الغسيل الكيميائى للغلايات البخارية بمحطات الطاقة قبل التشغيل الاول وطرق الحفظ الكيميائى لها أثناء فترات الايقاف

Chemical cleaning of steam boilers in power stations before first operation and methods of chemical preservation during shutdown periods

Prepared by

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Contents

- The purpose of chemical cleaning of boilers before the initial operation.
- Chemical cleaning steps and chemicals used.
- The step of forming the internal protection layer for the boiler pipes.
- Chemical tests and measurements necessary for the chemical cleaning.
- The formation of the boilers internal protective layer.
- Methods of preservation of boilers and their purpose.

Introduction

Thermal efficiency of steam boilers depends on heat transfer through metals so the deposition of non metallic materials including metals oxides on the heat transfer surfaces cause a lot of problems which reduce the boiler efficiency and ends up destroying the boiler metal .

- During construction and operation of the boiler, the scale is formed.

Internal boiler surface cleaning

▷ Construction : grease, oil, debris, rust, mill scale, paint, Welding flux.

▷ Operation : hard scale

scale → overheating tubes → rupture

- Pipes in steam boilers classified in two types (water pipes and steam pipes)
- scale must be removed by chemicals or steam blowing

☐Chemicals

▷ Alkaline solvent : Remove oil substance

▷ Acid solvent : Remove scale and rust

☐ Steam blowing : Steam lines (superheater, reheater)

Purpose of Cleaning

1) Remove the deposits and scales

2) Inspect surfaces of boiler tubes

3) Prevent overheating or corrosion

4) Recover heat efficiency

- Ensure safe and normal operation
- Recover heat efficiency

preventive measure against unexpected accident

Chemical Cleaning Chemicals

Main agents	Inorganic acids	• Hydrochloric acid • Phosphoric acid, Hydrofluoric acid, • Nitric acid, Sulfuric acid
	Organic acids	• Citric acid, Glycolic acid, • Formic acid, Malic acid, • Oxalic acid, Gluconic acid
	Chelating agents	• EDTA(ethylenediamine tetraacetic acid)
	Alkali agents	• Ammonia, Sodium hydroxide, • Sodium carbonate, • Sodium phosphate, Hydrazine
Aids		• Acid inhibitor, Reducing agents, • Copper dissolved agents, • Copper dissolved isolating agents, • Dissolution accelerators, Wetting agents

■ Inorganic Acid

1) Hydrochloric acid (HCl)

- In the past, widely used for chemical cleaning
- strong dissolving power(high solubility)
- Used in low temperature(to 60℃)

<Reaction formula>

(1) $Fe + 2HCL \rightarrow FeCl_2 + H_2$

(2) $FeCl_2 + H_2O \rightarrow Fe(OH)_2 + 2HCl$

(3) $4Fe(OH)_2 + O_2 \rightarrow 2(Fe_2O_3 . 2H_2O)$ Rust

(4) CaO stable poor soluble scales $+ 2HCL \rightarrow CaCL_2$ highly soluble in water $+ H_2O$

As iron present in iron salt has the property to react with moist air when kept for along time period and this phenomena is called (Rusting) hence, on reaction with water , $FeCL_2$ gives HCl.

2) Sulfuric acid (H_2SO_4)

- Highly reactive
- Generates a large amount of heat when diluted
- requiring careful handling
- Not used for the removal of scale containing a large amount of calcium

ex) $CaCO_3 + H_2SO_4 \rightarrow CaSO_4$ poor soluble $+ H_2CO_3$

hard scale

3) Phosphoric acid (H_3PO_4)

- Relatively low corrosive action

(anti-corrosive phosphate coatings) •Relatively expensive,

Low solubility of the salts - not used for large scale plants

4) Nitric acid (HNO_3)

- Highly reactive and high solubility of salts
- Passivizes stainless steel or aluminum
- Strongly corrosive to mild steel

$3Fe + 8\,HNO_3 \longrightarrow Fe_3O_4 + 4H_2O + 8NO_2$

Ca or Mg (salts) with HNO_3 *give Ca &Mg nitrates which are highly soluble in water*

Nitric acid reacts with aluminum and form protective layer Al_2O_3 (make aluminum unreactive)

Stainless steel alloy with nitric acid formed highly protective layer of ion oxides increase the wide range of corrosion resistant.

5) Hydrofluoric acid (HF)

- Readily dissolves silica not for Ca and Mg
- Difficult to handle
- Extremely corrosive
- Strongly toxic

$3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2$

$Fe_3O_4 + \frac{1}{4}\,O_2 + H_2O \longrightarrow Fe(OH)_3$

$HF + Fe(OH)_3 \longrightarrow FeF_3 + H_2O$ Water Insoluble iron source

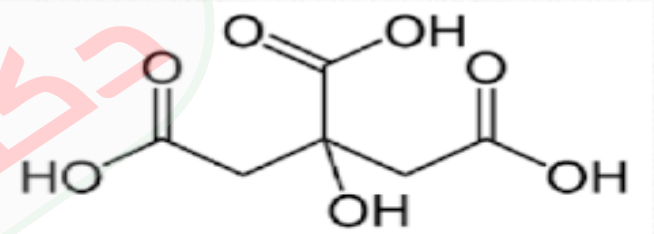
$SiO_2 + 4HF \longrightarrow SiF_4 + 2H_2O$ Decomposed by water easily

$4HF + 2H_2O + 2CaO \longrightarrow CaF_2 + 2HF + Ca(OH)_2 + 2\,H_2O$ insoluble ionic compound

■ Organic Acid

Used extensively for high pressure boilers

1) Citric acid

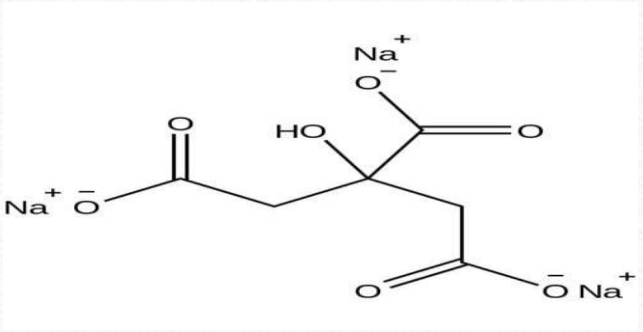


$C_6H_8O_7$

Citric Acid

- **Relatively large solubility than other organic acids**
- **Not readily precipitating iron hydroxides like inorganic acids.**
- **Usually heated to 80~100℃ to completely reaction**
- **Easy to handle, low solubility of calcium salt**

Citric acid + iron + water → iron citrate + hydrogen gas

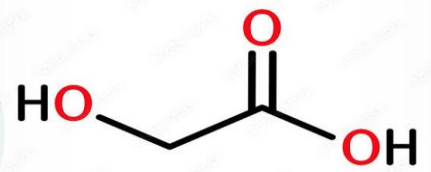


Citric acid is an Excellent Chelating agent, binding metals by making them soluble. It is used to remove the build up of lime scales from the metal alloys of boilers and evaporators, it can be used to treat water, which makes it useful in improving the effectiveness of soaps and laundry detergents.

