EFFECT OF COLUMN DIAMETER ON
THE FREQUENCY RESPONSE OF
WATER FLUIDIZED BEDS

BY

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ABSTRACT

The effect of column diameter on the frequency response of water fluidized beds was investigated.

Studies were made on four columns ranging from four to ten inches in diameter. Water was used to fluidize the beds which consisted of spherical glass beads .0185 inches in diameter. A trace solution of sodium chloride was sinusoidally introduced into the beds. Inlet and outlet concentrations were continuously measured by an electrical conductivity recorder. Separate frequency response tests were conducted on the inlet calmning section in an attempt to obtain the frequency response of this region alone. Results of the tests were expressed as Bode plots.

As the bed diameter was increased, the system became more backmixed in nature. In an attempt to quantify this data, theoretical frequency response curves were calculated based on the mixing cell model. However, over the range of frequencies tested, poor correlation was obtained between this theoretical model and the empirical data.

ACKNOWLEDGMENTS

The author wishes to express his indebtedness to Dr. Deran Hanesian for his guidance during the course of this study; and to his wife, Agnes Maiuro, for her encouragement and patient endurance, as well as her aid in typing the manuscript.

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INTRODUCTION

Scaling up results from small to large size fluidized beds is an important and difficult problem. It has been recognized that large units generally give results differing from small scale laboratory units. A basic problem facing the designer of a fluidized system is that the flow behavior of large beds differs substantially from small units.[1]

The purpose of this study was to investigate the effect of column diameter on the frequency response of the fluidized bed.

The dynamic characteristics of tubular flow systems, including fluidized systems, may be conveniently expressed in terms of frequency response data. The frequency response method yields results which are reproducible and relatively easy to compare with those obtained from theoretical models.

In frequency response testing a sine wave of a given amplitude and frequency is used as the input signal to the system being studied. The output signal should also be a sine wave with the same frequency; but the amplitude and angular displacement of the wave will be altered in accordance with the dynamics of the system. The ratio of the output wave amplitude to the input wave amplitude, coupled with the angular displacement between the two waves constitute the data of frequency response.

In reality, the flow in a fluidized bed, as well as most other physical processes, is extremely complex and non-linear in nature. However, a system will respond linearly for a given amplitude and range of frequencies. A linear system is one that may be described by linear differential equations. In frequency response terms, a system is linear if the frequency of the output wave equals the frequency of the input wave. Therefore, to employ the frequency response technique readily, it is imperative to remain within the linear bounds of the system.

The purpose of this study was to investigate the effect of bed diameter on the frequency response of fluidized beds, not to develop a rigorous fluid bed model. In an attempt to quantify the empirical data obtained, a rather simplified model was used, the mixing cell model. In this model, one attempts to account for the longitudinal mixing by assuming that the bed acts as a series of noninteracting perfect mixers.[2] Theoretical frequency response curves were calculated based on the mixing cell flow model. These theoretical curves were then compared to the experimental curves to arrive at the number of perfect mixers for each column.

Much work has been performed on the dynamic analysis of fluid bed systems by step, pulse and frequency response techniques. However, an exhaustive search of the literature has revealed that the bulk of this work has been performed on small size columns, 4 inch diameter and less. There is a lack of data for a broad range of column diameters. It is for this reason that the 4 to 10 inch beds were evaluated.

A listing and summarization of previous work on longitudinal dispersion of liquid in fixed and fluidized beds is presented in AIChE Preprint 33E, November 26-30, 1967.

APPROACH TO THE PROBLEM

Theoretical responses were calculated for each column over the range of frequencies tested by use of the mixing cell model. A computer was employed in the calculation of the theoretical responses for N perfect mixing cells. Bode plot data was obtained for values of N ranging from 1 to 200.

A frequency response analysis was performed on each column and the results plotted on Bode diagrams. These experimental results were then compared to the theoretical frequency responses.

Each column consisted of two sections, the packed calmning section and the fluidized section. As it was the intent of this work to develop a scale-up correlation for fluidized beds, only the response of the fluidized section was desired. Therefore, the inlet conductivity cell was placed as close as possible to the base of the fluidized bed. (See Fig. 2) However, due to the construction of the cell, the signal measured was not the conductivity directly at the base of the fluidized bed. But rather, it was the conductivity 3-3/4 inches below the fluid-bed base. It was therefore necessary to determine the response of this section alone. The response of the fluidized section could then be obtained by subtracting the packed calmning section response from the overall system response.

To obtain the response of the calmning section alone, one must run frequency response tests on each column with the fluidized section emptied. This was attempted. However, when the glass beads were removed from the columns, air bubbles formed on the conductivity electrodes. This resulted in completely meaningless conductivity readings and prevented experimental determination of the calmning section response. This difficulty necessitated a different approach to the problem. As experimental determination of the calmning section response was impossible, a theoretical response based on the mixing cell model was calculated for this region.

EXPERIMENTAL APPARATUS AND EQUIPMENT

The experimental equipment included a low frequency sine wave generator which applied a 3-15 psig. air signal to a Mason Neilon control valve. This control valve was placed in the tracer inlet line. The control valve's opening and closing varied the amount of salt solution feed into the fluidized bed, thus causing the electrical conductivity of the bed to rise and fall.

The apparatus used for the experimentation is shown in Figures 1 and 2. The range of column diameters studied required the construction of an apparatus which was adaptable to all four columns.

Two 14 inch square steel plates were drilled and tapped at the centers to afford an entrance and exit for the liquid. Also, each plate was covered with soft rubber. This rubber functioned as a gasket at the plate and column interfaces. Each column consisted of two sections, the 8 inch calmning section and the 4.5 foot fluidizing section. In assembling each column, the calmning section was set down on the plate and filled with Raching Rings. A gasket and bed support screen were then placed over this first section. Another gasket followed and next the fluidizing section was bolted and clamped to the calmning section. The entire column was then clamped between the two steel plates. Dow Hi-Vac grease was applied between the gaskets, column and plates to insure a water-tight seal. The glass beads for the fluidizing section were added after the column was assembled, through the fitting in the top plate. To change columns with this system, only loosening the clamps and a replacement of the column was required. All four columns were made of Lucite with a wall thickness of 1/8 inch.

The apparatus was constructed so that one conductivity cell was placed within the calmning section, and measured the conductivity at the base of the fluidized bed. The second conductivity cell was lowered through the top plate and positioned at the upper edge of the fluidized bed. These two cells transmitted the signals to a Beckmann Honeywell two pen electrolytic conductivity indicator recorder. The recorder range was 0-10,000 micromhos, with a linear 0-10 scale.

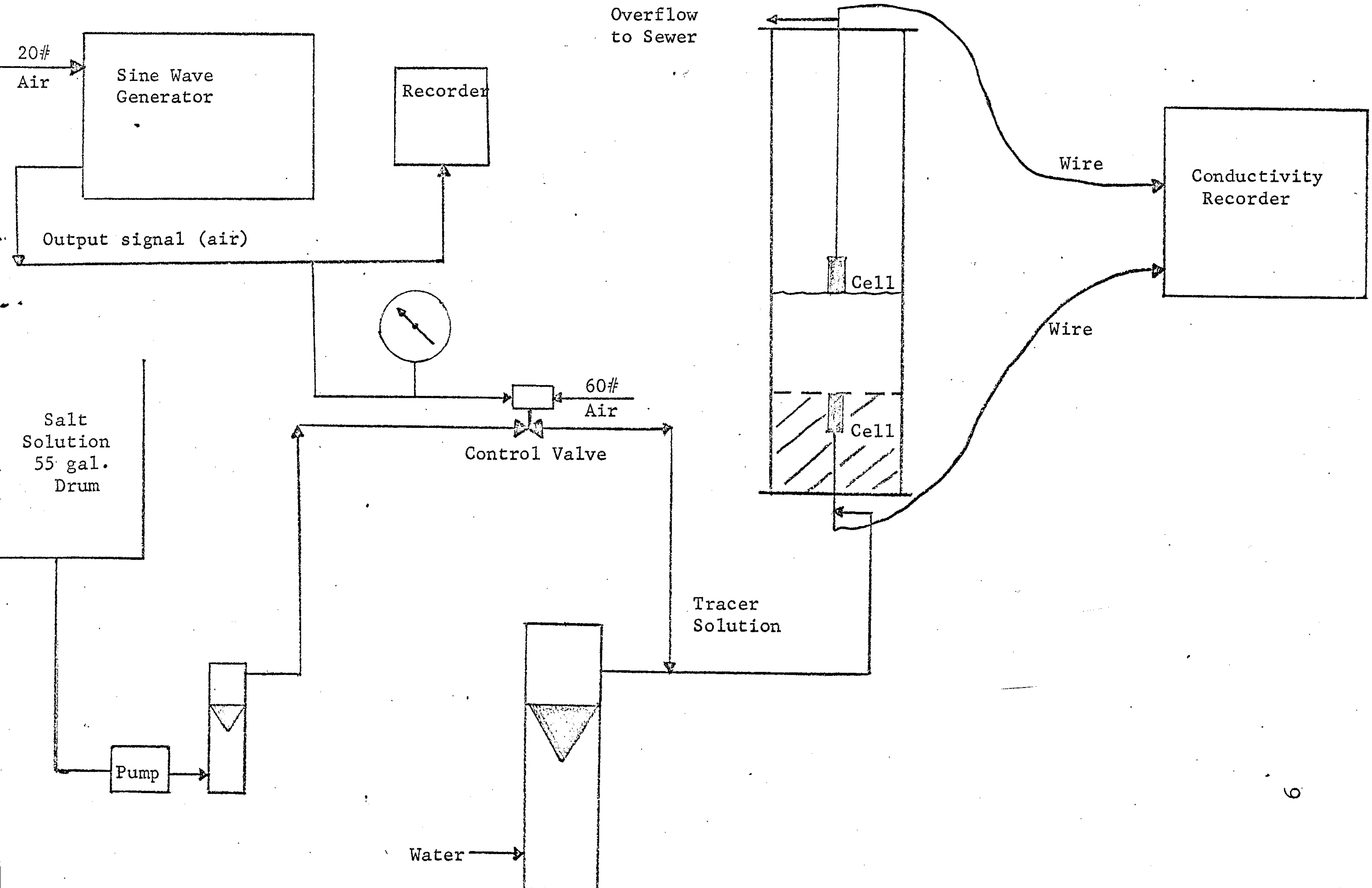
A pneumatic recorder was positioned in parallel with the control valve as a check on the air signal being supplied to the valve by the sine wave generator.

A saturated solution of sodium chloride was used for the trace signal. The salt solution was stored in a 55 gallon polyethylene drum. This solution was delivered to the bed by means of a centrifugal pump which provided a nearly constant head of 22 psig.

The fluidizing water for the system was checked for variations in static pressure, only slight fluctuations were noted. The water was fed into the columns by a 3/4 inch pipe through a rotameter. The overflow was carried to the sewer by a one inch rubber hose. The rotameters used for the fluidizing liquid were two Fischer-Porter rotameters. These meters were rated at 2.7 and 8.8 gallons per minute at 100% flow. The meters were calibrated and found to be linear.

