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LABORATORY TESTS OF A HYDRAULIC PRESSURE SURGE RELIEVER

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16. ABSTRACT <p>A 4-inch Flexflo® model 887 pressure surge reliever valve was tested in the laboratory to determine the valve's capability to reduce positive pressure surges in water pipelines. The valve was supplied by the Grove Valve and Regulator Company. The valve was placed on a pipeline upstream of a quick closing gate valve. During the tests, the gate valve was slammed shut to produce a sharp pressure wave traveling upstream. Performance of the surge reliever valve was determined by measuring the reduction in the pressure wave as it traveled past the valve.</p>			
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by
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**Hydraulics Branch
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Denver, Colorado
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CONTENTS

	Page
Acknowledgments	ii
Purpose	1
Introduction	1
Conclusions	2
Application	3
Relief valve	3
Test setup	3
Testing and results	4
Surge reliever tests — 4-in pipeline	4
Results — 4-in pipeline	5
Relief valve opening and closing characteristics	5
Surge relief potential	5
Surge reliever tests — 6-in pipeline	6
Results — 6-in pipeline	7
Relief valve performance	7
Bibliography	8
Appendix	15

FIGURES

Figure

1 Flexflo® model 887 surge relief valve	9
2 Quick closing gate valve	9
3 Test apparatus for first phase of tests using 4-in-diameter pipe	10
4 Water discharging through relief valve	10
5 Pressure relief — 4-in pipe test series	11
6 Unrelieved surge pipe failure on 4-in pipeline	12
7 Test apparatus for second phase of tests using 6-in-diameter steel pipe	12
8 Pressure relief — 6-in pipe test series	13

PURPOSE

The purpose of the studies described in this report was to evaluate the positive pressure surge reliever capability of the Grove Flexflo® Model 887 Surge Reliever Valve for hydraulic applications.

INTRODUCTION

Pressure surges are a major design concern whenever liquid flows in a closed conduit. Pressure waves exceeding the maximum hydraulic gradient of a system can be created by abrupt changes in the flow. Wave travel speed is approximately the speed of sound within the liquid. At normal temperature, water pipelines can be subjected to pressure waves traveling in excess of 4000 ft/s.

To effectively safeguard pressure conduits against positive pressure surges, any mechanism allowing fluid to be drawn off must operate at a speed approaching that of the wave speed. Optimum response is achieved by using continuous active response devices. Surge tanks and standpipes are examples. Problems arise due to the large height and volume requirements sometimes needed to achieve hydraulic stability in these free surface devices. On small systems, a safety relief valve is normally installed and the pipe stress safety factors increased.

Several general categories of pressure relief valves predominate in pipeline safety. One category utilizes the “weak link” principle. A membrane is sized to withstand a set pressure above which it fails. The membrane structures are generally placed on exit pipes teed to the main line. Inherent problems are reliability and replacement. A second common category of pressure surge reliever valves use pressure sensors to activate mechanical valves. These types of valves offer the advantages of continuous operation. However, experience has shown problems may occur in speed of operation and the long-term reliability of moving parts.

A relatively new type of pressure surge reliever valve, the Flexflo® surge reliever valve, has been developed by the Grove Valve and Regulator Company. The valve was designed to function as a rapid-activating, positive-pressure surge reliever which utilizes an elastic material as the only operating mechanism. The valve is designed to provide continuous protection against positive surge pressures.

Laboratory tests were conducted using a 4-in Model 887 Flexflo® Surge Reliever Valve furnished by the company. The 4-in relief valve was not a standard valve size manufactured by the company. It was requested specifically for testing purposes. The study was initiated to: (a) determine the valve's capability to reduce surge pressures, (b) determine the valve's response time, (c) define the valve's boot opening and closing characteristics, and (d) determine the reliability of the valve to the extent possible.

CONCLUSIONS

1. The Flexflo® surge reliever valve is capable of significantly reducing pressure amplitudes of common hydraulic transients.
2. The valve is capable of reacting to overpressure in 8 to 10 milliseconds.
3. The valve opens sharply, then closes as a function of the pressure reduction in the pipeline.
4. Although the valve testing period was of a short duration, the valve proved reliable in all laboratory tests.
5. Complex systems incorporating a relief valve or valves can be mathematically modeled to provide detailed system/valve sizing information.

APPLICATION

The valve may be considered as an alternative to other costly surge protection devices and allow a reduction in pipe head class ratings required in design of some pipelines.

RELIEF VALVE

The surge reliever tested was rated as a class 150, 275-lb/in² maximum differential valve. The valve contains a cylindrical core having two rows of slots. Slots are separated on the inside of the core by a conical barrier. Flow entering the core must pass through the first set of slots, along the barrier on the outside of the core, and back through the second set of slots into the discharge side of the valve. The valve seals along the outside surface of the cylindrical core. A flexible boot made of nitrile or other elastic material is seated between the core and the outer shell of the valve (fig. 1).

Regulation of the valve is achieved by back pressuring the valve boot using compressed gas. The valve opens when line pressure exceeds the back pressure (set pressure) applied to the boot. The degree of opening is a function of the differential pressure across the valve boot. The boot again seals against the valve core as line pressure falls below the set pressure.

The manufacturer recommends the use of a pressure regulator connected to a gas supply to maintain accurate set pressures where significant temperature fluctuations can occur. Nitrogen gas or dry air is recommended.

TEST SETUP

The surge reliever valve was tested in the hydraulic laboratory at the Bureau of Reclamation's Engineering and Research Center. The test program included surge reliever tests on two separate piping systems. First, tests were conducted using a 108.5-ft length of 4-in. i.d. thin-walled aluminum pipe. The second phase of testing used a 151.5-ft length of 6-in i.d. steel wall pipe.

Pressure surges for both test setups were created by the sudden closure of a 4-in manually operated quick closing gate valve (see fig. 2). Instrumentation read gate valve stroke, pressure upstream and downstream of a surge reliever, surge reliever jacket pressure, and steady-state discharge.

The gate stroke was recorded using an LVDT (linear variable differential transducer) connected to the gate lever arm. Pipeline pressures 5.9 ft upstream and downstream of the relief valve centerline were recorded using 500-lb/in² variable reluctance pressure cells. A four-channel strip chart recorder was used to record gate stroke and pressure data. Steady-state pipeline discharge was measured using an orifice venturi meter placed downstream of the quick closing valve.

