Performance Evaluation of the Demineralization Plant of Kaduna Refining and Petrochemical Company Limited, Kaduna, Nigeria

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ABSTRACT —This paper provides an over view on the performance of the demineralization unit of Kaduna Refining and Petrochemical Company Limited. It also offers to the oil and gas Companies the best alternative resin for the ion-exchange processes. Performance evaluation of the demineralization plant of the company has been carried out with the view of enhancing the performance of the unit,. Demineralization Plant is a major unit in the external treatment of boiler water by the use of ion exchange resins to purify the water. The evaluation was based on the study of three years data; 1997 which parameters (pH, conductivity and silica) were closed to the design values and compare to the most recent past (2000 and 2001), which were discovered to be beyond the design value. To solve the existing problem a resin (Amberlite) different from Lewatit presently employed by the KRPC was used for the ion exchange process and at twenty-hour demineralization time, Arberlite resins prove to be more effective than the lewatit. To safeguard the incessant failure of the boiler tubes and to end under-utilization of the Demineralizer and Boiler units, a rehabilitation of the raw water and demineralization unit plants is recommended, while Amberlite resins should replace lewatit resins.

I. INTRODUCTION

Raw water fed to boilers causes problems such as scaling, corrosion and carry over of dissolved solids and silica in the boilers and their auxiliary equipment. To prevent these, a proper water treatment (chemical and Mechanical) is applied to each boiler system (Tetsuo, *et al* 1999).

The Mechanical boiler water treatment involves one or a combination of the following; coagulation, sedimentation, filtration, ion exchange, and dearation treatment (Schroeder, 1991). However the main focus of this work is ion exchange processes. In ion exchange treatment, all the dissolved cations and anions in raw water are removed or exchanged using ion exchange resins to obtain the appropriate quality of treated water for [1]each boiler system. This process is called demineralization and before it is undertaken, the water must be made as free as possible of organic, colloidal and suspended substances by filtration (Tetsuo *et al*, 1999).

For the past four years, the performance of the demineralization unit of KRPC has been unsatisfactory due to incessant silica break through and high conductivity, which resulted in its carryover to the boilers. The actual pH value, conductivity and silica observed are between 8-10, 10-80µs/cm and 0.2-20ppm respectively as against the design specifications of pH 7-8, conductivity, 10µs/cm (maximum) and silica of 0.2ppm (Maximum). The design specifications of polisher outlet water are pH 7-8, conductivity 1.0µs/Cm and silica, 0.05ppm (maximum). However, the polishers has been non-functional and on bypassed. The poor performance of these units leads to the precipitation of the unwanted ions in form of bicarbonate as was analyzed by Institute Desoudure France, 1995. The institute reported on the damaged furnace wall tubes of KRPC boiler 70BO3 (Kemmer, 1988). This in turn impairs heat transfer in boilers, causing pitting, corrosion and eventual damage to boiler tubes. The failure of boiler tube resulted into unscheduled boiler shut down, steam load shedding and some time shutting down of the whole refinery due to reduction in steam generation and frequent regeneration of the demineralizer unit which raises the cost of operation (Kemmer, 1988). The plant is presently available but with very poor performance as the quality of demineralized water deteriorated. Therefore, the essence of this study is to make known to the organization and other oil producing companies that employ demineralization unit the consequences of the poor performance of this unit and guide the management on the way forward to produce demineralized water that will meet the design specification. To achieve this, practical experiment was carried out using alternative resins in comparison with the existing one in order to see their performance. The outcome of this study will enhance production of demineralized water that will meet the design specification at minimum cost of production.

II METHODOLOGY

This study was carried out via:-

(1) Physical inspection of the demineralization unit of K.R.P.C

(2) Measurements of output capacity, pH, conductivities in comparison to Manufacturer's specification in the operating manual. Two kinds of data (quantitative and qualitative) were sought for, from the establishments, which were based on measurements, observation, and existing records. For performance evaluation of the demineralization unit, routine tests were carried out to check the specification and material. The main focuses are: feed water quality and status of equipment, use of alternative resins for experiment and Reference materials. Although study was carried out to compare the design specification of the feed water quality with present condition of the up-stream equipment/instrument, the present status of Demineralizer unit were also put into consideration. The experiments were carried out in two sets, for 20hours. The first set consist of the present resins in use in KRPC and the second set consist of an alternative resins produced by Rohm and Haas. The comparison is as shown in Table 1, the anion exchanger, a weak resins was introduced as an additional bed in the alternative set.

