

Table 5C-37 ANALYSIS DATA OF HOUSE SERVICE COOLING SYSTEM
REQUESTED BY JICA TEAM (GSTP)

September 9, 1982

ITEM	Unit	Gardner 1	Snyder 1	Snyder 2
Conductivity	at 25 ⁰ C	4.5	10	10
pH		9.0	9.6	9.5
Turbidity	ppm	Z	Z	Z
Hydrazine	ppb	8	5	5
Silica	ppm	0.018	0.012	0.018
Dissolved Oxygen	ppb	very high 60	60	60

b. Condenser Cooling Water

Gardner/Snyder and Malaya Thermal Plants utilize Laguna lake water as a cooling medium of the condenser while Tegen Thermal Plant make use of the Pasig River. It will be observed in the attached 1980 data, the water quality varies from rainy to dry season. During rainy season, the salt concentration and turbidity are high. The turbidity is about 40 ppm.

The attached sheet showed the material, protection method and actual plugged ratio of the main condensers of Gardner/Snyder and Malaya Thermal Plants.

Gardner-1 was initially operated with admiralty tube in the main condenser. All tubes were replaced with cupro-nickel material in 1979 when the main condenser reached 10% ratio of the tube plugged.

Gardner-2, Snyder-1 and -2, Malaya-1 and -2, have current cathodic protection in its main condenser. Only the cathodic protection of Malaya-1 and -2 are working. The ball cleaning device of Malaya-2 was under water.

The current cathodic protection is operated based on the conductivity of the cooling water. The chemical group was the one maintaining it before the management of its data was transferred to the maintenance group.

Table 5C-38 QUALITY ANALYSIS OF LAGUNA LAKE WATER

(January - December 1980)

	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul	Aug	Sept.	Oct	Nov.	Dec.
P. Alkalinity ppm as CaCO3	0	0	0	0	0	0	0	0	0	0	0	0
M.O. Alkalinity ppm as CaCO3	54	80	80	85	87	84	71	65	62	75	42	52
Chloride ppm as NaCl	250	250	270	260	263	614	625	587	578	567	210	220
Sulfate ppm as Na2SO4	50	50	53	50	51	50	51	45	45	49	48	53
T. Hardness ppm as CaCO3	91	93	100	98	112	214	214	200	198	195	85	80
Ca Hardness ppm as CaCO3	27	28	34	30	32	50	60	55	56	62	39	23
Mg Hardness ppm as CaCO3	64	65	66	68	80	164	157	145	142	133	46	57
Silica ppm as SiO2	0.4	0.4	0.45	0.38	0.4	0.39	0.44	0.30	0.30	0.35	0.35	0.35
pH	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.5	7.6	7.5	7.1

— Dry Season ————— Rainy Season ————— Dry Season —————

Table 5C-39 CONDENSER COOLING WATER TREATMENT

Material of cooling tube	GARDNER-1	GARDNER-2	SNYDER-1	SNYDER-2	MALAYA-1	MALAYA-2	
	Cupro-Nickel	Admiralty Metal	Admiralty Metal	Admiralty Metal	Al-Brass	Al-Brass 90-10 Cupro-Nickel (Air Cooling Zone)	SVS - 316
Protect Method	Sacrificial Anode	Impressed Current Cathodic Protection (Not working)	Impressed Current Cathodic Protection (Not working)	Impressed Current Cathodic Protection (Not working)	Impressed Current Cathodic Protection	Impressed Current Cathodic Protection Ball, cleaning (Not working)	
Plugged Tube Ratio	Date	August 1982	August 1982	July 1982	June 1982	August 1982	Sept. 1982
	No. of Plug Tube	-	-	-	-	517	3177
	%	-	-	-	-	3.01	31.52
	No. of Plug Tube	-	-	-	-	531	1495
	%	-	-	-	-	3.05	14.8
	No. of Plug Tube	0	266	255	58	1048	4672
Total	0	1.09	1.05	0.17	3.01	23.13	
	No. of Total Tube	14748	24400	24400	34800	34800	20160

Malaya-2 ball cleaning device was operated for about 6 months since the units initial operation. During the process of its operation, the ratio of ball recovery was low and there was no spare ball available.

Malaya-2 main condenser has 316 SS tube materials. At present the number of tubes plugged was about 23%. The unit experienced frequent condenser leakage. It might be due to the presence of scale in between the tube and high concentration of chloride which causes service corrosion of the tube.

Malaya-2 main condenser will be retube using Al-Brass materials in the next overhauling. In 1979 Gardner-1 was retubed changing the materials from Al-Brass to cupro-nickel. JICA team is wondering why Malaya 2 main condenser tube is to be replaced with Al-Brass materials instead of the cupro-nickel type which is resistant to Laguna Lake water corrosion.

Leak Test with Half Condenser Operation

On August 25, 1982, during start-up of Malaya-2 there was an indication of condenser leakage so that on September 3, 1982, half condenser operation was performed and subsequently leak test was done on one side of the condenser. NAPOCOR utilized the soap sud method in finding the leaky tubes.

JICA team recommends the use of the vinyl sheet method in finding the leaky tubes. In the case of Malaya-2 main condenser vinyl shut method is not applicable because of the following.

- 1) There were plenty of tube plugged on both side of the condenser. The vinyl sheet will not stick since the plug protrude for about 1 to 1.5 cm.
- 2) The vinyl sheet available at the plant is too thick.
- 3) No good connection between two compartment of the condenser.
- 4) The person who will perform the said method will lose interest due to hot condition inside the condenser.

During the soap sud test of Malaya-2 main condenser, 200 tubes were found to be leaking at side B main condenser side A was not checked. All leaky tubes were plugged.

The preparation for determining the leaky tubes was observed to consume more time. Like for instance, the preparation of scaffolding to be used for inspection, it took them 12 hours to complete the work.

Recommendation

Cooling water management is directly related to Plant efficiency which will result on condenser low vacuum. Improper treatment of cooling water will cause condenser tube corrosion and ultimately will contaminate the feed-water system.

The current cathodic protection and the ball cleaning device should be repaired immediately and placed on operation.

In the determination of leaky tubes by soap sud method, the process just cover only one side which is less effective. Like in the case of the heat exchanger, the reliability of the said method is very low.

The vinyl sheet method is very effective and covers wide area of the condenser. In order that the said process could be applied to NAPOCOR's Thermal Plants main condenser, the following should be implemented.

- 1) The plug should protrude to the tube plate for at least 2 to 5 mm.
- 2) Vinyl sheet should have a thickness of below 0.1 mm.

The material should be vinyl coated.

All scaffoldings needed for the inspection of the main condenser should always be placed near its side. In this manner, preparation time during condenser leakage determination will be shorter.

The method being used in Japan for the determination of condenser leakage, is based on the conductivity reading often passing thru cation resin. During half condenser operation, the corresponding conductivity is taken and compared it with the result on the other side. The side with the higher reading is the one to be checked.

During inspection of main condenser always use low voltage source of lighting.

10) Disposition of Abnormality in Feedwatera. Unit Start-up

During start-up of drum and once-through type boilers, the water quality limits recommended by the boiler maker should always be followed. Below are the water quality limits recommended by boiler manufacturer.

Feedwater Quality Limit During Start-up(G-2, S-1, S-2 and M-1)

<u>Process</u>	<u>N₂H₄</u>	<u>Fe</u>	<u>Cu</u>	<u>SiO₂</u>	<u>micro S/cm</u>
	<u>ppb</u>	<u>ppb</u>	<u>ppb</u>	<u>ppb</u>	<u>(After Cation)</u>
<u>Fire Boiler:</u>					
Raise Temp. up					
to 370°F, (177°C)	10-70	200	--	--	1
Raise Temp.					
400°F (204°C)	10-70	100			
500°F (260°C)		100			
680°F (360°C)		100		80	
<u>Turbine Rolling</u>		100	10	40	
<u>On Load</u>		60	5	30	

In the start-up of once-through units at Gardner/Snyder Thermal Plant, it was observed that the Plant experience problem in the supply of demineralized water. On September 2, 1982, during start-up of Snyder-1, the water quality items being analyzed were iron (Fe), silica (SiO₂) and chloride (Cl⁻) only. In the analysis of water quality, pH, hydrogen, dissolved oxygen and conductivity (often passing thru cation resin) should be included.

In addition, during the start-up of the above unit, the iron was being analyzed utilizing the millipore filter. As recommended by UTL team, iron should be analyzed utilizing the TPTZ method. The said method will give the true value of iron. Likewise, dissolved oxygen should always be analyzed. As reported by UTL team, they observed that high concentration of dissolved oxygen excess during start-up of once-through units. To minimize presence of dissolved oxygen, an additional dosage of hydrazine is needed.

In the start-up of once-through units, it was observed that the corrosion products from the boiler were all being removed by the condensate polisher. In the presence of high concentration of iron in the system, blowdown could not be done due to lack of demineralized water.

Moreover, during start-up, the condensate polisher was being operated not H-OH type. All impurities were absorbed by the polishers causing its overloading.

Recommendation

During start-up of once-through units, it was observed that presence of high concentration of dissolved oxygen excess. JICA team recommends frequent analysis of dissolved oxygen should be done so that right treatment should be implemented.

