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MARINE ENGINEERS MANUAL

This manual is a comprehensive field guide to aid in an Engineers understanding of Boiler, Diesel, and Fresh Water Generator Systems. The object of any water treatment program is to avoid corrosion of system components, stop the formation of scale and enable undesirable solids to be removed easily. By implementing this philosophy a vessel can greatly extend equipments life, reduce maintenance and enables thermal efficiency to be maintained at the designed level.

The key systems requiring water treatment on a motor vessel are diesel engine cooling circuits and the steam plant. Successful treatment of either largely depends on the quality of feed water being used. Thus a modern and efficient water treatment program should particularly concentrate on optimizing production of water via the fresh water generator and or other type of distilling plant.

If distilled water was used at all times, treatment would be relatively easy to control. It is a well known fact that motor vessels often have distilled water shortages for numerous operational and technical reasons which require the vessel to acquire shore side water. As experience has taught us shore side water varies enormously from port to port and no single program can be adjusted to accurately treat the various minerals found in water. The effects of scale forming minerals can be minimized by keeping them to acceptable levels in the system and ensuring that they are not allowed to precipitate.

The modification of these minerals, results in "sludges" as opposed to " scale" and these have to be removed regularly. There is no "magic" chemistry that can handle this in a system without controlled mechanical assistance, whether it by blowdown in a steam system or run-down in a cooling water circuit.

Unfortunately, current "wet chemistry" test methods only give readings related to "totally dissolved solids" levels present in sample water. Thus the water condition that appears to be correct during a voyage fail to tell the operator that they may have large volumes of sludge and scale in the system as is often found when inspections are made.

The same minerals are present in seawater in far greater concentrations and therefore every effort must be made to minimize seawater leakage into your critical water systems.

The minerals shown below cause most of the scaling problems found on motor vessels.

Shown as compounds

Calcium Carbornate	(CaCO3)
Calcium Sulfate	(CaSO4)
Magnesium Silicate	(MgSiO3)

There are many other soluble (*) components in water which are in relatively low percentage and would not normally impact water treatment. Very poor quality shorewater may be turbid and contain high levels of insoluble (**) components such as sand and clay which cannot be treated and ill form heavy sludges in the systems.

(*) Soluble = readily dissolved in water
(**) Insoluble = may dissolve very slowly but usually remains in suspension

The first step to increase the quality of water in critical systems is to maximize onboard production. Reading through this engineer's manual will give a greater understanding of the chemistry side of water systems and what is truly critical and perhaps what is slightly over emphasized.

The manual is not intended to be a substitute for rigorous failure analysis. Rather, the information should serve as an aid to in-plant investigation and as a readily accessible reference source in the field. Although an experience skilled observer can detect and correctly diagnose many failures based solely upon visual inspection, however there is no substitute for laboratory investigations.

Critical, unprejudiced observations, bolstered by experience and common sense, are probably the most important factors in correct identification of critical system failures. This manual alone cannot substitute for the trained, experienced analyst. Failure analysis is a learned skill. We hope this manual will aid the novice and experienced observer select the most likely failure modes quickly and simply.

FRESH WATER GENERATORS
(Maximizing Production)

On many vessels, potable and reserve feed water cannot be segregated, but most ship's engineers could improve their reserves with some planning of production and a study of optimum tank utilization.

Direct Distillation to Systems:

If distilled water shortages are anticipated due to tank contamination or segregation problems, it is perfectly acceptable to connect a temporary hose to the F.W.G fresh water pump outlet line to discharge directly to the cooling systems header/reserve tanks and or auxiliary boiler feed tank (Hotwell).

If this is being considered, it is most important to connect the hose after any salinometer or "dumping" devices. This will ensure that contaminated distillate is monitored in the normal way, avoiding pollution of system being filled.

Distilling in Coastal Waters:

It is very common for Fresh Water Generators to be shut down when the vessel is in Coastal waters. This is only necessary if there is a risk of contamination in the potable water.

If the water is produced for steam and cooling systems, there is no need to stop production unless there is a high risk of drawing oil and debris into the F..W.G. sea suctions.

Causes of Low Production:

On many vessels sailing today the F.W.G can produce at least 1m3 an hour, under normal running conditions. If this is not the case please refer to the vessel's trial figures and ensure that the plant is functioning correctly.

Most plants which under produce are "fouled" either on the jacket water side of their elements or on the external surfaces of their elements and demisters (Hardness Scale). In many cases the ship's staff, often acid clean the seawater side and yet still suffer from poor production.

In this case, check the jacket water side. It must be remembered that being part of the main engine system it could have contamination from Hardness Salts, Oxides, Oil & Silt.

Any other causes can only be mechanical and the plant must be maintained to a high standard.

The causes and consequences of scale in F.W.G. systems

The vast majority of motor vessels have F.W.G.'s using diesel engine cooling water as the heating medium. Some have steam injection enabling production to be maintained. A few have reverse osmosis plants and some vessel's have multi flash evaporators.

However all systems have the same problem of "SCALE." Scaling of elements in simple evaporators and preheaters of "flash" type units is the result of the elevated temperature in seawater feed. This causes the precipitation of hardness salts, which is aggravated by the concentrating effect in the feed as the pure vapor is boiled off. Most plants increase the feed density by 100% resulting in 1 part distillate for every 2 parts feed.

The build of scale on heating surfaces is mainly calcium carbonate, with a smaller percentage of sulfate and silicate. It rapidly reduces heat transfer, decreasing production and increasing "foaming" in the plant. The result is "carry over" of solids, which foul the demister and ultimately cause contamination of the distillate.

Steam Injection:

Some Fresh Water Generators are fitted with steam injection, so that the plant can be operated when the main engine is stopped. Vessels equipped with this should make maximum use of it whenever possible, particularly where shore water supplies are expensive or of unknown low quality.

Precautions when using Steam Injection:

When changing from Jacket Water System heating to steam, it is most important that procedures are carried out in such a way that the risk of Jacket Water leaking into the steam drains is avoided.

It is quite common for vessels to get unusual readings in a boiler due to "interference" from the ingress of Jacket System Treatment. When utilizing steam injection it is likely that the heating element temperatures will exceed 100 deg C, this greatly increases the precipitation of hardness salts and the elements will scale rapidly.

To avoid this problem, ensure the inlet steam temperature does not exceed 140 deg C max. and that the evaporator treatment is never stopped even for short periods.

