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Re-circulatory closed cooling water system: A case study of controlling corrosion rate at gas based power plant

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ABSTRACT

In a closed system, water circulates in a closed cycle and is subjected to alternate cooling and heating without air contact. Heat, absorbed by the water in the close system, is normally transferred by a water-to-water exchanger to the respondent-circulating water of an open respondent-circulating system, from which the heat is lost to atmosphere in this paper a detailed analysis is made to the closed cooling water system at power plant. The water quality indexes like PH, TDS, Conductivity and Iron pick up were used to evaluate the operational condition of cooling water systems. The paper analyzes various chemical treatment adopted to control corrosion rate and scaling synergetic effect of various combination are evaluated. Factors involved in this aspect are the water chemistry, system characteristics, environmental limitations, personal preferences and cost in adopting and implementation of operation of plant. This paper also demonstrates that the recovery and reuse of cooling water aspects like water make up monthly average besides corrosion rate reduction.

KEYWORDS

Water reuse/recycle;
Power industry;
Closed cooling system;
Corrosion rate;
Nitrite based treatment;
Morphlene.

INTRODUCTION

Water resources are finite. Closed systems are not subject to scale formation except when hard makeup water must be used. In closed systems, the oxygen concentration is lower than that of aerated systems. Therefore, the potential for corrosion is much lower. However, some corrosion exists, and loose corrosion products can cause fouling of piping, automatic valves, and vents. Theoretically, closed water systems should not require corrosion inhibitors. Any oxygen introduced with the initial makeup water should soon be depleted by oxidation of system metals, after which corrosion should no longer occur[1]. However, closed systems usually lose enough water and leak enough air to require corrosion protection. The inhibitors most commonly used are molybdate, silicate, or nitrite based. The use of chromates may be restricted because of regulations that classify them as carcinogens[2].

The amount of inhibitor needed depends on the system water temperature and its metallurgy. Closed systems usually require little additional treatment after the initial charge. Therefore, relatively high treatment levels can be used to provide a greater margin of safety at relatively low cost. An alkaline pH is maintained to prevent acidic corrosion. The closed re-circulating cooling water system evolved from methods used for the cooling of early engine designs. In a closed system, water circulates in a closed cycle and is subjected to alternate cooling and heating without air contact. Heat, absorbed by the water in the closed system, is normally transferred by a water-to-water exchanger to the re-circulating water of an open re-circulating system, from which the heat is lost to atmosphere[3].

Some closed systems, such as chilled water systems, operate at relatively low temperatures and require very little makeup water. Because no concentration of dissolved solids occurs, fairly hard makeup water may be used with little danger of scale formation. However, in diesel and gas engines, the high temperature of the jacket water significantly increases its tendency to deposit scale. Over a long period, the addition of even small amounts of hard makeup water causes a gradual buildup of scale in cylinders and cylinder heads. Where condensate is available, it is preferred for closed system cooling water makeup[4].

GEOGRAPHICAL LOCATION AND SPECIFICATIONS OF POWER PLANT

Samalkot Power Station (SPS) is located at Peddapuram in the state of Andhra Pradesh, the plant capacity is located at Peddapuram in the state of Andhra Pradesh, The Plant Capacity is 220 MW with an output capacity of 220 MW, The core machinery comprising of Gas Turbine Generator, Heat Recovery Steam Generator and Steam Turbine Generator along with their respective auxiliaries has been designed and supplied by Ansaldo. The construction of the project was initiated in October 1999 and the commercial operation commenced in December 2002.

The Plant uses its primary fuel as natural gas, which is sourced from Gas Authority of India Limited (GAIL). It is also capable of using Naphtha as an alternative fuel. Raw water needed for the Plant is pumped to the in-plant open water reservoir from the Samalkot Irrigation canal. It is a Combined cycle power plant. The power generated from the Gas Turbine and the Steam Turbine generators are stepped up to 220 KV and fed to a 220 KV outdoor substation. This power is transported by APTRANSCO through overhead transmission lines. In TABLE 1 given below is a year-on-year analysis of the plant's performance.

