

“Corrosion Management of Water Transport pipes (Fire Water, Service Water, etc) of Power Plants”

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ABSTRACT

The service water system provides cooling to various components in a power plant while using the water from nearby reservoirs (rivers, lakes, etc) or 1st Stage RO permeate from desalination units as the heat transfer medium. These components vary widely both in their configuration and in the risk associated with operational failure. Because the water chemistry will vary depending on the source, the corrosion environment will be site specific.

Service Water System Piping are susceptible to corrosion attack from diverse processes that include general wall loss and pitting, the latter generally identified as being of microbial origin and related to the presence of internal deposits.

The reliability of Fire Protection System (FPS) is most important in preventing and mitigating the consequences of fires. FPSs are subject to degradation through various types of fouling and corrosion, which can impact performance and service life. Corrosion degradation can result in material replacements and major maintenance costs.

Fouling either associated with microbiological growth or related to sedimentation, can impact the function of individual components such as valves and sprinklers, or can result in the failure of the FPS in preventing and mitigating the consequences of fires.

Recently many cases of failures of service water pipelines & equipment and fire protection system pipelines due to corrosion have been reported from different power plants operating on fresh water and 1st stage RO permeate of seawater desalination system.

The present paper intends to provide the details of the studies conducted to identify various factors responsible for failure of service water and fire water systems and to identify the possible control measures. The studies are expected to help different utilities in taking preventive actions in avoiding such failures.

Key Words: *Service Water System, Fire Water System, Tubercles, internal corrosion, Nodular growth, Oxygen Corrosion, Microbiologically Induced Corrosion*

INTRODUCTION:

A power plant's service water system, especially the service water piping, is a critical part of the plant infrastructure, is crucial to achieving a plant life of 40 years, and is key to life extension. Service water piping systems are low-temperature, low-pressure piping systems, with nominal conditions that typically would not be considered particularly challenging. The primary mode of degradation considered in design was general corrosion. A typical corrosion allowance of 0.040 to 0.120 inches (1–3 mm) is applied for uncoated carbon steel piping to account for degradation in service. Service water systems may attain 25–40 years of life without much special attention; however, for longer lives, some repair or replacement should be expected. The keys are to take appropriate mitigation actions early in order to avoid surprises, or to do the required repair or replacement once and no more.

Power plants use fresh water (untreated or partially treated) or 1st stage RO permeate of desalination system (coastal power plants) as service water. Apart from pipelines equipment in service water

circuit like coolers, air compressors, pumps, etc are susceptible to severe corrosion and fouling. Similarly fire protection system is highly susceptible to corrosion and fouling induced damages.

Recently many cases of corrosion & fouling induced damages in service water and fire water systems were investigated and reasons for such failures were analysed along with developing strategies for corrosion management of both systems at different power plants.

The present paper intends to provide the details of the studies conducted to identify various factors responsible for failure of service water and fire water systems and to identify the possible control measures. The studies are expected to help different utilities in taking preventive actions in avoiding such failures.

SOME CASES OF FAILURES OF COMPONENTS IN SERVICE WATER

CASE 1: FAILURES OF COMPONENTS IN 1st STAGE PERMEATE OF DESALINATION SYSTEM:

Some of the stations were experiencing repeated failures of heat exchangers of air compressors, pumps and pipes in the service water. 1st stage RO permeate was used at these as service water (Fig. 1 to 8) .



Fig. 1 and 2: Severely corroded inner surface of Heat Exchanger Shell and Water Boxes



Fig. 3 & 4: Plugged Heat Exchanger Tubes and Corrosion and Fouling on external surfaces of Tubes (Corrosion due to Service Water)



Fig. 5 & 6: Severely Corroded and Cavitation affected Impeller Blades of Pumps



Fig. 7 & 8: Severely Corroded Service Water Pipelines

Typical water chemistry of 1st stage RO permeate water used as service water is indicated in **Table 1**.

As can be seen from Table 1 the 1st Stage RO permeate of desalination system of two stations is highly corrosive with Larsen Skold index of 171 and 61, chlorides of 360 ppm & 306 ppm and sulphate of 50 ppm & 6 ppm and RSI 13.49 & 13.44 respectively. Added to this is the continuous influx of dissolved oxygen in the system thereby increasing the corrosivity of the service water.