FIGURE 1

EXPERIMENTAL EQUIPMENT LAYOUT



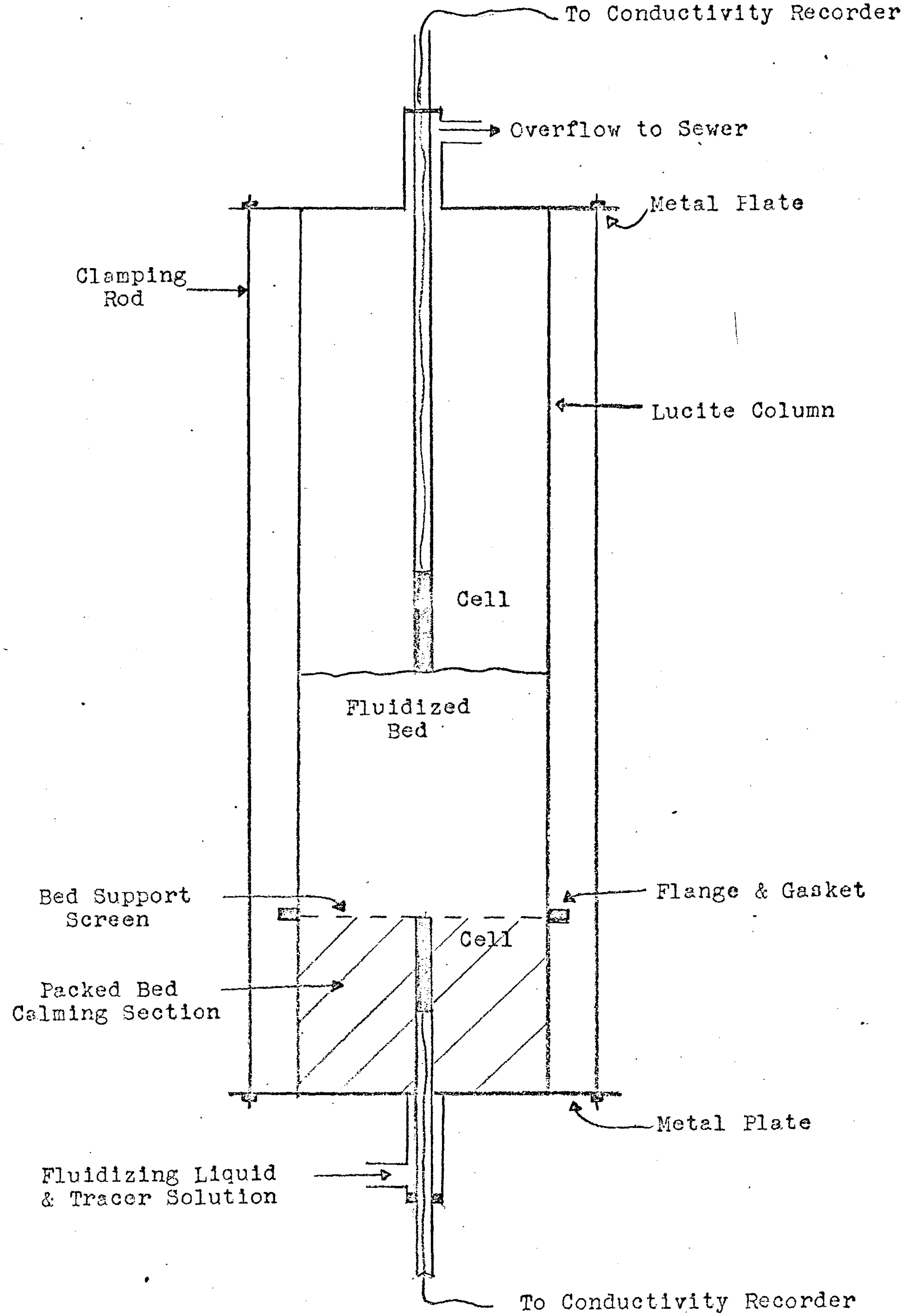


Figure 2
COLUMN ASSEMBLY

THEORETICAL ANALYSIS

General Theory

In the mixing cell model the system is represented as a series of finite, perfectly mixed cells. By definition the concentration in a perfect mixer has a value at every point equal to the concentration at the outlet C_o. For continuous flow through the mixer we have the material balance:

$$C_i = C_o + T \frac{dC_o}{dT} \qquad (1)$$

where T is the average time of residence (volume of the mixer divided by the constant volumetric flow rate). If C_i is varied sinusoidally, then the value of the signal at any place in the system is given by:

$$C = X e^{jwt} \qquad (2)$$

X is a complex number which can be represented by a radius vector in the complex plane, having a certain length (magnitude) and a phase angle with respect to the positive real axis. In the frequency response analysis, the relationship between two signals C and their vectors X is of interest. It can be expressed by the ratio of their respective magnitudes (amplitude ratio) and the difference between their respective phase angle (phase lag).
If the concentrations for the two signals are recorded, the complex ratio between X_o and X_i is called the harmonic response

function of the entire system (transfer function). This function depends on the frequency w of the applied signal in a way which is characteristic of the system.

Substitution of equation 2 into equation 1 yields:

$$X_i = X_o + jwTX_o \qquad (3)$$

and for the transfer function of one perfect mixer

$$\frac{X_o}{X_i} = \frac{1}{1 + jwT} \qquad (4)$$

The value of the amplitude ratio (AR) and phase angle (Ø) are:

$$AR = (1 + w^2T^2)^{-\frac{1}{2}}$$

$$\phi = -\arctan (wT)$$

Applying the result of equation 4 to a system containing N perfect mixers in cascade having equal times of residence (T/N), the transfer function is:

$$G(s) = \left[\frac{1}{\frac{T}{N}s + 1}\right]^N \qquad (5)$$

or

$$G\ (jw) = \left[\frac{1}{\frac{T}{N}jw + 1}\right]^N$$

where

T = Time Constant (min.) = V/q

V = Total volume of N mixers (ft^3)

q = Flow rate (ft^3/min.)

N = Number of perfect mixing cells

From the transfer function, the amplitude ratio and phase angle may be obtained.

$$G(jw) = \left[\frac{1}{\sqrt{1+(wT/N)^2}}\right]^N \qquad (6)$$

$$G(jw) = -N \text{ arc tan } (wT/N) \qquad (7)$$

where

$G(jw)$ = amplitude ratio = AR

$G(jw)$ = phase angle = ϕ

w = frequency (cycles/min)

When a sinusoidal disturbance is introduced into a flow system, the outgoing signal is smaller in amplitude and exhibits a phase lag with respect to the entering signal. In general, the amplitude ratio is ≤ 1 and the phase angle ≤ 0.[3]

Application of General Theory

The system studied consisted of two regions, the packed calmning section and the fluidized section, each with its own transfer function. The mixing cell model assumes that the response of each element is independent of conditions in the other elements. The elements are considered non-interacting and the total system transfer function is the product of the individual transfer functions.

$$G = G_1 \cdot G_2 \tag{8}$$

where

G = total system transfer function

G_1 = packed calmning section transfer function

G_2 = fluidized bed transfer function

Also,

$$AR = AR_1 \cdot AR_2$$

$$\phi = \phi_1 + \phi_2$$

Amplitude ratios will be utilized throughout this discussion, to obtain the number of mixing cells in each section. Values for N can be obtained from the phase angle curves of Bode plots, since a system with N mixing cells exhibits a phase lag of

$N\pi/2$ as the frequency approaches ∞. However as real systems exhibit dead time, which effects the phase angle but not the amplitude ratio, the experimental determination of N from phase angle diagrams was not attempted.

$$AR = AR_1 \cdot AR_2$$

$$\left[1 + \left(\frac{wT}{N}\right)^2\right]^{-N/2} = \left[1 + \left(\frac{wT_1}{N_1}\right)^2\right]^{-N_1/2} \cdot \left[1 + \left(\frac{wT_2}{N_2}\right)^2\right]^{-N_2/2} \quad (9)$$

where

N = number of mixing cells in total system. This value is determined from the experimental frequency response curve of the total system.

N_1 = number of mixing cells in section 1 (packed calmning section)

N_2 = number of mixing cells in section 2 (fluidized bed)

T, T_2, T_3, w
= are known quantities.

N, N_2
= unknown quantities

but

$$N = N_1 + N_2 \quad (10)$$

therefore

$$N_2 = N - N_1 \quad (11)$$

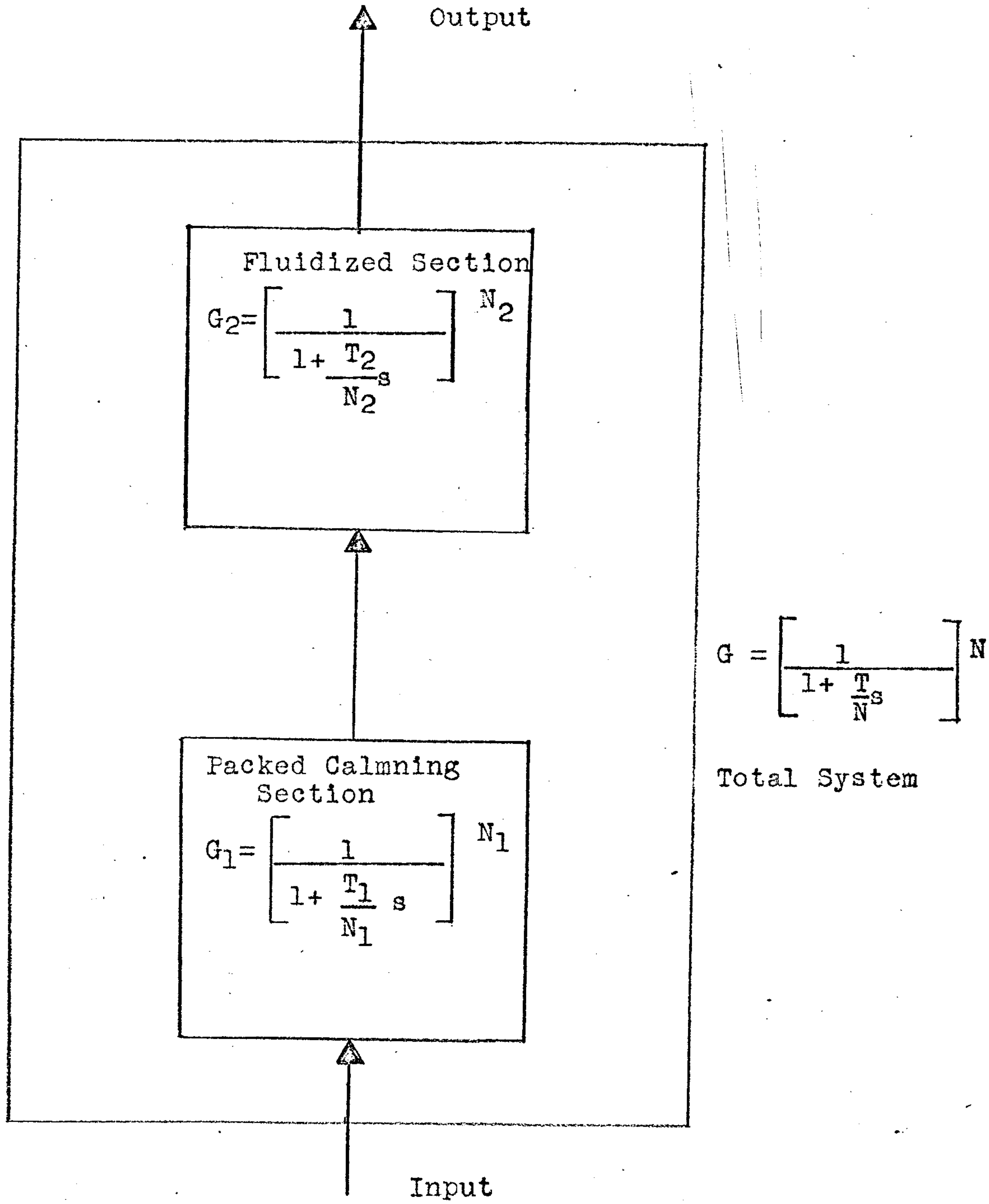


Figure 3
BLOCK DIAGRAM OF SYSTEM

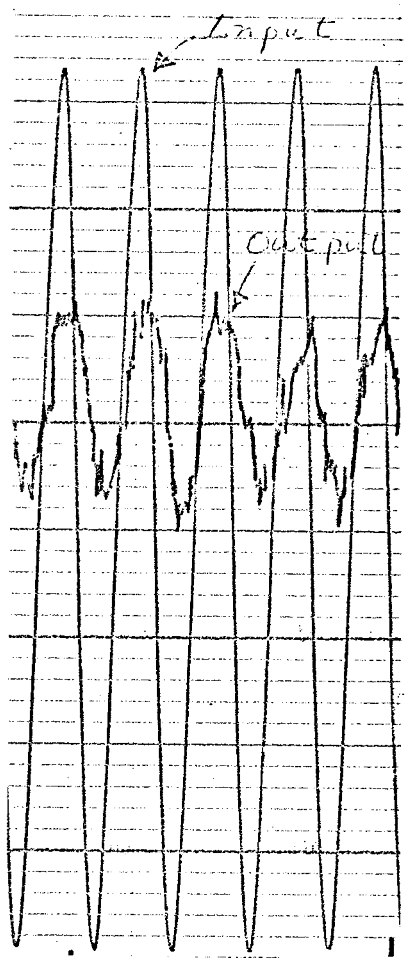
Equations 9 and 10 comprise two equations in two unknowns which were solved for N_2, the number of mixing cells in the fluidized region. The solution was performed by a trial and error technique on a computer. This calculation yielded the amplitude ratio of the fluidized bed and in turn the number of perfect mixing cells.