Treatments:

Most modern Polyelectrolyte based treatments react immediately when introduced to mineral salts in seawater. They are designed to modify the crystal structure as temperatures rise and precipitation is imminent.

The resultant crystal is simplified in form, non adherent and will remain in suspension in the brine. This completely avoids scaling of the elements. Proper use of the treatment can result in clean elements for years of operation. The unit is far more likely to fail mechanically, before it fouls.

Multistage Flash Evaporators and other similar designed systems in which the seawater is preheated before shell entry, require the dosage of the selected chemical product by a pump and tank system, discharging into the inlet line of the feed heater. Some vessels have these type of dosing systems already equipped from the shipyard. In these cases, check the metering pump flow rate and make a solution up, so that regardless of the total solution dosed per 24 hrs, the correct amount of treatment is injected. It is strongly recommended that the correct solution is made up for a 24 hr period, as bulk quantities used over several days are more likely to be overlooked or misjudged.

- Always maintain treatment at designed output even if true output I slow, because the volume of seawater feed remains constant and scale is related to seawater, not production.
- If plant is partially scaled, increasing dosage by as much as 50% above normal will slowly remove the deposits.
- If plant is badly scaled, it should be cleaned with an acid wash then neutralize with an alkaline.

Dosing Routine

1. Mix product with fresh water to make diluted solution according to manufacturer's recommendation.
2. Open tank valve
3. Adjust flow rate to empty tank in just over 24 hours.
4. NEVER use flowmeter needle valve as a stop valve.
5. Start FWG, according to manufacturer's instructions.
6. Re-adjust flow rate once vacuum is stable.

Note: Always start treatment immediately before running plant, NEVER wait until plant is producing because during the start-up, conditions are unsettled and scaling can occur rapidly.

Gravity Metering System Requirements

If gravity system is fitted it is most important to check the following points:

1. Tank must be located just above the dosing point. Typically the next deck above is a practical location.
2. Tank should be plastic lined or polypropylene.
3. Tank must have a dust cover.
4. A fresh water supply must be fitted to discharge directly into tank.
5. The flow meter must be mounted at a solid and easy to reach point, ina vertical position.
6. The discharge from the tank to the flowmeter must be watertight.
7. The discharge from the flowmeter to the seawater feed to the shell must be vacuum tight as it is subject to full shell vacuum when running.
8. Periodically check the integrity of all joints and glands on the metering system because air leaks in particular, will cause inaccurate operation of the flowmeter.
9. A bad air leak on the flowmeter outlet pipe cannot be easily seen but will cause foaming in the shell.
10. The fine orifices in the flowmeter can easily become choked. Ensure that the unit is cleaned on a regular basis.

Metering Pump System

Pumped systems are usually fitted by the fresh water generator manufacturer. Operational instructions provided by the supplier should be followed. The water and air tight integrity of this system applies as described previously.

Monitoring the F.W.G. Performance

Ideally, the dosage of the treatment should be carried out on the same watch everyday, preferably by one man who carries out all treatment. The made water should be recorded with the total running hours and treatment consumption for the same period.

Example:

Plant : 30 m3/day
Running Hours : 24
Production : 32m3
Treatment Dosage : 0.9 ltrs

Conclusion

Today's modern evaporator treatments have been developed to handle a wider range of temperatures and also have antifoaming properties, which enable higher production to be achieved without excessive foaming and carry over. Properly applied and monitored, these treatments will maintain a high level of plant cleanliness for unlimited periods.

DIESEL ENGINE COOLING WATER SYSTEMS

Most manufacture's state that distilled water must be used in these circuits, but many vessels still utilize shorewater as an alternative. Modern diesel engines have very low tolerance for heat transfer reduction at critical points around their systems and many reports of scuffed liners, cracked heads etc. are the result of deposits on water side of these areas.

Unfortunately, this is often not recognized at inspection, because scale, sludge, and oxide layers seen by the human eye often "appear" to be insignificant. In reality, build-ups of less than 1.0mm cause a tremendous increase in heat gradients across the metal concerned.

Water born contaminants in diesel engines cooling water systems

Apart from the more obvious contaminants which are a component of shore water (hardness, salts, silt, etc.) the diesel engine invariably suffers from some form of lubricating or fuel oil leakage.

Oil Contamination of Diesel Engine Cooling Water Systems:

Often, the areas most sensitive to overheating are the most difficult to inspect and a film of oil or carbonized oil can have dramatic effects. Oil as you may know forms a bond for suspended solids in the water, which if left, are difficult to remove even with chemical cleaning techniques. Constant checks should be made for oil in the system, and the source rectified to remove even with chemical cleaning techniques.

Oil can be seen afloat in reserve or header tanks, but more important, can easily be seen by periodic removal of covers, as follows:

Jacket Systems:

1. The Turbo Charger on many units is cooled by Jacket Water and there is a very high heat transfer in volute casing's water space. Most Blowers have inspection covers and it is usually a rectangular plate with four or more bolts and a gasket. A film of sticky or slimy oil on the internal surfaces will indicate that oil is in circulation.

2. Most slow speed engines have easily removed "U" shaped pipes, feeding Jacket Water up to the heads. These are easily removed and an inspection of the entry to the head will also show sticky or slimy oil residue indicating oil in circulation.

Piston, Fuel Valve and Auxiliary Systems:

Oil contamination in these systems is easily seen in the coolant storage tanks. It will appear as "Globules" of oil on or near the water surface. It can also be recognized by a "milky" appearance of the coolant.

The Removal of Oil:

Oil found in this manner, must be removed at an early stage avoiding major overheating problems, failure and expensive repairs. If oil remains in an "oily" state and not full carbonized it can easily be removed by introducing 5-10% of an emulsifier into the system, just after the engine is shut down.

Temperatures should be maintained at around 50-60 deg C by controlling the cooling water system. Circulation should be made for up to 24 hours and the system "OVERFLOWED" by adding make up, to float free oil off the top.

When free oil has been removed, the engine should be drained as quickly as possible, refilled, re-circulated again for 30 minutes, drained and refilled with good quality make up.

Immediately a good quality cooling treatment should be injected to the recommended levels in accordance with manufacture's recommendation.

Note:

- Seriously contaminated engines should be only cleaned after technical advice is given from a technical chemical specialist.
- Lightly contaminated systems may possible be cleaned while the vessels is operating but please consult your chemical/Technical specialist.

