Memorandum

TO: H. M. Martin
Through: J. C. Schuster
A. J. Peterka
FROM: C. E. Brockway

DATE: August 6, 1964

SUBJECT: Analysis of Cole pitometer discharge measurements using electronic digital computers

INTRODUCTION

The computation of discharges in pipes using a velocity distribution obtained from Cole pitometer measurements is very time-consuming when performed by manual methods. A program for the IBM 7090 computer has been written in Fortran II to determine average velocities and discharges from original field data. The program was written to analyze the Cole pitometer measurements obtained during the turbine acceptance tests at Green Springs Powerplant and to perfect a program for future use.

The Cole pitometer consists of two orifices mounted in a plane, one directed upstream and one directed downstream. A pressure differential between the upstream and downstream orifices is measured with a manometer and the velocity at the point is determined from

\[ V = \frac{C}{\sqrt{2gh}} \]

Where:
- \( V \) = point velocity -- ft/sec
- \( C \) = pitometer coefficient -- variable with \( \sqrt{2gh} \)
- \( g \) = gravitational acceleration -- ft/sec^2
- \( h \) = pressure differential -- feet of flowing fluid

CODE REQUIREMENTS

The ASME Test Code for hydraulic prime movers stipulates that velocity traverses will be made on at least two diameters of a pipe, 90° apart, with velocities determined at the midpoints of annular rings which divide the pipe into equal areas. The code further stipulates that the velocity traverses will be plotted and a smooth curve drawn through the test points assuming the velocity distribution follows the one-seventh power law from the pipe wall to the nearest measured velocity point. The mean of the average velocities determined on two diameters is multiplied by the corrected pipe area to determine the discharge.

Average velocity for each traverse is normally determined from the velocity profile using a planimeter. However, equivalent results can be obtained by a mathematical procedure as outlined in this memorandum.
ESSENTIALS OF COMPUTER PROGRAM

The ADP program uses the average pipe diameter, the geometry of the pitometer, and the manometer readings as input. Two traverses, A and B, are computed simultaneously in the program. Theoretical velocities, \( \sqrt{2gh} \), at each point on a traverse are computed by algebraic methods. The pitometer coefficient corresponding to the theoretical velocity is determined using Newton forward difference interpolation in a difference table computed from the calibration curve for a given pitometer and stored in the computer memory. Corrected velocities for each point are then computed by multiplying the pitometer coefficient by the theoretical velocity.

The velocities at points between the wall and the nearest measured velocity point are computed from the one-seventh power law and the profiles of the computed velocities are punched on cards to be plotted by an x-y plotter. All profiles are in dimensionless form so that regardless of velocity values, all plots may be made on one paper size. The ordinate represents the pipe diameter and the abscissa values are decimal parts of the centerline velocity. A polynomial curve of degree \((n-1)\) is fitted to the \(n\) measured velocity points by solving the set of simultaneous equations corresponding to the points on the traverse. The resulting \(n\) by \(n+1\) array corresponding to the set of simultaneous equations is solved by a matrix reduction technique called a complete Gauss elimination.

The area under the velocity profile between the two measured velocity points nearest the walls is determined by infinite integration of the fitted polynomial. The areas under the velocity profile from each wall to the nearest measured velocity point are determined by integration of the curves computed by the one-seventh power law. Average velocity for each traverse is determined by dividing the total area under the velocity profile curve by the traverse diameter. The average fluid velocity is the mean of the average velocities determined for the A and B traverses.

A pipe coefficient, equal to the ratio of the average pipe velocity to the centerline velocity, is also determined. Use of the pipe coefficient permits the computation of subsequent discharges from one determination of velocity at the pipe centerline. Discharge is determined by multiplying the centerline velocity by the pipe coefficient and by the corrected pipe area. The corrected pipe area is equal to the pipe area minus 1.25 times the projected area of the pitometer when the orifices are at the pipe centerline. This area correction is specified by the ASME Test Code.
An example of the printed output for a typical traverse taken at Green Springs Powerplant is shown in Table 1. A velocity profile, plotted by an x-y plotter, corresponding to the data for Diameter B in Table 1 is shown in Figure 1. The complete program, together with a list of input variables, is included as addendum to this memorandum.