The presence of high concentration of corrosion product in the condensate and feedwater system should be avoided in order to minimize its deposition to the boiler system and turbine blade. If the corrosion products are carried over to the boiler and turbine, during stoppage of the units the deposits will go into the feedwater system during start-up.

In case that the presence of corrosion products could not be avoided in the condensate and feedwater system, JICA team recommends that blowdown should be done so that the condensate polisher will not be overloaded. The condensate polisher should be operated H-OH type.

The dissolved oxygen should be controlled with the addition of the right concentration of hydrazine.

For rapidity of analysis, iron should be analyzed utilizing millipore filter if the iron concentration is more than 500 ppb. If the iron is below 500 ppb, iron analysis should be done using TPTZ method.

In Japan, the start-up of the unit is based on the attached start-up data. To facilitate start-up of once-through unit, JICA team recommends installation of blowing pipe at the condensate pump discharge.

Figure 5C-16 START-UP ON SNYDER UNIT NO. 1 (September 2, 1982)

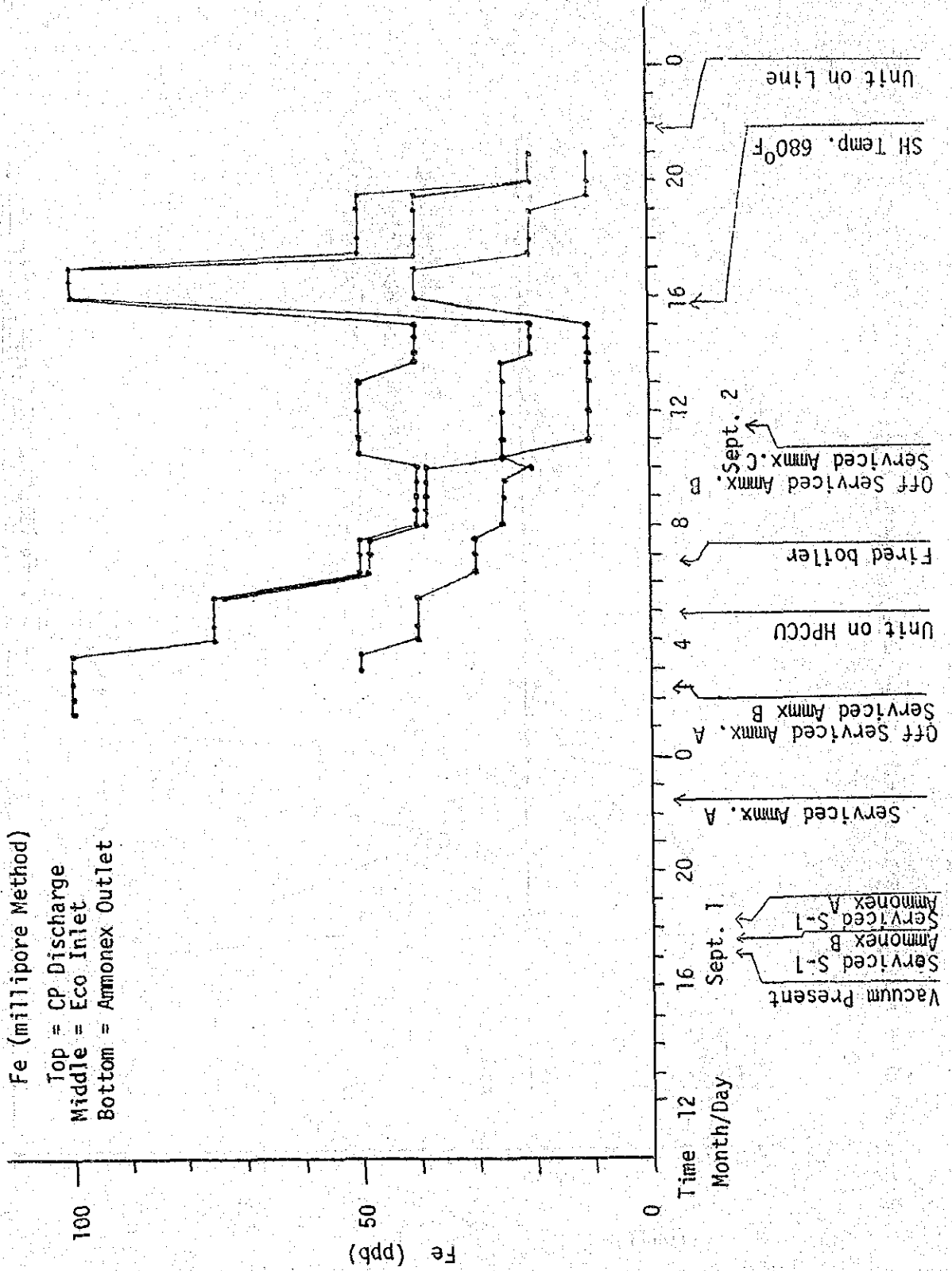


Figure 5C-17 START-UP ON SNYDER UNIT NO. 1 (September 2, 1982)

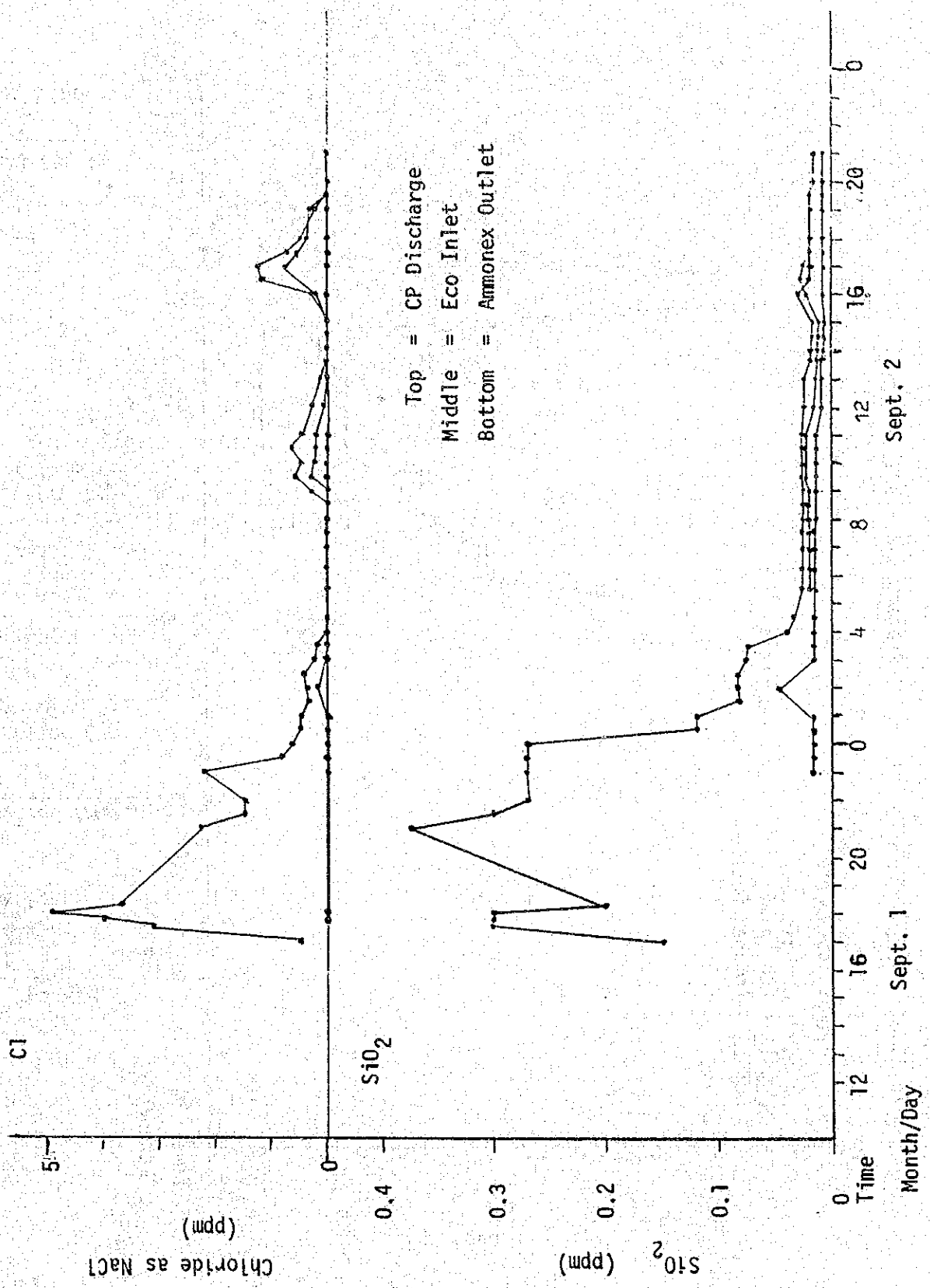
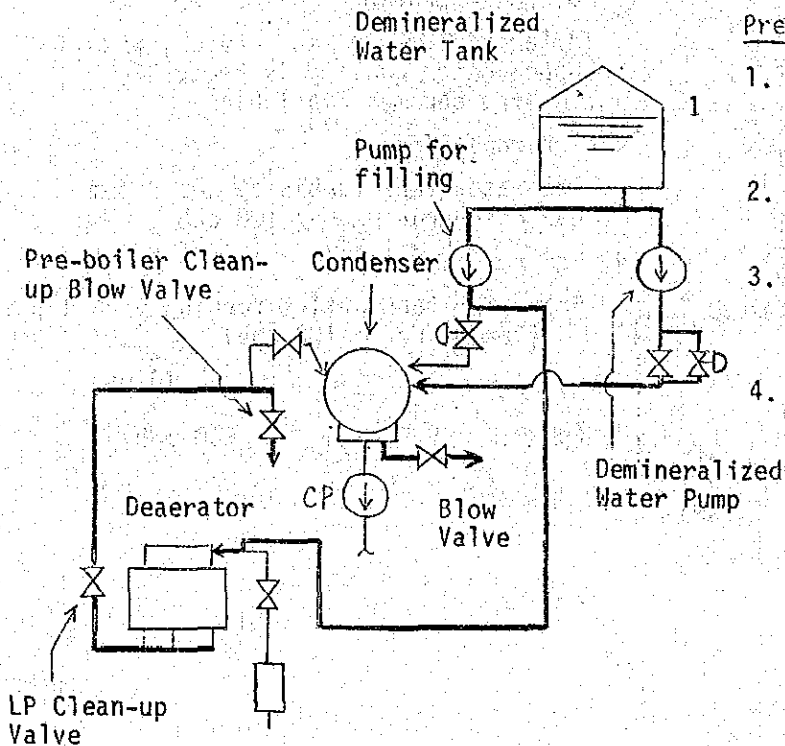