2) Glycolic acid (hydroxyacetic acid) and formic acid

- most widely used for utility boiler
- used at relatively high temperatures(80-100℃)
- Readily decomposed and become harmless (if they have to remain in the boiler)
- Used with other organic acids as additives

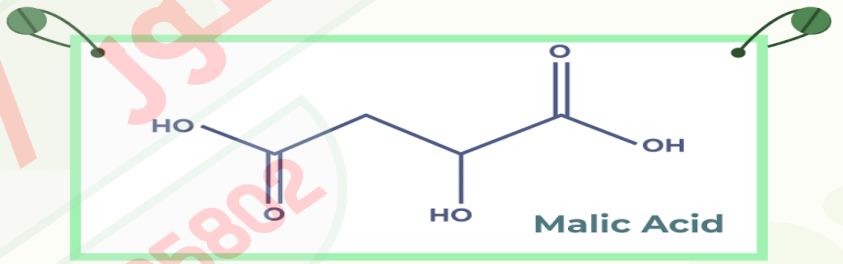
Formic acid



Glycolic acid

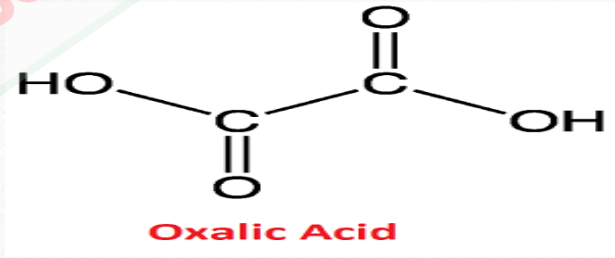
3) Malic acid

- solubility of reaction products is relatively large
- strong reactivity to form complex salts with iron ions



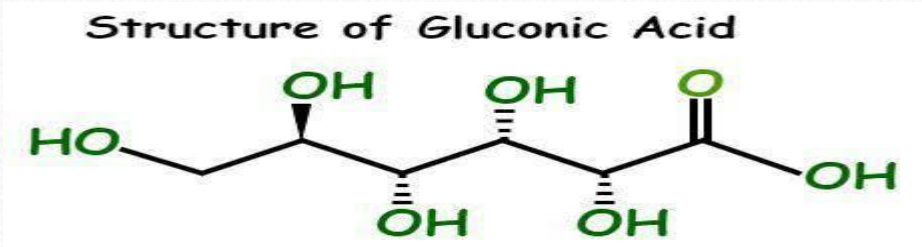
4) Oxalic acid

- Used at relatively low temperatures(about 60℃)
- Form deposit as ferrous oxalate, calcium oxalate



5) Gluconic acid

- Weakly acidic, non-toxic
- Sequesters iron, copper, calcium, magnesium, etc.
- pretreatment agent in metal plating
- dissolves iron rust in alkaline solution



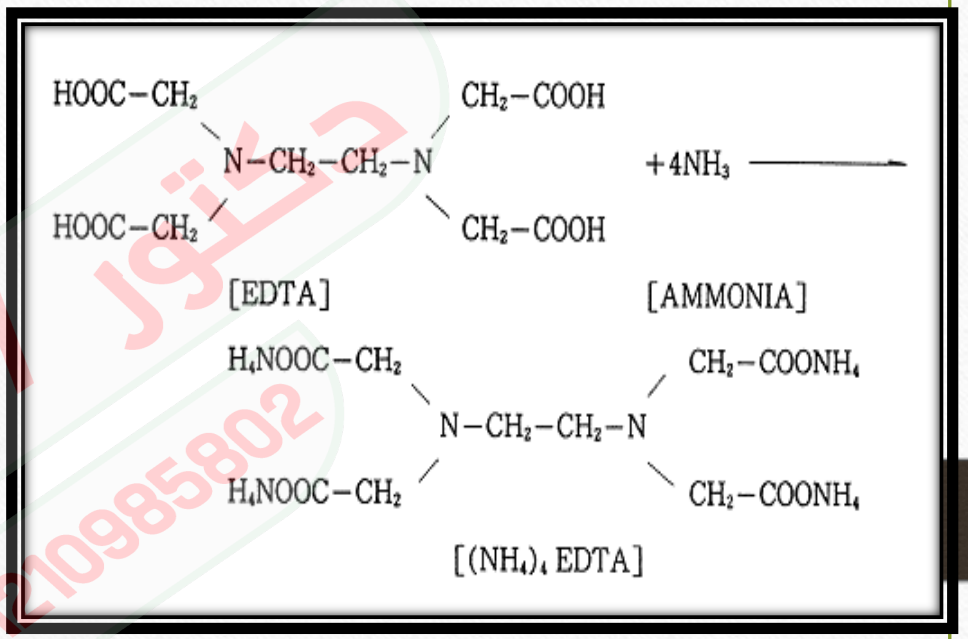
▪ Chelating agent

EDTA (ethylene di amine tetra acetic acid)

- Can be used in wide pH range
- high expensive

EDTA slightly soluble in water and insoluble in organic solvents, used to remove metallic salts from solution.