Corrosion of Diesel Engine Cooling Systems:

A. Oxygen Corrosion

The corrosion process in these systems is normally due to the presence of dissolved oxygen in water. Air enters these "open" systems and the oxygen dissolves into the water and attacks Ferrous and Non Ferrous Metals. The presence of air should be kept to a minimum to avoid "air locks" which can cause serious local overheating of the engine by interrupting heat transfer. This is normally controlled by the use of air vents to high points on the system (i.e. cylinder covers). These vents and atmospheric seals should be maintained in good working order.

B. Acidic Corrosion

This is normally the result of acidic gases (i.e. combustion gasses) entering the system via poor seat seals, especially around the cylinder head area. These gases lower pH of the cooling water leading to the attack of the metal. Acidity can also be caused by the presence of sea water or shorewater resulting in high chlorides.

Cavitation Corrosion/Erosion:

Cavitation is normally caused by vibration and/or turbulent water flow in the system with air pockets. The damage caused by this phenomena, appears like deep pitting corrosion.

It is the result of high and low pressure waves in the system, creating vapor bubbles on metal surfaces. These bubbles expand and then collapse at a very fast rate with high impact pressure. This action removes the protective layer of oxide on the metal surface and "eats" into the metal.

Cavitation Corrosion/Erosion is therefore both mechanical and chemical in nature. The mechanical aspects are typically design oriented, but it has been found that modern, highly effective "filming" corrosion inhibitors greatly reduce the loss of metal.

Products of Corrosion:

The Various forms of corrosion described, result in a soluble and particulate metal oxides in the cooling water. They are mainly Iron Oxides, but some Copper Oxide is usually present due to corrosion of heat exchanger tubes.

These form a hard oxide scale, often in areas of the greatest heat exchange.

Removal of Oxides:

Iron Oxides is best removed by acid cleaning, followed by neutralization of the system. However this process which is called "Pickling and Passivation", requires particular expertise and it is recommended to consult with your technical chemical advisor. Copper oxides can be excessive and must be removed by a special process.

Pre-Commission Cleaning:

When an engine system is first built it is inevitable that many of the components become corroded before completion. Many problems that occur later in a vessels life can be attributed to poor or no pre-commission cleaning. It is in the OWNERS best interest to specify pre-commission cleaning when building a new vessels or carrying out major overhauls.

To many times vessels engines are ignored or neglected internally on a new build or major overhaul because of time constraints or excessive work. This is an unfortunate situation as it will undoubtedly come back to cause issues in months and years to come.

Hardness Scale:

The presence of Calcium Carbonate, Sulfate and Magnesium Silicate with many other salts in shorewater or through seawater contamination are bound to result in the build up of scale, particularly in areas of high heat exchange.

As described in the section on water quality, this can be greatly reduced by utilizing distilled water in these systems. However, if scale has built up for any reason, it must be removed before overheating occurs and to avoid “under deposit corrosion”.

The Removal of Hardness Scale:

Engines found to have scale build up must first be cleaned to remove all signs as described previously. Scale removal is removed by adding a solution (typically 10%) of an acid based descalant into the system.

This solution must be circulated at 50-60 deg C for 6-8 hours, preferably just after the engine has been shut down. This method takes advantage of the residual heat in the system, simplifying and accelerating the job.

After circulation, the system must be drained and refilled with make up and a 1% solution of an Alkaline to act as a neutralizing agent. Circulate solution for 30 minutes and refill with good quality make up.

Then immediately correct dosage of cooling treatment at recommended dosages.

Reduction of Nitrite in Cooling Systems:

Bacteria

The bacteriological contamination of diesel engine cooling circuits being treated with a Nitrite/Borate product can cause a significant reduction in nitrite concentration. In such cases, it is important to determine that the “disappearance” of the nitrite is not due to a loss of water resulting in intake of fresh “make-up” added.

If there is no evidence of water loss and despite the fact that additional treatment is added to the system, the nitrite levels still remain low and perhaps decrease then this would suggest quite strongly that there is a Bacterial Contamination within the cooling circuits.

The bacterial phenomenon is not that uncommon and unfortunately sometimes it gets over looked as a problem within a system, until it gets quite serious. Typically however it is not a difficult problem to solve, however waiting to long to realize this situation could have negative effects on an engines performance and repair issues.

Destroying the Bacterial Contamination:

It is recommended to use a Anti-Foulant and/or Biocide type product in conjunction with your nitrite/Borate treatment to kill the bacteriological contamination within the cooling circuits. The Anti-Foulant needs to be dosed in a location that will give the maximum circulation.

After dosing this Anti-Foulant/Biocide into the system once a week for 4-6 weeks the Bacterial contamination should be destroyed and nitrite levels will climb and hold at recommend levels.

However, sometimes when the situation is quite serious and nitrite levels still remain low with no increase it is recommended to decontaminate the circuit immediately

This is a typical cleaning procedure to decontaminate your cooling circuts.

- Flush completely the cooling circuit that is contaminated and refill with freshwater. Be sure that the fresh water used is of good quality.
- Add 5 liters of Sodium Hypochlorite 12% or 2 large 3" Chlorine Tablets for every 5 tons of water. The Chlorine tablets dissolve quickly and will have similar effect as Sodium Hypochlorite 12%.
- Circulate the solution in the entire circuit for at least 6-12 hours and check that the active chlorine is at least 2-5 PPM. If the reading is below that level add more Sodium Hypochlorite or Chlorine tablets to achieve desired levels. The concentration needs to be maintained for the duration of the cleaning so periodically check chlorine levels. The engine needs to be cold when

performing this procedure as chlorine tends to evaporate more rapidly when temperatures exceed 25 – 30 deg C.

- Check Level of chlorine hourly.
- After the above procedure is followed empty the circuit and flush it with fresh water in order to eliminate all traces of chlorine.
- Refill immediately with good quality fresh water and recommended dosage of your nitrite/borate treatment, which will eliminate any chance of corrosion from residual chlorine.

Chlorine is highly corrosive if left in the circuit over an extend period of time. One should make sure that the circuit is properly free of all traces of chlorine Check for residual chlorine with your test kit and make sure total active chlorine is "Zero".

Note: Pseudomonas Aeruginosa, even in colonies in excess of 50,000 PPM can be easily destroyed with the decontamination operation described above.

