinforced GRP and ebonite linings for scrubbing towers and deck water seals. However particular attention must be given to the preparation and application of the coating, if breakdown was to be avoided. No experience had been had with glass flake epoxy resin coatings, but these might be more susceptible to porosity than the coatings previously referred to. Despite the satisfactory experience of ebonite, a GRP solution might be preferred since it was more easily repaired should it become damaged in service.

In the fan casings, however, GRP had not proved completely satisfactory in the long term, due to the high velocity water impingement, and ebonite was to be preferred for this component.

Fan impellers had been a problem area, but a satisfactory materials choice seemed to be Nickel Aluminium Bronze, and also Titanium. The latter had been in service for approximately two years, and was reported as being in a satisfactory condition.

No materials problems had arisen in either deck lines, or between boiler uptakes and scrubbers. The former had been installed in coal tar epoxy coated steel, and the latter in galvanised steel.

He could give a catalogue of materials tried and used in the system and the results obtained. However, the responsibility for materials specification should lie with the system designer, who should ensure that the materials specified were suitable for the duty. He would appreciate the author's view on this problem of co-relating the design, materials selection and operational practice.

MR. D.J.H. ODDS, M.I.Mar.E., said that as one of the major suppliers featured in this report F.A. Hughes welcomed user information of this kind.

They had been in this particular business since 1964, and continued to seek out operating experiences at every opportunity.

He would now comment on the paper with particular reference to the histogram; they found this very misleading in its originally published form; and it had been altered after representation had been made to the Institute. It took no account of time the systems have been in service and did not accurately reflect points raised in the text of the report. All faults were attributable to the I.G.S. manufacturer; irrespective of whether he supplied the equipment, or even whether he specified it; or indeed whether he was consulted.

1) Histogram

For example, it indicated 12 FMV fan faults - whereas the paper stated: "The impeller housings suffer most and not one of the 18 inspected had retained its coating of paint". Should one add the 18 to the 12 indicated, or was the histogram 50 per cent in error ? Did the histogram relate to the number of faults per ship ? The histogram did not indicate the age of the systems under review.

They did know that Hughes systems were ordered in 1971 and were the very first ships fitted by Shell.

Obviously age would have a considerable bearing on the number of faults that occur.

He would now comment on the problems the author associated with Hughes.

2) Scrubbing Tower

(i) Quench Section

As any reputable Inert Gas supplier would confirm, this is the most demanding zone from the point of view of materials of construction. Over the years Hughes have incorporated various improvements, and welding technology has effected a great improvement in plug welding which holds the Incoloy liner in position. Hughes were aware of the advantage of Incalloy or Hastalloy for the spray pipe, but these materials could not be obtained in the time available and Monel 400 was a reasonable substitute.

(ii) Weirs

The report states "the weir should have been made of nickel alloy". All Hughes weirs are rubber lined and have never been supplied in epoxy coated steel as stated in the report.

(iii) Hatches

Man size hatches are fitted to every section of the tower to permit access. They are secured by nuts and bolts - we do not fit quick release catches as they are not necessary. The report is therefore incorrect when it states "very close inspection of this scrubber unit is not possible as it cannot be entered .....". The fact that F.M.V. provide easier access is presumably the result of their experience with their tower, just as Hughes arrangement reflects our experiences with ours.

3) Fans

(i) Here the author is in confusion with another suppliers standard. All fans provided by Hughes systems for the last decade, have a fully supported impeller with a bearing on each end of the shaft - not overhung as stated in the report.

(ii) All Hughes fans are made from Nickel aluminium bronze. The British Standard quoted "BS 1400 AB2C" is one form for casting. The equivalent wrought form is BS 2875 and is also nickel aluminium bronze, this is used for the blades and discs. Not as stated in the report aluminium bronze. Currently we are trying out Ferralium as an alternative.

General

Two further comments are made under the heading Hughes - the reader would be forgiven for assuming they were Hughes responsibility or at least made to Hughes specification - the facts are not as stated in the report.

(i) Uncoated deck lines were not of our supply supply - indeed we always recommended epoxy lining.

(ii) The flame screen placed in the main inert gas line is again not of our supply. But this screen can only be used when the ship is loading and the inert gas system is not running. Not as the paper states "This screen tears at almost every inerting".

Report Conclusions

We were particularly interested to see that on page 7 the author lists certain items for the ideal Inert Gas System, since apart from item 19 (effluent line material) where we consider AISI 316L is not adequate. We recommend rubber line steel. All other features are virtually the same to Hughes long standing recommendations.

Looking back, we are reminded of the frenzied scurry which took place in the early 70's with owners trying to fit Inert Gas Systems to both new and existing tankers. A fine objective. The only trouble is they tried to do it "on the cheap".

Indeed wherever we offer a choice of specification, you can usually reckon the owner or shipyard will select the lower price solution and pay later in terms of earlier replacement and/or increased maintenance costs.

We must point out that we were given no prior opportunity to discuss comment or advise before the copies were sent out to over 100 important people in the Marine Industry.

Indeed we have only had 14 days notice and frankly this is far too short for a busy firm to investigate in depth and comment in detail. However I think it would be fair to say, that all of us welcome a report from a company of Shell's stature. It is therefore all the more unfortunate, to say the least, that the author was not just that little bit more determined in his quest.

We all could have benefited much more from full comparisons area by area rather than one bit of Hughes and another bit of another system. For example both F.M.V. and Hughes boiler-up-take valves were examined but not Peabody as it was found difficult.

The Author's disclaimer on the beginning of the report is not good enough; to then go ahead with listing quazi comments which must be unnecessarily disturbing to our existing and future customers.

MR. A. BELL, B.Sc., M.I.Mar.E., said that he wished to comment particularly on those parts of Dr. Levens paper which dealt with his company's Howden Engineering - equipment. In general they were in full agreement with Dr. Levens findings although they referred to practices which had been discontinued and indeed not followed on eight of the ships out of the nine in Dr. Levens fleet supplied with their equipment.

It should probably also be mentioned that the ship he quoted was on lighterage duties and loaded and discharged frequently - they understood on average once a week. The inert gas system therefore, was used about eight times as frequently as on normal tanker service.

Early units with low gas inlet temperatures had gas inlets of mild steel lined with glass fibre reinforced epoxy resin, as described by Dr. Levens. These gave good service with low gas inlet temperatures, but higher gas inlet temperatures, as found, for instance with auxiliary boilers or before air heaters on main boilers, caused failure of the lining of the duct. If this was not noticed before corrosion of the steel allowed hot gases to pass direct to the body of the base tank, it then caused failure of the base tank lining.

Titanium had therefore been used for inlets for 5 years. All Dr. Levens' ships except the one he quoted were fitted with titanium inlets.

Apart from two or three failures due to welding faults titanium inlet ducts had given no trouble. Welding of this material was not difficult.but it required scrupulous attention to shielding and rigid inspection.

The glass fibre and resin lining system had been extremely successful since the first ships were equipped in 1963 and indeed had outlasted the life of the first ships fitted. The essential design requirement was that the surfaces to be lined should be simple.

Dr. Levens recorded rusting of internal coated steel fittings. These fittings were the securing bars for the packing, they were in fact only required for transport before installation, as the packing is self-supporting and interlocking. Reinforced plastics were now used for the transport retaining bars.

Nozzles were required only for distribution of water to the top row of packing, not atomisation of water and, therefore, did not require accurate sizing or profile, they were now always supplied in bronze with cupro-nickel piping.

