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SOUR WATER
STRIPPING SURVEY EVALUATION

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Foreword

In 1972, The American Petroleum Institute Panel on Sour Water Strippers arranged for a survey to be conducted on sour water stripping practices. The survey was conducted by the distribution of a set of questionnaires to API member oil refineries in order to secure quantitative data concerning the current methods of stripping sour waters.

The 73 questionnaires returned form the basis of this report and the profiles derived therefrom. Without this demonstrated cooperation of the petroleum industry, it would not be possible to secure the information compiled in this report. The contributions and support of the Committee on Refinery Environmental Control's Sour Water Stripper Panel is acknowledged and appreciated.

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TABLE OF CONTENTS

	<u>Page</u>
Foreword	i
Table of Contents	ii
Table of Illustrations and Tables	iv

Section

I. Introduction	1
II. Data Presentation and Interpretation	4
Part 1 - Tables I, II, and III - Sour Water Strippers	4
Removal Efficiency	5
Steam Consumption	12
Disposition of Off-Gases and Stripped Water	17
Flue Gas Stripper	18
Fuel Gas Strippers	18
Summary	18
Part 2 - Table IV - Sour Water Oxidizers	32
Part 3 - Table V - Stripper Feed-Bottom Heat Exchangers	34
Part 4 - Table VI - Tower Overhead Coolers	36
Part 5 - Tables VII and VIII - Metallurgy	38
Non-refluxed	38
Refluxed	39
Tower Column	40
Trays	41

TABLE OF CONTENTS (Con't.)

<u>Section</u>	<u>Page</u>
Tower Overhead Line	41
Bottom to Charge Exchangers	42
Overhead Coolers	42
Overhead Accumulator	43
Accumulator Off Gas Line	44
III. Tray by Tray Calculations	47
IV. Maintenance and Operating Techniques	53
V. Recommendations for Additional Work	59

TABLE OF ILLUSTRATIONS AND TABLES

	<u>Page</u>
TABLE I Sour Water Strippers, Steam Stripping - Refluxed	20
TABLE II Sour Water Strippers, Steam Stripping - Non-Refluxed	25
TABLE III Sour Water Strippers, Flue Gas and Fuel Gas Strippers	30
TABLE IV Sour Water Oxidizers	33
TABLE V Feed-Bottom Exchangers - Overall Heat Transfer Coefficient	35
TABLE VI Tower Overhead Coolers	37
TABLE VII Sour Water - Steam Stripping - Refluxed - Metallurgy	45
TABLE VIII Sour Water - Steam Stripping - Non-Refluxed - Metallurgy	46
FIGURE 1 Removal Efficiency vs. Stripping Steam Rate - Refluxed	8
FIGURE 2 Removal Efficiency vs. Stripping Steam Rate - Non-Refluxed	9
FIGURE 3 Removal Efficiency vs. Total Steam Rate - Refluxed	10
FIGURE 4 Removal Efficiency vs. Total Steam Rate - Non-Refluxed	11
FIGURE 5 Effects of Varying Steam Rate to Remove H_2S , NH_3 and Phenols from Sour Water - Code No. 34	15
FIGURE 6 Removal Efficiency vs. Steam Rate - Ten Run Test by Code No. 34	16
FIGURE 7 Removal Efficiency of NH_3 , H_2S and Phenols	19
FIGURE 8 Tray Efficiency (or HETP) vs. Per Cent Recovery	51
FIGURE 9 Sour Water Stripper Tray and Packing Efficiencies	52
FIGURE 10 Typical Sour Water Feed Drum	58

SECTION I
INTRODUCTION

SECTION I. INTRODUCTION

The objective of this report was threefold:

1. Tabulate the questionnaire data in summary form.
2. Present interpretations based on analysis of the data.
3. Recommend areas where added work would be beneficial in developing sour water stripping technology.

The approach was to subject the coded questionnaires to a rigorous screening to extract all meaningful data. These comprehensive data covering operating types and conditions are presented in Tables I through Table VIII.