Smooth curves carefully drawn by one individual to average the measured velocity points for each Green Springs test were integrated with a planimeter to find the difference between the discharge determined by the computer and the discharge computed manually. Table 2 is a comparison of six discharges determined manually with a planimeter and by the computer. In this comparison, the average curves for the velocity profiles were drawn by one individual and the computer discharge averaged 0.10 percent higher than the discharge computed manually. Had another individual drawn the velocity curves, the difference between the discharges indicated by the two methods may have been in the opposite direction. The agreement between the two methods of discharge computation is satisfactory for velocity distributions measured by the pitometer.

Since the fitted polynomial is forced to pass through every measured point on the velocity profile, an erroneous velocity point will result in a distorted profile. However, any large velocity error can be easily detected by inspection of the profile which is plotted on the x-y plotter. Figure 2 shows the effect on the computed polynomial of an assumed error of 1 foot in the manometer differential used to calculate the velocity at Point No. 8 of a typical traverse. The dashed line in Figure 2 is the polynomial fit through the correct velocity points, and the line of circles is the resulting fitted polynomial including the erroneous velocity. The oscillations of the incorrect polynomial about the correct profile are damped out but not rapidly enough to give an accurate representation of the profile. In general, the velocity points obtained with pitometers define a smooth curve so that the mathematical fitting of an nth degree polynomial is a good representation of the correct profile.

With the increase in prototype testing and the use of pitometers for field discharge measurements, this computer program should result in considerable time savings. In addition to the use on Green Springs Powerplant data, the program has been used successfully to reduce data from Fremont Canyon Power Conduit friction tests; discharge measurements for friction factor determination, Salt River Project, Arizona, and laboratory pitometer studies.
**TABLE 1**

TRAVERSE NO = 1

<table>
<thead>
<tr>
<th>POINT</th>
<th>UHIGH</th>
<th>ULOW</th>
<th>DELH</th>
<th>VU</th>
<th>P COEFF</th>
<th>VCOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRAVERSE ON DIAMETER A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>47.980</td>
<td>46.310</td>
<td>1.670</td>
<td>10.363</td>
<td>0.852</td>
<td>8.82</td>
</tr>
<tr>
<td>2</td>
<td>48.190</td>
<td>46.100</td>
<td>2.090</td>
<td>11.593</td>
<td>0.849</td>
<td>9.84</td>
</tr>
<tr>
<td>3</td>
<td>48.400</td>
<td>45.910</td>
<td>2.490</td>
<td>12.653</td>
<td>0.847</td>
<td>10.71</td>
</tr>
<tr>
<td>4</td>
<td>48.560</td>
<td>45.780</td>
<td>2.780</td>
<td>13.370</td>
<td>0.845</td>
<td>11.30</td>
</tr>
<tr>
<td>5</td>
<td>48.720</td>
<td>45.620</td>
<td>3.100</td>
<td>14.119</td>
<td>0.844</td>
<td>11.91</td>
</tr>
<tr>
<td>6</td>
<td>48.770</td>
<td>45.560</td>
<td>3.210</td>
<td>14.367</td>
<td>0.844</td>
<td>12.12</td>
</tr>
<tr>
<td>7</td>
<td>48.680</td>
<td>45.660</td>
<td>3.020</td>
<td>13.935</td>
<td>0.844</td>
<td>11.76</td>
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<tr>
<td>8</td>
<td>48.570</td>
<td>45.770</td>
<td>2.800</td>
<td>13.418</td>
<td>0.845</td>
<td>11.34</td>
</tr>
<tr>
<td>9</td>
<td>48.460</td>
<td>45.880</td>
<td>2.580</td>
<td>12.880</td>
<td>0.846</td>
<td>10.90</td>
</tr>
<tr>
<td>10</td>
<td>48.300</td>
<td>46.040</td>
<td>2.260</td>
<td>12.055</td>
<td>0.848</td>
<td>10.22</td>
</tr>
<tr>
<td>11</td>
<td>48.050</td>
<td>46.240</td>
<td>1.810</td>
<td>10.788</td>
<td>0.851</td>
<td>9.18</td>
</tr>
</tbody>
</table>

