HYDRAULICS BRANCH
OFFICIAL FILE COPY

PAP-485

BUREAU OF RECLAMATION
HYDRAULICS BRANCH

OFFICE FILE COPY

When Borrowed, Return Promptly

TAYLOR PARK NEEDLE VALVE TESTS

BY

[redacted]

T. J. Isbester

PAP-485

PAP-485
D-1531
PAP file
~~PAP-48~~

Form DFC-11
(12-61)
Bureau of Reclamation

INFORMATIONAL ROUTING

Memorandum
Chief, Division of Water and Land Technical Services

Denver, Colorado
October 4, 1985

FOR Chief, Division of Research and Laboratory Services

Hydraulic Tests of Taylor Part 48-in Interior Differential Needle Valve (Memorandum from Chief, Division of Water and Land Technical Services, Subject: Needle Valve Investigation, dated March 21, 1985)

The attached report describes tests performed on the No. 2 needle valve at Taylor Park Dam to determine operating chamber pressures.

The data collected in this study provide valuable background information to assess operating characteristics of interior differential needle valves at other Bureau of Reclamation structures.

GPO 852320

W. R. [illegible]

Attachment

Copy to: D-1530
D-1531 (PAP file)
D-1532
D-1532 (Isbester)
D-430
D-252
D-400
D-250
(with attachment to each)

CAPugh:flh

Taylor Park Needle Valve Tests

T. J. Isbester

October 1, 1985

PAP-485

Taylor Park Needle Valve Tests

The tests were conducted during the week of May 20, 1985, to provide information on needle valve internal opening and closing chamber pressures when the valve is operated through out its range of travel. The reservoir water surface was at elevation 9300.30. A travel report describing the tests is attached. The valve used for the tests was a paradox controlled 48-in interior differential needle valve similar in design to the Bartlett valve which failed causing a loss of life. The Taylor Park valve has been in service since 1937, but was modified with a converging nozzle seat in the early 1950's (appendix figure 1A). The right valve (No. 2) was used for the tests. A drawing of an interior differential needle valve is attached to this report for reference (appendix figure 2A).

Prior to testing, the valve was equipped with model EEP 300-S sight glass flow indicators, Armstrong model 2AV float type air vent valves, and Durable external inline check valves on the opening and closing chamber vent lines. The valve body vent line was also equipped with a model EEP 300-S sight glass flow indicator and an Armstrong model 2AV float type air vent valve.

The tests were performed in 2 phases. The first phase consisted of operating the valve with a dry conduit through opening and closing cycles for friction evaluation. The second phase was performed with the conduit watered up, the guard gate fully open, and flow through the valve to obtain dynamic loading. Limited additional testing was performed to investigate effects of opening bleed valves, changing position, and to obtain forces necessary to maintain the needle in a fixed position.

Instrumentation

Pressure transducers were installed on the opening (VO) and closing (VC) chamber vent lines, and in the opening (PO) and closing (PC) chamber flow passages just above the paradox valve flange. The valve flow passage vent line also was equipped with a pressure transducer. The valve position pointer on the control pedistal was fitted with a bracket containing a potentiometer to provide needle position.

A four channel oscillograph was used to record opening and closing chamber vent line pressures and opening and closing chamber flow passage pressures above the paradox valve flange. A two channel oscillograph was used to record valve position and valve flow chamber pressures. An electrical intertie between the two recorders was achieved through a switch attached to event markers, which produced a simultaneous mark on both oscillograph records when activated.

Phase I Opening and Closing Cycles (Conduit Dry)

These tests were used to obtain pressures required to operate the needle valve through out its range of travel. The pressure data, when applied to effective areas of the opening and closing chambers provides the resultant force necessary to move the needle at a constant rate of travel. This force overcomes the internal friction in the valve. While hand wheel operation of the valve does not lend itself to a constant travel rate, the data indicated that the rate was sufficiently constant to provide good results. Figures 1, 2, 3, and 4 are graphs of the pressures at the transducer locations versus time of travel. All pressures were referenced to the centerline elevation of the valve. The needle position is shown above the data on the graphs in increments of 10 percent of total travel. Figures 1 and 3 are opening cycles, and figures 2 and 4 are closing cycles. The differences between identical tests (figure 2 vs. figure 4) are probably due to variations in hand wheel operation.