The existing demineralization unit comprises of two columns with the first column having two beds. The lower bed containing weaker cationic resins, while the upper bed contains strong cationic resins. The feed goes through the bottom of the column and passes through the top of the column; this is in turn fed to a second column, which contains a single bed of anionic resins. This is illustrated in Figure 1. The alternative demineralizers have the same configurations as the existing one, though the second column is loaded with weak anionic resins at the bottom and a strong anionic resin at the top to remove all carryover of ions in the water.

TABLE 1: EXPERIMENT WITH AMBERLITE RESINS IN COMPARISONS WITH LEWATITE RESINS

BAYER A.G Resins currently in used in KRPC	ROHM & HAAS-AMBERLITE (Alternative Resins)
Cation Resins	
Weak resin Lewatite CNP –80 Strong resin: Lewatite S-100WS	Amberlite IRC 86RF Amberjete 1200 H
Anion Resin	
Weak resin – none Strong resin: Lewatite MP – 500WS	Amberlite IRA 96 RF Amberlite IRA 900 Cl

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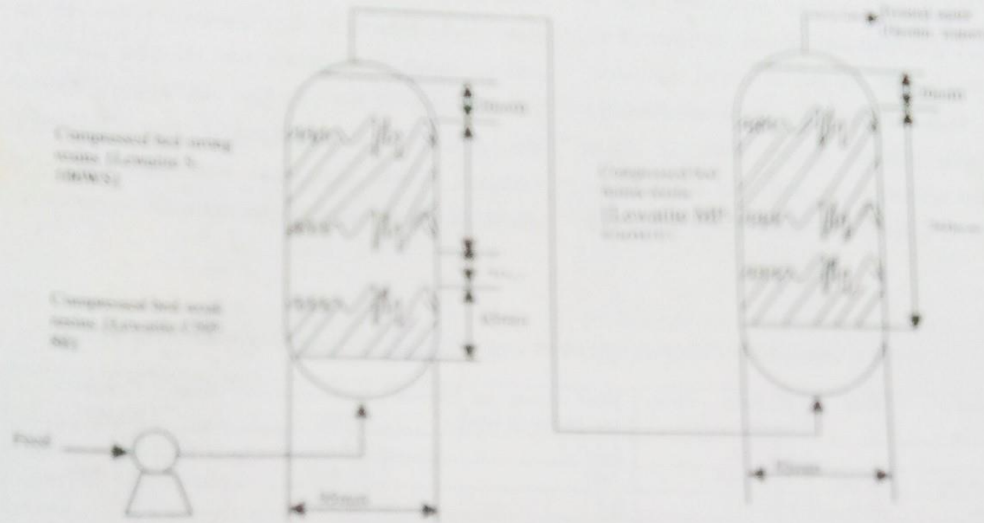