| TRAVERSE ON DIAMETER B | | | | | | |
| 1 | 48.260 | 46.580 | 1.680 | 10.394 | 0.852 | 8.85 |
| 2 | 48.510 | 46.330 | 2.180 | 11.840 | 0.849 | 10.04 |
| 3 | 48.730 | 46.120 | 2.610 | 12.955 | 0.846 | 10.96 |
| 4 | 48.900 | 45.950 | 2.950 | 13.773 | 0.845 | 11.63 |
| 5 | 49.050 | 45.880 | 3.230 | 14.412 | 0.844 | 12.15 |
| 6 | 49.010 | 45.870 | 3.140 | 14.209 | 0.844 | 11.99 |
| 7 | 48.900 | 46.020 | 2.880 | 13.608 | 0.845 | 11.49 |
| 8 | 48.780 | 46.140 | 2.640 | 13.029 | 0.846 | 11.02 |
| 9 | 48.690 | 46.250 | 2.440 | 12.526 | 0.847 | 10.61 |
| 10 | 48.550 | 46.390 | 2.160 | 11.785 | 0.849 | 10.00 |
| 11 | 48.370 | 46.590 | 1.780 | 10.698 | 0.851 | 9.10 |

VELOCITY = SUM A(i) TIMES X TO THE (I)TH POWER

<table>
<thead>
<tr>
<th>I</th>
<th>TRAVERSE ON DIAMETER A</th>
<th>TRAVERSE ON DIAMETER B</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.5775363E-02</td>
<td>1.7853481E-02</td>
</tr>
<tr>
<td>9</td>
<td>-3.3194917E-01</td>
<td>-3.6805787E-01</td>
</tr>
<tr>
<td>8</td>
<td>3.0688687E 00</td>
<td>3.1191080E 00</td>
</tr>
<tr>
<td>7</td>
<td>-1.5350647E 01</td>
<td>-1.5038879E 01</td>
</tr>
<tr>
<td>6</td>
<td>4.8270710E 01</td>
<td>4.4220012E 01</td>
</tr>
<tr>
<td>5</td>
<td>-9.6175201E 01</td>
<td>-8.1359546E 01</td>
</tr>
<tr>
<td>4</td>
<td>1.1995567E 02</td>
<td>9.2301848E 01</td>
</tr>
<tr>
<td>3</td>
<td>-8.8653655E 01</td>
<td>-6.0548886E 01</td>
</tr>
<tr>
<td>2</td>
<td>3.3009284E 01</td>
<td>1.7718702E 01</td>
</tr>
<tr>
<td>1</td>
<td>-9.5192337E-01</td>
<td>3.3422327E 00</td>
</tr>
<tr>
<td>0</td>
<td>8.6572534E 00</td>
<td>8.3732134E 00</td>
</tr>
</tbody>
</table>

AREA A = 44.251 VELOCITY A = 11.074 AREA B = 44.144 VELOCITY B = 11.047

PIPE COEFFICIENT = 0.917 AVG VELOCITY = 11.060 DISCHARGE = 138.659
<table>
<thead>
<tr>
<th>Run No.</th>
<th>*Qp, cfs</th>
<th>**Qc, cfs</th>
<th>difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>138.71</td>
<td>138.66</td>
<td>-0.04</td>
</tr>
<tr>
<td>2</td>
<td>129.25</td>
<td>129.29</td>
<td>+0.03</td>
</tr>
<tr>
<td>15</td>
<td>70.37</td>
<td>70.26</td>
<td>-0.15</td>
</tr>
<tr>
<td>17</td>
<td>103.00</td>
<td>103.34</td>
<td>+0.33</td>
</tr>
<tr>
<td>20</td>
<td>87.94</td>
<td>87.93</td>
<td>-0.01</td>
</tr>
<tr>
<td>26</td>
<td>117.21</td>
<td>117.49</td>
<td>+0.24</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td>+0.10</td>
</tr>
</tbody>
</table>

*Qp is the discharge determined by integration of the velocity profile using a planimeter.