Figure 5C-18 CLEAN-UP PROCEDURE (An example in Japan)

- Super Critical Boiler -

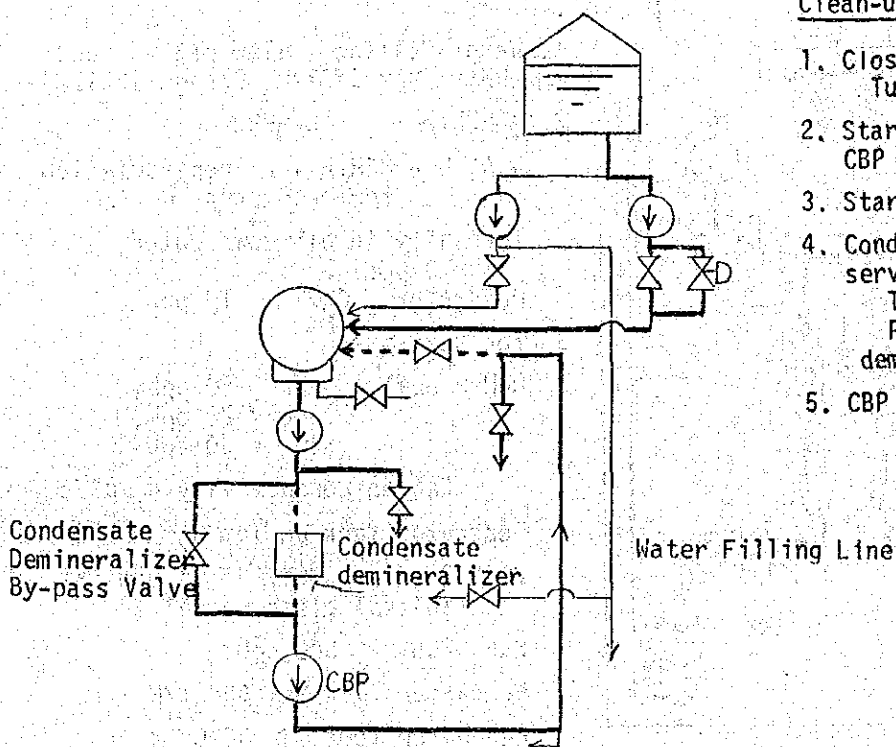


Preparation

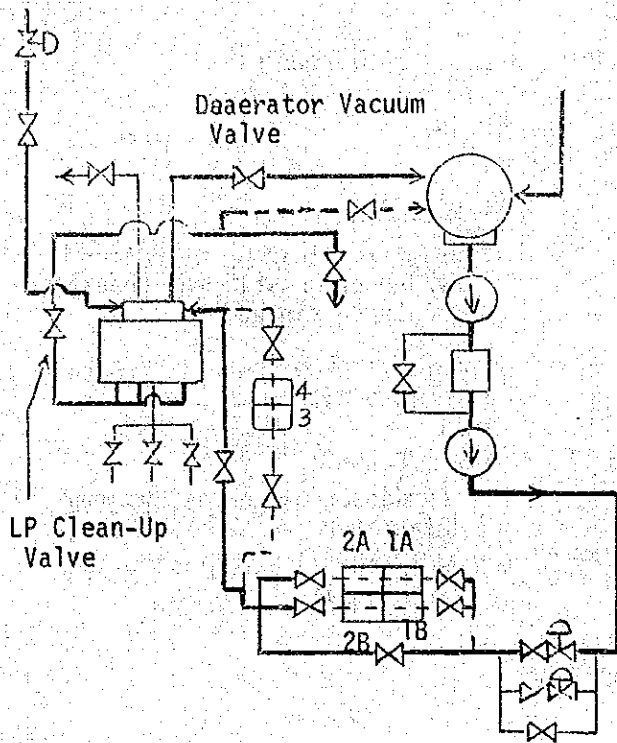
1. Prior to clean-up operation condenser hotwell and deaerator should be rinsed.
2. Hotwell Blow, Deaerator Blow
Turbidity < 3 ppm
3. Water Level after Blow
Condenser - NWL + 200 mm
Deaerator - NWL + 200 mm
4. Operation is essentially done individually.

Clean-up Around Condenser

1. Close blow valve
Turbidity < 3 ppm
2. Start chemical injection (to CBP discharge) N_2H_4 1 - 5 ppm
3. Start vacuum up
4. Condensate demineralizer in service
Turbidity < 5 ppm
Pre filter = 2 towers
demineralizer = 2 towers
5. CBP discharge O_2 < 200 ppb
(Target < 100 ppb)

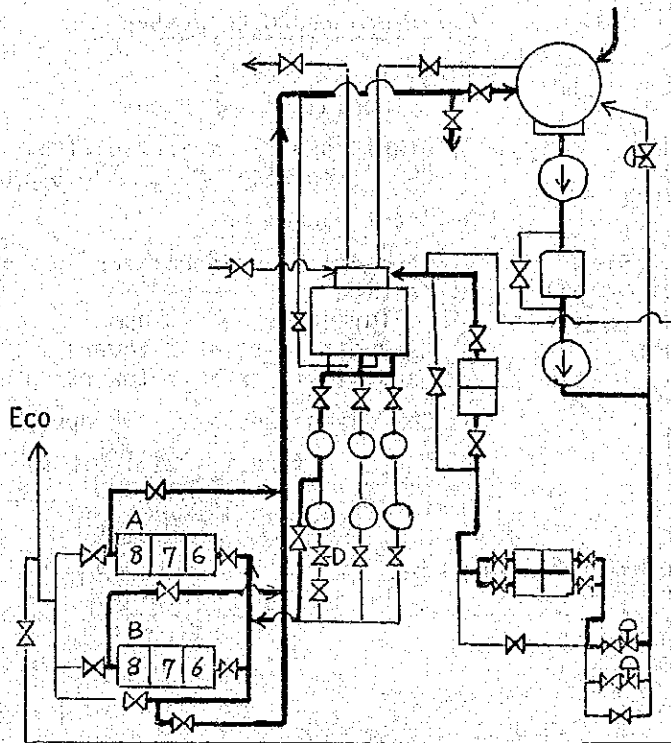


Low Pressure Clean-Up



1. Start deaerator vacuum up
(LP Htr: Bypass, Blow off)
-NH₄OH injection (pH 9.3 - 9.5)
2. LP Htr. in service
Deaerator inlet turbidity < 3 ppm
CBP discharge O₂ < 100 ppb
After LP 1.2 Htr. in service, when upper water quality is kept, LP 3.4 Htr. becomes available.
3. Recirculation
Deaerator tank turbidity < 3 ppm
CBP dsicharge O₂ < 100 ppb
4. For next step
Deaerator tank outlet turbidity < 1 ppm
(Target Fe < 100 ppb)
O₂ < 10 ppb
(pH 9.3 - 9.5, N₂H₄ > 200 ppb)

PRE BOILER Clean-up



1. Water filling → Blow off without HPHtr (Max 255T/H. Design 128T/H)
2. A-HPHtr → B-HPHtr
→ A, B - HPHtr ---> recirculation for each steps ⇔
Turbidity in blowdown water < 3 ppm
Deaerator O₂ < 10 ppb
3. for next step
HPHtr outlet = Fe < 50 ppb,
Cu < 20 ppb,
SiO₂ < 30 ppb
Cation conductivity < 1uS/cm
Deaerator tank outlet O₂ < 10 ppb
pH 9.3 - 9.6, oil < 1 ppm (at initial clean-up only)
N₂H₄ 200 - 300 ppb
Feedwater flow Max 508 T/H
Feedwater temp. > 60°C

Boiler Cold Clean-up

1. To boiler at about 10% MCR Feed water flow rate
2. Blow off → recirculation
Start-up separator turbidity < 3 ppm
3. for next step
Eco inlet Fe < 50 ppb, Cu < 20 ppb
SiO₂ < 30 ppb,
cation conductivity < 1 uS/cm
Deaerator tank O₂ < 10 ppb
Water-wall outlet Fe < 200 ppb
(Target Fe < 100)