Figures 5, 6, 7, and 8 are graphs of the force on the needle with the conduit unwatered. A closing force was defined as negative. The area of the opening chamber was 837.23 in^2. The area of the closing chamber was 2665.69 in^2. Therefore, the ratio of closing chamber area to opening chamber area was 3.18 to 1.

With the valve chambers watered up and pressurized to the invert elevation of the gooseneck piping, a net closing force of 1,797 pounds would occur on the needle.

<u>Phase II Opening and Closing Cycles (Flow through the valve)</u>

Once the force necessary to operate the valve in the dry had been obtained, the only remaining force needing to be determined is the hydrodynamic force resulting on various portions of the valve. The major dynamic force occurs at the downstream end of the needle and results from turning the flow from radially inward to directly downstream. This force is in the upstream direction. Another surface which is subjected to dynamic pressure loading is the annular ring of the outer body of the needle which has a nominal area of 234.44 in^2. Dynamic force from flow through the valve is in the downstream direction. The downstream portion of the needle in the vicinity of the needle seal ring may be subjected to negative pressure at some openings which would produce a force on the needle in the downstream direction. At other openings this force tends to oppose the force from the annular ring. Separation of these individual forces to define the magnitudes is impossible.

Three series of opening and closing cycle tests were performed for Phase II. Opening limits utilized were 25 percent 50 percent and 100 percent. The tests went smoothly and no adverse conditions were noted. Pressures versus time for these tests are shown on figures 9, 10, and 11. Incremental needle position is shown on the graphs above the pressure data. Figures 12, 13, and 14 contain the needle force information for the three opening limit tests.

<u>Additional Tests</u>

Some additional records were obtained to provide operational pressure information. Data were taken while moving the valve from one fixed intermediate position to another. Figure 15 shows the changes in pressure required to accomplish a change from a 25 percent opening to a 50 percent opening. The force difference between opening and closing chambers is shown in figure 16. Two sets of data are shown on figure 16, as the opening chamber vent transducer was inadvertently wetted during a purging operation.

The frictional force was evaluated from the dry opening and closing cycle tests. The data covers travel rates which provide for full travel in 1.5 to 2.5 minutes. The friction force versus travel rate data are shown on figure 17. The difference between opening and closing friction may be due to internal leakages.

The effects of the hydraulic forces acting on the needle are shown in figure 18. In this figure, dry opening and closing cycles are compared with opening and closing cycles with flow through the valve. The pressure data indicates a reversal in the direction of the force on the needle when the valve is about 20 percent open. This reversal is probably due in part to the negative pressure on the needle in the vicinity of the seat, tending to pull the needle toward the closed position. Also, contributing to the closure tendency may be the pressure acting on the upstream surface of the annular ring on the outer body of the needle.

The force required to maintain the needle in a fixed position is shown in figure 19. The reversal of hydraulic forces at about 20 percent valve opening is also apparent in this figure. At 100 percent opening, the needle is against a stop and the force is not significant.

The reversal of thrust at small-openings is quite significant. The Taylor Park nozzle seat was modified in the 1950's to minimize the low pressure area on the needle. The original nozzle seat contained a short radius curve which would tend to further reduce needle pressure. A number of valves such as the Bartlett valves still leave the original flare, and force reversal may be more pronounced. The most important factor for safe operation is to make small - slow changes when the valve is below a 20 percent opening. The seat position should always be approached slowly. The internal porting of the valve is arranged to restrict flow out of the opening chamber as the closed position is approached.

Manual venting of the opening and closing chambers while the valve is in operation should be accomplished with caution. Normally this should not be required if the valve is equipped with automatic air vents as the Taylor Park valve was. These vents functioned very well, bleeding small quantities of air when air was present. Long term sustained operation was not addressed during the Taylor Park tests.

If air becomes visible in either opening or closing chamber sight glasses after long periods of operation at fixed openings, the handwheel should be moved slightly in the direction of the chamber side with the visible air. This will displace the paradox piston slightly and will provide flow to purge the air but not sufficient force to overcome friction and move the needle. The venting will occur through the automatic air vent.