**Qc is the discharge determined by the computer using an infinite integration of the polynomial fitted to the velocity profile.
FIGURE 1

NUMBER 1  GATE 80
DIA. B

- o - MEASURED VELOCITY
- o - POLYNOMIAL FIT
+ 1/7 POWER LAW
FIGURE 2

NUMBER 2 GATE 70
DIA. A

- - MEASURED VELOCITY
○ POLYNOMIAL FIT
● ⅔ POWER LAW
COLE PITOMETER DISCHARGE MEASUREMENTS

ODIMENSION UHIGHA(20), ULOWA(20), DELHA(20), UHIGHB(20), ULOWB(20),
1 1DELHB(20), PDA(20), PCB(20), VCA(20), VCB(20), VUA(20), VUB(20), X(20),
2 TEMPX(20), YCA(20), YCB(20), YCADC(20), YCBDC(20), YCAD(20), YCBD(20),
3 Y(20), Z(20), VD(20), E(20), HI(20), H(20), P(20), V(20), C(20), Dl(20),
4 D2(20), A(20), Z(20), SUMP1(20), SUMP2(20), SUMP(20), R(2,200),
5 SUMV(2,100), CV(2,100)
1 FORMAT (5F8.0,4I4)
81 FORMAT (10F8.3)
7 READ IN DIFFERENCE TABLE FOR INTERPOLATION ON CALIBRATION CURVE
1 DO 11 K=1,14
1 READ INPUT TAPE 5,1, V(K), C(K), D1(K), D2(K)
100 READ INPUT TAPE 5,1, AM, TD, D, G, STEM, NTRAV, NPT, MPRINT, MPUNCH
1 AREA = .7854*C*D -1.25*(AM +(0.5*TD -STEM)*.0725)
1 DO 10 NJ=1,NTRAV
1 READ INPUT TAPE 5,2, SPG, GATE, KTRAV
2 FORMAT (2F8.0,18)
2 WRITE OUTPUT TAPE 6,3, KTRAV
3 FORMAT (15HI TRAVERSE NO =, 14)
3 WRITE OUTPUT TAPE 6,4
4 FORMAT (1H0, 1X, 6H POINT, 6X, 6H UHIGH, 7X, 5H ULOW, 7X, 5H OELH,
1 18X, 3H VU, 5X, 8H PCOEFF, 4X, 6H VCORR)
1 IF (SPG -1.0) 21,22,21
1 TEMP = 2.0* G* ABSF(SPG-1.0)
21 GO TO 23
22 TEMP = 2.0* G
23 DO 12 N=1,NPT
12 ZCN) = P(N)* TD
12 READ INPUT TAPE 5,1, UHIGHA(N), ULOWA(N), UHIGHB(N), ULOWB(N)
12 DELHA(N) = UHIGHA(N) - ULOWA(N)
12 DELHB(N) = UHIGHB(N) - ULOWB(N)
12 VUA(N) = SQRTF(TEMP* DELHA(N))
12 VUB(N) = SQRTF(TEMP* DELHB(N))
12 COMPUTE PITOMETER COEFFICIENT AND CORRECTED VELOCITY
13 K=1
24 IF(V(K) - VUA(N)) 25,26,27
25 K=K+1
26 GO TO 24
27 PCA(N) = C(K)
28 GO TO 28
27 S = (VUA(N) - V(K-1)) /2.0
28 PCA(N) = C(K-1) + S*(D1(K-1) + (S-1.0)/2.0 * D2(K-1))
28 K=1
29 IF (V(K) - VUB(N)) 30,31,32
30 K=K+1
31 GO TO 29
31 PCB(N) = C(K)
32 GO TO 33
32 S = (VUB(N) - V(K-1)) /2.0
33 PCB(N) = C(K-1) + S*(D1(K-1) + (S-1.0)/2.0 * D2(K-1))
33 VCA(N) = PCA(N) * VUA(N)
COLE PITOMETER DISCHARGE MEASUREMENTS

\[ V_{CB}(N) = P_{CB}(N) * V_{UB}(N) \]

12 CONTINUE

WRITE OUTPUT TAPE 6, 5

5 FORMAT (24H0 TRAVERSE ON DIAMETER A)

\[ LC = (N_{PT} + 1) / 2 \]

DO 13 N = 1, NPT

\[ V_{CA}(N) = V_{CA}(N) / V_{CA}(LC) \]

13 WRITE OUTPUT TAPE 6, 6, N, UHIGHA(N), ULOWA(N), DELHA(N), VUA(N), PICA(N), VCA(N)

6 FORMAT (I0, 3X, F10.3, 2X, F10.3, 2X, F10.3, 2X, F10.3, 2X, 1F10.3, 1X, F10.3)

WRITE OUTPUT TAPE 6, 7

7 FORMAT (24H0 TRAVERSE ON DIAMETER B)

DO 14 N = 1, NPT

\[ V_{CB}(N) = V_{CB}(N) / V_{CB}(LC) \]