Aluminium bronze was a generally accepted material for inert gas fan impellers. However, from fabrication, corrosion and light weight considerations, titanium impellers were preferable, but appreciably more expensive.

Water washing could do much to reduce fouling and corrosion problems with fan impellers. Frequent light washing was infinitely preferable to infrequent and hence necessarily heavy washing. His company now normally arranged for automatic washing every time a fan was stopped.

For a number of years they had offered fans and deck seals with glass fibre reinforced resin linings, but owners and yards frequently opted for the cheaper tar epoxy lining.

It was regrettable that many yards and owners - though clearly not Dr. Levens fleet since his most recent ships were to the highest specification - chose the cheaper options which led to increased maintenance, and reduced safety margins; manufacturers were fully aware of their duties to provide equipment to the highest standard and using the most suitable materials where safety is involved, but if expensive materials and high standards made the equipment uncompetitive it would not be sold unless owners and yards were prepared to accept the extra cost; even although the total equipment cost was less than 1/6 of the complete inert gas installation.

Referring to Dr. Levens' summary of ideal materials:

(1) Our experience with 60 ships over five years old and 10 over 12 years old shows that glass fibre reinforced epoxy resin is completely suitable for all low temperature areas.

(2) We prefer titanium to Incoloy 825 for hot gas inlets and any areas of high temperature - we know of no corrosion failures with commercially pure titanium - though a few welding failures have occurred.

(3) We do not think stainless steel of any grade a reliable material in such severe service as scrubber drains - particularly as less expensive alternatives - mild steel lined with rubber or plastic - F.R.P. - or rigid P.V.C. are available.

Finally Dr. Levens mentioned water carry-over at low flow with the older design of deck seal. Although this was a little outside the main subject of the paper, they would like to point out that the current design had been modified to run completely dry at low flows as had been proved by numerous units now in service.

MR. JAN Fr. BEEN LARSEN, B.Sc., said that it was with great interest he had read Dr. Levens' contribution to improve and extend life of inert gas systems.

His company's experience coincided in almost every case mentioned in this paper, but there were a few comments he would like to make.

Flue Gas Line

Most of the corrosion experienced down-stream of the single side flue gas valves in their earlier systems was caused by flue gas percolating into the flue gas line when the system was not in operation.

They experienced severe corrosion, specially on the flue gas expansion bellows, but also in the parts of the scrubber.

It was also obvious that the material AISI 316 L was not suitable for this corrosive atmosphere.

Although Incoloy 825 might be unsuitable where stationary acid was present, the inner layer of the bellows had been changed to this material, as well as the lower part of the scrubber. With their double disc flue gas valve, and with due care given to the insulation of the flue gas pipe and bellows, the condensation of $H_2\ SO_3$ and $H_2\ SO_4$ was greatly reduced.

However, as some condensation of $H_2\ SO_3$ and water was unavoidable, the bellows are positioned vertically to obtain a self-draining effect.

Even though build-up of a layer of corrosive soot took place during operation of the system, it seemed to them that the choice of Incoloy 825 had greatly prolonged the life of the bellows, as they had no reports which made them believe otherwise.

Inert Gas Deck Line

They had also reason to believe that deck lines internally coated with coal tar epoxy were suitable for this purpose. On board the s.s. "Myrtea" there was a stoved epoxy coated piece of pipe. This was installed in June 1975, and it would be most interesting to know the state of this pipe.

Cooling Water Line

With respect to the cooling water pipes, 90/10 Cu-Ni pipes were used in the scrubber, while the pipe line from the sea chest to the scrubber connection was al-bronze (CuZuZoAl), containing 76-79% Cu, 1,8 - 2,3% Al, traces of Ar and the rest Zn.

There were two good reasons for using al-bronze pipes:

(1) The material proved excellent resistance against corrosion by sea water.

(2) The price was half of that for 90/10 Cu-Ni pipes, and for a cooling water line of ND 200, the difference in cost was quite considerable.

The critical spots were of course the welds and these should preferably be carried out by TIG or MIG with a welding rod containing 90 per cent Cu, 8 per cent Al and no zinc. The weld should give full penetration.

The cooling water line had given them far fewer headaches than the effluent line.

The Effluent Line

The effluent overboard line of commercial quality AISI 316 L was from their experience not quite suitable for this purpose. They had had reports of various numbers of pin-holes, and the leakages had occurred very randomly without any particular pattern and more frequently on some vessels than on others. The leakages occurred not only at welded joints or bends, but even on straight pipes all over the surface.

Based on this, they had changed the material of the effluent line from AISI 316 L to mild steel pipes, internally lined with 4 mm rubber as their standard.

There were various types of rubber suitable for this purpose, and even though the harder types had better properties against corrosive H_2SO_3 and H_2SO_4 mixtures, they had a tendency to crack at certain temperatures when subject to rough handling, e.g. during transport, and they had been recommended by the rubber manufacturer to use a softer type.

For retrofits there were obviously difficulties in adjusting the rubber lined pipes during installation onboard, but this could be solved by using an adequate number of adjustment pieces of, for example, Incoloy 825.

Effluent pipes of glass fibre reinforced plastic (GFRP) had been used with success, but this material required a quite different and more careful approach with respect to supporting, than ordinary steel pipes. Furthermore, the classification societies required an additional closable non-return valve, remotely operated from the upper deck. The GFRP effluent line would most likely be a more expensive solution than rubber-lined mild steel piping.

The drain from the loop on the effluent line was now also, by their standard, rubber-lined inside. A rubber-lined diaphragm valve was fitted by flange connections.

They noted that the diameter of this drain might be too small, and would consider increasing the diameter sufficiently to avoid blockages.

By having a rubber-lined, or GFRP, effluent line, the drain line could perhaps be deleted, and the bottom of the loop fitted with a flanged nozzle and a rubber-lined diaphragm valve only.

The effluent lines were extremely seldom exposed to the sun on open deck, but it was important to keep this in mind when using rubber-lined effluent pipes.

Scrubber

For the scrubber, they took note of the problems pointed out by Dr. Levens regarding the damage to the coal tar epoxy coating and the sea-water sprays in the hot gas stream, and would do their utmost to improve the scrubber accordingly.

Blowers

As far as the blowers were concerned, there was nothing to be said about the prime movers as their standard delivery were electric motors. Turbines had only been supplied at the request of their customers.

For the blowers themselves there were two main problems:

(1) The inside coating of the blower housing.

(2) The material and design of the impellers.

It was obvious that coal tar epoxy coating inside the blower housing was not as suitable as expected. Whether this was a result of improper application of the epoxy or simply that coal tar epoxy was unsuitable, was difficult to say.

They had reached the conclusion that the blower housings should be internally lined with rubber or glass fibre reinforced epoxy resin, which they now used as standard.

The problems with the impellers had been carefully considered by the blower manufacturer as well as themselves.

The impellers of their earlier systems were of all-welded construction. Severe stress occurred where the impeller plate was welded to the hub.

The problem was presented to the blower manufacturer with their proposal of changing the design so that the impeller plate was riveted to the hub. This was done, and the problem seemed to be solved.

Then impellers of Ni-Al-bronze showed severe corrosion in way of the vanes, which after some time completely corroded away.

Based on this experience, they had, in co-operation with the blower manufacturer developed a stainless steel impeller of AISI 316. The first one was installed in 1972 and they had reason to believe that these impellers lasted considerably longer than those of Ni-Al-bronze.