Boiler Hot Clean-Up

1. Boiler firing after pressure increase at 5% MCR₂ feedwater flow rate and 246 kg/cm² (WW outlet)
2. WW outlet temperature 170°C
3. Eco inlet Fe < 50 ppb, Cu < 20 ppb
SiO₂ < 30 ppb
cation conductivity < 1 uS/cm
Deaerator tank outlet O₂ < 10 ppb
WW outlet Fe < 100 ppb
(Target < 50 ppb)

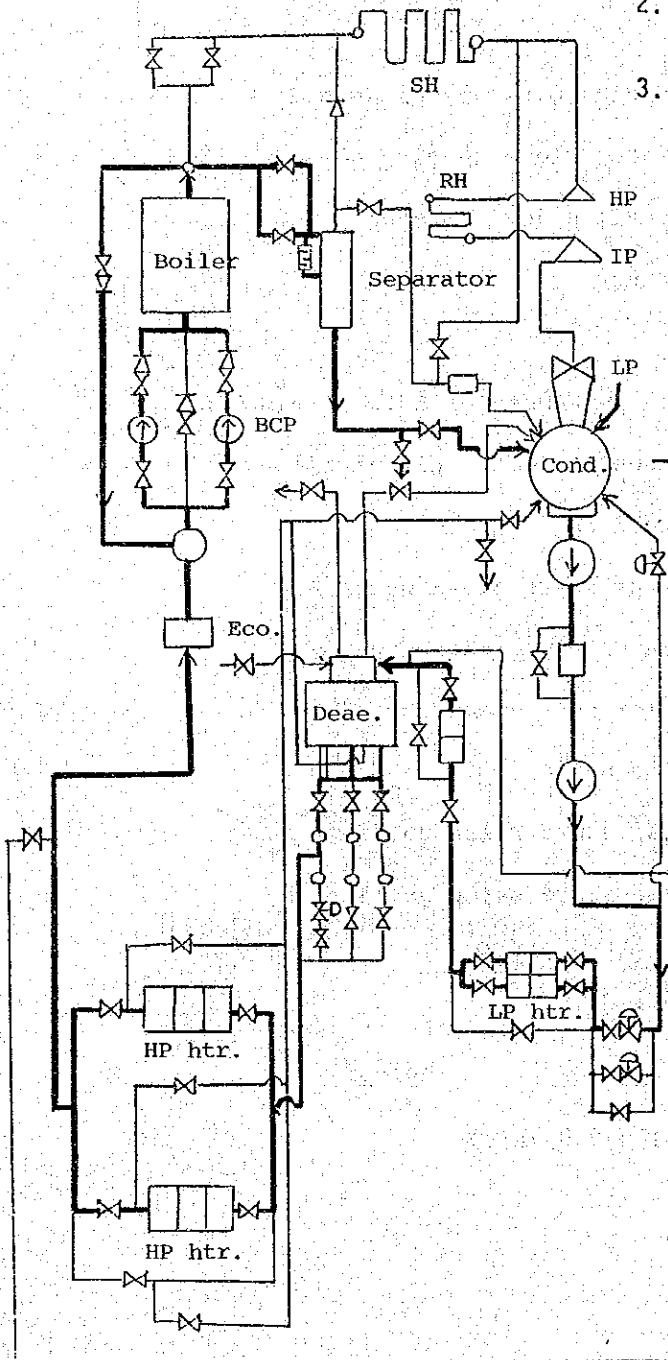


Table 5C-40 EXAMPLE OF WATER QUALITY ANALYSIS DATA
DURING UNIT START-UP

(In case of Kyushu Electric Power Co.)

1. Outage period 21 days
2. System Lay up
 - (1) Deaerator: Water flooding with 50 ppm as N_2H_4
 - (2) Boiler water wall: Water flooding with 50 ppm as N_2H_4
 - (3) LP Heater, HP Heater cell side: N_2 seal
 - (4) Condenser: Not treating
3. Start up schedule
 - April 3 - 0:44 pm - 1:50 pm Condenser Hotwell Flushing
 - 6:48 pm - Condensate water circulation
 - 7:23 - Vacuum up
 - April 4 - 7:30 am - Low pressure clean up
 - 1:15 pm - High pressure clean up
 - 6:00 - Boiler cold clean up
 - April 5 - 1:59 am - Fired boiler
 - 2:30 - Temperature raise up, Step 1
 - 5:49 - Temperature raise up, Step 2
 - 10:00 - Turbine rolling
 - 0:45 pm - On line
4. Consumption of Demineralized Water 680 m^3
(179,000 gals)

Table 5C-40 EXAMPLE OF WATER QUALITY ANALYSIS DATA

Start up Procedure	Date Time	Sample	PH	MS /cm	Si O ₂ ppb	N ₂ H ₄ ppb	Fe ppb	O ₂ ppb	Turb. ppm	REMARKS
Hotwell Flushing	April 3 1:50 pm	CP out				3800			3.2	April 3, 0:44 pm 1:50 pm Condenser Hotwell Flushing 7:23 pm Vac. up
Clean up around condenser	April 4 7:00 am	CP out						170	0.3	
Low Pressure Clean-up	7:30	CP out	8.7	1.9		600	70	170	0.3	April 4 7:30 am Low pressure clean up 1:15 pm High Pressure Clean up
		CBP out					19	170		
	8:30	CP out	9.0	2.2	9	1000	60	170		
		Dea inlet	9.1	3.0	8		50	200		
	11:00	Dea tank	9.1	3.8	8	1380	50	200		
		CP out	9.3	4.5		1100		170		
	1:00 pm	Dea inlet	9.3	3.8				170		
		Dea tank	9.3	3.9		150		120		
		CP out	9.4	6.2	8	900	65	90		
		Dea inlet	9.4	6.4	6		25	5		
		Dea tank	9.4	6.3	6	700	25	0		
High Pressure Clean-up	2:30	CP out	9.4	5.6	8		150	170		
		Dea inlet	9.4	4.5	6		50	170		
		Dea tank	9.4	5.5	6	1100	50	90		
		#8hr out	9.4	5.3	6		70			
	5:30	CP out	9.4	5.1	8		80	120		
		Dea inlet	9.4	4.9	6		45	120		
		Dea tank	9.4	5.2	6	850	50	10		
		#8hr out	9.4	5.5	7		40			
Boiler Cold Clean-up	8:00	CP out	9.4	4.8			215	170		6:00 Boiler Cold Clean up 6:00 - 7:00 Blowing
		Dea inlet	9.4	5.0		1375	18			
		Dea tank	9.4	6.1			20	5		
		Eco inlet	9.5	7.6		925	15	0		
		Waterwall out	9.5	7.8			490			
	10:00	Starting Separator -Dr.	9.5	8.0			860			
		CP out					150			
		Dea inlet	9.4	6.5		1050	40			
		Eco inlet	9.5	7.1		900	45			

Table 5C-40 EXAMPLE OF WATER QUALITY ANALYSIS DATA

Start up Procedure	Date Time	Sample	PH	MS / cm	Si O ₂ ppb	N ₂ H ₄ ppb	Fe ppb	O ₂ ppb	Turb ppm	R E M A R K S
	April 5 0:00am	Waterwall out Starting Dv	9.5	8.0			75 115			
		CP out			8		100	170		
		Dea inlet	9.4	6.4	6	1050	35	60		
		Eco inlet	9.4	5.9	6	920	36	0		
		Water well out	9.4	6.1	7		43			
	2:00	CP out					135	170		April 5 1:59 am ired Boiler
		Dea inlet	9.5	7.2		570	31	40		
		Eco inlet	9.5	7.2		340	29	0		
		W.W out					32			
	4:00	CP out					140			2:30 Temperature raise
		Dea inlet	9.5	8.3		570	38			
		Eco inlet	9.5	7.4		490	13			
		W.W out					16			3:30 - 8:10 Turbine warming
	7:00	CP out					340	140		5:49 Temperature raise
		Dea inlet	9.5	6.8		250	8	50		
		Eco inlet	9.5	8.2		250	16	0		
		W.W out					5			
	9:30	CP out			8		150	60		
		Dea inlet	9.5	6.7	9	91	8	5		
		Eco inlet	9.5	7.1	8	77	7	0		
		W.W out			8		10			
		SH out			6		3			
	11:30	CP out					700	40		10:00 Turbine start
		Dea inlet	9.5	6.7		67	9	10		
		Eco inlet	9.5	7.3		57	8	0		
		W.W out					5			0:45 pm on line
	2:30 pm	CP out					1060	10		
		Dea inlet	9.5	7.2		75	39	0		
		Eco inlet	9.5	7.0		47	21	0		1:00 LP Heater in Service
		W.W out					7			

Table 5C-40 EXAMPLE OF WATER QUALITY ANALYSIS DATA

Start up Procedure	Date Time	Sample	PH	MS / cm	Si O ₂ ppb	N ₂ H ₄ ppb	Fe ppb	O ₂ ppb	Turb. ppm	REMARKS
	3:30	CP out					1100	0		2:10 LP heater in Service
		Dea inlet				24	140	0		
		Eco inlet				15	60	0		4:30 LP Heater Drain in System
		W.W out					28			
		LP Hr Drain			13		1100	0		
		HP Hr Drain			15		10			
	4:30 pm	CP out					900	0		5:00 HP Heater Drain in system
		Dea inlet	9.5	8.1		18	120	0		
		Eco inlet	9.5	8.1		12	60	0		
		W.W out					7			
		LP Hr.Dr	9.5	7.9			850	0		
		HP Hr Dr	9.5	7.0			17			
	6:00	LP Hr Dr					70	0		
		HP Hr Dr					15			

b. Condenser in Leakage

JICA team found out on their survey that the cause of deterioration of all units were due to condenser in leakage and improper water treatment. It was observed that condenser in leakage is not properly detected due to the absence of continuous conductivity monitoring instruments. The detection of condenser in leakage is only done analytically.