TABLE I - SOUR WATER STRIPPERS - STEAM STRIPPING - REFLUXED

TABLE II - SOUR WATER STRIPPERS - STEAM STRIPPING - NON-REFLUXED

TABLE III - SOUR WATER STRIPPERS - FLUE GAS AND FUEL GAS STRIPPERS

TABLE IV - SOUR WATER OXIDIZERS

TABLE V - FEED-BOTTOM EXCHANGERS - OVERALL HEAT TRANSFER COEFFICIENT

TABLE VI - TOWER OVERHEAD COOLERS

TABLE VII - SOUR WATER - STEAM STRIPPING - NON-REFLUXED - METALLURGY

TABLE VIII - SOUR WATER - STEAM STRIPPING - TOWER - REFLUXED - METALLURGY

These tables form the data basis for the remaining interpretation and analysis.

Emphasis in the discussion was placed on process design, mechanical design, metallurgy, maintenance and operating techniques where practical.

In addition, a tray by tray analysis between actual results and computer calculations was made.

Statistics concerning removal efficiencies and steam usage were derived from the data and were useful to interpret the data.

The report is arranged so that the data discussion centers about each of the Base Tables and the most important statistics derived from these tables.

Some Definitions and Assumptions used in the report follow:

1. The 73 reported strippers resulted from 63 replies to the questionnaire. Of the 73 strippers reported;
 - 31 were classified as refluxed steam strippers which cool the overhead in some manner and return the condensate to the tower, feed drum or feed line.
 - 24 were classified as non-refluxed steam strippers which dispose of the offgas without cooling. (Includes KO pot type).
 - 5 were classified as flue gas strippers.
 - 2 were classified as fuel gas strippers.
 - 4 were classified as oxidizing units.
 - 7 were classified as rejects which lacked sufficient information to be classified or considered.
2. The "average" used in this report is the arithmetic average

or arithmetic mean.

3. The range is a measure of general variability of the distribution. It is the difference between the highest and lowest value of a set of data.
4. The number of cases or items of data considered in a set is denoted by the symbol n .
5. Zeros were considered as no data on the assumption that no attempt is being made to remove the contaminant and to include it as a data point would unreasonably bias the sample.
6. In the report there are five, 2-stage strippers. In calculating the efficiency or percent removal of these units the two towers were considered as one unit. In other words, the percent removal was based on the raw feed to the 1st stage and that remaining in the bottoms of the 2nd stage. In the master tables each tower was treated as a separate unit in the recorded data.

SECTION II
DATA PRESENTATION
AND INTERPRETATION

PART 1 - TABLES I, II, & III - SOUR WATER STRIPPERS

SECTION II. DATA PRESENTATION AND INTERPRETATION
PART 1 - TABLES I, II AND III - SOUR WATER STRIPPERS

See the following tables for tabulations of results.

TABLE I STEAM STRIPPING - REFLUXED

TABLE II STEAM STRIPPING - NON-REFLUXED

TABLE III FLUE GAS AND FUEL GAS STRIPPERS

When considering removal of sulfides, ammonia, and phenols from sour water by stripping, the type of operation can have an effect on their removal. The operation referred to is whether the strippers are re-fluxed or non-refluxed and whether the stripping media is steam, flue gas or fuel gas.

Since operations are different the steam strippers will be discussed separately from flue gas and fuel gas.

REMOVAL EFFICIENCY

Following is a comparison of the percent removal for refluxed and non-refluxed steam strippers.

	% Removal		
	<u>NH₃</u>	<u>H₂S</u>	<u>Phenols</u>
Average of all reported results:			
Refluxed	74.4%	96.0%	35.6%
Non-Refluxed	82.7%	95.39%	45.8%
Average of the results where sulfides showed 90% or better removal:			
Refluxed	84.0%	99.40%	39.8%
Non-Refluxed	78.1%	98.85%	65.6%
Average of the results where ammonia showed 90% or better removal:			
Refluxed	95.7%	99.77%	39.1%
Non-Refluxed	95.9%	99.65%	55.5%

As shown in the above results for ammonia removal, when averaging all results, the non-refluxed units exhibit better removal than the refluxed. When considering those reported results where 90% or better sulfur removal was attained the refluxed units were better than the non-refluxed. Considering those results where ammonia exhibited 90% or better removal, refluxed and non-refluxed towers appeared equal.

One explanation appears to satisfy these observations. Ammonia is

harder to remove than sulfides. To achieve low steam rates, tower design is critical. Poor design may be offset, to some degree, by the use of excessive steam within the capacity of the tower to handle the vapor load.