The Chemistry of Sodium Nitrite & Borate:

Corrosion Inhibitors are mainly designed to "film-on" clean metal surfaces as they cannot act effectively if the metal surfaces are covered with contaminants. In fact, serious "under deposit" corrosion can take place in a scaled or otherwise fouled system, despite having the correct level of treatment in the system.

The major components in most diesel treatments are Sodium Nitrite and Borate in combination with specific inhibitors and organic dispersants. These components constantly film steel and alloy components inhibiting corrosion to take place. The borate stabilizes the pH of the water which compliments the active inhibitors.

Wetting agents, ensure that the soluble inhibitors get right into the surface grain of the metal. Polymers keep solids in suspension and in particular arrest the formation of scale, caused by precipitation of hardness salts. The Polymers also have the ability to keep surfaces clean, avoiding build ups of sludge. Sludges cause many problems in a cooling system, which unlike a boiler, cannot be "blowndown".

The chemistry design of a good quality cooling water treatments will keep all solids in a fine suspension so that they are continuously removed by natural changes of water (i.e. running down a unit for maintenance).

Dosing Methods for Cooling Treatments:

Most quality treatments are added directly to the system and should be dosed at a point of good circulation throughout the system. Many modern vessels have expansion

tanks, which there is little or no circulation. If this is the case, the product should be dosed directly by using a by-pass feeder fitted across the circulating pump suction and discharge, or connect a semi-automatic dosing unit.

Generally, the piston and the fuel valve cooling system have direct flow through their reservoirs. Also keep in mind that most auxiliaries are similar, or part of the main system. Jacket systems usually have return pipes from each cylinder head in which automatic air release valves are fitted. The "turnover" of water in expansion tanks of this type is virtually zero.

Influence of Oxygen and Temperature:

Oxygen excess is water system may be also of the main reasons of the oxidation of Nitrite converting into Nitrate. The reduction of Nitrite level for causes other than leaks of water in the system will result in a serious loss of protection of the metals, thus starting corrosion and scale.

In new building of ships of same class, same type of Engine Manufacturer, same yard construction, same water cooling system (high-low temperature) one can be faced with few cases of unusual Nitrite reduction and suddenly, after a certain period of time this phenomenon disappears with no apparent reason. Or in some rare cases it may continue on for many years. This phenomenon was brought to the attention of leading universities around the world and yet the results of these studies did not lead to any real resolution or reason.

Uniservice worked with one leading university in Germany and did some field tests and determined that this problem seems to occur in new vessels and not older vessels. The reasoning was based on the study of temperature variations which are far more extensive in new construction then on older vessels. The High-Low temperature variation is believed to be one reason why Nitrite reduction might occur, however the real influence of all parameters is still uncertain. There has been some success using a Phosphonate based anti-corrosion type product. Please consult a Uniservice Technician for more advice.

BOILER,STEAM AND CONDENSATE SYSTEMS

Water & Steam Formed Deposits:

Deposits can occur anywhere water or steam is present in a boiler. While wall and screen tubes are usually the most heavily fouled, roof and floor tubes often contains deposits as well. Super heaters and reheaters frequently contains deposits that are formed elsewhere and are carried into the systems with boiler water. Steam is not often generated in economizers. Deposits in these tubes are usually made up of corrosion products moved from their origination sites.

Deposition can be substantial during steam generation. Tube orientation can influence the location and amount of deposition. Deposits are usually heaviest on the hot side of steam-generating tubes. Because of steam channeling, accumulations are often heavier on top portions of horizontal and slanted tubes. Also, deposition often occurs immediately downstream from circumferential-weld backing rings, which disturb flow and are favored sites for steam blanketing. Because deposits tend to concentrate in the hottest regions of steam-generator tubes, those tubes near the bottom rear wall of boilers using chain-gate strokers, and screen tubes are susceptible to deposition. Coarse particulate matter is likely to be found in horizontal runs and where flow velocity is small.

Most economizers are designed to operate without producing steam. Waterborne deposits usually enter the economizer from sources such as the returned condensate. Oxides formed as a result of elevated oxygen concentrations prior to or inside the economizer may be moved and deposited in the economizer.

Mud and steam drums often contain deposits. Because drums are readily accessible, a visual inspection can provide many details about water chemistry and deposition processes. For example, typically you will see sparkling black magnetite crystals precipitating in steam drums when iron is released by decomposition of organic complexing agents.

Super heater deposits are caused by carryover of boiler water, sometimes associated with foaming or high water levels. Such deposits will usually be concentrated near the superheater inlet or in nearby pendant U-Bends. Contaminated attemperation water can also add deposits immediately downstream from the introduction point. Chip scale and exfoliated oxide particles can blown through the superheater, accumulating in pendant U-Bends, or even more seriously, can be carried into turbines.

Regardless of the type of system the same basic problems occur and similar chemistry is required to obviate them.

The following diagram and key shows the source of contaminants and describes their effect on each part of the system. (See next page)

Brief Description of Contaminants and Conditions in a typical system:

1. Shorewater contaminants are described in the section on "Water Quality" with the exception of **Oxygen**.

   The dissolved Oxygen content of water can be up to 8PPM.

   This has to be removed to avoid corrosion by **Oxidation** of metals.

2. Fresh Water Generator Distillate has high purity, but the distilling process generates relatively high volumes of Carbon Dioxide which lowers the pH of the water making it aggressive to system metals.

3. If reserve feed tanks and pipelines are not coated or made from alloys impervious to acid attack, high levels of dissolved iron oxide will be feed to the system.

4. The hotwell is collecting point for contaminants from make up feed system and condensate returns, but the oxides are in an "ionic" form and invisible. Therefore, contaminants discussed 1,2,6 & 9 will be present at this point.

5. The boiler acts as a "distiller" and as incoming feed is boiled and passes off as steam, all non-volatile components will be left behind, except in the case of "carryover".

6. Carbon Dioxide will carry over with the steam and re-dissolve at places where the steam condenses as it does its work, picking up Hydrogen, Oxygen and forming Carbonic Acid, (H_2CO_3). That is why condensate has a low Ph and is corrosive.

7. The exhaust gas economizer, being supplied with the same feed as the boiler on most vessels, is subjected to similar containments and resulting problems. It is usually prone to scale, sludge deposits and under deposit corrosion.

8. The L.P. Steam Systems supply all of the steam "services" and can suffer from effects of "carry over", and corrosive steam.