There is a single assembly comprising of one Gas Turbine Generating (GTG) unit connected to its Heat Recovery steam Generator (HRSG) and one steam Turbine Generating connected to its Heat Recovery Steam Generator (HRSG) and one Steam Turbine Generating (STG) unit. The gas turbine generating unit is capable of delivering power in continuous operating and consists of combustion chamber, starting system equipment, filtered air intake system, fuel system, turbine and compressor wash system, AC generator & exciter, fire protection system, exhaust emission control arrangement, bypass stack, piping necessary instrumentation and control, and other associated auxiliary system equipments. The detail specifications are given in TABLE 2 and 3 respectively. The HRSG is a dual pressure unit and generates high pressure and low pressure steam for the steam turbine generator from the GT exhaust gas.

TABLE 1 : Plant performance for the past 8 years

SPS Samalkot Plant Performance									
Parameters	**Units**	**FY 04-05**	**FY 05-06**	**FY 06-07**	**FY 07-08**	**FY 08-09**	**FY 09-10**	**FY 10-11**	**FY 11-12**
PLF	%	61	45.28	50.55	60.61	52.5	80.86	75.96	68.39
Availability	%	98.3	89.39	97.4	97.4	97.08	90.25	96.75	97.33

METHODS AND MATERIALS

Normally cooling water systems are only operated by operator's experience according to field investigation. The plant has 60Cu.Mtr/Hr capacity of the DM Plant, but the average consumption of DM water is 10-12 Cu. Mtr / Day. Since the consumption is very less our frequency of DM Plant running is almost once in a 2 months. RINFRA generate the DM water quality of pH 6.8+/-0.2, conductivity of max 0.5 micro mhos/ cm. A dedicated online pH meter and conductivity meters in the outlet lines of mixed bed used to measure water quality parameters. The capacity of the D.M. water storage tank in our plant is 2 X 300 m^3. During normal operation daily D.M. water consumption is 10 to 12 m^3. So D.M. water is stored in the tank for approx 25 days.

An alkaline pH is maintained to prevent acidic corrosion. Addition of the phosphate is to increase the pH and control the scaling. Chromate treatments in the range of 500-1000 ppm as CrO_4^{2-} are satisfactory unless bimetallic influences exist. The toxicity of high-chromate concentrations may restrict their use[5], particularly when a system must be drained frequently. Current legislation has significantly reduced the allowable discharge limits. Molybdate treatments provide effective corrosion protection and an environmentally acceptable alternative to chromate inhibitors[6]. Nitrite- molybdate-azole blends inhibit corrosion in steel, copper, aluminum, and mixed-metallurgy systems[7]. Molybdates are thermally stable and can provide excellent corrosion protection in both soft and hard water.

System pH is normally controlled between 7.0 and 9.0 and recommended treatment control limits are 200-300 ppm molybdate as MoO_4^{2-}. Molybdate inhibitors is not be used with calcium levels greater than 500 ppm. Nitrite is another widely accepted non chromate closed cooling water inhibitor[8]. Nitrite concentrations in the range of 600-1200 ppm as NO_2^- will suitably inhibit iron and steel corrosion when the pH is maintained above 7.0. In all cases, the pH of the circulating water maintained in the alkaline range, but below 9.0 when aluminum is present. When high nitrite levels are applied, acid feed may be required for pH control[9]. Morpholine gives better protection to the system by increases pH which important factor that influence corrosion[10].

The closed cooling System supplies DM Water to the various coolers of auxiliary equipment like lube oil coolers for feed pumps, steam turbine, gas turbine etc. 3x50% capacity DM cooling water pumps are used to supply the DM water after cooling in the plate type heat exchanger. Hot water return from above coolers is re-circulated back to the suction of the DM Cooling Water Pumps for flowing through the plate heat exchangers, where water is cooled by rejecting heat to the auxiliary cooling water. This cold water is then circulated through the coolers as mentioned above. An overhead tank is provided for make-up the losses in the closed cooling water system and also to take care of expansion of the closed cycle water. This tank has a provision of topping up by the DM water supply through a float control valve. The pH of the DM cooling water in the closed loop is maintained at around 9.5 by dosing of phosphate from chemical injection skid.

