FLOW LOSSES IN FLEXIBLE HOSE

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INTRODUCTION

The objectives of this study are to determine an empirical method for predicting flow losses in flexible hose while using a gas (air) and a liquid (water) as the test mediums. The effect of straight sections and sections with bending will be considered. Other considerations in the study are hose characteristics such as types of material and convolutions, convolution/unit length, convolution heights, diameter, bend angle, and other geometric factors.

A further objective is to obtain a sufficient quantity of data so correlation of results may be achieved in a reliable and comprehensive manner.

The initial "planned program for work" was organized into four phases, (1) planning, (2) development of facilities, (3) data production, and (4) correlations and reporting.

The efforts during this reporting period, which covers the period from March 14, 1965, to June 14, 1965, have been directed toward the completion of Phase III, Data Production, and the initiation of Phase IV, or correlation of data. A discussion of the accomplishments in this period is in the following section of this report.

Before the discussion of current work, it is appropriate to summarize the effort and accomplishments of the first nine months of this contract.

SUMMARY OF PREVIOUS WORK

Phase I - Summary

a) Literature Survey

A literature survey was initiated in July 1965, and has been continued to date. A list of papers and reports investigated is contained in Appendix I. To summarize the results of this survey to date the following information is submitted. (Appendix I also contains a plot of data obtained through our literature survey.)

1. Smooth tubes

Many empirical formulae have been proposed to represent the friction factor for smooth tubes over all or part of the range of Reynolds' Numbers up to as high as $R = 10^8$. Practically all have the form

$$f = A + \frac{B}{R^n},$$

the constants A, B, and n being adjusted to fit various sets of experimental results. Blasius published five such equations to cover the range represented by

$$f = \frac{0.3164}{R^{0.25}}. \tag{1}$$

The equation

$$f = 0.0072 + \frac{0.6104}{R^{0.35}} \tag{2}$$

was proposed by Ch. H. Lees to represent the data of Stanton and Pannell which extended from R = 2500 to R = 430,000 approximately. M. Jakob and S. Erk published the formula

$$f = 0.00714 + \frac{0.6104}{R^{0.35}} \tag{3}$$

in connection with their experiments which covered the range R = 85,000 to R = 470,000 approximately.

L. Schiller reported experiments made under his direction by R. Hermann at the Physikalischen Institut Leipzig. Here Schiller proposed the formula

$$f = 0.00540 + \frac{0.396}{R^{0.300}}. \tag{4}$$

The range of measurement was from $R = 20,000$ to $R = 1,900,000$ and the formula was reported to fit the results within ± 0.5 per cent.

Probably the most suitable single equation yet proposed is this one by E. C. Koo

$$f = 0.00560 + \frac{0.500}{R^{0.32}} \tag{5}$$

It represents the single friction factor for smooth tubes over the range of Reynolds' Numbers 3,000 to 3,000,000.

A notable contribution to the knowledge of turbulent flow was made by Von Karman in an equation of the form

$$\frac{1}{\sqrt{f_{max}}} = A \log R_{max} \sqrt{f_{max}} + B$$

wherein $R_{max} = \frac{v_{max} \cdot d}{\upsilon}$, and v_{max} is the maximum velocity in the pipe. This equation represents the friction factors only when the effect of viscosity has become negligibly small.

Based on theory by Prandtl, Nikuradse showed that the equation of Von Karman could also be written

$$\frac{1}{\sqrt{f}} = A \log R \cdot \sqrt{f} + B,$$

where $R = \frac{\bar{v}d}{\upsilon}$ and v is the average velocity instead of the less convenient maximum velocity.

Two sets of constants were proposed,

$$\frac{1}{\sqrt{f}} = 2.0 \log R\sqrt{f} - 0.8 \tag{I}$$

which fit the plotted points over a very wide range of the variables and

$$\frac{1}{\sqrt{f}} = 1.95 \log R\sqrt{f} - 0.55 \qquad (II)$$

which seemed to be in better agreement with an analysis based on the maximum velocity.

Nikuradse concluded that Blasius equation (1) represented the friction factors over the range of turbulent flow in which the effect of viscosity is important and placed the upper limit of this at about R = 100,000.

Above this value the viscosity seemed to have a negligible influence on the flow and Von Karman's equation using the constants (I) given previously would apply over a wide range, possibly up to $R = \infty$.

Since the Von Karman equation can be solved for f when R is known, only by successive approximations, Nikuradse proposed the empirical formula

$$f = 0.0032 + \frac{0.221}{R^{0.237}} \qquad (6)$$

to represent the friction factors from $R = 10^5$ to $R = 10^8$.

2. Friction Factor in Corrugated Hose

A. H. Gibson (1) gave the results of experiments on a pipe of 2.0 in. maximum bore, 1.8 in. minimum bore, and 0.4 in. pitch of corrugations. He observed that the loss of head was proportional to the mean velocity raised to an index greater than two. By dimensional analysis he then argued that this would lead to the apparently paradoxical result that an increase of viscosity would cause a decrease in the loss of head at a given rate of discharge. Further tests which he performed using water at two different temperatures in the corrugated pipe confirmed these deductions.

Webster and Metcalf (2) performed experiments on corrugated pipes having diameters 3, 5 and 7 feet. They found that a maximum value of f was reached, after which f decreased with increasing Reynolds Number.

Neill (3) gives an analysis of previous results and after completing an experimental investigation into the losses in "standard" corrugated piping having a minimum diameter of 15 in. with corrugations 1/2 in. deep, and 2 2/3 in. pitch, suggests the formula

$$f = 0.16\,(K_c/D)^{1/2}$$

where K_c is the depth of the corrugations, D is the minimum diameter of the pipe, and f is the friction factor in the expression for the loss of head.

$$h = \frac{4flv^2}{2gD}$$

In taking pressure measurements, two of the tapping points for pressure measurement were situated at the crest of the corrugations and two at the trough, for each section where the pressure was recorded.

From figure 4 of Neill's work it is seen that the index of the mean velocity v in the equation

$$h = kv^n$$

is approximately 2.31 over the upper portion of the velocity range. Alternatively, the value 2.423 was derived from a statistical analysis using the method of least squares.

In the calculations of f and of the mean velocity v, the minimum diameter of the pipe was used throughout, since it was felt that the corrugations might often contain pockets of "dead water" which do not contribute an effective part in the main pattern of flow.

C. M. Daniel (4) used the Weisbach-Darcy equation for frictional pressure loss and calculated friction coefficients for annular and helical type hoses. He indicates that the helical type hose has a lower pressure loss than the annular type. Very little worthy information was obtained from this paper.

R. C. Hawthorne (5) developed an analytical method for calculating pressure losses in corrugated hose and assumed that the corrugations behave as a series of uniformly spaced orifices. In this paper it was stated that corrugation height did not affect the flow. The empirical results were developed on this basis.

John Allen (6) found a critical Reynolds Number of 1700 instead of the usual 2300. Also, the index of velocity was reported to be of the order of 2.4 at a Reynolds Number of approximately 40,000, whereas for parallel piping the index does not exceed 2.0 after the transition region. This indicates a definite dependency on geometry.

The results of two experimental efforts were published in 1958, one by Koch (7) and the other by Nunner (8), both of which reported friction factors for flow tubes with artificial uniform roughnesses. Koch made use of thin orfice-like ring-shaped discs inside of smooth pipe, whereas, Nunner installed rubber rings of semi-circular cross sections. Both authors presented friction factor versus Reynolds Number results which indicate much higher friction factors than for typical rough pipe. For instance, friction factors as high as 0.4 were reported by Koch and as high as 0.3 were reported by Nunner. Both these results indicate a tendency toward increased friction factors in the neighborhood of Reynolds Numbers of 10^5 or so. These increases occur as a change from an otherwise constant value following the laminar to turbulent transition. A somewhat similar experiment was carried out in 1940 by Mobius (9) in which he investigated flow through artifically roughened pipes, the roughnesses being produced by small rings of square cross sections in which he reported friction factors as high as 0.1.

In 1953 Wieghardt (10) conducted some interesting experiments for flow over rectangular ribs placed at right angles to the flow stream and also flow over circular cavities. Both situations produced an increase in the drag coefficient of the plate to which the ribs were attached or in which the holes were drilled and in some cases vortex patterns were observed within the holes. Photographs of these patterns are shown accompanying his article. Wieghardt also presents some interesting nomograms for determining pressure drops and drag coefficients over such flow obstructions. Wieghardt's work receives some discussion in Schlichting's text (4th edition) on pages 554 and 555. A very interesting example of the increased friction factor due to internal regular roughnesses was reported in 1949 by Wiederhold (11) and also in 1950 by Seiferth and Kruger (12). Both these papers report a water duct in which a mass flow decreased by 57% during a long period of usage. It was found that this increase in friction factor which was of the order of 0.06 was due to a rib-like deposit of aluminum oxide on the walls of the duct.

This work is mentioned briefly in Schlichting's text on page 529. These results are of particular interest because of the geometrical similarity to the convoluted tubing which are the subject of this investigation.

With heat transfer being his main interest, Doenecke (13) presented some heat transfer and friction studies of turbulent forced convection over rough plates. This work took place in 1963.

Naval architects and Marine engineers for some time have studied flow over rough surfaces. An article entitled "Boundary Layer Characteristics for Smooth and Rouge Surfaces" by F. R. Hama (14) presents a rather good bibliography of the literature in this area. Specifically, there are two references which deserve mention, both being dissertations from the State University of Iowa. The first by W. D. Baines (15), the second by W. F. Moore (16) concerning investigation of Boundary Layer Development Along A Rough Surface.

The most recent article of interest is one which appeared in the February, 1965 issue of The Journal of the Royal Aeronautical Society. This article by R. D. Mills (17), entitled "On the Closed Motion of Fluid in a Square Cavity" presents a two dimensional incompressible solution for the vortex motion of a fluid in such a cavity. In his work, Mills references the photographic results of Wieghardt (10) and Baturin (18) who have photographed this vortex flow in rectangular cavaties as well as the experimental results of Roshko (19), Mills (20), and Linke (21). Mills approached the problem from the standpoint of a periodic solution to the boundary layer equations. His analysis yields an infinite series expression for the velocity distribution in the cavity which he compares with the work of Roshko and others.

An article which has come to our attention very recently is that of V. K. Migay (22), entitled "The Aerodynamic Effectiveness of a Discontinuous Surface." Migay's work is concerned with delay of the separation point in a diffuser by means of supplying the diffuser wall with convolutions placed normal to the flow stream. In an auxiliary experiment, using water and sawdust, he found vortex formations within the convolutions or cavities. But more interesting, he found that "at high speeds, intense ultrasonic radiation was registered." He goes on to discuss the concept, previously considered in this work, of a Helmholtz resonator.

Another interesting area of investigation is that of cross flow over cylinders at high Reynolds Number. Roshko (23) presents some results of very high Reynolds Number flow over cylinders in which the drag coefficient first decreases and then again increases this phenomena being due to boundary layer separation and motion of the separation point along the surface of the cylinder. A striking variation in the drag coefficient of the cylinder is produced by the motion of this separation point. It is felt that this phenomena could also be part of the friction factor increase of the subject investigation.

"The Study of Flow Over a Corrugated Surface" is the subject of a NACA technical note by Corrsin and Kistler (24). This Technical Note 3133, published in 1954, reported the results of a wind tunnel flow in which one wall was corrugated sinusoidally. Velocity profiles and friction coefficients were reported for the turbulent boundary layer which was formed. The main subject of the paper, however, was the propagation of the turbulence produced in the boundary layer into the potential flow in the main stream of the wind tunnel.

It was stated by Clauser (25) that "the customary zero velocity point is located at the variable height minus $\sqrt{\frac{2}{c_f}}$", where c_f is the local skin friction coefficient. By adjusting the boundary condition in this manner such that the zero velocity occurs not at the wall but at some midpoint between the top of the protrusion and the bottom, he found that data for rough pipes could be fitted more reasonably.

A similar effect was noted by Moore (16). He showed that

> "When plotted in terms of the parameters normally used for pipe flow, $\frac{U_o - U}{U^*}$ and y/δ, the velocity profiles differ systematically from the one for smooth plates, but when th the origin for y is adjusted by adding 2/3 k to all the y values, the rough-plate profiles are brought into fair agreement with the smooth plate profile."

In Moore's nomenclature U^* is the shear velocity, $\sqrt{\tau wall/\rho}$.

Another quite pertinent report is NACA Report 1174, entitled "The Structure of Turbulence and Fully Developed Pipe Flow" by John Laufer (26). This work makes up the primary reference on turbulent flow in ducts as discussed in the text book, TURBULENCE, by Hinze (27). It is quite pertinent to quote from page 486 of Hinze's book.

> "We conclude, therefore, that at present, determination of the velocity distribution close to a rough wall is still in the purely empirical stage and that there is no way to predict this distribution for an arbitrary roughness pattern; at any rate, it is not possible to express the effect of such a roughness pattern in terms of one single roughness parameter."

The general description of turbulent pipe flow as given by Laufer and repeated by Hinze, is as follows: The flow adjacent to the wall is responsible for the production of small eddies of great energy intensity. This energy is dissipated in the form of a diffusion of eddy energy toward the center of the tube where there exists large elongated eddies. It is felt that a possible explanation for the increased friction factor of the subject research could lie in the existence of large eddies at the wall, that is, in the convolutions rather than the small high intensity eddies as described by Laufer.

The experimental results of Knudsen and Katz (28) which were called to our attention by Mr. Dale Blount describe the observation of eddy patterns in the area between fins on a transverse helical finned tube. The fact that these eddies were observed for all turbulent flows (even at very low Reynolds Numbers) supports the contention that the mere existence of an eddy or vortex in the convolution is not in itself responsible for the sudden increase in friction factor. If the eddy phenomena plays a significant roll it must be due to a sudden change in character of eddy flow in the cavity. It is doubtful that flow visualization will be possible at such high Reynolds Numbers to detect any such suspected changes in the character of the eddies at the onset of this increase in friction factor.

Pepersack (29) prepared graphs to predict pressure losses in straight and curved sections of flexible hose. The pressure drops reported are from 4 to 19 times the loss through an equivalent smooth tube. A multiplying factor was recommended for predicting pressure loss. Also presented are recommended pressure loss coefficients of 90° bends for hose with $R/D = 6$ to 36 versus Reynolds Number.

A considerable amount of the information presented in this survey was obtained through the cooperation of Mississippi State University personnel. The survey is still in progress; however, we feel that the above abstracts represent the majority of applicable results.

b) Test Facility and Calibration

The test facilities for air and water were completed on schedule and preliminary diagrams of the systems were submitted with the Monthly Report for June 14, 1965 - July 14, 1965. Standard techniques for calibration were used and need not be discussed here. A schematic diagram of the air and water systems used in the final testing is included on the following pages.

Three graduate students were employed effective September 1, 1965. They will be employed by this research project through the termination date.