Conclusions

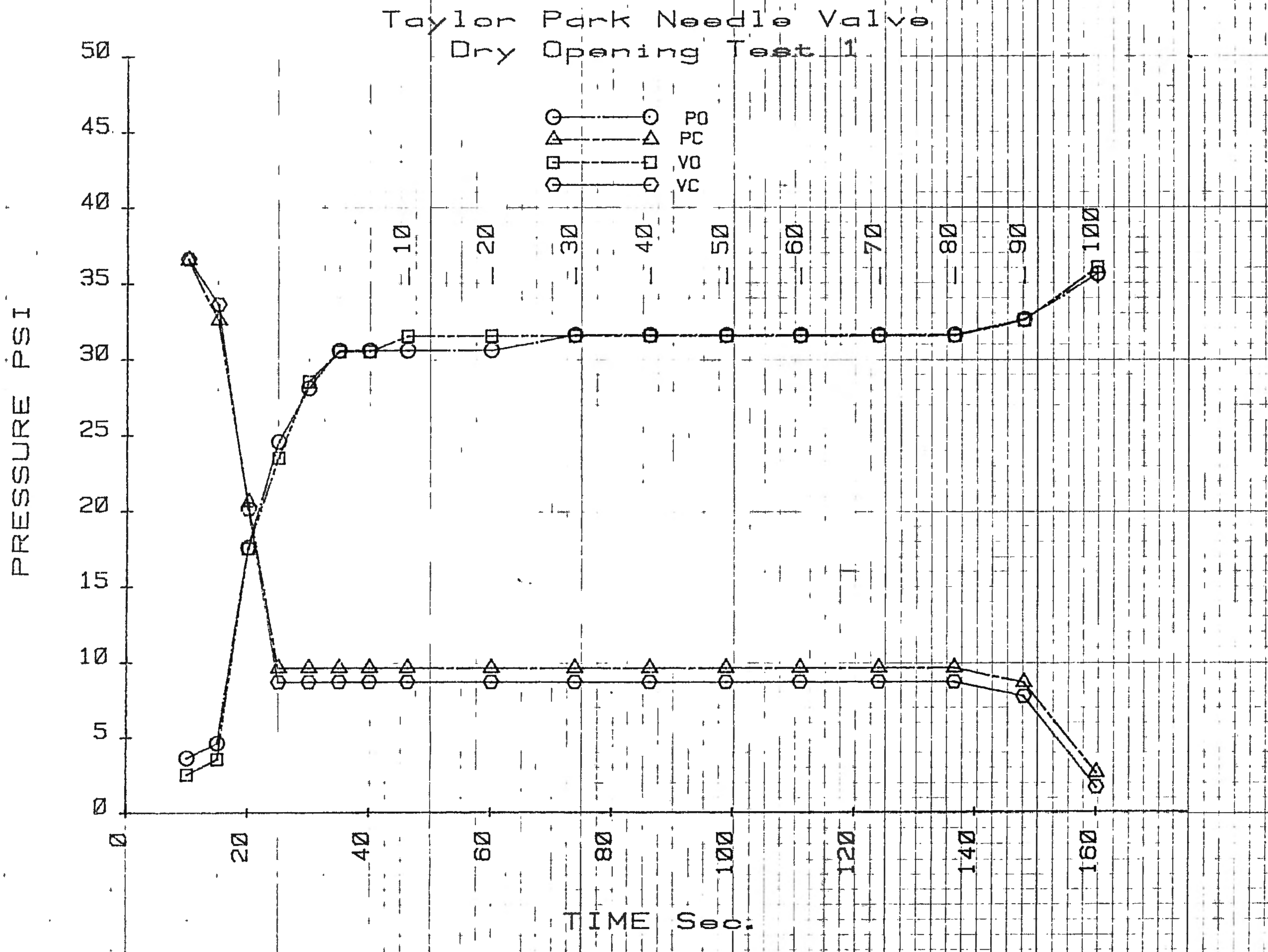
Extreme caution should always be observed when operating an interior differential needle valve. While this study did not address mechanical failures of components within the valve or in the paradox control valve, following the operating instructions in a step by step fashion will minimize the potential for damage to the structure or loss of life.

Both the needle valve and the paradox control valve require a good deal of careful maintenance at periodic intervals. Water quality can heavily influence the maintenance intervals. During maintenance tolerances must be checked and if excessive deviations are present, components should be returned to original specification. Excessive tolerances can increase leakage and reduce the retarding action of the water resulting in a higher rate of needle travel if mechanical failure occurs. The internal flow passages, vent ports and vent lines in the valve should be carefully inspected and scale should be thoroughly removed.