The Closed Cooling Water pumps are operated and controlled from the DCS in Central Control Room. This water flows through Plate Type Heat Exchangers. SPS CCW system treatment design is to maintain pH at 9.5 dosing Phosphate through phosphate dosing skid and injection pump. Un-controlled pH due to addition of phosphate, Increased Corrosion Rates and Continuous Iron Pick Up are the problems encountered.

Based on the problems that are encountered to control the Iron pick up and increasing corrosion rates in the system intern to safe guard the main equipment, coolers etc the following program (TABLE 3) is introduced to the DMCW system. A small pump with head more than 4 Bar is used for dosing Morpholine/ phosphate/ molydate/ nitrate at Mixed Bed outlet. It will be dosed through the impulse line. In view of the evaluating the effectiveness of controlling water quality indexes PH, conductivity, TDS and Iron pick up measured periodically for each treatment alone and different combinations proposed. Through water logging meter the water added for makeup too measured.

TABLE 2 : Plant specifications

Manufacturer	Siemens AG
Model	94.2
Fuel	Natural Gas, Naphtha, HSD
Output	140512 KW with Natural gas at 29° C ambient
Natural gas flow	9.284 KG/sec at 19.0 KG/cm2

TABLE 3 : STG unit details

STG Unit	
Manufacturer	Ansaldo
Type	Condensation, Extraction
No. of Cylinders	2 (HP & LP)
Steam exhaust	Horizontal

RESULTS AND DISCURSION

Since the storage time is more slowly pH drops and conductivity rises in the DM Tank. DM Water pH in storage tank decreases due to absorption of CO_2 from atmospheric air. pH of DM water in storage tanks decreases by 0.4 due to absorption of CO_2 from atmospheric air. Long storages of DM water in DM tank lead to reduction in pH and increasing some TDS in turn resulting in corrosion in the long run.

TABLE 4 : Data showing the water quality parameters unit and range for programmed control in CCWS

CLOSED COOLING WATER SYSTEM – PROGRAM CONTROL		
Parameter	Unit	
pH		7.5-10.0
Conductivity	µS/Cm	<7000
Turbidity	NTU	<10
Iron	Ppm as Fe	<1.0
Nitrate	Ppm as NO2	400-600
Corossion Rate	MPY-MS	<1.0
Total Bacterial Count	Per ml	<10,000 Col
Sulphate Reducing Bacteria	Per 100 ml	<100 MPN

Product performance data developed in laboratory studies simulating Nitrite-based treatment provides effective steel protection with results comparable to those obtained with molybdate; however, acceptable Admiralty corrosion inhibition is not achieved. On considering cost of chemical treatment molybdate is not economical.

Phosphate is used as anti-scaling agent. Periodically water chemical parameters are measured for every week. To reduce corrosion rate morphlene is added to DM tank, during 2005 similar periodic measurements taken as done in previous year (2004) the results are tabulated in TABLE 4 Morpholine is a colorless, mobile, organic chemical compound having the chemical formula O(CH2CH2)2NH. Hence Morpholine is dosed at Mixed Bed outlet during DM generation, then pH of DM water can be increased to 7.5-8.2. Then pH of DM water after 25 days will maintain at neutral level. The increase in Total dissolved solids due to addition of Morpholine is negligible.