<u>Phase II - Testing Techniques</u>

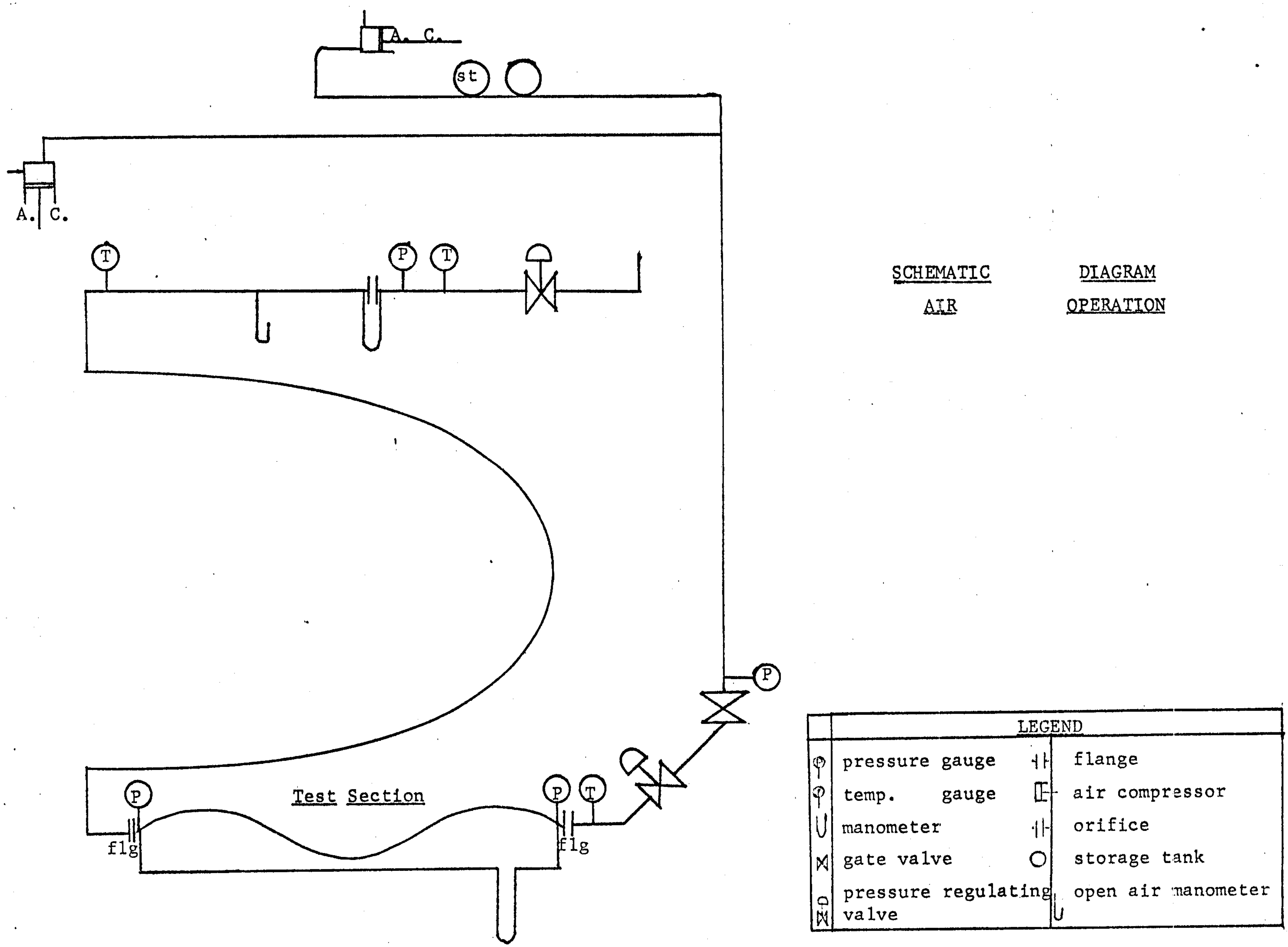
a) Initial Test and Review of Problems

The initial testing period proved to be educational in that much information was gained concerning facility limitations and hose characteristics. For instance, it was determined that a 30° bend angle spread was adequate for determination of bend angle effects.

On the air system, problems with pressure gauge calibration and manometer fluctuations were encountered and overcome. To obtain a suitable spread in pressure drops two manometer fluids were required, mercury and carbon tetrachloride. On the water system the same problems arose and were overcome in the same way, with the same two manometer fluids. Pressure gauges on the water system did not hold their calibration for any length of time and as a result they were not used in final testing. Temperature effects were found to be critical in determining Reynolds Number for air and water; therefore, care was taken to record the temperatures at the vicinity of the inlet and outlet sections.

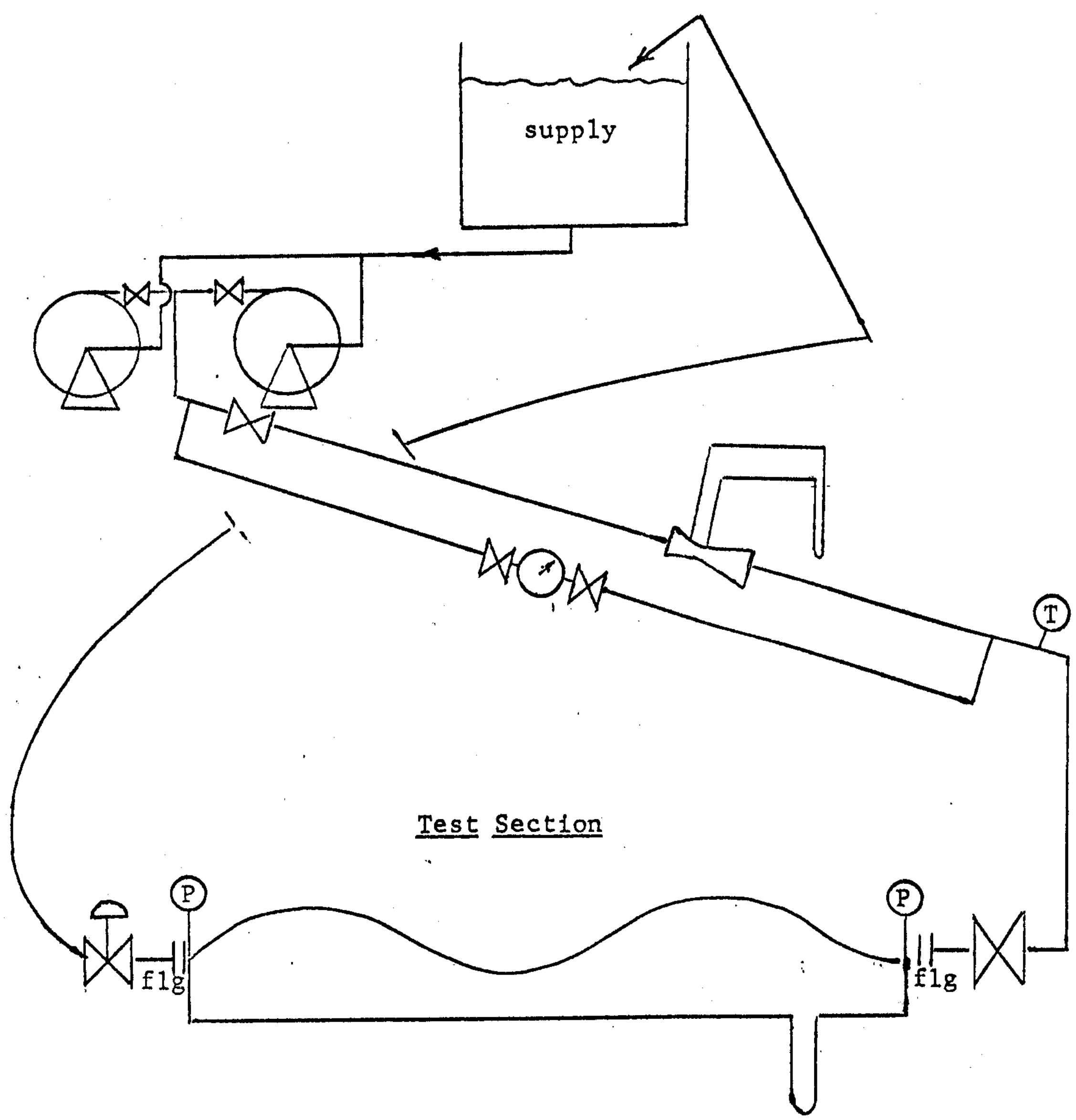
SCHEMATIC DIAGRAM

AIR OPERATION



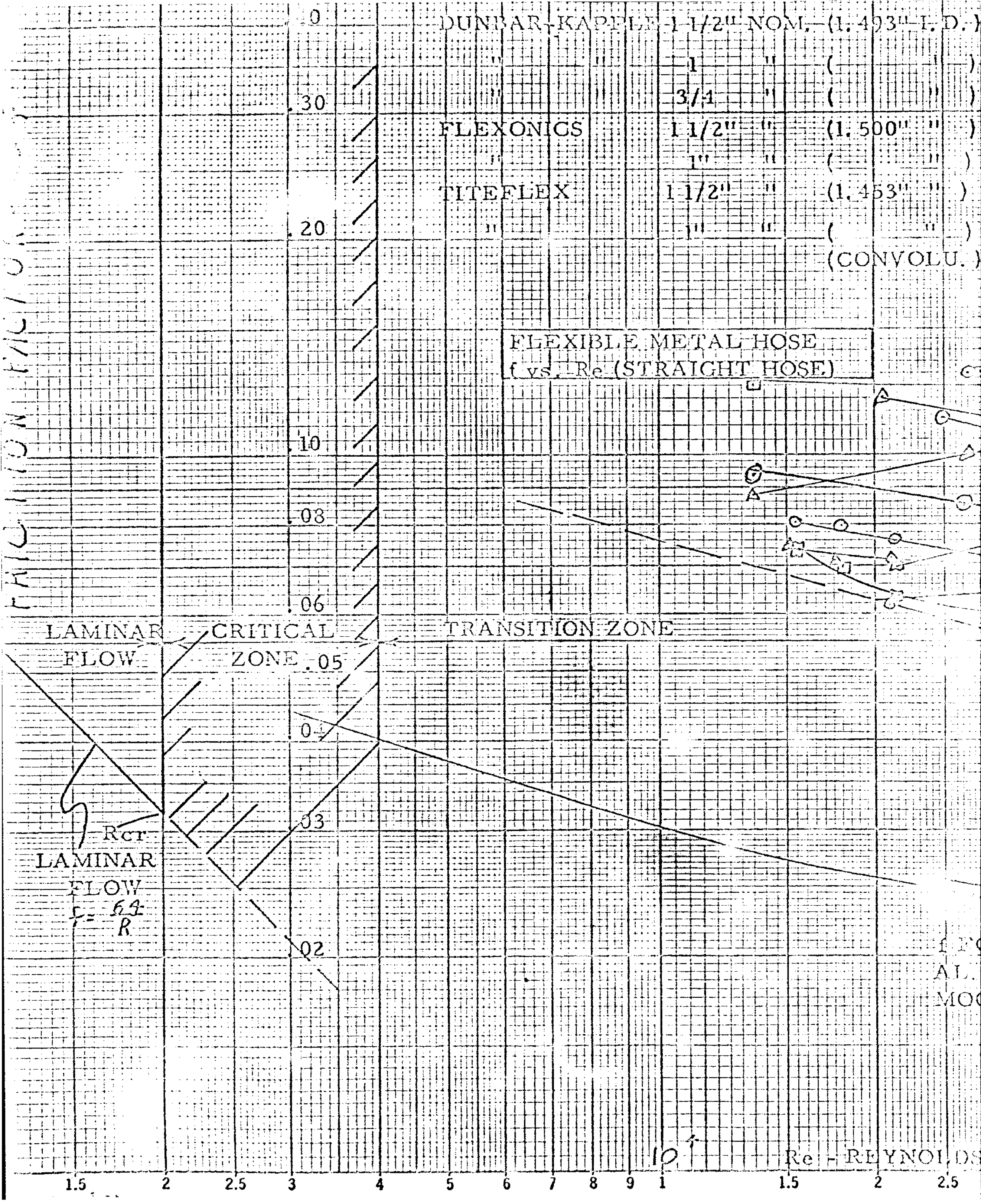
SCHEMATIC DIAGRAM

WATER OPERATION

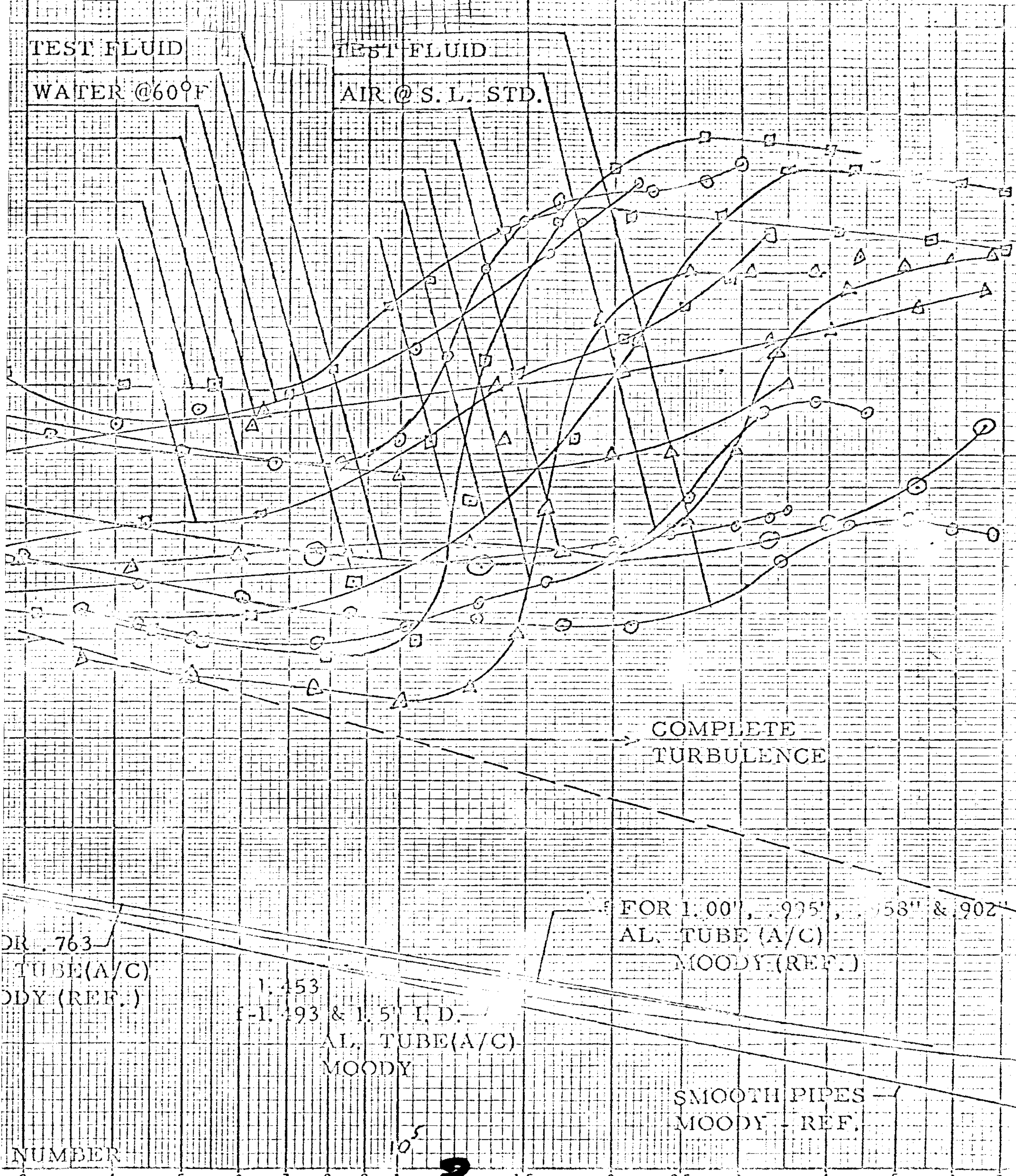


LEGEND

temp. gauge	venturi
pressure gauge	gate valve
manometer	pressure regulating valve
disc flow meter	flange



DUNBAR-KAPPLE 1 1/2" NOM. (1.493" I.D.)
" " 1 " (" ")
" " 3/4 " (" ")
FLEXONICS 1 1/2" " (1.500" ")
" 1" " (" ")
TITEFLEX 1 1/2" " (1.453" ")
" 1" " (" ")
(CONVOLU.)
FLEXIBLE METAL HOSE
f vs. Re (STRAIGHT HOSE)
LAMINAR FLOW
CRITICAL ZONE
TRANSITION ZONE
Rcr
LAMINAR FLOW
f = 64/R
Re - REYNOLDS
.30
.20
.10
.08
.06
.05
.04
.03
.02
1.5
2
2.5
3
4
5
6
7
8
9
1
1.5
2
2.5



TEST FLUID
WATER @60°F
TEST FLUID
AIR @ S. L. STD.
COMPLETE TURBULENCE
FOR 1.00", .925", .958" & .902"
AL. TUBE (A/C)
MOODY (REF.)
OR .763
TUBE(A/C)
ODY (REF.)
1.453
1.493 & 1.5" I. D.
AL. TUBE(A/C)
MOODY
SMOOTH PIPES
MOODY - REF.
NUMBER
10^5
3
4
5
6
7
8
9
1
1.5
2
2.5
3
4
5
6
7

2

The carbon tetrachloride manometer was very accurate on measurements when flow rate was increasing but failed to repeat data points as the flow rate was decreased from a maximum. The manometer was unstable in this situation and "cavitated" or failed to stabilize. As a result all data points taken on the decreasing flow rate runs were discarded.