9. Condensate systems suffer from low pH conditions, as described in "6" and other contaminants due to "carry over" and in-leakage of seawater, or oil.

10. Low or medium Pressure Superheated Steam Systems are usually for running turbine machinery such as generators. High steam quality is essential in these type of systems.
11. Boiler water sampling line must draw from a point close to the surface to give accurate analysis of conditions at the area of the highest dissolved solids concentration. It must have a cooling coil to give representative samples.

Carry Over:

If a boiler is mal-operated there is risk of water containing solids passing over the steam. This is usually caused by sudden pressure drops coupled with high "take off" and aggravated by high water levels.

If the boiler water is a high solid's levels, the risk of carryover is greatly increased as water being more dense will rise and foam more rapidly.

Damage Caused from Carry Over:

Thermal Shock can damage valves and other equipment as globules of water in the steam strike components creating very sudden temperature changes (thermal shock).

The physical impact of water droplets can seriously damage components. This is especially important in the case of vessels which have auxiliary turbines fitted.

Serious blade damage or complete loss can occur very quickly if a boiler "Primes" and carry over occurs.

The long term effect of carry over, results in deposition of contaminants carried by water, from the boiler. These can result in seizure of valves spindles, damage to seats, corrosion and again, in the case of turbines, a build-up on the nozzles and blades changing designed shapes, which can seriously reduce the machine's efficiency and cause im-balance. Remember a motor vessel equipped with turbine machinery must be especially alert to symptom's causes and remedies for "Carry Over".

EXHAUST GAS ECONOMIZERS

In most modern designs, it's a "multi stage" unit in which upper areas act as feed heater and middle to lower areas act as a steam/water mixture generator. Usually the source of feed is from the auxiliary boiler and very often this same boiler acts as a receiver for the steam/water mixture returning from the unit.

Some vessels have direct feed to the economizer and an independent "receiver" at its outlet to separate steam and water, before discharging into the L.P. system.

Other vessels have what is known as composite designs. One thing in common with all, is the problem of deposition and corrosion in the waste heat sections in the system.

Exhaust Gas Economize tubes are exposed to a large volume of relatively low temperature gas, as compared with normal furnace tubes. This requires a much lower circulation rate of feed water to achieve high volume of Steam production in some or all modes of operation.

This ultimately results in increased deposition of all contaminants in these tubes. It is aggravated by operating procedures which allow tubes to "dry out", when shutting the plant down. Also when changing modes, drops in L.P. steam pressure cause "dry periods", resulting in rapid deposition and corrosion.

Under Deposit Corrosion:

Most forms of deposition are porous and therefore tend to "leach" or soak up dissolved chemicals transported in the water. Thus water which is tested and found to contain say: 100ppm Alkalinity which represents "free caustic", will be leached into a deposit and concentrate by a factor of hundreds.

This results in a pocket of extremely aggressive caustic (1000ppm's) which attacks the steel and is known as Caustic Gouging. This is particularly common in systems with slow circulation.

Most designs of Exhaust Gas units are very difficult to inspect thoroughly and problems are often only seen when serious failure or loss of production occurs. To avoid these problems it is obvious that strict control of contaminants and chemical conditions in the whole system is important.

Operating Hints for Exhaust Gas Economizers:

Systems where output is controlled by throttling flow to individual elements:

- High Water quality is essential in these designs as the tubes which are throttled, inevitably dry out seconds after they shut off. Any solids in the water immediately deposit on these tubes and it is unavoidable.
- If possible, the system should be operated in such a way that less elements are in use at a feed throughput and elements not required, completely shut off.
- All elements should be circulated when the vessel reaches its destination to re-dissolve as many of the contaminants as possible.
- The action taken in the last paragraph will cause an increase in the conductivity, of the receiving units (auxiliary boiler or steam/receiver).
- The unit should be blown down thoroughly until well within limits.
- The system should remain fully flooded with treated water during shut down periods.

Systems which are fully flooded:

- Good control of water and solid levels greatly reduce the risk of deposition and/or corrosion.
- When shutting down these systems it is vital that circulation is maintained until the up take temperatures have dropped well below boiling point at ambient pressure (100 deg C).
- If circulation is stopped to early, water in the economizer tubes will flash off and leave deposits behind. Once the system is cool, it must remain full of treated water.

Composite Boiler Systems:

The exhaust gas section of these designs suffer from large changes in thermal circulation patterns dependant on the operational mode. If the furnace area is “cool”, suspended solids tend to settle around this area of low circulation.

The reverse is true when the furnace is in use and the exhaust gas section is out of action (i.e. in harbor). This often results in unusual readings after changing modes and is best corrected by special attention to surface and bottom blowdown immediately after change over.

All Auxiliary Boilers with Exhaust Gas Economizers circulating directly from their water spaces:

When these units are in exhaust gas mode, the furnace area has little or no circulation. Also the temperature of the water between the upper areas, where incoming feed and the E.G.E. suction and discharges are higher than that of the water below. This causes a similar problem to that described in the section on “composite boilers”.

Solids will tend to accumulate around the furnace area. When the furnace is fired, sudden thermal activity “stirs up” these soft sludge’s, dramatically effecting readings and the visual appearance of the water.

This problem is greatly reduced by blowing down the unit daily, regardless of the mode of operation.

Hotwell Temperature Control:

Very few motor vessels have de-aerators fitted to reduce oxygen in the boiler feed. Those that have still require an oxygen scavenger but use less. Dissolved oxygen can be greatly reduced by maintaining high hotwell temperatures approaching boiling point. This is due to the fact that dissolved oxygen levels decrease as water temperatures approach boiling point. The excess oxygen is released to atmosphere at the tanks surface.

Many systems are operated with no control of this temperature. Hotwell's are often "overcooled" or the other extreme where they are boiling, which is a direct waste of energy as water vapor is released to the atmosphere.

The "over-cooled" Hotwell leads to high oxygen levels and also means that a loss of thermal energy has taken place. Ideally the temperature is controlled at 80-90 deg C. either by bypassing the drain cooler, or reducing cooling water flow dependant on system design. Very often, the maximum acceptable temperature, prior to wasteful loss of vapor is a function of feed pump design.

In view of this, the ideal temperature for any particular vessel must be evaluated with respect to the risk of feed pump cavitation caused by "boil off" of feed water at the low pressure area of the pump impeller suction. In our experience 80 deg C. can be safely used on most motor vessels.