The method of chloride analysis being used by Malaya and Gardner/Snyder Thermal Plants was observed to be less accurate. Like in the case of Gardner/Snyder Thermal Plant, the detection limit of chloride is about 0.15 ppm while Malaya is about 0.1 ppm. JICA team attributed it to the type of cell being used in the analysis. Both Thermal Plants are using a shorter cell in chloride analysis which is not so accurate.

Comparing the minimum detection limits of chloride to the attached graph, it will be noted that the 0.1 ppm chloride has an equivalent of 1.2 micro S/cm while the 0.15 ppm chloride has an equivalent of 1.8 micro S/cm. The equivalent conductivity of the minimum detection limit of chloride is way beyond the maximum limit value of feedwater conductivity of 0.3 micro S/cm.

Likewise, it was observed that the condensate polisher is being operated as NH_4 type. Since chloride analysis is not so accurate a detection limit is high, the whole feedwater system is already contaminated before the chemical section will realize the presence of chloride.

Continuous sodium monitoring instruments were installed at the condensate pump discharge and condensate polisher outlet of Gardner/Snyder once-through units. The said instruments properly monitored any abnormality in the feedwater system. Last August 16, 1982, Snyder-1 experienced condenser in leakage. It was noted that the sodium concentration at the condensate pump discharge keeps on increasing. JICA team monitored its corresponding conductivity often passing thru cation resin. With the increase in sodium concentration, the conductivity also increased. The maximum chloride was about 0.1 ppm, 20 ppb sodium and 2.4 micro S/cm conductivity often passing cation resin. Sawdust was poured in the tunnel and the chloride concentration gradually decreased.

Gardner-1 and Malaya-2 drum type boilers have no sodium monitoring instruments. The conductivity monitoring instruments are not working. In the detection of condenser in leakage, chloride analysis is just being done.

The disposition of condenser in leakage of all once-through units is taking care of by the condensate polishers while the drum type boilers are being protected by blowing down and by injection of disodium and trisodium phosphate. The condensate polishers should be operated H-OH type in case of condenser in leakage. It was observed that it is not being operated as such.

Last August 25, 1982 at Malaya-2, JICA team observed that said unit experienced condenser in leakage. In order to minimize concentration of chloride in the boiler saline, blow down and injection of disodium and trisodium phosphate were done. Continuously blow down was intermitted due to lack of demineralized water. The chloride at the boiler drum reached up to 6 ppm. Half condenser operation could not be performed due to great power demand. Half condenser inspection was done on September 3, 1982 and the leaky tubes were plugged.

Recommendation

- 1) Condenser tube leak should be treated at early stage.
- 2) All units should be provided with continuous conductivity monitoring instruments.
- 3) Maintenance of the sodium analyzer should be done once a month to make it always reliable.
- 4) Improvement of chloride analysis in order to increase its detection limit.
- 5) During condenser leakage the following procedure should be implemented so that contamination of the boiler system will be avoided.

In case of once-through boiler, the following steps should be followed:

- a) Condensate polisher should be operated H-OH type.

b) For the drum type boiler with a drum pressure of 170 kg/cm². The following standard treatment are needed.

- Boiler water conductivity after passing thru cation resin should be maintained below 5 micro S/cm. Conductivity beyond 5 micro S/cm, blowing down of the boiler saline should be done.
- In case that the boiler saline conductivity, after passing cation resin of 5 micro S/cm cannot be controlled, injection of disodium and trisodium phosphate should be done. the molar ratio of 2.5 - 2.6 sodium phosphate and 1.0 ppm phosphate residual should be maintained.

11) Overhauling

a. Inspection

During overhauling of Gardner-2, JICA team inspected the condenser, deaerator, etc. Below is the result of inspection:

Condenser (steam side) and Hotwell

Condenser tube surfaces is reddish brown color, of ferric oxide. The upper tubes were damaged due to turbine blade breakage. The hotwell accumulated plenty of sludge deposits.

Deaerator Tank and Flash Tank

The wall of the deaerator was coated with black magnetite and the bottom position with little reddish brown coating.

The manhole of the deaerator and flash tank were noted to be opened for quite sometime. Plenty of dust particle accumulated inside the manhole.

Recommendation

During unit overhauling, inspection of condenser, deaerator, flash tank, etc. should be done in order to determine the effectiveness of chemical management. The record of the past inspection should always be kept and used for comparison purposes. Once the unit is uncovered for overhauling, inspection should be done as early as possible. All deposits and sludge should be taken, weighed and analyzed to be used as reference for the next overhauling. On this manner effectiveness of chemical treatment could easily be determined.

Table 5C-41 ITEM FOR INSPECTION DURING OVERHAULING

EQUIPMENT	ITEMS FOR INSPECTION	DISPOSITION
Raw water tank clean well Demineralized Water Tank Condenser Water Tank	Volume and distribution of deposits, Growth of duckweed, living things, lyning and point	Cleaning
Demineralizer Plant, Condensate Polisher	Inside of Resin Tower, etc. (See. 5.3.3 - 3.4 Demineralizer, Condensate Polisher)	Makeup of Resin, etc.
Condenser (Steam Side)	Corrosion, mechanical destoration of condenser tube, volume and distribution of deposite in hotwell.	Cleaning
Feedwater Water Deaerator heater	Corrosion of tube plate, tube, volume and distribution of sludge in water chamber.	Ditto
Deaerator	Protective film inside deaerator Volume and distribution of mud	Ditto
Boiler Header	(Cut the inspection hole) Corrosion Volume and distribution of mud	Ditto
Drum Flash Tank	Corrosion of internal and orifice volume and distribution of mud	Ditto

Turbine	Color, volume and distribution of scale on blade. Erosion of blade with drain.	Ditto
Condenser (cooling water side) Heat exchanger (cooling water side)	Number of clogging tube with shell or other things. Scale of tube. Corrosion of tube plate and tube. Situation of Zinc plate, or cathodic electrode.	Ditto

b. Boiler and Auxiliaries Preservation Treatment

At present, Gardner/Snyder and Malaya Thermal Plants have no actual standard preservation treatment being implemented during unit's shutdown. Wet storage of the boiler often chemical cleaning is done with 500 ppm N_2H_4 being maintained in the system. In the case of Gardner 2 it was wet stored for two weeks with the above concentration of Hydrazine.

Last August 29, 1982 Snyder-1 tripped and was started on September 3, 1982. JICA team advised the chemical section to treat the deaerator and boiler system with 10 ppm N_2H_4 during the shutdown period.

Recommendation

During outage of the unit, entry of oxygen in the system could not be avoided without proper treatment. Presence of dissolved oxygen in the system will cause corrosion of the tube metal surfaces. The best method of treatment are with the use of oxygen scavenger and pH control chemicals. The boiler and its auxiliaries could be preserved by floating them with the right concentration of chemicals and pressurizing with 0.3 - 0.5 kg/cm^2 Nitrogen gas to prevent entry of oxygen.

The other type of treatment process are the steam sealing and dry treatment.

In the preservation of the equipment, the following should be considered in every unit.

- a) Outage period
- b) System material, equipment
- c) Standard of treatment

In case of Japan, attached is the procedure on the preservation treatment.

Table 5C-42 PRESERVATION TREATMENT SPECIFICATION (IN CASE OF KYUSHU ELECTRIC)

System Outage Period	B O I L E R	CONDENSATE FEEDWATER SYSTEM	DEAERATOR	HEATER SHELL SIDE
°Unit with heater made of steel Boiler Banking <100 Hrs	No treatment (the same as operation condition) water full filling, N ₂ H ₄ 5~10ppm (blr: full filling and nitrogen blanket, SH except for being filled with water; only nitrogen blanket, RH: dry lay-up after draining. These treatment is available to the following condition)	steam sealing (0.1~0.3atg) N ₂ H ₄ 1ppm steam sealing (Incase of no steam, partially filled deaera- tor with water is stored as follows: Nitrogen blanket N ₂ H ₄ 5~10ppm	steam sealing (condenser: under vacuum Low Pressure Side: Vacuum keep steam sealing	
<10 days	water flooding of unit with chemical conc. of N ₂ H ₄ 10~20ppm	steam sealing or nitrogen blanket N ₂ H ₄ 10~20ppm Nitrogen blanket N ₂ H ₄ 50ppm NH ₄ 5ppm	steam sealing or nitrogen blanket Nitrogen blanket or water flooding with N ₂ H ₄ 50ppm NH ₄ 5ppm	
<1 month	water flooding of unit with chemical conc. of N ₂ H ₄ 50ppm NH ₄ 5ppm (pH>10)	nitrogen blanket N ₂ H ₄ 100ppm NH ₄ 5ppm or dry lay-up	Nitrogen blanket N ₂ H ₄ 100ppm* NH ₄ 5ppm or nitrogen blanket	
>1 month	water flooding of unit with chemical conc. of N ₂ H ₄ 100ppm NH ₄ 5ppm or nitrogen blanket	nitrogen blanket N ₂ H ₄ 100ppm NH ₄ 5ppm or dry lay-up	Nitrogen blanket N ₂ H ₄ 100ppm* NH ₄ 5ppm or nitrogen blanket	