The most important considerations to minimizing operational dangers are to thoroughly purge all air from the opening and closing chambers of the valve before placing the valve in service, and maintaining the chambers full of water during all operation. The gooseneck air vent should be wide open and free of scale to prevent siphon action from lowering the water level in the operating chambers. The gooseneck by-pass valve should never be left open since the elevation of the gooseneck ensures that the operating chambers are full of water and contain no air. If mechanical failure should occur with fully-watered up chambers the transfer of water from one chamber to another, or from chamber to drain, will retard the rate of movement of the needle and minimize the slamming tendency.

The automatic air vent system placed on the Taylor Park valve will eliminate the possibility of an operator forgetting to purge air from the operating chambers and in addition will provide the means of continuously purging air which may come out of solution due to temperature and pressure changes during long term sustained operation.

Operators should be aware of the reversal of force on the needle at small openings and should make small, slow adjustments to the handwheel when approaching the closed position.



Taylor Park Needle Valve
Dry Opening Test 1
PO
PC
VO
VC
PRESSURE PSI
TIME Sec.
0
5
10
15
20
25
30
35
40
45
50
20
40
60
80
100
120
140
160
10
20
30
40
50
60
70
80
90
100

Figure 1

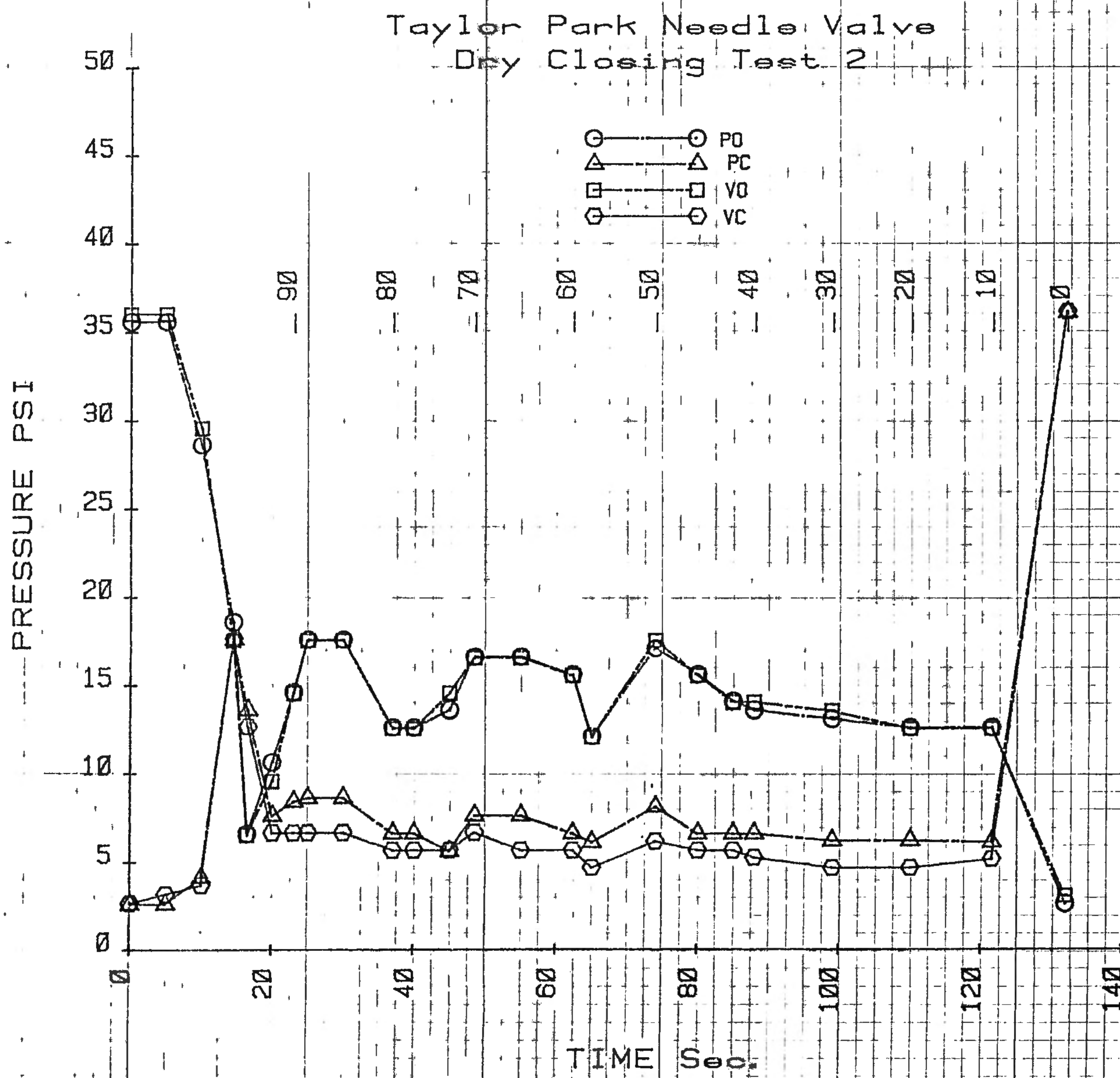

Taylor Park Needle Valve
Dry Closing Test 2
PO
PC
VO
VC
PRESSURE PSI
TIME Sec.