No other major problems occurred in initial testing as in the major testing period.

b) Analytical Approaches

In an effort to describe the flow semi-empirically, Mr. Kenneth Riley, a Ph. D. Candidate in Chemical Engineering, has devoted considerable time to the problem of predicting the flow losses. A summary of the preliminary study follows.

The friction factor concept is being used in the empirical determination of a method for the prediction of flow losses in flexible hose. The friction factor may be expressed as:

$$f_T = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{(P_o - P_L)\, gc}{\frac{1}{2}\rho v^2}\right) \qquad (1)$$

This equation shows explicitly how f_T is calculated from experimental data.

The object of this program is to find the relationship between f_T and the variables which characterize flow and system geometry. The approach taken is a mechanistic one. A physical model has been assumed and from this a mathematical model has been developed. The mathematical model will be corrected so as to correlate the experimental data.

The physical model assumes that the flexible hose consists of alternating sections of smooth pipe and circumferential depressions. For this model the friction factor can be expressed as the sum of two terms:

$$f_T = \xi f_s + (1-\xi) f_E \qquad (2)$$

Some standard correlation for the friction factor in smooth tubes can be used for f_s:

$$f_s = 0.046(Re)^{-1/5} \qquad (3)$$

Note that this model will be used only for turbulent flow.

Higbie's penetration theory was used to evaluate f_E. This theory assumes that the major loss of momentum is through rotating eddies that form in the depressions. Furthermore, momentum is transferred from the eddies to the walls of the depressions via the mechanism of fluid elements on the eddy circumference. The result from this theory is:

$$f_E = \frac{4}{\sqrt{\pi}}\left[\frac{\psi}{1-\xi+2\varphi}\right]^{1/2} (Re)^{-1/2} \qquad (4)$$

a relationship for f_T can therefore be predicted:

$$f_T = 0.046\ (\xi)\ (Re)^{-1/5} + \alpha\,(1-\xi)\left[\frac{\psi}{1-\xi+2\varphi}\right]^{1/2} (Re)^{-1/2} \qquad (5)$$

For purposes of correlating the experimental data the coefficients predicted from the penetration theory will be taken as unknowns.

$$f_T = 0.046(\xi)\ (Re)^{-1/5} + \alpha(1-\xi)\left[\frac{\psi}{1-\xi+2\omega}\right]^{\beta} (Re)^{-\alpha} \qquad (6)$$

This mechanistic approach should produce useful relationships and a clearer understanding of the process.

Re - Reynolds No., $\frac{D\bar{v}}{\nu}$

ξ - x/L

L - pitch of the convolutions

x - length of depressions

ψ - D/L

ω - C/L

C - depth of convolution

Several other aspects of data correlation were considered. These include dimensional analysis, boundary layer mixing length theories (after Prandtl) and others. This work is continuing; however, the original plan for correlation by equation (2) seems the most logical.

Phase III - Data Production

a) Testing of All Hose

The testing of all hose on the air and water systems, including all angles has been completed. Re-runs to check data have been accomplished where necessary. The facility is intact should there be a further need for data production.

b) Analysis of Data to the Present Reporting Period

All efforts in data analysis up to this reporting period have been concentrated on pressure drop versus velocity correlations and the verification of the relation between ΔP and V. A regression program was developed to analyze pressure drop as:

$$\Delta P = \alpha V^{\beta}$$

Data resulting from this program has been presented in previous monthly or quarterly reports.

c) Computer Technology

The computer programs used in reduction of all test data are included in Appendix II of this report. Standard FORTRAN IV computer language was used for programs scheduled for the IBM 7040 computer and FORTRAN II for the plotter programs.

SUMMARY OF WORK IN THIS REPORTING PERIOD

Phase III and Phase IV - Date Production and Correlation

As stated previously in these reporting periods the production of data has been completed for the water and the air system. This includes re-running all questionable points. The raw data has been coded for the computer and is being reduced to correlation parameter.

a) Analysis of Water Data

The following is a very brief summary of the results from the water system.

Note that f = Fanning's friction factor, and

$$f \equiv \frac{1}{4}\left(\frac{\Delta P}{\rho}\right)\left(\frac{D}{L}\right)\left(\frac{2gc}{v^2}\right)$$

Re = Reynold's Number, or

$$Re \equiv \frac{Dv\rho}{\mu}$$

Effect of bend angle. Typical results for hoses of 1 inch diameter can be used to illustrate the effect of bend angle on friction factor. The results for a 1 inch Close Pitch hose run at a Reynolds Number of 100,000

Bend Angle	Friction Factor
0	0.02473
30	0.02519
60	0.02712
90	0.02925
120	0.03200
150	0.03872
180	0.03985

Similar results on a 1 inch Open Pitch hose run at a Reynolds Number of 70,000 are as follows

Bend Angle	Friction Factor
0	.02301
30	.02403
60	.02638
90	.02983
120	.03199
150	.03454
180	.03751

For a 1 inch Helical hose at a Reynolds Number of 100, 000 the results are:

Bend Angle	Friction Factor
0	.02389
30	.02673
60	.02597
90	.02890
120	.02967
150	.02959
180	.03087

Two general conclusions can be drawn from this data:

1) Friction factor increases with increasing bend angle.
2) At equal Reynold's Numbers, the friction factor of the helical hose is less than that of the close pitch.

More detailed analysis of the data is impossible at this time. The date reported above are point values and hence may only reflect only general trends. A statistical analysis is now being made on the data so that more detailed conclusions can be made about the magnitude of the increase in friction factor with change in bend angle.

Effect of Reynold's Number. The following data shows the effect of Reynold's Number on friction factor for a 1 1/4 inch Open Pitch hose at 0^{o} bend angle.

Reynold's Number	Friction Factor
10,700	.01757
12,900	.02034
14,500	.01665
17,800	.01926
20,800	.01773
26,300	.01546
32,900	.01813
40,800	.01750
54,500	.02166
62,000	.02204
69,300	.01958
75,900	.02032
87,600	.02108
97,900	.02175
111,600	.02133
123,800	.02298
138,400	.02403
157,700	.02347
169,400	.02280
180,300	.02303
195,500	.02390

It appears from the data that the friction factor increases steadily with increasing Reynold's Number. Note that although the pipe wall is very rough and the flow is completely turbulent the friction factor is not constant.

An interesting experimental oddity is observed because of the result stated above. If the viscosity of the fluid flowing in the flexible hose is increased the pressure drop observed will decrease. This is because the Reynold's Number is inversely proportioned to the viscosity - a decrease in viscosity will cause an increase in Reynold's Number is inversely proportional to the viscosity - a decrease in viscosity will cause an increase in Reynold's Number and hence an increase in the friction factor. This, in turn, results in an increase in pressure drop for the same fluid velocity.

Consider the effects of a change in temperature on the water system. The density of water is not a strong function of temperature, hence, there will be very little change in velocity. The viscosity of water, however, is a strong function of temperature - a 30°F change causes a 34% change in viscosity. This means that an increase in temperature of the water would decrease the viscosity without greatly affecting the density. The increase in Reynolds Number could be as much as 30% and this would cause an appreciable increase in the friction factor. Pressure drop would be expected to increase.

Effect of Diameter. Typical results showing the effect of diameter are shown below for the Close Pitch base at 0° Bend Angle.

Diameter	Reynold's Number	Friction Factor
1/2	55,100	.02503
3/4	55,600	.01879
1	56,400	.02022
1 1/4	51,200	.02084
1 1/2	53,000	.01907
2	58,100	.01841
2 1/2	54,000	.01550
3	55,100	.01613

This data shows that there is a trend of a decreasing friction factor for an increasing diameter. This can be explained by noting that the wall geometry has less effect as the cross-sectional area of the hose becomes larger. In the limit, as the diameter got infinitely large the flexible hose would approach a smooth pipe in a hydraulic sense.

Appendix III contains typical water data as obtained from the computer program.

b) Analysis of Air Data

Typical results from the air system are included in Appendix IV. Due to time restrictions imposed by the due date of this report a detailed analysis was not possible.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

A. Progress toward accomplishment of the stated objectives has been made and is in accord with the planned work schedule submitted to NASA. No technical conclusions need be iterated at this time.

2. Recommendations

The following recommendations are made relative to the research undertaken during this period.

a) A study of two-phase flow in convoluted flexible hose should be undertaken during the next year. A proposal to this effect has been submitted to MSC.

b) Additional effort should be expended toward gaining an understanding of the effect of hose geometry on friction factor and a further study of theory in this respect should be made.

c) Since the transport properties of the working medium are greatly affected by temperature it would be advantageous to consider a restricted study at cryogenic temperatures. Further comments on this problem are being prepared.

