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SUBJECT: FLOODING CHARACTERISTICS OF 1/4-in.
FLUOROTHENE RASCHIG RINGS
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ABSTRACT

The objective of this study was to compare the flooding characteristics of Fluorothene Raschig rings at low liquid rates with the existing literature data on carbon rings.

Visual observations of flooding in the air-water system were correlated with pressure drop using a 3-in. i.d. glass column having an 18-in. long Fluorothene Raschig ring packed section. A comparison of extrapolated literature data with these experimental data indicates the gas flow rates required to flood Fluorothene packing are slightly higher than for carbon packing. At a liquid flow rate of 537 lbs/hr-ft², Fluorothene rings flooded at a gas velocity of 842 lbs/hr-ft² whereas carbon rings are reported to flood at a gas velocity of approximately 755 lbs/hr-ft².

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INTRODUCTION

The purpose of this study was to determine the flooding characteristics of 1/4-in Fluorothene Raschig rings at low liquid rates. Plastic Raschig rings will be used in the Volatility program to study the operation of a hydrogen fluoride off-gas scrubber column.

The study was made in a 3-in. i.d. column using an air-water system. Water flow rates were varied from 134 to 672 lbs/hr sq. ft. column cross section. Flooding was defined as the point where the column pressure drop increased rapidly with gas rate.

The results were compared with an extrapolation of the data on carbon rings given by Schoenborn and Dougherty⁽¹⁾, showing that flooding occurs at slightly higher gas rates when plastic rings are used. The results of the one run made using 1/4 inch steel rings were consistent with an extrapolation of Schoenborn and Dougherty's data.

EQUIPMENT AND PROCEDURE

A 3-in. i.d. glass column, 4 foot high (Fig. 1), was used in this study. The packing material was 18 inches of randomly dumped Fluorothene packing supported 6 inches from the bottom of the column on a copper screen which was in turn supported by a 2-1/2-in. o.d. glass column. Four commercial rotometers (4.6 scfm capacity) were provided in the entering air lines. The water was introduced through a 1/4-in. glass tube and flowed over a copper distributor screen 5-in. above the packing. A bottom outlet was provided whose height could be adjusted to maintain a constant depth of water in the column.

The liquid flow rates was adjusted, but before the air flow was started, a pressure reading was taken and the water level in the bottom of the column was marked as a reference point. The air flow was then started, and the height of the water drain was adjusted so that the water level in the bottom of the column remained constant at the reference point. After the column pressure had reached steady state, an additional five minutes were allowed before reading the new pressure and raising the air flow rate. Pressure measurements were made with an open end U-tube manometer. The water flow rate was regulated by trial and error using a graduated cylinder and a stopwatch.

Frequently during each run, a dye was injected into the water stream so that the distribution of the liquid flow through the packing could be observed.

THE EFFECT OF GAS AND LIQUID VELOCITIES ON COLUMN FLOODING

For Fluorothene packing, the gas velocity at flooding decreased from 1152 lbs/hr sq. ft. to 842 lbs/hr. sq. ft. and the pressure drop of the flooding point ($\frac{\Delta P}{h}$) decreased from 4.85 to 3.91 inches of H₂O/ft of packing

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$\frac{1}{4}$ - inch O.D. GLASS TUBING
TO HOLD #6 MESH COPPER
SCREENING IN PLACE (4 used)

MANOMETER

METER STICK

H₂O INPUT FROM TAP

COPPER SCREENING WITH
 $\frac{1}{2}$ - inch HOLE IN CENTER

COPPER SCREEN PACKING
RETAINER

18-inches DRY-DUMPED
RASCHIG RINGS ($\frac{1}{4}$ -inch
tubing cut into $\frac{1}{4}$ -inch
lengths)

COPPER SCREENING, BOTTOM
PACKING SUPPORT

AIR INLET TUBES (4 used)

RUBBER STOPPER

$2\frac{1}{2}$ - inch O.D. GLASS COLUMN
SUPPORTING COPPER SCREEN-
ING

Fig. 1. Column Detail

as the liquid velocity was increased from 134 lbs/hr sq. ft. to 537 lbs/hr sq. ft. (see Table 1 and Fig. 2).