TESTING AND RESULTS

Surge Reliever Tests — 4-in Pipeline

Figure 3 shows the test apparatus for the first phase of surge reliever tests. A 10-hp Worthington pump was used to supply water to the system. A length of 4-in i.d., 150 lb/in² class, thin-walled aluminum pipe was placed between the pump and the quick closing valve. The surge relief valve was placed on a tee section 10.0 ft upstream of the quick closing valve.

Initial steady-state pipeline discharges of 0.36, 0.72, and 0.90 ft³/s were used in the testing. For each discharge, a series of surge tests were conducted at different relief valve set pressures. Set pressures were varied from 20 to 80 lb/in² in 10-lb/in² increments. Preliminary surge tests caused axial displacements in the pipe installation of up to 2.0 in. The pipeline was then anchored securely at the quick closing valve and tied down at two intermediate locations. Pipeline movements in the downstream direction were reduced to about 0.5 in. Further anchoring was felt impractical.

Results — 4-in Pipeline

The relief valve was subject to transient pressure waves exhibiting low wave celerities and steep wave fronts. Wave celerities and shape of the wave fronts were determined from the downstream pressure transducer oscillograph records. Wave celerities in the range of 1750 to 2200 ft/s were recorded. Low wave speeds resulted partially from uncontrollable movement of the pipeline in both axial and bending modes. Slamming the quick closing valve shut produced steep linear wave fronts. Initial pressure waves at the relief valve climbed at the rate of 2.5×10^4 to 3.5×10^4 lb/in² per second depending on gate valve closure.

Relief Valve Opening and Closing Characteristics

Relief valve reaction time was defined as the time between when the surge pressure reached relief valve set pressure and the initial movement of the relief valve jacket. Displacement of the elastic jacket was determined by an increase in the jacket back pressure above set pressure. Reaction times measured by the above method ranged from 8 to 10 milliseconds. An initial cracking pressure of 4 to 5 lb/in² was required to initiate opening of the valve. Water was not wasted from the pipeline when the pressure wave amplitude failed to exceed set pressure plus cracking pressure. Figure 4 shows the relief valve operating in response to a pressure surge.

A relief valve's closing characteristics are important to ensure that relief valve closure does not create new pressure waves of significant amplitude. Oscillating or sharp closing valves are not normally desirable. The Flexflo[®] surge reliever valve exhibited a well-damped sloping decay closure in all tests. Higher frequency secondary pressure waves superimposed on the primary wave showed no short-term effects on the amount of relief valve opening.

Surge Relief Potential

Pressure surge relief was based on pressure heads measured 5.9 ft upstream and downstream of the relief valve. Space constraints of the laboratory test setup would

not allow for sufficient length between the quick closing valve and the surge reliever valve to achieve peak unrelieved surge pressure. The quick closing valve could not be fully closed before the reflected wave from the surge reliever reached the downstream pressure transducer. Therefore, the measured peak downstream surge pressure developed by the gate valve closure was lower than would be obtained for similar conditions with no relief.

Figure 5 shows the percent overpressure in the pipeline upstream and downstream of the relief valve. Pressure relief was found to be independent of pipeline discharge over the limited discharge range tested.

Following the surge reliever tests, the surge reliever valve was removed and a blind flange was installed in its place. A series of surge tests were conducted to define system response without relief valve operation. Pressure waves were created by valve closure times of 1.0, 0.5, and 0.33 seconds. Corresponding peak pressures of 125, 195, and 320 lb/in² were measured, respectively. During the second test using a valve closure time of 0.33 second, the aluminum pipe tee failed due to overpressure (see fig. 6). Gate closure times around 0.10 second were used during the prior pressure relief tests with the relief valve installed.

Surge Reliever Tests — 6-in Pipeline

The test setup using aluminum pipe was replaced with a 151.5-ft length of 6.0-in i.d. 1/8-in-thick steel wall pipe. The larger diameter was selected to permit an expanded testing range of steady-stage discharges. Figure 7 shows the test setup as modified for the second phase of testing. The supply pump was replaced with a high-head variable speed pump to increase the coverage of head and discharge available. A contraction in the pipeline was placed upstream of the quick closing valve to couple the 6-in pipe to the 4-in gate valve. The relief valve was moved to a position 22.6 ft upstream of the gate valve. Pressure cells were again placed 5.9 ft upstream and downstream of the pressure relief valve.

Results — 6-in Pipeline

Steady-state discharges of 1.0, 2.0, and 3.0 ft³/s were used in the test program. Pipeline movements resulting from the pressure surges created were less than 0.25 in. The steel pipe test apparatus yielded a wave celerity range of 3300 to 3500 ft/s. Slope of initial wave fronts at the relief valve were reduced by a factor of nearly 2.5 compared to the 4-in pipe test for similar rates of gate closure.

Relief Valve Performance

Figure 8 shows the pressure relief obtained using the 4-in Flexflo® valve on the 6-in pipeline. A reduction in the valve's performance is evident as larger demands are placed on the valve by increasing steady-state discharges. Pressure relief capacity of the valve was comparable between the two test setups for steady-state discharges of 1.0 ft³/s or lower. Although the 4-in valve reduced surge pressures when tested on pipelines carrying more than 1.0 ft³/s, the valve performance decreases as a function of line discharge. As no manufacturer-supplier pressure relief specifications are currently available for the 4-in valve, comments on recommended valve sizing cannot be made.

Manufacturer-supplied valve sizing tables are available for standard valve sizes. Valves are normally sized to handle the steady-state discharge capacity of a system. Numerical modeling of a pipeline and relief valve(s) are required to obtain closer estimates of valve response and surge pressure relief.

A numerical model of the 4-in pipeline tests is presented in the appendix. The 6-in pipeline tests were not mathematically modeled because speed characteristics for the high-head pump used were not available.