APPENDIX I

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APPENDIX II

Computer Programs for Reduction of Data from the Air and Water Systems

```
C      THIS PROGRAM CALUATES FLOW RATE, REYNOLDS NUMBER, PRESSURE DROP,
C      AND FRICTICN FACTOR FOR THE WATER SYSTEM.  THE PROGRAM IS WRITTEN
C      IN FORTRAN IV FOR AN IBM 7040 COMPUTER.  THE CALCULATICN PROCEDUR
C      IS, A VALUE OF RFR(M) IS READ AND CONVERTED INTO A FLOW RATE.
C      THIS VALUE, ALONG WITH THE PRESSURE DROP, IS USED TO CALCULATE
C      FRICTION FACTOR.
C
C
C      FLOW OF WATER IN FLEXIBLE HOSE
C
C      CALCULATICN OF FRICTION FACTOR
C
C      DIMENSION VARIABLES
C
       DIMENSION PL(20),PLT(20),PH(20),PHT(20),RFR(90),PHI(90),PLO(90)
       DIMENSICN GPM(90),DP(90),V(90),RE(90),Q(90),FF(90),T(90)
       DIMENSION DIAM(3,8),PITCH(3,8),DEPTH(3,8),AXIALA(3,8)
       READ 57,(PL(M),PLT(M),PH(M),PHT(M),M=1,10)
  57   FCRMAT(F15.0,3F10.0)
       DC 73 I=1,3
       DC 73 K=1,8
       READ 37,DIAM(I,K),PITCH(I,K),DEPTH(I,K),AXIALA(I,K)
  37   FCRMAT(4F10.0)
  73   CCNTINUE
C
C      READ HEADER CARD
C
  78   READ43,NN,D,N,LANG
  43   FCRMAT(I10,F10.0,2I10)
C
C      READ DATA CARDS
C
       IF(N.EQ.N/2*2)GO TO 130
       NIK=N+1
       DC45I=2,NIK,2
       IF(I.EQ.N+1)GO TO 54
       READ44,RFR(I-1),PHI(I-1),PLO(I-1),RFR(I),PHI(I),PLO(I),T(I-1),T(
       GC TO 45
    54 READ56,RFR(I-1),PHI(I-1),PLO(I-1),T(I-1)
    56 FCRMAT(3F10.0,30X,F10.0)
    45 CCNTINUE
       GC TO 58
   130 DC40I=2,N,2
       READ44,RFR(I-1),PHI(I-1),PLO(I-1),RFR(I),PHI(I),PLO(I),T(I-1),T(
    44 FORMAT(8F10.0)
    40 CCNTINUE
    58 DC420I=1,N
       IF(RFR(I))415,405,405
   405 IF(RFR(I)-1000.0)413,406,406
   406 NGAL=RFR(I)/1000.0
       GAL=NGAL
       TIME=(RFR(I)-GAL*1000.0)/60.0
       GPM(I)=GAL/TIME
       GC TO 420
   413 GPM(I)=61.8195450*RFR(I)**.4987379
```

```
      GC TO 420
  415 GPM(I)=RFR(I)*(-1.0)
  420 CCNTINUE
C
C     CALCULATE PRESSURE DROP
C
      DC440I=1,N
      DP(I)=DELP(PLO(I),PHI(I),D,LANG,PL,PLT,PH,PHT,10)
 440  CCNTINUE
C
C     ARRANGE IN ASCENDING ORDER OF GPM
C
      NI=N-1
      DC 430 I=1,NI
      II=N-I
      DO 430 J=1,II
      IF(GPM(J)-GPM(J+1))430,430,421
 421  CALL ORDER(GPM,J,90)
      CALL ORDER(RFR,J,90)
      CALL ORDER(DP,J,90)
      CALL ORDER(T,J,90)
 430  CCNTINUE
C
C     CALCULATE FLOW PARAMETERS
C
      DI=D/12.0
      DC 71 I=1,N
      Q(I)=GPM(I)*0.1336806/60.0
      V(I)=(4.0/3.14159)*Q(I)/(DI**2)
      VISKIN=3.8E-04*(T(I)**(-.845))
      RE(I)=(DI*V(I))/VISKIN
      FF(I)=(DP(I)*DI*144.0*64.348)/(62.4*4.0*(V(I)**2)*10.0)
      PRINT 84,GPM(I),V(I),RE(I),DP(I),FF(I)
 84   FCRMAT(30X,F10.2,F15.4,1PE20.8,0PF15.4,F15.5)
 71   CCNTINUE
 1    FCRMAT(I10)
      GC TO 78
      END
```

```
C     THIS SUBPROGRAM CONVERTS EXPERIMENTAL READINGS TO PRESSURE DROP -
C     IN UNITS OF POUNDS PER SQUARE INCH.  THE SUBPROGRAM IS WRITTEN IN
C     FORTRAN IV.  THREE TYPES OF EXPERIMENTAL READINGS CAN BE HANDLED
C     BY THE SUBPROGRAM, READINGS GIVEN IN INCHES OF MERCURY, READINGS
C     IN INCHES OF CARBON TETRACHLORIDE, AND READINGS FROM BOURDON TYPE
C     GAGES.  THE LATTER READINGS ARE CORRECTED USING A CALIBRATION
C     READ IN BY THE MAIN PROGRAM.
C
C
      FUNCTION DELP(A,B,D,L,PL,PLT,PH,PHT,N)
      DIMENSION PL(N),PLT(N),PH(N),PHT(N)
      IF(A)431,201,435
 431  DELP=(B-A)*.455
      RETURN
 201  PRINT55,D,L,A
   55 FORMAT(30X,9HBAD DATA F6.3,I5,F6.1)
      DELP=0.0
      RETURN
 435  IF(A.GT.1000.0)GOTO36
      IF(A.LT.1.0)GOTO201
      DO110M=1,N
      K=M
      IF(PL(K)-A)110,111,112
 110  CONTINUE
      GOTO201
 111  PLOT=PLT(K)
      GOTO200
 112  PLOT=PLT(K)+((PLT(K-1)-PLT(K))/(PL(K-1)-PL(K)))*(A-PL(K))
 200  IF(B.LT.1.0)GOTO201
      DO310M=1,N
      K=M
      IF(PH(K)-B)310,311,312
 310  CONTINUE
      GOTO201
 311  PHIT=PHT(K)
      GOTO35
 312  PHIT=PHT(K)+((PHT(K-1)-PHT(K))/(PH(K-1)-PH(K)))*(B-PH(K))
 35   DELP=PHIT-PLOT
      RETURN
 36   AC=A-1000.0
      DELP=(B+AC)*0.0216
      RETURN
      END
```

```
C     THIS SUBROUTINE IS USED BY THE MAIN PROGRAM TO SORT IN ASCENDING
C     ORDER A LIST OF VALUES.  IT USES THE - PUSH DOWN - METHOD BY
C     MOVING THE LARGEST NUMBER TO THE BOTTOM OF THE LIST BY INTER-
C     CHANGING SUCCESSIVE PAIRS.
C
C
      SUBROUTINE ORDER(A,J,NDIM)
      DIMENSION A(NDIM)
      TEMP=A(J)
      A(J)=A(J+1)
      A(J+1)=TEMP
      RETURN
      END
```

```
C     THIS PROGRAM CALCULATES FLOW RATE, REYNOLDS NUMBER, AND FRICTION
C     FACTOR FOR THE AIR SYSTEM.  THE PROGRAMIS WRITTEN IN FORTRAN IV
C     FOR AN IBM 7040 COMPUTER.  ISOTHERMAL FLOW IS ASSUMED BY THE
C     PROGRAM IN MAKING CALCULATIONS ON THE TEST SECTION.
C
C
C     FLOW OF AIR IN FLEXIBLE HOSE
C
C     DIMENSICN VARIABLES
C
      DIMENSION RE(30),CS(30,10),PUT(80),HGTS(80),PUO(80),HGO(80)
      DIMENSION DPTS(80),RATTS(80),PTS(30),PTSC(30),TTS(80)
      DIMENSION TO(80),APO(80),DPO(80),RATIO(80),ATO(80),DENO(80)
      DIMENSION VISO(80),SCFM(80),ATTS(80),APTS(80),POS(30),POSC(30)
      DIMENSION G(80),TC(80),VISTS(80),RETS(80),FF(80),V1(80),V2(80)
      DIMENSION CR(10),RAT(10),A(10,10),REC(10),V(80),ZO(20),ZOC(20)
C
C     READ IN GAGE CORRECTION
C
      READ1,NZ
      READ45,(ZO(I),ZOC(I),I=1,NZ)
      READ1,MM
  1   FORMAT(I10)
      READ45,(POS(I),POSC(I),I=1,MM)
 45   FORMAT(2F10.0)
      READ1,NM
      READ45,(PTS(I),PTSC(I),I=1,NM)
C
C     READ IN ORIFICE COEFFICENT MATRIX
C
      READ64,NROW,NCOL
 64   FORMAT(2I10)
      DO50I=1,NROW
 50   READ13,RE(I),(CS(I,J),J=1,NCOL)
 13   FORMAT(E10.0,6F10.0)
      READ136,ND
 136  FORMAT(I10)
      DO137I=1,ND
 137  READ138,CR(I),REC(I),RAT(I),(A(I,J),J=1,5)
 138  FORMAT(F10.0,E10.0,6F10.0)
C
C     GIVE VALUE FOR DIA
C
      DIA=4.026
C
C     READ HEADER CARD
C
 78   READ43,NN,D,N,LANG,DIAO
 43   FORMAT(I10,F10.0,2I10,F10.0)
C
C     PUNCH HEADINGS FOR OUTPUT
C
      IF(NN-2)3,4,5
  3   PRINT6,D,LANG
    6 FORMAT(/20X,11HCLOSE PITCH,6X,10HDIAMETER =F6.3,5X,7HANGLE =I4//)
```

```
      GC TO 9
 4    PRINT7,D,LANG
   7  FORMAT(/20X,10HOPEN PITCH,7X,10HDIAMETER =F6.3,5X,7HANGLE =I4//)
      GCTO 9
   5  PRINT8,D,LANG
   8  FCRMAT(/20X,7HHELICAL,10X,10HDIAMETER =F6.3,5X,7HANGLE =I4//)
    9 PRINT32
   32 FORMAT(45X,4HSCFM,13X,2HRE,12X,2HFF)
C
C     READ DATA CARDS
C
   10 READ 34,(PUT(I),HGTS(I),PUO(I),HGO(I),TTS(I),TO(I),I=1,N)
  34  FCRMAT(6F10.0)
      DC 175 M=1,N
C
C     CALCULATE PHYSICAL PROPERTIES
C
      APO(M)=GAGE(PUO(M),3.0,D,LANG,MM,POS,POSC,30,ZO,ZOC,20,NZ)+14.696
      IF(HGO(M).LT.0.0)DPO(M)=-HGO(M)*0.0575
      IF(HGO(M).GE.0.0)DPO(M)=HGO(M)*0.49115
      RATIO(M)=DPO(M)/APO(M)
   18 ATO(M)=TO(M)+459.69
      DENO(M)=(2.70*APO(M))/ATO(M)
      VISO(M)=.0191*((295.3+120.)/(.555*ATO(M)+120.))*(ATO(M)/532.)**1.5
C
C     CALCULATE SCFM
C
      SCFM(M)=W(DIAO,RATIO(M),RAT,A,CR,DPO(M),DENO(M),DIA,VISO(M),REC,
     110,CS,NROW,RE)/4.58
 175  CCNTINUE
C
C     ARRANGE IN ASCENDING ORDER OF SCFM
C
      NI=N-1
      DC 430 I=1,NI
      II=N-I
      DC 430 J=1,II
      IF(SOFM(J)-SCFM(J+1)) 430,430,421
 421  CALL ORDER(SCFM,J,80)
      CALL ORDER(PUT,J,80)
      CALL ORDER(HGTS,J,80)
      CALL ORDER(TTS,J,80)
      CALL ORDER(TO,J,80)
      CALL ORDER(ATO,J,80)
 430  CCNTINUE
C
C     CALCULATE PHYSICAL PROPERTIES FOR TEST SECTION
C
      DC 300 M=1,N
      ATTS(M)=TTS(M)+459.69
      IF(HGTS(M).LT.0.0)DPTS(M)=-HGTS(M)*0.0575
      IF(HGTS(M).GE.0.0)DPTS(M)=HGTS(M)*0.49115
      DI=D/12.0
      TC(MI=(295.3+120.)/(.555*ATTS(M)+120.)
      VISTS(M)=.01908*TC(M)*(ATTS(M)/532.)**1.5
```

```
C
C     CALCULATE REYNOLDS NUMBER
C
      RETS(M)=6.31*4.58*SCFM(M)/(D*VISTS(M))
      RATTS(M)=DPTS(M)/APTS(M)
      APTS2=APTS(M)-DPTS(M)
      DENTS1=(2.70*APTS(M))/(ATTS(M))
      DENTS2=(2.70*APTS2)/(ATTS(M))
      AIRN=(SCFM(M)*4.58*SQRT(ATTS(M)))/(APTS(M))
      V1(M)=(18.32*SCFM(M))/(DENTS1*3.14159*(DI**2)*3600.)
      V2(M)=(18.32*SCFM(M))/(DENTS2*3.14159*(DI**2)*3600.)
      VS=SQRT(1.4*1715.0*ATTS(M))
      XMACH1=V1(M)/VS
      XMACH2=V2(M)/VS
      XN=(1.-(APTS2/APTS(M))**2)/(1.4*XMACH1**2)-2.0*ALOG(APTS(M)/APTS2)
      FF(M)=XN*DI/(4.0*10.0)
      PRINT83,SCFM(M),RETS(M),FF(M)
   83 FORMAT(40X,F10.3,1PE20.8,0PF10.5)
  300 CONTINUE
      PRINT 1450
 1450 FORMAT(1H1)
      GO TO 78
      END
```

```
C     THIS SUBPROGRAM CONVERTS EXPERIMENTAL PRESSURE READINGS TO UNITS
C     (PSIG) WHICH THE MAIN PROGRAM USES TO CALCULATE FLOW RATE, ETC.
C     THE SUBPROGRAM IS WRITTEN IN FORTRAN IV.  TWO TYPES OF EXPERI-
C     MENTAL READINGS CAN BE USED BY THE SUBPROGRAM, READINGS IN INCHES
C     OF MERCURY, AND READINGS FROM BOURDON TYPE GAGES.  THE LATTER
C     READINGS ARE CORRECTED USING A CALIBRATION READ IN BY THE MAIN
C     PROGRAM.
C
C
      FUNCTION GAGE(X,A,D,L,MM,Z,ZC,NMAT,ZO,ZOC,MO,NZ)
      DIMENSION Z(NMAT),ZC(NMAT),ZO(MO),ZOC(MO)
      IF(X.GT.100.0)GOTO56
      IF(X.GT.0.0)GOTO54
      X1=-X
      DO71JFK=1,NZ
      IJ=JFK
      IF(ZO(IJ)-X1)71,72,73
 71   CONTINUE
      GO TO 201
 72   GAGE=ZOC(IJ)
      RETURN
 73   GAGE=ZOC(IJ)+((ZOC(IJ-1)-ZOC(IJ))/(ZO(IJ-1)-ZO(IJ)))*(X1-ZO(IJ))
      RETURN
 56   XC=X-1000.0
      GAGE=XC*.49115
      RETURN
 54   IF(X.GE.A)GO TO 76
  201 PRINT 55,D,L,X
   55 FORMAT(30X,9HBAD DATA F6.3,I5,F6.1)
      GAGE=X
      RETURN
 76   DO95J=1,MM
      KI=J
      IF(Z(KI)-X)95,96,97
 95   CONTINUE
 96   GAGE=ZC(KI)
      RETURN
 97   GAGE=ZC(KI)+((ZC(KI-1)-ZC(KI))/(Z(KI-1)-Z(KI)))*(X-Z(KI))
      RETURN
      END
```

```
C     THIS SUBPROGRAM CALCULATES THE MASS FLOW RATE OF AIR IN THE TEST
C     SYSTEM.  IT IS WRITTEN IN FORTRAN IV FOR AN IBM 7040 COMPUTER.
C     THE SUBPROGRAM USES EXPERIMENTAL DATA TAKEN AT THE ORFICE METER.
C     FIRST, THE PROGRAM ASSUMES AN INITIAL VALUE FOR THE ORIFICE
C     COEFFICENT.  A MASS FLOW RATE BASED ON THIS ASSUMPTION IS THEN
C     CALCULATED.  THIS MASS FLOW RATE IN USED TO DETERMINE A NEW VALUE
C     OF THE ORIFICE COEFFICENT.  THE ASSUMED AND CALCULATED VALUES ARE
C     THEN COMPARED AND IF FOUND EQUAL THE MASS FLOW RATE DETERMINATION
C     IS FINISHED.  IF THEY ARE NOT EQUAL THE CALCULATED VALUE IS USED
C     AS THE NEW ASSUMED VALUE.  THIS PROCESS IS CONTINUED UNTIL THE
C     VALUES MATCH.
C
C
      FUNCTION W(DIAO,R,RAT,A,B,DPO,DENO,DIA,VISO,REC,ND,CS,NROW,RE)
      DIMENSION RAT(ND),A(ND,10),B(ND),CS(30,10),REC(ND),RE(30),P(50)
C
C
C     ESTABLISH ORIFICE PARAMETERS
C
      IF(DIAO.EQ.0.75)KEN=1
      IF(DIAO.EQ.1.00)KEN=2
      IF(DIAO.EQ.1.25)KEN=3
      IF(DIAO.EQ.1.50)KEN=4
      IF(DIAO.EQ.1.75)KEN=5
      IF(DIAO.EQ.2.00)KEN=6
C
C     COMPUTE VALUE OF Y
C
      IF(R-RAT(KEN))14,15,16
 15   Y=A(KEN,3)
      GOTO17
 14   Y=A(KEN,1)-A(KEN,2)*R
      GOTO17
 16   Y=A(KEN,4)-A(KEN,5)*R
C
C     ASSUME INITIAL VALUE FOR C
C
 17   C=B(KEN)
   11 W=1891.0*Y*(DIAO**2)*C*(SQRT(ABS(DPO*DENO)))
      REOS=6.31*W/(DIA*VISO)
      IF(REOS.LT.REC(KEN))GOTO110
      CN=B(KEN)
      GOTO150
C
C     LAGRANGE INTERPOLATION FOR CS
C
 110  DO 25 I=1,NROW
      KLR=I
      IF(REOS-RE(I))25,24,26
  24  CN=CS(I,KEN)
      GOTO 150
  26  IF(I-2)31,31,44
  44  IF(I-NROW)160,170,170
   25  CONTINUE
      PRINT80,REOS
```

```
 80   FORMAT(5X,16H THE VALUE RE = E15.8,20H CANNOT BE EVALUATED)
      W=0.0
      RETURN
 31   NJ=KUR-1
      NK=KUR+1
      GO TO 130
160   NJ=KUR-2
      NK=KUR+1
      GO TO 130
170   NJ=KUR-2
      NK=KUR
130   DO 53 K=NJ,NK
      P(K)=1.0
      DO 53 J=NJ,NK
      IF(J-K)74,53,74
 74   P(K)=P(K)*(REOS-RE(J))/(RE(K)-RE(J))
 53   CONTINUE
      CN=0.0
      DO 120 L=NJ,NK
120   CN=CN+P(L)*CS(L,KEN)
150   IF(ABS(C-CN).LT.0.0001)GOTO36
      C=CN
      GOTO11
36    CONTINUE
      RETURN
      END
```

```
C     THIS PROGRAM DRAWS A LOG - LOG GRAPH OF ANY DESIRED NUMBER OF
C     CYCLES.  IT IS WRITTEN IN FORTRAN II FOR AN IBM 1620 COMPUTER
C     WITH A CALCOMP 563 PLOTTER.  TWO PLOT PACKAGES WERE USED, ONE
C     DEVELOPED BY PROCTOR AND GAMBLE, AND THE OTHER BY J.H.MACKEY.
C     INITIALLY, THE PROGRAM READS THE VALUES REQUIRED FOR DRAWING
C     THE AXES.  AFTER THE AXES ARE DRAWN, THE PROGRAM READS THE POINTS
C     WHICH ARE TO BE PLOTTED.  THESE POINTS ARE THEN PLOTTED ON THE
C     GRAPH.
C
C
C     PLOT OF LOG(Y) VS. LOG(X)
      DIMENSION X(100),Y(100),V(2),DP(2)
      READ 10,NCYCLX,SIZEX,ZMINX
      READ 10,NCYCLY,SIZEY,ZMINY
   10 FORMAT(I10,2F10.0)
   68 CALL PLOT(0.,0.,3)
      ACYCLY=NCYCLY
      HIGHY=ACYCLY*SIZEY
      CALL LRILEY(0.,NCYCLX,SIZEX,ZMINX,HIGHY)
      ACYCLX=NCYCLX
      HIGHX=ACYCLX*SIZEX
      CALL LRILEY(90.,NCYCLY,SIZEY,ZMINY,HIGHX)
   78 READ 20,N,K
   20 FORMAT(2I10)
      READ 30,(X(I),Y(I),I=1,N)
   30 FORMAT(F20.0,F20.0)
      CALL LSCALE(X,N,1.,SIZEX,ZMINX)
      CALL LSCALE(Y,N,1.,SIZEY,ZMINY)
      CALL RMARK(X,Y,N,K)
      CALL PLOT(0.,0.,3)
  115 CONTINUE
      PAUSE
      GO TO 68
      END
```

```
C     THIS SUBROUTINE IS USED TO MAKE EIGHT DIFFERENT SYMBOLS FOR
C     POINTS ON THE LOG - LOG GRAPH PRODUCED BY THE MAIN PROGRAM.
C     IT IS WRITTEN IN FORTRAN II FOR AN IBM 1620 CUMPUTER WITH A
C     CALCOMP 563 PLOTTER.
C
C
      SUBROUTINE RMARK(X,Y,N,K)
      DIMENSION X(1),Y(1)
      DO 1 J=1,N
      XA=X(J)
      YA=Y(J)
      CALL PLOT(XA,YA,3)
      IF(K-1)2,3,4
    4 IF(K-3)5,6,7
    7 IF(K-5)8,9,10
   10 IF(K-7)11,12,12
    2 PUNCH TAPE 100
  100 FORMAT(42H011111555555555511111333337777777777333339)
      GO TO 1
    3 PUNCH TAPE 200
  200 FORMAT(52H7777022222444446666688888222224444466666888889333333)
      GO TO 1
    5 PUNCH TAPE 300
  300 FORMAT(40H5507881122334455667788112233445566679111)
      GO TO 1
    6 PUNCH TAPE 400
  400 FORMAT(74H1110333355555555777777711111111333333335555555577777777
     1711111111333395555)
      GO TO 1
    8 PUNCH TAPE 500
  500 FORMAT(66H01111555555551111333377777777333344448888888844442222666
     16666622229)
      GO TO 1
    9 PUNCH TAPE 600
  600 FORMAT(58H05557881122334455667788112233445566711111555333777777733
     1139)
      GO TO 1
   11 PUNCH TAPE 700
  700 FORMAT(34H0222266666666222244448888888844449)
      GO TO 1
   12 PUNCH TAPE 800
  800 FORMAT(60H03333377777777773333333566778811223344556677881122333445
     19777)
    1 CONTINUE
      CALL PLOT(0.,0.,3)
      RETURN
      END
```

```
C     THIS SUBROUTINE IS USED TO DRAW LOGARITHMIC AXES.  IT IS WRITTEN
C     IN FORTRAN II FOR AN IBM 1620 COMPUTER WITH A CALCOMP 563 PLOTTER.
C
C
      SUBROUTINE LRILEY(THETA,NCYCLE,SIZE,ZMIN,HT)
      CALLPLOT(0.,0.,3)
      ZM=ZMIN
      JZ=ZMIN
      M=0
11    IF(JZ)9,9,10
9     ZM=ZM*10.
      JZ=ZM
      M=M+I
      GCTO11
10    IF(THETA)1,2,1
    2 S=0.
      C=1.
      X=.25
      XX=.5
      GCTO3
1     S=1.
      C=0.
      X=.15
      XX=.35
3     DO6J=1,NCYCLE
      ZK=J-1
      NN=J-1
      ZM=ZMIN
      IF(NN)20,20,21
21    DC15N=1,NN
15    ZM=ZM*10.
20    DC6L=1,10
      R=L
      Z=(LOGF(R)/LOGF(10.)+ZK)*SIZE
      CALLPLOT(Z*C,Z*S,2)
      CALL PLOT(Z*C+HT*S,Z*S+HT*C,2)
      IF(L-1)12,12,6
12    CALLDRAW(2,Z*C-X*S,Z*S-X*C,.1,THETA,ZM,M)
6     CALLPLOT(Z*C,Z*S,3)
      ZM=10.*ZM
      CALLDRAW(2,Z*C-X*S,Z*S-X*C,.1,THETA,ZM,M)
      Z=.5*SIZE*(ZK+1.)-4.
      Z=.5*SIZE*(ZK+1.)-40.*.08
      CALLDRAW(1,Z*C-XX*S,Z*S-XX*C,.15,THETA,V,80)
      CALLPLOT(0.,0.,3)
      RETURN
```

