DREW MARINE

High-Pressure Steam Cycle and Boiler Water Treatment

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High Pressure Boilers

- **Pressure range**
  - **60-84 bar**
- **Critical needs**
  - **High quality makeup water**
    - External pre-treatment through distillation and mechanical deaeration
  - **High purity steam to the turbine**
  - **No excess hydrate alkalinity**
  - **Precise control of <u>total</u> system water treatment**

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Steam Cycle

- Steam cycle
  - Begins at the boiler where thermal energy in superheated steam is converted to mechanical energy in the propulsion turbine
  - Steam is then converted into condensate in the main condenser
  - Condensate is combined with distilled makeup water and is pumped as feedwater through heaters to a thermal deaerator and then returning to the boiler
- Cycle chemistry
  - Treatment control throughout the steam cycle

HP and LP Similarities

- **Both need pretreatment providing good quality makeup water and oxygen removal**
  - **Critical to high pressure**
- **Both use an internal treatment**
- **Both use an oxygen scavenger/reducing agent**
- **Both use an after-boiler steam treatment program**

HP and LP Differences

- **High pressure**
  - **Makeup water is very pure and corrosive**
    - Low level of dissolved solids
  - **Based on coordination of phosphate and pH so that no free caustic exists**
  - **Lower chemical treatment levels**
  - **Lower tolerances for variations in chemical levels and TDS**
  - **Production of high purity steam**
- **Low pressure**
  - **Based on phosphate precipitation**
  - **Lower heat transfer rates and boiler water conditions are such that adequate rinsing of internal tube surfaces prevents high localized caustic concentrations and gouging**

History of Coordinated Phosphate pH Control

- **Shoreside high pressure systems experienced failures from localized caustic concentrations in 1930's and 1940's**
  - **Excess hydrate alkalinity led to metal damage in the form of caustic embrittlement (cracking) or gouging**
- **New boiler water treatment was developed using the alkalinity derived from phosphate alone, eliminating sodium hydroxide**
  - **The sodium to phosphate ratio determines the pH of the water (3:1)**
  - **Ratio of trisodium to monosodium or disodium phosphate is adjusted to desired pH and phosphate levels can be attained without creating free caustic (3:1)**
  - **As trisodium phosphate hydrolyzes in the water it produces a hydroxyl ion (OH) which controls the pH level**
  - **Monosodium or disodium phosphate do not produce OH**
  - **Use of two different phosphates prevented complete program control at times**

ULTRAMARINE[SM] HP BWT Program

ULTRAMARINE Coordinated Phosphate Treatment

- **Drew Marine pioneered the "modified phosphate-pH treatment"**
  - **Utilizes disodium orthophosphate and caustic so that no "free caustic" is generated in the boiler water**
  - **Sodium to phosphate ratio is approximately 2.75:1 and provides margin of safety for good control of the program**
  - **Went into effect in the marine industry in the 1960's and has been highly successful**

$$Na_2HPO_4 + NaOH \rightarrow Na_3PO_4 + H_2O$$

Na_2HPO_4	+	$NaOH$	→	Na_3PO_4	+	H_2O
disodium ortho phosphate		sodium hydroxide		trisodium ortho phosphate		water

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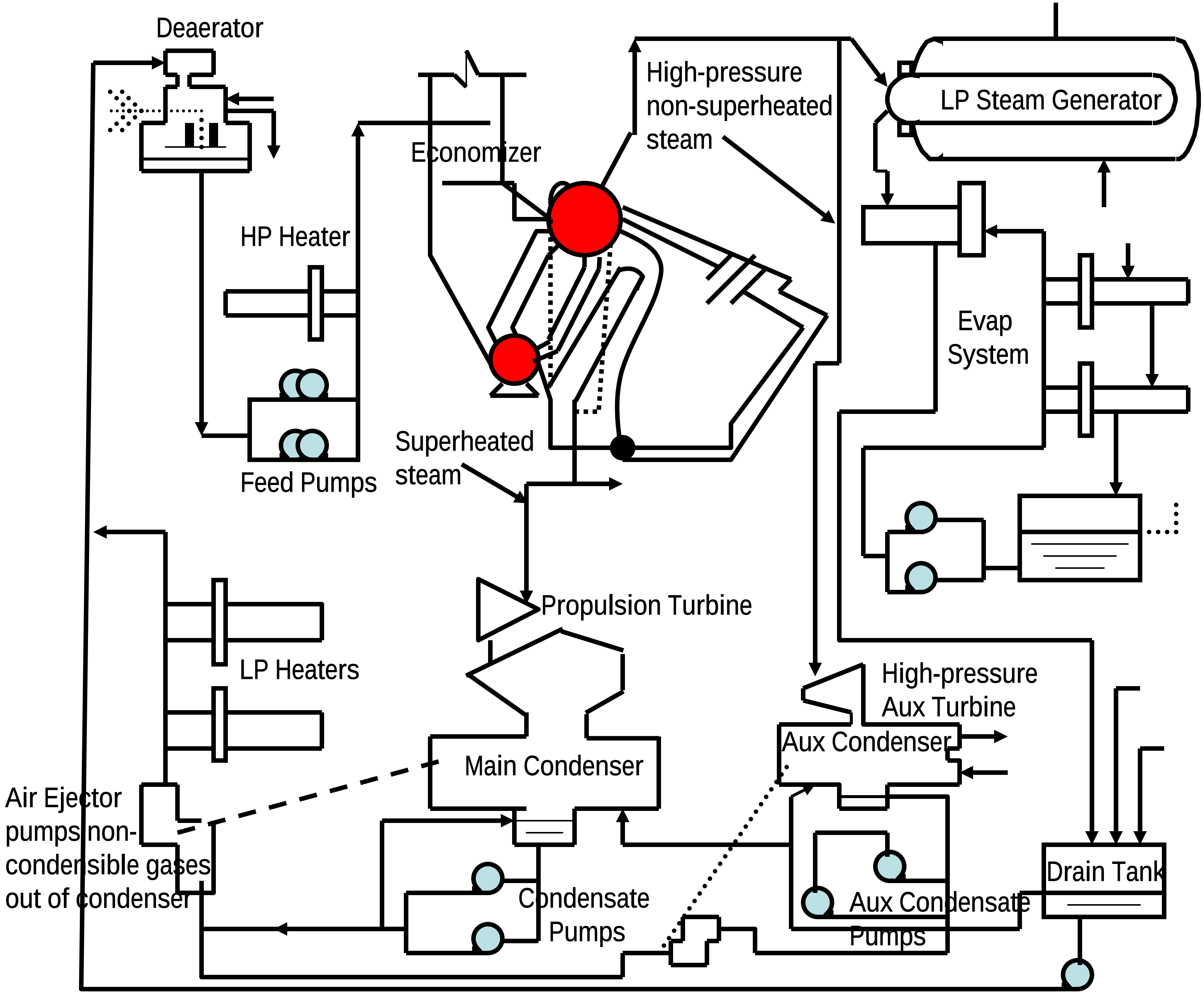
Deaerator
Economizer
High-pressure
non-superheated
steam
LP Steam Generator
HP Heater
Evap
System
Feed Pumps
Superheated
steam
Propulsion Turbine
LP Heaters
High-pressure
Aux Turbine
Aux Condenser
Main Condenser
Air Ejector
pumps non-
condensible gases
out of condenser
Condensate
Pumps
Drain Tank
Aux Condensate
Pumps