Figure 2

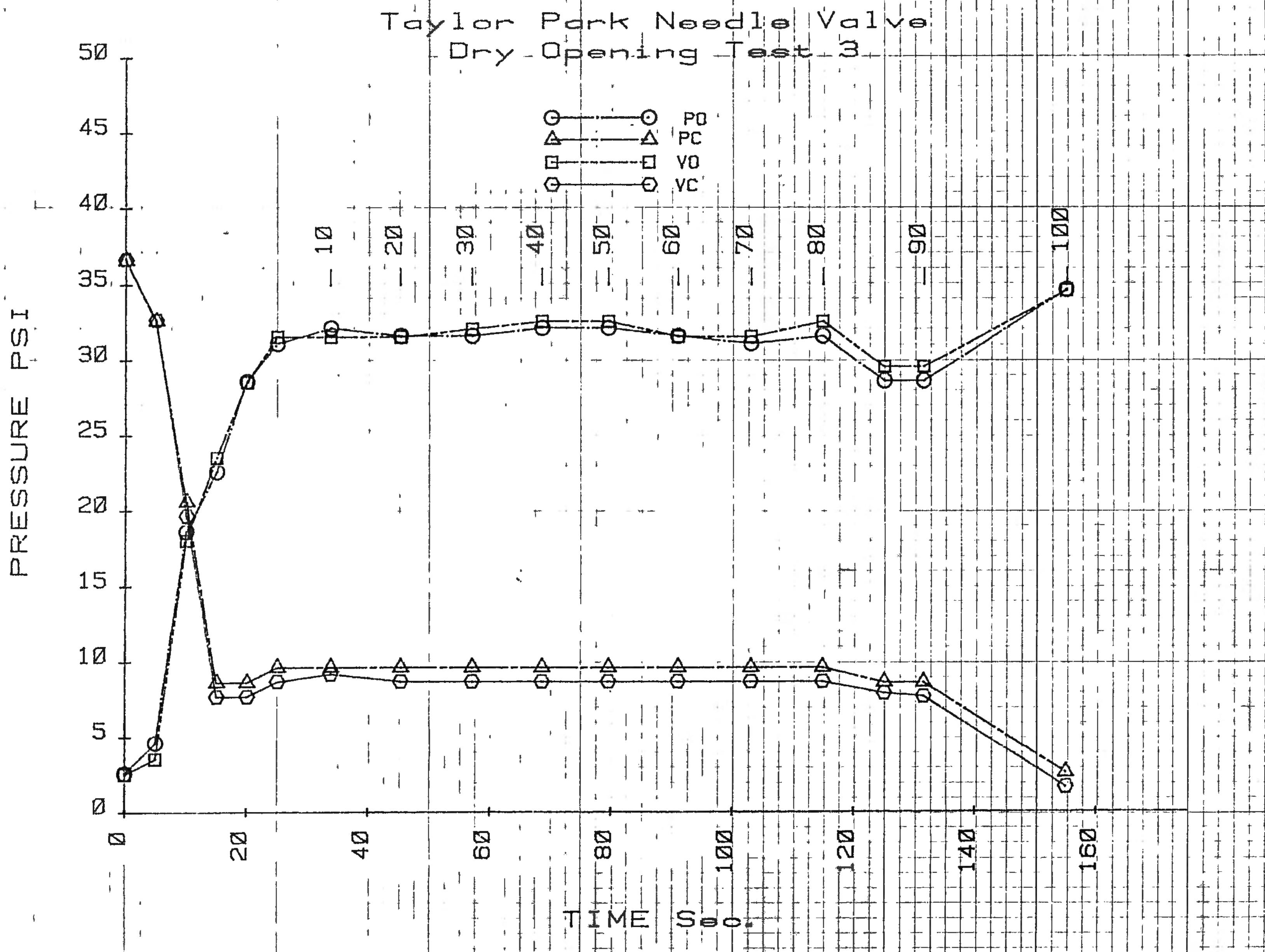

Taylor Park Needle Valve
Dry Opening Test 3
PO
PC
VO
VC
PRESSURE PSI
TIME Sec.
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
140
160
10
20
30
40
50
60
70
80
90
100