APPENDIX III

Typical Results from Water Date Including:

1" Close Pitch Hose at all angles
1" Open Pitch Hose at all angles
1" Helical Hose at all angles

CLOSE PITCH DIAMETER = 1.012 ANGLE = 0

GPM	VEL	RE	DP	FF
4.35	1.7342	1.1409206 E 04	0.2047	0.02131
4.82	1.9207	1.2790777 E 04	0.2366	0.02008
6.22	2.4800	1.6515342 E 04	0.3685	0.01876
7.19	2.8661	1.9086592 E 04	0.4641	0.01769
9.23	3.6819	2.4518930 E 04	0.7962	0.01839
10.05	4.0087	3.3784914 E 04	0.9180	0.01788
11.65	4.6470	3.9164228 E 04	1.3104	0.01900
13.04	5.2026	4.3846907 E 04	1.6607	0.01921
13.10	5.2252	4.5540805 E 04	1.6832	0.01930
15.15	6.0435	5.0933307 E 04	2.2750	0.01950
16.81	6.7037	5.6497493 E 04	2.9029	0.02022
18.35	7.3187	4.8149015 E 04	3.2987	0.019[illegible]
18.75	7.4788	6.3029929 E 04	3.5490	0.019[illegible]
19.50	7.7779	6.7789747 E 04	4.8515	0.0251[illegible]
19.61	7.8202	5.2077668 E 04	4.5045	0.02306
21.47	8.5646	7.2181206 E 04	6.2881	0.02684
22.22	8.8637	7.4702138 E 04	4.8548	0.01939
22.30	8.8948	7.7523659 E 04	6.5347	0.02586
25.64	10.2274	6.7284993 E 04	6.4519	0.01931
25.64	10.2274	8.6194685 E 04	5.6420	0.01689
26.28	10.4841	6.9817709 E 04	7.0752	0.02015
26.90	10.7295	9.3515087 E 04	8.2178	0.02235
26.90	10.7295	9.3515087 E 04	8.2178	0.02235
27.00	10.7707	9.0773365 E 04	8.6632	0.023[illegible]
28.90	11.5273	1.0046788 E 05	10.4950	0.02[illegible]
30.80	12.2851	1.0648523 E 05	11.2871	0.02[illegible]
30.96	12.3505	1.0408813 E 05	11.3841	0.023[illegible]
31.58	12.5945	8.3871509 E 04	10.7921	0.02130
31.58	12.5945	8.3871509 E 04	10.9746	0.02166
33.30	13.2823	1.1576403 E 05	13.0693	0.02319
33.91	13.5262	9.0076185 E 04	12.8123	0.02192
34.50	13.7609	1.1927729 E 05	14.3844	0.02378
34.80	13.8806	1.2124409 E 05	14.4854	0.02354
35.02	13.9686	1.1772559 E 05	15.0385	0.02413
36.00	14.3592	1.2542492 E 05	16.2066	0.02461
38.00	15.1570	1.3137788 E 05	17.7318	0.02416
38.15	15.2187	1.2826067 E 05	19.0989	0.02582
38.15	15.2187	1.0134716 E 05	15.6526	0.02116
39.30	15.6755	1.3692221 E 05	19.9620	0.02543
40.58	16.1865	1.0779193 E 05	19.6761	0.0235[illegible]
41.00	16.3536	1.4174982 E 05	21.5842	0.02527
41.05	16.3731	1.3799002 E 05	21.8158	0.02548
42.00	16.7525	1.4632908 E 05	22.6425	0.02520
43.00	17.1513	1.4866444 E 05	23.9008	0.02544
43.75	17.4510	1.4707413 E 05	24.8063	0.02550
44.00	17.5502	1.5329713 E 05	25.0620	0.02547
45.46	18.1338	1.2076026 E 05	23.7287	0.02259
45.88	18.3005	1.2187046 E 05	26.1328	0.0244[illegible]
45.90	18.3080	1.5869065 E 05	26.5087	0.02470
46.20	18.4277	1.6096199 E 05	28.1534	0.02590
46.30	18.4657	1.5562637 E 05	27.7987	0.0255[illegible]

47.90	19.1058	1.6560528 E 05	28.9167	0.02480
48.10	19.1855	1.6758163 E 05	30.6700	0.02609
48.50	19.3451	1.6767967 E 05	31.6293	0.02646
48.50	19.3451	1.6897525 E 05	31.5380	0.02638
48.71	19.4273	1.6373036 E 05	30.8824	0.02562
51.00	20.3433	1.3547379 E 05	30.4806	0.02306

CLOSE PITCH DIAMETER = 1.012 ANGLE = 30

GPM	VEL	RE	DP	FF
6.30	2.5129	2.2381035 E 04	0.2970	0.01473
6.47	2.5789	1.9478682 E 04	0.4231	0.01992
9.02	3.5978	3.2043959 E 04	0.8911	0.02155
9.97	3.9754	3.0026979 E 04	1.0237	0.02028
10.95	4.3672	3.2985785 E 04	1.4560	0.02390
11.23	4.4793	3.9895084 E 04	1.5842	0.02472
12.99	5.1801	3.9126072 E 04	1.7972	0.02097
14.37	5.7317	5.1050076 E 04	2.4752	0.02359
18.07	7.2085	5.4446545 E 04	3.5763	0.02155
19.61	7.8202	5.9066933 E 04	6.0742	0.03110
20.40	8.1369	7.2471925 E 04	5.9406	0.02809
24.70	9.8520	8.8685521 E 04	7.4257	0.02395
26.20	10.4503	9.3076687 E 04	9.3069	0.02668
28.90	11.5273	1.0376565 E 05	10.6931	0.02519
29.50	11.7666	1.0480009 E 05	11.5842	0.02619
30.30	12.0857	1.0879236 E 05	12.9703	0.02780
31.58	12.5945	9.5127779 E 04	12.7983	0.02526
33.80	13.4817	1.2007603 E 05	14.9825	0.02581
34.80	13.8806	1.2494964 E 05	16.4046	0.02666
36.30	14.4789	1.2895740 E 05	18.2288	0.02722
37.20	14.8379	1.3356685 E 05	19.7480	0.02808
38.15	15.2187	1.1494881 E 05	19.1959	0.02595
39.30	15.6755	1.3961503 E 05	21.3741	0.02723
40.00	15.9547	1.4362028 E 05	23.2366	0.02858
41.20	16.4334	1.4636487 E 05	24.6833	0.02862
43.75	17.4510	1.3180966 E 05	24.9034	0.02560
44.50	17.7496	1.5808827 E 05	27.7785	0.02760
46.10	18.3878	1.6377234 E 05	31.0660	0.02877
47.20	18.8266	1.6768014 E 05	32.9069	0.02907
47.92	19.1122	1.4435703 E 05	31.4534	0.02696

CLOSE PITCH DIAMETER = 1.012 ANGLE = 60

GPM	VEL	RE	DP	FF
4.59	1.8297	1.3819740 E 04	0.2047	0.01915
6.47	2.5817	2.1010181 E 04	0.4968	0.02334
6.56	2.6184	1.9777047 E 04	0.5314	0.02426
7.49	2.9878	2.4315148 E 04	0.7128	0.02500
7.81	3.1162	2.3536738 E 04	0.6097	0.01966
8.81	3.5143	2.6543660 E 04	0.9245	0.02344
12.27	4.8941	3.6725258 E 04	1.5879	0.02076
15.20	6.0628	5.5151607 E 04	2.9703	0.02530
15.50	6.1840	4.6404865 E 04	2.5616	0.02097

17.70	7.0596	5.2975362 E 04	3.3215	0.02087
19.61	7.8202	5.9066933 E 04	5.7102	0.02923
20.40	8.1369	7.4019262 E 04	6.2376	0.02950
20.48	8.1679	6.1292253 E 04	4.6410	0.02178
23.00	9.1740	8.3453090 E 04	7.4257	0.02762
24.00	9.5728	7.2304912 E 04	7.7031	0.02632
27.00	10.7694	9.7966670 E 04	9.3069	0.02512
28.39	11.3219	8.5516004 E 04	11.6980	0.02857
30.80	12.2851	1.1175457 E 05	13.5644	0.02814
33.20	13.2424	1.2046272 E 05	15.4855	0.02765
33.91	13.5262	1.0216517 E 05	15.8486	0.02712
34.80	13.8806	1.2626815 E 05	17.6168	0.02863
36.10	14.3975	1.1716951 E 05	17.5598	0.02652
36.50	14.5587	1.3243642 E 05	19.6410	0.02901
38.65	15.4171	1.1644765 E 05	19.8856	0.02619
38.70	15.4362	1.3895262 E 05	21.9782	0.02888
39.14	15.6130	1.1792736 E 05	21.3554	0.02743
40.00	15.9547	1.4513581 E 05	24.0171	0.02954
40.60	16.1940	1.4577458 E 05	25.7570	0.03075
41.51	16.5577	1.2506226 E 05	24.8332	0.02836
42.87	17.0993	1.2915322 E 05	24.2238	0.02594
43.00	17.1513	1.5602100 E 05	27.7843	0.02957
44.00	17.5502	1.5964939 E 05	30.1086	0.03060
44.19	17.6242	1.4342934 E 05	29.9558	0.03019
45.00	17.9491	1.6327778 E 05	31.6524	0.03076
46.70	18.6271	1.6767667 E 05	33.3961	0.03013
47.52	18.9527	1.4315204 E 05	31.1679	0.02717