RESULTS AND DISCUSSION

The frequency response tests were conducted to obtain the total system amplitude ratio curve, from which by a comparison with the theoretical model N could be obtained.

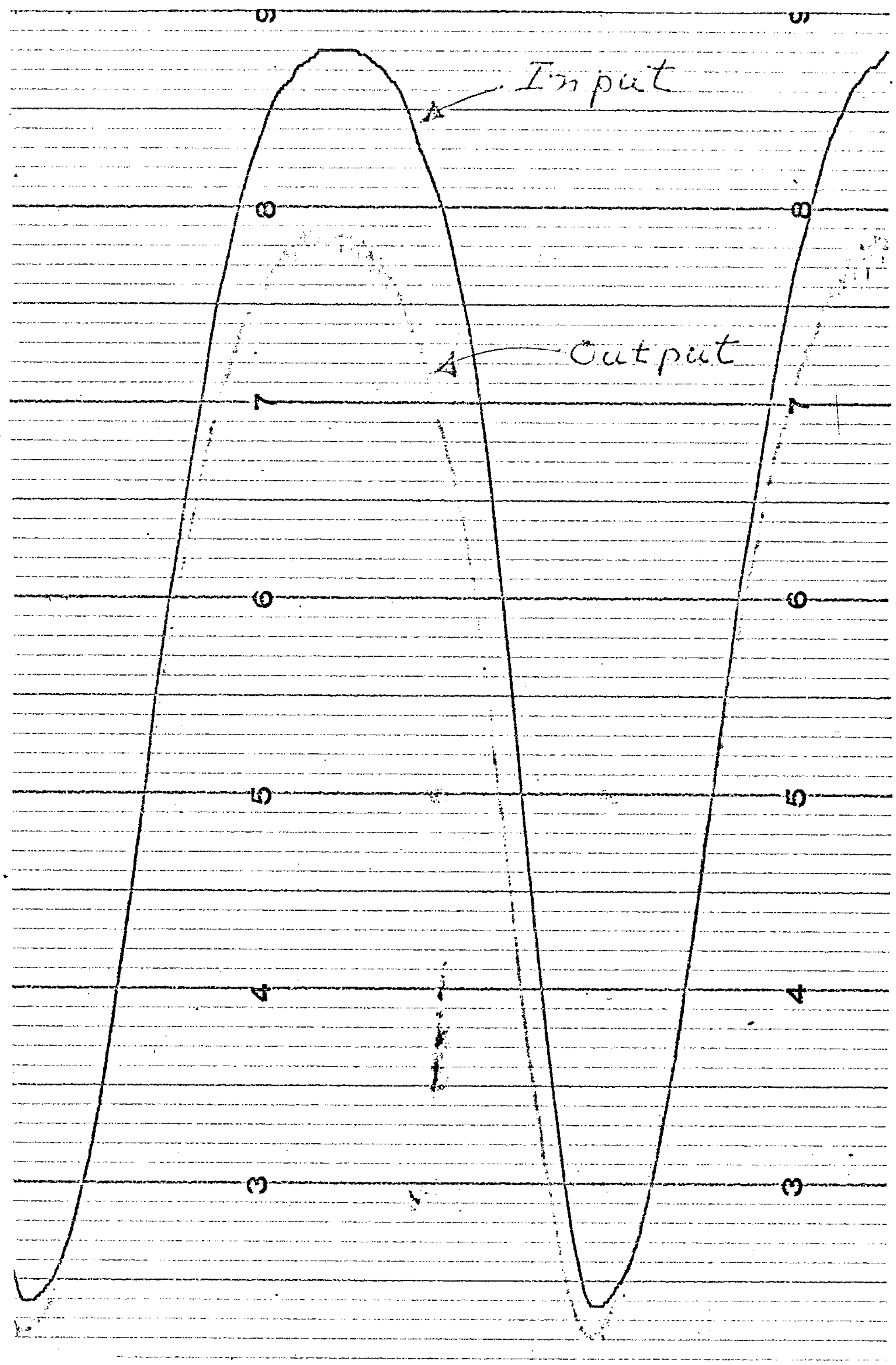
These tests were run on each column over a range of frequencies ranging from 7.50 cycles/min to 0.12 cycles/min. The input signal to the bed was sinusoidal in shape, while the outlet wave was less sinusoidal, in appearance it was more triangular. This effect was more noticeable at the lower frequencies. Typical experimental frequency response tests are presented in Figures 4 and 5. The system responded linearly over the range of frequencies tested. Figures 7, 8, 9, 10 are amplitude ratio plots obtained from the experimental data superimposed over the theoretical amplitude ratio plot for the N value which best fit the experimental data. Figure 6 contains the experimental amplitude ratio curves for all four bed diameters, computed from curves similar to those in Figures 4 and 5. It can be seen from Figure 6 that for a given frequency as bed diameter increases the amplitude ratio decreases.

Perfect plug flow is postulated for a system where no amplitude attenuation of the incoming sinusoidal occurs. A plug flow system can be thought of as consisting of an infinite number of infinitesmally small perfect mixing cells, which would result in



TYPICAL FREQUENCY RESPONSE TEST
(HIGH FREQUENCY)

Figure 4

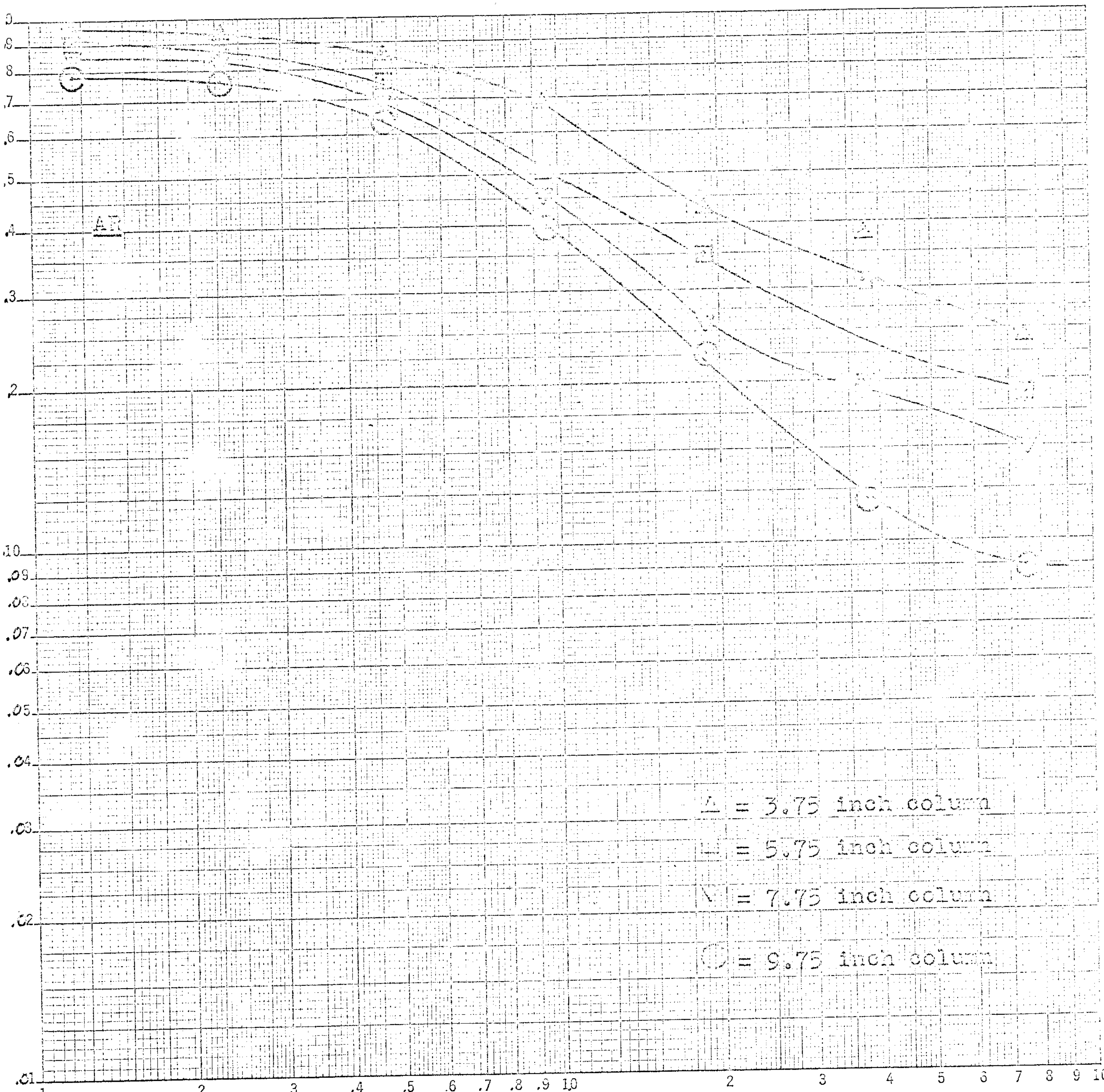


TYPICAL FREQUENCY RESPONSE TEST
(LOW FREQUENCY)

Figure 5

an amplitude ratio equivalent to unity. For a given frequency as the amplitude ratio decreases, more attenuation of the input sinusoidal, the system becomes less plug flow in nature, i.e., exhibits more backmixing. Hence, the experimental data tabulated in Figure 6 indicates that an increase in bed diameter results in increased backmixing. Kramer and Alberda[4] have demonstrated that the frequency response diagrams of real systems generally lie between those for one perfect mixer and for perfect plug flow. However, it is not at all necessary that the diagram for a real system coincides with one for a certain number of perfect mixers.

