

Survey of Construction Materials and Corrosion in Sour Water Strippers—1978

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SUMMARY

In December of 1977, questionnaires were sent out to gather information on experiences with corrosion in sour water strippers. This survey was sponsored by the Panel on Materials of Construction for Sour Water Strippers of the Subcommittee on Corrosion. It updates the results of a 1972 survey, which were presented in API Publication 944, November 1974.

Replies were received from 13 companies and affiliates, representing 92 strippers at 71 locations. The tabulated data are presented here in the same general format as the 1972 report, except that Appendix Tables 2, 3, and 4 have been separated into materials experience and process conditions sections.

The major conclusion of the 1972 report was that the location and severity of corrosion varied with the design of the sour water stripper. In acidified type units, corrosion was severe in the feed section, the stripper tower, and the bottoms section, while corrosion in the overhead section was negligible. The corrosion was caused primarily by inadequate pH control on the acid injection. The lack of corrosion in the overhead section was believed to be due to the absence of ammonia in that section, the ammonia being neutralized by the acid injection. Ammonium sulfide salts in the overhead section were cited as causing under-deposit corrosion and contributing to erosion-corrosion. In non-acidified, condensing type units, severe corrosion and erosion-corrosion occurred in the overhead section, while corrosion in the feed section, stripper tower, and bottoms section was negligible. In non-acidified, non-condensing type units, corrosion throughout was negligible. In addition to the corrosion characteristics of the various units, the 1972 survey found that plugging of non-acidified type units presented a major operating problem. Plugging of the tower and bottoms was due to carbonate deposition and corrosion products. Plugging of the overhead system was due to ammonium sulfide salts and corrosion products.

In general, the results of this most recent survey bear out the conclusions of the earlier survey. One discrepancy exists in that the number of plants indicating that they acidify the feed dropped from eight in 1972, to three in 1978. This lack of information makes it difficult to draw specific conclusions about the relationship between plant design and corrosion experience. However, the data presented in this report does not contradict the findings of the earlier study on any point, and it should be noted

that these two surveys were never intended to make broad conclusions that will apply in every case. Further study is needed to fully define the relationship between corrosion of materials in these units and the sour water chemical composition, temperature, and fluid velocity.

Table I provides a summary of the units surveyed.

Table I--Summary of Types of Units Surveyed

Starting Year of Survey Period	Total Number of Plants(a)	Type of Unit-Number of Plants		Stripping Media-Number of Plants						Other Compounds Present Number of Plants(b)			
		Acidi- fied	Non-Acidified		Steam	Reboiler	Flue Gas	Steam and Flue Gas	Others	Desalter Water		Spent Caustic	
			Con- densing	Non- Condensing						Yes	No	Yes	No
Pre-1972	13	2	6	5	6	5	0	0	2-Steam and Fuel Gas	4/3	9/10	2	11
1972	35	1	14	19	22	8	2	2	0	2/4	32/30	2/1	32/33
1973	4	0	1	3	2	1	0	0	1-Steam and Reboiler	0	4	1	3
1974	7	0	6	1	4	3	0	0	0	0	7	0	7
1975	4	0	2	2	1	2	0	0	1-Steam and Reboiler	0	4	1	3
1976	11	0	5	6	8	2	0	0	1-Steam and Reboiler	0	11	0	11
1977	17	0	9	8	13	4	0	0	0	1	16	2	15
1978	1	0	1	0	1	0	0	0	0	0	1	0	1
Total	92	3	44	44	57	25	2	2	5	7/8	84/83	8/7	83/84

Notes:

- (a) The total number of plants surveyed since 1972 is one more than itemized here. One plant reported that it was out of service and supplied no plant design information.
- (b) A slash indicates a change in the operation of some units. The first number refers to the original operation; the second number describes the current operation.

MATERIALS USED AND CORROSION EXPERIENCE IN FEED SECTION

Table II summarizes the reported experiences with materials used in the feed section of the units. The equipment in this section includes feed surge drums, heat exchangers, pumps, valves, and piping.

Acidified Type Units

As mentioned previously, only three plants reported that they acidify the feed, compared with eight plants in the 1972 survey.

Carbon steel was reported to be a satisfactory material of construction for the feed drum and feed piping upstream of the acid injection point. One plant, after experiencing corrosion problems on carbon steel tubes in the preheat exchanger, switched to 18-8 stainless tubes. The condition of the stainless tubes is not known because no shutdown inspection has been performed since they were installed. Another plant uses a Sakaphen coating on carbon steel tubes in the preheat exchanger, which seems to give sufficient extra lifetime. No problem was reported with carbon steel piping downstream of the acid injection point by one plant; the other two reported using Alloy 20 and Teflon-lined piping in this area without commenting on their experience (it is assumed that these materials are satisfactory). Valves with Teflon internals are used by two plants in the acid streams and in mixing equipment. One of these plants employs all carbon steel valves in the feed streams, while the other uses valves with a carbon steel body and stainless steel trim. Neither plant commented on their experience with these materials. The one plant reporting on the material of the sour water feed pump uses a cast-iron-cased pump, with a cast-iron impeller.