CLOSE PITCH DIAMETER = 1.012 ANGLE = 90

GPM	VEL	RE	DP	FF
3.59	1.4331	1.0964634 E 04	0.1410	0.02150
5.52	2.2017	1.6845397 E 04	0.3139	0.02028
6.52	2.6013	1.9903194 E 04	0.4868	0.02252
7.43	2.9656	2.2690148 E 04	0.6734	0.02397
9.84	3.9233	3.0017931 E 04	1.0601	0.02156
12.23	4.8782	4.3679879 E 04	1.4851	0.01954
13.33	5.3182	4.0690973 E 04	2.1066	0.02332
14.80	5.9032	5.2858725 E 04	3.1683	0.02846
17.36	6.9243	6.2001856 E 04	4.5514	0.02972
17.75	7.0805	5.4174296 E 04	3.8720	0.02418
19.61	7.8202	5.9833892 E 04	6.3882	0.03270
23.19	9.2490	7.0766357 E 04	7.7714	0.02844
26.20	10.4503	9.3076687 E 04	11.3861	0.03264
29.05	11.5877	8.8659732 E 04	13.0953	0.03053
30.10	12.0059	1.0693161 E 05	13.4653	0.02925
32.00	12.7638	1.1368145 E 05	15.6836	0.03014
33.80	13.4817	1.2007603 E 05	17.6128	0.03034
34.80	13.8806	1.2362858 E 05	19.8410	0.03224
35.02	13.9686	1.0687711 E 05	18.3778	0.02949
36.00	14.3592	1.2789163 E 05	22.1742	0.03367
38.00	15.1570	1.3499672 E 05	24.1161	0.03287
40.00	15.9547	1.4210181 E 05	26.0521	0.03204
40.58	16.1865	1.2384600 E 05	25.0216	0.02990

41.00	16.3536	1.4565436 E 05	27.9823	0.03276
42.80	17.0715	1.5042099 E 05	30.2115	0.03245
43.50	17.3508	1.5453572 E 05	32.2407	0.03353
45.00	17.9491	1.5986454 E 05	34.1748	0.03321
45.46	18.1338	1.3874578 E 05	32.2590	0.03071
46.00	18.3479	1.6166742 E 05	34.5650	0.03215

CLOSE PITCH DIAMETER = 1.012 ANGLE = 120

GPM	VEL	RE	DP	FF
3.61	1.4417	1.1030686 E 04	0.1274	0.01919
4.02	1.6040	1.3053910 E 04	0.2981	0.03627
5.80	2.3123	1.7691728 E 04	0.4231	0.02478
5.86	2.3371	1.9019944 E 04	0.4698	0.02693
6.99	2.7893	2.2699786 E 04	0.6264	0.02521
7.44	2.9692	2.4164309 E 04	0.8132	0.02888
8.19	3.2649	2.6570825 E 04	0.9418	0.02766
8.49	3.3864	3.0644318 E 04	1.1881	0.03244
9.23	3.6819	2.9963734 E 04	1.1124	0.02569
9.60	3.8291	2.9297502 E 04	1.1147	0.02380
11.81	4.7110	3.8339387 E 04	1.8882	0.02664
12.63	5.0377	4.5587483 E 04	2.5743	0.03176
13.86	5.5270	4.2288493 E 04	2.3523	0.02411
14.18	5.6577	4.6043511 E 04	2.7937	0.02732
16.67	6.6491	6.0169703 E 04	4.8325	0.03422
16.85	6.7225	5.4709103 E 04	4.0085	0.02777
17.14	6.8377	5.2316966 E 04	3.8493	0.02578
17.91	7.1439	5.8138590 E 04	4.6592	0.02858
19.61	7.8202	6.3642312 E 04	6.1789	0.03163
19.61	7.8202	5.9833892 E 04	7.1890	0.03680
20.50	8.1768	7.3993935 E 04	7.7228	0.03616
20.56	8.2009	6.6740590 E 04	7.6895	0.03580
21.05	8.3972	6.4248906 E 04	6.1652	0.02737
21.47	8.5646	6.9700618 E 04	8.8861	0.03793
24.00	9.5728	8.6627046 E 04	9.9010	0.03383
24.70	9.8520	8.9153668 E 04	11.9802	0.03864
24.79	9.8860	8.0454125 E 04	10.1920	0.03265
24.79	9.8860	7.5639669 E 04	10.6697	0.03418
27.50	10.9689	9.9260158 E 04	13.7624	0.03581
29.05	11.5877	9.4302915 E 04	14.0894	0.03285
29.70	11.8474	9.0647250 E 04	14.1514	0.03156
30.10	12.0059	1.0864475 E 05	16.2876	0.03538
31.30	12.4846	1.1297611 E 05	18.3118	0.03678
33.80	13.4817	1.2199976 E 05	20.5441	0.03539
33.91	13.5262	1.1007898 E 05	18.3478	0.03140
33.91	13.5262	1.0349174 E 05	18.6975	0.03200
34.50	13.7609	1.2387249 E 05	22.6713	0.03748
36.62	14.6071	1.1887576 E 05	22.3455	0.03279
37.00	14.7581	1.3355003 E 05	24.9995	0.03594
38.65	15.4171	1.1795968 E 05	23.7153	0.03124
38.70	15.4362	1.3895262 E 05	26.9317	0.03539
39.14	15.6130	1.2706212 E 05	26.3088	0.03379
40.00	15.9547	1.4437841 E 05	29.0618	0.03574
40.00	15.9547	1.4362028 E 05	31.0949	0.03824

41.51	16.5577	1.3474969 E 05	30.2720	0.03457
41.97	16.7402	1.2808247 E 05	30.1855	0.03372
42.00	16.7525	1.5159733 E 05	33.2231	0.03706
43.70	17.4305	1.5690515 E 05	35.3533	0.03643
43.75	17.4510	1.4201976 E 05	34.6217	0.03559

CLOSE PITCH DIAMETER = 1.012 ANGLE = 150

GPM	VEL	RE	DP	FF
3.76	1.4986	1.1612465 E 04	0.1729	0.02410
7.53	3.0028	2.3268647 E 04	0.7143	0.02480
8.60	3.4303	3.1204199 E 04	1.3861	0.03688
10.81	4.3121	3.3414596 E 04	1.4969	0.02520
12.50	4.9858	4.5354941 E 04	2.8713	0.03616
13.70	5.4639	4.2340365 E 04	2.4934	0.02615
15.82	6.3101	5.7401213 E 04	4.2064	0.03307
17.34	6.9168	5.3598593 E 04	4.2269	0.02766
19.50	7.7779	7.0753706 E 04	7.8218	0.04048
19.61	7.8202	6.0599054 E 04	6.9160	0.03541
20.91	8.3387	6.4617185 E 04	6.2107	0.02796
21.30	8.4959	7.7284815 E 04	9.9010	0.04295
23.10	9.2138	8.3815928 E 04	12.0792	0.04455
26.28	10.4841	8.1241870 E 04	11.6102	0.03307
27.00	10.7694	9.7966670 E 04	14.3584	0.03876
27.60	11.0088	1.0014371 E 05	16.2836	0.04207
30.80	12.2851	1.1175457 E 05	18.9179	0.03924
32.00	12.7638	1.1610865 E 05	20.9401	0.04024
32.18	12.8338	9.9449659 E 04	17.3997	0.03307
33.80	13.4817	1.2263976 E 05	23.2616	0.04007
34.50	13.7609	1.2517963 E 05	25.1005	0.04150
36.62	14.6071	1.1319134 E 05	23.7249	0.03481
37.00	14.7581	1.3425062 E 05	27.5219	0.03956
38.00	15.1570	1.9701449 E 04	29.3588	0.04001
39.00	15.5558	1.4150741 E 05	31.1977	0.04036
40.50	16.1542	1.4695000 E 05	33.7182	0.04045
41.97	16.7402	1.2972040 E 05	30.9680	0.03460
42.00	16.7525	1.5239260 E 05	35.8425	0.03998

CLOSE PITCH DIAMETER = 1.012 ANGLE = 180

GPM	VEL	RE	DP	FF
3.96	1.5786	1.2847250 E 04	0.2678	0.03365
5.28	2.1048	1.6310561 E 04	0.3276	0.02315
5.30	2.1141	1.7205332 E 04	0.4396	0.03079
6.06	2.4171	2.2217238 E 04	0.5941	0.03183
6.33	2.5245	2.0544744 E 04	0.5422	0.02663
6.79	2.7072	2.2032152 E 04	0.6998	0.02989
8.02	3.1995	2.6037987 E 04	0.9655	0.02953
8.96	3.5720	2.9069295 E 04	1.1167	0.02740
9.23	3.6819	2.8530923 E 04	1.1557	0.02669
10.36	4.1323	3.7981945 E 04	1.7822	0.03268
10.75	4.2889	3.4903961 E 04	1.6243	0.02765
12.71	5.0704	4.1263660 E 04	2.3296	0.02837

12.96	5.1689	4.0054170 E 04	2.2704	0.02661
15.31	6.1051	4.9684826 E 04	3.5217	0.02958
15.40	6.1426	5.6459648 E 04	4.2894	0.03559
16.76	6.6849	5.4403353 E 04	4.3316	0.03035
17.00	6.7796	5.2535622 E 04	4.3179	0.02941
17.60	7.0201	6.4525312 E 04	5.9002	0.03748
18.46	7.3637	5.9927468 E 04	5.3098	0.03066
19.61	7.8202	6.0599054 E 04	7.8715	0.04030
19.87	7.9245	6.4491586 E 04	6.3700	0.03176
20.48	8.1679	6.3293752 E 04	6.4928	0.03047
21.30	8.4959	7.8090290 E 04	9.7030	0.04209
21.90	8.7343	7.1081788 E 04	7.3710	0.03025
23.08	9.2046	7.4909336 E 04	8.6450	0.03195
24.00	9.5728	8.7989062 E 04	11.7822	0.04025
24.00	9.5728	7.4180408 E 04	11.1930	0.03824
25.00	9.9717	8.1151781 E 04	10.4650	0.03295
26.80	10.6897	9.8254452 E 04	13.9604	0.03825
27.70	11.0497	8.5625065 E 04	14.1054	0.03617
28.00	11.1683	1.0265391 E 05	15.8776	0.03985
29.50	11.7666	1.0815322 E 05	18.4088	0.04163
31.50	12.5643	1.1548564 E 05	20.6351	0.04092
33.91	13.5262	1.0481521 E 05	21.0737	0.03606
34.00	13.5615	1.2400861 E 05	22.6653	0.03858
34.50	13.7609	1.2648428 E 05	25.0072	0.04134
35.40	14.1199	1.2911485 E 05	27.1374	0.04261
37.00	14.7581	1.3564980 E 05	29.1704	0.04193
37.65	15.0176	1.1637229 E 05	26.1924	0.03636
39.00	15.5558	1.4224517 E 05	31.2016	0.04037
39.30	15.6755	1.4408209 E 05	33.3337	0.04247
40.50	16.1542	1.4771613 E 05	35.3686	0.04243
41.20	16.4334	1.5104789 E 05	35.7531	0.04145
41.51	16.5577	1.2830621 E 05	33.2452	0.03797

OPEN PITCH DIAMETER = 1.012 ANGLE = -0

GPM	VEL	RE	DP	FF
2.25	0.8960	6.5026910 E 03	0.0591	0.02307
2.76	1.1003	7.9856028 E 03	0.0728	0.01883
3.39	1.3513	9.8072777 E 03	0.1274	0.02184
4.23	1.6877	1.2248717 E 04	0.1638	0.01800
5.47	2.1836	1.5847345 E 04	0.2502	0.01643
11.41	4.5498	3.3245207 E 04	1.1966	0.01810
18.52	7.3864	5.3972092 E 04	3.2942	0.01890
19.35	7.7200	5.6409584 E 04	3.5672	0.01874
19.61	7.8202	5.7527487 E 04	4.0768	0.02087
24.00	9.5728	7.0420447 E 04	6.7340	0.02301
27.70	11.0497	8.1285011 E 04	8.9544	0.02296
30.96	12.3505	9.0853814 E 04	10.8244	0.02222
33.91	13.5262	9.9502468 E 04	12.8219	0.02194
39.14	15.6130	1.1485384 E 05	18.6669	0.02397
43.75	17.4510	1.2837434 E 05	24.2642	0.02494
49.87	19.8906	1.4632081 E 05	33.3442	0.02639

OPEN PITCH DIAMETER = 1.012 ANGLE = 30

GPM	VEL	RE	DP	FF
2.58	1.0280	7.2568929 E 03	0.0682	0.02022
2.82	1.1241	7.9352036 E 03	0.0864	0.02142
3.38	1.3483	9.5177748 E 03	0.1137	0.01959
4.40	1.7558	1.2394750 E 04	0.1729	0.01756
5.46	2.1776	1.5372199 E 04	0.2684	0.01772
7.19	2.8696	2.0399199 E 04	0.4868	0.01851
11.36	4.5326	3.2221441 E 04	1.2421	0.01893
19.61	7.8202	5.5592466 E 04	4.9686	0.02544
20.00	7.9774	5.6709789 E 04	4.2087	0.02071
24.00	9.5728	6.8051753 E 04	7.0343	0.02403
27.70	11.0497	7.9099077 E 04	9.7552	0.02501
30.96	12.3505	8.8410554 E 04	12.0711	0.02478
33.91	13.5262	9.6826627 E 04	14.6085	0.02500
39.14	15.6130	1.1176517 E 05	22.3320	0.02868
43.75	17.4510	1.2492207 E 05	27.2585	0.02832
47.52	18.9527	1.3567176 E 05	33.1481	0.02889

OPEN PITCH DIAMETER = 1.012 ANGLE = 60

GPM	VEL	RE	DP	FF
2.17	0.8671	5.9914732 E 03	0.0546	0.02274
2.92	1.1663	8.0587086 E 03	0.0705	0.01623
3.43	1.3675	9.4494092 E 03	0.1183	0.01980
4.58	1.8269	1.2623257 E 04	0.2229	0.02091
4.95	1.9746	1.3742428 E 04	0.2593	0.02082
6.24	2.4877	1.7189682 E 04	0.3913	0.01979
7.56	3.0141	2.0826777 E 04	0.5414	0.01866
10.17	4.0563	2.8230197 E 04	1.0465	0.01991
15.54	6.2000	4.3149810 E 04	2.6481	0.02157
19.61	7.8202	5.4815006 E 04	5.5965	0.02865
19.61	7.8209	5.4430816 E 04	4.3725	0.02238
24.00	9.5728	6.7100051 E 04	7.7213	0.02638
27.70	11.0497	7.7452339 E 04	10.2056	0.02617
30.96	12.3505	8.6569963 E 04	13.3906	0.02748
33.91	13.5262	9.4810824 E 04	16.5297	0.02829
39.14	15.6130	1.0943837 E 05	23.6912	0.03043
43.75	17.4510	1.2232136 E 05	30.5556	0.03141
46.71	18.6295	1.3058188 E 05	33.6374	0.03034

OPEN PITCH DIAMETER = 1.012 ANGLE = 90

GPM	VEL	RE	DP	FF
2.67	1.0636	7.8244932 E 03	0.0364	0.01007
4.52	1.8021	1.3256855 E 04	0.1592	0.01535
5.36	2.1368	1.5718849 E 04	0.1820	0.01248
11.41	4.5498	3.3469806 E 04	1.4696	0.02223
16.30	6.5033	4.7839910 E 04	3.1167	0.02307
18.29	7.2964	5.3674036 E 04	4.0586	0.02387
19.61	7.8202	5.7527487 E 04	5.8012	0.02970
24.00	9.5728	7.0420447 E 04	8.7314	0.02983

27.70	11.0497	8.1285011 E 04	11.3977	0.02923
30.96	12.3505	9.0853814 E 04	15.8066	0.03244
33.91	13.5262	9.9502468 E 04	17.7418	0.03036
39.14	15.6130	1.1485384 E 05	24.6660	0.03168
43.75	17.4510	1.2837434 E 05	33.2644	0.03420