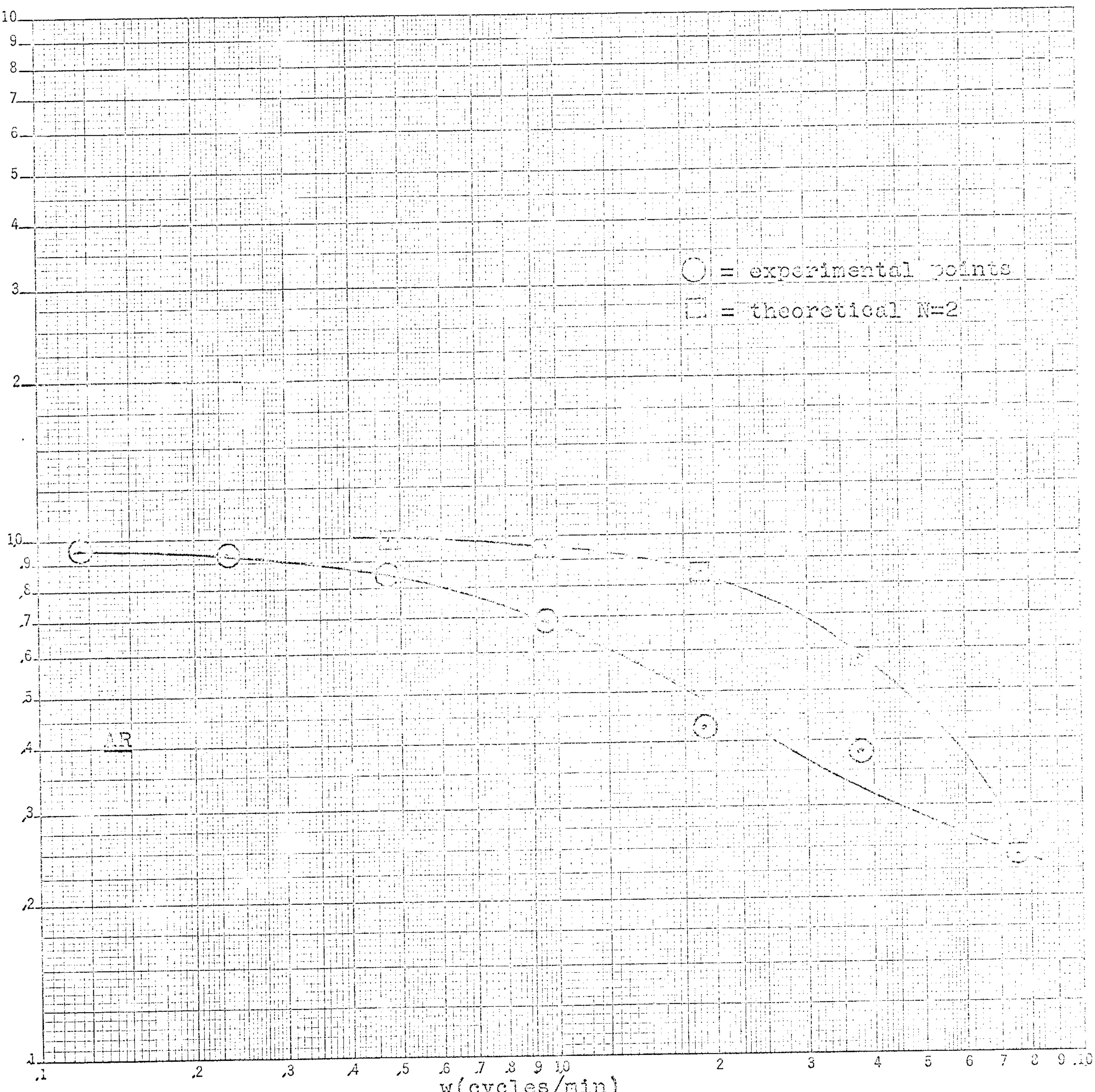
A theoretical model, the mixing cell model, was employed in an attempt to quantify the empirical data obtained. However, attempts to represent the mixing phenomena of the total system by the mixing cell model proved unfruitful. The model yielded amplitude ratio curves whose shapes did not agree with the plots of the experimental values. It is perhaps significant however, that the curves did approach each other at the highest test frequency, 7.5 cycles/min. It seems logical to test at still higher frequencies to see if this trend is continued. This was attempted. A sinusoidal input of 15 cycles/min was introduced into the system. However, the noise inherent in the system obscurred the outlet sine wave making a computation of the amplitude for this higher frequency impossible.



w(cycles/min)

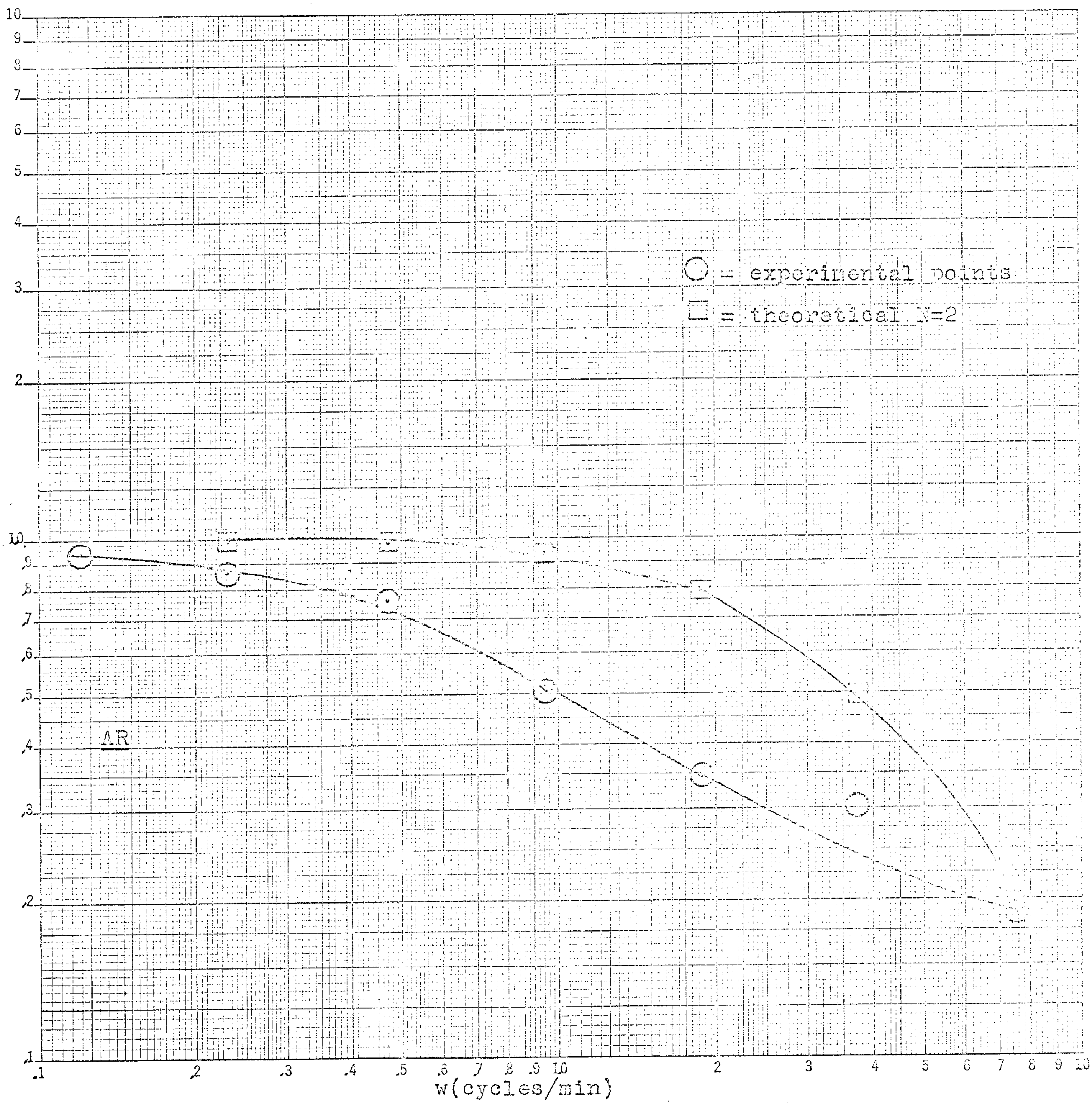
EXPERIMENTAL AMPLITUDE RATIO CURVES

FIGURE 6



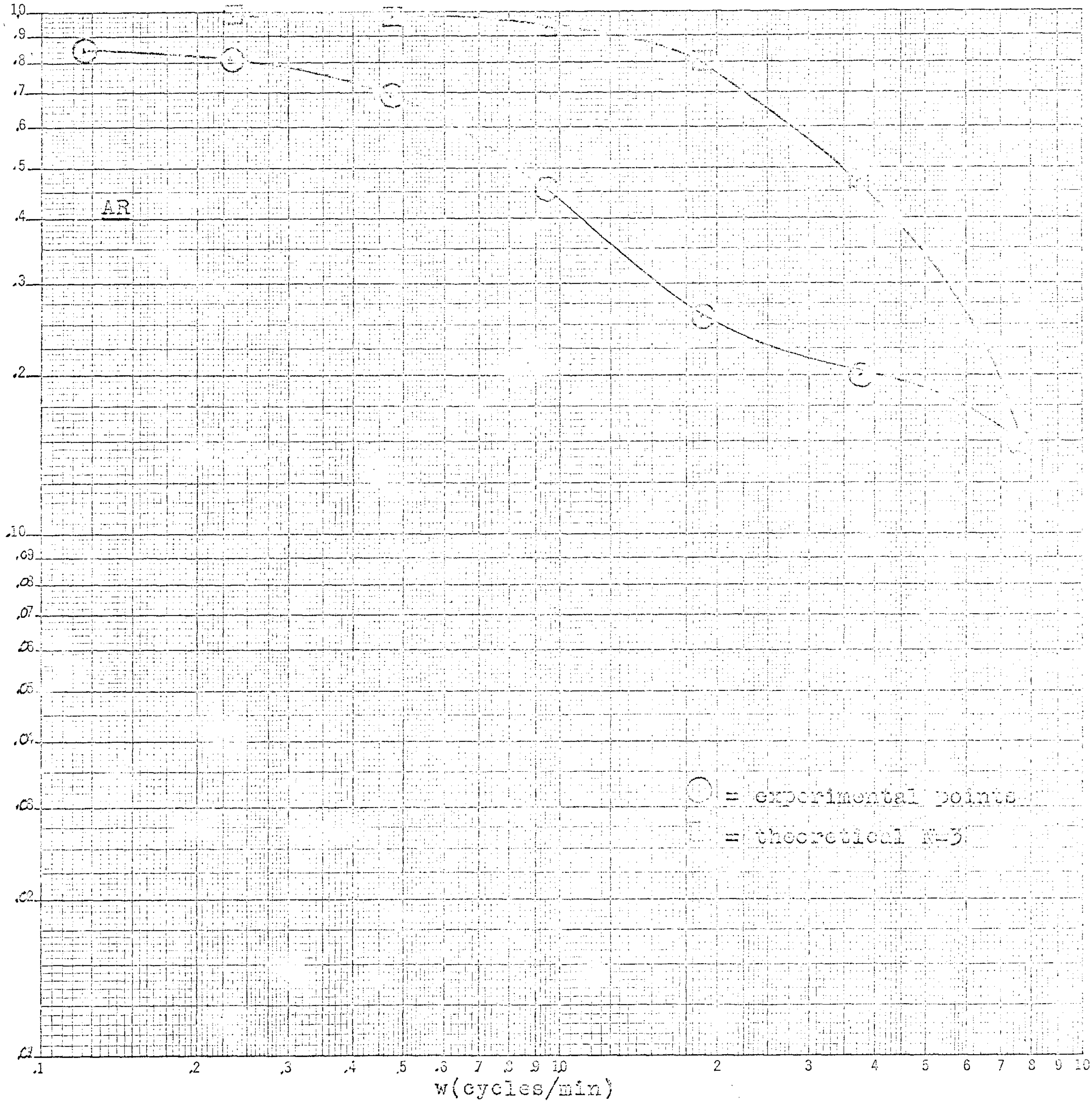
AMPLITUDE RATIO CURVES (3.75 INCH COLUMN)