Please remember that this form of control reduces oxygen and therefore requires less product, but it also means that less energy is required in the auxiliary boiler or E.G.E. to produce steam.

Thus, it is a significant fuel saving device, where an oil fired unit is operating. Some designs of waste heat unit have difficulty in producing enough steam, when vessels are running at reduced speed, therefore the introduction of feed at high temperature is very beneficial to overall economy.

This also reduces the risk of reaching "dew point" on gas side of the E.G.E. This in turn will greatly reduce corrosion in that area.

TREATMENT AND PRESERVATION OF CARGO BOILERS

Water Tube Boilers:

Most large modern tankers have one or more water tube boilers for cargo operations. Many in fact have dual pressure units. The reality is the larger water tube boilers often suffer badly from corrosion as they are idle for long periods.

This also applies to the H.P. sections of the dual pressure designs. In the smaller tankers, additional auxiliary boilers are often employed for cargo operations and these can suffer from corrosion during idle periods.

To preserve these Boilers when they are shut down, it is extremely important to ensure that they are completely full of treated water, unless they are in a circuit with an exhaust gas unit and acting as a receiver.

Short term (up to 3 months) preservation requires the injection of an effective Oxygen Scavenger (i.e. Hydrazine or OBWT-4) at a dosage of .5 liters per ton of total system capacity and filling the boiler until all air has been released from the highest point on the unit.

Note: There is no need to change existing treated water. An easy way to ensure that no air leaks into the boiler, as it cools down, is illustrated on next page. If the boiler is filled until the temporary "header" drum has a permanent level, it assures the operator that no air is present.

A DAILY CHECK of the level will quickly prove any leaks and the system can be topped up.

Return Boiler to Service:

1. Run down boiler to normal lighting up level.
2. Remove flexible hose.
3. Light up boiler.
4. When boiler is on line carry out tests and correct/maintain levels as normal.

Tug & Barge Boilers (Lay-up or idle)

As cargo boilers these too are far more susceptible to corrosion during lay-up or idle periods then during normal operating conditions. Therefore adequate precautions must be taken during lay-up.

Several methods may be adopted to combat the harmful effects of low pH and oxygen attack on metal surfaces and to protect the fireside against acidic attack from deposits containing water.

Many times it is advisable to use a organic sludge conditioner (Liquid Coagulant) prior to boil lay-up. The rate of the blowdown should be increased as the Sludge conditioner will help remove sludge/oil from boiler so when it is shutdown there will be less residual in the system to cause problems. Never drain a boiler while under pressure. Heat from the refractory will cause remaining sludges to bake on internal surfaces.

Using an Organic Oxygen Scavenger or Hydrazine at a dosage of .05 liter per ton of water should be dosed as soon as boiler is shut down. This will ensure adequate long term protection of the boiler in lay-up or idle time.

For specific instructions on your system please contact your local Uniservice Technical Representative.

Handling of Fireside:

The Fireside of all laid-up boilers should be thoroughly cleaned to remove all soot and carbon deposits. It is good practice to keep a small heater in the fireside during the lay up period to prevent corrosion due to moisture or humidity which joins with sulfur laden soot and starts a Sulfuric acid attack on boiler metal.

Fire-Side Corrosion:

In simple terms, combustion involves the rapid reaction of oxygen with the basic chemical elements in fuels- carbon, hydrogen, and sulfur- with a consequent release of heat and the formation of combustion products. "Foreign" material present is fuel forms the combustion by product referred to as "ash".

Oil-ash corrosion is a high temperature, liquid-phase phenomenon generally occurring where metal temperatures are in the range of 1100 to 1500 deg F (593 to 816 Deg C). It is found in superheater and reheater sections of the boiler, especially utility boilers.

It may affect the tubes, which are cooled, or it may affect support and attachment equipment, which operates at higher surface temperatures than the tubes.

General Description:

Fire-side corrosion may become a problem when fuel supply or fuel type is changed. This change may result in the formation of an "aggressive" ash. Oil-ash corrosion occurs when molten slag containing vanadium compounds forms on the tube wall according to the following sequence:

1. Vanadium compounds and sodium compounds present in the fuel are oxidized in the flame to V_2O_5 and Na_2O.
2. Ash particles stick to metal surfaces, with Na_2O acting as a binding agent.
3. $V_2O_2 + Na_2O$ react on the metal surface, forming a liquid (eutectic).
4. The liquid formed fluxes the magnetite, exposing the underlying metal to rapid oxidation.

It is believed that corrosion occurs by catalytic oxidation of the metal by vanadium pentoxide (V_2O_5) or complex vanadates. The resulting rapid oxidation of the metal then reduces the wall thickness, which in turn, reduces load-carrying area. This reduction in load-carrying area results in an increase in stresses through the thinned region. The combined influence of increased stress level and high metal temperatures eventually results in failure by creep rupture.

Critical Factors:

A corrosive slag may develop when fuel oil that contains high levels of vanadium, sodium, or sulfur, or a combination of these elements, is used; when excessive amounts of excess air are available for the formation of V_2O_5; or when metal temperatures exceeding 1100 deg F (593 C) are achieved. As the temperature increases, the range of compositions of Na_2O-V_2O_5 that forms liquids expands considerably.

Elimination:

The first step in combating oil-ash corrosion is chemical analysis of both the fuel and ash to determine whether corrosive constituents are present. It is also important to know the fusion temperature of ash.

Annual surveys of tube-wall thickness using ultrasonic testing can give early warning of impending problems. If tube failure occurs, a wall thickness survey can determine the extent and severity of the problem.

Elimination of oil-ash corrosion is accomplished by controlling the crticial factors that govern it. First, if fuels containing very low quantities of vanadium, sodium, and sulfur cannot be specified, then recommendation of a fuel-treatment additive to prevent the formation of low-melting eutectics may be necessary. The use of magnesium compounds has proven to be economically successful in mitigating problems of oil-ash corrosion.

Corrosion-Fatigue Cracking:

Corrosion fatigue can occur in any locations where cyclic stresses of sufficient magnitude are operative. Corrosion-fatigue failures most frequently occur in boilers that are in "peaking" service, used discontinuously, or otherwise operated cyclically. Rapid boiler start-up or shutdown can greatly increase the susceptibility to corrosion fatigue. Some serious corrosion fatigue problems can be eliminated or greatly reduced merely by sufficiently modifying start-up and shutdown rates.