With sulfide removal there is very little difference between the re-fluxed and non-refluxed unit with all percent removals being within 1% of each other.

With regard to phenol removal, the non-refluxed units showed a 10 to 26% increase in removal as compared to the refluxed units.

In summary, the above results show that the sulfides are more easily removed than the ammonia and ammonia is more easily removed than phenols. One can also conclude that steam stripping of phenols is not very effective.

Only 14 companies reported on removal of cyanide. These reported results were very erratic. For reflux towers, the average removal was 44.2% and for non-reflux was 32.9%. The average for all results was 37% removal and it can be concluded under conditions reported that cyanides are not readily removed by steam stripping.

To illustrate the effect of efficiency removal as affected by stripping steam rates and total steam rates the following charts were prepared.

FIGURE I Removal Efficiency vs. Stripping Steam Rate - Refluxed

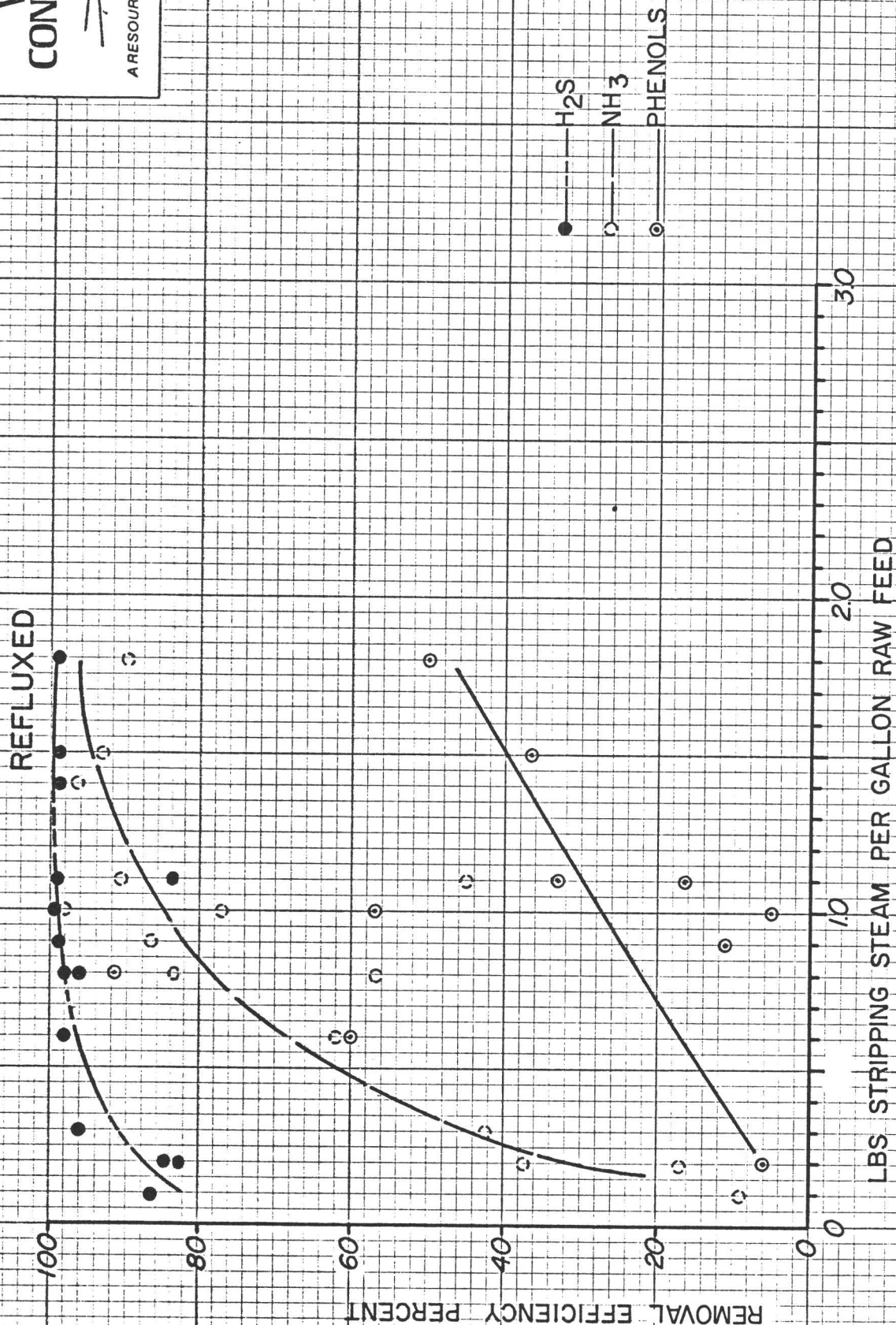
FIGURE II Removal Efficiency vs. Stripping Steam Rate - Non-Refluxed