As Dr. Levens had earlier pointed out to them, the welding of the Ni-Al-bronze vanes was incomplete. This had been presented to the blower manufacturer, who just recently have given the following answer (freely translated):

"The special material BS 2825/CR 105 must be welded with care. Extensive welding tests with both test pieces and entire wheels were performed before the method was finally decided.

Fillet welds on both sides of the blades, as suggested by Shell, causes great stresses and subsequent cracks. Instead one-sided welding was chosen, with the blade side trimmed 45° to achieve good penetration. As access is difficult, half of the blade is trimmed from one side, and the other half from the other.

30 mm, at the tip end of the blades, are

welded from both sides. Where the welds meet, approximately at the middle of the blades, a slight overlap may occur."

Mr. Larsen's company continue to improve this design in co-operation with the blower manufacturer, and also consider completely different designs.

Water Seal/Non-return Valve

Regarding the water seal, the internal gas inlet duct was now made of Incoloy 825, giving the best possible prevention of leakages of hydrocarbon gases as mentioned by Dr. Levens.

The inside coating of the water seal by coal tar epoxy would be reconsidered, as for the scrubber.

The O-ring at the disc seat of their earlier type of non-return valve had been redesigned. The shape of groove had been improved and the rubber ring was now being vulcanized to the groove.

Mr. Larsen would be glad to give Dr. Levens a drawing, for comments.

Level Floats

The monel level floats in the scrubber and in the water seal had proved unsuitable due to severe corrosion. They changed the material of the floats to AISI 316, but no remarkable improvement was noted.

As their standard, they now used stoved epoxy coated floats, which so far seemed to last.

Finally, he would like to express his company's appreciation of this paper which they regarded as most important for them, in order to improve our system.

MR. D.J. HOPKINS said that his company was Henry Wiggin & Co. Ltd., who made most of the nickel alloys mentioned by Dr. Levens and he would like to talk on two topics he had mentioned.

Preferential corrosion of plug welds, used to hold INCOLOY alloy 825 sheet to a steel base, should not occur if a correct welding technique was used to avoid iron dilution. Even better would be to use INCONEL alloy 625 welding products which were even more corrosion resistant and, having a higher nickel content, would be unaffected by iron dilution. In fact, INCONEL alloy 625 was an excellent material and should be considered for use in scrubbers in applications where INCOLOY alloy 825 had failed.

Preferential attack at corners in an INCOLOY alloy 825 sheet structure was attributed to faster corrosion rates of cold worked material. They had very little evidence of this happening in general - for instance, cold bent tubes were regularly used used in very corrosive sulphuric acid environments without the bend regions corroding preferentially. He would like to ask Dr. Levens if he thought that the preferential corrosion was really due to cold work or were there possibly other factors.

CORRESPONDENCE

MR. J. RILEY, B.Sc., F.I.Mar.E., sent the following written contribution.

Hot Gas Expansion Bellows

Non-metallic bellows had been used giving good in-service performance.

Air Sealing

An air sealing connection between the uptakes and boiler isolation valve substantially reduced corrosion and deposits in the piping and around the uptake valve.

The effectiveness of the original method of supplying the sealing air from the forced draught fans was now open to question. Slow steaming and reduced rates of cargo discharge currently prevailing had resulted in the throttling-in of forced draught fan control dampers thereby reducing the effective air sealing supply pressure.

Recent installations supplied by his company, Airfilco Engineering, Inc., had small independent air blowers to supply air whenever the boiler uptake valves were shut.

This arrangement had proved positive and successful.

Sea Water Valves

His company had had excellent results using diaphragm valves, including non-return applications. These valves eliminated all contact between sea water and base metal.

Effluent Lines

On early installations where stainless steel effluent lines were specified, they had achieved substantial improvement of in-service performance by supplying seal water continuously to the base of the scrubber unit. This supply was on continuously from the same source as the seal supply to the seal deck unit, and was particularly important for avoiding the stagnant liquor in the effluent piping "U" seal.

Demister Supports

Although the paper stated that corrosion of demister supports was observed but not considered harmful, failure was obviously time-dependent. The supports could be supplied in the same material as the mesh i.e. polypropylene.

Blowers

They had found that epoxy coatings for the fan casings were totally inadequate and had standardised on 1/8th inch rubber lining. The rubber lining also reduced transmitted noise.

Deck Water Seals

This item was the most important safety device in the system to prevent back-flow of hazardous gases. Epoxy coating was totally inadequate. Rubber lining was preferred. Level indication was better achieved for long term reliability using static ultrasonic level devices.

Scrubber Inlet Foot

The venturi inlet was fabricated from Incoloy 825 which had proved to be completely successful for all of the scrubber internals.

The only failure had been on one occasion where a sheet of nimonic alloy was inadvertently used, and rapid corrosion of the welded area and severe pitting of the nimonic resulted.

Sulphur Compounds Removal

Sulphur trioxide existed in two forms both having a tremendous affinity for water, forming sulphuric acid.

How was the sulphur trioxide measured ?

Sulphur dioxide removal efficiency depended on the sea water temperature, the lower the temperature, the more sulphur dioxide was absorbed.

A unit commissioned on the West Coast of the USA early in October gave the following readings:

Before scrubber	1400 ppm
After scrubber	8 ppm
After deck seal	0 ppm - undetectable

The fuel oil sulphur content was 1.54 per cent. The sea water temperature was 66 degrees F.

MR. E. HOWEY, F.I.Mar.E., wrote that the paper gave considerable and useful detail of problems that had been encountered with materials in a number of types of inert gas installations, ably challenged by some of the manufacturers' representatives.

The conditions under which most of the materials operated, particularly the scrubber, blowers and effluent lines, must be described as severe. It followed that preventative maintenance was essential to keep an I.G. installation in an efficient condition, otherwise failure may well give rise to a hazard which could not occur where no I.G. installation was fitted.

Would the author kindly give his views on the subject of preventative maintenance relative to the materials employed with the involvement of an appropriate time factor, where possible.

MR. C.F. DAY, F.I.Mar.E., wrote the following:

It was always timely to read of, and discuss, the various aspects of inert gas systems especially when so well presented.

The design of the system and the selection of materials to perform satisfactorily in such an hostile environment were of paramount importance if successful and enthusiastic operation by ship staff was to be ensured. As the author has kindly mentioned BP and at the risk of repeating some of the information contained in the paper "The Development and Operation of an Inert Gas System for Oil Tankers", 1972, plus some updating of information, the following contribution is offered.

Piping

Starting at the boiler uptakes, the hot gas pipe line to the scrubbing tower inlet had given long and trouble-free service when made of mild steel and then galvanised after all work had been completed. As this line had to rise above the top of the tower, to give a warning period should flooding occur, sufficient flexibility could be incorporated to avoid vibration and expansion problems. In new building it was possible to eliminate bellows pieces entirely from this part of the system. When it was necessary in retro-fit installations, the position and choice of material for a bellows piece could save many hours of work from the staff, as the author had pointed out.

The scrubbing tower inlet pipe was possibly in the worst environment of any on board ship. The choice of Incoloy or titanium was recommended providing the quality control of welding was strictly enforced. Initially, before the deck seal was introduced into the system, the integrity of this pipe was essential, as the scrubbing tower base formed the water seal to prevent cargo gases reaching the boiler uptakes. It also ensured that hot gases could not enter the tower without being cooled Good access for planned inspections and maintenance of the inlet pipe and weir plate was still essential as their importance was undiminished.