Figure 3

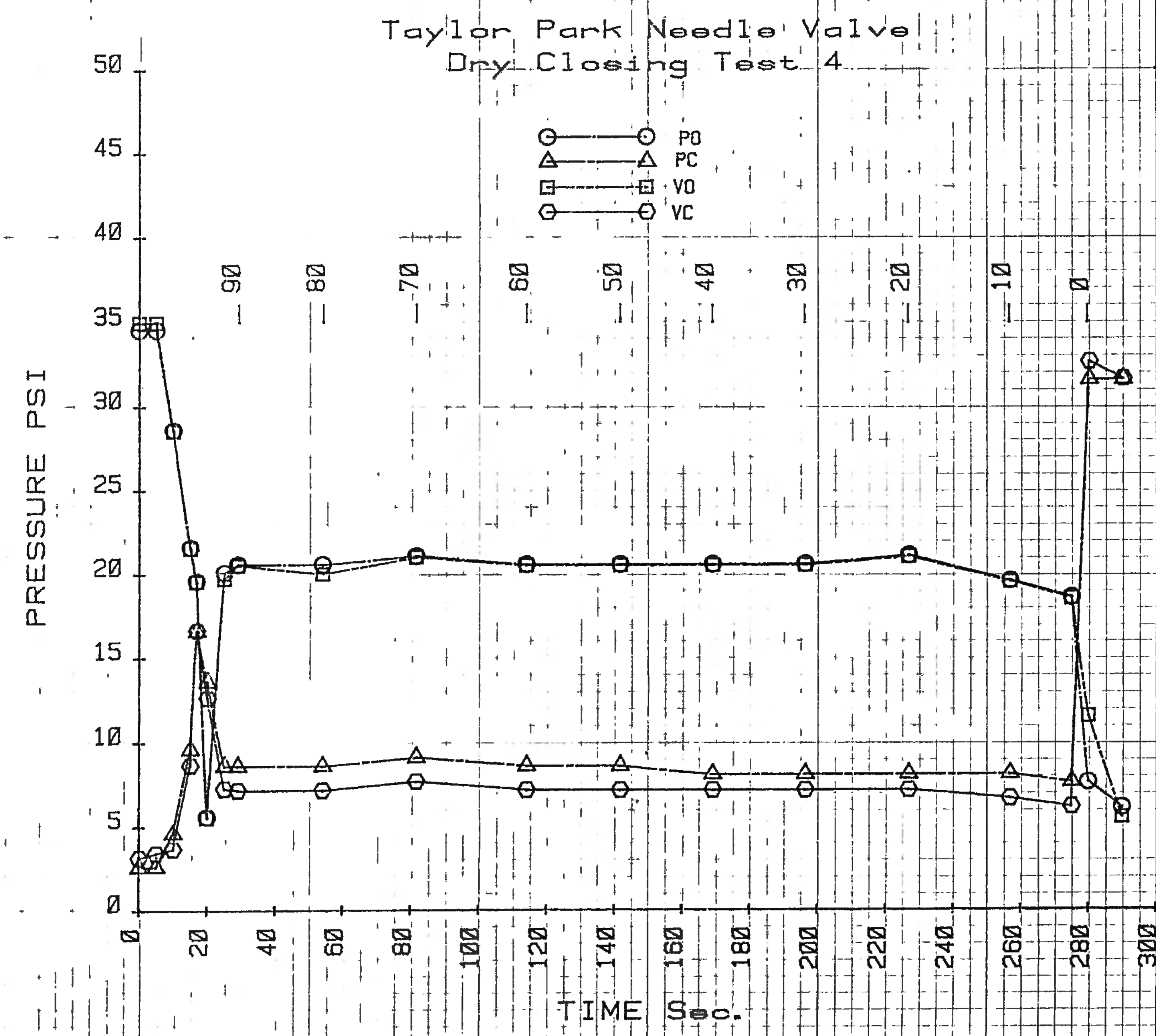

Taylor Park Needle Valve
Dry Closing Test 4
PO
PC
VO
VC
PRESSURE PSI
0
5
10
15
20
25
30
35
40
45
50
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
TIME Sec.

Figure 4