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Propulsion Steamship System Components

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System Components

- **Pre-boiler**
  - First stage heater
  - Deaerator
  - Feed pump
  - Feedwater heaters
  - Economizer

- **Boiler**
  - Propulsion boiler with superheaters and desuperheaters
  - Steam drum purification

- **After-Boiler**
  - Turbines
  - Main condenser
  - Condensate pump
  - Air ejector condenser
  - Steam lines
  - Pressure reducing stations
  - Heat exchangers
  - Condensate return lines

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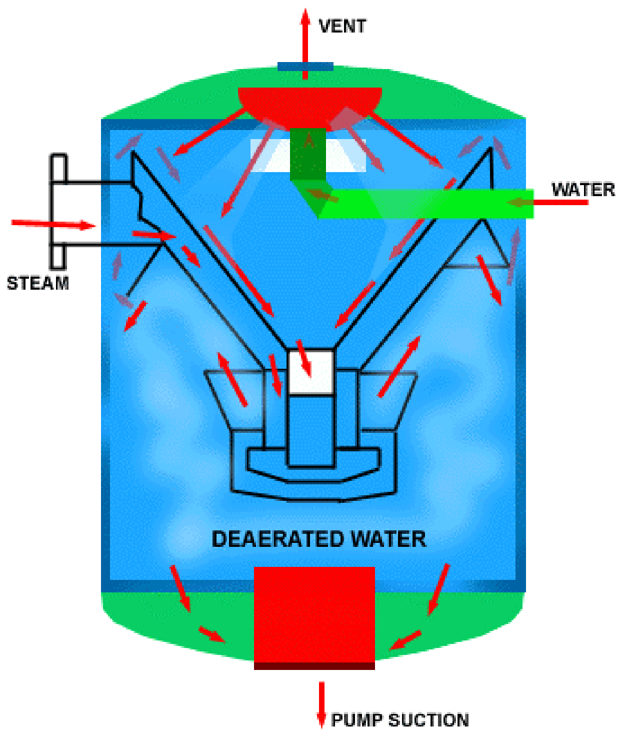
Deaerator

- **Function**
  - **Thermally removes dissolved gases in feedwater**
    - Dissolved gases are extracted by steam heating and raising the temperature to a level where they come out of solution
    - Spray nozzles atomize distillate and condensate into a steam space raising its temperature which liberates dissolved gases
- **Problems**
  - **Spray nozzle malfunction and dissolved gases will not be effectively removed**
    - Detect by steam space/water space - pressure/temperature conditions
  - **Vent malfunction - valve in vent line should be open far enough to allow full removal of gases without permitting excessive quantities of steam or slugs of water to escape**
    - Gases must be vented to the atmosphere

Deaerator Removes Dissolved Oxygen



- **Spray type deaerator is a component of the pre-boiler system**
- **Steam heats and removes oxygen from droplets that are in a spray pattern**
- **Dissolved oxygen is removed to less than 0.007 ppm or 7 ppb**
- **Steam space temperature and water space temperature difference should not be more than 1°C or 2°F**

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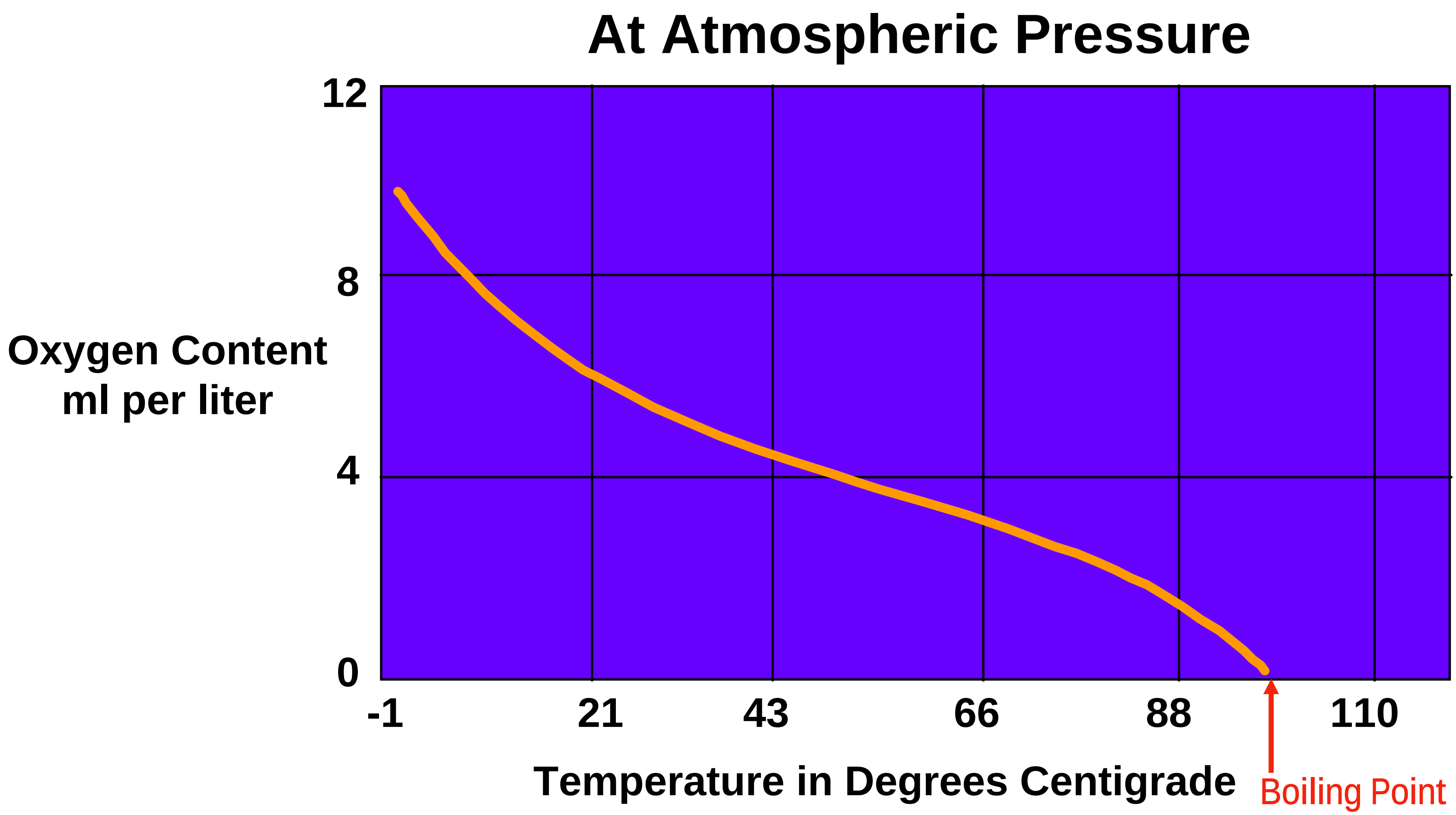
Dissolved Gases

- Oxygen and carbon dioxide are the two most aggressive gases in distilled seawater
  - Combination of both is more damaging than the two gases acting independently
  - Enters the boiler through the makeup feed system
- Water at 10°C or 50°F at atmospheric pressure usually contains between 8-10 ppm of dissolved oxygen
- As water is heated its ability to hold dissolved gases in solution decreases
- Oxygen is re-absorbed after cooling and standing in an open storage tank
- Dissolved oxygen is very harmful