CASE 2: FOULING AND CORROSION OF COMPONENTS IN SERVICE WATER (FRESH WATER):

Problems of Fouling and Corrosion of Coolers, heat exchangers, pipelines operating on fresh water based service water, were being experienced as some stations.



Fig. 9: Leak in service water pipe



Fig. 10: Corroded service water pipes

Table 1: Water Chemistry of 1st Stage Permeate of Desalination System of Two Stations

SNo	Parameter	Unit	Seawater		1 st Stage RO Permeate		2 nd Stage RO Water	Raw Water (fresh)	RO Water
1	pH		8.0	8.03	6.6	6.92	6	8	6.35
2	Conductivity	µmhos/cm	57400	56800	1000	940	25	464	13.2
3	Total hardness	ppm as CaCO ₃	6500	7502	12	22	8	162	2
4	CaH	ppm as CaCO ₃	1100	1146	6	3	4	100	1
5	MgH	ppm as CaCO ₃	5400	6356	6	19	4	62	1
6	P alk.	ppm as CaCO ₃	0	0	0	0	0	0	0
7	M alk.	ppm as CaCO ₃	120	130	6	8	4	165	5
8	Chloride	ppm as Cl	22000	21300	360	306	30	41	1.8
9	Turbidity	NTU	450	17.20	0.1	0.50	0.1	0.24	0.1
10	SiO ₂	ppm as SiO ₂	0.235		0.01			12.2	0.544
11	Sulphate	ppm as SO ₄	3248	3164	50	6	6	0	0.1
12	Iron	ppm as Fe	0.02	1.1	0.01	0.003		0.02	0.001

13	RSI		5.20	5.16	13.44	13.49	14.46	6.68	15.36
14	LSI		1.42	1.44	(-) 3.44	(-) 3.28	(-) 4.23	0.66	(-) 4.36
15	Larsen Skold Index		516.01	480.50	170.67	61.35	17.4	1.75	0.712

Scaling Severity keyed to index

LSI	RSI/PSI	Condition
3.0	3.0	Extremely severe scaling
2.0	4.0	Very severe
1.0	5.0	Severe
0.5	5.5	Moderate
0.2	5.8	Slight
0.0	6.0	Stable Water
-0.2	6.5	No scaling very slight tendency to dissolve solids
-0.5	7.0	No scaling slight tendency to dissolve solids
-1.0	8.0	No scaling moderate tendency to dissolve solids
-2.0	9.0	No scaling strong tendency to dissolve solids
-3.0	10.0	No scaling very strong tendency to dissolve solids

Larsen Skold Index:

$$\text{Larsen-Skold index} = (\text{epm Cl}^- + \text{epm SO}_4^{2-}) / (\text{epm HCO}_3^- + \text{epm CO}_3^{2-})$$

Index << 0.8 chlorides and sulfate probably will not interfere with natural film formation.

0.8 << index << 1.2 chlorides and sulfates may interfere with natural film formation. Higher than desired corrosion rates might be anticipated.

Index >> 1.2 the tendency towards high corrosion rates of a local type should be expected as the index increases.



Fig. 11: Compressor Cooler – Fouling & deposition



Fig. 12: Severe Biofouling, MIC, Deposition on Cooler Tube Plate



Fig. 13: Fouling in PHE inlet



Fig. 14: Tubercles in cooler sample pipe

Fig. 9 to 14 indicate the internal corrosion, deposits, microbiologically induced corrosion of pipes, coolers, PHE, etc due to service water of different stations.

The water chemistry of these stations are indicated in **Table 2**. As can be seen all the waters are corrosive in nature and without proper care will cause corrosion in the system. Generally in such systems the velocity is comparatively much lower than that in cooling water system. Further, there is no specific treatment given to service water except may be some chlorination. There are no defined lay-up practices being followed in service water systems. There is no monitoring of corrosion and fouling in such systems. Targeted microbiological control of service water systems are not adopted resulting in severe biofouling/microbiologically induced corrosion in the system.

CASE 3: BIOFOULING AND CORROSION OF COMPONENTS IN FIRE WATER SYSTEM:

Fire fighting system is a critical component of power plants, its availability and reliability is of paramount importance for the safety, availability of the plant. However; at most of the plants a number of failures in the fire water system are reported either due to fouling/biofouling or due to corrosion.