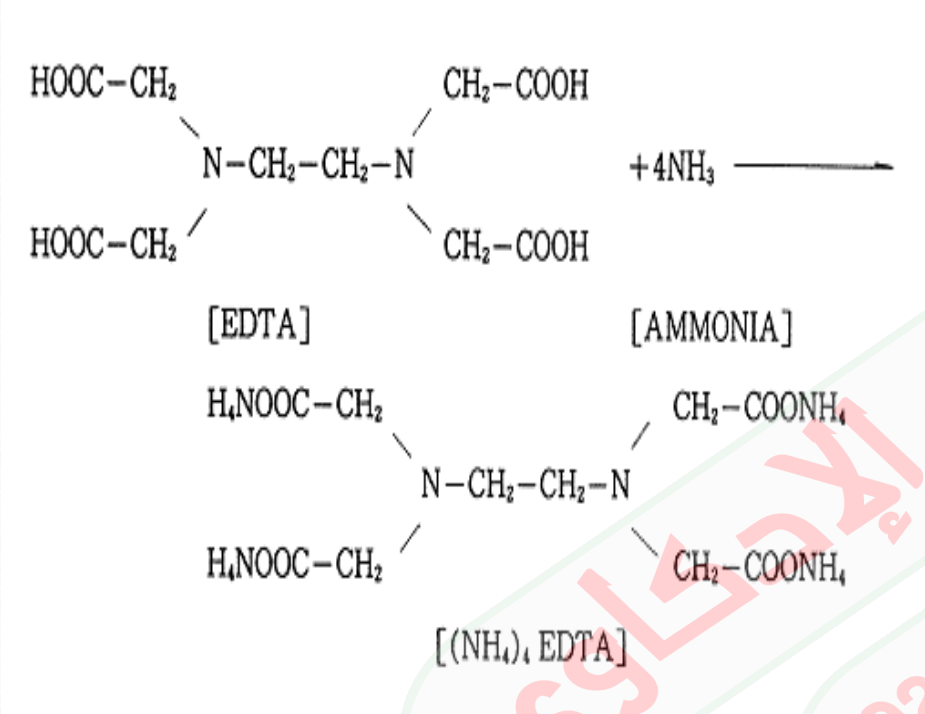
VERSENE aqueous solution used to remove calcium and other types of scales from boilers, evaporators , heat exchangers and also to prevent scale formation



EDTA & di ammonium salt of EDTA (VERCENE)

- $Fe + Fe_3O_4 + 8NH_4^+ + 4EDTA \rightarrow 4Fe(II)EDTA + 4H_2O + 8NH_3$
- Oxidant + Fe(II)EDTA → Fe(III)EDTA
- Cu + Fe(III)EDTA + EDTA → Cu(II)EDTA + Fe(II)EDTA

VERSENE Chemical Data Sheet



Typical Properties†

Calcium Chelation Value	130 mg as $CaCO_3$ per gram of VERSENE™ Tetraammonium EDTA
Equivalent Chelation Capacity	One gram of VERSENE™ $(NH_4)_4$ EDTA has the equivalent chelation capacity of 1.3 mmoles of EDTA
Metal Chelation Capacity	**Parts chelant per part metal** (w/w)
Ca	19.2
Mg	31.6
Fe	13.8
Cu	12.1
Mn	14.0
% Assay	38 wt% as $(NH_4)_4$EDTA
Appearance	Light, straw-colored liquid
Specific Gravity at 25/25°C	1.17
Bulk Density	1170 kg/m³ or 9.8 lb/U.S. gal.
pH	9.0-9.5 (1wt% solution)
Freezing Point	-21°C /-6°F
Viscosity, Centistokes	**Temperature** — **Viscosity, Centistokes**
	0°C/32°F — 15.6
	20°C/68°F — 7.3
	40°C/104°F — 4.1
Water Solubility	Completely miscible

† The data provided for these properties are typical values, intended only as guides, and should not be construed as sales specifications.

▪ Alkali agents

1) Ammonia

- effective for scale containing large quantity of Cu
- used below 60 ℃ owing to its volatility

2) Sodium hydroxide

To dissolve silica, vegetable oils and fats

3) Sodium carbonate

used as alkaline boiling agent to remove oils

▪ Cleaning aids

- Make up for the disadvantages of the main chemical
- improve its advantages of the main chemical
- selection of these aids is important

▪ Cleaning aids Examples

1) Acid inhibitor

reduces corrosion of the material

2) Reducing agents

prevent corrosion of base metal by oxidative ions

Oxidative ions : Fe^{3+} and Cu^{2+}

$2Fe^{3+} + Fe \rightarrow 3Fe^{2+}$

$Cu^{2+} + Fe \rightarrow Fe^{2+} + Cu$

3) copper dissolution accelerator

- improves the effect of copper removal
- preventing Cu deposition during acid cleaning (ammonia dissolves copper)

4) Silica dissolution accelerator

accelerate removing silica during acid cleaning

5) Degreasing and wetting agents

- oils are practically insoluble
- accelerate emulsification of oil in solution

■ Neutralization and passivation agents

- after acid cleaning, surface is activated
- metal surface stabilization by forming magnetite

1) Pre-treating agents

- prevent iron ion's re-precipitation during flushing

① dissolve iron hydroxide, etc.

② practically not corrosive at low concentrations

③ Metal ion sequestering ability is strong enough

2) Neutralization agents

neutralize to pH 9~10(mostly ammonia)

3) Passivation agents

form a passive thin film on the metal surface

① Sodium phosphate

② Hydrazine (magnetite, soft but stable)

③ Nitrites (hematite, excellent stability in dry state)

Table 1. Summary of Typical Iron Oxide Removal Solvents

Solvents and Conditions of Use	HCl	HF	HAF	Ammoniated EDTA	CA (Citrates)	
					Ammonium	Sodium
Typical Use Concentration, %	5-6	1-2	3-6	4-6	2-6	2-6
Typical Use Temperature, °F (°C)	150-160 (66-71)	150 (66)	200 (93)	Iron: 180-200 (82-93) or 265-300 (129-149) Copper: <150 (66)	Iron: 180-200 (82-93) or 240-275 (116-135) Copper: <150 (66)	Iron: 180-200 (82-93) Copper: <150 (66)
Contact Time, Hours – Poor Circulation	4-6	Minimal	12-24	12-48	12-48	12-48
-Good Circulation	N.R.	Minimal	6-12	6-24	6-24	6-24

Constituents in Deposit: Capacity for Constituents in Question						
Solvents and Deposit Constituents	HCl	HF	HAF	Ammoniated EDTA	CA (Citrates)	
					Ammonium	Sodium
Iron Oxides	High	High	High	High	High	High
Copper, Metallic	Low[a]	Trace[b]	Trace[b]	Medium	Medium	Trace[b]
Copper, Oxide	Medium[a]	Trace[b]	Trace[b]	Medium	Medium	Trace[b]
Nickel Oxide	High	--	--	High	High	High
Zinc Oxide	High	--	--	High	High	High
Aluminum Oxide	Low	High	--	Trace	--	--
Chromium Oxide	--	--	--	--	--	--
Calcium Salts	High[c]	Medium[c]	Low[c]	Medium[c,d]	--	--
Magnesium Salts	High	--	Low	Medium	--	--
Silica	Low[e]	High	Low[e]	--	Low[e]	--
Carbonates	High	--	--	High	--	--
Phosphates	High	--	--	Medium[d]	--	--
Calcium Sulfate	Low	--	--	Trace	--	--
Organics	Trace[f]	--	--	--	--	--

[a]With sufficient copper complexor present – such as thiourea.