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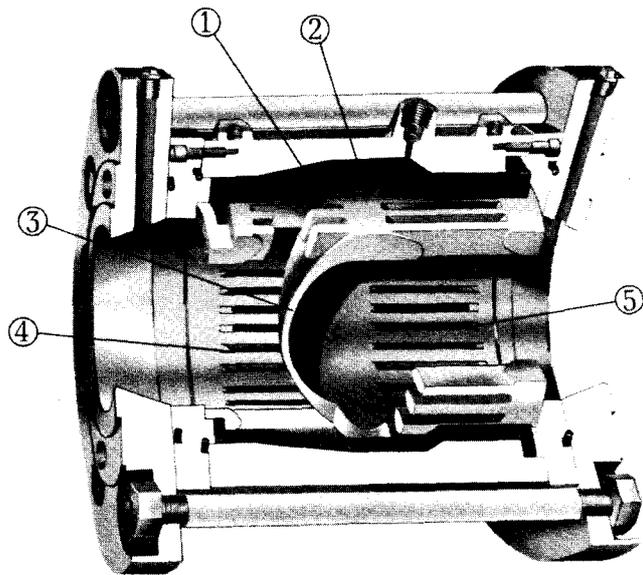


Figure 1.—Flexflo[®] Model 887 surge reliever valve, (1) elastic boot, (2) valve seat, (3) valve core, (4) inlet slots, and (5) outlet slots. (Drawing courtesy of Grove Valve and Regulator Company). Photo No. P-801-D-80323.

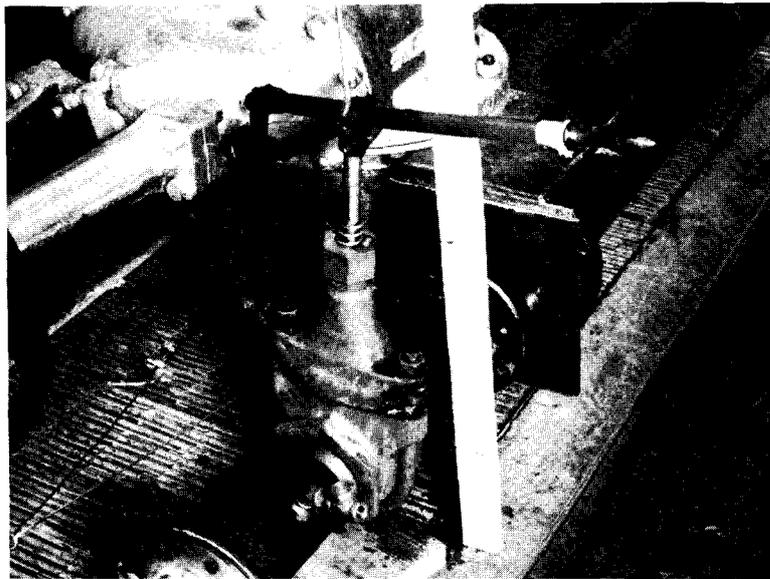


Figure 2.—Quick closing gate valve. Photo No. P-801-D-80324.

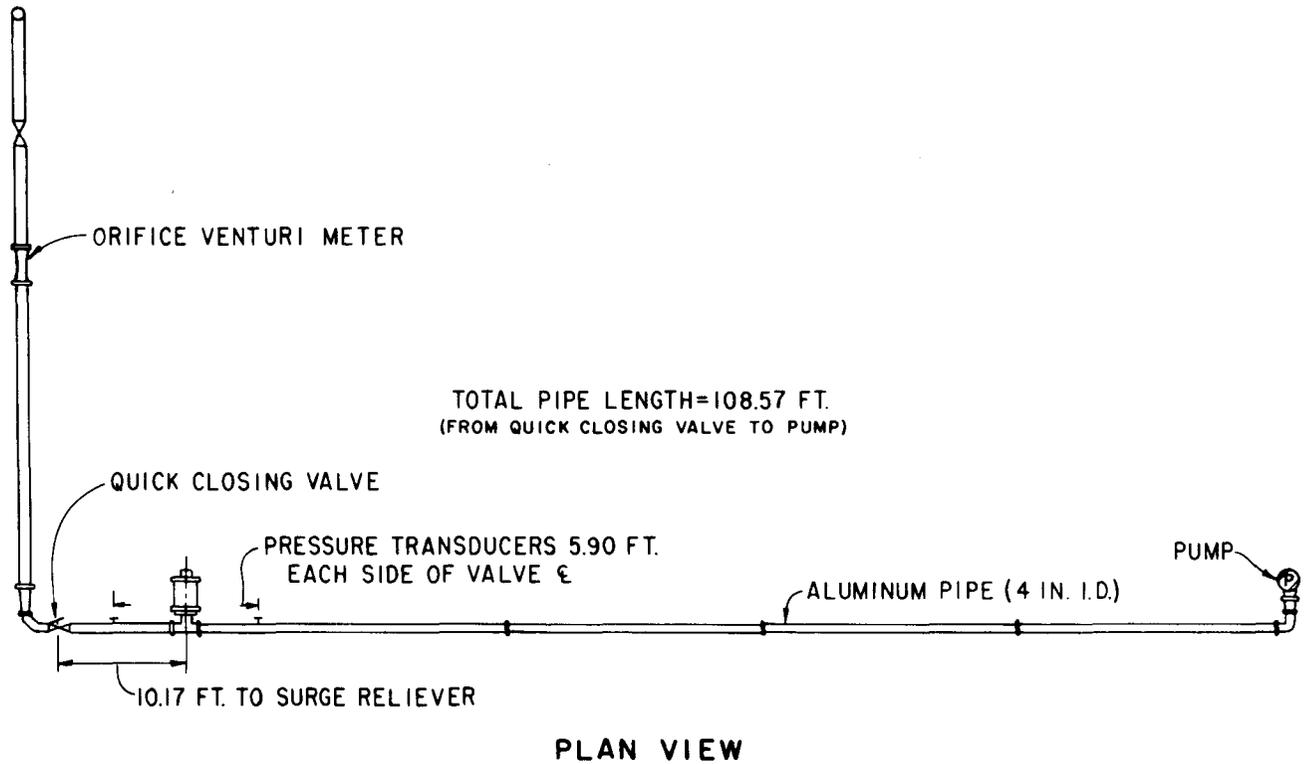


Figure 3.—Test apparatus for first phase of tests using 4-in-diameter pipeline.