Solubility of Oxygen in Water



Deaerator Removes Dissolved Oxygen

- **Non-condensable gases are removed through a vent line which is a vital part of the deaerator**
  - **Failure or closing of the vent prevents proper elimination of non-condensable gases**
    - Deaerator outlet will have above normal gas concentrations
    - Feedwater pH will be difficult to maintain due to re-absorption of carbon dioxide in the feedwater
- **Valve on vent lines should be open far enough to allow full removal of entrained gases**

Deaerator Removes Dissolved Oxygen

- **In some cases the vent valve has an orifice drilled in the gate**
  - **Assures some venting even when gate valve is closed**
  - **Prevents a vacuum from collapsing the deaerator tank if the level control valve fails**
  - **A large quantity of cold condensate entering the deaerator could create a vacuum by condensing the steam**
  - **Provides supplementary safety device if the vacuum breaker is inoperable**
- **Gases released by the deaeration process must be vented to the atmosphere and never brought back into the system**
- **Temperature/pressure relationship to steam/water spaces must correspond to boiling conditions**

Steam Saturation Temperatures

Shell Press BAR	Saturation Temperature ºC	Shell Press PSI	Saturation Temperature ºF
1.0	121	15	250
1.5	127	22	262
2.0	133	30	274
2.5	139	37	283

- **Steam space temperature of the deaerator should be the saturation temperature of steam at the shell pressure**

- **Properly operating deaerator will maintain the water space temperature within 1°C of the steam space temperature**
  - **Water space temperature should not be more than 1°C lower than the steam space temperature**
  - **If water space is more than 1°C lower, it indicates a venting construction or a nozzle atomization problem**
    - Check accuracy of thermometers before making any changes
- **Deaerator thermometers lose calibration over time and may need to be calibrated**

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Deaerator Storage Section

- **A good place to continuously inject oxygen scavenger and neutralizing amine**
  - **Chemicals can also be injected to feed pump suction**
- **Increasing chemical feed to offset deaerator mechanical or operational problems is not a good idea**
  - **Copper alloy parts of the low pressure end of the cycle may be damaged by oxygen since the overfeed can result in increased decomposition to ammonia**

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Feedwater Heaters

- Steel cylinders with copper alloy tubes
- Steam from the turbine heats the feedwater that flows through copper alloy tubes
- Steam condenses on the outside of the tubes and condensate is generally drained into the condenser hotwell
- Excessive ammonia and oxygen in the steam can cause corrosion on the outside surfaces of the copper tubing
- Carbon dioxide can cause corrosion of the carbon steel heater shells as well as condensate and feedwater piping

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Economizer

- **Function**
  - **Decreases stack temperature and increases system efficiency by absorbing heat from the stack gases and adds this heat as sensible heat to the feedwater**
- **Problems**
  - **Vunerable to dissolved oxygen attack from the water side if improper lay-up**
    - Source of iron transport to the boiler
  - **Prone to acid attack (combustion end products) from the fire side**

Boiler Water-Side Internals

- **Deposit accumulations**
  - **Caustic cracking or caustic corrosion**
    - Excess hydroxide alkalinity
  - **Metal oxides such as iron and copper**
    - Copper from heat exchangers transported to the boiler due to low pH and/or ammonia
    - Copper on boiler tubes cause overheating and galvanic corrosion
  - **Overheating due to barrier of normal heat transfer**
- **Oxygen pitting**
  - **Occurs primarily during boiler lay-up or incidental or temporary shutdown due to the ingress of oxygen.**
  - **Pay close attention to proper lay-up procedures during these times**

Boiler Water-Side Internals

- Prime places for iron and copper deposit accumulations
  - Horizontal or gently sloping boiler tubes
  - Boiler tubes of high heat flux
- Metal oxide deposits provide an ideal place to concentrate dissolved solids
- “Free” caustic alkalinity in the bulk boiler water will concentrate in the deposits and cause caustic gouging on the metal surface under the deposit

Boiler Water-Side Internals

- **Feedwater is continuously mixed with treated boiler water in the steam drum and descends through downcomer tubes into the lower sections of the boiler and into the mud drum**
- **Non-volatile components of the treatment are consumed by contaminants in the feedwater**
- **Volatile components of the treatment evolve from the boiler into the steam which proceeds through the internal steam drum purification equipment and into the superheaters and other parts of the steam/condensate system**

Boiler Water-Side Internals

- **Internal steam drum purification equipment**
  - Cyclone separators
  - Baffling
  - Mechanically removes entrained water droplets from the exiting steam

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Superheater

- Vertical design
  - Inlet and outlet headers at the bottom
- Horizontal design
  - Headers at the sides of the boiler
- Either configuration insures good drainage
  - Lowers the amount of deposit accumulation on the steam side

Superheater

- **Function**
  - **Converts saturated steam to superheated steam thereby increasing the total amount of work available in the steam**
    - Steam from the steam drum is routed back into the boiler where the combustion process adds the heat required to superheat the steam to the desired system temperature level
    - Design temperature superheated steam is required to extract maximum efficiency from system turbines

Superheater

- **Problems on the steam side**
  - Deposits insulate the metal from cooling effects of the incoming saturated steam and lead to overheating of the metal on the fireside causing failure of superheater tubes
  - Silica from shore water makeup vaporizes with steam and deposits on tubes
  - Boiler water carryover with saturated steam causes internal sodium solids deposits
  - Iron oxide buildup indicates an iron-steam reaction
  - Oxygen corrosion during poor layup practice
  - Fatigue due to vibration and mechanical conditions – not chemical

Superheater

- **Problems on the fire side**
  - **Tube temperatures are very high and are prone to slag type deposits**
  - **Slag deposits will alter the gas paths and may lead to exceptionally high localized temperatures in the superheater**

Desuperheater

- Direct contact spray
  - Uses feedwater from boiler feed pump as coolant
- Surface type
  - Found on most ships
  - Control desuperheater in one drum and main unit in the other
- Can be internal or external to the boiler

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Desuperheater

- **Function**
  - **Removes excess heat so it can be used in low pressure operations**
  - **Located at any convenient point after the superheater**
- **Problems**
  - **Dissolved solids can cause deposits**
  - **Underdeposit corrosion on tubes is the most common failure**
    - Occurs mainly where the tubes pass through the tube support plate

Desuperheater

- **Problems**
  - **Internal desuperheater**
    - Possible in-leakage at flange joints
    - Pressure inside the desuperheater is lower than the boiler drum pressure so boiler water in-leakage carrying dissolved solids and chemical compounds such as caustic and phosphate can occur into the desuperheated steam-condensate and precipitates can deposit in the turbine
    - Supports are bars or tubes with little or no resistance to vibrational or lateral movement may be one of the primary reasons for flange gasket failures
  - **External desuperheater**
    - In-leakage into the desuperheater would be whatever water is used to desuperheat

Steam Turbine

- **Function**
  - **Rotating machinery that efficiently converts heat energy to mechanical energy to turn a generator that makes electrical energy**
  - **Pressure and temperature are reduced in the process, hence high pressure and low pressure sections**
  - **Steam purity and proper boiler water chemical and mechanical control are important**
    - Monitor by conductivity