To last the life of the ship, the main distribution piping downstream of the scrubber tower should be coal tar epoxy coated after good preparation and shotblasting. A smooth finish was specified to minimise friction losses due to scale and sooting of the line.

One major change of material for the gas inlet pipe in the deck water seal was worthy of mention. The Incoloy pipe in way of the weld failed in two ships and was detected by the regular tests for gas between the engine room and deck seal. GRP pipe was now being used and up to date 100 per cent integrity of this essential pipe had been recorded. Access for planned inspections of the pipe and weir plate was a feature of good design.

It might be of interest to mention that the non-return valve at the poop front leaked gases so alarmingly that the water seal had to be introduced into the system in the early 1960's. The non-return valve should not be relied upon except to prevent liquid, from the accidental overfilling of tanks, passing down the I.G. delivery line, through the water seal and overboard.

Heavy duty rubber bellows had been in successful service for the last fifteen years at the fan inlet and outlet connections.

Materials for salt water piping need not present problems if the recommendations were followed. However, after bitter experience in the early 1960's only GRP piping had survived the years as a suitable material for the effluent lines. With safeguards, it was now permitted below the load water line if the siting of the line could not avoid such a route. If steel piping was preferred, rubber lining was suitable, but only if applied to the very highest of standards after careful pipe manufacture and preparation. To avoid stagnant water in the loop seal of the overboard line, a low flow of water should be maintained through the tower when the system was shut down. This would provide a make-up feed to the seal in the base of the tower and could also be directed to the deck seal for the same purpose.

GRP was specified for drain lines from the fan casings, demisting devices, etc. Loop seals were used in preference to valves and needed little attention, as air would not be drawn in or inert gas blown out, provided the seal water was maintained. Large bore drains avoided problems.

I.G. Equipment Manufacture

The names of inert gas fan and scrubbing tower manufacturers had been established in the marine industry for many decades and their equipment would provide long and reliable service. The shipowner had to provide the manufacturer and shipyard with his detailed operational procedures and requirements. Information must be fed back from the ships and facilities provided to allow testing and evaluation of materials and design changes. BP had been fortunate in their associations and had been able to concentrate its development with a small group of manufacturers at the building stage. The comments were therefore confined to such experiences.

Electric motor driven fans were exclusively preferred for system design characteristics, controls and maintenance. Primary energy capacity had of necessity to be considered and, in retrofitting, the choice might dictate only turbine drive. The fan impeller material of nickel aluminium bronze and latterly titanium had proved its superiority over coated materials. Casings coated with rubber or fibre glass scrim had proved successful, provided the coating was applied under the most strict control.

Scrubbing tower materials, design and performance were well documented and precise selection could be made. A GRP scrubbing tower to suit the shipboard environment had been developed within BP and accepted by the authorities. It still had to be evaluated at sea before it can be offered as a tried unit.

Demisters of the mattress or cyclone type, internal or external to the towers were available and, like the dry or wet water seals, their selection depended on many factors including flow rates.

The control of water to gas rate was important and lack of attention could seriously affect SO_2 removal, solid removal, solid removal, pressure drops and gas flow, all of which could have accumulative effects elsewhere.

Combustion control over the operating range of the boilers should be as precise as possible to help the I.G. system to operate more comfortably.

Finally, as the product carrier application had been touched upon, it might be of interest to future installers that, in the BP Fleets 50 per cent of the I.G. installations were in sophisticated 24/24/25,000 dwt product ships. The first was at sea in 1969 and by 1974 twenty-two ships were in service. A formidable amount of information was, therefore, already available and shared with equipment manufacturers. No contamination had been recorded that could be associated with the inert gas installation and up to fifteen parcels might be carried during one voyage.

Dr. Levens had added valuable knowledge and had confirmed that the subject was alive and developing.

MR. R. BJØRK, B.Sc., wrote that Dr. Levens' paper on metallurgy of inert gas systems was very interesting reading and it provided very valuable information to makers of such systems.

The guide lines given in his conclusions agreed well with his company's (F.M.V.) opinions, but he had some additional comments and suggestions.

Flue Gas Line

The greatest problem with the flue gas line had been to obtain a gas-tight valve to prevent leakage of gas into the scrubber in the non-operating mode. With the F.M.V. double disc flue gas valve, this problem was now solved. However, the valve should be regularly cleaned and protected from exposure to hot flue gas, when not in operation. This could be done by locating the valve away from the gas uptake, preferably high up in a vertical part of the flue gas line, and by providing sealing air to purge continuously the line upstream of the valve.

To keep the whole line clean, steam soot blowing of the line downstream of the flue gas valve could also be arranged, but blowing should of course be carried out with the flue gas valve open, and with the scrubber cooling water supply on, to prevent pressurising the scrubber and to condense the steam and flush out soot and particles.

Regarding bellows material, he would like to mention that bellows with an inner layer of Inconel 600 had been tried with success, but the price of this material was about twice that of Incoloy 825.

Scrubber abd Effluent Lines

The corrosion in the scrubber and effluent piping was mainly due to attack by the combination of warm sea water and sulphuric acid, but the intermittent use of the inert gas system was also an influencing factor. The problem could most likely be solved by using exotic materials of high quality and suitable lining where this was possible. However, flushing after shut-down of the system was in any case extremely important. The scrubber and effluent lines should be flushed thoroughly with sea water to get rid of the contamination effectively. Furthermore, fresh water flushing of scrubber and effluent lines as well as blowers, was important to remove salts and acidic particles.

Previous experience had shown that even scrubber lines in 316L, and effluent lines, in TIG welded Al-bronze were not subjected to corrosion when sufficient sea and fresh water flushing was carried out at every shut-down of the system.

When lining the effluent line with rubber, the corrosion problem was of course eliminated for this part, but the inlet or quench section of the scrubber must be made from corrosion resistant steel.

One of Dr. Levens' alternatives, Inconel 625 should be a good, but perhaps expensive solution, as this alloy with its high Mo-content offered good resistance against chloride pitting as well as stress corrosion.

Coating/Lining

From Dr. Levens' paper they had noticed that H.B.C.T. epoxy coating had varying success.

The failures could most likely be blamed on the surface treatment and anchor pattern, ambient air temperature and humidity, venting, curing time, film thickness of each coat and spraying equipment. One could appreciate that a very strict control is required to achieve a good result.

By applying stoved epoxy coating, most of the above factors were not critical and a good result was more easily achieved, but the cost involved was of course higher.

For vital components like scrubber, fans and deck water seal, lining offered the best solution, but the effect of thermal expansion must be kept in mind to avoid cracking.

Scrubber Performance/Cleaning Efficiency

One interesting point mentioned in Dr. Levens' paper was the performance of the scrubber, i.e. efficiency of soot and S02 removal.

Improving this would of course reduce problems of corrosion and harmful effects on the blowers caused by build up of particles, but more sophisticated scrubbing equipment might be required. This would of course increase the cost of the plant and probably the complexity. Generally, particle removal efficiency was a function of pressure drop, while sulphur oxides removal was a function of wetted contact area and water/gas flow ratio.

On increasing these efficiencies, it would also be necessary to accept higher pressure drop across the scrubber and probably more water, both resulting in higher power consumption, which was often a limiting factor for retrofits.