The dependability of fire protection systems (FPSs) is most important as it relates to their capability to control and suppress fires. A number of factors (problems) have an impact on a system's capability to carry out this function as needed. These problems include (but are not limited to):

- Mechanical/physical limitations
- Plugging and fouling of the system
- Corrosion by several different mechanisms

Therefore, in the case of any emergency or preplanned impairment, it is typically necessary to take FPSs out of normal operating status. This often requires establishment of compensatory measures.

Table 2: Water Chemistry of Service Water at Some Stations

S.No	Parameters	Unit	Station A	Station B	Station C	Station D	Station E
1	pH		7.70	7.13	7.9	7.91	6.80
2	cond	µmhos/cm	320	145	460	362	332
3	Total hardness	ppm as CaCO ₃	120	20	168	128	114
4	CaH	ppm as CaCO ₃	72	16	68	90	62
5	MgH	ppm as CaCO ₃	48	4	100	38	52
6	P alk.	ppm as CaCO ₃	0	0	0	0	0
7	M alk.	ppm as CaCO ₃	132	12	174	82	90
8	T. alk.	ppm as CaCO ₃	132	12	174	82	90
9	Chloride	ppm as Cl	21	14	40	21.3	15.6
10	Turbidity	NTU	11		4.9	3.11	1.3
11	SiO ₂	ppm as SiO ₂	8		10.8	2.04	18.9
12	Sulphate	ppm as SO ₄	24	51.5	25	64.19	33
13	Iron	ppm as Fe	0.18		0.03	0.17	0.02
	PSI		7.52	12.37	7.18	8.05	8.22
	RSI		7.43	11.36	7.07	7.45	8.80
	LSI		0.13	- 2.12	0.41	0.23	-1.00
	Larsen Skold Index		1.46	46.25	1.24	6.06	4.06



Fig. 15 to 18: Typical Failures in Fire Water System



Fig. 19: Dark brown coloured fire water due to Biofouling



Fig. 20: Black Coloured water from Fire Hydrant due to SRB

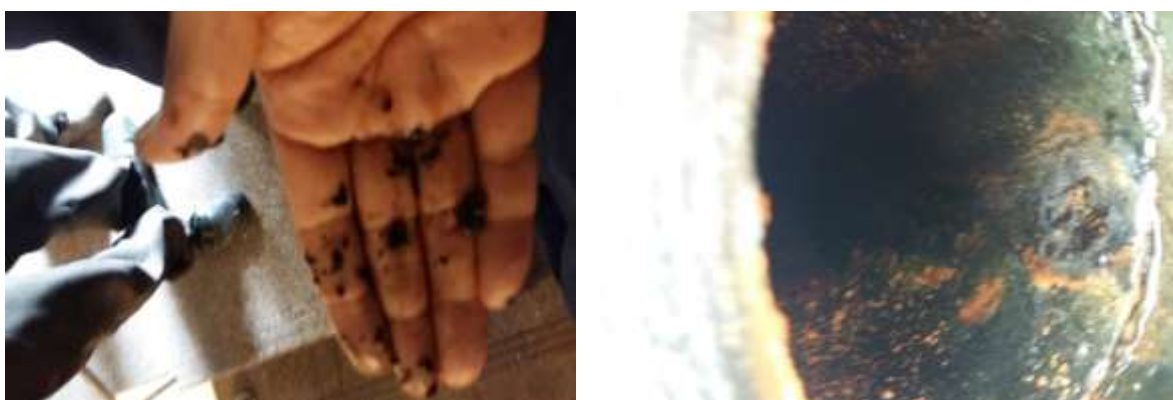


Fig. 21 & 22: Deposits from the fire hydrant and Fire Water Pipe

Typical Water quality of fire water at different locations of a plant analysed is indicated in **Table 3**. While **Table 4** indicates the data of another station.