Steam Turbine

- **Problems**
  - **Silica from shore water makeup vaporizes with the steam and deposits on turbine blades**
  - **As boiler pressures and temperatures increase, turbine materials designed to handle these thermal conditions are more susceptible to attack**
    - Caustic and chloride

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Steam Condensers

- **Function**
  - **Changes steam into a hot water as condensate by transferring steam's thermal energy to the process fluid while the steam converts to condensate**
- **Problems**
  - **Seawater in-leakage**
    - Detected by condensate line salinity alarm
    - Loss of boiler water alkalinity relates to condenser seawater in-leakage and boiler water becomes increasingly contaminated
  - **Ammonia concentration in air removal sections**
    - Steam jet condenser drains should be discharged overboard
  - **Damage is more critical than in low pressure**

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Steam Condenser In-leakage

- **Main and auxiliary condensers**
  - Leaks can cause scale and alkalinity reduction in the boiler water from hydrolysis of magnesium chloride and other seawater contaminants
- **Leaks start slowly**
  - As contamination increases it is essential to locate and repair the leak

Steam Condenser In-leakage

- **Detection by salinity meter**
  - **Set to alarm at a predetermined conductivity level**
    - Visual and audible alarm
  - **First indication of leakage**
- **Salinity meters installed at or near potential problem areas**
  - **Main condenser**
  - **Auxiliary condenser**
  - **Evaporator**
  - **Evaporator condenser**
  - **Distilled water tank**
  - **First stage heater**
  - **Drain cooler**

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Ammonia in the Steam Condenser

- **Hydrazine is used as an oxygen scavenger in the pre-boiler system**
- **Hydrazine volatilizes out of the boiler with the steam and breaks down in passing through the superheater**
  - **Above 204°C (400°F) decomposes forming nitrogen and ammonia**
  - $3N_2H_4 \rightarrow 4NH_3 + N_2$
- **When steam condenses in the condenser, gaseous ammonia dissolves in the condensate**
- **Ammonia when combined with oxygen and carbon dioxide becomes aggressive to copper alloy materials**
  - **Ammonia by itself is not harmful**

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Ammonia in the Steam Condenser

- **Ammonia can concentrate**
  - In the air removal sections of the condenser
  - In the condenser drains of the steam jet air ejector system where copper tube materials are dissolved
- **Air ejector drains should be discharged overboard rather than being reused**
  - Eliminates the chance of transporting copper or copper oxides to the boiler where they can precipitate and cause severe localized corrosion

Controlling Ammonia

- Do not reuse air ejector drains
  - Drains should be discharged overboard rather than being reused
  - Eliminates the chance of transporting copper or copper oxides to the boiler where they can precipitate and cause severe localized corrosion
- Vent deaerator to atmosphere
  - Do not vent to first stage heater or another part of the condensate system
- Detected by simple field test
  - Maximum concentration 0.5 ppm in condensate
  - In the presence of oxygen the ammonia level must be kept at a minimum

Minimizing Copper

- Minimize copper pickup from condensate system by maintaining low levels of oxygen and ammonia
- Maximum level of ammonia in condensate is 0.5 ppm

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High-Pressure Steam System Scale and Deposits

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Feedwater Quality

- **Use good quality distilled makeup water**
  - **Conductivity <10 μS/cm**
- **Reserve feedwater <15 μS/cm conductivity**
- **Condensate and drain returns <3 μS/cm conductivity**
- **Total iron <0.010 ppm or <10 ppb***
- **Total copper <0.005 ppm or <5 ppb***
- **Total hardness <0.05 ppm***
- **Dissolved oxygen from deaerator <0.007ppm or 7 ppb***
- **pH 8.3-9.0 @ 25ºC***

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*Suggested by The American Society of Mechanical Engineers (ASME)
• Note: Iron and copper in the feedwater are the products of corrosion in the preboiler system

Calcium and Magnesium Formed Scale

- **Introduced into the boiler from seawater in-leakage or shore water makeup**
- **Like those found in low pressure systems**

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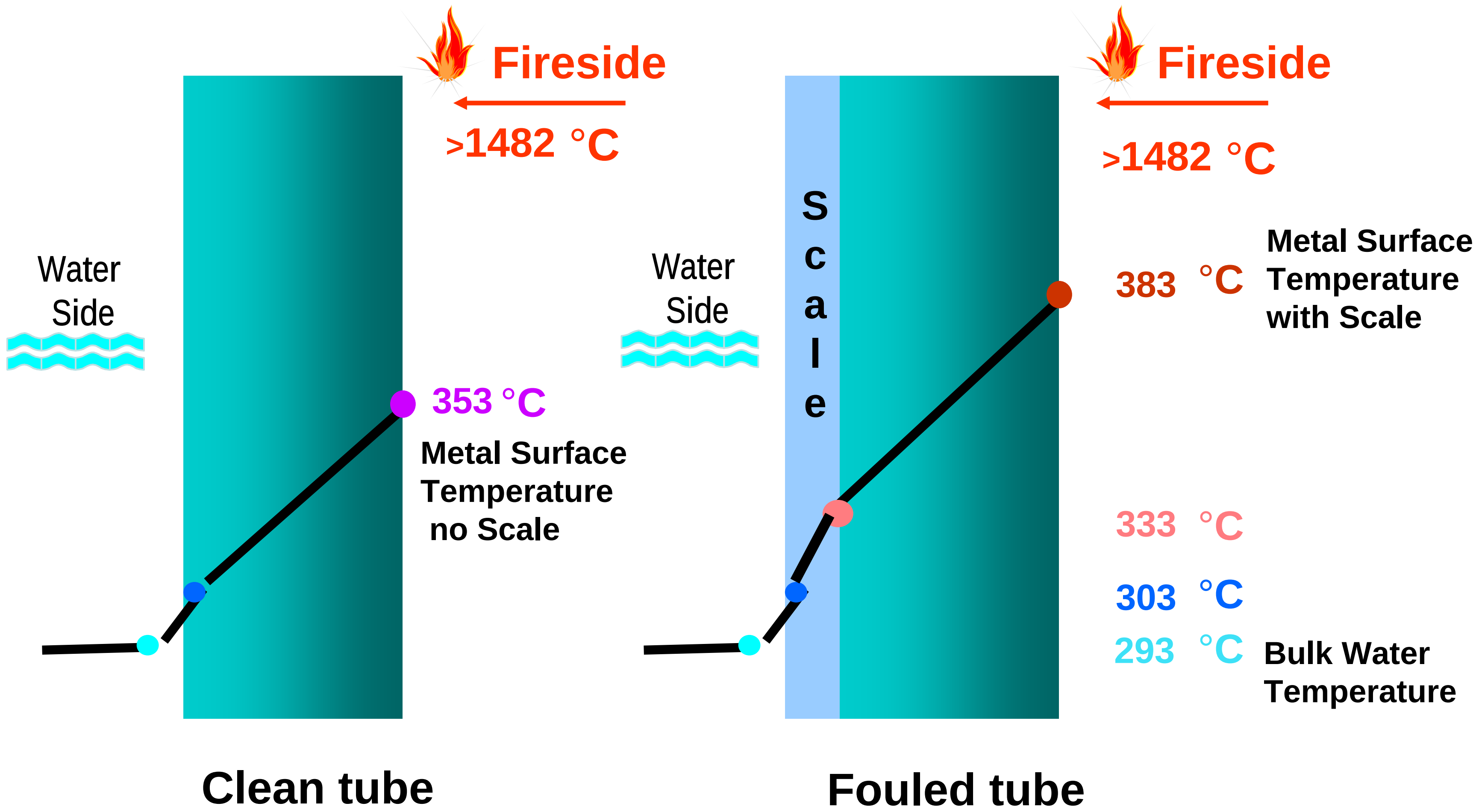
Silica Formed Scale