Non-Acidified, Condensing Type Units

Most of the plants employ unlined carbon steel feed drums or tanks, and they all reported little or no corrosion problems. Fifteen of the plants had no problem with carbon steel tubes in the preheat exchanger. The others either were experiencing severe corrosion of carbon steel tubes or were using some ferrous or non-ferrous alloy for these tubes. The major problem with carbon steel tubes seems to be corrosion from the stripper bottoms side on a feed/bottoms exchanger. A wide variety of alloy materials were being used successfully, and feed lines of carbon steel brought good results. Different kinds of materials were used for valves, especially carbon steel bodies with 12 percent chrome or Type 316

stainless steel trim. However, there were no problems reported with any of the listed materials. Nor were any problems reported with cast-iron and carbon steel pumps.

Non-Acidified, Non-Condensing Type Units

Carbon steel was used with good experience for the feed drum or tank. Most of the plants reported having carbon steel tubes in the preheat exchanger and only a few reported severe corrosion problems. Exceptions to the many kinds of alloy tube materials successfully in use were 90-10 cupro-nickel and Admiralty brass, both of which had failed in this service. Carbon steel was employed with good results for the feed lines. No problems were reported with carbon steel or other type valves, and a wide variety of materials were used satisfactorily for feed pumps.

Table II--Summary of Materials Used and Performance in Feed Section

<u>Type of Unit</u>	<u>Equipment</u>	<u>Materials(a)</u>	<u>Number of Plants Using(b)</u>	<u>Remarks(c)</u>
Acidified	Feed drum or tank	CS	2	No problem; corrosion less than 0.1 mm/a
	Preheat exchanger tubes	CS	1	Corrosion problems, replaced with 18-8 SS Since 1974, no inspection Seems to give sufficient extra lifetime
		18-8 SS	1	
		CS with Sakaphen coating	1	
	Lines, downstream acid injection	CS	1	No corrosion problems (d)
		Alloy 20	1	
		Teflon- lined CS	1	
	Other feed lines	CS	1	No corrosion problems (Acid lines)
		Alloy steel	1	
	Valves, body/trim	Teflon	2	(In mixing equipment); (in acid streams) (d)
		CS/SS	1	
		CS/CS	1	
Non- acidified, condensing	Pump, casing/ impeller	CI/CI	1	(d)
	Feed drum or tank	CS	33	Slight pitting - 2; no corrosion since put in service in 1976; no corrosion -7; pitting to 3 mm depth; negligible metal loss; no problem - 5; low corrosion - 3; not inspected since 1975; 0.6 to 6.0 mpy with localized deep pits; 0.5 mm/yr maximum corrosion; (d) - 10
		Fiberglass lined bottom, Plasite 7122 lined walls and top	2	
		Cement lined	3	
		Epoxy lined	2	
		Aluminum coated and epoxy sealed	1	
		Carboline coated	1	
	Preheat exchanger tubes	CS	24	Substantial corrosion on bottoms side; average life 2-1/2 years, corrosion on bottoms side; 1 to 2 years life, corrosion on bottoms side; severe pitting; no problem - 3; 2 year life; no evidence of corrosion problems; pitting, 25 mpy on bottoms side; 200 to 300 mpy; extensive pitting on bottoms side; pitting on bottoms side; ok since 1973; (d) - 10
		Aluminized CS	2	
		316 SS	2	
		304 SS	5	
		7 Mo	1	
		E-Brite 26-1	6	

Table II--Summary of Materials Used and Performance in Feed Section (continued)

<u>Type of Unit</u>	<u>Equipment</u>	<u>Materials(a)</u>	<u>Number of Plants Using(b)</u>	<u>Remarks(c)</u>
		Duplex phase SS	1	No corrosion
		70-30 Cu-Ni	1	Corrosion negligible
		Admiralty	1	(d)
		Incoloy 800	1	(d)
		Ti	5	Corrosion is negligible; (d) - 4 (feed vs overhead)
	Lines	CS	23	No significant corrosion - 3; 10 mpy; 5 mpy - 2; no problem; no measurable corrosion - 2; 5-8 mpy; (d) - 13
		Cement lined CS	3	No significant corrosion - 2; lining lost, causing pump problems
	Valves, body/trim	CI or CS/11-13% Cr	24	No corrosion problems; satisfactory service; no corrosion - 3; (d) - 19
		CS/316 SS	8	No problem - 2; (d) - 6
		CS/CS	2	(d) - 2
		316 SS/ 316 SS	3	(d) - 3
		CS/Monel	1	(d)
		Monel/Monel	1	(d)
		CI/bronze	1	(d)
	Pump, casing/ impeller	CI or CS/CI	13	No corrosion problems; satisfactory service; (d) - 11
		CI or CS/CS	4	(d) - 4
		CS/11-13% Cr	7	No problem; (d) - 6
		CS/316 SS	3	(d) - 3
		316 SS/316 SS	1	(d)
		410 SS/316 SS	1	(d)
		CS/Ni-Resist	1	(d)
		Ni-Resist/ Ni-Resist	2	(d) - 2
		Durimet 20/ Durimet 20	1	(d)
		CS/bronze	1	Bronze impeller not satisfactory
Non-acidified, non-condensing	Feed drum or tank	CS	20	Minor shell pitting; 0.05 inch loss in top portion of vessel; no significant corrosion - 3; no corrosion - 2; no corrosion problems - 2; general mild corrosion - 2; 3 mpy; no corrosion in 10 years; no unusual corrosion; 0.1 mm/yr maximum corrosion rate; (d) - 5
		Cement lined CS	7	Adequate protection; no corrosion problems; corrosion only to exposed manways and nozzle liners - 2; only minor gunite repair needed - 2; (d)
		Resco lined CS	1	Slightly spalled after 19 months
		Coal tar epoxy coated CS	2	Coating blistered and failing after 3 years; (d)
		Concrete pit	2	No corrosion; (d)