OPEN PITCH DIAMETER = 1.012 ANGLE = 120

GPM	VEL	RE	DP	FF
2.85	1.1380	7.9767034 E 03	0.1001	0.02420
3.66	1.4611	1.0241152 E 04	0.1365	0.02002
4.63	1.8480	1.2953676 E 04	0.2275	0.02086
7.34	2.9293	2.0532462 E 04	0.5915	0.02158
11.76	4.6926	3.2892178 E 04	1.7153	0.02439
15.11	6.0282	4.3152874 E 04	2.8801	0.02481
19.29	7.6952	5.3938984 E 04	4.9959	0.02641
19.61	7.8202	5.5980446 E 04	6.3472	0.03249
24.00	9.5728	6.8526685 E 04	9.3639	0.03199
27.70	11.0497	7.9099077 E 04	12.2531	0.03142
30.96	12.3505	8.8410554 E 04	16.2066	0.03326
33.91	13.5262	9.6826627 E 04	20.5661	0.03519
39.14	15.6130	1.1176517 E 05	29.4405	0.03781
43.31	17.2760	1.2366970 E 05	34.8294	0.03654

OPEN PITCH DIAMETER = 1.012 ANGLE = 150

GPM	VEL	RE	DP	FF
3.10	1.2368	8.4842146 E 03	0.0910	0.01862
4.35	1.7342	1.1896345 E 04	0.2047	0.02131
5.76	2.2967	1.5755243 E 04	0.3640	0.02160
8.42	3.3565	2.3025167 E 04	0.8417	0.02339
10.66	4.2508	2.9159754 E 04	1.4787	0.02562
13.33	5.3182	3.6482123 E 04	2.4115	0.02669
14.96	5.9681	4.1535727 E 04	3.0257	0.02660
16.81	6.7037	4.6655012 E 04	3.8447	0.02679
19.29	7.6952	5.3555721 E 04	5.2780	0.02790
19.61	7.8202	5.4815006 E 04	6.9615	0.03564
22.35	8.9134	6.2478032 E 04	8.6905	0.03425
24.79	9.8860	6.9294990 E 04	10.7835	0.03454
27.00	10.7707	7.5496089 E 04	12.3077	0.03322
30.96	12.3505	8.6569963 E 04	18.9419	0.03888
33.91	13.5262	9.4810824 E 04	21.7783	0.03727
38.15	15.2187	1.0667423 E 05	26.8077	0.03624
42.87	17.0993	1.1985614 E 05	34.8351	0.03730

OPEN PITCH DIAMETER = 1.012 ANGLE = 180

GPM	VEL	RE	DP	FF
2.75	1.0988	7.4276641 E 03	0.1046	0.02714
3.70	1.4773	9.9860841 E 03	0.1911	0.02741
4.84	1.9300	1.3046336 E 04	0.2730	0.02295
6.33	2.5245	1.7064819 E 04	0.4959	0.02436

8.32	3.3193	2.2437534 E 04	0.9782	0.02780
10.38	4.1405	2.7988655 E 04	1.4787	0.02700
14.46	5.7668	3.8981823 E 04	3.2032	0.03016
15.04	5.9980	4.0544978 E 04	3.3488	0.02914
19.61	7.8202	5.2862401 E 04	6.0060	0.03075
22.35	8.9134	6.0252456 E 04	9.1089	0.03589
26.28	10.4841	7.0869759 E 04	13.1683	0.03751
28.39	11.3219	7.6533199 E 04	16.3016	0.03981
33.91	13.5262	9.1433499 E 04	21.5762	0.03692
38.15	15.2187	1.0287431 E 05	28.8465	0.03899
41.05	16.3731	1.1067795 E 05	35.6176	0.04160

HELICAL DIAMETER = 1.061 ANGLE = 0

GPM	VEL	RE	DP	FF
4.77	1.7307	1.4149529 E 04	0.1638	0.01795
6.00	2.1773	1.7800114 E 04	0.2866	0.01985
7.35	2.6682	2.1813872 E 04	0.4049	0.01867
10.87	3.9443	3.2246612 E 04	0.9464	0.01997
12.63	4.5837	3.7473924 E 04	1.2740	0.01990
15.46	5.6115	4.5876524 E 04	1.8700	0.01949
20.20	7.3309	5.9933142 E 04	3.3715	0.02059
22.22	8.0639	6.5926422 E 04	2.7436	0.01385
24.00	8.7090	7.4749742 E 04	5.7282	0.02479
26.28	9.5381	8.2348898 E 04	6.8317	0.02465
26.28	9.5381	8.2348898 E 04	6.8317	0.02465
28.39	10.3003	8.8929673 E 04	8.3168	0.02573
29.70	10.7784	8.7566571 E 04	8.1188	0.02294
33.91	12.3057	9.9974542 E 04	12.0792	0.02618
33.91	12.3057	1.0624345 E 05	12.0792	0.02618
34.47	12.5086	1.0162292 E 05	11.3861	0.02389
38.65	14.0260	1.2109607 E 05	15.6346	0.02609
39.14	14.2042	1.2263484 E 05	15.6326	0.02543
40.11	14.5541	1.1824125 E 05	15.0445	0.02331
42.87	15.5564	1.3430883 E 05	19.4969	0.02644
43.31	15.7172	1.3569713 E 05	19.4969	0.02591
44.62	16.1899	1.3153126 E 05	20.1711	0.02526
45.46	16.4976	1.4243484 E 05	23.0799	0.02783
45.88	16.6492	1.4374431 E 05	23.0799	0.02733
48.31	17.5316	1.4243107 E 05	23.7441	0.02536
48.71	17.6743	1.5259471 E 05	26.5481	0.02790
49.48	17.9564	1.5503017 E 05	26.5481	0.02703
51.38	18.6429	1.5145960 E 05	27.8006	0.02626
51.75	18.7771	1.6211610 E 05	30.2144	0.02813
53.56	19.4345	1.6779149 E 05	31.3717	0.02726
54.26	19.6913	1.5997698 E 05	30.8882	0.02615

HELICAL DIAMETER = 1.061 ANGLE = 30

GPM	VEL	RE	DP	FF
5.79	2.0996	1.7165017 E 04	0.2502	0.01863
8.61	3.1238	2.5538202 E 04	0.5687	0.01913
13.79	5.0052	4.0919802 E 04	1.5470	0.02027

15.67	5.6847	4.8503725 E 04	2.5743	0.02615
18.07	6.5580	5.5954751 E 04	3.2680	0.02494
18.18	6.5978	5.3939740 E 04	2.7800	0.02096
19.61	7.1145	6.0341705 E 04	4.4554	0.02889
20.34	7.3805	6.2972713 E 04	4.3018	0.02592
20.56	7.4609	6.0996306 E 04	4.6637	0.02750
21.82	7.9173	6.7552547 E 04	3.9949	0.02092
22.35	8.1091	6.8777351 E 04	5.2475	0.02619
23.19	8.4145	7.1794413 E 04	6.0396	0.02800
24.00	8.7090	7.4307802 E 04	5.6311	0.02437
27.00	9.7988	8.0109573 E 04	7.5848	0.02593
27.70	10.0527	8.5772118 E 04	8.2178	0.02669
27.70	10.0527	8.5261435 E 04	8.2178	0.02669
33.91	12.3057	1.0462022 E 05	11.9802	0.02597
33.91	12.3057	1.0060461 E 05	12.3305	0.02673
34.47	12.5086	1.0672638 E 05	11.9802	0.02513
38.65	14.0260	1.1967333 E 05	15.5356	0.02592
39.14	14.2042	1.2047244 E 05	15.5356	0.02527
39.63	14.3802	1.1756498 E 05	15.7536	0.02501
41.97	15.2296	1.2994319 E 05	19.3979	0.02745
43.31	15.7172	1.3330441 E 05	18.9029	0.02512
45.04	16.3445	1.3362363 E 05	21.0353	0.02585
45.88	16.6492	1.4205548 E 05	22.9809	0.02721
46.30	16.7995	1.4248439 E 05	22.9809	0.02673
48.31	17.5316	1.4958389 E 05	26.3501	0.02814
49.10	17.8159	1.4565348 E 05	25.2783	0.02614
51.00	18.5076	1.5697169 E 05	27.4104	0.02627
51.75	18.7771	1.6021143 E 05	29.9173	0.02785
52.84	19.1743	1.6262578 E 05	30.9757	0.02765
52.84	19.1743	1.5675856 E 05	30.3989	0.02714

HELICAL DIAMETER = 1.061 ANGLE = 60

GPM	VEL	RE	DP	FF
7.58	2.7491	2.2615502 E 04	0.4368	0.01897
9.52	3.4560	2.8430898 E 04	0.7598	0.02088
13.57	4.9259	4.0523724 E 04	1.5470	0.02093
16.17	5.8686	4.9177295 E 04	2.6827	0.02557
19.61	7.1145	5.9255031 E 04	4.0594	0.02632
19.87	7.2095	5.9309587 E 04	3.3897	0.02141
20.56	7.4609	6.2139726 E 04	4.8515	0.02861
20.56	7.4609	6.2139726 E 04	4.5545	0.02686
22.35	8.1091	6.6710726 E 04	5.5446	0.02768
22.73	8.2472	6.9108892 E 04	4.8544	0.02343
23.19	8.4145	7.0081730 E 04	5.3465	0.02479
24.79	8.9939	7.4907897 E 04	6.5347	0.02652
26.28	9.5381	7.9440013 E 04	6.7327	0.02429
27.70	10.0527	8.3725991 E 04	8.2178	0.02669
28.39	10.3003	8.5788329 E 04	8.3168	0.02573
29.05	10.5421	8.6725530 E 04	8.8119	0.02603
33.91	12.3057	1.0249052 E 05	11.9802	0.02597
33.91	12.3057	1.0249052 E 05	11.9802	0.02597
37.14	13.4771	1.1224691 E 05	14.1074	0.02549
38.65	14.0260	1.1753338 E 05	15.5356	0.02592

38.65	14.0260	1.1538626 E 05	15.5456	0.02594
40.58	14.7259	1.2264786 E 05	17.2607	0.02613
42.42	15.3939	1.2821119 E 05	19.2969	0.02673
45.88	16.6492	1.3866669 E 05	22.9809	0.02721
45.88	16.6492	1.3866669 E 05	22.9809	0.02721
45.88	16.6492	1.3696661 E 05	22.6858	0.02686
48.71	17.6743	1.4720447 E 05	26.2530	0.02759
51.75	18.7771	1.5734659 E 05	29.1445	0.02713
51.75	18.7771	1.5447216 E 05	30.0183	0.02795
52.48	19.0428	1.5957290 E 05	30.9738	0.02804
52.48	19.0428	1.5665779 E 05	30.6767	0.02777
52.84	19.1743	1.5773920 E 05	30.4863	0.02722

HELICAL DIAMETER = 1.061 ANGLE = 90

GPM	VEL	RE	DP	FF
7.04	2.5555	2.1153406 E 04	0.4322	0.02173
9.24	3.3548	2.8623950 E 04	1.0891	0.03176
10.34	3.7539	3.1073606 E 04	0.9646	0.02247
13.39	4.8600	4.1466362 E 04	2.2772	0.03165
14.18	5.1472	4.3917090 E 04	2.2772	0.02821
15.19	5.5121	4.5627068 E 04	2.2295	0.02409
16.30	5.9165	5.0480776 E 04	3.1670	0.02970
16.53	5.9980	5.1176102 E 04	3.0689	0.02800
16.53	5.9980	5.1176102 E 04	3.2709	0.02984
17.34	6.2927	5.3690645 E 04	3.5324	0.02928
18.18	6.5978	5.4614216 E 04	2.9575	0.02230
19.61	7.1145	6.0703129 E 04	4.5545	0.02953
19.61	7.1145	6.0703129 E 04	5.2475	0.03403
20.69	7.5078	6.4058450 E 04	4.8572	0.02828
21.20	7.6935	6.3684312 E 04	4.0722	0.02258
21.47	7.7918	6.6481645 E 04	6.2376	0.03372
22.64	8.2161	7.0101697 E 04	6.3107	0.03069
23.19	8.4145	7.1794413 E 04	7.0297	0.03259
25.55	9.2700	7.6734365 E 04	6.6839	0.02553
26.28	9.5381	8.1381397 E 04	8.3168	0.03001
26.28	9.5381	8.1381397 E 04	8.5149	0.03072
30.96	11.2361	9.5869142 E 04	12.1782	0.03166
31.58	11.4580	9.7762884 E 04	11.9802	0.02995
32.76	11.8895	9.8417188 E 04	11.2749	0.02618
37.65	13.6625	1.1657215 E 05	16.4346	0.02890
38.15	13.8455	1.1813297 E 05	15.9316	0.02728
39.63	14.3802	1.1903504 E 05	17.7818	0.02822
41.05	14.8957	1.2709408 E 05	19.6950	0.02914
41.05	14.8957	1.2709408 E 05	19.6950	0.02914
44.19	16.0339	1.3272366 E 05	21.8177	0.02786
45.04	16.3445	1.3945526 E 05	23.6643	0.02908
45.04	16.3445	1.3945526 E 05	23.4740	0.02884
47.92	17.3876	1.4835582 E 05	27.0374	0.02935
47.92	17.3876	1.4835582 E 05	26.8451	0.02915
48.31	17.5316	1.4512093 E 05	25.3792	0.02710
51.00	18.5076	1.5791189 E 05	29.6376	0.02840
52.11	18.9105	1.6134885 E 05	30.5989	0.02809
52.48	19.0428	1.5763059 E 05	30.7911	0.02787

HELICAL. DIAMETER = 1.061 ANGLE = 120

GPM	VEL	RE	DP	FF
4.60	1.6684	1.3211812 E 04	0.2047	0.0241
6.97	2.5288	2.0024877 E 04	0.4550	0.0233
9.00	3.2643	2.5849216 E 04	0.7826	0.0241
11.65	4.2277	3.3478475 E 04	1.3195	0.0242
15.23	5.5260	4.3759909 E 04	2.3205	0.0249
15.71	5.6996	4.9785873 E 04	3.0693	0.0310
17.60	6.3849	5.0561370 E 04	3.1486	0.0253
18.18	6.5978	5.7630847 E 04	3.7611	0.0283
19.61	7.1145	6.1785048 E 04	5.2475	0.0340
21.13	7.6664	6.0709155 E 04	4.5272	0.0252
21.47	7.7918	6.7666555 E 04	6.0396	0.0326
22.39	8.1241	7.0552294 E 04	5.7396	0.0285
23.19	8.4145	7.3074015 E 04	6.5347	0.0302
24.79	8.9939	7.8106244 E 04	7.0297	0.0285
26.28	9.5381	7.5530719 E 04	6.7327	0.0242
26.28	9.5381	8.2831868 E 04	7.6238	0.0275
27.70	10.0527	8.7300845 E 04	9.4059	0.0305
30.96	11.2361	9.7577830 E 04	11.1881	0.0290
31.58	11.4580	9.0734506 E 04	10.4950	0.0262
33.91	12.3057	1.0624345 E 05	13.6874	0.0296
35.02	12.7082	1.0063452 E 05	13.5094	0.0274
36.62	13.2891	1.1540663 E 05	15.3175	0.0284
38.65	14.0260	1.2109607 E 05	17.7578	0.0295
41.05	14.8957	1.1795702 E 05	19.0929	0.0282
41.51	15.0636	1.3081731 E 05	20.2932	0.0293
43.75	15.8763	1.3707131 E 05	22.3243	0.0290
45.88	16.6492	1.3184282 E 05	22.7886	0.0269
45.88	16.6492	1.4458736 E 05	25.3129	0.0299
47.92	17.3876	1.5011955 E 05	27.4334	0.0297
49.87	18.0958	1.5714989 E 05	29.9404	0.0303
51.75	18.7771	1.6211610 E 05	31.9619	0.0297
52.11	18.9105	1.4974914 E 05	31.1852	0.0286