FIGURE III Removal Efficiency vs. Total Steam Rate - Refluxed

FIGURE IV Removal Efficiency vs. Total Steam Rate - Non-Refluxed



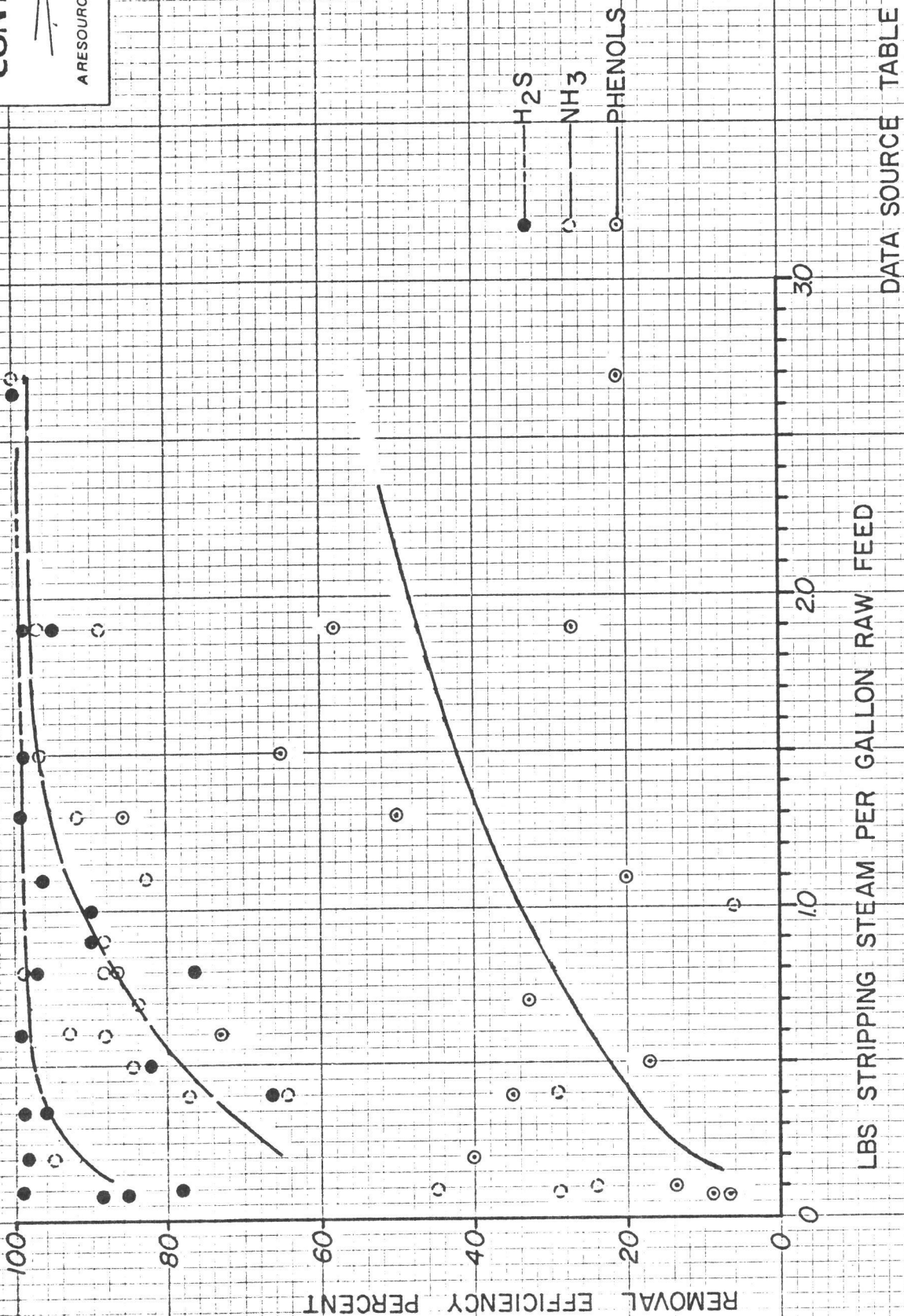
FIGURE 1
REMOVAL EFFICIENCY VS STRIPPING STEAM RATE
REFLUXED