Table II--Summary of Materials Used and Performance in Feed Section (continued)

<u>Type of Unit</u>	<u>Equipment</u>	<u>Materials(a)</u>	<u>Number of Plants Using(b)</u>	<u>Remarks(c)</u>
Preheat exchanger tubes	CS	CS	25	Corrosion of return bends in fin tube exchanger; replaced after 2 years; tube life in excess of 10 years - 2; tube life 2 to 4 years; 15 year life; 7 year life; light to medium pitting; superficial corrosion; ok after 5 years - 2; ok after 1 year; no corrosion in 10 years; 5 to 6 year life; lost bundle to corrosion; 9 years life - 2; pitted at 14 mpy; 4 years life; severe internal and external corrosion; 0.1 mm/yr; (d) - 4
		Al	1	Rolling problems at tube sheet
		E-Brite 26-1	1	(d)
		Ti	1	(d)
		Monel	1	No corrosion problems
		70-30 Cu-Ni	3	14 year life; superficial corrosion on bottoms side; (d)
		Ni alloy	1	(d)
		3Re60	1	(d)
		90-10 Cu-Ni	2	Failed in 2 years; failed in less than 1 year
		Aluminized CS	1	0.5 to 1.0 mm/yr corrosion
		316 SS	3	Ok after 5 years; (d) - 2
		Admiralty	1	Replaced after 2 years
Lines	CS	CS	16	No significant corrosion - 5; satisfactory; no problems; 5-6 mpy; (d) - 8
		Monel	6	No failures experienced; replacing with heavy schedule CS as necessary - 3; (d) - 2
		7% Cr - 1/2% Mo	1	(d)
		Cement lined CS	2	For 3-inch lines and larger - 2
Valves, body/trim	CS/11-13% Cr	CS/11-13% Cr	9	No major corrosion; good service; (d) - 6
		CS/316 SS	8	No significant attack; (d) - 7
		CS/CS	3	(d) - 3
		CS/Monel	13	Replacing with CS/12% Cr as necessary - 3; (d) - 10
		Monel/Monel	2	(d) - 2
Pumps, casing/ impeller	CS or CI/CI	CS or CI/CI	13	No corrosion; corrosion-erosion moderate to heavy; (d) - 11
		CS/CS	3	(d) - 3
		CS/11-13% Cr	3	(d) - 3
		Ni CI/CI	2	(d) - 2
		12% Cr/12% Cr	1	(d)
		CI/316 SS	2	(d) - 2
		CS/304 SS	1	(d)
		CS/Ni-Resist	2	No significant attack; (d)
		316 SS/316 SS	1	No corrosion
		408 SS/316 SS	1	No corrosion
		316 SS/CS	1	(d)
		All plastic	1	(d)
		CI/bronze	1	(d)
		304 SS/304 SS	2	(d) - 2

Notes:

- (a) The following notations are used: CS for carbon steel, SS for stainless steel, CI for cast iron, Mo for molybdenum, Ti for titanium, Cu for copper, Ni for nickel, and Cr for chrome.
- (b) Plants not yet in operation were excluded. Units that changed operation were included under their current operation unless a specific comment was made on the old operation. Equipment with documented materials failures have multilisting for each material.
- (c) Remarks in parentheses indicate special operating conditions that affected the materials.
- (d) No comment was made concerning the performance of the material used. Assume there is no problem with the material choice.

MATERIALS USED AND CORROSION EXPERIENCE IN STRIPPER TOWERS

Table III summarizes the reported experiences with materials used in the stripper tower section of the units. The equipment in this section includes the stripper tower, tower internals (trays or packing), and the reboiler.

Acidified Type Units

One plant reported corrosion of both the stripper tower walls and the bubble cap trays. The other two are apparently not experiencing any severe problems. One of these two has Type 316 stainless steel packing and did not comment on any corrosion problems. None of the three plants has a reboiler on the stripper tower.

Non-Acidified, Condensing Type Units

Most of the plants reported good experience with carbon steel construction for the stripper tower. Several plants have stainless steel lined or clad towers and all reported no problems. Cement linings were used successfully at several plants, with only minor repairs to the lining required. One plant reported that a Saureisen 54 lining failed in a few days. None of the plants with carbon steel trays indicated corrosion problems; however, the majority of the plants have alloy steel or non-ferrous tray materials for at least a portion of the tower. After 6 months, one plant replaced the top eight Type 316 stainless steel trays with aluminum, which has not suffered significant corrosion for more than a year.