HELICAL DIAMETER = 1.061 ANGLE = 150

GPM	VEL	RE	DP	FF
3.80	1.3780	1.0770258 E 04	0.1456	0.0251
4.98	1.8084	1.4133725 E 04	0.2502	0.0251
7.14	2.5920	2.0258343 E 04	0.5323	0.0260
8.90	3.2304	2.5247777 E 04	0.8053	0.0253
14.39	5.2213	4.0808219 E 04	2.1112	0.0254
16.26	5.9004	4.6116522 E 04	2.6890	0.0253
17.80	6.4607	5.5779909 E 04	3.7671	0.0295
20.00	7.2575	5.6723360 E 04	4.1541	0.0258
20.56	7.4609	5.8312808 E 04	4.3452	0.0256
21.47	7.7918	6.0899054 E 04	5.0505	0.0273
22.35	8.1091	6.9189301 E 04	6.5347	0.0326
22.35	8.1091	6.3379342 E 04	5.4554	0.0272
24.00	8.7090	6.8068038 E 04	6.5338	0.0282

26.28	9.5381	7.4547643 E 04	7.4756	0.02697
27.70	10.0527	8.5772118 E 04	9.6040	0.03119
27.70	10.0527	7.8569668 E 04	8.8133	0.02863
30.96	11.2361	9.5869142 E 04	11.9802	0.03115
30.96	11.2361	8.7818824 E 04	10.9928	0.02858
33.34	12.0994	1.0384887 E 05	13.1963	0.02959
33.91	12.3057	9.6178568 E 04	13.4680	0.02919
35.56	12.9048	1.1010667 E 05	15.6326	0.03081
36.62	13.2891	1.0386452 E 05	14.5255	0.02700
37.65	13.6625	1.1726546 E 05	17.3577	0.03052
39.14	14.2042	1.1101713 E 05	16.9577	0.02759
39.63	14.3802	1.2269578 E 05	19.4949	0.03094
41.51	15.0636	1.2929097 E 05	21.1574	0.03060
41.51	15.0636	1.1773394 E 05	19.8971	0.02878
43.31	15.7172	1.3410285 E 05	23.2817	0.03094
45.88	16.6492	1.4290035 E 05	25.3014	0.02996
45.88	16.6492	1.3012681 E 05	24.8275	0.02940
46.71	16.9485	1.4460873 E 05	26.8490	0.03068
48.31	17.5316	1.5047354 E 05	28.4860	0.03042
49.10	17.8159	1.5201012 E 05	30.7113	0.03176
49.87	18.0958	1.4143294 E 05	28.3947	0.02846
51.00	18.5076	1.5791189 E 05	32.0590	0.03072
52.11	18.9105	1.4780007 E 05	31.5774	0.02898

HELICAL DIAMETER = 1.061 ANGLE = 180

GPM	VEL	RE	DP	FF
6.07	2.2037	1.7564178 E 04	0.4049	0.02737
7.82	2.8387	2.2625068 E 04	0.6734	0.02743
9.98	3.6227	2.8874249 E 04	1.0783	0.02697
14.02	5.0871	4.0545319 E 04	2.1476	0.02724
17.00	6.1679	4.9159752 E 04	3.1850	0.02748
17.65	6.4037	5.5287652 E 04	3.0065	0.02407
19.61	7.1145	5.6705038 E 04	4.6683	0.03027
19.87	7.2095	5.7461737 E 04	4.3907	0.02773
20.41	7.4056	6.3938049 E 04	5.3693	0.03214
24.00	8.7090	6.9413673 E 04	6.9114	0.02991
24.00	8.7090	7.5191216 E 04	8.0198	0.03471
26.28	9.5381	8.2348898 E 04	8.3168	0.03001
27.70	10.0527	8.6791819 E 04	9.8020	0.03184
28.39	10.3003	8.8929673 E 04	10.9901	0.03400
29.05	10.5421	8.4023509 E 04	10.3831	0.03067
32.76	11.8895	1.0264986 E 05	13.2933	0.03087
34.47	12.5086	1.0799519 E 05	15.9336	0.03343
35.02	12.7082	1.0128825 E 05	14.5155	0.02950
38.65	14.0260	1.2109607 E 05	19.1859	0.03201
40.11	14.5541	1.1600046 E 05	20.0000	0.03099
42.87	15.5564	1.3430883 E 05	23.4759	0.03184
45.88	16.6492	1.4374431 E 05	27.2373	0.03225
47.11	17.0961	1.3626117 E 05	25.7926	0.02897
48.31	17.5316	1.5136222 E 05	30.1307	0.03218
48.71	17.6743	1.5259471 E 05	31.3852	0.03298
49.87	18.0958	1.5623360 E 05	31.7697	0.03185
51.38	18.6429	1.4858928 E 05	31.8764	0.03010

APPENDIX IV

Typical Results from Air Data Including:

Helical Hose at all angles

HELICAL DIAMETER = 1.299 ANGLE = 0

SCFM	RE	FF
39.588	4.5771093 E 04	0.02640
44.288	5.1205262 E 04	0.03118
59.111	6.8342923 E 04	0.02597
62.248	7.1970359 E 04	0.03020
65.213	7.5178031 E 04	0.03163
73.782	8.5429726 E 04	0.01747
75.758	8.7461545 E 04	0.01891
78.290	8.9990948 E 04	0.03189
87.257	9.7227092 E 04	0.02283
94.976	1.0807767 E 05	0.01759
95.332	1.0926433 E 05	0.03036
97.356	1.1256076 E 05	0.02255
101.237	1.1687769 E 05	0.02336
110.591	1.2058499 E 05	0.01959
116.593	1.2902800 E 05	0.01772
122.352	1.4104889 E 05	0.02723
127.626	1.4723521 E 05	0.02496
127.751	1.4558155 E 05	0.03065
153.751	1.7698794 E 05	0.02974
155.058	1.7569769 E 05	0.03292
156.656	1.7479658 E 05	0.02804
158.943	1.8323128 E 05	0.02469
164.837	1.8784404 E 05	0.02779
166.946	1.8970605 E 05	0.06343
167.947	1.8976534 E 05	0.03413
181.718	2.0827441 E 05	0.03110
188.557	2.1275246 E 05	0.03345
189.980	2.0714895 E 05	0.03201
190.391	2.1884707 E 05	0.02614
197.352	2.2554356 E 05	0.03235
209.390	2.3999100 E 05	0.03114
210.172	2.3882466 E 05	0.03569
216.313	2.4069808 E 05	0.03076
216.522	2.4465005 E 05	0.03696
220.554	2.5425686 E 05	0.03503
220.972	2.4897680 E 05	0.04313
223.862	2.5258829 E 05	0.03599
224.398	2.5212910 E 05	0.03702
235.565	2.7116676 E 05	0.03493
240.350	2.6855377 E 05	0.03891
241.745	2.7747528 E 05	0.03778
242.192	2.7678833 E 05	0.03930
251.301	2.7848172 E 05	0.02954
260.128	2.8747900 E 05	0.04641
261.664	2.9359112 E 05	0.03856
279.462	3.1268931 E 05	0.03757
303.444	3.3672484 E 05	0.03915
309.276	3.3812647 E 05	0.04142
311.693	3.5268196 E 05	0.03497
311.749	3.3812448 E 05	0.03621
315.040	3.5298790 E 05	0.04154

371.500	4.0187058 E 05	0.04461
372.820	4.1656948 E 05	0.03754
372.840	4.0331990 E 05	0.03990
380.042	4.2114786 E 05	0.04314
385.344	4.2355905 E 05	0.04195

HELICAL DIAMETER = 1.299 ANGLE = 30

SCFM	RE	FF
73.543	8.2863484 E 04	0.01675
82.282	9.2193274 E 04	0.03914
90.940	1.0105224 E 05	0.01896
94.270	1.0621764 E 05	0.02271
120.182	1.3522317 E 05	0.02736
142.372	1.5996680 E 05	0.02932
156.325	1.7564346 E 05	0.02993
167.048	1.8562423 E 05	0.02043
176.687	1.9852293 E 05	0.03168
188.526	2.1064943 E 05	0.03378
195.204	2.1932757 E 05	0.03236
206.542	2.3142050 E 05	0.03718
235.974	2.6330037 E 05	0.03936
238.970	2.6775513 E 05	0.03164
256.392	2.8373602 E 05	0.03776
296.428	3.2670746 E 05	0.04061
301.343	3.2945295 E 05	0.04376
311.410	3.4699316 E 05	0.03990
364.415	4.0383107 E 05	0.04231
374.932	4.1379039 E 05	0.04493

HELICAL DIAMETER = 1.299 ANGLE = 60

SCFM	RE	FF
33.992	3.8681294 E 04	0.02808
39.122	4.4582720 E 04	0.03501
47.965	5.4659250 E 04	0.03383
54.098	6.1385788 E 04	0.03634
55.063	6.2748343 E 04	0.03258
58.467	6.6532034 E 04	0.03261
61.737	7.0254177 E 04	0.03640
63.335	6.9710393 E 04	0.03773
73.700	8.3866850 E 04	0.03319
75.026	8.1914945 E 04	0.08763
83.113	9.3580259 E 04	0.03144
107.496	1.2215047 E 05	0.02650
120.373	1.3678384 E 05	0.03260
126.448	1.4247351 E 05	0.02737
138.636	1.5494777 E 05	0.04120
143.753	1.6311937 E 05	0.03440
153.419	1.7281441 E 05	0.03257
167.194	1.8918062 E 05	0.03406
186.241	2.1073249 E 05	0.03408
190.460	2.1405746 E 05	0.03283

199.424	2.2344476 E 05	0.03432
201.493	2.2028925 E 05	0.03360
205.908	2.3007080 E 05	0.03830
208.909	2.3538536 E 05	0.03648
219.597	2.4408320 E 05	0.03891
219.824	2.4360025 E 05	0.03580
227.675	2.5178491 E 05	0.03816
231.135	2.5897616 E 05	0.03823
233.185	2.5631077 E 05	0.03964
257.943	2.8429057 E 05	0.04612
259.745	2.8942379 E 05	0.04181
285.228	3.1191795 E 05	0.04876
294.960	3.2686366 E 05	0.04001
358.670	3.9434576 E 05	0.02576
367.300	4.0049331 E 05	0.04521
368.883	4.0383390 E 05	0.04122

HELICAL DIAMETER = 1.299 ANGLE = 90

SCFM	RE	FF
27.682	3.1322503 E 04	0.25858
37.711	4.1339078 E 04	0.18707
45.921	5.3015880 E 04	0.05814
73.782	8.5056716 E 04	0.04310
140.541	1.6201734 E 05	0.03868
145.570	1.6448059 E 05	0.04138
163.059	1.7898877 E 05	0.07206
168.100	1.9322473 E 05	0.03688
191.000	2.1490515 E 05	0.03945
210.668	2.4180429 E 05	0.03900
226.877	2.5817446 E 05	0.04037
232.366	2.6555909 E 05	0.04146
284.687	3.1809425 E 05	0.04069
302.107	3.3755867 E 05	0.04379
349.921	3.8154395 E 05	0.04455
367.295	4.0317672 E 05	0.04507
425.837	4.6556074 E 05	0.02610

HELICAL DIAMETER = 1.299 ANGLE = 120

SCFM	RE	FF
9.725	1.0850947 E 04	1.20426
19.949	2.2240716 E 04	0.44514
27.620	3.0524129 E 04	0.35036
27.652	3.0982295 E 04	0.04992
36.627	4.1038391 E 04	0.04263
47.329	5.3104190 E 04	0.03618
52.781	5.9220605 E 04	0.04157
61.380	6.8869435 E 04	0.03951
66.788	7.4936916 E 04	0.04217
87.665	9.8498351 E 04	0.03502
100.004	1.1158479 E 05	0.04699
122.910	1.3809981 E 05	0.02908

131.336	1.4715570 E 05	0.04171
150.340	1.6821458 E 05	0.03998
162.418	1.8097625 E 05	0.04063
171.857	1.9229034 E 05	0.04117
186.634	2.0801713 E 05	0.04051
187.867	2.0933284 E 05	0.04561
205.919	2.3008302 E 05	0.04434
218.237	2.4317295 E 05	0.04360
219.773	2.4522278 E 05	0.03662
221.804	2.4766059 E 05	0.04486
223.473	2.4686847 E 05	0.04177
234.838	2.6023861 E 05	0.04644
251.231	2.7993716 E 05	0.04299
267.002	2.9467431 E 05	0.04564
287.489	3.1858450 E 05	0.04550
292.713	3.2526284 E 05	0.04727
340.820	3.7563329 E 05	0.04561

HELICAL DIAMETER = 1.299 ANGLE = 150

SCFM	RE	FF
62.972	7.3672081 E 04	0.03727
63.176	7.3365755 E 04	0.04844
76.094	8.5379025 E 04	0.04728
144.056	1.6853419 E 05	0.04258
182.274	2.1324608 E 05	0.04710
190.589	2.2100216 E 05	0.04253
217.592	2.5305938 E 05	0.04814
221.303	2.5813801 E 05	0.04917
232.760	2.6086926 E 05	0.04168
287.040	3.3162760 E 05	0.04613
289.309	3.3255044 E 05	0.05152
289.610	3.3193486 E 05	0.04881
342.632	3.8267987 E 05	0.04701
350.971	3.9324653 E 05	0.05333
351.750	3.8979585 E 05	0.04925

HELICAL DIAMETER = 1.299 ANGLE = 180

SCFM	RE	FF
27.516	3.0533418 E 04	0.05186
30.782	3.4204831 E 04	0.05393
36.397	4.0444190 E 04	0.05100
47.383	5.2724549 E 04	0.03921
51.263	5.6499000 E 04	0.04449
51.347	5.7214376 E 04	0.04413
52.978	5.9031398 E 04	0.04591
63.879	7.1178229 E 04	0.04264
68.084	7.5655268 E 04	0.04596
81.499	9.0936346 E 04	0.04018
81.537	9.0979100 E 04	0.04824
100.702	1.1236370 E 05	0.04495
127.123	1.4145402 E 05	0.04570

139.314	1.5396147 E 05	0.04563
145.606	1.6179809 E 05	0.04400
169.327	1.8815592 E 05	0.04532
185.432	2.0662005 E 05	0.04602
189.027	2.1004736 E 05	0.04800
195.372	2.1591377 E 05	0.05522
202.833	2.2385506 E 05	0.05493
207.605	2.2943343 E 05	0.04705
208.074	2.2932828 E 05	0.05419
233.958	2.6305455 E 05	0.04503
239.866	2.6508602 E 05	0.05266
270.634	3.0031689 E 05	0.05599
272.847	3.0153562 E 05	0.05727
272.933	3.0370096 E 05	0.05147
336.934	3.7543359 E 05	0.05899
337.993	3.7912751 E 05	0.05261
346.426	3.8707768 E 05	0.05336