DATA SOURCE TABLE 1



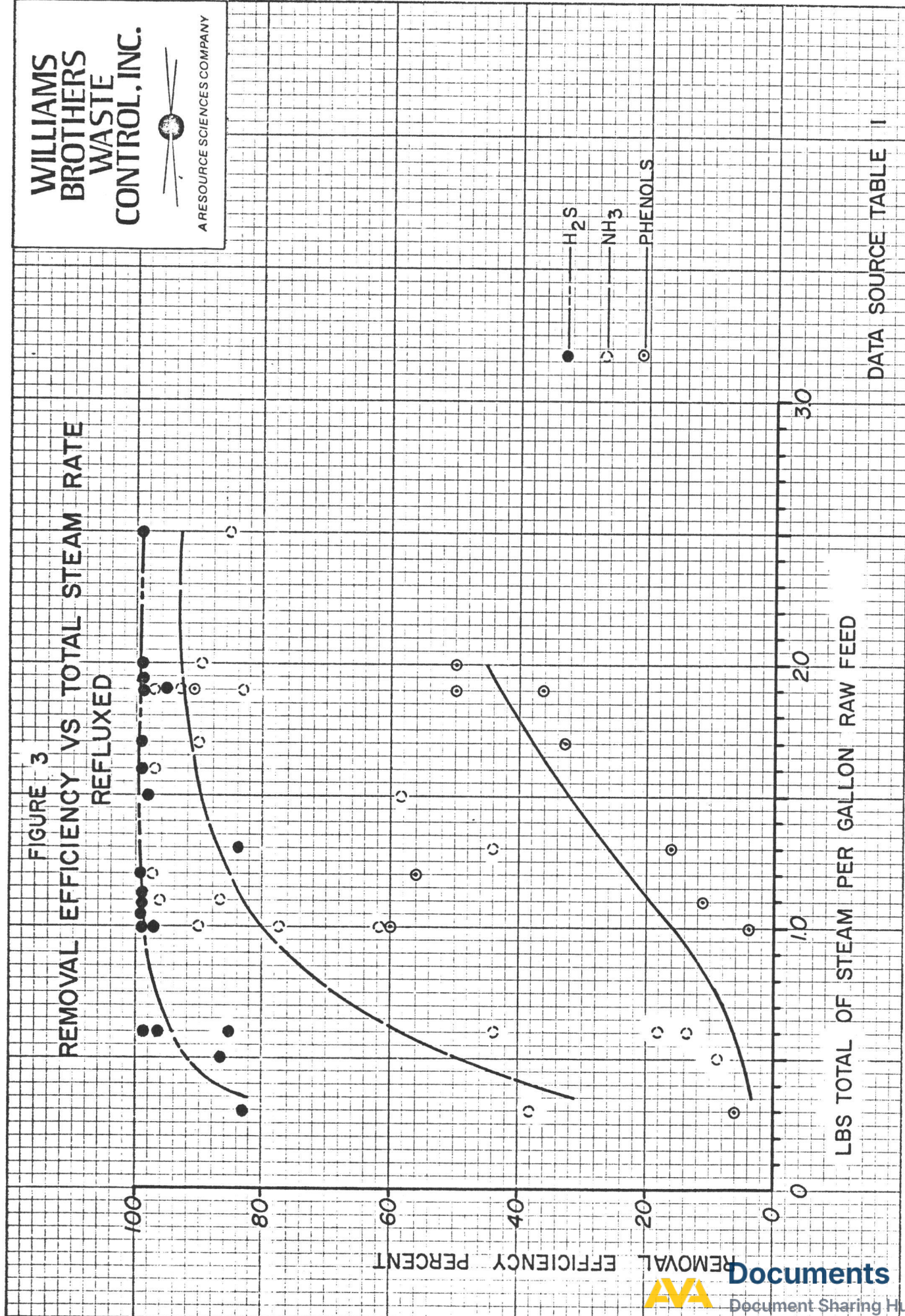
FIGURE 2
REMOVAL EFFICIENCY VS STRIPPING STEAM RATE
NON — REFLUXED



DATA SOURCE TABLE II



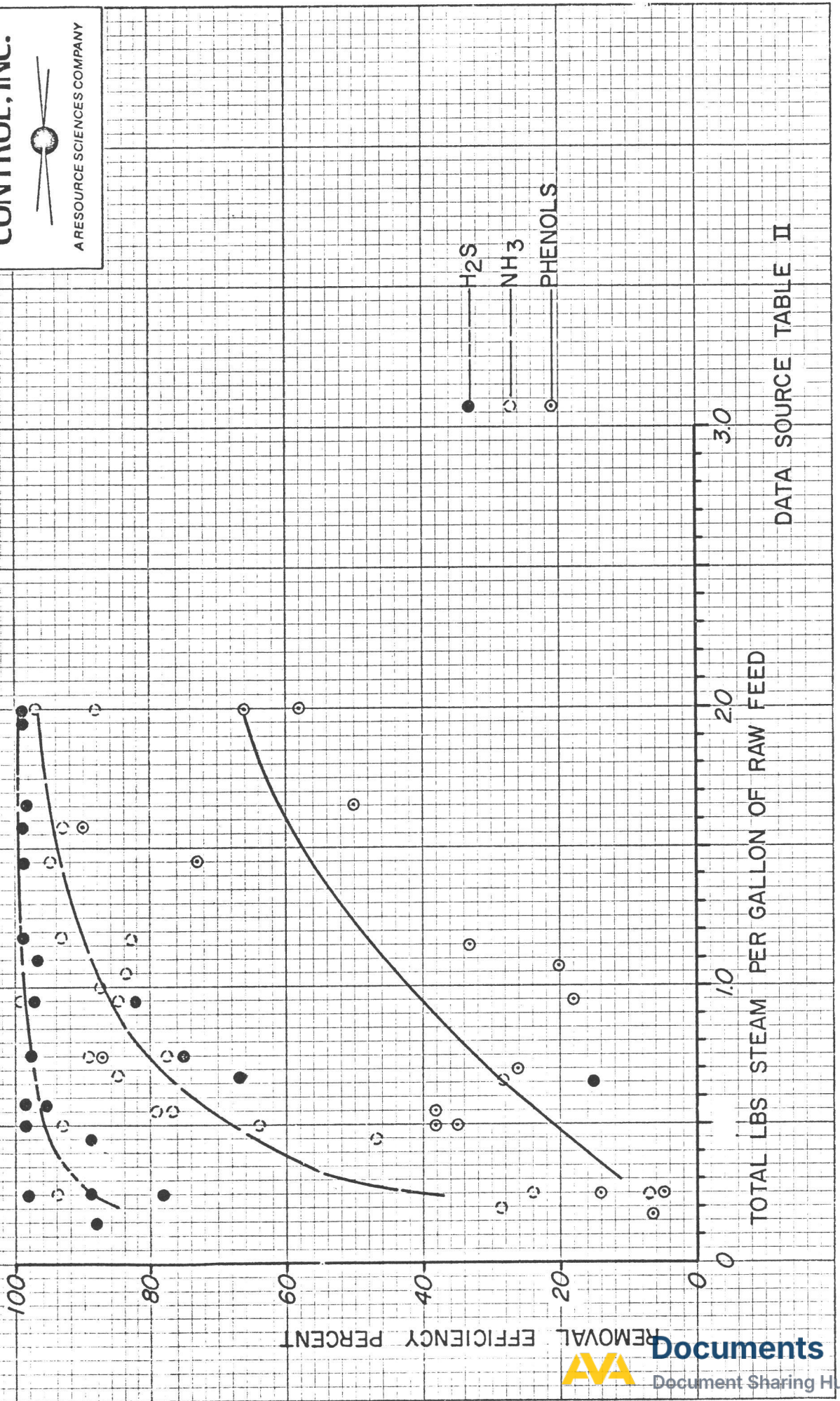
FIGURE 3
REMOVAL EFFICIENCY VS TOTAL STEAM RATE
REFLUXED



DATA SOURCE TABLE I



FIGURE 4
REMOVAL EFFICIENCY VS TOTAL STEAM RATE
NON — REFLUXED



DATA SOURCE TABLE II

STEAM CONSUMPTION

Following is a comparison of stripping steam rate vs. stripper raw feed rate.