One plant reported thinning of Type 410 stainless steel trays, which required replacement, and another plant reported cracking of Type 304 stainless steel trays. In general, however, the plants have had good results with all of the listed tray materials. A few plants disclosed severe corrosion of the tubes in both kettle and thermosyphon-type reboilers: two plants had high corrosion rates of carbon steel, one plant experienced E-Brite tube failure by pitting in 20 months, and one plant reported that titanium tubes cracked in 1 year.

Non-Acidified, Non-Condensing Type Units

With a few exceptions, carbon steel was a suitable material for both towers and internals. Several plants had good experience with other materials for tower linings and trays. About one-fourth

of the plants have cement-lined towers, and they reported only minor corrosion and spalling problems. One plant reported severe corrosion of carbon steel tubes in the reboiler; however, since the bundle was retubed with the same material, corrosion has been slight.

Table III--Summary of Materials Used and Performance in Stripper Towers

<u>Type of Unit</u>	<u>Equipment</u>	<u>Materials(a)</u>	<u>Number of Plants Using(b)</u>	<u>Remarks(c)</u>
Acidified	Tower	CS	3	Corrosion of whole column wall, cladding should be provided; 0.3 mm/a corrosion rate; (d)
	Packing	316 SS	1	Hy-pack packing (d)
	Trays	CS	1	Severe corrosion of bubble caps
Non-acidified, condensing	Tower	CS	25	Pitted to 1.5 mm depth in 80,000 hours; satisfactory; no problems; superficial pitting; severe pitting on top part; pitting of bottom head; no metal loss; corrosion in some areas before lining tower; 4-6 mpy; ok after 7 years; (d) - 15
		304 SS lined top/ CS bottom	4	(d) - 4
		Cement lined top	2	Requires repairs in 3-4 years - 2
		Cement lined (all)	7	No repairs required; minimal corrosion; no corrosion on shell; lining removed 5-1/2 years ago with no effect on corrosion rate; no corrosion (FA-22 castable lining); localized erosion (KS4 lining); no corrosion (KS4 lining)
		304 SS clad	1	No appreciable corrosion
		Alloy 20 lining	1	Negligible corrosion
		316 SS	2	Negligible corrosion; (d)
		405 SS top/ CS bottom	1	(d)
		CS, hot sprayed with Al and epoxy sealed	1	(d)
		Saureisen 54 lining	1	Failed in a few days
	Trays	CS	7	Satisfactory; no problems; (d) - 5
		316 SS	5	Top 8 trays replaced after 6 months; no corrosion; negligible corrosion; (d) - 2
		410 SS or 12% Cr	13	Top tray pitted; no corrosion problems - 3; very little corrosion; 10-20 mpy; replaced due to thinning; moderate corrosion; (d) - 5
		Al	2	No significant corrosion after 1 year (Al 3003); (d)
		Monel	1	No corrosion problems
		321 SS	1	Fine pits to 0.5 mm depth
		304 SS	3	Cracking experienced; (d) - 2
		316 SS top/ CS bottom	2	(d) - 2
		410 SS top/ CS bottom	1	(d)
		405 SS	3	(d) - 3
	Packing	Ceramic	1	(d)
		304 SS	4	(d) - 4
		316 SS	2	No appreciable corrosion; satisfactory
		410 SS	2	Corroded within 2 years; (d)
		CS	1	(d)

Table III--Summary of Materials Used and Performance in Stripper Towers (continued)

<u>Type of Unit</u>	<u>Equipment</u>	<u>Materials(a)</u>	<u>Number of Plants Using(b)</u>	<u>Remarks(c)</u>
Non- acidified, non- condensing	Reboiler tubes, kettle type	CS	7	No significant corrosion - 3; 200-300 mpy; some pitting; 10-20 mpy; some leaks while in desalter water service
		3Re60	3	No corrosion; tube surfaces roughened; (d)
		Duplex phase SS	1	(d)
		E-Brite 26-1	1	Failed by pitting in 20 months
		Ti	1	Ok for 3 years
	Reboiler tubes, thermosyphon type	CS	8	No significant corrosion; 2.8 mm corrosion in 35,000 run hours; no corrosion problems; severe corrosion, 75 mpy; (d) - 4
		304 SS	1	(d)
		Ti	1	Cracked, 1 year service life
		Aluminized CS	1	(d)
	Tower	CS	24	Erosion from catalyst in flue gas; minor corrosion; severe corrosion; no evidence of corrosion - 2; no significant corrosion - 2; light rusting; minor wall loss; some blisters; unsatisfactory; very little corrosion - 2; no corrosion problems - 3; slight corrosion and pitting; top section very heavily pitted; (d) - 6
		Cement lined	13	No significant corrosion; light corrosion on bottom head; light corrosion - 2; moderate to heavy corrosion; spalling of lining; (d) - 7
		304 SS top/ CS bottom	1	(d)
		CS top/304 SS bottom	2	No unusual corrosion; (d)
		316 SS top/ CS bottom	1	Good experience
		304 SS	1	(d)
		Epoxy coating	1	Corrosion occurs where coating breaks down
		405 SS top, with ceramic coating/ CS bottom	1	(d)
	Trays	CS	12	Satisfactory; thinning experienced; moderate corrosion; bottom trays corroded; ok after 5 years; no corrosion problems - 2; light to moderate pitting; (d) - 4
		304 SS	2	(d) - 2
		Monel	5	4 year life; badly corroded; low corrosion rate; erosion; (d)
		Inconel	2	2 year life; good service
		410 SS	2	(d) - 2
		316 SS	5	Fair service; good service; failed under deposits; (d) - 2
		316 SS top/ CS bottom	1	Erosion of valve holes on bottom trays
		CS top/304 SS bottom	1	(d)