[b]Dissolved copper will redeposit as metallic copper on bare steel surfaces.

[c]Except for calcium sulfate, which is difficult to dissolve.

[d]Removal may require long contact time.

[e]Provided ammonium bifluoride is added.

Commission Cleaning

■ Introduction

- To remove oil, grease, mill scale, rust.. Etc
- Condensate and feed-water systems :

  Mechanical cleaning → alkaline cleaning
- Economizer and boiler :

  alkaline boil-out → acid cleaning
- S/H, steam piping and R/H : steam blowing

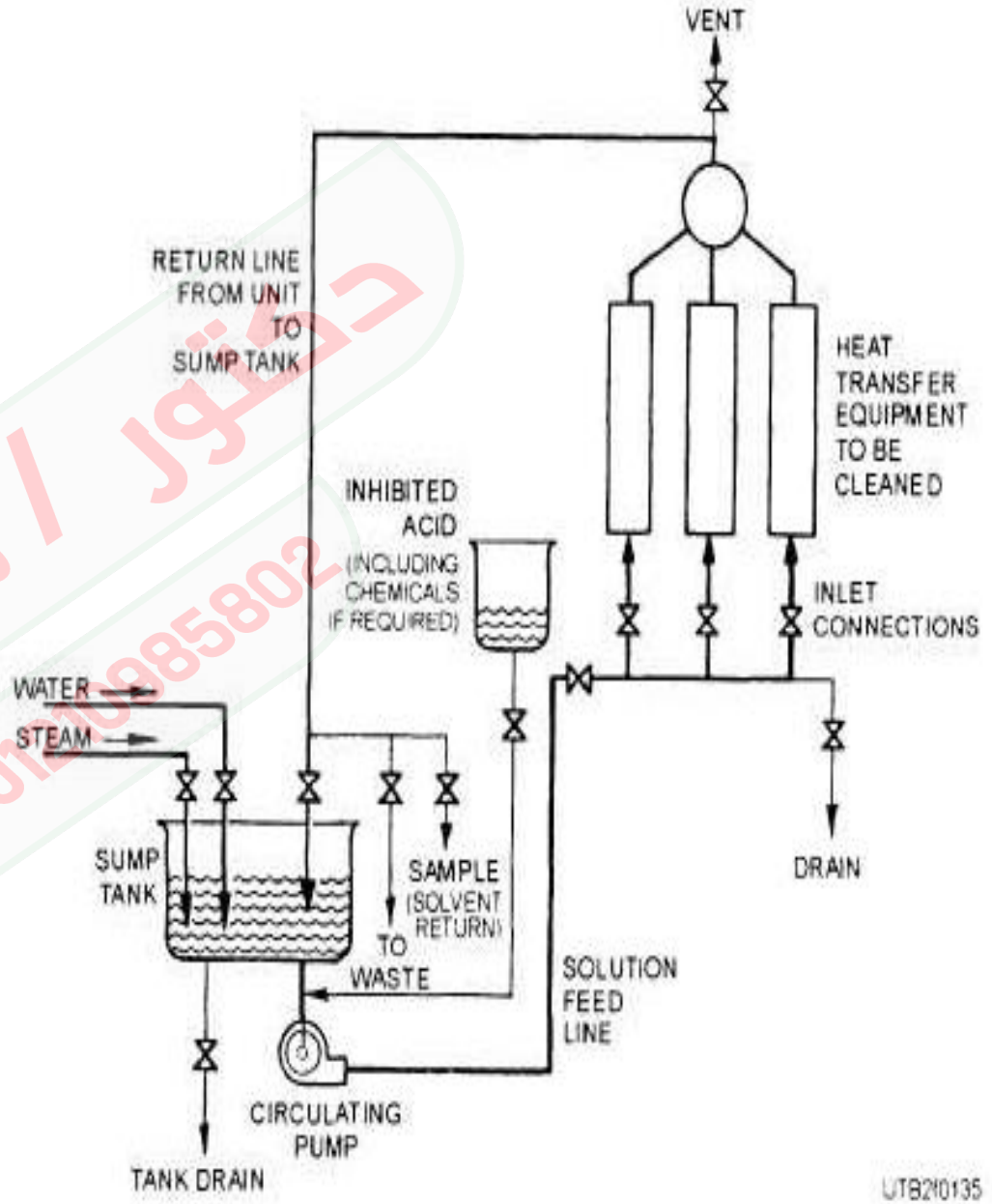
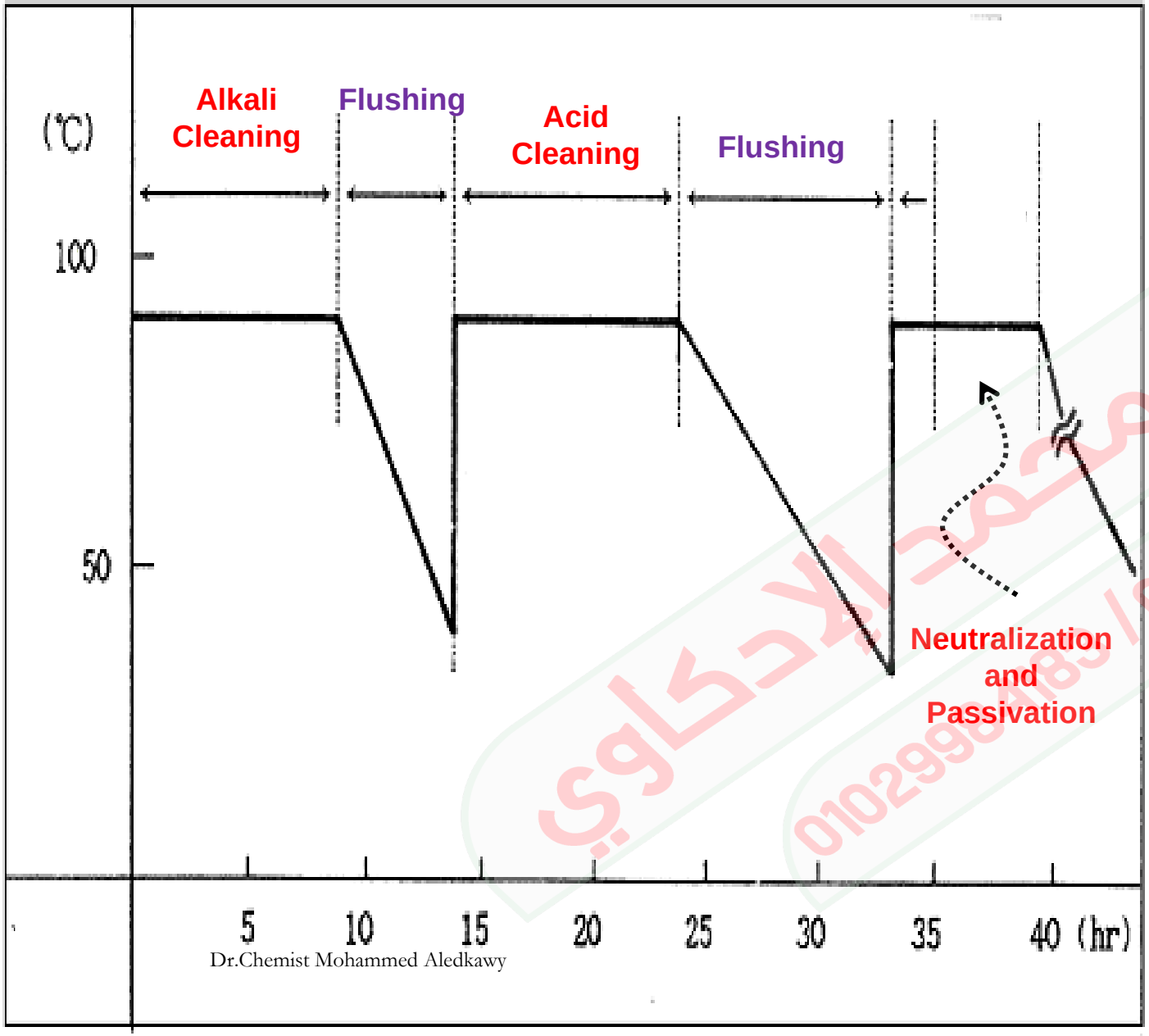