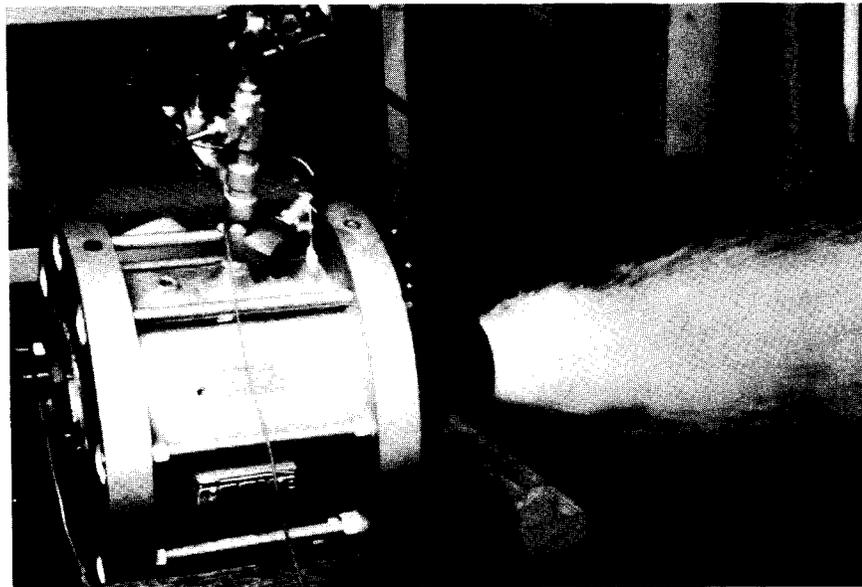


Figure 4.—Water discharge through relief valve. Photo No. P-801-D-80325.

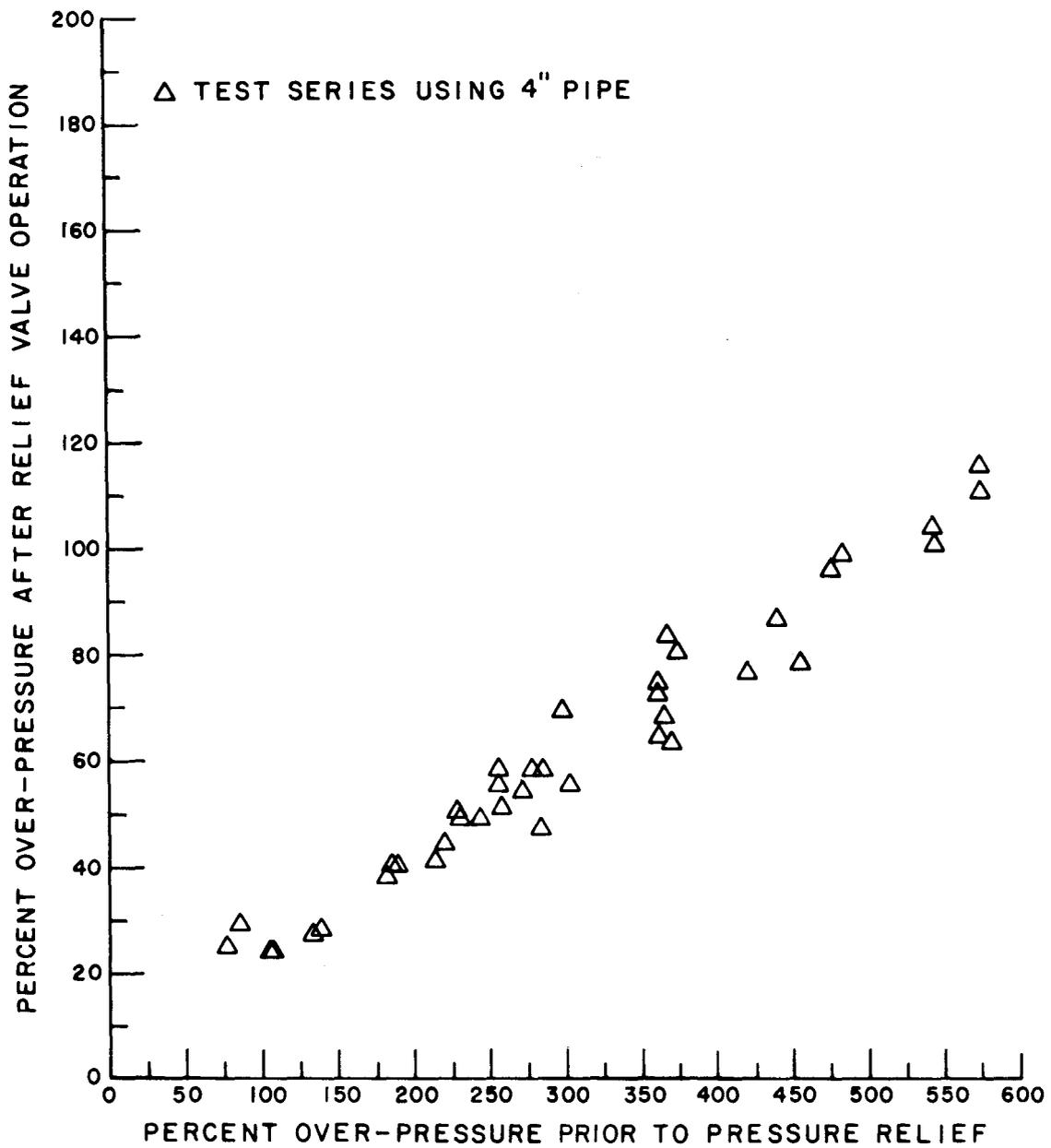


Figure 5.—Pressure relief — 4-in. pipe test series.

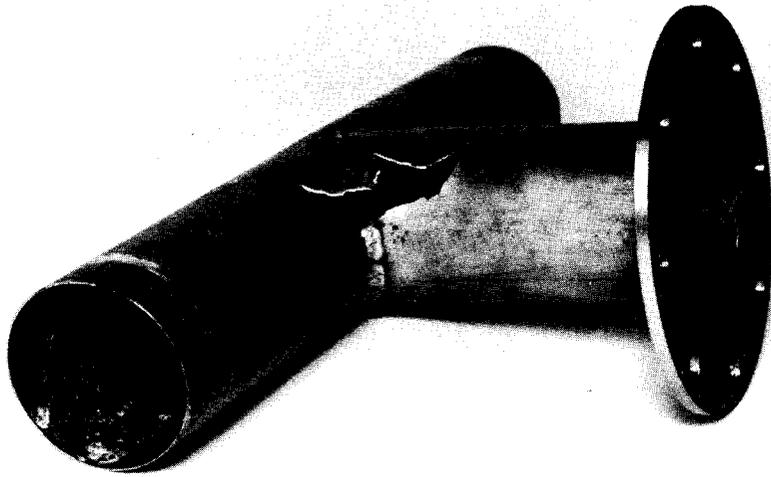


Figure 6.—Unrelieved surge pipe failure on 4-in pipeline.
Photo No. P-801-D-80326.