- **Silica from shore water makeup vaporizes with the steam and forms tenacious scale on superheater tubes and turbine blades**
- **Causes corrosion, overheating and rotor imbalances**
- **Detected by simple, ampoule field test**
  - **Maximum concentration is 6 ppm in the boiler water**

Temperature Profile Across HP Boiler Tube



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Deposits

- Deposits are an accumulation of suspended solids that can come from many different sources
- Scale from calcium and magnesium
- Oxides generated within the boiler
  - Iron and copper corrosion products
- Scale and oxides originating outside the boiler but transported into the boiler from the feedwater

Copper in Boiler Systems

- Copper is a major component of condensate system heat exchangers
- Metal
  - Improper acid cleaning
  - Overfeed of strong reducing agent
  - Erosion in condensate or pre-boiler
- Oxide
  - Corrosion product from alloys in the system
- Low pH and/or ammonia leaches copper out of heat exchangers and it is transported to the boiler
  - Copper deposits coat the boiler tubes causing overheating and galvanic corrosion

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High-Pressure Steam System Corrosion

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Corrosion in HP Systems

- **Oxygen corrosion**
  - Dissolved oxygen in condensate and feedwater
- **Copper corrosion from ammonia**
  - Copper plating of boiler tubes leads to premature boiler tube failure
- **Gouging corrosion**
  - From excessive free caustic
- **General low pH corrosion**
  - Not common in high-pressure
- **Improper lay-up**

“Gouging” Corrosion

- **Excessive concentrations of free caustic or hydroxide alkalinity can lead to metal loss or “gouging” corrosion**
  - **Water film at the hot tube surface especially beneath deposits contains highly concentrated sodium hydroxide**
  - **Destroys protective magnetite film**
  - **Wasting away of metals from alkali attack**
  - **Slow tube failure**
- **Can lead to caustic cracking or caustic embrittlement**
  - **Found at grain boundaries**
- **ULTRAMARINE^{SM} high pressure boiler water treatment program balances boiler water pH and phosphate so that no “free” caustic is generated**

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Caustic Corrosion Reactions

Fe_3O_4 + 4 NaOH → + 2 $NaFeO_2$ + Na_2FeO_2 2 H_2O

magnetite + caustic → soluble iron salts

removes protective oxide

Fe^o + 2 NaOH →Na_2FeO_2 + $2H^+$

iron metal + caustic → gouge + soluble iron salt + hydrogen

" caustic gouging" of base metal

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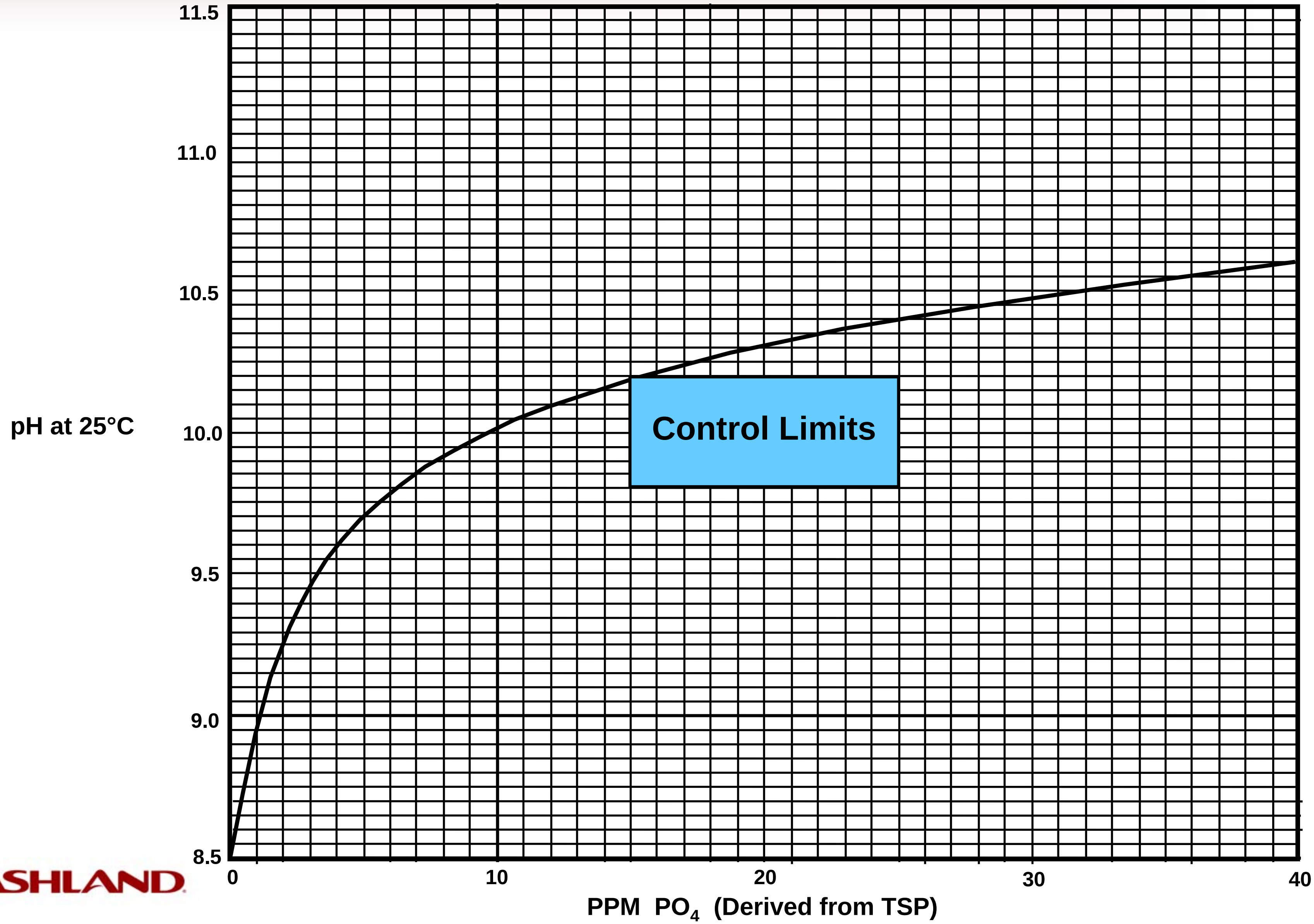
ULTRAMARINE℠ Coordinated Phosphate-pH Program



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Hydrogen Damage Corrosion

- Not usually found in marine high pressure boilers
  - More commonly found in ultra-high pressure boilers
- Most commonly associated with excessive deposition on tube surfaces coupled with a low pH boiler water excursion where the water chemistry is upset
  - Low pH contaminants can concentrate in the deposit
  - Under-deposit corrosion releases atomic hydrogen which migrates into the tube wall metal
- Seen by intergranular micro-cracking