System Outage Period	B O I L E R	CONDENSER FEEDWATER SYSTEM	D E A E R A T O R	HEATER SHELL SIDE
	<p><u>Unit with heater made of copper alloy</u></p>			
Boiler Banking	<p>based on unit with heater made of steel, no treatment (the same as operation condition)</p>			
< 100 Hrs		N ₂ H ₄ 5 ~ 10 ppm		<p>based on unit with heater made of steel.</p> <p>In case of water flooding, N₂H₄ should be kept at 20-30 ppm.</p>
< 10 days		N ₂ H ₄ 10 ~ 20 ppm		<p>In case of without sealing equipment and water filling equipment, water should be drained out at high temperature and it should be kept at dry condition.</p>
< 1 month	N ₂ H ₄ 50ppm			
> 1 month	N ₂ H ₄ 100ppm*		N ₂ H ₄ 20 ~ 30ppm	

Notes: * In JPN, N₂H₄ concentration is suppressed by the environmental aspects, if N₂H₄ concentration is less than specification valve, additional injection is possible.

In case of NPC, N₂H₄ concentration is possible to be increased conservatively to N₂H₄ 500ppm, NH₄ free.

12) Boiler Chemical Cleaning

Post operational chemical cleaning of NAPOCOR boilers is done depending on the density of deposits on the tube. During overhauling, water wall tube samples are taken from the hottest side to determine whether there is a need to chemically clean the boiler. In the case of Gardner-2, the density of deposits on the water wall tube was more than the allowable limits of 30 mg/cm^2 . The Quality Assurance Group, the Plant Management and the Region Technical Services Division decided that there is a need for chemical cleaning.

The chemical section of the plant prepared the corresponding procedure, management during the chemical cleaning process, analysis and take charge of the chemical cleaning. The operation group supervised the operation of the system.

Actually the chemical cleaning was delayed by five days from the original schedule due to the lack of the secondary superheater valves. The whole chemical cleaning process was successful as shown in the result of inspection. The quantity of scale removed during the process was about 3150 kgs Fe_3O_4 . The flash tank and boiler heater were inspected and found to be coated with thin film of magnetite.

a. Schedule

- Aug. 12 - Temporary piping flushing
- 13 - 19 - Pump and valves repair
- 20 - Secondary superheater flushing
 - Boiler filling and raising of temperature
 - Preparation of chemicals
- 21 - Acid cleaning
 - Displacement
- 22 - Passivation
- 23 - Inspection of Flash Tank
- 24 - Inspection of heater and sampling tube
- Sept. 5 - Wet storage (boiler fill)

b. Summary of Chemical Cleaning

(a) Temporary piping, boiler, SH flushing

Flushing of the temporary piping finished early. During the boiler and secondary superheater flushing, leak developed at the main stop valve, MV-4, MV-5, and CV-104. Likewise, the chemical cleaning pump broke down. The repair of leaky valves and pump took 5 days. In the meantime that the valves were being repaired, JICA team advised to relocate the chemical injection point.

(b) Acid Cleaning

During the acid cleaning process, the initial plan was to heat the system to about 195°F (90°C) - 200°F (93°C) but JICA team recommends to initially heat the system to 200°F (93°C) - 210°F (99°C) because during the chemical injection the temperature will drop. In addition, they recommend to drain the flash tank and prepare the acid solution with the same volume as of the flash tank.

The chemical injection was finished within 45 minutes. The normal flow was done in 3 hours and the reverse flow in 3 hours. After 4 hours of acid recirculation, the maximum iron concentration was about 15600 ppm which is the saturation point.

(c) Displacement

The flash tank was drained under nitrogen blanket. The filling and draining were done in 14 hours. The demineralized water used during displacement contained 30-20 ppm N_2H_4 . In the displacement process the target value of turbidity is 10 ppm. The actual analysis of the displaced water was 6 ppm turbidity and 5 ppm iron. Then passivation phase follows. The total volume of demineralized water consumed during displacement was 1080 m³.

(d) Passivation

The circulating water was heated to 200°F (93°C). Once the temperature equilibrium was reached, the passivating chemicals were injected. (N_2H_4 and NH_4OH). Once the pH of 10 was attained the solution was recirculated for 6 hours, thereafter the system was completely drained.

c. Inspection

(a) Test Plate

The test plate was installed in the heater discharge main line. It was made of the same material as of the waterwall tube. After the acid cleaning, the test plate surfaces has no pitting corrosion. There was a considerable lost in weight but the corrosion rate could not be computed due to the irregularity of the shape of the test plate.

(b) Flash Tank

The scale at the flash tank was completely removed. The sludge accumulated at its bottom was about 2 cm.

(c) Boiler Water Wall Header

The scale at the boiler water wall tube was completely removed and it was properly passivated. At the bottom header, there was an accumulation of about 1 cm thick of sludge. JICA team advised to remove all of them. In addition, it was observed that the water wall header surfaces was wet and it might be due to incomplete draining.

(d) Water Wall Sample Tube

The inside of the water wall tube sample showed clean surfaces which was indicative of effective passivation.

d. Consumption of Demineralized Water and Chemicals

Table 5C-43

	Concentration in the cycle	PROCEDURE			Total
		Acid Cleaning	Passivation	Wet Storage	
Hydroxy Acetic Acid (70% as CH_2OOH)	2%	1145 Gals (4.35 m^3)	-	-	1145 Gals (4.35 m^3)
Formic Acid (85% as HCOOH)	1%	480 Gals (1.8 m^3)	-	-	480 Gals (1.8 m^3)
Rodine 31A		195 Gals (0.7 m^3)	-	-	195 Gals (0.7 m^3)
Hydrozine (35% as N_2H_4)	500ppm	-	70 Gals (0.27 m^3)	70 Gals (0.27 m^3)	140 Gals (0.54 m^3)
Ammonium Hydroxide (28% as NH_4OH)	10 ppm as NH_3	-	10 Gals (0.04 m^3)	10 Gals (0.04 m^3)	20 Gals (0.08 m^3)
Nitrogen Gas (100% N_2)	2-5psig	10 Bottles	-	-	10 Bottles
Demineralized Water (estimate)		200 m^3	1100 m^3	200 m^3	1500 m^3

e. Data of Water Quality of Chemical Cleaning of G-2

Table 5C-44 DATA OF WATER QUALITY AT CHEMICAL CLEANING OF G-2

	Time	pH	Acid	Conductivity Micro S/cm	T-Fe ppm	Cu ppm	Turbidity ppm	N ₂ H ₄ ppm	NH ₃ ppm	Cl ppm	Temperature °F After HTR	Temperature °F Suction	Remarks
Pre-Heating	Aug. 20 9:30 P.M.	9.6		20.0			14.0		5.4	0.9			
	10:00	9.2		20.5			10.0		4.2	0.3			
Acid Cleaning	Aug. 21 5:50 A.M.	2.15	1.9		6200	0					212	175	
	6:40	2.7	2.4		5065	0					198	195	
	7:40	2.9	2.3		13632	0					195	195	
	8:15	3.8	2.0		12422	0					195	195	
	9:00	3.7	1.6	15678	15678	0					198	183	
	10:00	3.3	1.6		14598	0					190	182	
	11:00	3.4	1.6		13512	0							
	12:00	3.4					161						
	1:00 P.M.	4.2					104						
	6:30	5.2			97		70						
Displacement	8:00	7.6			121		44						
	Aug. 22 1:15 A.M.	7.8					36	55					
	1:45	7.5			5		10	58					
	2:15	8.1					6	66					
	11:00	10.0						1440	3133		200		
	12:30	10.0						1440	5100		195		
Passivation	3:00 P.M.	10.1						1120	2744		210		
	3:30	10.0						1042	2439		210		

Table 5C-45 BOILER CHEMICAL CLEANING PROCEDURE

Gardner #2 Boiler			In case of Japan				
Schedule	Chemicals	Analysis Item	Remarks	Schedule	Chemicals	Analysis Item	Remarks
Acid Cleaning (6 hr)	CH ₂ OOH 2%	Acid Concentration T-Fe Cu pH	Temp. 195-200°F Circulation Normal 3 Hr Reverse 3 Hr [End Point] Iron content is constant.	Acid Cleaning (6 Hr)	Organic Acid Inhibitor Reducing agent	Fe ²⁺ Fe ³⁺ Cu pH	Temp. 190-200°F Circulation Normal 3 Hr Reverse 3 Hr [End Point] Iron content is constant, Inspection of Test Tube.
	HC00H 1%						
Displacement (13 Hr)	N ₂ H ₄ 10 - 20 ppm	N ₂ H ₄ Turbidity	Temperature [End Point]	Washing (Filling and Blowing) (8 hr)	N ₂	pH T - Fe	Temp. 100°F [End Point] pH 5.0 T-Fe 100 ppm
	Rodine 31A						
Passivation (6 Hr)	N ₂ H ₄ 500 ppm	pH Turbidity	Temp 195 - 200°F	Rinsing (1 Hr)	Critical Acid 0.1%	pH T - Fe	Temp. 120-130°F [End Point] 1 Hr
	NH ₃ 10 ppm						
	NH ₃ 0.08%						
				Neutralization (1 Hr)			Temp 100 °F [End Point] pH 9.0
				Passivation (2 Hr)	N ₂ H ₄ 500 ppm	pH	Temp 195 °F

f. Quantity of Scale Removed During the Chemical Cleaning

Total volume of boiler water wall 152 m³ (40,000 gal)
 15600 ppm x 152 m³ = 2371 kg as Fe
 = 3272 kg as Fe₃O₄

g. Deposit Volume of Sample Tube

	Before Cleaning	After Cleaning
Fire Side	66.37 mg/cm ²	9.96 mg/cm ²
Rear Side	44.84 mg/cm ²	1.57 mg/cm ²