Pressure drop measurements for dry Fluorothene packing (Fig. 3) show that the pressure drop increased from 0.577 inches H_2O/ft to 6.72 inches/ft and was proportional to the 1.76 power of the gas velocity as the gas velocity was increased from 325 lbs/hr sq. ft. to 1222 lbs/hr sq. ft.

Results of a run made with steel rings at a liquid flow rate of 537 lbs/hr sq. ft. showed that the column flooded at a gas velocity of (G/ϕ) of 755 lbs/hr sq. ft. compared with 842 lbs/hr sq. ft. for Fluorothene rings. The pressure drop of the steel rings was 4.65 inches H_2O/ft at the flooding point.

Visual observation of a dye injected into the liquid stream showed that a large percentage of the water channeled down the sides of the column. Photographs taken of the packing as the dye flowed through it at rates slightly below flooding (Figs. 4, 5, 6,) confirmed that the liquid channeled down one side of the column while the air passed up the other side.

COMPARISON OF RESULTS WITH LITERATURE REFERENCES

The method recommended by Sherwood and Pigford was used to correlate the flooding data.⁽²⁾ The gas velocity function (G/ϕ) was plotted against the ratio of the liquid velocity to this function, $(L\phi/G)$.

In order to compare the data obtained with Fluorothene rings to the data for carbon packing published by Schoenborn and Dougherty, (Table 2) extrapolations of both sets of data were necessary (Fig. 7).

In order to determine the flooding points, a log-log plot was made of the pressure drop vs. gas velocity for each liquid flow rate (Fig. 2). These data (Fig. 2) showed that for dry packing the pressure drop was proportional to the 1.76 power of the gas velocity. For wet packing the curve approximated this power up to the flooding point. At the flooding point there was an abrupt increase in the pressure drop where the curve became almost vertical. At this point a liquid layer started to form on top of the packing and the air bubbled violently through the water.

A comparison of the experimental curve for dry Fluorothene packing with that obtained from Schoenborn and Dougherty for dry carbon packing shows that the pressure drop was slightly higher for the Fluorothene packing. This difference could be real; however, it could easily have been caused by errors in reading the gas flow rates from the rotameters. An error in reading the flow rate of 2 to 4 divisions of the rotameter scale could cause the differences found in the mass velocities (G) .

It is believed that the higher flooding rates for the Fluorothene packing were caused by reduced skin friction due to the smoother non-wetting surfaces of the Fluorothene rings. The fact that channeling did

Table 1. Experimental Flooding Velocities for 1/4"
Fluorothene and Steel Raschig Rings

Water Mass Velocity lb/hr sq. ft. L	Air Mass Velocity lb/hr sq. ft. G/φ	Liquid- Gas Ratio $\frac{L\phi}{G}$	Pressure Drop at Flooding in. H ₂ O/ft Packing $\frac{\Delta P}{h}$
FLUOROTHENE RINGS			
134	1152	0.116	4.85
268	1087	0.266	4.82
403	910	0.442	4.23
537	842	0.637	3.91
672	887	0.752	4.09
STEEL RINGS			
537	755	0.712	4.65

Fig. 2 FLOODING CHARACTERISTICS OF 1/4-INCH FLUOROTHENE RASCHIG RINGS

FIG. 3 PRESSURE DROP OF DRY $\frac{1}{4}$ -IN RASCHIG RINGS

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$L = 134 \text{ lbs/hr-ft}^2$
 $G/\phi = 1107 \text{ lbs/hr-ft}^2$
 $\frac{1}{4}$ -inch FLUORETHANE
RASCHIG RINGS

DARKENED AREA IS
CAUSED BY DYE
INJECTED WITH WATER
AT THE TOP OF THE
COLUMN

Fig. 4 Liquid Distribution Pattern in 3 inch I.D. Column

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$L = 268 \text{ lbs/hr-ft}^2$
 $G/\phi = 1044 \text{ lbs/hr-ft}^2$
 $\frac{1}{4}$ -inch FLUORETHANE
RASCHIG RINGS

DARKENED AREA IS
CAUSED BY DYE
INJECTED WITH WATER
AT THE TOP OF THE
COLUMN

Fig. 5 Liquid Distribution Pattern in 3 inch I.D. Column

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$L = 672 \text{ lbs/hr-ft}^2$
 $G/\phi = 864 \text{ lbs/hr-ft}^2$
 $\frac{1}{4}$ -inch FLUORETHANE
RASCHIG RINGS