FIGURE 7



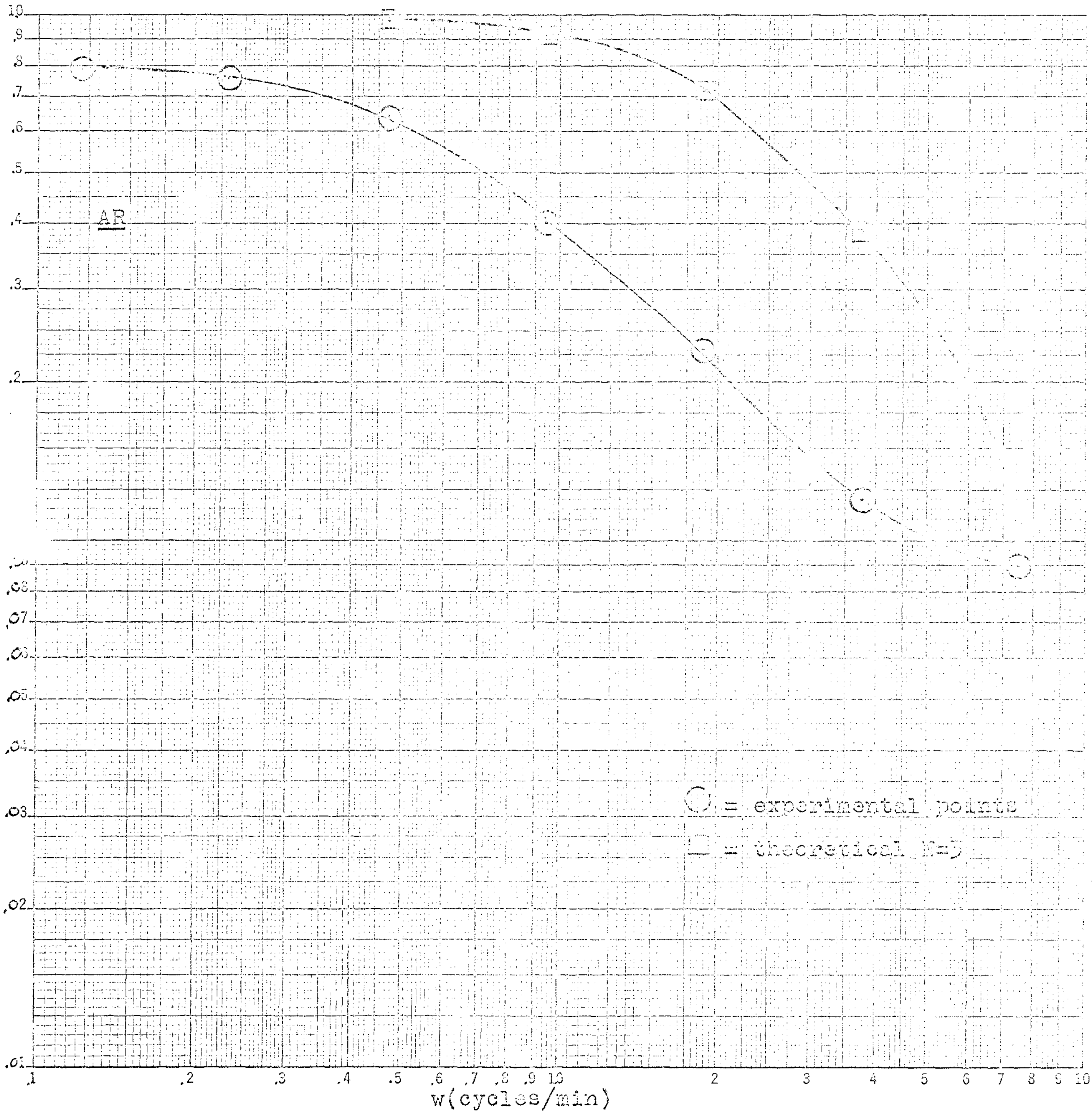
AMPLITUDE RATIO CURVES (5.75 INCH COLUMN)

FIGURE 8



AMPLITUDE RATIO CURVES (7.75 INCH COLUMN)

FIGURE 9



AMPLITUDE RATIO CURVES (9.75 INCH COLUMN)

FIGURE 10

Hence, the theoretical values of N which yielded the best fit to the experimental data were chosen for the number of mixing cells for the total system, fluidized section and packed calmning section.

It is felt that better correlation between model and experimental data could have been obtained, if the response of the empty column could be obtained. It appears that at the low flow velocity utilized, a correction to the amplitude is required for interaction with the bed support and column wall. As was mentioned previously, this was attempted. The low flows had to be maintained due to the fact that the small beads chosen, .0185 in. diameter, were easily driven from the column. At these low flows, air bubbles entering the system dissolved in the water would accumulate on the conductivity electrode. This was not too severe a problem when beads were in the column, as they would circulate through the cell and displace the air bubbles. But when attempts were made at running the column empty, to measure entrance, column wall and bed support responses, bubbles accumulated on the electrodes and made conductivity measurement impossible.

The interaction with the bed support and column wall undoubtedly contributed to the disagreement between empirical results and theoretical predictions.

The values of N for the total system are listed in tables 6-9 As the N values were extremely low, computation of meaningful N_1 and N_2 values was impractical.

CONCLUSIONS

For the flow rate employed in this study, as bed diameter increased the flow pattern in the bed became less plug flow in nature and exhibited increased backmixing.

The fluidized and packed bed systems used in this study were linear.

It is believed that the poor correlation between experimental data and the theoretical mixing cell model, is in part due to the interaction of the wall and bed support.

The theoretical model used did not accurately describe the mixing phenomena in the fluidized beds studied. It is obvious that a different model, perhaps more sophisticated than the mixing cell model is required to describe the system.

RECOMMENDATIONS

1--

This study may be performed using a considerably larger bead size. This will allow the use of higher flow rates, without the fear of displacing beads from the column. At higher flow rates air bubbles do not accumulate on the conductivity cells, which tend to introduce noise into the system. Also, the higher flows and the resulting lower noise level will allow testing at higher frequencies. At the higher flow rate it will also be possible to test the effect of the empty column response, the wall response and bed support response, without having air bubbles hindering the measurement.

2--

A study similar to the one performed over a range of flow rates may be of value.

3--

Utilization of a different model perhaps the axial diffusion model in arriving at a scale-up factor for fluidized beds.

FOOTNOTES

[1]Olaf Winter, Gas Mixing In Fluidized Beds: Model Experiments For Scaling-Up Purposes, Chemical Engineering Progress, Volume 62, 1966, pp. 1-9

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APPENDIX

INSTRUMENT LIST

1. Conductivity Cells, Type Cel-VH20KFT and Cel-VH20KFT-Y-15
   Beckman Instruments

2. Ultra Low Frequency Sinusoidal Signal Generator,
   Model SG-101P, Procedyne Associates Inc., New Brunswick,
   New Jersey

3. Consotrol Controller, Mode 58, Foxboro Co.,
   Foxboro, Massachusetts

4. Control Valve, Model #37-24681, Mason Neilon Inc.,
   Norwood, Massachusetts

5. Electrolytic Conductivity Recorder, Model Y15302816-02-99
   Beckman/Honeywell

6. Rotameters -- Three -- .68 gpm,, 2.7 gpm., 8.8 gpm.,
   Fischer-Porter, Warminster, Pennsylvania

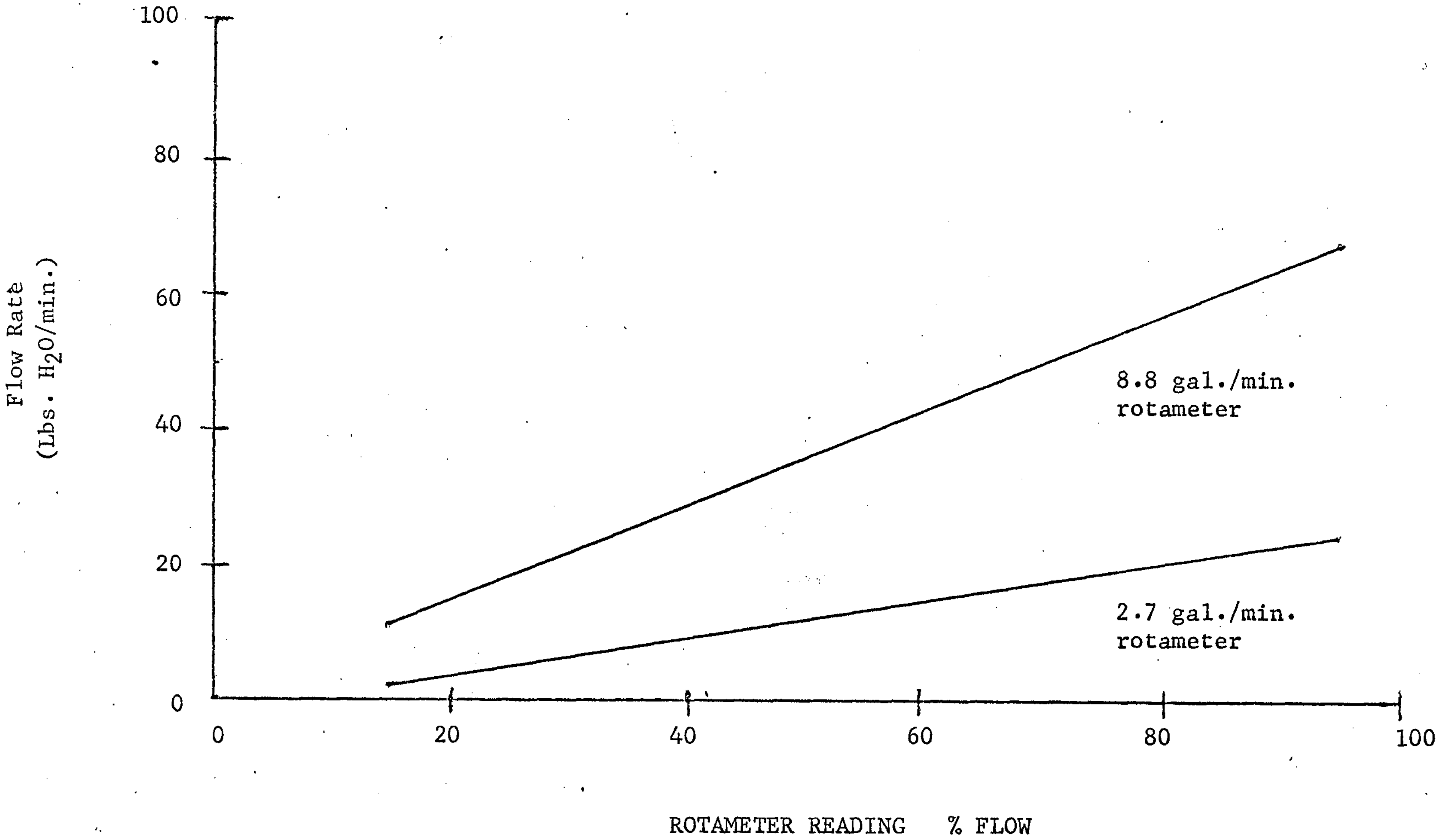


Figure 11

ROTAMETER CALIBRATION CURVES

TABLE 1

EXPERIMENTALLY DETERMINED
OVERALL SYSTEM AMPLITUDE RATIO

3.75 INCH COLUMN

w (Cycles/min)	Amplitude Ratio (AR)
7.50	.24
3.75	.38
1.88	.43
0.94	.69
0.47	.86
0.23	.94
0.12	.96

TABLE 2

EXPERIMENTALLY DETERMINED
OVERALL SYSTEM AMPLITUDE RATIO

5.75 INCH COLUMN

w (Cycles/min)	Amplitude Ratio (AR)
7.50	.19
3.75	.31
1.88	.35
0.94	.51
0.47	.76
0.23	.86
0.12	.92

TABLE 3

EXPERIMENTALLY DETERMINED
OVERALL SYSTEM AMPLITUDE RATIO

7.75 INCH COLUMN

w (Cycles/min)	Amplitude Ratio (AR)
7.50	.15
3.75	.20
1.88	.26
0.94	.46
0.47	.69
0.23	.82
0.12	.85

TABLE 4

EXPERIMENTALLY DETERMINED
OVERALL SYSTEM AMPLITUDE RATIO

9.75 INCH COLUMN

w (Cycles/min)	Amplitude Ratio (AR)
7.50	.09
3.75	.12
1.88	.23
0.94	.40
0.47	.64
0.23	.76
0.12	.79

NUMERICAL COMPUTATIONS

Time Constant Calculation

Danckwerts[5] has shown that if a volume V is fed with a flow rate q, regardless of the transfer function of the region, the average time of travel through the region is V/q. This is the time constant (T) for a mixing process.

The time constant of the overall system studied is equal to the sum of the time constants of two sections.

$$T = T_1 + T_2$$

$$T = V/q$$

$$q = \text{constant to each section.}$$

Hence, in order to calculate the time constants for each section it is necessary to compute the void volume in each section.

Fluidized Section

$$V_2 = V_s \cdot (E_2) + V_E$$

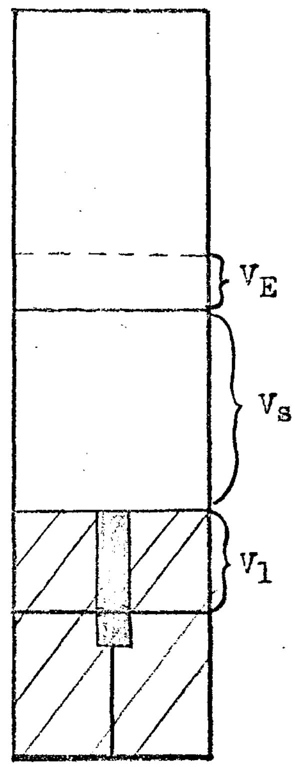
where

V_2 = void volume of fluidized region

V_s = volume of static bed

E_2 = calculated voidage factor (.44)

V_E = expanded volume



Packed Section

$$V_1 = V_p(E_1)$$

where

V_1 = void volume of packed region

V_p = volume of packed region

E_1 = calculated voidage factor for packing section (.65)

The voidage factor (E_2) for the static bed was experimentally determined by filling a cylinder with a known volume of water. To this the beads were added up to a given volume. The total volume of beads and water was then read, from this data the voidage factor was easily calculated. In a similar fashion, the voidage factor (E_1) for the packed calmning section was obtained.