Figure 1-35.—Acid cleaning by circulation method.

Commission Cleaning Process



■ **Pre-boiler Cycle cleaning**

1) Manual cleaning(condenser, FWH, Dea. ST)

2) Cross flushing

3) Preheating of circulation water (90℃)

4) Circulation of alkaline solution(90℃)

(0.5 percent Na_3PO_4)

5) Rinse to remove alkaline material

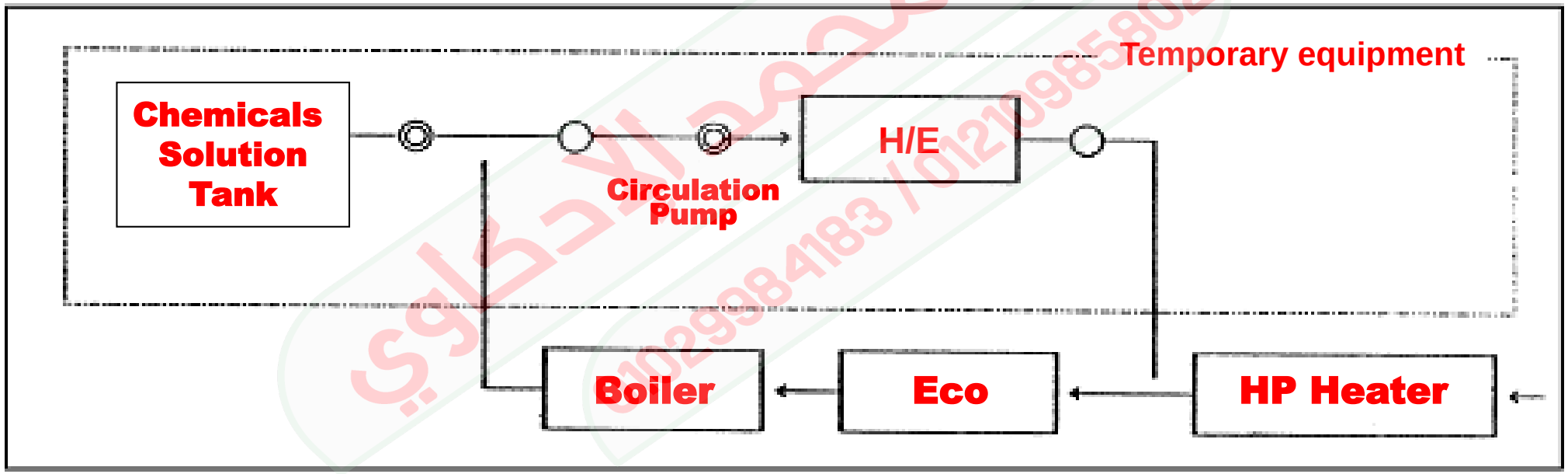
6) Wet lay-up(demi water, 100ppm hydrazine)

※ **Cleaning end point :** Until oil concentration is not changed

■ **Alkaline boil-out procedure**

1) The boil out procedure is similar to the alkaline cleaning procedure of preboiler system.

2) After washing ending, test piece and tube install



■ Chemical Cleaning of Boilers

- **Alkaline boil-out : lubricants, oil, rust, sand,**

drum-type boiler by any of the following combinations :

1) Sodium hydroxide	**2,000 ppm**
Sodium carbonate or sodium phosphate	**2,000 ppm**
2) Sodium phosphate	**5,000 ppm**
Sodium hydroxide	**500 ppm**

- **Acid cleaning : scale, mill scale, corrosion products**

■ Acid Cleaning procedure (Mostly Circulation method)

1) Blend concentrated inhibited acid and hot water
2) Prevent the spillage of the solvent to super heater
3) Soak or circulate(4 to 6 hours)
4) Sample and check periodically the degree of reaction in the boiler.
5) Drained by pressurizing with nitrogen
6) Rinse (pH is between 5 and 6) with water containing alkaline media using N_2H_4 200 ppm solution
7) Neutralize and passivation of the metal with water containing N_2H_4 500 ppm solution

Chemical Cleaning procedure

Establishment boiler chemical cleaning process Table

Process	Use chemicals		Cleaning condition	Analysis item	Criterion
	Chemicals	Concentration			
BLR flushing and Hydraulic test	N_2H_4	50 ppm	Hydraulic : BLR Header Pressure	Turbidity, N_2H_4	Turbidity : satisfactory
Super heater and HP heater water filling	N_2H_4	100 ppm	Super heater and HP heater full water	Cl^-, N_2H_4, pH	Cl^- : 0.1 ppm under N_2H_4 : 100 ppm over
alkaline cleaning	Na_2CO_3 Na_3PO_4 Surfactant	0.1% 0.2% 0.05%	90±5℃ Until the oil oncentration is fixed, circulation	pH, Temp	Oil, Turbidity fixation
Water flushing	N_2H_4	100 ppm	Until below pH 9, flushing	pH ,Temp N_2H_4	pH 9 under