Analysis of Scale Deposit

Fe₃O₄ Main Component
 Cl 0.018% as NaCl
 SiO₂ none

h. Test Plate Analysis

<u>Weight</u>	<u>Before Cleaning</u>	<u>After Cleaning</u>	<u>Loss in Weight</u>
	(gr)	(gr)	(gr)
#1	55.01610	54.91750	0.09860
#2	57.01720	56.91155	0.10565

Surface Area unknown

i. Recommendation

(a) Schedule of Chemical Cleaning

Gardner-2 boiler acid cleaning was scheduled at the middle of the overhauling period. The acid cleaning finished on August 22 and wet storage of the boiler was done on September 5, 1982. The protection film created during passivation is effective only for one week. In Japan, the chemical cleaning is done 7

to 10 days before the unit start. In this case the boiler feed pump can be used in filling the boiler circuit. In using the boiler feed pump, the pre-boiler and heater are simultaneously being flushed.

In this regard, JICA team strongly recommend that chemical cleaning should be done 7 - 10 days before the start of the unit.

(b) Preparation before Acid Cleaning

i. Boiler Hydrostatic Test

Prior to chemical cleaning, the boiler circuit should be hydrostatic tested to avoid unnecessary delay. Like in the case of Gardner-2, the acid cleaning was delayed by 5 days due to the leaking secondary superheater valves.

ii. Operation of Circulating Water Pump (CWP)

During chemical cleaning the circulating water pump should be placed in operation to cool the high temperature drain which leak to the condenser hot well.

iii. Scale removal test of sample tube

The quality of scale deposits inside the water wall tube depends on the condition of operation periods. High heat rate could not remove the scale deposited. In this regard, proper chemical cleaning is needed to restore the effectiveness of the water wall tube. Prior to the chemical cleaning, scale from the water

wall tube should be analyzed to determine the effective chemicals or kind of acid needed for its proper removal.

(c) Chemical Cleaning Procedure

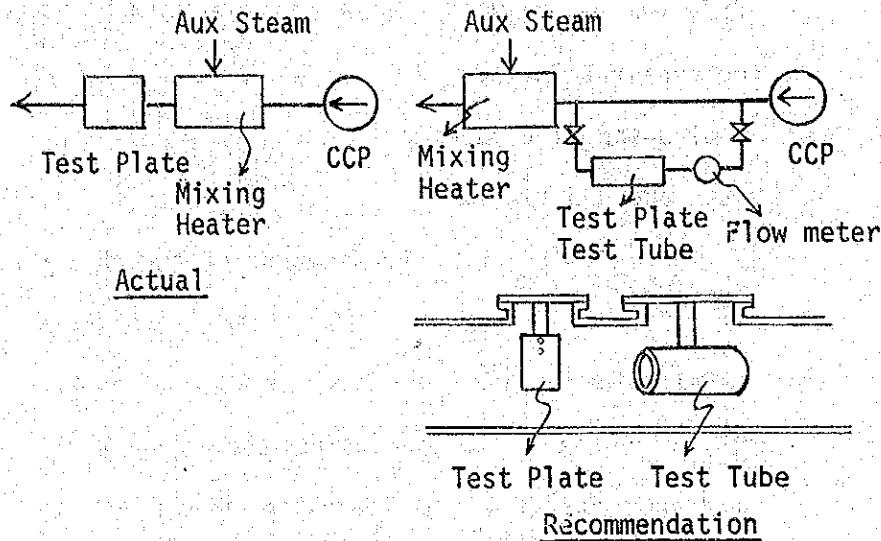
i. Test Tube and Plate

To determine the effectiveness of the chemical cleaning process, JICA team recommends installation of the test tube and plate during acid cleaning. The operating condition where the test materials are installed should be the same as that of the waterwall tube.

In case of Japan, the loss in weight of the test tube is limited within 3 to 5 mg/cm² during total washing hours.

JICA team observed that the test plate was installed after the mixing heater. Its condition was different from the water wall tube so that the effect is not conclusive. JICA team recommends test plate and tube should be installed before the mixing heater with corresponding flowmeter so that velocity is the same as that of the water wall tube.

Please refer to the diagram shown below:



In case of Gardner-2, the test plate was installed after the mixing heater. In this case, the test plate was exposed to a fast velocity wherein corrosion rate is high.

ii. Procedure for Mixing the Chemicals

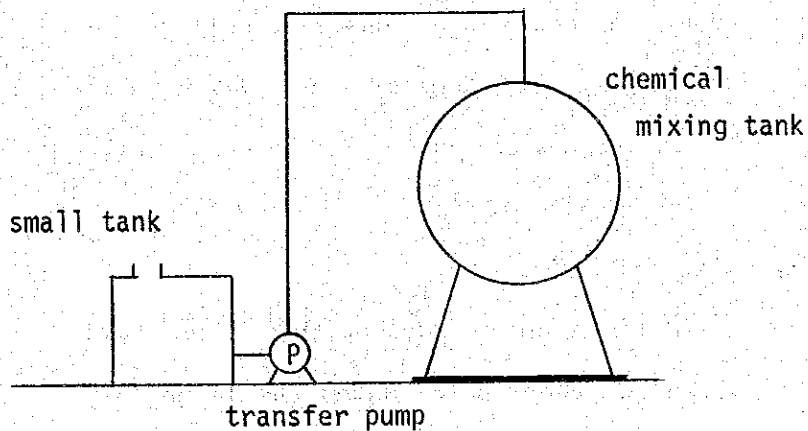
(1) Hydrazine Mixing

JICA team observed that hydrazine was directly mixed in the condensate storage tank during chemical cleaning process. JICA team recommends that a separate hydrazine tank with corresponding injection pump be provided for every chemical cleaning. In this way, contamination of the boiler make-up water will be avoided. It was noted last September 9, 1982, the make-up water to the boiler was contaminated

with the chemicals at the condensate storage tank. The feedwater pH and N_2H_4 concentration tremendously increased.

(ii) Acid Mixing

During the preparation of the acid cleaning chemicals, JICA team observed that 55 gals drums were individually being lifted with the use of a chain block. the procedure was dangerous, we are recommending that 250 gals rubber lined tank and transfer pump be used in mixing the chemicals. Please refer to the diagram below:



iii. Procedure of Cleaning

(i) Displacement

JICA team observed that the NAPOCOR displacement process during chemical cleaning was continuous filling and draining. The process was observed to be time consuming and consumed plenty of demineralized water. JICA team recommends that during the displacement process filling method should be used. In Japan, the said method will take only about 8 hours and will consume only 2 times of the boiler volume. In case of Gardner-2 the displacement was about 14 hours and consumed 1100 m³ or 290,000 gals of demineralized water which is equivalent to about 7.2 times of the volume of the boiler.

(ii) Rinsing

JICA team recommends that after acid cleaning, the rinsing water should contain 0.1% citric acid.

(iii) Fe⁺³ Analysis During Acid Cleaning

During the acid cleaning process, Fe⁺³ should be analyzed. Excess of Fe⁺³ is indicative of metal corrosion. In this respect, Fe⁺² and Fe⁺³ should separately be analyzed. If the Fe⁺³ exceeds 500 ppm, hydrazine or reducing agent should be injected into the system.

(iv) Check of System Flow Rate

In chemical cleaning using organic acid, maintenance of the right velocity and temperature of the system is important. In case of once-through boiler, there is a difficulty to maintain the right velocity in the system so that proper checking of vents should be done to have a laminar flow. Likewise, checking of the temperature in all side of the boiler should be done.

Reference - 10 Test Method for Iron ($\text{Fe}^{3+}/\text{Fe}^{2+}$) (for Chemical Cleaning)

1. Summary of Method

Fe^{3+} (ferric ion) in sample forms a red-violet complex with sulfosalicylic acid at a pH of about 2. By the titration of this solution with EDTA solution, yellow complex is formed. Accordingly, Fe^{3+} can be determined first and Fe^{2+} can be titrated after oxidation to Fe^{3+} .