When speaking about scrubber efficiency, one should also consider the operating conditions, such as flue gas quality, water flow rate and scrubber loading.

Burner control was important, when using the inert gas plant. Most plants would not handle heavy soot and particle burdens, occurring under unstable conditions. It was essential that complete combustion with a reasonable excess oxygen level should take place when operating the inert gas plant.

On VLCC the draft difference was quite large, and due to this scrubber cooling water pressure might need adjustment to avoid loss of performance. Overloading of the scrubber could easily occur when purging the aft tanks, and then the efficiency decreased.

However, by improving the scrubbing equipment through careful process and constructional design, and by ensuring favourable operating conditions, the flue gas processing could be improved.

Finally, he would mention that F.M.V. were very interested in further information about results from investigations being made by Shell, with respect to corrosion problems and performance of inert gas plants, both of which they found to be of very great value for further development.

MR. G.I.L. TOWN, of Industrial Marine Contractors (Yorkshire) Limited, complimented Dr. Leven on an excellent detailed analysis of operational problems experienced with I.G. Systems within the Shell Fleet.

His company had been actively engaged in similar type investigations and surveys of I.G. Systems and concurred with the recommendations for remedial work. As an extension of their existing services they could provide a package for supply of hardware and skilled engineers to carry out the following rectification programme mainly at sea.

I.G. Uptake Valve

Design and installation of small purge air blower to "back off" gases to uptake valve.

Scrubber

Internal surfaces flaked glass material coated.

I.G. Fans

(i) Flaked glass coating of casing internally.

(ii) Reclaimation of existing Alu-Bronze impellers including flaked glass coating.

(iii) Fitting of anti-vibration mounts and additional stiffening of existing bedflame, where excessive vibration is experienced.

Effluent Line

Renewal in FRP pipe (BONDSTRAND). Our company represents Bondstrand in the U.K. Marine Field for this product which has been used on many such installations and has an excellent track record in the Marine Field.

Deck Sea

Internal surfaces coated with flaked glass material.

Deck Distribution Lines

Internal flaked glass coating.

Each project is engineered from vessel survey, system design and installation to suit owners' individual requirements.

MR. J.M.G. KEEN, of Tampinex Engineering Limited, wrote that the author's conclusions and suggested materials of construction omitted to emphasize the many advantages of coatings combining flake glass; such coatings had given many years of excellent service in the marine field.

The vehicle in which the flakes of glass were carried could vary according to the application and duties involved (vinyl ester, bisphenol and chlorinated polyesters and modified epoxy resins). The flakes of glass were of 2 to 3 microns in thickness lying parallel to the sub-strate and gave an almost impervious coating of glass. There were approximately 125 layers in a coating of 880 mm. As the flakes were not locked together in a rigid woven mat the coating was able to flex without damage within the elastic limit of the sub-strate. This characteristic completely eliminated the problems associated with lamination between sub-strate and coating. Fan casings and similar relatively thin walled items of equipment which could be subject to some flexing could operate without damage to the coating material.

Another advantage was having the material, i.e. the carrier and the flakes, correctly mixed during manufacture and it was not necessary to rely on the skill of the operator to the extent necessary for the glass fibre type application. The material could be applied by using standard spray equipment with the exception of pipe internals. This required application of the coating by a portable machine which his company marketed and which was not only able to apply the coating evenly and at a predetermined speed but had an interchangeable head by means of which a detector unit could be passed through the pipe by the same machine, instantly detecting any points where additional applications of coatings might be required.

It was of interest to note that the coatings referred to cured at ambient temperature and, therefore, could be applied either at sea or shore, modifications could be made to steelwork without the need to heat cure any repairs which might prove necessary after such modifications.

The cost of flake glass coating could be 20 per cent lower than other materials used for similar duties.

AUTHOR'S REPLY

The author thanked Mr. R.F. Thomas for his constructive contribution and would take up the individual points raised, in order.

He agreed entirely that GRP was probably the best liner material for scrubbing towers, overboard drains, etc, especially in view of its ease of repair, when compared to a vulcanised rubber lining. As to the point in regard to glass flake epoxy coatings the author had little experience but the experience available indicated it was a useful, tough coating which could of course, be repaired cold without too much difficulty. Its strong point seemed to be that, even at corroded "holidays", it had no tendency to peel back as might a coal tar epoxy coating. It did, however, require good surface preparation and, shot blasting, whereas tar epoxy might stick a little better on less well prepared surfaces.

The author had no experience of unsupported GRP scrubbing towers but believed there were some land-based units in the U.S.A. His main concern would be what the effect of vibration at sea would be on an unsupported tower.

His company had some problems with nickel aluminium bronze fans but this had been a fan design rather than a corrosion problem and he saw no reason for not continuing to use this material for gas impellors.

Mr. Thomas' last point, the problem co-relating the design, materials selection and operational practice of a unit, concerned all ship owners. Each item of equipment was often a compromise between the shipbuilder, owner and the supplier of the equipment. The latter should be responsible for the good design and long lasting nature of the package. They should also know sufficient about the problems of operation to supply robust equipment with correct material choices in peripheral equipment, i.e. attention to detail as well as the main body; and should adopt, on occasions, more generous views with regard to guarantees. The shipbuilder in his turn could often be responsible for supplying materials that, in his view, gave no problem, i.e. no large guarantee claims had been made against the shipbuilder in regard to the equipment. From the ship owner's viewpoint more than 366 days service was needed before a piece of equipment could be considered reliable but often second best might be taken at the building stage as large cost penalties often arose because the shipyard lacked experience, for example, with the welding of a new salt-water pipeline material and so, in fear, they increased the price. Thus compromises would always have to be made and, in fairness, there were many manufacturers and shipbuilders who were enlightened enough to listen to the owners' pleas and upgrade original materials, without imposing great cost penalties, though often the latter were the unavoidable deciding factor regarding the final choice. The situation could often work in reverse and the owner could find himself persuaded by a knowledgeable manufacturer or builder to pay out the extra cash needed to prevent future problems.

It was encouraging to hear from Mr. D.J.H. Odds that suppliers welcomed user information of the type presented, even though this might sometimes be in the form of criticism. The author hoped that some positive results would come out of the report and that it did not appear to be simply a list of criticisms; though the latter could, of course, have positive effects as far as the shipowner was concerned.

In regard to the original histogram, this was altered in deference to requests made by F.A. Hughes and Co. Ltd.; it was the author's view that the original histogram was unambiguous, having been presented in the normal manner. As to the actual composition of the histogram it was intended that it should be kept as simple as possible, highlighting the major areas of concern.

If it was to contain too much information then that information might become lost in a welter of appended explanation. Perhaps a Table showing the ratio of number of failures reported from ships to the total operational ship-years might be more suitable.