This is used as a pH booster without any increase in TDS. From the result it is evident the average of Conductivity is found to be increased by three units only and further TDS is not increased. But still there is ap-

TABLE 5 : The average and maximum and minimum values of various water quality parameters during 2004 & 2005

		Phosphate treatment			Phosphate along with morpholene		
		2004			2005		
S.No.	Description	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM
1	pH	8.91	9.00	8.70	8.94	9.30	8.60
2	Conductivity µs/cm	25.05	32.00	18.00	28.58	42.00	22.00
3	Iron as Fe mg/lit	0.27	0.30	0.22	2.92	9.00	0.24
4	Total Hardness as $CaCO_3$ mg/lit	0.00	0.00	0.00	0.00	0.10	0.04
5	P-Alkalinity as $CaCO_3$ mg/lit	3.42	4.00	2.90	3.07	3.50	2.90
6	Total Alkalinity as $CaCO_3$ mg/lit	18.59	20.00	15.00	12.42	20.00	0.00
7	TDS	39.00	56.00	12.00	34.60	52.30	9.80
8	Phosphate/Nitrite in mg/lit	3.11	4.10	2.40	2.44	3.80	0.00

TABLE 6 : The average and maximum and minimum values of various water quality parameters during 2006 & 2007

		Nitrite based treatment			Nitrite based treatment along with morpholene		
		2006			2007		
S.No.	Description	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM
1	Ph	8.21	9.20	7.60	8.80	9.50	8.20
2	Conductivity µs/cm	1025.77	1155.00	950.00	1014.00	1186.00	942.00
3	Iron as Fe mg/lit	0.10	0.20	0.09	0.00	0.00	0.00
4	Total Hardness as $CaCO_3$ mg/lit	0.01	0.02	0.00	0.00	0.00	0.00
5	P-Alkalinity as $CaCO_3$ mg/lit	2.32	3.80	1.90	2.40	3.80	2.10
6	Total Alkalinity as $CaCO_3$ mg/lit	2.20	3.90	2.10	2.38	3.77	1.90
7	TDS	7.64	9.78	2.69	7.33	9.65	2.49
8	Phosphate/Nitrite in mg/lit	377.62	407.00	320.00	379.20	409.30	325.60

preciable rate of iron pick up suggestion needs improvement though the Morpholine gives better protection to the system, increases pH and does not increase TDS.

Then in 2006 Nitrite based treatment with azole is adopted and similar evaluation studies performed based on water quality controlling parameters (TABLE 5). The iorn pick up rate is found to be reduced quantitatively. But appreciable hike is noticed in PH. The high conductivity is due to high ion mobility of Nitrite ion. Being PH is too very crucial factor to control Corrosion rate. Combination of Morphlene and Nitrite based treatment is considered.

The results of TABLE 6 support that there is declined iron pickup rate that is the measurement corrosion tendency. During normal operation daily D.M. water consumption is 10 to 12 m^3per day during 2004 to 2006. The D.M water consumption during 2007 to 2010 is found to be 8 to 11m^3 per day. This indicating the synergetic effect of combination of appropriate chemical treatments to control corrosion and scaling and PH maintains during closed recirculation cooling system operation.

TABLE 7 : The average and maximum and minimum values of various iron pickup rate from 2008 & 2012

	Iron as Fe2+,ppm		
Year	**AVERAGE**	**MAXIMUM**	**MINIMUM**
2008	0.00	0.00	0.00
2009	0.02	0.04	0.01
2010	0.04	0.07	0.03
2011	0.07	0.08	0.03
2012 (up to August)	0.07	0.08	0.04

CONCLUSIONS

It therefore becomes evident that a well designed and efficiently administered Cooling water treatment regime is an absolute necessity to protect the process equipment against the water related problems.

The success of a water treatment program depends to a large extent on proper implementation, religious monitoring and a proactive approach in anticipating and addressing problems at site. Conscious focus throughout the treatment operation and Periodic Review shall be carried out towards Improvisations, Optimization. Those who has conventional dosing systems given as design in the CCW (DMCW) may critically review about the parameters and keeping the main equipment life into consideration an evaluation may be carried out based on the site conditions and a best suitable CCW treatment may be adopted. the feed water pH is maintained in the stipulated limits. Phosphate along with Morphlene treatment can increase the PH of DM water without appreciable rise in TDS but Iron pickup rate is considerable. Nitrite based treatment can reduce iron pickup rate.

The synergetic effect of combination of morplene and nitrite based treatment is very quantitative in reduction of iron pickup rate. Further there is considerable decline in water makeup amount.

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