Acid cleaning	HAA Formic Acid Inhibitor Ammonium Bifluoride Thiourea Sorbic Acid	2.0% 1.0% 0.3% 0.15% 0.1% 0.15%	90±5°C Fe^{2+} is fixed, circulation	pH, Fe^{2+}, Fe^{3+}, temp	Fe^{2+} fixation
Water flushing	N_2H_4	200 ppm	Until over pH 5, flushing	pH, T-Fe, N_2H_4, temp	pH 5 over
Neutralization preparation	Citric Acid	0.1%	90±5°C 1 Cycle circulation		
Neutralization	Ammonia Water	750 ppm	90±5°C 1 Cycle circulation	pH, temp	pH 9～10
Passivation	N_2H_4	500 ppm	90±5°C 2 to 3 Cycle circulation	N_2H_4, pH	N_2H_4 50 ppm

Metal samples for test

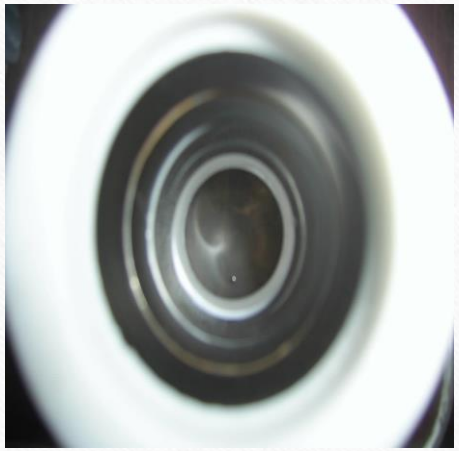
Test Piece (The circulating pump rear)

Chemicals injection equipment

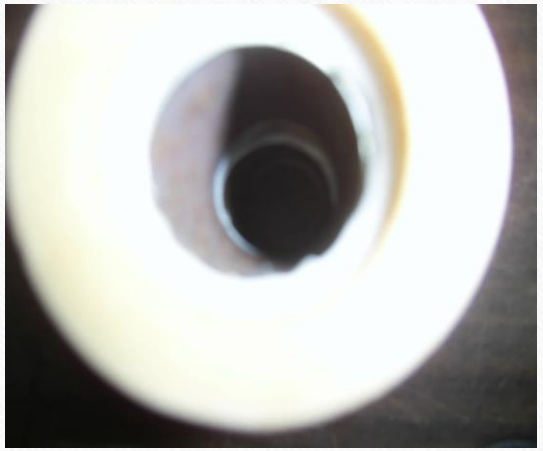
Heat exchanger

Test Tube(The circulating pump front)

Chemical washing equipment area

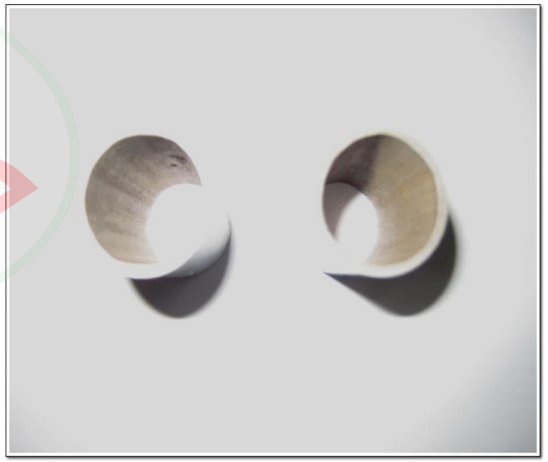


Test Piece



Test Tube

Before Cleaning



After Cleaning

Before Passivation

After Passivation

Responsibility

1. vendor

- supply chemicals and equipment
- operate equipment and supervise the cleaning.
- perform chemical analyses and monitor spent solvent to determine when the cleaning has been completed.

2. Plant personnel

- responsible for maintaining proper temperatures throughout the cleaning
- supplies water/steam, sets up solvent-delivery and waste-disposal system
- assure solvent is not inadvertently introduced to any part of steam plant

3. The boiler manufacturer

- responsibility to provide a boiler that can be cleaned safely and effectively.

Velocity and Scale Removal

Foot per second (fps)

Solvents and cleaning conditions	Velocity					
	Static	0.03 fps	0.1 fps	1 fps	2 fps	3 fps
Hydrochloric acid(5%) 6 hrs, 160-170°F	C	C	C	C	C	C
Phosphoric acid(3%) 6 hrs, 212°F	C	…	C	C	C	…
Ammonium citrate(5%) 6 hrs, 200-220°F	U	U	U	C	C	C
Formic Hydroxyacetic acid(3%), 6 hrs, 160-170°F	…	U	U	C	C	C
Ammonium EDTA(3%) 6 hrs, 275-300°F	…	U	U	C	C	C

U = Scale not removed(estimated 20-100% of scale remaining)

C = Scale completely removed(estimated 95-100% of scale removed)

Boiler type	Internal deposit quantity limits*		
	Clean surfaces, mg/cm²	Moderately dirty surface, mg/cm²	Very dirty surface, mg/cm²
Supercritical units >220 bar	less than 15	15～25	more than 25
Subcritical units (124 bar and higher)	less than 15	15～40	more than 40

* measured on the furnace side of tube samples and include soft and hard deposits

Note : For all practical purposes, $1\ mg/cm^2 = \sim 1\ g/ft$

The Steps of Chemical Cleaning Process

(1) Preparation

- prepared the source of (demi water) total quantity required of chemical cleaning steps (must be before starting which must be calculated before.
- Prepare all chemicals, mechanical equipment , instrument list required as vendor recommendation in manual procedure

Surfactant	230 kg
Hydrofluoric acid (40% solution)	6'000 kg
Inhibitor	350 kg
Citric acid (powder)	2'300 kg
Ammonia (19% solution)	3'950 kg
Sodium nitrite	800 kg
Lime	6'000 kg
Hydrochloric acid (if required for waste pH adjustment)	to be defined kg

- pH/ORP meter
- Turbidity meter
- Spectrophotometer
- Borescope
- Ultrasonic flow meter
- Temperature meter
- Titration set
- Corrosion meter (Corrator)
- Conductivity meter
- Thermocamera