14 WRITE OUTPUT TAPE 6, 6, N, UHIGHB(N), ULOWB(N), DELHB(N), VUB(N), PICA(N), VCA(N)

10 FORMAT (I0, 3X, F10.3, 2X, F10.3, 2X, F10.3, 2X, F10.3, 2X, 1F10.3, 1X, F10.3)

WRITE OUTPUT TAPE 6, 8

18 WRITE OUTPUT TAPE 7, 9, VCA0(I), YD(I)

9 FORMAT (2F8.3, I4)

compute velocity near wall and area

\[ X(1) = 0.01 \]

X(2) = 0.20

X(3) = 0.50

X(4) = 0.75

X(5) = 1.00

DO 15 I = 1, 5

\[ TEMPX(I) = (X(I) ** 0.1429) \]

\[ V_{CA}(I) = V_{CA}(I) * TEMPX(I) \]

\[ V_{CA}(I) = V_{CA}(I) / V_{CA}(LC) \]

\[ V_{CB}(I) = V_{CB}(I) * TEMPX(I) \]

\[ V_{CB}(I) = V_{CB}(I) / V_{CB}(LC) \]

\[ Y(I) = X(I) * Z(I) \]

\[ YD(I) = Y(I) / TD \]

15 CONTINUE

DO 16 I = 6, 10

M = 11 - I

\[ V_{CA}(I) = V_{CA}(NPT) * TEMPX(M) \]

\[ V_{CB}(I) = V_{CB}(NPT) * TEMPX(M) \]

\[ V_{CB}(I) = V_{CB}(I) / V_{CB}(LC) \]

\[ Y(I) = TD - X(M) * Z(I) \]

\[ YD(I) = Y(I) / TD \]

16 CONTINUE

\[ TEMP1 = 0.875 * Z(I) * VCA(I) \]

\[ TEMP2 = 0.875 * (TD - Z(NPT)) * VCA(NPT) \]

\[ TEMP1 = 0.875 * Z(I) * VCB(I) \]

\[ TEMP2 = 0.875 * (TD - Z(NPT)) * VCB(NPT) \]

IF (MPUNCH - 1) 300, 301, 300

300 ZFRU = 0.0

NSTOP = 8

LIFT = 3

DO 18 I = 1, 4

WRITE OUTPUT TAPE 7, 9, VCA0(I), YD(I)

9 FORMAT (2F8.3, I4)
COLE PITOMETER DISCHARGE MEASUREMENTS

DO 19 N = 1, NPT
19 WRITE OUTPUT TAPE 7,9, VCA(N), P(N)
DO 20 I = 7,10
20 WRITE OUTPUT TAPE 7,9, VCA(I), YD(I)
WRITE OUTPUT TAPE 7,9, ZERO, ZERO, LIFT
WRITE OUTPUT TAPE 7,9, ZERO, ZERO, LIFT
WRITE OUTPUT TAPE 7,9, ZERO, ZERO, NSTOP
DO 51 I = 1,4
51 WRITE OUTPUT TAPE 7,9, VCAO(I), YD(I)
DO 52 N = 1, NPT
52 DO 53 I = 7,10
53 WRITE OUTPUT TAPE 7,9, VCB(I), YD(I)
WRITE OUTPUT TAPE 7,9, ZERO, ZERO, LIFT
WRITE OUTPUT TAPE 7,9, ZERO, ZERO, NSTOP
301 NCOL = NPT + 1
FIT POLYNOMIAL TO VELOCITY POINTS BY GAUSS ELIMINATION
DO 61 I = 1, NPT
A(I,NCOL) = VCA(I)
B(I,NCOL) = VCB(I)
DO 61 J = 1, NCOL
A(I,J) = Z(I)**(-J + NPT)
B(I,J) = A(I,J)
61 CONTINUE
IF (MPRINT = 1) 200,201,200
200 WRITE OUTPUT TAPE 6,151, (( A(I,J), J = 1, NCOL ), I = 1, NPT )
WRITE OUTPUT TAPE 6,151, (( B(I,J), J = 1, NCOL ), I = 1, NPT )
201 CONTINUE
151 FORMAT ( 1HO, 23H MATRIX BEFORE SWEEPOUT // (12E10.3))
NPTM1 = NPT-1
DO 103 I = 1, NPTM1
K = I+1
DO 103 N = K, NPT
IF (ABSF(A(I,I)) - ABSF(A(N,I))) 101, 103, 103
101 DO 102 J = 1, NCOL
RT = A(I,J)
R1 = B(I,J)
A(I,J) = A(N,J)
B(I,J) = B(N,J)
A(N,J) = RT
B(N,J) = R1
102 CONTINUE
103 CONTINUE
DO 63 IP = 1, NPT
RA = A(IP,IP)
RB = B(IP,IP)
DO 64 J = IP, NCOL
A(IP,J) = A(IP,J)/RA
B(IP,J) = B(IP,J)/RB
DO 63 I = 1, NPT
IF (I-IP) 66,63,66
COLE PITOMETER DISCHARGE MEASUREMENTS