Corrosion From Improper Lay-up

- **Mostly due to oxygen**
  - **Insufficient oxygen scavenger reserve**
  - **Improper water levels**
    - No header tank
  - **Not using deoxygenated feedwater**
  - **Inability to fill boiler completely**
- **General corrosion**
  - **Low boiler water pH**
  - **Adjust with SLCC-A™ corrosion inhibitor**

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Other Problems In High-Pressure Boiler Systems

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Phosphate Hideout

- Sodium phosphate can precipitate under certain boiler water conditions
- Fast loss of soluble phosphate residual during normal steaming
  - Dissolved phosphate precipitates on high heat transfer surfaces such as water wall and main generating tubes
- High phosphate residual reappears when boiler is shut down or operated at low steaming
  - Precipitated phosphate re-dissolves
- Delicate balance between phosphate and pH is upset creating deposits causing localized overheating and tube failure
- Frequently an indication that the boiler is dirty and should be cleaned

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Carryover

- **Steam contamination from excessive solids in the boiler**
- **Mechanical carryover**
  - **Droplets in steam leaving the boiler**
  - **Affected principally by the design of the baffles and drum internals in the steam drum which are able to remove about 99.9% of the boiler water from the steam**
  - **The remaining 0.1% boiler water in the steam is not sufficient to lead to problems**
  - **Affected by any contaminant in the boiler water that can cause foaming**
    - Excessively high dissolves or suspended solids
    - Excessively high alkalinity
    - Oil
  - **Inability of water level control system during rough seas**
- **Vaporized carryover**
  - **Vaporized silica carried over with the steam from a boiler drum**

Causes of Carryover

- High total dissolved solids or suspended solids
- Design of baffles and drum internals that separate droplets of water from steam
- Boiler liquid levels too high
- Sudden changes in boiler load
- Operational problems

Carryover

- Massive carryover is relatively rare in high pressure boilers
- Leads to deposits on the steam side of the superheater and insulates the metal from being properly cooled
  - Overheating failures
- Leads to deposits on turbines

Detecting and Combating Carryover

- **Drop in superheat temperature is a direct indication of carryover**
- **Inspection tank will have visual oil floating on top of the water**
- **Stop the source of contamination**
- **Minimize the firing rate of the boiler**
- **Blowdown surface and bottom**

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Blowdown

- Excessive solids concentrations in the boiler can cause carryover, foaming and priming
- Limiting dissolved solids in the boiler water is set mainly for minimizing carryover
- Controlled by periodic checks of total dissolved solids by conductivity
- Conductivity is the best indication of the concentrations of all ionized dissolved materials

Pre-Commission Cleaning

- **Prior to initial light-off clean all wetted surfaces of the boiler, economizer feedwater piping, and superheater to bare metal**
  - **Superheater is usually plugged and cleaned by flushing out with water**
  - **Remove oils and mill scale with 5% LAC at 60-70°C for 4-6 hours**
  - **Remove mineral scale with 10% SAF-ACID at 60-70°C for 4-6 hours, flush, neutralize with 1% GC**
  - **Remove oxides same as mineral scale but add 5% NaCl**
- **Passivate all metal surfaces**
  - **Use 1.3 liters AMERZINE per ton of boiler water**
- **Use only warm deaerated feedwater for light-off**

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ULTRAMARINE[SM] Coordinated Phosphate-pH Boiler Water Treatment Program

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Boiler Pressures 60-84 Bar

- **ULTRAMARINE[SM] coordinated phosphate-pH with AMERZINE® corrosion inhibitor or DREWPLEX® OX corrosion inhibitor**

Control Parameter	Control Limit	Test Kit PCN
Boiler water pH	9.8-10.2	0246-01-8, 0246-02-6
Boiler water phosphate	15-25 ppm	0390-01-3
Boiler water chloride	Max 16 ppm	0372-01-1
Boiler water neutralized conductivity	Max 120 μS/cm	0173-05-4
Boiler water hydrazine	0.03-0.1 ppm	0369-01-8 or
Feedwater DEHA	0.2-0.5 ppm	0387-01-0
Boiler water silica	Max 6 ppm	0376-01-3
Condensate pH	8.6-9.0	Phenolphthalein/acid
Condensate ammonia	0.5 ppm	0384-01-6
Feedwater iron	0.01 ppm max	laboratory test
Feedwater copper	0.005 ppm max	laboratory test
Feedwater oxygen*	<0.007 ppm	-

*Not more than deaerator performance warranty

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Product Dosing

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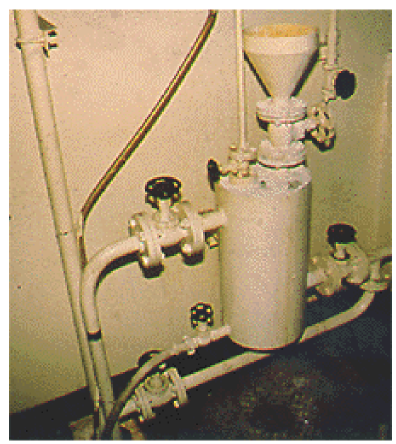
Product Dosing

- Pump and tank set designed to continuously dose oxygen scavenger and neutralizing amine.
- PCN 0124-65-1
- 16 bar maximum discharge pressure with polypropylene dosing head.
- NOTE: High-Pressure Chemical Feed System, PCN 1AA3352 is required for >16 bar.



- Bypass pot feeder to dose phosphate and alkalinity.

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Program Monitoring and Control