Minimum Fluidization Mass Velocity Calculation

The mass flow rate (G_{mf}) at minimum fluidization[6] is given by:

$$G_{mf} = \frac{688\ D_p^{1.82} \left(\rho f \left[\rho s - \rho f \right] \right)^{.94}}{u^{.88}}$$

where

G_{mf} = mass flow rate (lb/hr-ft^2)

D_p = diameter of beads (in)

f = density of fluidizing medium (lb/ft^3)

s = density of beads (lb/ft^3)

u = viscosity of fluidizing medium (lb/hr-sec)

$$G_{mf} = \frac{688\ (.0185)^{1.8} \left[62.3\ (155.7-62.3) \right]^{.94}}{(1.3)^{.88}}$$

$$G_{mf} = 1{,}310\ \text{lb/hr-ft}^2$$

The four columns were operated at approximately three times (2.96)this value. The study was limited to low flows because beads were driven out of the smaller columns at flows higher than three times the minimum fluidization velocity.

TABLE 5

Columns	Inside Diameter In	3.75"	5.75"	7.75"	9.75"
V	ft^3	.0404	.1097	.2300	.4235
V_1	ft^3	.0155	.0366	.0664	.1050
V_2	ft^3	.0249	.0731	.1636	.3189
q	ft^3/min	.09	.20	.36	.57
T	min	.45	.54	.64	.75
T_1	min	.17	.18	.19	.19
T_2	min	.28	.36	.45	.56
Height of Static Bed	in	4"	6"	8"	10"
Height of Fluidized Bed (Section 2)	in	6"	8.25"	10.5"	11"
Height of Packed Bed (Section 1)	in	3.75"	3.75"	3.75"	3.75"

PROGRAM STATEMENT FOR DETERMINATION OF N

```
PHASE ANGLE CALCULATIONS, ED M                          FORTRAN SOURCE LIST
      ISN        SOURCE STATEMENT

        0 $IBFTC PHANGL  NOLIST,NODECK,REF
        1           DIMENSION TO%5[
        2           DATA TO/0.45,0.54,0.64,0.75,0.0/
        3           I1#1
        4           I2#5
        5           I3#4
        6           XXI#1000.
        7           PRINT 102
       10           IWT#0
       11         5 DO 20 I#I1,I2,I3
       12           W#15.
       13           XI#I
       14           XI#XI/XXI
       15           DO 15 IW#1,9
       16           DO 10 IT#1,4
       17           G#%1.0/SQRT%1.0&%W*TO%IT[/XI[**2[[**XI
       20           WTX#W*TO%IT[/XI
       21           A#-XI*ATAN%WTX[
       22           A#A*57.29578
       23           PRINT 101,XI,W,TO%IT[,G,A
       24           IWT#IWT&1
       25           IF%IWT.NE.36[ GO TO 10
       30           IWT#0
       31           PRINT 102
       32        10 CONTINUE
       34           W#W/2.
       35        15 CONTINUE
       37        20 CONTINUE
       41           IF%XXI.GT.10.[ GO TO 30
       44           IF%I2.EQ.5[ GO TO 35
       47           IF%I2.EQ.25[ GO TO 25
       52           GO TO 200
            C
       53        25 I1#30
       54           I2#200
       55           I3#10
       56           GO TO 5
            C
       57        30 XXI#XXI/10.
       60           GO TO 5
       61        35 I1#1
       62           I2#25
       63           I3#1
       64           XXI#1.
       65           GO TO 5
       66       200 CALL EXIT
       67       101 FORMAT%7X,5%F12.4,6X[[
       70       102 FORMAT%1H1,7X,12HNO. REACTORS,7X,11HCYCLES/MIN.,7X,10HTIME%MIN.[
                   111X,4HGAIN,10X,11HPHASE ANGLE,/8X,12H------------,7X,11H----------
                   2-,7X,10H----------,11X,4H----,10X,11H-----------,/[
       71           END
```

CROSS-REFERENCE DICTIONARY

REFERENCES TO DEFINED SYMBOLS

VALUE	NAME	STATEMENT NUMBERS
00236	101S	194
00250	102S	125,217
00145	10S	212
00154	15S	
00226	200S	254
00160	20S	
00202	25S	252
00211	30S	242
00215	35S	247
00016	5S	261,265,274
00401	A	188,189,191,203
VIRTUAL	ATAN	180
VIRTUAL	EXIT	275
VIRTUAL	FILIO.	126,205,218
VIRTUAL	FILPR.	124,193,216
00371	G	175,201
VIRTUAL	HNLIO.	196,198,200,202,204
00375	I	129,137,234,236
00376	I1	116,128,256,267
00374	I2	118,132,244,249,258,269
00370	I3	120,130,260,271
VIRTUAL	IOHEF.	37,93
VIRTUAL	IOHFC.	32
VIRTUAL	IOHHC.	38,43,48,53,58,63,69,74,79,84,89
VIRTUAL	IOHIO.	66,92
VIRTUAL	IOHLP.	31
VIRTUAL	IOHRP.	36
VIRTUAL	IOHXC.	28,34,41,46,51,56,61,67,72,77,82,87
00411	IT	152
00372	IW	149,229,231
00373	IWT	127,206,208,209,214
VIRTUAL	.EXP3.	174
VIRTUAL	LITCT.	115,162,169,207,266,270,272
VIRTUAL	LTCR2.	
VIRTUAL	SETFP.	114
VIRTUAL	S.JXIT	278
00353	SNGCT.	117,119,121,135,190,210,226,239,245,250,255,257,259,263,268
VIRTUAL	SQRT	164
VIRTUAL	STHIO.	123,192,215
00404	TO	21,158,178,199
00400	W	136,156,176,197,225,227
00377	WTX	179,183
00403	XI	144,145,147,157,172,177,186,195
00402	XXI	122,146,238,262,264,273
00232	D.0000	140,143,159,160,161,163,167,168,170,171,173,184,185
00140	P.0026	211
00171	P.0042	240,241
00175	P.0045	246
00201	P.0050	251
00161	S.0073	131

CROSS-REFERENCE DICTIONARY

00163	S.0074	133
00024	S.0075	237
00043	S.0076	232
00145	S.0077	154,223
00047	S.0100	224
00350	P.0101	304
00353	P.0102	6
00350	P.0103	310
00350	P.0104	139
00351	P.0105	141
00352	P.0106	148,151

REFERENCES TO LOCATION COUNTERS

LC START	NAME	STARTING AND ENDING STATEMENT NUMBERS
00000		1-1
00350	DATCT.	4-4,20-26
00000	PLGCT.	282-298
00000	PRGCT.	2-2,113-281,299-300
00236	SFLCT.	3-3,27-93,301-311
00350	STRCT.	5-19,94-112

NO MESSAGES FOR ABOVE ASSEMBLY

PHASE ANGLE CALCULATIONS, ED M   IBLDR -- JOB PHANGL

MEMORY MAP

SYSTEM, INCLUDING IOCS	00000 THRU 12273
FILE BLOCK ORIGIN	12302
NUMBER OF FILES - 1	
1. S.FBOU 12302	
OBJECT PROGRAM	12325 THRU 16620

1.	DECK @PHANGL@	*	12325
2.	SUBR @OUSYFB@		00000
3.	SUBR @POSTX @		12740
4.	SUBR @CNSTNT@	*	13053
5.	SUBR @FPR @		13063
6.	SUBR @IOS @		13064
7.	SUBR @RWD @		13341
8.	SUBR @FCV @		14021
9.	SUBR @HCV @		14113
10.	SUBR @XCV @		14216
11.	SUBR @INTJ @		14237
12.	SUBR @FFC @	*	14553
13.	SUBR @FPT @		15162
14.	SUBR @XEM @	*	15532
15.	SUBR @XIT @		15743
16.	SUBR @XP3 @		15745
17.	SUBR @XPN @		16016
18.	SUBR @ATN @		16124
19.	SUBR @LOG @		16354
20.	SUBR @SQR @		16521

%* - INSERTIONS OR DELETIONS MADE IN THIS DECK[

INPUT - OUTPUT BUFFERS	77317 THRU 77776
UNUSED CORE	16621 THRU 77313

NO. REACTORS	CYCLES/MIN.	TIME%MIN.[	GAIN
1.0000	15.0000	0.4500	0.1465
1.0000	15.0000	0.5400	0.1225
1.0000	15.0000	0.6400	0.1036
1.0000	15.0000	0.7500	0.0885
1.0000	7.5000	0.4500	0.2841
1.0000	7.5000	0.5400	0.2397
1.0000	7.5000	0.6400	0.2040
1.0000	7.5000	0.7500	0.1750
1.0000	3.7500	0.4500	0.5098
1.0000	3.7500	0.5400	0.4428
1.0000	3.7500	0.6400	0.3846
1.0000	3.7500	0.7500	0.3350
1.0000	1.8750	0.4500	0.7643
1.0000	1.8750	0.5400	0.7027
1.0000	1.8750	0.6400	0.6402
1.0000	1.8750	0.7500	0.5795
1.0000	0.9375	0.4500	0.9214
1.0000	0.9375	0.5400	0.8922
1.0000	0.9375	0.6400	0.8575
1.0000	0.9375	0.7500	0.8180
1.0000	0.4688	0.4500	0.9785
1.0000	0.4688	0.5400	0.9694
1.0000	0.4688	0.6400	0.9578
1.0000	0.4688	0.7500	0.9434
1.0000	0.2344	0.4500	0.9945
1.0000	0.2344	0.5400	0.9921
1.0000	0.2344	0.6400	0.9889
1.0000	0.2344	0.7500	0.9849
1.0000	0.1172	0.4500	0.9986
1.0000	0.1172	0.5400	0.9980
1.0000	0.1172	0.6400	0.9972
1.0000	0.1172	0.7500	0.9962
1.0000	0.0586	0.4500	0.9997
1.0000	0.0586	0.5400	0.9995
1.0000	0.0586	0.6400	0.9993
1.0000	0.0586	0.7500	0.9990

NO. REACTORS	CYCLES/MIN.	TIME%MIN.[	GAIN
2.0000	15.0000	0.4500	0.0807
2.0000	15.0000	0.5400	0.0575
2.0000	15.0000	0.6400	0.0416
2.0000	15.0000	0.7500	0.0306
2.0000	7.5000	0.4500	0.2599
2.0000	7.5000	0.5400	0.1961
2.0000	7.5000	0.6400	0.1479
2.0000	7.5000	0.7500	0.1122
2.0000	3.7500	0.4500	0.5841
2.0000	3.7500	0.5400	0.4938
2.0000	3.7500	0.6400	0.4098
2.0000	3.7500	0.7500	0.3358
2.0000	1.8750	0.4500	0.8489
2.0000	1.8750	0.5400	0.7960
2.0000	1.8750	0.6400	0.7353
2.0000	1.8750	0.7500	0.6692
2.0000	0.9375	0.4500	0.9574
2.0000	0.9375	0.5400	0.9398
2.0000	0.9375	0.6400	0.9174
2.0000	0.9375	0.7500	0.8900
2.0000	0.4688	0.4500	0.9890
2.0000	0.4688	0.5400	0.9842
2.0000	0.4688	0.6400	0.9780
2.0000	0.4688	0.7500	0.9700
2.0000	0.2344	0.4500	0.9972
2.0000	0.2344	0.5400	0.9960
2.0000	0.2344	0.6400	0.9944
2.0000	0.2344	0.7500	0.9923
2.0000	0.1172	0.4500	0.9993
2.0000	0.1172	0.5400	0.9990
2.0000	0.1172	0.6400	0.9986
2.0000	0.1172	0.7500	0.9981
2.0000	0.0586	0.4500	0.9998
2.0000	0.0586	0.5400	0.9997
2.0000	0.0586	0.6400	0.9996
2.0000	0.0586	0.7500	0.9995