Table 3: Water Quality Mapping at different Locations of Station A

S.No	Parameter	Unit	Sampling Locations			
			1	2	3	4
1	pH		7.75	7.7	8.15	7.7
2	cond	µmhos/cm	375	386	414	372
3	Total hardness	ppm as CaCO ₃	160	178	194	160
4	CaH	ppm as CaCO ₃	110	108	104	104
5	MgH	ppm as CaCO ₃	50	70	90	56
6	P alk.	ppm as CaCO ₃	Nil	Nil	Nil	Nil
7	M alk.	ppm as CaCO ₃	112	119	115	112
8	T. alk.	ppm as CaCO ₃	112	119	115	112
9	Chloride	ppm as Cl	30	22	30	30
10	Turbidity	NTU	12	9	9	13.5
11	SiO ₂	ppm as SiO ₂	7	7.5	8	7.5

S.No	Parameter	Unit	Sampling Locations			
12	Sulphate	ppm as SO ₄				
13	Iron	ppm as Fe	0.16	0.14	0.17	0.15
14	Dissolved O ₂	ppm	5.8	5.8	5.5	5.5
15	ORP	mv	380	390	300	480
16	Total PO ₄	ppm	0.3	0.2	0.3	0.3
17	FRC	ppm	0.5	0.3	0.1	0.8

Sampling Location Details

- 1 Fire water tank
- 2 CHP Area
- 3 Store Area
- 4 New Chlorination area

Table 4: Fire water quality at Station B

Sr.No	Parameter	UNIT	ETP Fire water	Near switchyard Fire water	Fire water at sevice building 4th floor
1	pH	-	8.45	8.24	8.00
2	Cond.	µS/cm	560	542	640
3	Turb.	NTU	5.7	10.0	6.4
4	M-Alk	mg/l	166	152	158
5	TH	mg/l	204	200	230
6	CaH	mg/l	114	110	132
7	MgH	mg/l	90	90	98
8	Cl (as caco ₃)	mg/l	48	46	56
9	SiO ₂	mg/l	25.0	26.3	26.5
10	SO ₄	mg/l	44.0	50.0	64.0
11	Fe	mg/l	0.40	0.56	0.28
12	PO ₄	mg/l	0.65	0.40	0.46
13	FRC	mg/l	-	-	-
14	ORP	mv	70	80	190
15	DO	mg/l	6.80	6.56	6.93
17	Potential	mv	-450	-420	-320

Table 5 indicates the deposit analysis from fire water system of station A, while **Table 6** provides the microbiological characteristics of water and fire line deposit.

Table 5: Chemical analysis of deposit from fire line of Station A

S. No.	PARAMETER	As	Sample 1	Sample 2	Sample 3
1	LOI at 105 oC	%	2.69	8.43	11.42
2	LOI at 500 oC	%	2.26	10.31	13.47
3	LOI at 800 oC	%	2.45	10.22	13.59
1.	Calcium	CaO (%)	0.1	0.1	0.1
2.	Magnesium	MgO (%)	0.1	0.1	0.1
3.	Sillica	SiO ₂ (%)	4.3	5.7	3.8
4.	Copper	CuO (%)	0.1	0.1	0.1
5.	Iron	Fe ₂ O ₃ (%)	78.3	79.6	84.5
6.	Sodium	Na ₂ O (%)	0.4	0.9	1.1
7.	Sulphate	SO ₄ (ppm)	67	62	52

Table 6: Microbiological Characteristics of Water samples and fire line deposits

S.No	Parameter	Test Results (Sample details)			Unit	Acceptable Value
		Make up Water	Cooling water	Pipe deposit		
1	Total Viable Count	3.1x10 ⁵	5.7x10 ⁵	4.4x10 ⁷	CFU/ml	<1 x10 ⁵ * <2 x10 ³ **
2	Total Fungal Count	<10	<10	5x10 ²	CFU/ml	<10
3	Sulphate Reducing Bacteria	<2	<2	26	MPN/100ml	<100/100 ml
4	Sulfur Oxidising Bacteria:					
	a. Thiobacillus thiooxidans	0	0	0	"	<2
	b.Thiobacillus thioparus	0	0	0	"	

5	Acid Producing Bacteria	17	21	220	"	<100/100 ml
6	Gas Producing Bacteria	<2	<2	14	"	<100/100 ml
7	Nitrifying Bacteria	<1	<1	1	"	N.S.
8	Ammonia Producers	7	6	28	"	N.S.
9	Slime Formers: (Pseudomonas aeruginosa)	31	49	350	"	N.S.
10	Iron Bacteria	N.D.	N.D.	N.D.	P/A	<2
11	Manganese Bacteria	N.D.	N.D.	N.D.	P/A	<2

MECHANISM OF CORROSION OF STEEL IN WATER:

Corrosion occurs because metals tend to oxidize when they come in contact with water, resulting in the formation of stable solids. Corrosion in water distribution systems can impact consumers' health, water treatment costs, and the aesthetics of finished water.