Corrosion fatigue is a form of deterioration that can occur without concentration of a corrosive substance. The term refers to cracks propagating through a metal as a result of cyclic tensile stresses operating in an environment that is corrosive to the metal. The term and definition above are somewhat misleading in the case of boilers, since normal oxidation of metal to magnetite to induce corrosion fatigue in the presence of sufficient cyclic tensile stresses.

Cracks develop according to the following sequence:

- During the first phase of cyclic stress, the tube wall undergoes expansion. Since the oxide layer is brittle relative to the tube wall, the oxide layer may fracture, opening microscopic cracks through the oxide to the metal surface.
- The exposed metal surface at the root of the crack oxidizes, forming a microscopic notch in the metal surface.
- During the next expansion cycle, the oxide will tend to fracture along this notch, causing it to deepen.
- As this cyclic process continues, a wedge-shaped crack propagates through the tube wall, until rupture occurs or the tube wall is penetrated.

The cracks always propagate in a direction perpendicular to the direction of the principal stress. Hence, if the principal cyclic stress is produced by fluctuations in internal pressure, longitudinal cracks are produced. If the principal stress is a bending stress produced by thermal expansion and contraction of the tube, cracks will be transverse. Corrosion-fatigue cracking commonly occurs adjacent to physical restraints. Cracks may originate on the external surface, the internal surface, or both simultaneously. Cracks originating on the internal surfaces are often associated with pits. The pit site serves as a stress-concentrating notch , making it a preferred site for initiation of corrosion-fatigue cracks.

Boiler Cavitation:

Cavitation is favored anywhere low pressure regions form in water. Abrupt temperature changes and turbulent flow promote attack. Damage may occur only where water contacts surfaces. Pump impellors are usually damaged on the suction side, and valves show wastage on discharge sides. Less commonly, condensate lines and turbine components are attacked.

Cavitation is a process whereby small vapor spaces rapidly and collapse in a fluid. Pressure differences in the liquid cause vapor-bubble formation. The liquid actually boils at the reduced pressure. The steam bubbles quickly collapse, producing microjets that impinge on metal surfaces. The damage may affect only the normally protective oxide layer, or in severe cases, may directly attack the underlying metal, physically dislodging less resistant alloy phases.

Energy is required to form a cavitation bubble. Part of that energy is consumed in creating the bubble surface. Since it takes less energy to form the bubble on a pre-existing surface, cavitation bubbles form most rapidly on existing surfaces. Pressure may be lowest and turbulence highest at or near moving surfaces. Damage accumulates during thousands of cycles. Once the surface irregularities are formed, attack will tend to concentrate at damage sites, eventually producing deep, localized attack.

Elimination:

Cavitation damage can be reduced greatly by design, alloying, coating, and/or surface finishing. Design strategies concentrate on reducing turbulence, vibration, and rapid pressure changes. Maintaining sufficient head pressure, preventing packing leaks, and discharge-side throttling all reduce pump damage. Hard resistant alloys including 18-8 stainless steels are often recommended. Plasma coating and surface hardening techniques have had limited success in reducing attack.

UNISERVICE AMERICAS:
Testing – Dosing Chart For Cooling Water Treatments.

Most Engine Manufacturers Recommend:
Sodium Nitrites = 1500 – 2500ppm
pH = 8.50 - 10.50 * See Notes Below
Chlorides < 50ppm (absolute maximum 100ppm) * See notes below

Treatment: N.C.L.T.

Initial Dosage : 6 to 8 liters (1.5 – 2.0 Gallons) per ton water in system.

Sodium Nitrite Test Result:	Dosage Per Ton Water:
0 ppm	6 liters
500ppm	4 liters
1000 ppm	2 liters
1500 – 2500ppm	Maintain

Treatment: Colorcooling:

Initial Dosage: 14 – 16 liters (3.5 – 4 gallons) per ton water in system.

Sodium Nitrite Test Result:	Dosage Per Ton water:
0 ppm	14 liters
500ppm	9 liters
1000ppm	5 liters
1500 – 2500ppm	Maintain

TREATMENT: COLORCOOLING O.S.

Initial Dosage 28 - 32 liters (7-8 Gallons) Per Ton water in System.

Sodium Nitrite Test Result:	Dosage Per Ton water:
0 ppm	28 - 30 liters
500ppm	19 - 20 liters
1000ppm	9 - 10 liters
1500 – 2500ppm	Maintain

- In reference to the two “RED” products “COLORCOOLING” and “COLORCOOLING O.S.”. It is important to remember that the red color is a pH indicator only. The purpose of the red pH indicator is to demonstrate there is a pH of 8.30 or higher. The color will disappear at a pH < 8.30
- It is important to test sodium nitrites at least once weekly to assure that there is sufficient inhibitor in the system for proper protection.
- It is best to maintain chlorides <50ppm.
  If chloride contamination occurs >50ppm. We recommend immediate infusion of fresh feed water to remove excess chlorides. If it is necessary to operate with chlorides between 50 – 100ppm, we recommend maintaining sodium nitrites at the high end of scale “2500ppm” until chlorides may be removed.
  Chlorides should be tested regularly for best maintenance.

BOILER WATER (4 Part) TREATMENT:

Products: Hardness Control (phosphate)
Alkalinity Control (P & T Alkalinity)
Hydrazine – Oxygen Scavenger
Condensate Control (Condensate pH)

PRESSURE RANGE:	0 - 450 psi	450 – 850 psi	800 – 1200 psi
	0 – 32 Kg.	32 - 60 Kg.	60 - 80 Kg.