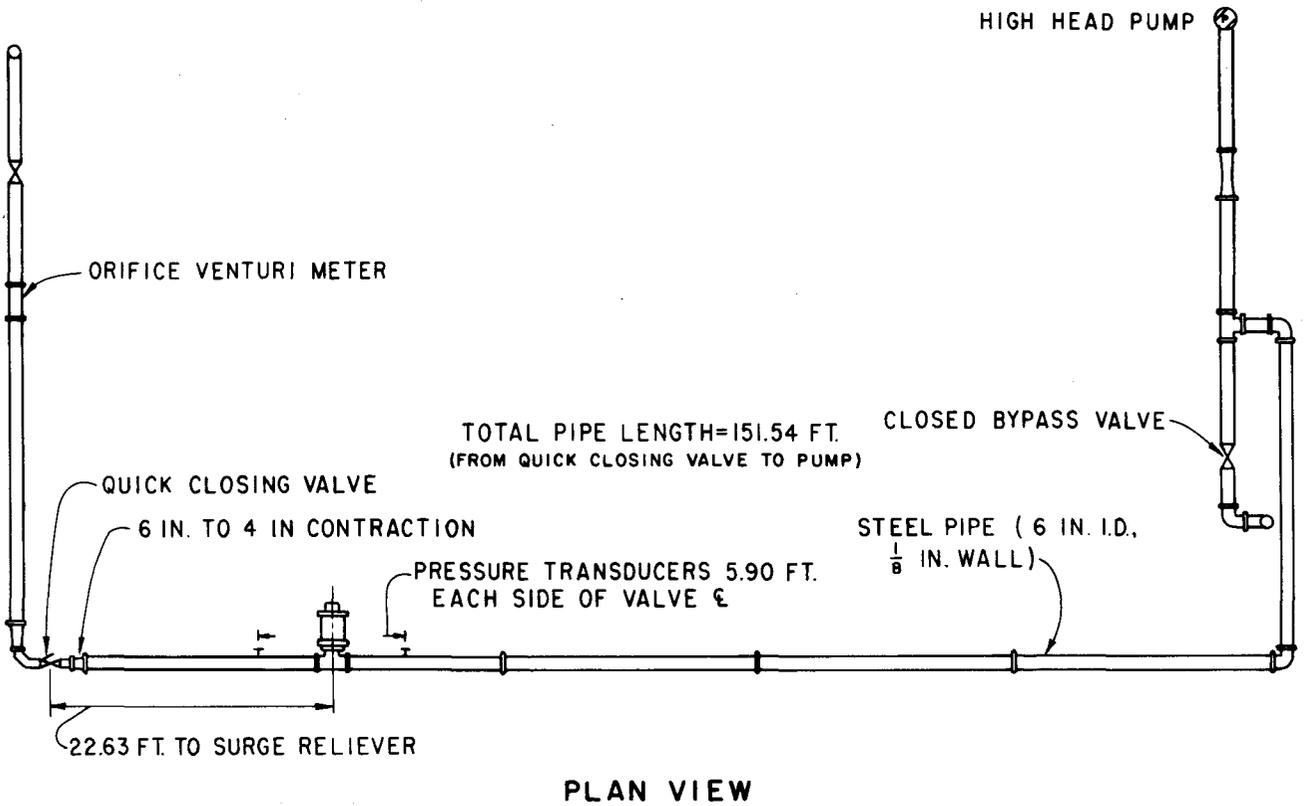


Figure 7.—Test apparatus for second phase of tests using 6-in-diameter steel pipe.