Figure 1 Experimental Set-up of the Existing Demineralization Unit

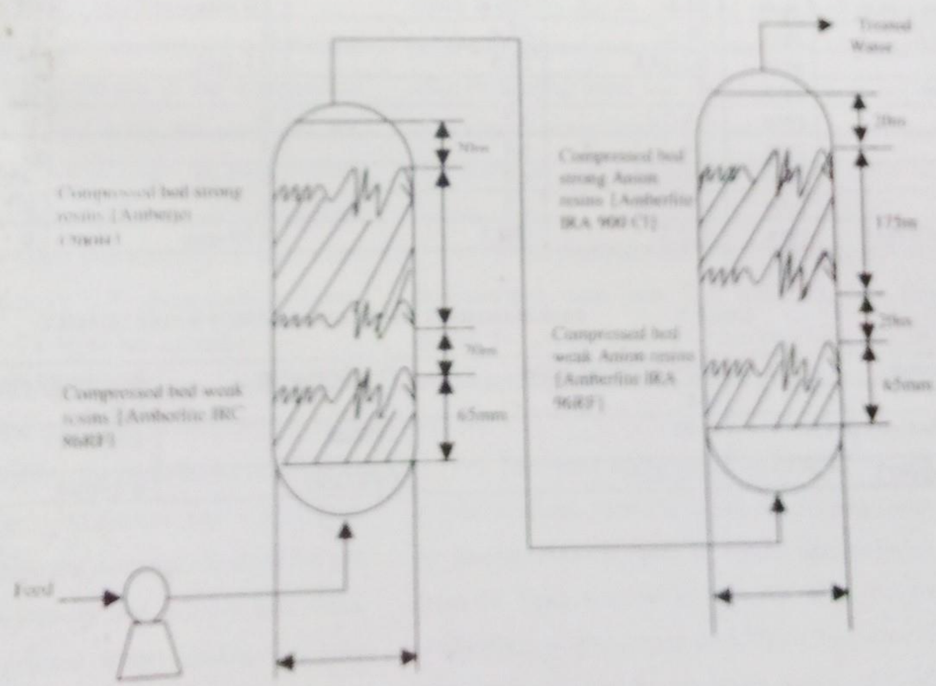

Figure2: Experimental Setup for the Alternative Demineralization Unit

The record of three years (1997,2000 & 2001) past operating data, present condition of the demineralizer plant and the up stream equipment, Books, Magazines/Journals, Seminar/Conference papers were referred to, in order to obtain information relevant to the study. The demineralizer unit of KRPC is designed to demineralize boiler feed water using ion exchange resins to reduce the contaminants. The boiler units consist of high pressure boilers producing high pressure steam, 52.8kg/Cm^{2}g max (42kg/cm^{2}g normal) medium pressure steam 18.2kg /m^{2}g max (16.5kg/cm^{2}g normal), and the low pressure steam, 5.0kg/cm^{2}g max (3.5g/cm^{2}g normal) (chinyoda, 1980). The boiler feed water must meet certain specification to prevent tubes failures as shown on Table 2.

TABLE 2: DESIGNED WATER QUALITIES FROM KADUNA RIVER TO DEMINERALIZER UNIT OF KRPC.

Parameter	Unit	Kaduna River water	Feed water to demin unit (filtered water)	Demineralized water outlet	Polisher outlet
Ph		7.0-7.8	6.5-7.5	7-8	7-8
Conductivity	µs/cm	33.3-105	110	10 max	1.0 max
Total ion	ppm	0.02-5.5	0.3	0.1 max	0.01
Free Cl_2	ppm	0	<0.5	0	0
Organic matter	ppm	20-138	3-6	1	Less than 1
Turbidity	NTU	20-3000	<1.0	0	0
Ca^{++}, Mg^{++}	ppm	12-38	42	0	0
NH4	ppm	0.1-1.0	10.8	0	0
$Na^+ + K^+$	ppm	52.4	47.8	2.0	0.2
Total cation	ppm	91.4	100.6	2.0 max	0.2 max
HCO_3	ppm	20-62	65.4	0	0
CL^-	ppm	0.2-24.8	29.5	0.1 max	0.05 max
$SO^{-2}4$	ppm	0	1.1	0	0
NO_3	ppm	0.3-3.2	3.2	0	0
F	ppm	1.4	1.4	0	0
SiO_2	ppm	0.8-8.3	1.7	0.2 max	0.05 max
CO_2	ppm	1.7-22.8	2.2	0	0
Total Anion	ppm	122.5	104.5	0.30 max	0.1 max

TABLE 3: DESIGN DEMINERALIZED AND POLISHED WATER QUALITY

Parameter	Demineralizer outlet	Polisher outlet	Recovered condensate
pH	7-8	7-8	6-8
Conductivity µs/cm	5-10	1.0max	10max
SiO_2 (ppm)	0.02-0.2	0.01-0.05	0.17max

III. RESULTS AND DISCUSSION

The result of the study carried out on the resins currently in use in KRPC and the alternative Amberlite resins are tabulated in Table 5

TABLE 5: WATER QUALITY ANALYSES ON THE USE OF THE EXISTING AND THE ALTERNATIVE RESINS

S/N	Time (h)	Treated sample	pH	Conductivity (µs/cm)	SiO_2	Turbidity (^{0})
1	0	Filtered water (feed water)	7.5	98	10.5	2.2
2	4	1st set using Lewatit resins	7.7	7.7	0.09	
		2nd set using Amberlite resins	7.5	3.9	0.01	
3	7	1st set using Lewatit resins	7.8	6.8	0.08	
		2nd set using Amberlite resins	7.6	4.3	0.05	
4	20	1st set using Lewatit resins	8.0	7.5	0.15	
		2nd set using Amberlite resins	7.9	5.2	0.09	
5	Average	1st set using Lewatit resins	7.8	7.3	0.12	
		2nd set using Amberlite resins	7.7	4.5	0.05	

A. *Data Presentation and Analysis*

Comparison between Tables 2 and 4 shows that in 1997, the performance of the demineralizer was satisfactory as shown by the values of pH, conductivities and silica levels of demineralized water. The values were within specifications despite the high level of silica and turbidity of feed water, which were 9.8ppm and 5.5^0 respectively as against the design values of 1.7ppm and 1.0 max.