	<u>Stripping Steam Rate</u>	
	Refluxed	Non-Refluxed
Average of all results:		
Average, lbs./gal. of raw feed	0.85	0.83
Range, lbs./gal. of raw feed	0.1 - 1.8	0.07 - 2.7

Average of results with ammonia above 90% removal:

Average, lbs./gal. of raw feed	1.21	1.29
Range, lbs./gal. of raw feed	0.5 - 1.8	0.6 - 2.7

As shown in the above, stripping steam consumptions are nearly the same for refluxed and non-refluxed units.

Following is a comparison of total steam rate vs. stripper raw feed rate.

	<u>Total Steam Rate</u>	
	Refluxed	Non-Refluxed
Average of all results:		
Average, lbs./gal. of raw feed	1.25	0.94
Range, lbs./gal. of raw feed	0.3 - 2.1	0.2 - 2.0

Average of results with ammonia above 90% removal:

Average, lbs./gal. of raw feed	1.57	1.13
Range, lbs./gal. of raw feed	1.0 - 2.0	0.3 - 2.0

As would be expected, the total steam consumption for refluxed units is higher than the non-refluxed units.

It is interesting to note the increased steam consumption when considering those units that remove 90% or more of ammonia as compared to an average of all results.

Code No. 34 presented some very interesting data that illustrates increased steam requirements in relation to sulfide, ammonia and phenol removal. This data is presented in Figures 5 and 6. Following the table is a graph which plots Removal Efficiency Percent vs. Pounds of Steam per Gallon of Raw Feed for this data. This information is very valuable as the data were obtained on the same unit and consequently the number of variables were significantly reduced.