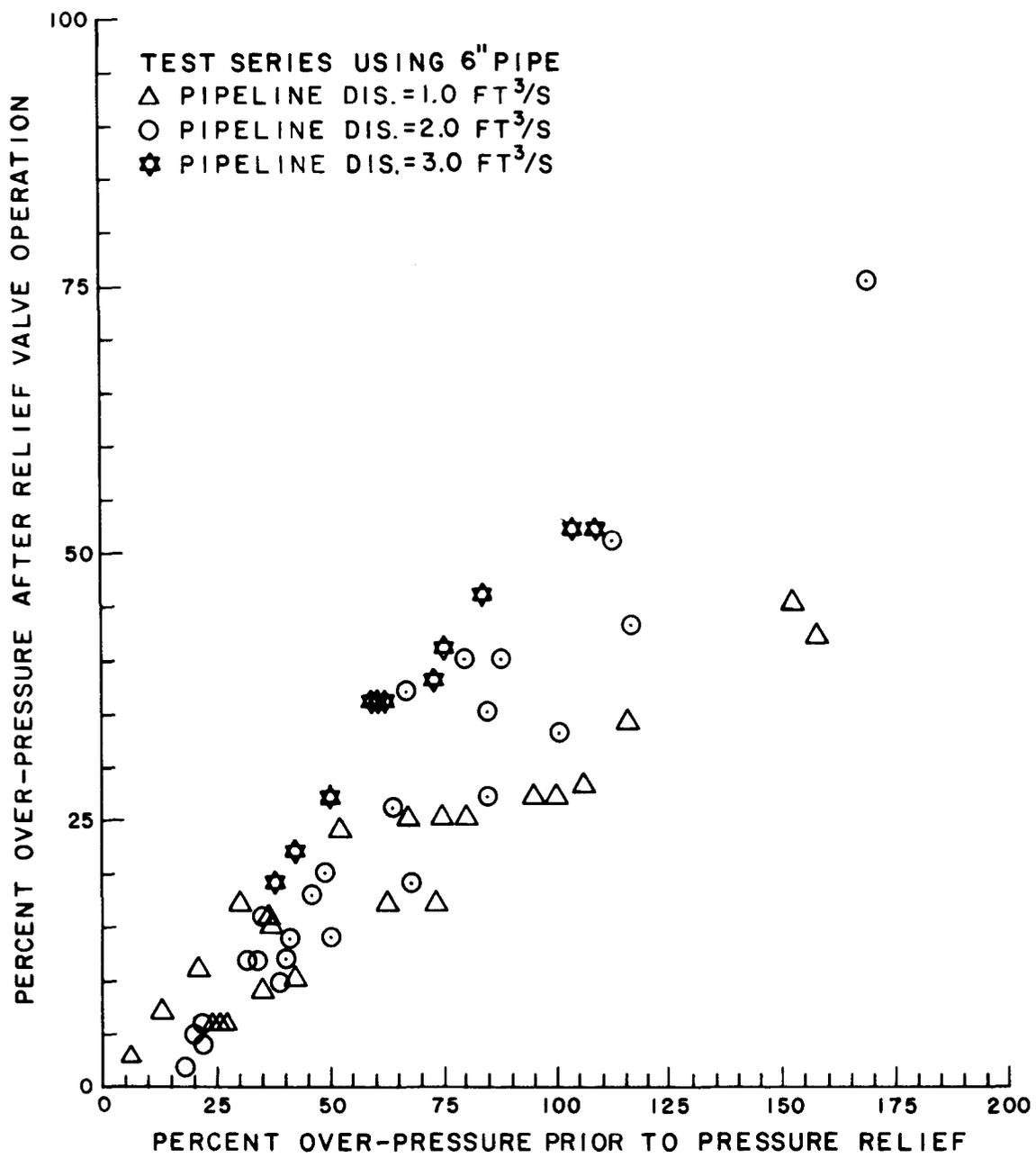


Figure 8.—Pressure relief — 6-in. pipe test series.

APPENDIX

NUMERICAL MODEL

A simplified mathematical simulation model of the initial test setup was developed. Valve characteristics measured in the laboratory tests were used to define the model boundary conditions. Transients were modeled numerically by the method of characteristics. Pump measurements in the second quadrant, dissipation zone, were extrapolated from information available on similar pumps of higher specific speeds.

Two basic considerations were used to define the boundary conditions of the relief valve. A delay in the valve response was defined similar to the measured laboratory component. The discharge through the valve was then determined by an iterative approach to obtain a simultaneous solution to the valve discharge equation and the characteristic equation for the head at the valve. Due to the sharp wave fronts measured in the laboratory tests, nodes were placed at 1.25 ft intervals.

The manufacturer specifies flow through Flexflo® surge reliever valves as:

$$Q = F(P_S)^{0.5}$$

where: Q = discharge through the valve (gal/min)

F = a manufacturer-supplier flow factor

P_S = valve set pressure (lb/in²)

An equation defining the flow factor was not available for the 4-in valve size. Flow factors supplied for similar 12-, 10-, 8-, and 6-in relief valves were used to estimate the 4-in valve flow factor for use in the math model. Flow factor for the 4-in valve was estimated as:

$$F = 20[(P_R/P_S) \times 100]^{0.56}$$

where: P_R = allowable pressure use above set pressure (lb/in²)

P_S = set pressure (lb/in²)

To simplify the model, three primary assumptions were made: (1) a rigid pipe system, (2) uniform head loss across the relief valve tee branch, and (3) a linear rate of gate valve closure.

The numerical model and laboratory data on the 4-in pipe tests are shown on figure A-1. Under the assumptions used in the model, pressure relief values obtained from the numerical model were comparable, although generally lower than laboratory data (figs. 4 and A-1). Better correlation between the math model and physical model could be expected if estimates of flow factor and rate of gate closure were refined.