Table III--Summary of Materials Used and Performance in Stripper Towers (continued)

<u>Type of Unit</u>	<u>Equipment</u>	<u>Materials(a)</u>	<u>Number of Plants Using(b)</u>	<u>Remarks(c)</u>
	Packing	Carbon	1	(d)
		Ceramic	7	(d) - 7
		Al	2	(d) - 2
		304 SS	1	(d)
	Reboiler tubes, kettle type	CS	1	No problem
	Reboiler tubes, thermosyphon type	CS	3	Severe corrosion at first, only slight corrosion after retubing; (d) - 2
		CS, coated	1	(d)

Notes:

- (a) The following notations are used: CS for carbon steel, SS for stainless steel, Al for aluminum, Ti for titanium, and Cr for chrome.
- (b) Plants not yet in operation were excluded. Units that changed operation were included under their current operation unless a specific comment was made on the old operation. Equipment with documented materials failures have multilisting for each material.
- (c) Remarks in parentheses indicate special operating conditions that affected the materials.
- (d) No comment was made concerning the performance of the material used. Assume there is no problem with the material choice.

MATERIALS USED AND CORROSION EXPERIENCE IN OVERHEAD SYSTEMS

Table IV summarizes the reported experiences with materials used in the overhead section of the units. The equipment in this section includes the overhead exchanger, the distillate drum, and various piping, valves, and the reflux pump.

Acidified Type Units

None of the plants reported any corrosion in this section of the unit. Barring one use of Sakaphen-coated steel for the overhead exchanger tubes and the distillate drum, all materials were carbon steel.

Non-Acidified, Condensing Type Units

The overhead line to the exchanger was constructed exclusively of carbon steel, except for one plant's cement-lined carbon steel line. Carbon steel was satisfactory for this line in almost every case. One plant reported corrosion in the uninsulated areas of the line, and another plant experienced corrosion on this line until the overhead temperature was raised above 185 F.

Corrosion was most severe in the overhead exchanger (shell and tube, and air-fin). Only one plant reported carbon steel to be satisfactory for tubes; three plants indicated use of carbon steel without commenting on their experience; all of the others reported corrosion of carbon steel tubes or use of a different material. A variety of other materials brought mixed results. Aluminum appears to be a satisfactory material for the exchanger tubes if erosion-corrosion conditions are avoided. The only reported failures of titanium tubes were due to hydriding where there was a bi-metallic couple. Some plants reported good experience with stainless steel tubes, but some reported failures due to erosion-corrosion, pitting, and cracking.

Mixed corrosion was experienced with all of the materials used in the rundown line, the distillate drum, and the reflux lines. Erosion-corrosion appears to be a major problem in the piping, and some plants reported using carbon steel lines with stainless steel or Inconel elbows to reduce this problem. Most plants reported no problem with carbon steel for the distillate drum, and some used a cement lining successfully. A number of different materials were reported for the reflux pump and valves; while most performed well, a few specific instances of failure were noted. Carbon steel

construction for the off-gas line appears to be satisfactory, provided that no further condensation occurs in the line.

Non-Acidified, Non-Condensing Type Units

Little or no corrosion was reported in the overhead section of this type of unit. Carbon steel was used with good experience in almost every plant.

Table IV--Summary of Materials Used and Performance in Overhead Section

Type of Unit	Equipment	Materials(a)	Number of Plants Using(b)	Remarks(c)
Acidified	Overhead line	CS	1	Corrosion rate 0.2 mm/a; no overhead line - 2
	Overhead exchanger tubes, shell and tube	CS	2	(d) - 2
		Sakaphen coated	1	(d)
	Rundown line	CS	2	No corrosion; 0.15 mm/a
	Distillate drum	CS	1	No corrosion
		Sakaphen coated	1	(d)
	Reflux lines	CS	1	0.1 mm/a
	Valves, body/trim	CS/11-13% Cr	1	(d)
	Off gas line	CS	2	(d) - 2
Non-acidified, condensing	Overhead line	CS	41	No significant corrosion - 7; light corrosion - 4; no corrosion since operating overhead at above 185 F; no defects in 92,000 hours; 0 to 10 mpy with 40 mpy at uninsulated areas; minimal corrosion - 5; no problem - 8; 5 mpy; (d) - 13
		Cement lined	1	Satisfactory
	Overhead exchanger tubes, shell and tube	CS	3	Failed in 15 months; severe shellside pitting; (d)
		Al	5	2 to 4 year tube life; failed in 3 weeks due to high velocity; 1 tube leak in 6 years; no significant corrosion; (d)
		Ti	7	8 month life due to hydriding where iron particles were embedded in tube; (d) - 6
		316 SS	2	(d) - 2
	Overhead exchanger tubes, air fin	70-30 Cu-Ni	1	Failed in 3 weeks
		Alclad	2	12 to 30 month life due to erosion - 2
		CS	6	No defects; 18 month life; 1 year life; retube outlet pass every 6 months; (d) - 2
		Al	2	4 year life; no corrosion
		304 SS	2	Cracked; (d)
		304 SS clad CS	1	(d)
		316 SS	4	No corrosion; 50 mpy maximum corrosion rate; pitting; (d)
		Duplex phase SS	1	No corrosion
		3Re60	1	Failed due to erosion after 2 months
		7 Mo	2	Failed due to erosion after 1 year; (d)
		Alclad	3	4 to 8 mpy - 2; 2 to 3 mpy
		Inconel 600	2	Corrosion at outlet end; excellent condition after 4 years
		Ti	7	No failures from mid-1974 to date; good condition; no problem; severely hydrided; tubes hydrided when SS header box corroded; (d) - 2