Various methods can be used to diagnose, evaluate, and control corrosion problems. Techniques for controlling it include distribution and plumbing system design considerations, water quality modifications, corrosion inhibitors, cathodic protection, and coatings and linings.

Corrosion can cause higher costs for a water system due to problems with:

- Decreased pumping capacity, caused by narrowed pipe diameters resulting from corrosion deposits;
- Decreased water production, caused by corrosion holes in the system, which reduce water pressure and increase the amount of finished water required to deliver a gallon of water to the point of consumption;
- Water damage to the system, caused by corrosion-related leaks;
- High replacement frequency of water heaters, radiators, valves, pipes, and meters because of corrosion damage; etc

Corrosion is a form of oxidation i.e.; it involves removal of electrons from the metals. An atom of iron becomes oxidized, when it leaves its neutral metallic states and enters solution as a positively charged ion:



This separation of charge constitutes an electric current, the magnitude of which is a measure of the rate of corrosion. For the continuation of current, the electrons liberated by the oxidation process must be absorbed in a compensating reduction reaction in which oxygen or water is reduced.



The oxidation and reduction reactions may occur close together or at widely separated sites on the metal surface, the electric circuit being completed by a flow of electrons in the metal and by transport of charged ions in the solution. Negative ions migrate to balance the positive metal ion released at the anodic site of oxidation and positive ions travel the other way to balance the negative hydrogen ions at the cathodic site of reduction.

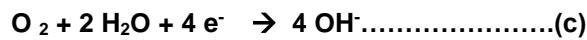
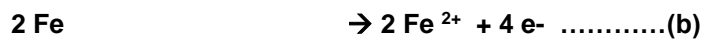
Driving force for the corrosion reactions is the difference between the free energies of the starting materials (ions & oxygen or water) and those of the corrosion products (oxides and ionic species such as Fe²⁺ and OH⁻). This difference is normally experienced as an electrical potential. It varies with the materials the temp. and the solution composition-especially with pH.

Aqueous Corrosion:

The aqueous corrosion of iron under aerobic conditions can be represented as:



The product, ferrous hydroxide is further oxidized to magnetite (Fe₃ O₄) or hydrated ferric oxide Fe (OH)₃ i.e. rust. The above reaction (a) can be re-written as:



The consumption of metal & release of electrons is termed as "anodic reaction", whereas consumption of electrons and dissolved species in the environment is termed as "cathodic reaction ", In case electrons are withdrawn from metal surface through electrical forces, then reaction (b) will speed up and reaction (c) will slow down. However, if additional electrons were supplied to the metal surface, the cathodic reaction would speed up and the anodic reaction would be inhibited. This is the basis of protection of metals by cathodic protection.

During the corrosion process, electrons are transferred through the metal from one site of the metal surface to another (electronic conduction). The current flowing round the circuit is proportional to the corrosion rate.

KEY FACTORS AFFECTING CORROSION OF IRON IN WATERS:

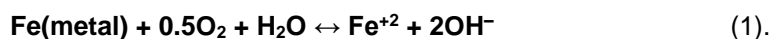
Key water quality parameters that are expected to influence corrosion of iron in waters include pH, alkalinity, and buffer intensity.

Role of pH: Weight loss is generally found to increase with increasing pH in the range 7 to 9, as is the degree of tuberculation. In contrast, by-product release was decreased at higher pH.7 Again; this is consistent with increased corrosion by-products being incorporated into the scale layer. However, one study found that both weight loss and iron concentration decreased as pH was raised from 8.5 to 9.2.10

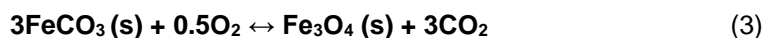
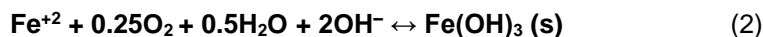
Alkalinity: Increasing alkalinity generally leads to lower weight loss and corrosion rate. Also, fewer customer complaints of red water were received when the alkalinity was maintained at greater than 60 mg/L as CaCO₃.