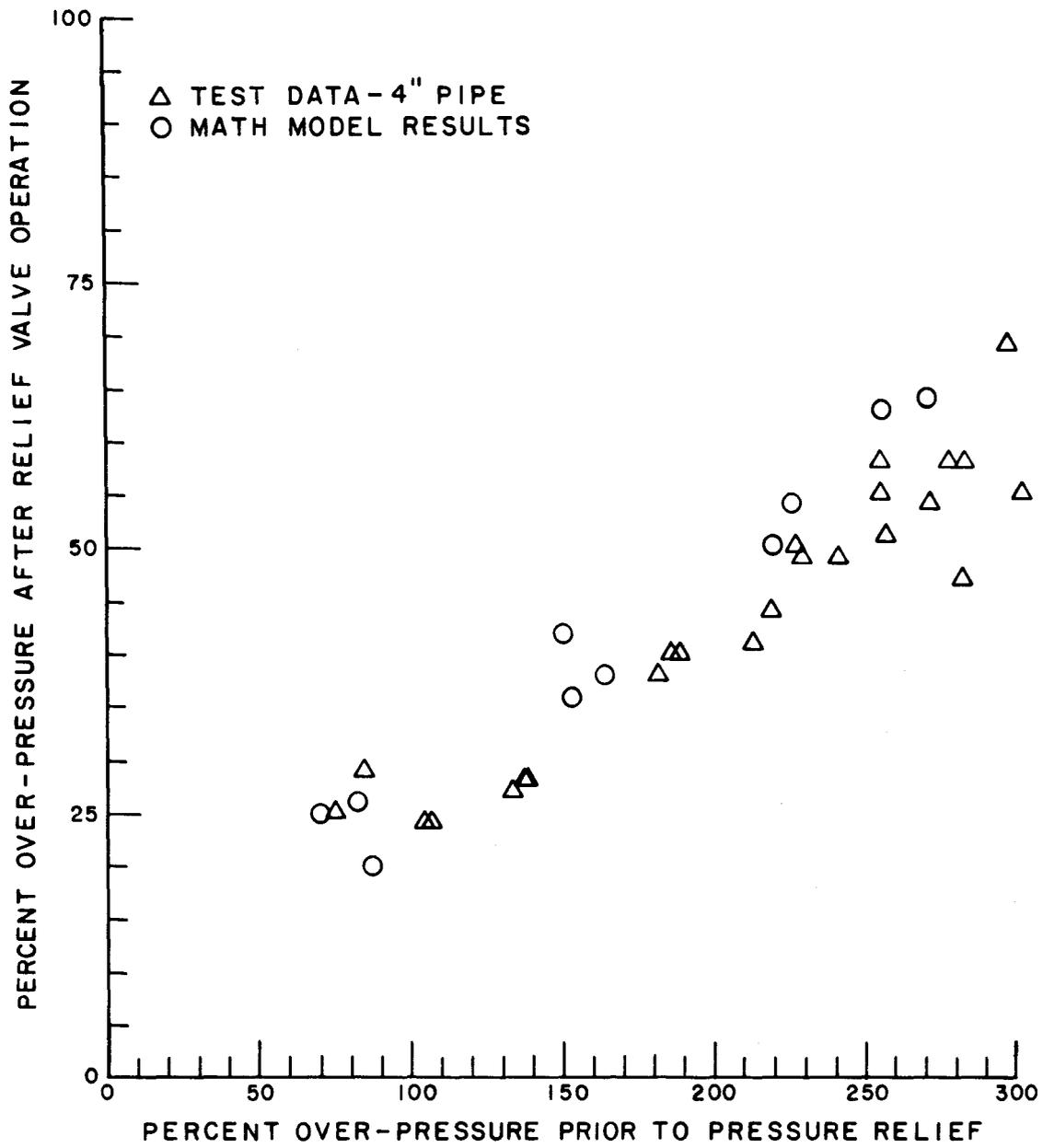


Figure A-1. — Comparison of numerical model and physical model results for pressure relief on a 4-in pipe.

```

1      PROGRAM HAMMER (INPUT,OUTPUT,TAPE5,TAPE6=OUTPUT,TAPE7,TAPE10)
      C WATER HAMMER ANALYSIS WITH WORTHINGTON 10HP PUMP UPSTREAM BOUNDARY
      C AND A QUICK CLOSING VALVE AS THE DOWNSTREAM BOUNDARY
      C THE TRANSIENT IS CAUSED BY THE VALVE CLOSURE WHILE THE PUMP IS STILL
5      C IN OPERATION
      DIMENSION Q(80),QP(80),H(80),HP(80),Q2(2),H2(2),QP2(2)
      DIMENSION HP2(2),WH(72)
      DIMENSION Q1(9),QP1(9),H1(9),HP1(9)
10     DATA WH/ -1.623, -1.342, -1.098, -0.823, -0.589, -0.353, -0.143, 0.107,
      10.310, 0.500, 0.810, 0.860, 0.890, 0.928, 1.141, 1.424, 1.636, 1.837,
      21.984, 2.085, 2.158, 2.176, 2.223, 2.313, 2.385, 2.533, 2.593, 2.704,
      32.714, 2.850, 2.949, 3.049, 3.034, 2.879, 2.739, 2.54, 2.041, 1.934, 1.801,
      41.647, 1.470, 1.281, 1.081, 0.833, 0.685, 0.500, 0.317, 0.141, 0.082,
15     50.030, -0.136, -0.197, -0.418, -0.488, -0.553, -0.750, -0.935, -0.961,
      6-0.923, -0.937, -1.037, -1.233, -1.545, -1.749, -1.849, -2.005, -2.147,
      7-2.275, -2.281, -2.299, -2.207, -2.039, -1.862/
      DATA PI,G,DX,FM/3.1416,32.2,0.0873,1.0/
      DATA N,TD/79,0.0/
      DATA K,JPR,QT/0,1,0.0/
20     DATA XL,D,F,A,RN,RO/98.0,3.9,0.035,1800.0,5200.,5200./
      PRINT*, " ENTER THE AMOUNT OF TIME PRIOR TO VALVE ACTION"
      READ*, SS
      PRINT*, " ENTER THE FOLLOWING PUMP CHARACTERISTICS"
      PRINT*, " RATED HEAD, INITIAL HEAD"
25     READ*, HR,HO
      PRINT*, " RATED DISCHARGE, INITIAL DISCHARGE"
      READ*, QR,QO
      PRINT*, " ENTER THE TIME OF VALVE CLOSURE, MAXIMUM COMPUTER RUN
30     1TIME, AND INITIAL STARTING TIME"
      READ*, TC, TM, T
      PRINT*, "ENTER THE SET PRESSURE, COEFFICIENT OF DISCHARGE"
      READ*, PS, CD
      D=D/12.0
      DT=XL/(A*FLOAT(N))
35     AR=.7854*D*D
      R=F*A*DT/(2.*G*D*AR*AR)
      B=A/(G*AR)
      C STEADY STATE
      V=QO/QR
40     AL=RO/RN
      WRITE (7,300) N,XL,A,D,F,TC, TM, HO, QO, V, AL, PS
300  FORMAT (1H1,26H THE PARAMETERS ARE NOW... /8H N = I10/
18H XL = F10.2/8H A = F10.2/8H D = F10.2/8H F = F10.5/
28H TC = F10.2/8H TM = F10.2/8H HO = F10.2/8H QO = F10.2/
45     38H V = F10.2/8H AL = F10.2/8H PS = F10.4)
      C FINDING THE CORRECT VALUES OF WH AND WB
      I=(PI+ATAN2(V,AL))/DX+1
      N1=N+1
      H(1)=HO
      Q(1)=QO
50     DO 40 I=2,N1
      Q(I)=QO
40     H(I)=HO-(FLOAT(I)-1.0)*R*QO*ABS(QO)
      DO 41 I=1,9
55     H1(I)=H(N1)-(FLOAT(I)-1.0)*R*QO*ABS(QO)
41     Q1(I)=QO
      DO 42 I=1,2