Table IV--Summary of Materials Used and Performance in Overhead Section (continued)

<u>Type of Unit</u>	<u>Equipment</u>	<u>Materials(a)</u>	<u>Number of Plants Using(b)</u>	<u>Remarks(c)</u>
Rundown line		CS	29	Up to 500 mpy; 12 mpy; less than 5 mpy - 2; 20+ mpy; 80 to 150 mpy - 2; elbows failed - 2; less than 1 year life; 1-1/2 year life; corroded through in 2 years; 200 mpy; nil corrosion - 2; erosion corrosion - 3; negligible corrosion - 4; (d) - 6
		304 SS	4	Negligible corrosion; (d) (at elbows) - 3
		316 SS	3	Light corrosion; no problems; (d)
		Al	7	22 mpy, higher at impingement areas; minimal corrosion at less than 5 fps, up to 200 mpy at 50 fps; no corrosion - 3; minimal corrosion; (d)
		Monel	1	Minor corrosion during start-up
		Inconel 600	1	(d) (at elbows)
Distillate drum		CS	26	No corrosion - 4; pits 1 mm deep after 80,000 hours; 2 year life; general corrosion and pitting - 2; blistering in a defective plate - 2; 6 mpy; negligible corrosion - 4; mild corrosion; (d) - 9
		Al	3	No problems - 2; (d)
		Cement lined	9	Minor repairs to lining; corrodes at exposed nozzles; very successful; (d) - 6
		Butyl rubber lining	1	Lining failed
		Epoxy phenolic coating	2	Coating failed; (d)
Reflux lines		CS	23	Erosion corrosion; no corrosion - 2; no defects; no appreciable corrosion - 4; severe corrosion; several leaks; 8 to 25 mpy; 10 to 20 mpy; up to 500 mpy; (d) - 10
		Al	3	10 mpy; (d) - 2
		Teflon lined Al	1	Prevents erosion corrosion
		Cement lined CS	4	Satisfactory; no corrosion problems; loss of lining; (d)
		304 SS	3	(d) - 3
		316 SS	1	(d)
		Alloy 20	1	(d) (in high velocity areas)
Reflux pump, casing/impeller		CS or CI/CI	11	Impeller corroded badly without inhibitor present; (d) - 10
		CS/12% Cr	2	(d) - 2
		12% Cr/12% Cr	2	(d) - 2
		CS/316 SS	1	(d)
		316 SS/316 SS	5	Severe erosion corrosion; (d) - 3
		CS/Ni-Resist	3	(d) - 3
		Ni-Resist/ Ni-Resist	2	(d) - 2
		316 SS/Monel	1	(d)
		Alloy 20/ Alloy 20	6	(d) - 6

Table IV--Summary of Materials Used and Performance in Overhead Section (continued)

<u>Type of Unit</u>	<u>Equipment</u>	<u>Materials(a)</u>	<u>Number of Plants Using(b)</u>	<u>Remarks(c)</u>
		Hastelloy C/ Hastelloy C	2	(d) - 2
		Hastelloy B/ Hastelloy B	1	No problems
		Ti/Ti	1	No failures
		Teflon coated	1	Coating failed
	Reflux valves, body/trim	CS/11-13% Cr	16	Not satisfactory; gates have failed due to cracking; negligible corrosion; (d) - 13
		CS/316 SS	4	Failed; (d) - 3
		CS/CS	1	Corroded
		316 SS/316 SS	5	Failed; (d) - 4
		CS/304 SS	1	(d)
		CS/Monel	4	(d) - 4
		Monel/Monel	1	(d)
		Al/316 SS	1	Aluminum corrodes where it contacts the 316 SS
		CS/Teflon	9	A few mechanical failures; (d) - 8
		Alloy 20/ Alloy 20	7	3 weeks life; failed; (d) - 5
		Hastelloy B/ Hastelloy B	3	No problem; (d) - 2
		CI/Alloy 20	2	(d) - 2
		Ti/Ti	1	Negligible corrosion
	Off gas line	CS	35	No significant corrosion - 7; no corrosion problems - 2; no defects in 92,000 hours; 20 to 30 mpy, up to 150 mpy at uninsulated areas; corroded where steam tracing is inadequate; ok in general; mild corrosion - 2; (d) - 20
		Teflon lined	1	No problem
		Al	3	No corrosion in 1-1/2 years; first 24 feet are aluminum, remainder CS; (d)
Non- acidified, non- condensing	Overhead or off gas line	CS	30	No problems - 6; 10 mpy; no significant corrosion - 5; moderate corrosion - 3; less than 3 mpy; no known corrosion in 10 years; 6 to 8 mpy; mild corrosion; pitting to 1.2 mm/yr; (d) - 10
		Cement lined CS	1	(d)
		Monel	1	No failures
		Al	1	No significant corrosion
	Overhead drum or knockout pot	CS	2	Localized pitting; (d)
		Cement lined CS	1	Corrosion at exposed nozzles
	Reflux cooler	CS	3	7 year life; no significant corrosion; (d)
		3Re60	2	Little corrosion; (d)
		70-30 Cu-Ni	2	14 year life; superficial corrosion
		Admiralty	1	2 year life