Buffer Intensity: Higher buffer intensity is often associated with increased alkalinity, although the two parameters are not exactly equivalent. However, their effect on iron corrosion seems to be similar. Several studies found the maximum weight loss for cast iron samples occurred at the minimum buffer intensity (pH 8.4) presumably because higher buffer intensity attenuates pH changes due to corrosion reactions at anodic and cathodic areas. However, one study found the opposite effect: weight loss for iron coupons in stagnant water increased with increasing buffer intensity.

Dissolved Oxygen: Dissolved oxygen (DO) is an important electron acceptor in the corrosion of metallic iron:



DO can also play a role in the oxidation of ferrous iron (Fe^{+2}) or iron scales, for example:



Thus, oxygen concentration can have varying effects on iron corrosion. As expected, the corrosion rate increases with increasing DO. However, effects on iron concentration and tuberculation may be mixed depending on the type of scale formed. Higher turbidity (a surrogate for iron concentration) was seen at lower oxygen saturation, but it is also reported that water free of DO will not tuberculate. DO is also responsible for the ability of buffering ions, including phosphates, to inhibit corrosion. For example, in water with $\text{DO} < 1 \text{ mg/L}$, solutions with phosphates had a higher corrosion rate compared to waters with no phosphates; in water with $1\text{--}6 \text{ mg/L DO}$, this trend was reversed. Thus some DO is required for inhibitors to function.

Biological Activity

Microbes are present in many distribution systems, and they can influence iron corrosion in a number of ways. Bacteria have been found in iron tubercles. Growth of a bacterial biofilm on a pipe wall may serve as a barrier to corrosion, but biofilms can also produce a differential aeration cell, leading to localized changes in oxygen concentration and electrical potential. The biopolymers in the biofilm may also uptake soluble metals. Various bacteria can affect iron speciation by reducing Fe^{+3} or oxidizing Fe^{+2} . Bacteria also may consume oxygen, cause localized pH gradients, and produce corrosive metabolites such as H_2S or iron phosphide. Thus, the role of biological activity in a water pipe can be mixed, but is generally considered to be detrimental to most aspects of iron corrosion. In cases where such activity is dominant, it is not surprising that biocides such as chlorine effectively reduce overall corrosion problems despite their oxidative properties.

Temperature

The effect of temperature on iron corrosion is often overlooked. Many parameters that influence corrosion can vary with temperature: dissolved oxygen (DO) solubility, solution properties (e.g. viscosity and ion mobility), ferrous iron oxidation rate, thermodynamic properties of iron scale (leading to formation of different phases or compounds), and biological activity. Moreover, heterogeneous iron scale formed on pipes may have large differences in physical properties such as scale density and coefficients of thermal expansion. If the scale is exposed to temperature gradients or cycling, these differences can cause mechanical stresses in the scale, leading to spalling or crack formation.

POSSIBLE REASONS OF CORROSION, FOULING AND BIOFOULING IN SERVICE WATER AND FIRE WATER SYSTEMS:

Possible reasons of Corrosion and Fouling including scale deposition and biofouling/Microbiologically Induced Corrosion in the Service Water System are:

- i) Untreated water except for clarification and some chlorination is used (no chemicals to control Scaling, Fouling, Corrosion and Biofouling are used in the Service Water (possibility of treatment chemicals mixing with potable water exists).
- ii) High concentration of DO as the system is open to atmosphere and there is a continuous make-up of around $470 \text{ m}^3/\text{hr}$ of service water to the system adding more oxygen.
- iii) No targeted microbiological control. In absence of proper biocide dosing biofouling and microbiologically induced corrosion is taking place.
- iv) Varying temperatures in the system.
- v) Use of ERW pipe without annealing leading to suspected seam weld corrosion.
- vi) Monitoring of Corrosion, Fouling, Deposition and biofouling are not available in the systems.

- vii) No flushing of the system is being adopted.