NO. REACTORS	CYCLES/MIN.	TIME%MIN.[	GAIN
3.0000	15.0000	0.4500	0.0670
3.0000	15.0000	0.5400	0.0419
3.0000	15.0000	0.6400	0.0265
3.0000	15.0000	0.7500	0.0171
3.0000	7.5000	0.4500	0.2932
3.0000	7.5000	0.5400	0.2109
3.0000	7.5000	0.6400	0.1489
3.0000	7.5000	0.7500	0.1042
3.0000	3.7500	0.4500	0.6621
3.0000	3.7500	0.5400	0.5694
3.0000	3.7500	0.6400	0.4761
3.0000	3.7500	0.7500	0.3883
3.0000	1.8750	0.4500	0.8921
3.0000	1.8750	0.5400	0.8506
3.0000	1.8750	0.6400	0.8004
3.0000	1.8750	0.7500	0.7423
3.0000	0.9375	0.4500	0.9711
3.0000	0.9375	0.5400	0.9588
3.0000	0.9375	0.6400	0.9429
3.0000	0.9375	0.7500	0.9229
3.0000	0.4688	0.4500	0.9926
3.0000	0.4688	0.5400	0.9894
3.0000	0.4688	0.6400	0.9852
3.0000	0.4688	0.7500	0.9797
3.0000	0.2344	0.4500	0.9981
3.0000	0.2344	0.5400	0.9973
3.0000	0.2344	0.6400	0.9963
3.0000	0.2344	0.7500	0.9949
3.0000	0.1172	0.4500	0.9995
3.0000	0.1172	0.5400	0.9993
3.0000	0.1172	0.6400	0.9991
3.0000	0.1172	0.7500	0.9987
3.0000	0.0586	0.4500	0.9999
3.0000	0.0586	0.5400	0.9998
3.0000	0.0586	0.6400	0.9998
3.0000	0.0586	0.7500	0.9997

NO. REACTORS	CYCLES/MIN.	TIME%MIN.[	GAIN
4.0000	15.0000	0.4500	0.0675
4.0000	15.0000	0.5400	0.0384
4.0000	15.0000	0.6400	0.0219
4.0000	15.0000	0.7500	0.0126
4.0000	7.5000	0.4500	0.3412
4.0000	7.5000	0.5400	0.2438
4.0000	7.5000	0.6400	0.1680
4.0000	7.5000	0.7500	0.1128
4.0000	3.7500	0.4500	0.7207
4.0000	3.7500	0.5400	0.6336
4.0000	3.7500	0.6400	0.5407
4.0000	3.7500	0.7500	0.4478
4.0000	1.8750	0.4500	0.9166
4.0000	1.8750	0.5400	0.8832
4.0000	1.8750	0.6400	0.8417
4.0000	1.8750	0.7500	0.7921
4.0000	0.9375	0.4500	0.9781
4.0000	0.9375	0.5400	0.9687
4.0000	0.9375	0.6400	0.9565
4.0000	0.9375	0.7500	0.9410
4.0000	0.4688	0.4500	0.9945
4.0000	0.4688	0.5400	0.9920
4.0000	0.4688	0.6400	0.9888
4.0000	0.4688	0.7500	0.9847
4.0000	0.2344	0.4500	0.9986
4.0000	0.2344	0.5400	0.9980
4.0000	0.2344	0.6400	0.9972
4.0000	0.2344	0.7500	0.9961
4.0000	0.1172	0.4500	0.9997
4.0000	0.1172	0.5400	0.9995
4.0000	0.1172	0.6400	0.9993
4.0000	0.1172	0.7500	0.9990
4.0000	0.0586	0.4500	0.9999
4.0000	0.0586	0.5400	0.9999
4.0000	0.0586	0.6400	0.9998
4.0000	0.0586	0.7500	0.9998

NO. REACTORS	CYCLES/MIN.	TIME%MIN.(	GAIN
5.0000	15.0000	0.4500	0.0747
5.0000	15.0000	0.5400	0.0400
5.0000	15.0000	0.6400	0.0210
5.0000	15.0000	0.7500	0.0111
5.0000	7.5000	0.4500	0.3912
5.0000	7.5000	0.5400	0.2833
5.0000	7.5000	0.6400	0.1954
5.0000	7.5000	0.7500	0.1294
5.0000	3.7500	0.4500	0.7636
5.0000	3.7500	0.5400	0.6841
5.0000	3.7500	0.6400	0.5955
5.0000	3.7500	0.7500	0.5030
5.0000	1.8750	0.4500	0.9322
5.0000	1.8750	0.5400	0.9044
5.0000	1.8750	0.6400	0.8694
5.0000	1.8750	0.7500	0.8267
5.0000	0.9375	0.4500	0.9824
5.0000	0.9375	0.5400	0.9748
5.0000	0.9375	0.6400	0.9649
5.0000	0.9375	0.7500	0.9522
5.0000	0.4688	0.4500	0.9956
5.0000	0.4688	0.5400	0.9936
5.0000	0.4688	0.6400	0.9911
5.0000	0.4688	0.7500	0.9877
5.0000	0.2344	0.4500	0.9989
5.0000	0.2344	0.5400	0.9984
5.0000	0.2344	0.6400	0.9978
5.0000	0.2344	0.7500	0.9969
5.0000	0.1172	0.4500	0.9997
5.0000	0.1172	0.5400	0.9996
5.0000	0.1172	0.6400	0.9994
5.0000	0.1172	0.7500	0.9992
5.0000	0.0586	0.4500	0.9999
5.0000	0.0586	0.5400	0.9999
5.0000	0.0586	0.6400	0.9999
5.0000	0.0586	0.7500	0.9998

NO. REACTORS	CYCLES/MIN.	TIME%MIN.[	GAIN
6.0000	15.0000	0.4500	0.0860
6.0000	15.0000	0.5400	0.0445
6.0000	15.0000	0.6400	0.0222
6.0000	15.0000	0.7500	0.0109
6.0000	7.5000	0.4500	0.4384
6.0000	7.5000	0.5400	0.3242
6.0000	7.5000	0.6400	0.2267
6.0000	7.5000	0.7500	0.1508
6.0000	3.7500	0.4500	0.7958
6.0000	3.7500	0.5400	0.7235
6.0000	3.7500	0.6400	0.6407
6.0000	3.7500	0.7500	0.5511
6.0000	1.8750	0.4500	0.9429
6.0000	1.8750	0.5400	0.9192
6.0000	1.8750	0.6400	0.8890
6.0000	1.8750	0.7500	0.8518
6.0000	0.9375	0.4500	0.9853
6.0000	0.9375	0.5400	0.9789
6.0000	0.9375	0.6400	0.9706
6.0000	0.9375	0.7500	0.9599
6.0000	0.4688	0.4500	0.9963
6.0000	0.4688	0.5400	0.9947
6.0000	0.4688	0.6400	0.9925
6.0000	0.4688	0.7500	0.9898
6.0000	0.2344	0.4500	0.9991
6.0000	0.2344	0.5400	0.9987
6.0000	0.2344	0.6400	0.9981
6.0000	0.2344	0.7500	0.9974
6.0000	0.1172	0.4500	0.9998
6.0000	0.1172	0.5400	0.9997
6.0000	0.1172	0.6400	0.9995
6.0000	0.1172	0.7500	0.9994
6.0000	0.0586	0.4500	0.9999
6.0000	0.0586	0.5400	0.9999
6.0000	0.0586	0.6400	0.9999
6.0000	0.0586	0.7500	0.9998

NO. REACTORS	CYCLES/MIN.	TIME%MIN.[	GAIN
7.0000	15.0000	0.4500	0.1002
7.0000	15.0000	0.5400	0.0511
7.0000	15.0000	0.6400	0.0246
7.0000	15.0000	0.7500	0.0115
7.0000	7.5000	0.4500	0.4812
7.0000	7.5000	0.5400	0.3640
7.0000	7.5000	0.6400	0.2595
7.0000	7.5000	0.7500	0.1749
7.0000	3.7500	0.4500	0.8206
7.0000	3.7500	0.5400	0.7548
7.0000	3.7500	0.6400	0.6777
7.0000	3.7500	0.7500	0.5923
7.0000	1.8750	0.4500	0.9508
7.0000	1.8750	0.5400	0.9301
7.0000	1.8750	0.6400	0.9036
7.0000	1.8750	0.7500	0.8707
7.0000	0.9375	0.4500	0.9874
7.0000	0.9375	0.5400	0.9819
7.0000	0.9375	0.6400	0.9747
7.0000	0.9375	0.7500	0.9655
7.0000	0.4688	0.4500	0.9968
7.0000	0.4688	0.5400	0.9954
7.0000	0.4688	0.6400	0.9936
7.0000	0.4688	0.7500	0.9912
7.0000	0.2344	0.4500	0.9992
7.0000	0.2344	0.5400	0.9989
7.0000	0.2344	0.6400	0.9984
7.0000	0.2344	0.7500	0.9978
7.0000	0.1172	0.4500	0.9998
7.0000	0.1172	0.5400	0.9997
7.0000	0.1172	0.6400	0.9996
7.0000	0.1172	0.7500	0.9994
7.0000	0.0586	0.4500	1.0000
7.0000	0.0586	0.5400	0.9999
7.0000	0.0586	0.6400	0.9999
7.0000	0.0586	0.7500	0.9999

NO. REACTORS	CYCLES/MIN.	TIME%MIN.[	GAIN
8.0000	15.0000	0.4500	0.1164
8.0000	15.0000	0.5400	0.0595
8.0000	15.0000	0.6400	0.0282
8.0000	15.0000	0.7500	0.0127
8.0000	7.5000	0.4500	0.5193
8.0000	7.5000	0.5400	0.4015
8.0000	7.5000	0.6400	0.2923
8.0000	7.5000	0.7500	0.2005
8.0000	3.7500	0.4500	0.8402
8.0000	3.7500	0.5400	0.7800
8.0000	3.7500	0.6400	0.7084
8.0000	3.7500	0.7500	0.6274
8.0000	1.8750	0.4500	0.9567
8.0000	1.8750	0.5400	0.9384
8.0000	1.8750	0.6400	0.9148
8.0000	1.8750	0.7500	0.8854
8.0000	0.9375	0.4500	0.9890
8.0000	0.9375	0.5400	0.9841
8.0000	0.9375	0.6400	0.9778
8.0000	0.9375	0.7500	0.9697
8.0000	0.4688	0.4500	0.9972
8.0000	0.4688	0.5400	0.9960
8.0000	0.4688	0.6400	0.9944
8.0000	0.4688	0.7500	0.9923
8.0000	0.2344	0.4500	0.9993
8.0000	0.2344	0.5400	0.9990
8.0000	0.2344	0.6400	0.9986
8.0000	0.2344	0.7500	0.9981
8.0000	0.1172	0.4500	0.9998
8.0000	0.1172	0.5400	0.9997
8.0000	0.1172	0.6400	0.9996
8.0000	0.1172	0.7500	0.9995
8.0000	0.0586	0.4500	1.0000
8.0000	0.0586	0.5400	0.9999
8.0000	0.0586	0.6400	0.9999
8.0000	0.0586	0.7500	0.9999

NO. REACTORS	CYCLES/MIN.	TIME%MIN,(	GAIN
9.0000	15.0000	0.4500	0.1342
9.0000	15.0000	0.5400	0.0693
9.0000	15.0000	0.6400	0.0327
9.0000	15.0000	0.7500	0.0145
9.0000	7.5000	0.4500	0.5532
9.0000	7.5000	0.5400	0.4361
9.0000	7.5000	0.6400	0.3242
9.0000	7.5000	0.7500	0.2268
9.0000	3.7500	0.4500	0.8560
9.0000	3.7500	0.5400	0.8007
9.0000	3.7500	0.6400	0.7341
9.0000	3.7500	0.7500	0.6575
9.0000	1.8750	0.4500	0.9614
9.0000	1.8750	0.5400	0.9450
9.0000	1.8750	0.6400	0.9238
9.0000	1.8750	0.7500	0.8971
9.0000	0.9375	0.4500	0.9902
9.0000	0.9375	0.5400	0.9859
9.0000	0.9375	0.6400	0.9802
9.0000	0.9375	0.7500	0.9730
9.0000	0.4688	0.4500	0.9975
9.0000	0.4688	0.5400	0.9964
9.0000	0.4688	0.6400	0.9950
9.0000	0.4688	0.7500	0.9932
9.0000	0.2344	0.4500	0.9994
9.0000	0.2344	0.5400	0.9991
9.0000	0.2344	0.6400	0.9988
9.0000	0.2344	0.7500	0.9983
9.0000	0.1172	0.4500	0.9998
9.0000	0.1172	0.5400	0.9998
9.0000	0.1172	0.6400	0.9997
9.0000	0.1172	0.7500	0.9996
9.0000	0.0586	0.4500	1.0000
9.0000	0.0586	0.5400	0.9999
9.0000	0.0586	0.6400	0.9999
9.0000	0.0586	0.7500	0.9999