FIGURE 5

CODE NO. 34
EFFECT OF VARYING STEAM RATE TO REMOVE H₂S,
NH₃, AND PHENOLS FROM SOUR WATER

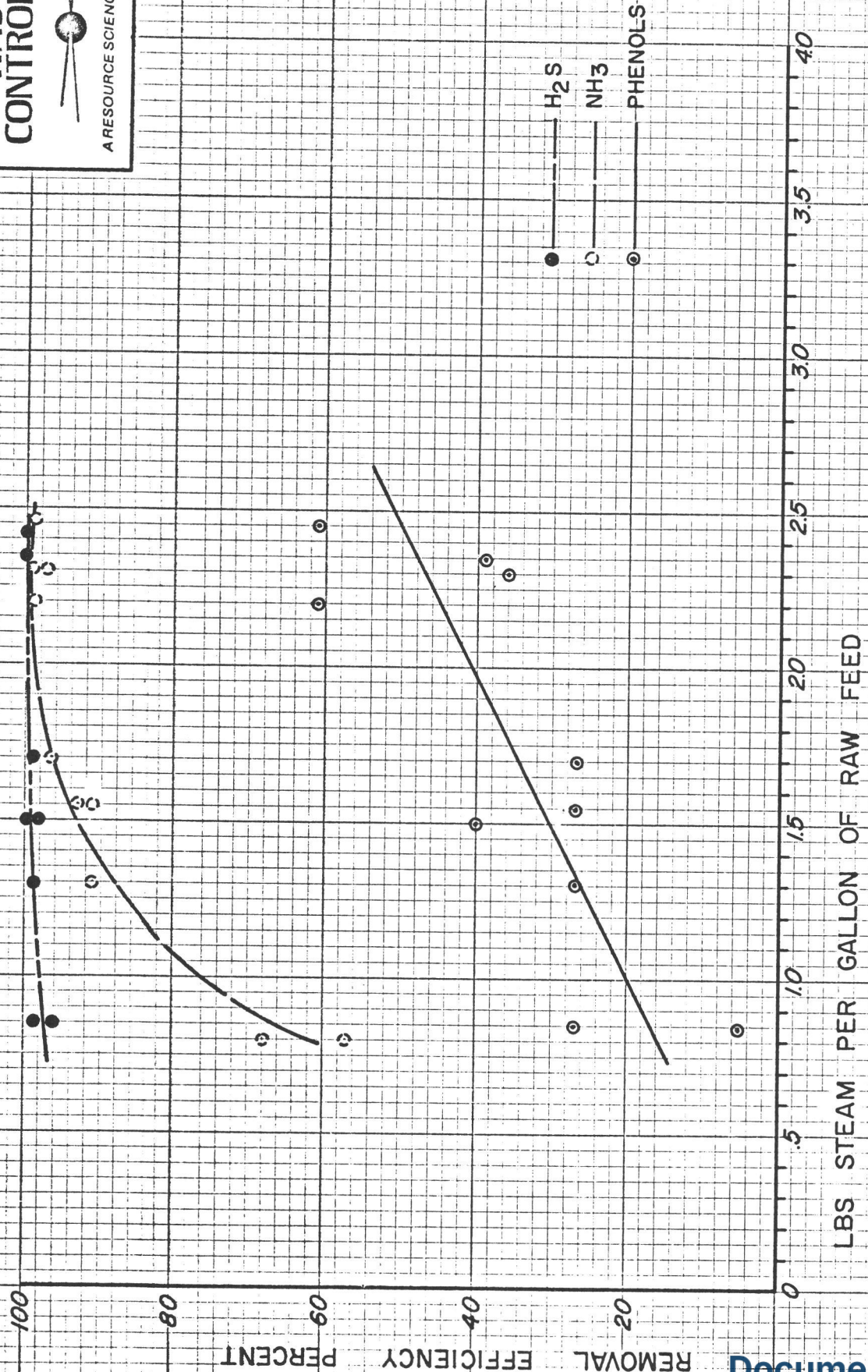
Test Run	1	2	3	4	5	6	7	8	9	10
Fresh feed - gpm	201	198	140	191	159	156	103	132	115	128
Total feed - gpm	240	233	177	206	183	177	124	157	143	135
Steam - Mlb/hr	10.0	9.7	12.9	15.0	14.6	16.0	14.6	18.3	17.0	17.2
Steam - lbs/gal:										
Raw feed	0.83	0.82	1.53	1.31	1.53	1.71	2.36	2.31	2.46	2.24
Total feed	0.70	0.70	1.22	1.21	1.33	1.51	1.96	1.94	1.98	2.12
Tower Top - °F	230	229	226	231	235	228	235	227	230	333
H ₂ S, Feed - ppm	3,840	4,667	5,206	3,307	3,993	4,327	4,488	4,795	4,160	2,400
H ₂ S, Bottoms - ppm	54	96	28	7	11	8	14	13	13	6
H ₂ S Removal - %	98.6	98.0	99.5	99.8	99.7	99.8	99.7	99.7	99.7	99.8
NH ₃ , Feed - ppm	1,340	2,200	2,983	2,097	1,930	1,886	3,620	3,233	1,220	1,180
NH ₃ , Bottoms - ppm	580	687	280	201	125	67	54	76	12	6
NH ₃ , Removal - %	56.7	68.8	90.6	90.4	93.5	96.5	98.5	97.7	99.0	99.5
Phenols, feed - ppm	340	484	721	384	655	351	716	544	640	880
Phenols, bottoms - ppm	320	357	531	285	390	255	431	347	250	336
Phenols, removal - %	5.9	26.2	26.4	25.8	40.5	27.4	39.8	36.2	60.9	61.8

NOTE: Tower was 7' dia. X 35' high with 15 ft. of packing in tower with 3" raschig rings.

The overhead gas is cooled to 175°F-195°F. Tower pressure was in the range of 6.5 to 7.2 psig.



FIGURE 6
REMOVAL EFFICIENCY VS STEAM RATE
TEN RUN TEST BY CODE 34



REF. FIGURE 5
CODE 34 10 RUN TEST

DISPOSITION OF OFF-GASES AND STRIPPED WATER

Off-Gases

	<u>Refluxed</u>	<u>Non-Refluxed</u>
Incinerated in some manner	19	19
Sulfur plant	10	2
Vented to atmosphere	0	6
Scrubbers	2	0
Gas plants	0	1

Stripped Water

	<u>Refluxed</u>	<u>Non-Refluxed</u>
Desalter	14	12
Sewer	10	5
Bio-system	4	8
Cooling towers	1	--
FCC Unit	1	--
Oxidizers	1	--