DARKENED AREA IS
CAUSED BY DYE
INJECTED WITH WATER
AT THE TOP OF THE
COLUMN

Fig. 6 Liquid Distribution Pattern in 3 inch I.D. Column

Table 2 Data on 1/4" Carbon Rings from
Schoenborn and Dougherty⁽¹⁾ for
Comparison to Experimental Data

L	G/ ϕ	L ϕ /G	$\Delta P/h$
800	520	1.54	4.91
950	475	2.00	4.60
950	483	1.97	4.66
1200	453	2.63	4.59
1900	363	5.24	3.77

FIG.7 CORRELATION OF FLOODING RATES FOR $\frac{1}{4}$ -IN. FLUOROTHENE RASCHIG RINGS

occur to a great extent further substantiates this belief.

All experimental data collected during this investigation are shown in Table 3. It should be noted that the data for $L = 672$ are internally consistent but do not agree with the trend of $\Delta P/h$ established by lower rates.

CONCLUSIONS

1. Fluorothene Raschig rings flooded at slightly higher gas velocities than carbon or steel rings.
2. The pressure drop through wetted Fluorothene packing was slightly smaller than that through carbon rings.
3. Severe channeling occurred in the Fluorothene ring packing.

NOMENCLATURE

- L = Liquid mass velocity in lb/hr sq. ft. cross section.
 G = Air mass velocity in lb/hr sq. ft. cross section.
 ϕ = Gas density correction factor = $\sqrt{\frac{\text{gas density}}{0.075}}$.
 ΔP = Pressure drop across packing in inches of H_2O .
 h = Height of packing in ft.

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1. Schoenborn, E. M. and W. J. Dougherty, Trans. Am. Inst. Chem. Engrs., 40, 51 (1944).
2. Sherwood, T. K. and R. L. Pigford, Absorption and Extraction, 2nd edn. McGraw-Hill Book Co., Inc., New York (1952).

Table 3 Summary of Data and Calculated Values:
1/4" Raschig Rings

Gas	Pressure Drop Inches H ₂ O/Ft. packing						
Mass Velocity	$\Delta P/h$						
lbs/hr sq. ft.	L=537						
G	L=0	L=134	L=268	L=403	L=537	L=672	Steel Rings
133	-	-	0.08	0.13	-	-	-
267	-	-	-	0.24	-	-	-
342	0.58	-	-	-	0.50	0.41	-
355	-	-	-	0.66	-	-	-
399	-	-	-	0.81	-	-	-
442	1.00	0.84	0.82	0.94	1.01	0.90	1.50
488	-	-	-	1.15	-	-	-
531	1.34	-	-	-	1.42	1.29	2.10
620	1.78	-	1.52	1.86	1.99	1.81	2.94
665	-	1.89	-	-	2.25	-	3.34
709	2.18	-	1.92	2.28	2.63	2.39	3.73
732	-	-	-	-	2.83	2.52	-
753	2.41	2.26	-	-	3.02	-	4.65
776	-	-	-	-	3.23	2.81	6.75
798	2.62	-	2.47	3.09	3.44	3.04	-
821	-	-	-	-	3.59	3.25	-
842	2.97	2.51	2.81	3.43	3.91	3.59	-
864	-	-	-	-	4.57	3.83	-
886	3.15	3.09	3.02	3.94	4.96	4.09	-
911	-	-	-	4.23	7.52	6.25	-
931	3.49	3.41	3.33	5.94	-	-	-
946	-	-	3.54	6.30	-	-	-
975	3.88	3.67	3.81	6.75	-	-	-
999	-	-	3.99	7.75	-	-	-
1020	4.17	-	4.23	-	-	-	-
1044	-	-	4.38	-	-	-	-
1064	4.46	4.17	-	-	-	-	-
1086	-	-	4.82	-	-	-	-
1107	4.80	4.48	6.94	-	-	-	-
1132	-	-	8.50	-	-	-	-
1152	5.02	4.85	-	-	-	-	-
1198	5.51	6.90	-	-	-	-	-
1220	-	9.15	-	-	-	-	-
1242	6.25	-	-	-	-	-	-
1358	6.72	-	-	-	-	-	-

Blanks indicate no existing data

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