- one diesel driven circulation pumps 850 m^3/h, 10 bar head (chemical resistant)
- two electrical circulating pumps 600 m^3/h each, 10 bar head (chemical resistant)
- two electrical emergency pumps 250 m^3/h each, 10 bar head (chemical resistant)
- diesel power generator
- 2 X air driven pumps 10 m^3/h, 6 bar head
- circulation tank 10 m^3
- hard piping/flexible hoses for temporary cleaning circuit
- 2 X 4t/h auxiliary steam boilers (saturated steam)
- temporary piping for lines to waste water tanks and demi water line
- valves and flanges DN50, DN100, DN150, DN250
- waste water treatment equipment (hoses, pumps and air injection devices)
- evaporating pond
- lime dosing system
- air injection system

Chemical Cleaning Connections

- Pump Station to Condensate Storage Tank U2
- Discharge line to Waste water Pool
- 01-02 Boiler Feedwater Inlet
- 03 Outlet BCP
- 04A - 04B Outlet DSH 1A - DSH1B
- 05A - 05B Outlet DSH 2A - DSH 2B
- 06 Inlet to RH DSH
- 06A - 06B Outlet RH DSH 1A - DSH 1B
- 07 Outlet Furnace Drain
- 07A - 07B – 07C Outlet Drain Receiver Tank
- 08 Back Filling Superheater
- 09 BCP Motor filling line flushing
- 10 Storage Tank Outlet for Chemical Cleaning

Lines Velocity Calculations

Component TAG\Description		Number	Ext. Diameter	Thickness	Section	Min. Flow	Required velocity
			mm	mm	m^2	m^3/h	m/s
ST-8	Feedwater from boiler circulation pump discharge	1	406.4	51	0.073	131	0.5
ST-7	WCV outlet pipe downstream pump	1	406.4	61	0.063	114	0.5
ST-6	WCV outlet pipe from valve to pump	1	457.2	69	0.080	144	0.5
ST-5	WCV outlet pipe upstream pump	1	457.2	69	0.080	144	0.5
ST-4	WCV vent line	1	73	12	0.002	3	0.5
ST-3	Water Collecting Vessel	1	600	87	0.142	256	0.5
ST-2	WCV inlet pipe	3	355.6	41	0.176	317	0.5
ST-1	Separator	3	550	85	0.340	612	0.5
F30A	Separator inlet pipes (lat 1.5 mt)	12	219.1	42	0.172	309	0.5
F-30	Separator inlet pipes	12	219.1	34	0.215	387	0.5
F-29	Furnace outlet manifold	1	558.8	79	0.126	227	0.5
F-28	Vestibule risers	2	88.9	15.24	0.005	10	0.5
F-27	PCP vestibule (EVA side) outlet header	2	219.1	48	0.024	43	0.5

Velocity calculations for all lines (inlet and outlet) for all parts in boilers will be cleaned for determine the rate flow of all steps of chemical cleaning

- Process Description

(1) Mechanical Erection

- make the erection of temporary lines on supply (inlets) lines such as (economizer inlets , boiler circulation pump RH spray inlet and on return (outlet lines) such as boiler storage tank , temporary hoses from RH and SH spray.

- From the tables of tag numbers of equipment in all boiler which recommended by vendor a lot of mechanical works must be done before chemical cleaning begins such as Remove all internals of the all Check valves & Control valves & filters &internal of the pumps and install special blinds & orifice plates of all flow meters.

- Back filling to super heat banks (SH) by using vacum pump for make isolation to prevent any chemicals arrive to it through all chemicals steps by make cutting for SH drains (header) and filling with vacum pump (demi water with ammonia soln at pH > 9.5

(2) Leak Test

- By using vacuum pump and filling all temporary pipes at 10 bar and using small temporary pump to increase pressure to 15 bar
- Make inspection for all circuit of cleaning for any leakage or passing and repair it at minimum 1 hour at fixed pressure 15 bar.
- After end this step, prepare for flushing step.

(3) Primary Flushing step

- Make flushing by pump which achieved required calculated velocity of flow such as (0.5 m/s)
- This step need 48 hours at least and depend on turbidity measurements

The main parameters

(1) Turbidity (0.2 → 0.25 ABS by using ABS turbidity meter or < 20 NTU

(2) Velocity (must be reached to 0.5 m/s in all suction of circuit as calculation

(3) After arrive to flushing water with pH ≥ 9.5 and turbidity < 20 NTU

(4) Stopped the pump of flushing and kept the water in all circuit for another step

(4) Heating (warm up for all circuit)

- **Make heating for water inside the boiler by using temporary auxiliary boiler until reach to temperature > 45 °C then prepared for another step (degreasing or alkaline) (16-24 hour until heating)and reached to required tempr. If 55 °C or 65 °C As manual recommendation**

(5) Alkaline (degreasing phase) 1 phase

- **this step using for removal oils and grease from pipes by adding (surfactant &low foam) and make circulation for all circuit and keep temperature > 45 °C.**
- **Required parameters**
- **temperature keep from 55 ° ± 5 ° C.**
- pH keep (9.5 – 10) as recommendation with using ammonia solution (100 ppm)
- **Grease content < 200 ppm**

How to measure Grease content ? By using Macherey Nagel Test

Surfactants

- Organic chemical compounds have in its molecules at least one hydrophilic and one hydrophobic group.
- Its rule to reduce the surface & Interfacial tension of liquid (the natural force exiting in liquid that hold its surface together .
- Conc. Of surfactant 0.15% or from o.1- 0.15% as recommendation (different type of surfactants)

MACHEREY- NAGEL Test

- **The light blue paper turns dark blue on contact with hydrocarbons, particular gasoline, heating oil, lubricating oil etc.**
- **The test paper must be moved back and forth a few times in the test soln.**
- **In the presence of oil, blue discoloration appear.**
- **The intensity and size of the blue spots are indicative of the quantity of oil contained in the test sample**
- **Water that is free of oil will neither moisten no discolor the paper**
- **The limit of sensitivity of the test paper is largely depended up on the solubility of hydrocarbons**

Substances	Lower limit (ppm)	Lower limit (ppm)
Petroleum ether	250	400
gasoline	10	25
Fuel oil	5	10
Lubricating oil	1	5

- After arrive to grease content < 200 ppm prepare for acid phase circulated about 4 – 6 - 10 hours as recommendation