66 \( R_A = A(I, IP) \)
67 \( R_B = B(I, IP) \)
DO 67 J = IP, NCOL
A(I, J) = A(I, J) - RA * A(IP, J)
67 B(I, J) = B(I, J) - RB * B(IP, J)
63 CONTINUE
IF (MPRINT = 1) 202, 203, 202
202 WRITE OUTPUT TAPE 6, 152, ( ( A(I, J), J=1, NCOL ), I=1, NPT )
WRITE OUTPUT TAPE 6, 152, ( ( B(I, J), J=1, NCOL ), I=1, NPT )
152 FORMAT ( 1HO, 22H MATRIX AFTER SWEEPOUT // (1ZE10.3 ) )
203 CONTINUE
DO 68 J = 1, NPT
E(2, J) = B(J, NCOL)
PTN = NPT
DO 70 I = 1, 2
SUMP(I) = 0. C
SUMP2(I) = 0. C
DO 69 J = 1, NPT
L = J - 1
VL = L
SUMP(I) = SUMP1(I) + E(I, J) * Z(L)**(-L+PTN)/( -VL + PTN)
SUMP2(I) = SUMP2(I) + E(I, J) * Z(NPT)**(-L+PTN)/( -VL + PTN)
69 CONTINUE
SUMP(I) = SUMP2(I) - SUMP1(I)
70 CONTINUE
AB2 = SUMP(2) + TEMPB1 + TEMPB2
AA2 = SUMP(1) + TEMPA1 + TEMPA2
VELA = AA2 / TD
VELB = AB2 / TD
VAVGP = (VELA + VELB) / 2.0
QP = VAVGP * AREA
PCOP = 2.0 * VAVGP / (VCA(LC) + VC8(LC))
WRITE OUTPUT TAPE 6, 91
91 FORMAT ( 1HO, 47H VELOCITY = SUM A(I) TIMES X TO THE (I)TH POWER )
WRITE OUTPUT TAPE 6, 92
92 FORMAT (1HC, 3X, 2H I , 6X, 23H TRAVERSE ON DIAMETER A , 5X, 23H TRAVERSE 1 ON DIAMETER B )
DO 73 J = 1, NPT
IR = NPT - J
WRITE OUTPUT TAPE 6, 93, IR, E(I, J), E(2, J)
93 FORMAT (2X, I4, 13X, 1PE16.7, 11X, 1PE16.7)
73 CONTINUE
WRITE OUTPUT TAPE 6, 94, AA2, VELA, AB2, VELB, PCOP, VAVGP, QP
94 FORMAT (1HO, 1X, 7HAREAA =, F8.3, 2X, 11HVELOCITYA =, F8.3, 2X, 7HAREA
1B =, F8.3, 2X, 11HVELOCITYB =, F8.3 // 1X, 18HPipe COEFFICIENT =,
2F8.3, 2X, 14H AVG VELOCITY =, F8.3, 2X, 11HDISCHARGE =, F8.3 )
601 FORMAT (1HL, 6X, 54HDIMENSIONLESS DISTANCE AND VELOCITY FOR POLYNOMIAL
1AL FIT / 6X, 13H TRAVERSE NO =, 14, 10HDIMETER A )
602 FORMAT (1HL, 6X, 54HDIMENSIONLESS DISTANCE AND VELOCITY FOR POLYNOMIAL
1AL FIT / 6X, 13H TRAVERSE NO =, 14, 10HDIMETER B )
604 FORMAT (6X, 8HDISTANCE, 5X, 8HVELOCITY, 5X, 8HDISTANCE, 5X, 8HVELOCITY)
COLE PITOMETER DISCHARGE MEASUREMENTS