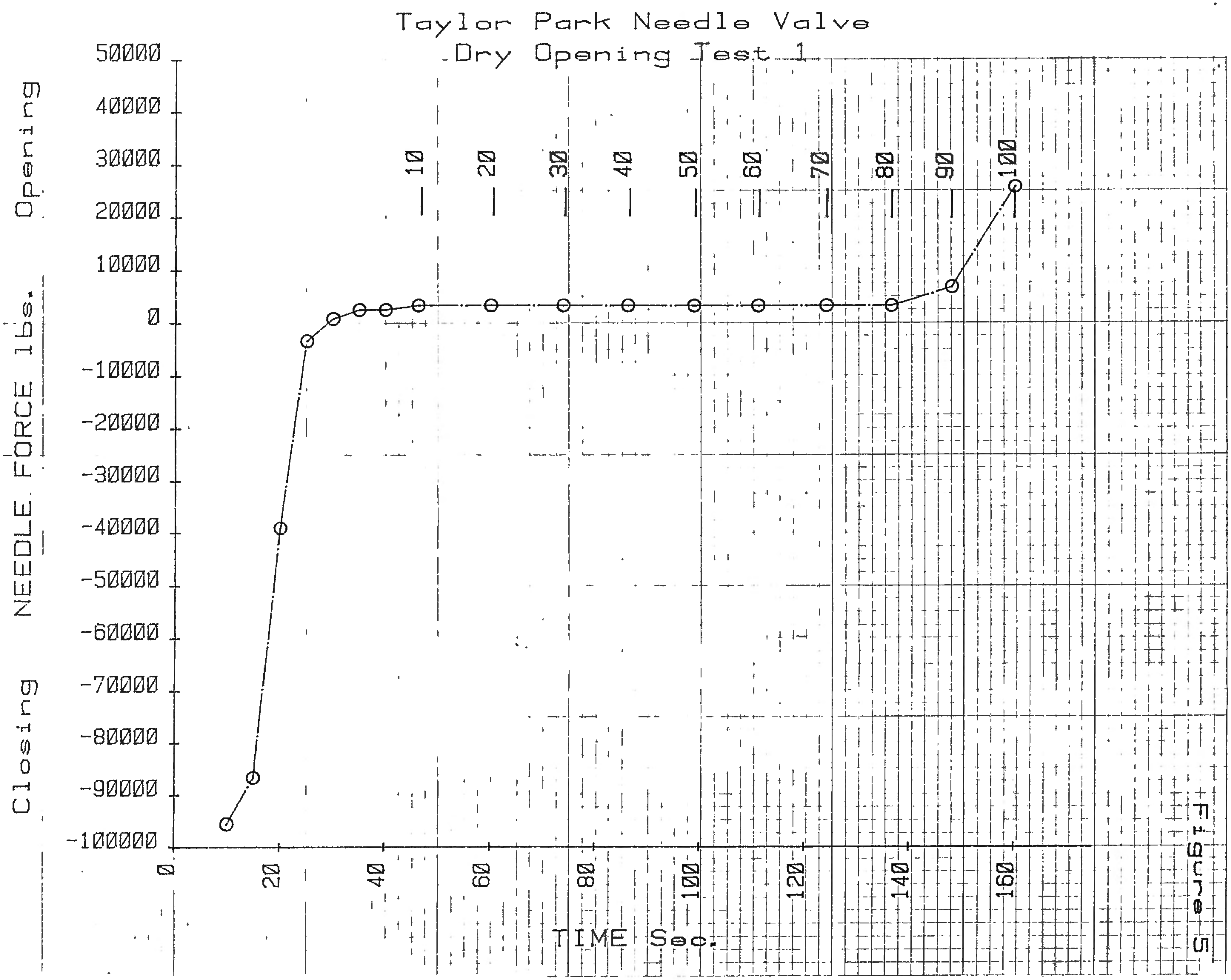

Taylor Park Needle Valve
Dry Opening Test 1
NEEDLE FORCE lbs.
Opening
Closing
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-100000
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
TIME Sec.