Reasons of Corrosion & Fouling Induced Damages to Fire Water System:

- i) High dissolved Oxygen due to continuous make-up to the system.
- ii) Use of ERW pipes.
- iii) Complete recirculation to the system is not available.
- iv) Full system drain or flushing is not available.
- v) There are lot of dead ends in the system leading to stagnancy in the system and consequently enhanced microbiological contamination/fouling/corrosion.
- vi) Non availability of sufficient ARV or ARVs not in use to remove oxygen.
- vii) Sufficient microbiological control is not available.
- viii) No chemical treatment is being adopted to control Corrosion and Fouling in the system.
- ix) Use of uncoated pipes.
- x) Non-availability of Corrosion monitoring in the system thus warnings are not available.
- xi) No schedule of draining, flushing of fire water is available.

Control Measures

Following methodology is suggested for controlling Corrosion & Fouling Induced damages in the Service Water System:

- i) Isolation of Service Water System from Potable Water System including from water going to toilets/wash rooms.
- ii) All Coolers, Heat exchangers in the system fouled with scale deposition should be cleaned off-line with inhibited sulphamic acid. It should be ensured that all these equipment are properly neutralized and treated with alkaline solution prior to installing back in the system.
- iii) The entire system is to be flushed thoroughly using around 1 ppm of chlorine/hypo with 2 ppm linear alkyl benzene sulphonate (LABS) and 5 ppm of polyacrylate (or available dispersant) (on the basis of make-up rate of service water. There will be foaming in the system so dosing of LABS should be done slowly to avoid excessive foaming. Once the parameters are stabilized at the outlet, the system should be thoroughly flushed with fresh service water to remove all settled debris in the system. The process can be repeated as and when system fouling is observed.
- iv) The Service Water System will be treated with same chemicals as are being used for cooling water system. Continuous dosing of chlorine to maintain FRC of 0.2 to 0.5 ppm (ORP > 500 mV) is to be ensured. RSI to be > 4 and Chloride should be < 250 ppm as chloride.
- v) Corrosion monitoring as per IS 8188 is to be carried out at the outlet side of all critical coolers and heat exchangers. Duplicate Coupons of all metallurgies involved are to be installed and coupons to be tested on 30 days and 90 days basis. Accordingly coupon rack shall be suitably designed. No pre-passivated coupon is to be used for monitoring.
- vi) **Long term solution will be replacement of metallic pipes with non-metallic pipes and fittings such as CPVC/GRP/HDPE in phased manner.**

Control Measures for Fire Water Systems:

- i) Identify all the sections which are forming dead ends and take action for providing drain points with valves and converting all possible sections to recirculating one.
- ii) Any blinded ARV to be made operational and if required additional ARV should be provided to remove the trapped air.
- iii) A schedule of flushing/draining/recirculation of the system should be developed and implemented. While flushing it should be monitored that all chemical parameters of fire water at the inlet and outlet are similar. Till that time flushing should be continued.
- iv) Once in 6 months the flushing may be carried out by adding 5 ppm LABS and 10 ppm Polyacrylate or available dispersant to removed sediments (precautions need to be taken as the chemicals will cause foaming).

- v) Arrangements of dosing sufficient chlorine so that even at the farthest end residual chlorine is available, to be developed so that at all times sufficient chlorine is present in the system.
- vi) There is a need to remove the existing deposits/tubercles from the system, however; complete system cannot be isolated for chemical cleaning so there are two options – a) either carry out cleaning using short stretches of system that can be isolated and temporary pipes, tanks and pumps with inhibited sulphamic or HCl solutions (details can be worked out if this option is selected. B) Use of SHMP at 50 – 100 ppm dose rate will help in removing iron deposits though time taken will be longer but it is online and no stopping of any section is required. It will require frequent draining of affected water.
- vii) Subsequently regular dosing of 10 to 15 ppm of SHMP with 1 ppm zinc can be dosed as a control measure. Regular chlorine dosing is required to maintain FRC of 0.5 – 1.0 ppm with ORP > 550 mV.
- viii) Alternately organo-phosphates with dispersants (as are used in cooling water system) can be used. In either mode it is to be ensured that the system water is circulated at least once in a day..
- ix) Corrosion coupons to be installed at strategic locations and monitoring to be carried out as IS 8188.
- x) Differential pressure gauges can be installed at strategic locations to monitor fouling/ biofouling in the system.
- xi) Readymade clamps may be used for short term repairs rather than local welding or using bolt/wood pieces for the purpose.

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