Table IV--Summary of Materials Used and Performance in Overhead Section (continued)

<u>Type of Unit</u>	<u>Equipment</u>	<u>Materials(a)</u>	<u>Number of Plants Using(b)</u>	<u>Remarks(c)</u>
	Reflux lines	CS	2	No significant corrosion; 0.1 mm/yr general corrosion
		Cement lined	4	(d) - 4
		Monel	2	(d) - 2
	Reflux pump, casing/impeller	316 SS/316 SS	1	(d)
		Teflon lined CI	1	(d)
		Monel/Monel	1	(d)
		12% Cr/12% Cr	1	(d)
	Reflux valves, body/trim	CS/12% Cr	4	(d) - 4
		CI/12% Cr	1	(d)
		CS/316 SS	4	(d) - 4
		CS/Monel	6	(d) - 6
		CS/Alloy 20	1	Good results
		CS/CI	1	(d)

Notes:

- (a) The following notations are used: CS for carbon steel, SS for stainless steel, CI for cast iron, Al for aluminum, Ti for titanium, Cu for copper, Ni for nickel, and Cr for chrome.
- (b) Plants not yet in operation were excluded. Units that changed operation were included under their current operation unless a specific comment was made on the old operation. Equipment with documented materials failures have multilisting for each material.
- (c) Remarks in parentheses indicate special operating conditions that affected the materials.
- (d) No comment was made concerning the performance of the material used. Assume there is no problem with the material choice.

MATERIALS USED AND CORROSION EXPERIENCE IN BOTTOMS SYSTEMS

Table V summarizes the reported experience with materials used in the bottoms section of the units. The equipment in this section includes the bottoms cooler (air cooled, water cooled, or feed/bottoms exchanger), the bottoms pump, and stripped water lines.

Acidified Type Units

As mentioned before, only three plants reported having an acidified-feed-type unit. There seems to be no problems with the use of carbon steel in this section of the units. One plant reported corrosion of the carbon steel tubes in a feed/bottoms exchanger, but the corrosion was apparently from the feed side.

Non-Acidified, Condensing Type Units

Most plants reported good experience with carbon steel in this section; however, a few observed corrosion of carbon steel tubes in feed/bottoms exchangers, noting that the corrosion was from the bottoms side. Several plants used stainless steel tubes with good result, and both titanium and 90-10 cupro-nickel tubes performed well in coolers using sea water as the cooling medium. Construction materials varied for pumps and valves, with little or no corrosion problems reported. Carbon steel was used almost exclusively for the bottoms piping.

Non-Acidified, Non-Condensing Type Units

Carbon steel construction in this section was generally successful. One plant reported heavy corrosion of carbon steel tubes from the bottoms side of a feed/bottoms exchanger. The plants reporting use of stainless steel tubes had good experience or made no comment at all. Two plants disclosed failure of 90-10 cupro-nickel tubes in the feed/bottoms exchanger. No problems were indicated with any of the materials used in the pump or valves, and only light corrosion of carbon steel piping was reported.