NO. REACTORS	CYCLES/MIN.	TIME%MIN.[	GAIN
10.0000	15.0000	0.4500	0.1530
10.0000	15.0000	0.5400	0.0803
10.0000	15.0000	0.6400	0.0382
10.0000	15.0000	0.7500	0.0168
10.0000	7.5000	0.4500	0.5831
10.0000	7.5000	0.5400	0.4679
10.0000	7.5000	0.6400	0.3546
10.0000	7.5000	0.7500	0.2530
10.0000	3.7500	0.4500	0.8690
10.0000	3.7500	0.5400	0.8180
10.0000	3.7500	0.6400	0.7558
10.0000	3.7500	0.7500	0.6834
10.0000	1.8750	0.4500	0.9652
10.0000	1.8750	0.5400	0.9503
10.0000	1.8750	0.6400	0.9310
10.0000	1.8750	0.7500	0.9067
10.0000	0.9375	0.4500	0.9911
10.0000	0.9375	0.5400	0.9873
10.0000	0.9375	0.6400	0.9822
10.0000	0.9375	0.7500	0.9756
10.0000	0.4688	0.4500	0.9978
10.0000	0.4688	0.5400	0.9968
10.0000	0.4688	0.6400	0.9955
10.0000	0.4688	0.7500	0.9938
10.0000	0.2344	0.4500	0.9994
10.0000	0.2344	0.5400	0.9992
10.0000	0.2344	0.6400	0.9989
10.0000	0.2344	0.7500	0.9985
10.0000	0.1172	0.4500	0.9999
10.0000	0.1172	0.5400	0.9998
10.0000	0.1172	0.6400	0.9997
10.0000	0.1172	0.7500	0.9996
10.0000	0.0586	0.4500	1.0000
10.0000	0.0586	0.5400	0.9999
10.0000	0.0586	0.6400	0.9999
10.0000	0.0586	0.7500	0.9999

PROGRAM STATEMENT FOR DETERMINATION OF N_2

```
PHASE ANGLE CALCULATIONS, ED M                    FORTRAN SOURCE LIST
       ISN        SOURCE STATEMENT

  $IBFTC DELTA    NOLIST,NODECK,REF
          REAL N,N1,N2,NN
          DIMENSION N%10[,T0%10[,T1%10[,T2%10[
          DATA N/2.,2.,3.,3.,     6*0./
          DATA T0/0.45,0.54,0.64,0.75,6*0./
          DATA T1/0.17,0.18,0.19 ,0.19,6*0./
          W#7.50
          DO 30 IN#1,4
          IT#IN
          T2%IT[#T0%IT[-T1%IT[
          PRINT 100
          PRINT 101,N%IN[,T1%IT[,T2%IT[,T0%IT[,W
          PRINT 102
          M#N%IN[*50.
          N1#0.
          DO 10 IM#1,M
          N1#N1&0.02
          N2#N%IN[-N1
          G1#%1.0/SQRT%1.0&%W*T1%IT[/N1[[[**N1
          G2#%1.0/SQRT%1.0&%W*T2%IT[/N2[[[**N2
          NN#N%IN[
          G #%1.0/SQRT%1.0&%W*T0%IT[/N%IN[[[[**NN
          DEL#G-G1*G2
          PRINT 103,N1,N2,G1,G2,G,DEL
       10 CONTINUE
       20 CONTINUE
       30 CONTINUE
          CALL EXIT
      100 FORMAT%1H1,8X,1HN,14X,2HT1,13X,2HT2,13X,2HT0,11X,5HOMEGA,/[
      101 FORMAT%5%2X,F13.2[,/[
      102 FORMAT%/,7X,2HN1,13X,2HN2,13X,2HG1,13X,2HG2,13X,1HG,13X,5HDELTA,/
      103 FORMAT%2%2X,F13.2[,3%F12.3,3X[,E15.8[
          END
```

```
PHASE ANGLE CALCULATIONS, ED M                    IBMAP ASSEMBLY DELTA
        CROSS-REFERENCE DICTIONARY


REFERENCES TO DEFINED SYMBOLS
 VALUE    NAME      STATEMENT NUMBERS

 00231    100S      174
 00267    101S      178
 00300    102S      193
 00341    103S      277
 00206    10S
 00212    20S
 00212    30S
 00403    DEL       274,288
 VIRTUAL  EXIT      306
 VIRTUAL  FILIO.    175,190,194,290
 VIRTUAL  FILPR.    173,177,192,276
 00417    G         269,272,286
 00420    G1        233,271,282
 00404    G2        250,270,284
 VIRTUAL  HNLIO.    181,183,185,187,189,279,281,283,285,287,289
 00440    IM        204,292,294
 00434    IN        159,163,304
 VIRTUAL  IOHEC.    131
 VIRTUAL  IOHEF.    74,83,116,133
 VIRTUAL  IOHFC.    79,121,126
 VIRTUAL  IOHHC.    45,50,55,60,65,70,87,92,97,102,107,112
 VIRTUAL  IOHID.    73,82,84,115
 VIRTUAL  IOHLP.    76,118,125
 VIRTUAL  IOHRP.    81,123,130
 VIRTUAL  IOHXC.    48,53,58,63,68,77,85,90,95,100,105,110,119,128
 00453    IT        164,165
 VIRTUAL  .EXP3.    232,249,268
 VIRTUAL  LITCT.    220,227,237,244,256,263
 VIRTUAL  LTCR2.
 00370    M         201,205
 00422    N         11,180,195,213,251,254
 00436    N1        202,208,210,211,217,230,278
 00421    N2        215,235,247,280
 00437    NN        252,266
 VIRTUAL  SETFP.    155
 VIRTUAL  S.JXIT    309
 00365    SNGCT.    156,196,209
 VIRTUAL  SQRT      222,239,258
 VIRTUAL  STHIO.    172,176,191,275
 00405    T0        22,169,186,255
 00371    T1        33,168,182,219
 00441    T2        171,184,236
 00435    W         157,188,216,234,253
 00225    D.0000    221,225,226,228,229,231,238,242,243,245,246,248,257,261,262,26
 00013    S.0043    166,218
 00212    S.0045    161,179,212,301
 00007    S.0046    305                                                   265,267
 00211    S.0047    206
 00063    S.0050    295
 00362    P.0051    336
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CROSS-REFERENCE DICTIONARY

00365	P.0052	6
00362	P.0053	342
00362	P.0054	158,203
00363	P.0055	197
00364	P.0056	303

REFERENCES TO LOCATION COUNTERS

LC START	NAME	STARTING AND ENDING STATEMENT NUMBERS
00000		1-1
00362	DATCT.	4-4,10-43
00000	PLGCT.	313-330
00000	PRGCT.	2-2,154-312,331-332
00231	SFLCT.	3-3,44-133,333-343
00362	STRCT.	5-9,134-153

NO MESSAGES FOR ABOVE ASSEMBLY

```
PHASE ANGLE CALCULATIONS, ED M                     IBLDR -- JOB   DELTA

                        M E M O R Y   M A P

SYSTEM, INCLUDING IOCS                             00000 THRU  12273

FILE BLOCK ORIGIN                                  12302

     NUMBER OF FILES -      1

     1.  S.FBOU                  12302

OBJECT PROGRAM                                     12325 THRU  16676

     1.  DECK @DELTA @           12325
     2.  SUBR @OUSYFB@           00000
     3.  SUBR @POSTX @           13001
     4.  SUBR @CNSTNT@           13114
     5.  SUBR @FPR   @           13123
     6.  SUBR @IOS   @           13124
     7.  SUBR @RWD   @           13401
     8.  SUBR @ECV   @           14061
     9.  SUBR @FCV   @           14327
    10.  SUBR @HCV   @           14421
    11.  SUBR @XCV   @           14524
    12.  SUBR @INTJ  @           14545
    13.  SUBR @FFC   @  *        15061
    14.  SUBR @FPT   @           15470
    15.  SUBR @XEM   @  *        16040
    16.  SUBR @XIT   @           16251
    17.  SUBR @XP3   @           16253
    18.  SUBR @XPN   @           16324
    19.  SUBR @LOG   @           16432
    20.  SUBR @SQR   @           16577

   %* - INSERTIONS OR DELETIONS MADE IN THIS DECK[

INPUT - OUTPUT BUFFERS                             77317 THRU  77776

UNUSED CORE                                        16677 THRU  77313
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TABLE 6

COMPUTER DATA FOR DETERMINATION OF N_2
(NUMBER OF PERFECT MIXERS IN FLUIDIZED SECTION)

3.75 INCH COLUMN
N=2

N_1	N_2	AR_1	AR_2	AR	Delta ($AR-AR_1 \cdot AR_2$)
.2	1.8	.819	.499	.372	.0362
.4	1.6	.751	.511	.372	.0119
.6	1.4	.710	.527	.372	.0020
.8	1.2	.683	.545	.372	.0001
1.0	1.0	.663	.568	.372	.0044
1.2	0.8	.648	.597	.372	.0148
1.4	0.6	.636	.637	.372	.0326
1.6	0.4	.626	.693	.372	.0616
1.8	0.2	.618	.783	.372	.1116

TABLE 7

COMPUTER DATA FOR DETERMINATION OF N_2
(NUMBER OF PERFECT MIXERS IN FLUIDIZED SECTION)

5.75 INCH COLUMN
N=2

N_1	N_2	AR_1	AR_2	AR	Delta ($AR-AR_1 \cdot AR_2$)
0.2	1.8	.815	.438	.331	.0266
0.4	1.6	.744	.453	.331	.0069
0.6	1.4	.702	.471	.331	.0003
0.8	1.2	.673	.493	.331	.0014
1.0	1.0	.652	.520	.331	.0085
1.2	0.8	.636	.554	.331	.0219
1.4	0.6	.623	.600	.331	.0432
1.6	0.4	.613	.664	.331	.0764
1.8	0.2	.604	.765	.331	.1319

TABLE 8

COMPUTER DATA FOR DETERMINATION OF N_2
(NUMBER OF PERFECT MIXERS IN FLUIDIZED SECTION)

7.75 INCH COLUMN
N=3

N_1	N_2	AR_1	AR_2	AR	Delta ($AR-AR_1 \cdot AR_2$)
0.3	2.7	.769	.335	.239	.0188
0.6	2.4	.694	.349	.239	.0035
0.9	2.1	.652	.366	.239	.000003
1.2	1.8	.625	.387	.239	.0031
1.5	1.5	.606	.413	.239	.0118
1.8	1.2	.592	.448	.239	.0265
2.1	0.9	.581	.496	.239	.0494
2.4	0.6	.572	.567	.239	.0856
2.7	0.3	.564	.687	.239	.1489

TABLE 9

COMPUTER DATA FOR DETERMINATION OF N_2 (NUMBER OF PERFECT MIXERS IN FLUIDIZED SECTION)

9.75 INCH COLUMN
N=3

N_1	N_2	AR_1	AR_2	AR	Delta $(AR-AR_1 \cdot AR_2)$
0.3	2.7	.769	.282	.205	.0116
0.6	2.4	.694	.297	.205	.0010
0.9	2.1	.652	.316	.205	.0007
1.2	1.8	.625	.338	.205	.0064
1.5	1.5	.606	.367	.205	.0175
1.8	1.2	.592	.406	.205	.0348
2.1	0.9	.581	.458	.205	.0608
2.4	0.6	.572	.536	.205	.1011
2.7	0.3	.564	.666	.205	.1707