Dosage Requirements Per Ton water In System:

Test Results:

Phosphate:

0 – 9ppm	30gm. / 1oz	30gm. / 1oz	30gm. / 1oz
10 – 12ppm	15gm / 0.5oz	15 gm / 0.5oz	20gm 0.60oz
13 - 15 ppm	“ “ “ “	“ “ “ ‘	15gm / 0.50oz
15- 18ppm	15gm / 0.5oz	15gm / 0.50oz	10gm / 0.33oz
20 – 40ppm	Satisfactory	Satisfactory	Satisfactory
> 40ppm	Blowdown	Blowdown	Blowdown

P-Alkalinity:

0-20ppm	0.15 liter	0.15 liter	0.13 liter
30 – 50 ppm	0.10 liter	0.10 liter	0.09 liter
60 – 80ppm	0.10 liter	0.10 liter	0.05 liter
90 – 100ppm	0.05 liter	Satisfactory	Satisfactory
100 – 130ppm	Satisfactory	Satisfactory	Satisfactory
130 – 150ppm	Satisfactory	Blowdown	Blowdown
>150ppm	Blowdown	Blowdown	Blowdown

TOTAL ALKALINITY: (Alkalinity Control)

< 2 X P-Alkalinity	Maintain	Maintain	Reference
> 2 X P-Alkalinity	1 liter to boiler.	1 liter to boiler	Reference

HYDRAZINE:	**0 – 450psi**	**450 – 850psi**	**850 – 1200psi**
< 0.03	Increase dosage 25%	Increase 25%	Increase 25%
0.03 – 0.10	Maintain	Maintain	Maintain
>0.10	Blowdown	Blowdown	Blowdown
CONDENSATE pH:			
< 8.30	Increase Dosage 25%	Increase 25%	Increase 25%
8.30 – 8.60	Maintain	Maintain	Maintain
8.70 – 9.00	Maintain	Maintain	Decrease Dosage 20%

BOILER WATER TREATMENT: "One Shot BWT"

Initial Dosage: 5 liters per tons water in the boiler system.
Continuous Dosage: Adjust dosage rate daily in accordance with test results.
For use in low pressure boilers.

TEST RESULTS:

P-Alkalinity:	**Dosage Adjustment**
0 – 50	increase dosage 35%
50 – 80	Increase Dosage 25%
90 – 150	Maintain
>150	Blowdown – Reduce dosage 10%

PHOSPHATE:	
< 10 ppm	Increase dosage 25%
10 – 20ppm	Maintain

Hydrazine:	
< 0.03	Increase dosage 25%
0.03 – 0.10	Maintain

Condensate pH:	
< 8.30	Increase dosage 25%
8.30 – 9.00	Maintain
> 9.00	Reduce dosage 10%

TDS: ONE SHOT BWT is designed to be continuously dosed. It is designed for use within a system using distillate as feed water. TDS should be maintained < 700ppm.

In circumstances where it is impossible to maintain proper levels of **HYDRAZINE** due to excess oxygen in a system; it may be advisable to supplement the **"ONE SHOT"** product with additional **HYDRAZINE.** Likewise in situations where TDS is running higher than normal, (use of shore water as feed for example); it would be of benefit to supplement The **"ONE SHOT"** product with additional phosphate **"HARDNESS CONTROL".**

BOILER WATER TREATMENT: OBWT-3 / OBWT-4

Initial Dosages: OBWT-3 Initial dose 0.40 liter per ton water in the boiler
OBWT-4 Initial dose 0.20 liter per ton water in the boiler.

OBWT-3 should be dosed on a daily basis to maintain proper levels of both Alkalinity and Phosphate. Dosage should be determined by daily;
P- Alkalinity, Total Alkalinity, and Phosphate Tests.
OBWT-4 should be dosed on a continuous basis via a tank and flow meter or metering pump system. This will maintain proper level of oxygen scavenger within the system and will also maintain proper pH in the condenser.
Daily dosing of OBWT-4 is determined by daily testing of condensate pH.
These products are designed to be used within a system that is using distillate as feed. It may be necessary to dose additional phosphate to a system if unusual circumstances occur; such as the use of shore water as boiler feed.

This product is designed for use on low pressure boilers:

TEST RESULT:	**DOSAGE OBWT-3**
P-Alkalinity:	
< 50ppm	Increase 30%
50-90ppm	Increase 20%
100- 150ppm	Maintain
>150ppm	Blowdown Reduce dosage 10%.
TOTAL ALKALINITY:	
< 2 X P-Alkaliinity	No Action
> 2 X P-Alkalinity	Dose 2 liters OBWT-3 directly to the boiler. Test boiler water again after reasonable circulation time to determine if additional dosing or blowdown is needed.

PHOSPHATE:

<10 ppm	Increase 25%
<20ppm	Increase 10%
20 – 40ppm	MAINTAIN
>40PPM	Blowdown – Reduce dosage 10%

TEST RESULT:	**DOSAGE OBWT-4**

CONDENSATE pH

< 8.30	Increase dosage 25%
8.30 – 9.00	Maintain
>9.00	Decrease dosage 10%

In an open system we find it is best to dose sufficient product to maintain CONDENSATE pH between 8.70 and 9.00. That should provide sufficient Oxygen scavenger to the system for good protection.

Evaporator Treatment Dosing Chart

LIQUIVAP:

Liquivap is designed to be diluted with fresh water and dosed continuously via a tank and metering system into the evaporator feedwater line. It is best to dose downstream from the evaporator in order to allow mixing of the product with brine prior to entering the evaporator.
Liquivap is designed to be used in both "Low" and "High" pressure evaporators.

DOSAGE: Continuous at 25ml (1/2 oz.) per ton distillate production.

In a typical, 30 ton production per day, evaporator. We would recommend mixture of .750 liter LIQUIVAP into a 30 gallon mixing tank with fresh water to be set on a timed production cycle with the evaporator.
If brine density exceeds 1.5/32 (SPG 1.038) you will need to adjust the dosage accordingly.

LIQUIVAP C.F.

Liquivap C.F. is designed for systems where large quantities of distillate are produced on a daily basis.
Liquivap C.F. is designed to be dosed on a continuous basis (after dilution with fresh water) via a tank and metering device directly into the saltwater line leading to the evaporator.

DOSAGE: Continuous at 15ml (1/3oz) per ton distillate production.

The above dosing ratio is for brine density approximately 1.5/32 (SPG1.038)
In higher brine areas you will need to adjust the dosage accordingly.

CONCLUSION

We hope that this manual is informative and simplifies the application and understanding of the three most critical water systems on a vessel. The efficiency of each system obviously is quite critical as they affect that of each other.

It is our goal that this manual gives marine engineers a practical guide not only on the water treatment, but also in the operation of the subject systems to decrease maintenance, repair and time spent on treatment. Properly applied programs will give greatly increased service of these systems and cost reductions in the operation of the motor vessels.

The reality is there is no perfect scenario, but our efforts are to provide the vessel with a clearer understanding of some of the situational problems and chemistry issues within their critical water systems. We hope that this manual will help serve the c/engineer and his staff to maintain optimum operational efficiency.