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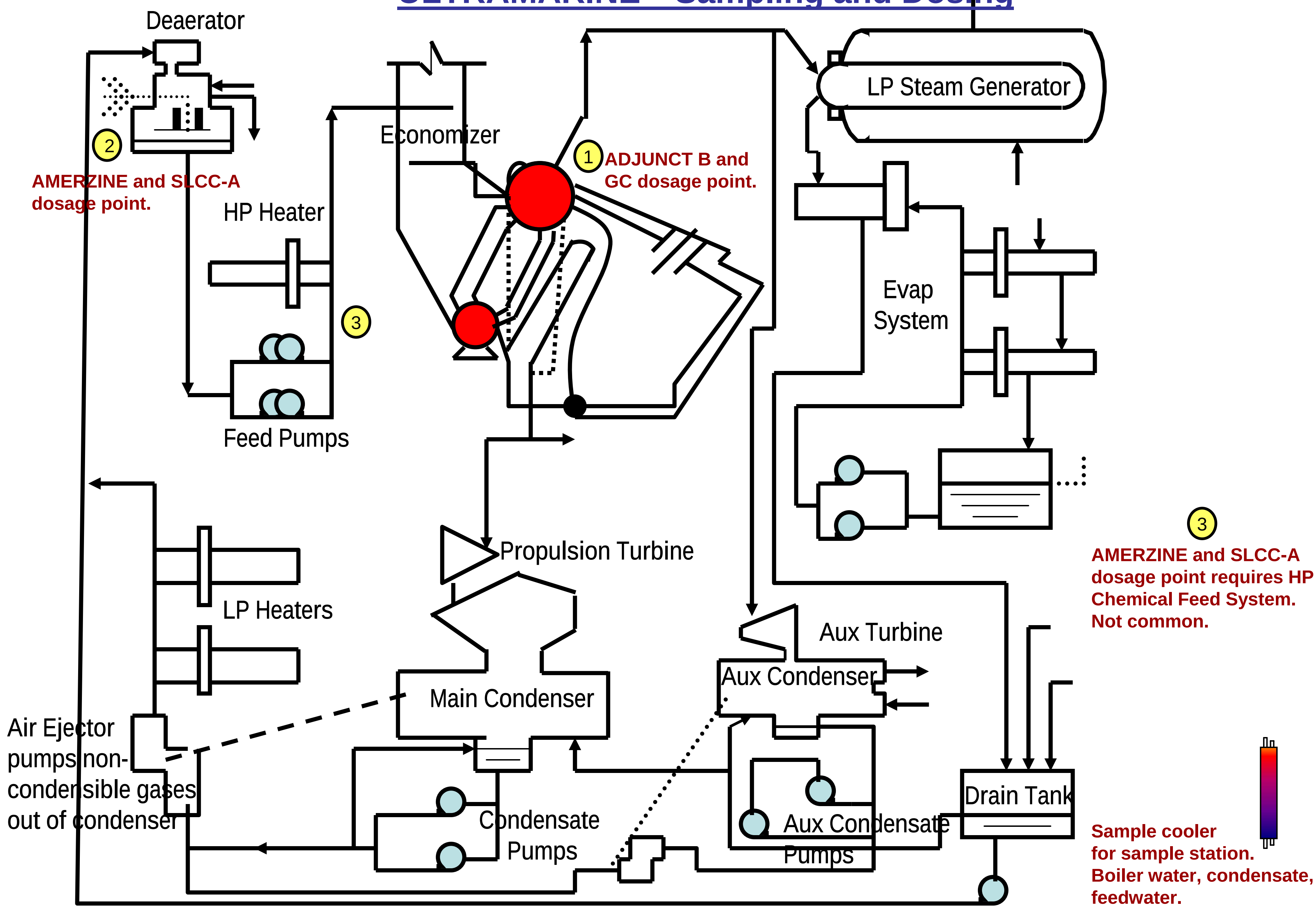
ULTRAMARINE[SM] Sampling and Dosing



Proper Sampling

- Cool to 25ºC
- Allow stream to run 5-10 minutes to flush out line
- Collect samples for oxygen scavenger testing with minimum contact with air and test promptly
- PCN 1AA3399
  - Stainless steel tube and shell

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Boiler Water pH Control

Water analyzer base method uses liquid pH indicators

or

Portable pH Meter, PCN 0390-01-3
Triode pH Electrode, PCN 0246-02-6

Requires calibration with two pH buffers

- Test daily per boiler
- Control limit is 9.8-10.2
- Adjust with GC™ concentrated alkaline liquid as necessary
- Increase surface blowdown if higher than control limit

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Measuring pH With A Meter

- **In buffered waters such as boiler water, pH measurement is straight forward**
  - **High conductivity samples are less likely to suffer from changes during sampling**

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Measuring pH With A Meter

- **In unbuffered waters such as high-purity waters/condensate, measurement results in wide fluctuations**
  - **The lower the conductivity of the sample the more pronounced the effect of atmospheric contamination resulting in unsteady readings**
  - **During sampling, water is exposed to the air that permits carbon dioxide to be either absorbed or released, resulting in a change in pH**
  - **Samples should not be allowed to free fall into the container**
    - Connect a piece of clean flexible tubing to the end of the sample line so that it reaches the bottom of the sample container.
    - Sample should fill the container and be permitted to overflow until 3-4 sample volumes have been displaced.
    - Analyze promptly at the point of sample collection.

Boiler Water Phosphate Control

Phosphate Vacu-vials* Test Kit
PCN 0390-01-3

- Test daily per boiler
- Control limit is 15-25 ppm
- Adjust with ADJUNCT® B boiler water treatment dosage as necessary
- Increase surface blowdown if higher than control limit

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*Registered trademark of CHEMetrics, Inc.

Boiler Water Chloride Control

Chloride HP Test Kit
PCN 0372-01-1

- Test daily per boiler
- Control limit is 16 ppm max so boiler water carryover does not occur
- Enters the boiler as a contaminant
- Alerts if there is seawater in-leakage
- Locate in-leakage source and correct
- Can create hydrochloric acid corrosion
- If higher than control limit, increase continuous surface blowdown and flash blow when boiler loads can be reduced

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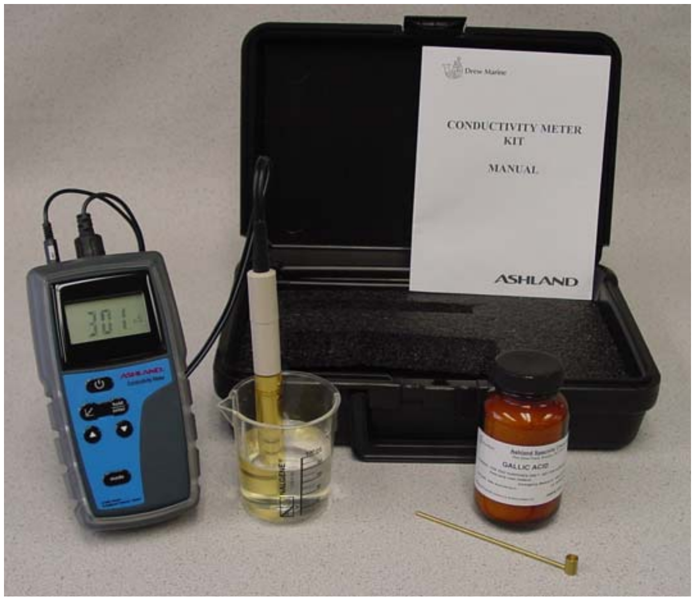
Boiler Water Neutralized Conductivity Control



Conductivity Meter Kit Complete
PCN 0173-06-2

- Test daily per boiler
- Control limit is 120 µS/cm
- Sample neutralization with gallic acid provides estimation of dissolved solids that include contaminants, treatment chemicals, and naturally occurring chemical constituents
- Controls the frequency of blowdown

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Boiler Water Hydrazine Control

AMERZINE corrosion inhibitor
Ampoule Test Kit
PCN 0369-01-8

- Test daily per boiler
- Control limit is 0.03-0.1 ppm
- Removes dissolved oxygen from the feedwater and passivates metal surfaces
- Adjust with AMERZINE® corrosion inhibitor dosage as necessary
- Low hydrazine level with high ammonia level indicates deaerator problem and adding more hydrazine will make it worse

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Boiler Water Silica Control

Silica Ampoule Test Kit
PCN 0376-01-3

- Test weekly per boiler
- Control limit is 6 ppm max
- Enters the boiler as shore water contaminant and can volatilize with the steam
- Can result in silica deposits in superheater tubes and on turbine blades
- If higher than control limit, increase continuous surface blowdown and flash blow when boiler loads can be reduced

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Feedwater DEHA Control Test

DREWPLEX OX corrosion inhibitor
Ampoule Test Kit
PCN 0387-01-0

- Test daily
- Take sample from feedwater just prior to the boiler
- Control limit is 0.2-0.5 ppm
- Removes dissolved oxygen from the feedwater and passivates metal surfaces
- Adjust with DREWPLEX® OX corrosion inhibitor dosage as necessary
- Low DEHA level with high ammonia level indicates deaerator problem and adding more DEHA will make it worse