DO 704 M=1,2
   IF (M-1) 612,611,612
611 WRITE OUTPUT TAPE 6,601, KTRAV
   GO TO 630
612 WRITE OUTPUT TAPE 6,602, KTRAV
630 DO 701 J=1,100
   IF (J-1) 621,620,621
620 R(J) = P(1)
   = GO TO 623
621 R(J)= R(J-1) + (P(NPT)- P(1))/100.0
623 ZP = R(J) * TC
   SUMV(J) = 0.0
   DO 701 N=1,NPT
624 SUMV(J) = SUMV(J) + E(M,N) * (ZP)**(NPT-N)
701 CONTINUE
   DO 702 J=1,100
      IF (M-1) 627,626,627
626 DV(J) = SUMV(J) / VCA(LC)
   GO TO 702
627 DV(J) = SUMV(J) / VCB(LC)
702 CONTINUE
   WRITE OUTPUT TAPE 6,604
   DO 703 J=1,50
703 WRITE OUTPUT TAPE 6,613; R(J), DV(J), R(J+50), DV(J+50)
613 FORMAT (4(5X,F8.4))
   IF (MPUNCH -1) 628,629,628
628 DO 705 J=1,100
705 WRITE OUTPUT TAPE 7,614; DV(J), R(J)
614 FORMAT (2F8.3, I4)
   WRITE OUTPUT TAPE 7,614; ZERO,ZERO,LIFT
   WRITE OUTPUT TAPE 7,614; ZERO,ZERO,LIFT
   WRITE OUTPUT TAPE 7,614; ZERO,ZERO,NSTOP
629 CONTINUE
704 CONTINUE
10 CONTINUE
   = GO TO 100
END(1,0,0,0,0,1,0,0,0,0,0,0,C,0)
<table>
<thead>
<tr>
<th>Variable name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>Theoretical velocity from pitometer coefficient curve.</td>
</tr>
<tr>
<td>C</td>
<td>Pitometer coefficient.</td>
</tr>
<tr>
<td>D1 or D2</td>
<td>First and second divided differences in forward difference table (pitometer calibration curve)</td>
</tr>
<tr>
<td>P(N)</td>
<td>Location of traverse point, N, as a decimal part of the traverse diameter.</td>
</tr>
<tr>
<td>AM</td>
<td>Projected area of the pitometer from orifices to constant area section of pitometer stem.</td>
</tr>
<tr>
<td>TD</td>
<td>Traverse diameter.</td>
</tr>
<tr>
<td>D</td>
<td>Average conduit diameter.</td>
</tr>
<tr>
<td>G</td>
<td>Acceleration of gravity</td>
</tr>
<tr>
<td>STEM</td>
<td>Distance from orifice tips to constant area section.</td>
</tr>
<tr>
<td>NTRAV</td>
<td>Number of traverses or number of discharges (one traverse consists of velocity measurements on two diameters, A and B).</td>
</tr>
<tr>
<td>NPT</td>
<td>Number of velocity points on traverse.</td>
</tr>
<tr>
<td>MPRINT</td>
<td>Control constant: if MPRINT $\neq 1$, the matrix solved to fit the polynomial curve to the velocity points and the solution matrix will be printed.</td>
</tr>
<tr>
<td>MPUNCH</td>
<td>Control constant: if MPUNCH $\neq 1$, the computed velocity profiles will be punched on binary coded decimal (BCD) cards for plotting on an x-y plotter.</td>
</tr>
<tr>
<td>SPG</td>
<td>Specific gravity of manometer liquid.</td>
</tr>
<tr>
<td>Variable name</td>
<td>Definition</td>
</tr>
<tr>
<td>---------------</td>
<td>------------</td>
</tr>
<tr>
<td>GATE</td>
<td>Percent gate opening.</td>
</tr>
<tr>
<td>KTRAV</td>
<td>Traverse number.</td>
</tr>
<tr>
<td>UHIGHA and ULOWA</td>
<td>Readings of high and low side of manometer for traverse A.</td>
</tr>
<tr>
<td>UHIGHB and ULOWB</td>
<td>Readings of high and low side of manometer for traverse B.</td>
</tr>
</tbody>
</table>