As to the exact composition of the histogram and, indeed, to the report itself, several points should be made. In the first place, the document was intended largely as a guide to users of Inert Gas Systems. It was intended (should they so wish) to indicate to them the areas in which faults might occur in particular systems and to help them avoid the type of errors made in the Shell Fleet. It was also pointed out that all faults should not be attributed solely to the manufacturer; as all operators know some of the faults were attributable to either the Shell companies or to shipyards, as was stated in the introduction to the paper. To be specific as far as the histogram was concerned only those faults listed under monitoring system, scrubber and deck-water seal could be exclusively attributed to the manufacturers. The author also recognised the commercial pressures which prevented manufacturers from putting forward the ideal everlasting piece of equipment in the first instance. Manufacturers did however compete on equal terms for orders to supply a piece of equipment to fulfil a given function. It was therefore reasonable to expect operators of such equipment later to make comparisons, especially in regard to important items concerning the safety of the vessel such as an inert gas installation. The author was sure that F.A. Hughes and Co. Ltd. would wholeheartedly endorse criticism of manufacturers of inferior equipment who had been able to undercut reputable firms, like themselves, because of this inferiority. He could only hope that in highlighting the problem areas which Shell Companies had encountered, manufacturers would be able to put forward a well-designed piece of equipment without fear of losing orders through cost considerations, because owners, yards and Inert Gas equipment suppliers would be more aware of the necessity for more sophisticated materials or alterations in design in certain areas.

As to the specific points of criticism the author would answer them one by one with a little more explanation. The histogram was of "Number of Faults Reported" type, that is to say the number of faults observed by engineering staff which were obvious malfunctions in need of repair or replacement; the histogram included the majority of these but obviously not all. For example the failure of numerous holding bolts within a scrubbing tower would be noted as a single and not a multiple failure. The apparent discrepancy described i.e. fan faults, arose because the author had personally inspected 18 fan casings and found them to be defective paintwise, whereas a ship's staff might only have reported this as a fault, for inclusion in the histogram, if an actual hole had appeared in the casing. That was the difference; the histogram reflected inconveniences to the ship whilst the report offered a little more, the author's own observations, often noted in advance of actual failure of the unit.

Mr. Odds made the point that the F.A. Hughes units were the first ordered in 1971. (The units were ordered by the builders, not Shell, but with the latter's approval) and the first to be fitted to Shell vessels and because of this he, presumably, was implying that some distortion in the histogram resulted from this due to the age of our Hughes' installations. It should however be pointed out, that the first two Hughes' units were actually first operated by Shell in 1973 during which year 15 F.M.V. units also became operative. The histogram thus reflected $16\frac{3}{4}$ ship years experience with F.A. Hughes equipment and 65 with F.M.V. This should clarify certain aspects of the histogram but its main purpose was to direct attention to the most problematical areas.

Mr. Odds then moved on to problems associated with Hughes' equipment and the author would answer using the same title headings:

Scrubbing Tower

(i) Quench Section

It was agreed that this was the most demanding area of any inert gas system as far as materials of construction were concerned. Hence, a perfect quench medium such as a sprayer pipe carrying cold salt water, must be of the highest grade materials available. Experience had shown that Monel 400 was not adequate for this job and lasted only a few months in normal usage. It was also surprising to hear that time was not available to purchase better acid resistant materials; it was believed that Hastelloy C, for example, had been available for many years longer than F.A. Hughes had been making inert gas units. This was possibly at very high cost but if the design demanded a spray pipe then the equipment price must reflect the need.

It was pleasing to hear that plug welding techniques had now improved so that longer life could be assured from welds attaching Incoloy 825 liners to steel in the gas inlet area. The technique of using upgraded welding rods had been practiced for many years with internal clad steel vessels. It was stressed however that given the present sprayer design and materials, the Incoloy 825 pitted rapidly through dew point corrosion, so that improvements in plug-welding alone would not remove all problems. It was stressed that the experimental quench sections in Hastelloy C-276 and EPE 53, fitted at the expense and direction of Shell International Marine and manufactured by F.A. Hughes were both in excellent condition after two years of service despite continuing problems with the spray pipes.

(ii) Weirs

In the final text the word weir had been deleted and "submerged baffle plate" substituted. The author apologised for implying that the weir was only painted steel, it was in fact rubber lined but it was the baffle plate surrounding the weir which was epoxy painted mild steel and which corroded so rapidly.

(iii) Hatches

The author would have been pleased if Mr. Odds had continued his quotation to include the words immediately following those picked out "as easily as can the F.M.V. units. The sentence was thus comparative. However, the point was taken. Man-sized covers were fitted and with the removal of a considerable number of nuts and bolts the whole scrubber tower could be inspected.

Fans

F.A. Hughes fans were not overhung, they were completely supported at both sides. The author apologised for this error. As to the material of the fan the author could only say that the material of the Impellor was not analysed and the statement was made in the knowledge that in the environment in which inert gas fans operated, aluminium bronze tended to de-alloy, leaving a coppery layer on the surface. This was precisely what was observed and was the origin of the author's statement that the blading was made of aluminium bronze. F.A. Hughes subsequently carried out a metallurgical analysis on one of the fans in question and confirmed that the material was nickel aluminium bronze with a nickel content of just under 5 per cent.

As to Ferralium (in the cast form) for fan blading materials there should be no problems. However, repairs, such as rebalancing, might prove a little awkward in the far corners of the world. The fabricated variety could prove dangerous unless of low carbon composition and therefore not subject to weld decay. When using materials such as Ferralium it was necessary to be careful that when ordering Ferralium that this was an unambiguous statement of composition.

The author was pleased that F.A. Hughes was carrying out their own trials as his company had been limited to trials on the Hughes scrubber and so far had replaced four complete sets of bolts, numerous spray pipes and fitted two experimental quench sections.

General

The uncoated deck lines were, indeed, not of F.A. Hughes supply. Interestingly enough, these lines had lasted longer than some painted ones. It was largely a question of whether or not water was allowed to lie in them as to how long they lasted in either the painted or unpainted condition.

It also indicated that the inert gas had been efficiently scrubbed and dried.

The flame screen placed in the main inert gas line was also not F.A. Hughes supply but it did tear when inert gas was passed through it i.e. at every loading, ballasting, simultaneous deballasting/ loading or discharging/loading. Clearly the screen could not tear when it was not in use.

Report Conclusions

With regard to the comments on page 7 of the report these of necessity had to be fairly general but the author was glad that there was some agreement. As to item 19, the operative words were "drains" and "in which water is liable to lie". For example, if it was a drain then stainless steel could be used, if not, then the material must be changed.

Mr. Odds states that Hughes are in general agreement with the conclusions. However, if these were more specific then the author would not be in agreement with him as far as items 6, 7 and 8 were concerned. Incoloy 825 only lasts in the absence of a spray pipe; painted steel was not avoided in the base of the Hughes scrubber, and all scrubbing tray holding bolts have been replaced in four out of six Hughes scrubbers. Furthermore, all material improvements had been made at Shell's initiation and expense. Point 8 could perhaps also be expanded to include a comment that although the bubble-cap trays did not corrode, the holding bolts most certainly did in Hughes' units.

The author was a little concerned at the accusation that shipowners attempted to do things "on the cheap", especially when safety equipment was involved. It was true that the lower price solution would most often be chosen. This was only common sense if two effective solutions were offered. The ball was in the manufacturer's court at the outset, it was he who offered the viable or non-viable piece of equipment. Shell approved the shipbuilders choice, backed by their own experience and expected to purchase equipment suitable for its purpose. Shell bought what was, and probably still is, considered to be the best and most cost effective material for those items supplied by the shipbuilder

The author considered that the report would have become too unwieldly if it had been prepared in the way suggested by Mr. Odds. It would certainly have become more difficult for operators to pick out trouble spots.

In the way it had been written it retained continuity within each unit. The author hoped that he had adequately answered all Mr. Odds' queries and made amends where necessary. He hoped too that readers of the report would note that all faults were not necessarily attributable to the manufacturers. He hoped, too, that the report had also been in some way constructive; and that it might enable the good supplier, among whom F.A. Hughes must surely fall as implied by the existing units fitted aboard Shell vessels, to be more competitive by highlighting areas where newcomers to the field may undercut by using less good materials or design criteria. The evidence would be open for the future owners to see.