```

```

        H2(I)=H(N1)
        Q2(I)=0.0
60      42  CONTINUE
        CVP=.5*Q0*Q0/H1(9)
        TA=1.0
        VO=V
        VOO=V
65      WRITE (7,301)
301  FORMAT (1X,/1X,53HEADS AND DISCHARGES AT 1.24 FT. INT. ALONG THE
        1PIPE ,/4X,23HTIME  TAU  NODE=  16,8X,2H32,6X,2H48,7X,2H64,7X
        2,2H75,7X,2H80,5X,4H1(1),5X,4H1(6),5X,4H1(9),5X,4H2(2),5X,2HQT)
70      50  WRITE (7,302) T,TA,(H(I),I=16,64,16),H(75),H(80),H1(1),H1(6),H1(9)
        1,H2(2),(Q(I),I=16,64,16),Q(75),Q(80),Q1(1),Q1(6),Q1(9),Q2(2),QT
302  FORMAT (1X,2F7.3,2X,3H H=,10F9.2/17X,3H Q=,11F9.3)
C      END OF STEADY STATE
60  T=T+DT
75      IF (T-TM) 65,65,150
        65  K=K+1
        CM=H(2)-Q(2)*(B-R*ABS(Q(2)))
        IF (T.LE.SS) GO TO 70
        IF ((T-SS)-TC) 68,69,69
80      68  TA=(1.0-((T-SS)/TC))**FM
        CV=TA*TA*CVP
        GO TO 70
        69  TA=0.0
        CV=0.0
C      PUMP BOUNDARY CONDITION
85      70  V=2.*VO-VOO
        X=PI+ATAN2(V,AL)
        I=X/DX+1
C      BALANCE OF HEAD AND TORQUE
90      80  A1=(WH(I+1)-WH(I))/DX
        AO=WH(I+1)-A1*I*DX
        DO 90 KI=1,5
        F1= HR*(AL**2+V*V)*(AO+A1*X)-(CM+B*QR*V)
        F1V= HR*(2.*V*(AO+A1*X)+AL*A1)-B*QR
        DV=-F1/F1V
95      V=V+DV
        X=PI+ATAN2(V,AL)
        IF (ABS(DV).LE.0.0001) GO TO 100
        90  CONTINUE
100     100  II=X/DX+1
        IF (II.EQ.I) GO TO 110
        I=II
        GO TO 80
C      UPSTREAM BOUNDARY CONDITION
105     110  VOO=VO
        VO=V
        QP(1)=V*QR
120     HP(1)=CM+B*QP(1)
C      BRANCHING PIPE BOUNDARY CONDITION
110     CPN1=(H(N)+Q(N))*(B-R*ABS(Q(N)))
        CM1=(H1(2)-Q1(2))*(B-R*ABS(Q1(2)))
        CM2=(H2(2)-Q2(2))*(B-R*ABS(Q2(2)))
        HP(N1)=.33333*(CPN1+CM1+CM2)
        HP1(1)=HP(N1)
        HP2(1)=HP(N1)

```

```

115      QP(N1)=(-HP(N1)+CPN1)/B
          QP1(1)=(HP1(1)-CM1)/B
          QP2(1)=(HP2(1)-CM2)/B
      C   FLEXFLO BOUNDARY CONDITION
          IF(TD.GT.O.015.AND.Q2(2).EQ.O.O)STOP
120      CP2=H2(1)+Q2(1)*(B-R*ABS(Q2(1)))
          HP2(2)=CP2
          IF(HP2(2).GT.PS*2.3)TD=TD+DT
          IF(TD.LE.O.0045)GO TO 259
          IF(HP2(2).GT.PS*2.3)HT=HP2(2)
125      IF(HP2(2).GT.PS*2.3)GO TO 260
          259 QP2(2)=O.O
          GO TO 271
          260 TT=(HT-CP2)/B+O.029*CD*PS**(-O.O6)*(HT/2.3-PS)**O.56
          IF(ABS(TT).LE.O.OO1)GO TO 270
          IF(TT.GT.O.OO1)GO TO 265
          IF(TT.LT.-O.OO1)GO TO 267
130      265 DO 266 J=1,5
          IF(TT.GT.10./(10.**(J-1)))HT=HT-(10./(10.**(J-1)))
          IF(TT.GT.10./(10.**(J-1)))GO TO 260
135      266 CONTINUE
          267 DO 268 J=1,5
          IF(TT.LT.-(10./(10.**(J-1))))HT=HT+(10./(10.**(J-1)))
          IF(TT.LT.-(10./(10.**(J-1))))GO TO 260
          268 CONTINUE
          GO TO 260
140      270 HP2(2)=HT
          QP2(2)=CD*O.029*PS**(-O.O6)*(HP2(2)/2.3-PS)**O.56
      C   DOWNSTREAM BOUNDARY CONDITTION
145      271 CP=H1(8)+Q1(8)*(B-R*ABS(Q1(8)))
          QP1(9)=-CV*B+SQRT(CV*CV*B*B+CV*CP*2.O)
          HP1(9)=CP-B*QP1(9)
          IF (T.LE.SS) HP1(9)=H1(9)
          IF (T.LE.SS) QP1(9)=QP1(1)
      C   INTERIOR POINTS
150      125 DO 130 I=2,N
          CP=H(I-1)+Q(I-1)*(B-R*ABS(Q(I-1)))
          CM=H(I+1)-Q(I+1)*(B-R*ABS(Q(I+1)))
          HP(I)=.5*(CP+CM)
          130 QP(I)=(HP(I)-CM)/B
          DO 131 I=2,8
155      CP=H1(I-1)+Q1(I-1)*(B-R*ABS(Q1(I-1)))
          CM=H1(I+1)-Q1(I+1)*(B-R*ABS(Q1(I+1)))
          HP1(I)=.5*(CP+CM)
          131 QP1(I)=(HP1(I)-CM)/B
160      DO 140 I=1,N1
          Q(I)=QP(I)
          140 H(I)=HP(I)
          DO 145 I=1,9
          Q1(I)=QP1(I)
          H1(I)=HP1(I)
165      145 CONTINUE
          DO 147 I=1,2
          Q2(I)=QP2(I)
          H2(I)=HP2(I)
170      147 CONTINUE
          QT=QT+Q2(2)*DT*62.4

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IF(K/JPR*JPR.EQ.K) GO TO 50
GO TO 60
150 STOP
END

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Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

When Congress authorized the reclamation of arid and semiarid lands in the West with the Reclamation Act of 1902, the Secretary of the Interior established the Reclamation Service within the United States Geological Survey. In 1907, the Reclamation Service became an independent agency within the Department of the Interior. By action of the Secretary of the Interior in 1923, the Reclamation Service became the Bureau of Reclamation. In November 1979, the name was changed to the Water and Power Resources Service by Secretarial Order, and in May 1981, the Secretary of the Interior changed the agency's name back to the Bureau of Reclamation.

A free pamphlet is available from the Bureau entitled "Publications for Sale." It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-922, P O Box 25007, Denver Federal Center, Denver CO 80225-0007.