2. Reagents

- a) pH Buffer Solution - Dissolve 10.7 g of ammonium chloride (NH_4Cl) and 20 ml of acetic acid (CH_3COOH) in water and dilute to 100 ml.
- b) 10% Sulfosalicylic Acid - Dissolve 10 g of sulfosalicylic acid " $\text{C}_7\text{H}_5\text{O}_3 (\text{SO}_2\text{NH}_2)$ " in water and dilute to 100 ml.
- c) Ammonium Persulfate
- d) 0.09M - EDTA Solution - Dissolve 33.5 g of disodium ethylenediamine-tetraacetate dihydrate $[(\text{CH}_2\text{COO})_2 \text{NCH}_2\text{CH}_2\text{N}(\text{CH}_2\text{COO})_2 \cdot \text{H}_2\text{O} \cdot \text{Na}_2 \cdot 2\text{H}_2\text{O}]$ in water and dilute to 1000 ml. The factor of this solution is determined as follows. Take 50 ml of iron standard solution (1 mg Fe^{2+} /1 ml) into a beaker and add 20 ml of pH buffer solution and about 2 ml of 10% sulfosalicylic acid and heat to 40 - 50°C. After adding about 2g of ammonium persulfate, titrate the solution with 0.09M EDTA solution until the color changes to light-yellow from red-violet. From ml(x) volume of EDTA solution required to titrate, calculate the factor (F) as follows.

$$F = \frac{25}{X}$$

3. Procedurea) Fe^{3+}

Take 5 ml of filtered sample into a beaker. Add 20 ml of pH buffer solution and 2 ml of 10% sulfocalicylic acid. If ferric ion (Fe^{3+}) is present, red-violet color develops. Titrate the solution with 0.09M EDTA solution until a yellow color, after heating to 50 - 60°C. From ml (a) volume of EDTA solution required to titrate, calculate the concentration of ferric ion (Fe^{3+}) as follows:

$$\text{Fe}^{3+} \text{ (ppm)} = a \times 1000 \times F$$

b) Fe^{2+}

After testing ferric ion, add about 2 g of ammonium persulfate into the same solution for the oxidation of Fe^{2+} . Titrate the solution with 0.09M EDTA solution until a yellow color. From ml (b) volume of EDTA solution required to titrate, calculate the concentration of ferrous ion (Fe^{2+}) as follows:

$$\text{Fe}^{2+} \text{ (ppm)} = b \times 1000 \times F$$

where, F = the factor of 0.09M EDTA solution

4. Remarks

- If pH of the sample is not adjusted at 2 - 2.5, the end point is not clear.
- When copper and nickel concentration is more than 500 ppm, the end point is not clear and gives higher value.
- Solution temperature should be kept at 50 - 60°C, for the slower reaction of room temperature. Titration should be done slowly near the end point to prevent getting of higher value.

- o If an accelerant (fluoride such as NH_4HF_2) exists in the sample, it is difficult to titrate for the formation of Fe - F Chelate, but possible to titrate by adding 20% aluminum sulfate as follows.

In case of testing at room temperature - - - -

Add 2 ml of 20% aluminum sulfate solution in 2 ml of the sample and wait for 2 minutes. The following procedure is the same as the text.

In case of testing at 50 - 60°C

Concentration (%) <u>of Accelerant</u>	Addition Volume (ml) <u>of 20% $\text{Al}_2(\text{SO}_4)_3$</u>
0.3	0.3
0.3	0.4
0.5	0.5
1.0	1.0

13) Corrosion Protection in Furnace Side

Gardner/Snyder and Malaya Thermal Plant used high sulfur fuel oil in the boiler. Below is the corrosive components of the said oil:

% Sulfur ---- 2.9 - 4.5

ppm Sodium ---- 8 - 19

ppm Vanadium ---- 13 - 54

The presence of corrosive components in the fuel oil will cause low and high temperature corrosion in the boiler system. Like in the case of Malaya Thermal Plant, its air heater always being clogged up. Improvement of the unit's efficiency is always a problem.

Inspection of Gardner-2 indicated corrosion on the furnace side of water wall tube and secondary superheater.

Gardner/Snyder and Malaya units are always being operated not on the rated capacity. Thus their corresponding heat rates are very high. If the abnormality in the boiler is repaired and the unit is operated full load, there will be high temperature corrosion and ultimately will cause tube failure. In this regard, it is necessary to protect the furnace side.

Snyder-1 and -2 and Malaya-2 gas ducts are being corroded by the furnace gas caused by low temperature corrosion. In the said units there were so many gas leaks and even in the control room odor of SO₂ gas could be felt. The concentration of SO₂ gas is way beyond the environmental limit of 0.1 ppm SO₂.

Malaya-2 air heater differential pressure increases due to clogging of elements. The effect will cause the reduction of the unit load.

Snyder-2 at present is using fuel oil additive. The result is not yet known.

All units have no protection from low temperature corrosion. In this matter, the air heater is being damaged due to defective steam coil heater.

Recommendation

Below is the effect of high sulfur fuel in the boiler.

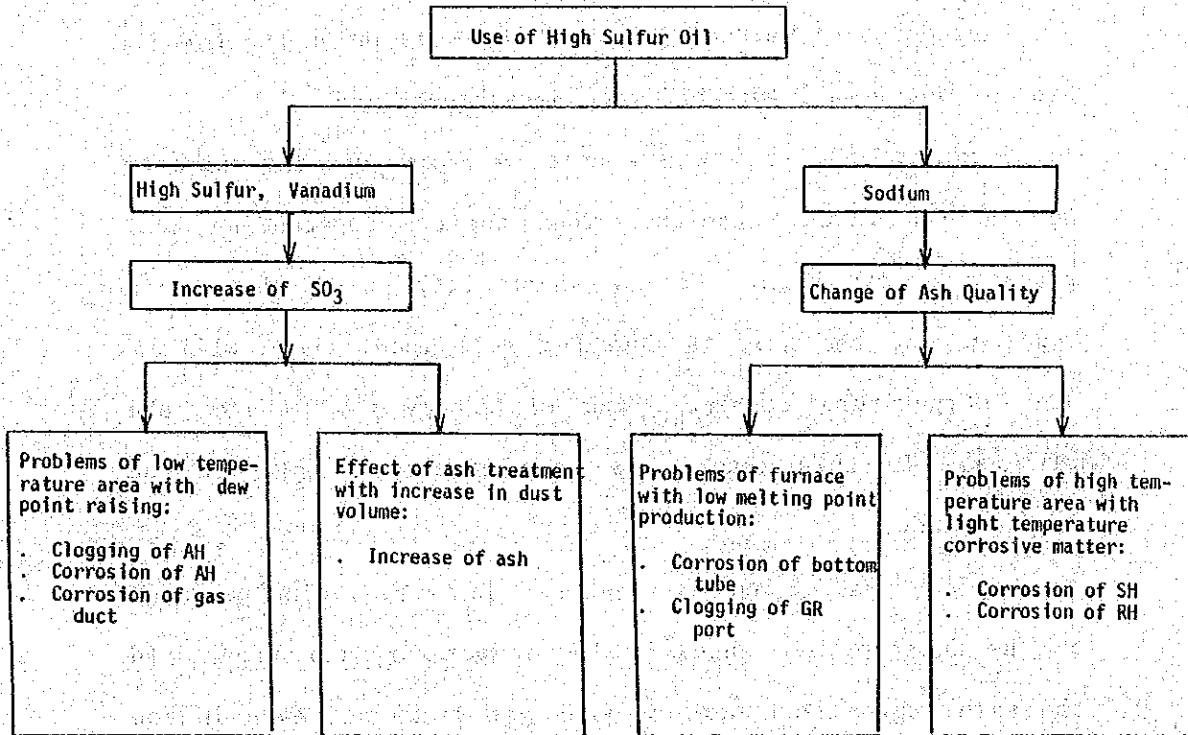


Table 5C-46 EFFECT OF HIGH SULFUR OIL

High temperature corrosion is due to the presence of sodium sulfate which causes sulfidation attack on the tube surfaces. It could be protected by following the protection method stated below. But in spite of implementing the necessary protection method, the system could not be protected completely if there is no careful inspection during overhauling and advance maintenance.

Disposition of High Temperature Corrosion

- (1) Prevention of gas inclination and cancellation of high temperature area
- (2) Protection of local high temperature area with refractory material
- (3) Injection of fuel oil additive to raise the melting point
- (4) Water washing of the furnace
- (5) Changing of tube material, for instance SUS 316, SUS 321 to SUS 347 and STBA 24 to HCM9M

For sodium corrosion, the best additive are magnesium compound, aluminum and manganese compound.

Using wrong type of fuel oil additive, the evaluation is very difficult and the price is very expensive. In Japan recently, the use of fuel oil additive is discontinued because the cost of boiler tube is lower compared to the cost of fuel additive.

Low temperature corrosion is caused by oxidation of SO_2 to SO_3 and ultimately formation of H_2SO_4 . With the increase in SO_3 concentration, the corresponding dew point decreases, thus H_2SO_4 is produced which caused corrosion of air heater, gas duct and stack. The H_2SO_4 condensation will cause presence of

sticky ash. Below is the protection of low temperature corrosion.

Protection of Low Temperature Corrosion

- (1) Low excess air operation should always be maintained.
- (2) Control of exhaust gas temperature
- (3) Injection of ammonia gas after multicyclone
- (4) Anti-corrosion material should be used, for instance cort-en steel
- (5) Steam coil air heater should be used to increase the metal temperature of the air heater.

JICA team recommends measurement of SO_2 , SO_3 analysis and the corresponding dew point, so that proper treatment could be done. In this regard JICA team recommends implementation of Items (2) and (5) of the protection method.