Mr. Odds' parting comment on the inspection of uptake valves also perhaps required some clarification. It was not inspected because it was not possible at the time; "difficulty" does not prevent the author from inspecting any system but instead must be taken as a criticism of the layout of a particular system, possibly brought about by the constraints imposed by space in the engine room.

Mr. Bell was correct in assuming that the vessel fitted with a three year old Howden unit was on lightening duties and thus had been heavily utilised. It was pleasing to note the improvements in design which had indeed been made by Howden Engineering Co. The author thought however that even with low gas inlet temperature, glass fibre reinforced epoxy resin would have difficulty in coping at the inlet foot. A recent report had suggested that delaminification of glass fibre slats within the scrubber tower could take place and developments along these lines must be awaited. It was encouraging that only one vessel had reported this defect. Although Titanium had been fitted to Howden units for some five years our experience with the remaining vessels was more limited than implied. When the report was written only one of these vessels had been taken for guarantee drydocking, the remainder had either only just been delivered or were laid-up.

The author agreed with the comments in regard to water-washing of fans, and automatic systems were preferred. His company had no experience of Titanium fans but he was interested to hear of their usefulness. The point was noted that welding could be a problem with Titanium. All the failures the author had observed had been a result of either weld corrosion or poor weld profile. This was an important point to bear in mind with Titanium impellors.

Mr. Bell's point in regard to equipment costs was also a relevant one and had been mentioned earlier. The cost of improved materials was often passed to the ship owner in greatly increased costs; it was often the Shipyard not the owner who needed educating that a small change in materials did not mean an automatically inflated cost. Shipowners were often not able to have the materials they would like because of penalties imposed by yards out of fear of, say, difficulties in fabricating a pipeline in a new material. It should be remembered that a ship's price might be fixed beforehand, and any upgrading of materials to improve the vessel meant someone had to pay. Although this might be only a fraction of total costs, it might not be possible to find the extra money at the time. Thus most equipment was a compromise involving price, availability and past experience of yard, owner and supplier.

The author again commented that AISI 316L steel had proved adequate in drained areas but if stagnant acid water was present pitting would develop.

In reply to Mr. Larsen several cases were known of Incoloy 825 bellows that leaked when fitted in the horizontal position; in the vertical position the condition was not known. The author hoped that Mr. Larsen was correct but suspected there might still be a tendency for moist acidic soot to collect here and cause some pitting.

The stoved epoxy pipe aboard "MYRTEA" had given no problems, nor had the remainder of the epoxy coated piping on "MYRTEA". However, the author would expect the stoved pipe to give excellent service. Certainly stoved epoxy paint lasted much longer than epoxy paint on impellor casings. In general epoxy painted lines for gas carriage had given few problems; they soon became covered in soot and paint films were often broken down, but unless water lay in the part of the line where there was no paint no problem would result.

Aluminium brass appeared on the surface to be a good choice for seawater piping material. It had, however, given many problems in carrying seawater, as Mr. Larsen pointed out, largely at welds. Even using TIG welding and aluminium bronze filler rods the author had encountered many problems with erosion through both over and under weld penetration. The only area in which the author thought aluminium brass piping could still be used without erosion problems in a high water velocity, was in large bore piping in which internal weld profiles could be dressed or in flanged piping free of welding.
It was curious to learn of pitting occurring on straight runs of AISI 316L piping and the author presumed great age, low water flow to scrubber or inability to drain was responsible. Certainly at welds and in areas in which water was allowed to stand he had experienced problems. The first thoughts on overcoming this were to use rubber lining but as all F.M.V. units were out on deck, exposed to the sun, this was not done and glass fibre lined (good after 3 years) and glass flake painted (good after 1½ years) were used instead. Mr. Larsen's information of GRP lines was interesting and although GFRP might be initially more expensive it could be patched by ships staff should problems occur.

As to the epoxy painting of impellor housings the author was not able to comment on the original quality of the epoxy coating. However, from the evidence of intermittent breakdown of stoved epoxy coatings, done under the best conditions in the factory, it was suggested that epoxy coating would fail in this position even if well put on.

A number of bronze fan failures had been inspected and were always associated with discontinuous welding along the vane and not with weld corrosion. The author was pleased to hear that fan manufacturers were actively looking into the problem, prompted by Mr. Larsen's company.

The author had seen the redesigned vulcanised ring for the DWS non-return valve and believed this was an improvement over the older "O" ring system, however, he was inclined to think that a full rubber to rubber seat might be the optimum solution.

Finally, he wholeheartedly endorsed Mr. Larsen's comments and his company's approach and felt sure that with their enlightened outlook improved systems would result.

Henry Wiggin did indeed make most of the nickel alloys mentioned earlier and as such their alloys had given excellent service in many iner gas scrubber inlets. Mr. Hopkins made two points. The first concerned dilution of welds Incoloy 825 by mild steel. The use of upgraded filler techniques was well known and had been practised for many years in Shell Refineries using clad coatings. He hoped that manufacturers using cladding and plug welding were also aware of the technique. As to the preferential attack at the corner of an Incoloy 825 sheet, he could only say that the influence of cold work was the only reason that sprung to mind, that would cause significantly increased corrosion at a severe bend.

In general the telex received from Mr. Riley and the report were in accord, however, he made many valuable points that added to our experience which I would fully endorse; viz - non metallic bellows had been found useful, air sealing of uptake valves was best fitted with independent air supply, rubber-lined diaphragm valves were excellent in salt-water service, stainless steel was good for scrubber drains provided the water did drain, rubber-lining for water seals and impellor housings was an improvement over epoxy paint and Incoloy 825 was generally good enough for use in scrubber tower bottoms. However, the author would add two further comments. Firstly, provided epoxy coated areas of deck seals could be inspected readily and touched up easily then there was no real problem with paint systems. If, however, velocities were very high and paints easily removed or, say, the gas inlet was not readily accessible, then certainly rubber-lining was better. It was, however, not easy to repair when damaged. Secondly, Incoloy 825 was good, providing the design of the inlet did not ask too much of it.

Two further interesting points were raised by Mr. Riley. Firstly, the use of static ultrasonic level devices removed one problematical area and, secondly, he raised the issue of the corrosivity of "inert" gases.

The sulphur trioxide measurements mentioned in the text were carried out using a system developed by Shell Research, Thornton Research Centre which was a hot water condensation method. The method measured an 'acidic' component in the gas which was fairly certain to be a mist of sulphur trioxide. Because of the temperature of measurement the acidity was certainly not due to SO_2 but our measurements had indicated other disturbing features which are mentioned now for interest but would probably be the subject of more detailed debate later.

On a typical inert gas installation with the boiler burning bunkers of 4% sulphur content one could expect about 10 - 20 p.p.m. SO_3 in the gas stream. Our measurements had shown that most of this passed straight through the scrubbing tower. In addition, about 150 p.p.m. NO could be expected to pass through the tower along with about 16% of carbon dioxide. At a gas throughput of 20,000 m^3/hr this was a considerable amount of acidic component being thrown into the tanks per hour, bearing in mind that the NO would convert quite quickly to NO_2, which was very soluble in water, to give a further acidic component in the tanks.