The performances of the demineralizers deteriorated in 2000 and 2001 as indicated by Table 4. The pH, conductivity and silica levels ranges from 8.8-9.2, 39.8µs/cm – 52.8µs/cm and 0.77-3.9ppm respectively as against the designed values of 7-8 pH, 10µs/cm max conductivity and 0.2ppm max silica. The feed water (filtered water) quality was poor while the river water (raw water) silica level was between 10-30ppm as against the design values of 0.8-8.3. The poor performance of the demineralizer was due to the following: poor quality of feed water, which in turn is due to, increased silica level of the river water, faulty regeneration and passing resin valve. High and low level of silica in the river water was observed during raining season (June to October) and dry season (November to April) respectively, the high level was due to excavation activities in the river by sand loaders.

In the year 2000 and 2001, the average conductivity of the demineralized water was 52.8 and 39.8µs/cm respectively as against the design value of 10µs/cm. This was as a result of insufficient regeneration of the ion exchanger, which also led to high pH.

The result of the study to compare the efficiency of an alternative resins {amberlite} and the existing resins {lewatit} in the demineralization plant of KRPC are presented in Table 5. From the Table it could be seen that using the alternative resin (Amberlite) the silica level of 0.05ppm was attained after 20h of operation as against the maximum design value of 0.2ppm after 22-24h operation using the existing resin (Lewatit). But when the existing resin (Lewatit was employed in the study, the silica level was 0.11ppm. Hence Amberlite proved to be more effective.

Hence, employing it in industrial scale, will not only reduce the cost of operation by reducing the rate of frequent regeneration, but will also allow extension of operation time above 24hrs without silica break through.

IV. CONCLUSION

Three years data on demineralization unit were collected and analyzed, and the result when compared with the design specifications shows that the performance of the plant is poor. The poor performance is attributed to equipment/instrument failure and incessant fouling of the resins due to poor feed water quality. However based on the limit of experimental analysis conducted on both the currently used and alternative resins, it can be concluded that the use of the alternative resin (Amberlite) instead of the existing Lewatit is effective and will not only improve the quality of demineralized water but also will allow extension of operation time above 24hrs without silica break through.

RECOMMENDATION

Based on the outcome of this study, the following recommendations are made:

(1) The demineralizer and filter water unit be urgently rehabilitated

(2) The present resins (Lewatit) employed by water treatment unit to demineralize water should be replaced with the following:

Cations resin -Weak resins - Amberlite IRC 86RF and Strong resins - Amberjet 1200H in the first Column.

Anion resins -Weak resins - Amberlite IRC 96RF and Strong resins Amberlite IRA 900 Cl and the single compartment of anion exchanger be modified to two compartments.

(3) The existing regenerating chemical should be used for the regeneration of the Amberlite resins.

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TABLE 4: AVERAGE YEARLY WATER QUALITY

	RIVER WATER				FILTERED WATER				DEMINERALIZER A, B, C								
									pH			Cond. (µs/cm)			SiO_2 (ppm)		
Period	pH	Cond. (µs/cm)	SiO_2 (ppm)	Turbidity (°)	pH	Cond. (µs/cm)	SiO_2 (ppm)	Turb. (°)	A	B	C	A	B	C	A	B	C
Design	7-7.8	33.5-105	0.8-8.3	20-3000	6.5-7.5	110	1.7	1.0 max	7	-	8	-	10		-	0.2	Max
1997	-	-	-	-	7.4	93	9.8	5.5	7.6	7.5	7.6	2.6	1.8	2.0	0.03	0.04	0.12
										(7.6)			(2.1)			(0.063)	
2000	7.8	89	16.4	198	7.7	98	11.7	13.0	9.2	8.6	8.7	43.8	45.1	69.5	2.3	4.4	5.1
										(8.8)			(52.8)			(3.9)	
2001	7.9	95	16.4	238	7.9	91	18.2	3.2	9.5	8.9	9.3	48.5	24.3	46.6	0.67	1.1	0.55
										(9.2)			(39.8)			(0.77)	

( ) – Average Mean Parameter