Table V--Summary of Materials Used and Performance in Bottoms Section

Type of Unit	Equipment	Materials(a)	Number of Plants Using(b)	Remarks(c)
Acidified	Bottoms cooler tubes, air cooled	CS	1	(d)
	Feed/bottoms exchanger tubes	CS	1	Corrosion problems, replaced with 18-8 SS in 1974 due to corrosion from feed side
	Pump, casing/impeller	CI/bronze	1	(d)
	Valves, body/trim	CS/11-13% Cr	1	(d)
		CS/CS	1	(d)
Non-acidified, condensing	Lines	CS	2	(d) - 2
	Bottoms cooler tubes, air cooled	CS	7	No significant corrosion - 2; some erosion at tube ends; negligible metal loss; no corrosion problems - 2; (d)
		Duplex phase SS	1	No corrosion
	Bottoms cooler tubes, water cooled	CS	2	No problem; 6 mpy on top half of bundle
		Ti	1	(d) (cooled with seawater possibly contaminated with hydrogen sulfide)
		90-10 Cu-Ni	2	(d) (cooled with salt water) - 2
	Feed/bottoms exchanger tubes	CS	18	No significant corrosion; substantial corrosion on bottoms side near outlet; average life 2-1/2 years; corrosion on bottoms side; 5 mpy; 8 year life; no appreciable corrosion; no problem - 5; 25 mpy on top half of bundle; (d) - 4
		316 SS	1	No problem
		304 SS	4	(d) - 4
		E-Brite 26-1	4	No problem - 2; (d) - 2
		Ti	1	(d)
	Bottoms/overhead exchanger tubes	Ti	1	(d)
		Ti	1	(d)
	Pump, casing/impeller	CS or CI/CI	15	(d) - 15
		CS/Ni-Resist	3	(d) - 3
	Valves, body trim	Alloy 20/ Alloy 20	1	(d)
		CS/316 SS	3	(d) - 3
		CS/12% Cr	6	(d) - 6
		316 SS/316 SS	1	(d)
		12% Cr/12% Cr	1	(d)
		CS/bronze	1	Bronze impeller not satisfactory
		CS or CI/ 12% Cr	22	(d) - 22
		CS/316 SS	4	Negligible corrosion; (d) - 3
		CS/416 SS	1	(d)
		CS/Monel	2	(d) - 2
		Monel/Monel	1	(d)
		CI/bronze	1	(d)

Table V--Summary of Materials Used and Performance in Bottoms Section (continued)

Type of Unit	Equipment	Materials(a)	Number of Plants Using(b)	Remarks(c)
Non-acidified, non-condensing	Lines	CS	36	Corrosion rate 10 to 35 mpy; no appreciable corrosion - 6; no problem - 3; no corrosion - 3; slight corrosion - 2; 10 mpy; (d) - 20
		Cement lined CS	3	No significant corrosion; no corrosion problems; (d)
	Bottoms cooler tubes, water cooled	2RK65	1	Fouled but not corroded
	Feed/bottoms exchanger tubes	CS	12	Heavy corrosion on bottoms side; 15 year life; 7 year life; light to medium pitting; superficial corrosion; no corrosion; ok after 5 years; 5 to 6 year life; 2 mpy; (d) - 3
		E-Brite 26-1	1	(d)
		70-30 Cu-Ni	2	14 year life; scattered pitting
		90-10 Cu-Ni	2	Failed within 2 years; failed within 1 year
		316 SS	2	Ok after 5 years; (d)
	Pump, casing/impeller	CS or CI/CI	10	(d) - 10
		CS/CS	3	(d) - 3
		Ni-Resist/CI	1	(d)
		316 SS/316 SS	2	(d) - 2
		CS or CI/316 SS	3	(d) - 3
		12% Cr/CI	1	(d)
		CS/bronze	1	(d)
		CS/12% Cr	1	(d)
	Valves, body/trim	CS/12% Cr	10	(d) - 10
		CS/316 SS	7	(d) - 7
		CS/Monel	3	(d) - 3
		CS/304 SS	2	(d) - 2
		CS/CS	2	(d) - 2
		314 SS/314 SS	2	(d) - 2
		316 SS/316 SS	1	(d)
	Lines	CS	27	No corrosion - 5; light corrosion - 2; no problems - 4; 4 mpy - 2; (d) - 15
		Cement lined CS	3	(d) - 3
		Monel	2	(d) - 2

Notes:

- (a) The following notations are used: CS for carbon steel, SS for stainless steel, CI for cast iron, Ti for titanium, Cu for copper, Ni for nickel, and Cr for chrome.
- (b) Plants not yet in operation were excluded. Units that changed operation were included under their current operation unless a specific comment was made on the old operation. Equipment with documented materials failures have multilisting for each material.
- (c) Remarks in parentheses indicate special operating conditions that affected the materials.
- (d) No comment was made concerning the performance of the material used. Assume there is no problem with the material choice.

PLUGGING PROBLEMS IN SOUR WATER STRIPPERS

As revealed in the previous survey, plugging of the sour water stripping system is encountered in numerous plants. Problems were described in the feed system (2), stripper or reboiler (33), overhead system (19), and bottoms system (2). Tables VI and VII summarize the various causes for plugging and reported solutions.

Two plants mentioned fouling of feed equipment by ammonium sulfide salts, which was handled by periodic cleaning.

More problems were experienced in the stripper tower than in any other section. The main reported cause of tower plugging was deposition of water hardness scale (calcium carbonate). Several plants controlled the problem by eliminating sources of hard water from the sour water feed. Some plants reported that the addition of antifoulants or scale inhibitors helped alleviate the problem. A number of plants required frequent chemical or mechanical cleaning to prevent plugging. Three plants reported plugging of the tower bottom due to excessive polysulfide injection at the catalytic cracking units.

The major cause of plugging problems in the overhead system was ammonium sulfide salt deposition. The plugging of instrument taps was particularly troublesome. Solutions to this problem were: temperature maintenance of at least 185 F by insulating and steam tracing the overhead lines, periodic water wash or steam out of the overhead, and relocation of instrument taps. Three plants reported plugging of the flame arrestor on the sour gas burner with sulfide salts, requiring occasional removal of the arrestor for steam out.

In one instance, the bottoms pump suction screen was plugged from spalling of the cement lining in the stripper. Another plant reported sulfide sludge fouling of the feed/bottoms exchanger.