(6) Acid phase 2 phase or 2

- Heating stopped & efficiency test (steel wood method) & inhibitor
- Parameters (temperature – iron conc. – pH – inhibitor efficiency – corrosion rate
- Acid phase performed in two steps (1) inhibitor (2) acid (HAF)
- Step (1) inhibitor
- Inhibitor Conc. 0.15% if acid HF 1%
  Inhibitor Conc. 0.2% + ammonium bi fluoride 0.3% if acid is citric acid 3%
- We must put inhibitor before acid to prevent or keep the internal pipes from corrosion through acid cleaning phase and make circulation of inhibitor arrive to all circuit after that performed inhibitor efficiency test

- **Inhibitor Test** by using any substances of inhibitors such as aromatic or aliphatic amines
- Inhibitor will be tested by steel wool method after prepared 1% HF or acid will be recommended in beaker representative of acid phase (immersed steel wood in it.
- Efficiency of the inhibitor will be checked by means of the floating of steel wool

- If steel wood immersed in 1% HF soln. Mean that inhibitor (Efficient)
- If steel wood bubbles & H_2 gas produced & steel wood floatation Mean that inhibitor (Not Efficient)

- **Step (2) Acid phase**

- **(HF acid 1% ± 0.1) or acid is citric acid 3%**
- **After sured that inhibitor circulated in all circuit, must be added the acid and make circulation**
- **This is the most important step .**
- **Take samples every 1 hour and determine (Acidity , ORP , PH , Iron conc.) until arrive to 3 samples stable in results this process at least take about 6 hours**
- **Iron concentration < 5000 ppm**
- **pH (3.5 -4) if (HF acid 1% ± 0.1) pH (1 -4) if acid is citric acid 3%**

Notes

- **Iron measurement in chemical cleaning process will be by using ferrover reagent and measure by spectrophotometer device and take care that samples will be very high concentration so sample must be diluted about 10 times to can be read in the spectrophotometer. < 5ppm at 3 measures stable.**
- **Corrosion rate will be measured using corrosion meter (Corrate device) the value of device give in mpy unit (mills per year which should converted to unit g/m2 *h by factor 0.54**
- **metal loss determination before chemical cleaning (installed some coupon (same type of boiler metals in different position in circuit with known (weight and width) and after ended calculate the change in mass then**

Evaluation and representation of the test results

The dried rings shall be weighed again on the analytical balance and be measured to determine the total surface. The difference in weight measured shall be the metal loss (Δm) of the total specimen. This value is converted to (g/m2) as specific loss to the following formula:

$$m_{AB} = \Delta m \times \frac{1}{A_{total}} \ (g/m^2)$$

Where:

Δm = mass difference (g)

m_{AB} = specific metal loss (g/m2)

A_{total} = total tube surface (m2)

After 3 stable samples of tempr & pH & Iron & corrosion rate measurements in acid phase or at less stable about 2 hours the all circuit drained in high speed for at least 15 min , and make drain for ammoniated water in super heated to insure no acids is in that part of boiler

(7) Rinsing & neutralization

The rinsing considered completed according to the conductivity measurements of entering water less than 100 µs.cm

(8) Temporary passivation step (formation of magnetite layer)

1. Heated until 40± 5 °c
2. Added citric acid 0.5 – 1 % to remove flush rust
3. Circulated at minimum speed for 8 hours for contact time for acidity, iron measured
4. When iron conc. Stable 3 times make neutralization with ammonia until 9.3-9.8 pH.
5. Circulated at least 4 hours
6. Add hydrogen peroxide H_2O_2 (O.35 ± 0.1 %) or sodium nitrite 0.6%
7. Circulated hydrogen peroxide H_2O_2 in circuit about 4 hours or more until ORP reached 150 mv

This indicated for end of passivation. Then make fast drain

(9) Final rinsing step

- Rinsing with ammoniated demi. water treated with 50 ppm ammonia and 100 ppm DEHA dimethyl hydroxyl amine pH 9.5-10 ,
- Circulated about 30 min then drained at maximum speed as possible

(10) Inspection

inspection with 48 hours of end of chemical cleaning before steam blowing

Steam Blowing

The purpose of blowing the steam lines is to remove any foreign material remaining in the steam piping after erection is completed.

- **Considerable damage, if such material enters turbine**

Initial Chemical cleaning over all steps for any newest water tube boilers Before initial filling to be in service

(1)Mechanical Erection
(2)Initial filling to make leak test
(3)Initial closed flushing
(4)Solution heating up and adjusted pH
(5)Degreasing 1 phase
(6)Acid phase 2 phase (inhibitor then add acid)
(7)Rinsing & neutralization
(8)Temporary Passivation
(9)Final rinsing step
(10)Steam blowing

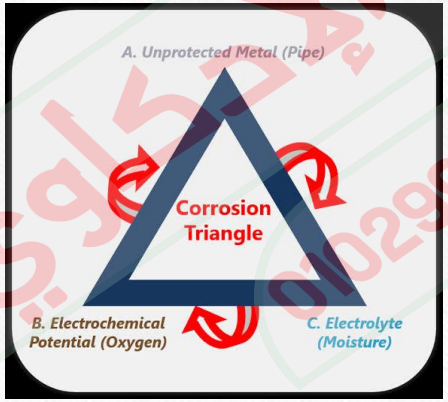
Steam boiler preservation at shutdown periods

Dry Preservation method

The dry method is passed on the preservation of the internal surfaces by an inert gas (nitrogen) that displaces the oxygen present or by the use of dry air that displaces all the water present in the system , thus in both the cases stopping the corrosion.

The dry method can be applied to the following sections:

- **Economizer**
- **Evaporators**
- **Superheaters**
- **Reheaters**



Dry preservation with dry air:

Instead of the use of an inert gas like nitrogen , also dry air is effective for the preservation .

Dry air can be injected through boiler nitrogen injection system.

The use of clean dehumidified air to preserve the boiler during lay-up periods or normal operations is routinely practiced internationally.

If relative humidity of air is below 30 % , corrosion rate is negligible.

- Dry air can be provided from instrument air and air must be clean and oil free.

A flow of dehumidified air through –out the entire system shall be ensured by opening valves where appropriate (vents and drain valves).

- A first phase of flushing of the system will be performed to evacuate the water present in the circuit , preferably flushing from highest points to the lower drains to the lower drains to improve the water evacuation by gravity.
- When humidity is stable and below the desired value , system will be bottled up and pressurized in order to have a positive pressure respect to the surrounding atmosphere.

Wet preservation

Filling by demineralized water treated with alkaline agent (ammonia solution) to keep pH more than 10 and deoxygenated agent such as (hydrazine solution or sodium sulphite) to keep oxygen dissolved at minimum values

Thank you,...