Mr. Howey's question although short would require a long and detailed reply to be fully answered. The sort of maintenance schedule needed for the various inert gas systems only became apparent after operation of the systems for some time when individual problem areas became known.

Clearly areas involving aspects of safety, such as the gas entry to the deck water, should receive considerable attention. The author can only answer Mr. Howey by saying that maintenance must depend on the type of system installed, its known problems, the quality of materials used in the system and on the experience gained with other types of unit. It was hoped that the paper would clarify some of the problem areas so that owners and Classification Societies might know in advance where to look to find corrosion before it became a problem.

The author thanked Mr. Day for his excellent written contribution which was constructive and added further valuable information from a company with great experience in the field of inert gas usage.

He could not add anything to Mr. Day's comments but was interested to hear of the failure of Incoloy 825 welds in a deck water seal. It seemed strange that this material could be used in the much more arduous region of the scrubber inlet yet it failed in the deck water seal. It was presumed that either the welding was at fault or a mechanical problem existed. In the two units the author had seen with Incoloy 825 inlet feet in the deck water seal there was no sign of preferential corrosion at the welds, indeed no sign of corrosion anywhere. The author argued that access for planned inspection of the inlet pipe and weir plate was essential and this was being built into Shell's existing units in which this facility was not present.

The author thanked Mr. Bjerk for his very constructive comments. He was right to stress the importance of keeping the flue gas line free of gas in the shut-down condition but care must be taken when installing soot blowing facilities downstream of the flue gas valve to ensure adequate safety precautions for protection of people entering the tower and indeed of the tower itself. Perhaps a second flue gas valve near the tower might be necessary.

Once again it was interesting to hear Mr. Bjerk's comments in regard to 316L stainless drains, they are adequate if in aerated salt water or if completely drained. I wonder if Mr. Day would agree. His suggestion was an excellent one that salt water should be supplied both to the DWS and the scrubber and hence ensure sealing water in both. It also ensures a continual supply of aerated, normal pH water to the scrubber drain which the author thought gave no problem with AISI 316L stainless steel.

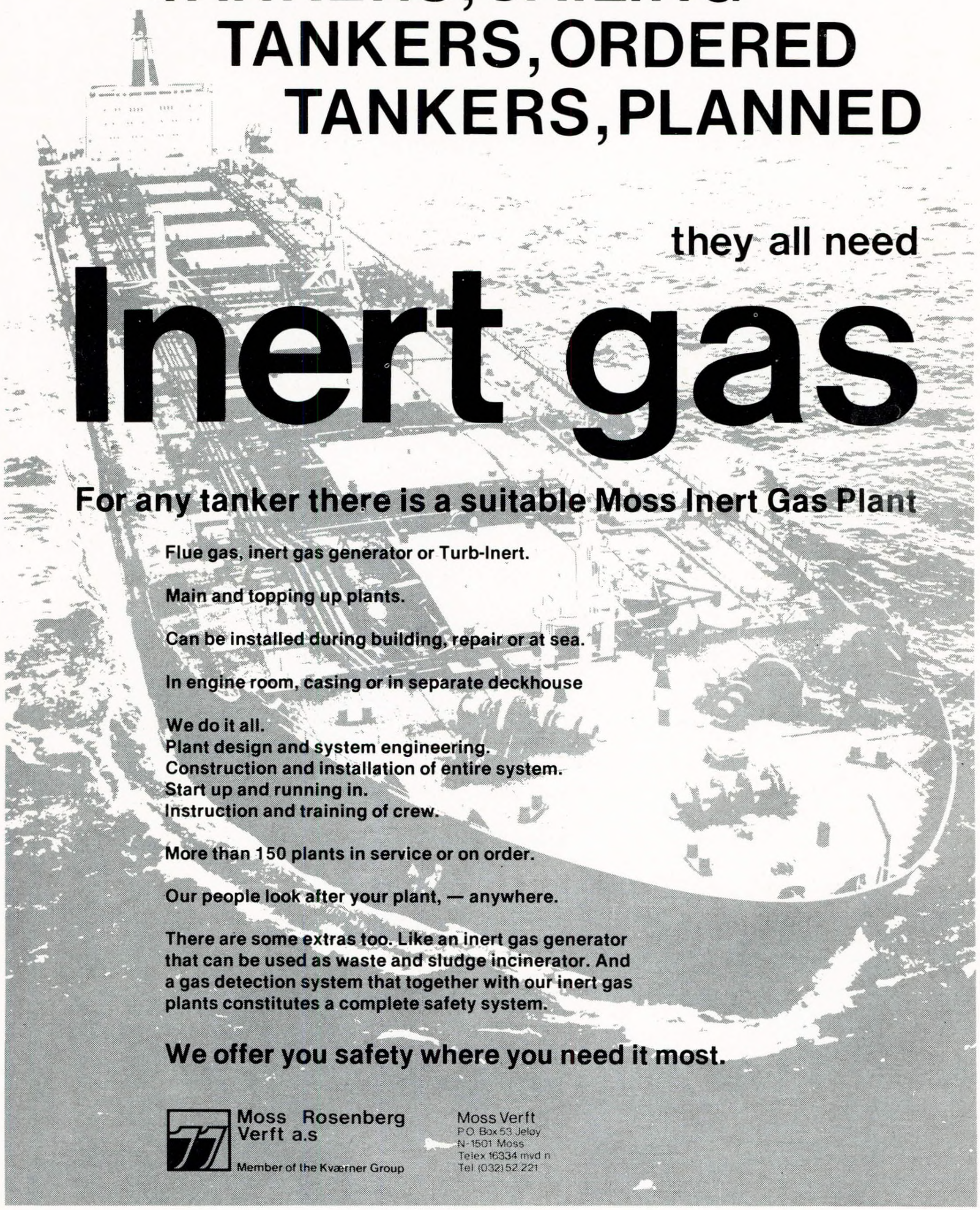
As to coatings, the author mentioned once again, that the importance of the coating may only be cosmetic if water can be kept out of the lines or drained from them. This was often not the case and so he agreed with Mr. Bjerk that stove coating or lining would give longer pipe life.

As far as results of inert gas quality measurements were concerned he was sure that these would be made available when completed. He had expected and had already noticed differences in performance dependent on water supply, type of scrubber, etc. as mentioned by Mr. Bjerk.

The author had little comment to make on Mr. Town's contribution except to say that he was always pleased to hear of skilled repair teams available to carry out repairs at sea.

Mr. Keen must excuse the author for not stressing the usefulness of his product. It was however mentioned as being a useful coating for scrubber drain lines and for fan casings. However, for the latter application he still preferred rubber lining in view of the excellent service it gave in this application.

TANKERS, NEW
TANKERS, SAILING
TANKERS, ORDERED
TANKERS, PLANNED



THE INSTITUTE OF MARINE ENGINEERS

Incorporated by Royal Charter 1933

The Memorial Building, 76 Mark Lane, London
EC3R 7JN

Telephone:	Telex:
01-481 8493	886841

Neither the Institute nor the publisher hold themselves responsible either for the statements made or for the opinions expressed in the Transactions.

Papers of full page length, or over, are indexed in British Technology Index

Published for THE INSTITUTE OF MARINE ENGINEERS by Marine Media Management Ltd. (England Reg. No. 1100685) both of 76 Mark Lane, London EC3R 7JN. Printed by Crown Printers (Bedford) Ltd., Bedford (England Reg. No. 910307).