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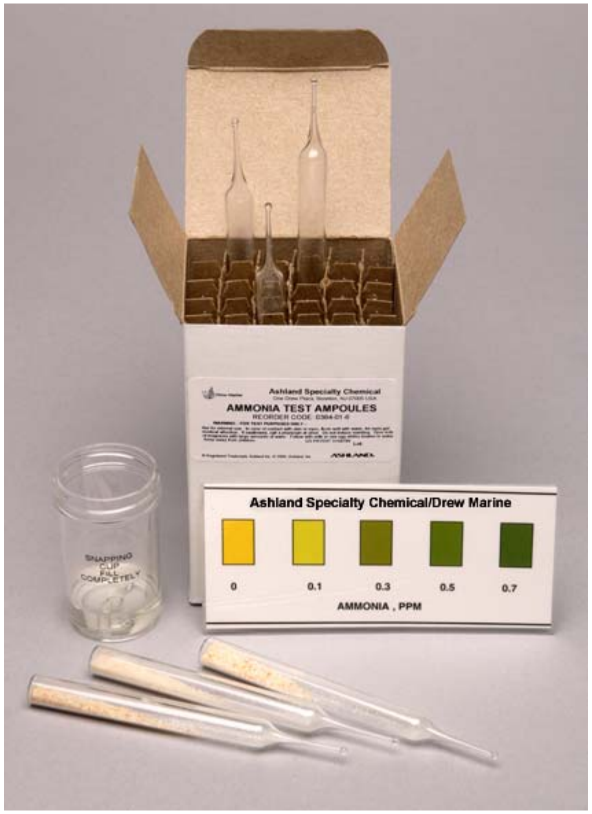
Condensate pH Control Test

- Test daily
- Control is 1-2 drops of N/50 Sulfuric Acid (pH 8.6-9.0)
- A pink color after addition of phenolphthalein ensures that the alkalinity is sufficient
- Back titration with acid ensures that the condensate is not excessively alkaline
- Adjust with SLCC-A™ condensate corrosion inhibitor dosage as necessary
  - If using DREWPLEX® OX inhibitor, SLCC-A inhibitor may be reduced or eliminated

Condensate Ammonia Control Test



Ammonia Test Ampoules
PCN 0384-01-6

- Test weekly
- Control is 0.5 ppm maximum
- Provides indication of efficacy of deaeration process and proper venting operation
- Provides overall view of oxygen scavenger treatment if excessive
- Venting the deaerator controls the ammonia level

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Boiler Water Alkalinity Reference Tests

- Provides a cross-check on treatment variations
- Test weekly per boiler
- Phenolphthalein and total alkalinity titrations ensure that there is no free hydroxide alkalinity present

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Feedwater Total Hardness Reference Test

Hardness Test Ampoules
PCN 0365-01-6

- Test weekly
- Indicates seawater in-leakage while at sea or shore water in-leakage while in port

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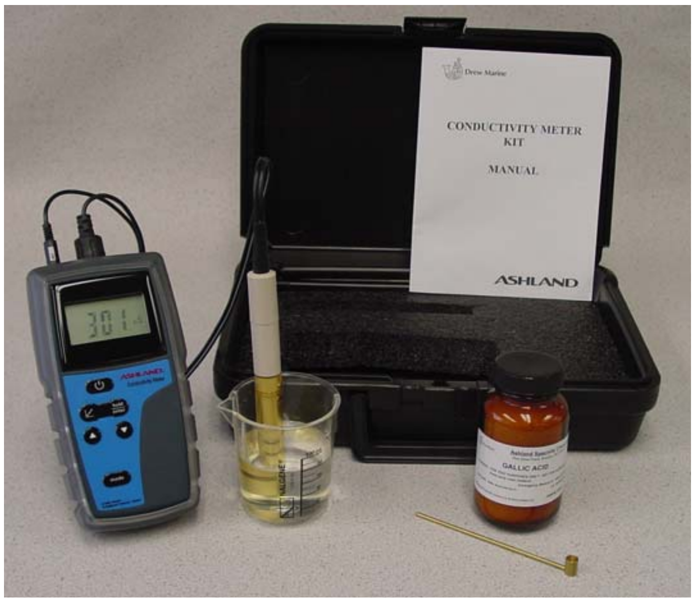
Feedwater Conductivity Reference Test



Conductivity Meter Kit Complete
PCN 0173-06-2

- Test daily
- Indicates the quality of condensate and makeup water entering the system
- If higher than 15 μS/cm consider using another source of makeup water, check for leaks and contamination, check distillate quality, check reserve feed tank quality
  - Distilled makeup should be <10μS/cm
  - Condensate should be <3μS/cm

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Record Test Results

DREW WATCH
ELECTRONIC SERVICES™
Software

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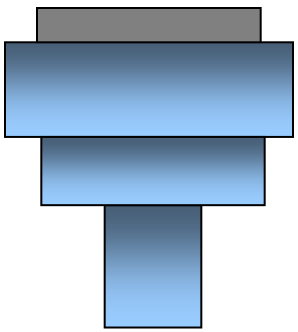
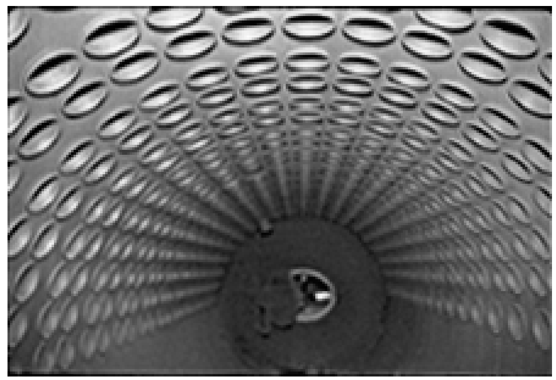
Three Step Approach

MINIMIZING STEAM GENERATING WATER RELATED PROBLEMS





1. Good Quality Distilled Makeup Water
(<10μS/cm conductivity)

2. Properly Applied Treatment Program

3. Good Sampling Monitoring and Control

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DREW MARINE

Proper HP Boiler Lay-Up

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Lay-Up

- Technical Paper TP-WT-3
- Short term
  - <3 months
- Long term
  - >3 months
- Steam blanketing
  - Up to 30 days
  - Boiler is on-line at a reduced load

Wet Lay-Up

- **Bottom blowdown boilers prior to securing from steaming (approximately 20 bar with fires secured)**
- **Fill boilers to overflowing with deaerated, hot feedwater**
- **Backfill economizers with deaerated, hot feedwater**
- **Superheaters can be drained and dried or backfilled with AMERZINE® inhibitor and SLCC-A™ inhibitor, vented and drained for protection**

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Wet Lay-Up

- **Prior to filling boilers, add AMERZINE® inhibitor or DREWPLEX® OX inhibitor to maintain 200 ppm hydrazine or DEHA reserve (approximately 1-1.3 liters per ton)**
- **Test boiler water pH and keep above 9.0 with SLCC-A™ inhibitor**
- **Check conditions weekly**
  - **Test boiler water for pH and oxygen scavenger reserve**
  - **Add deaerated feedwater as required**

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High-Pressure Steam Cycle and Boiler Water Treatment

Thank You.