Figure 5

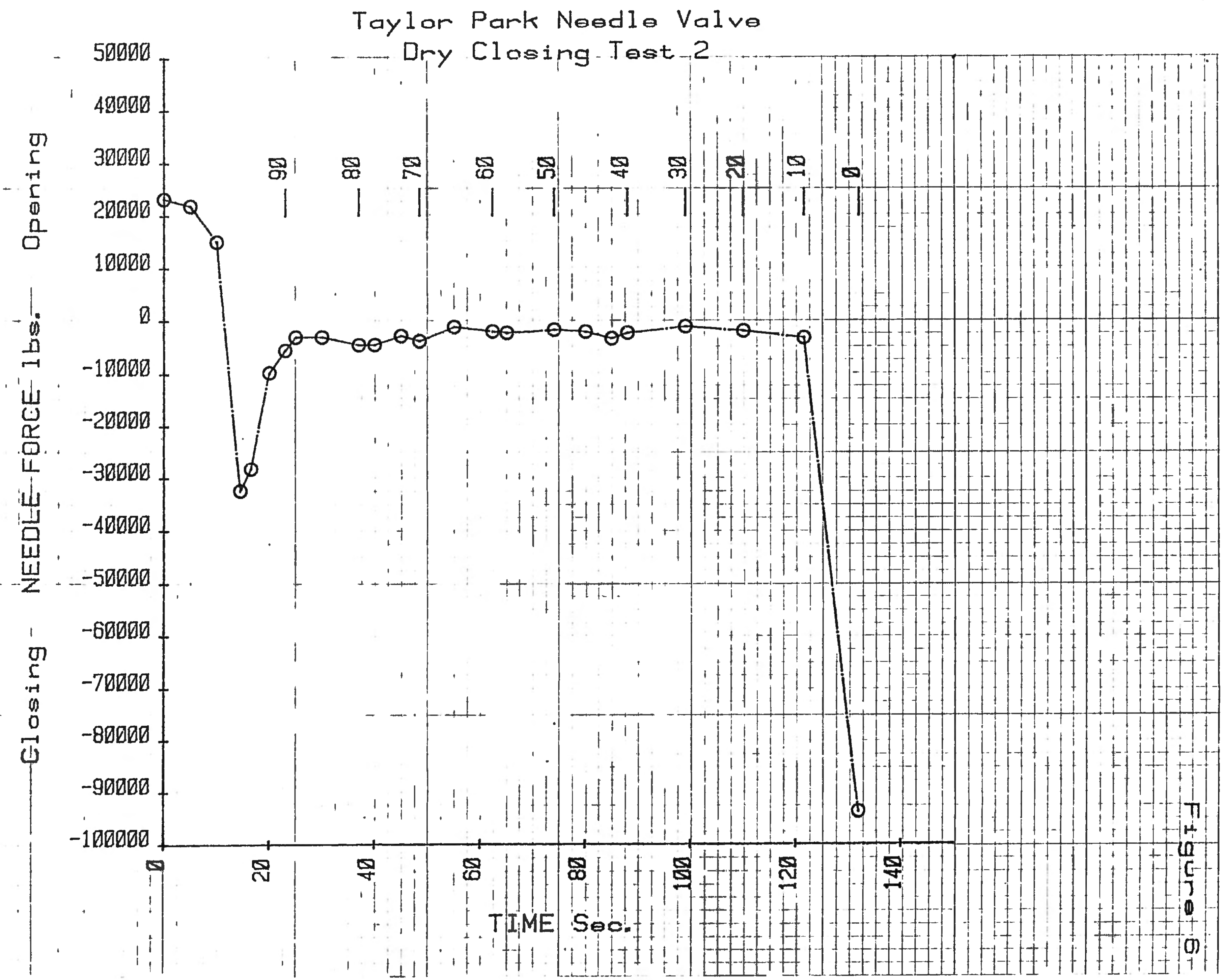
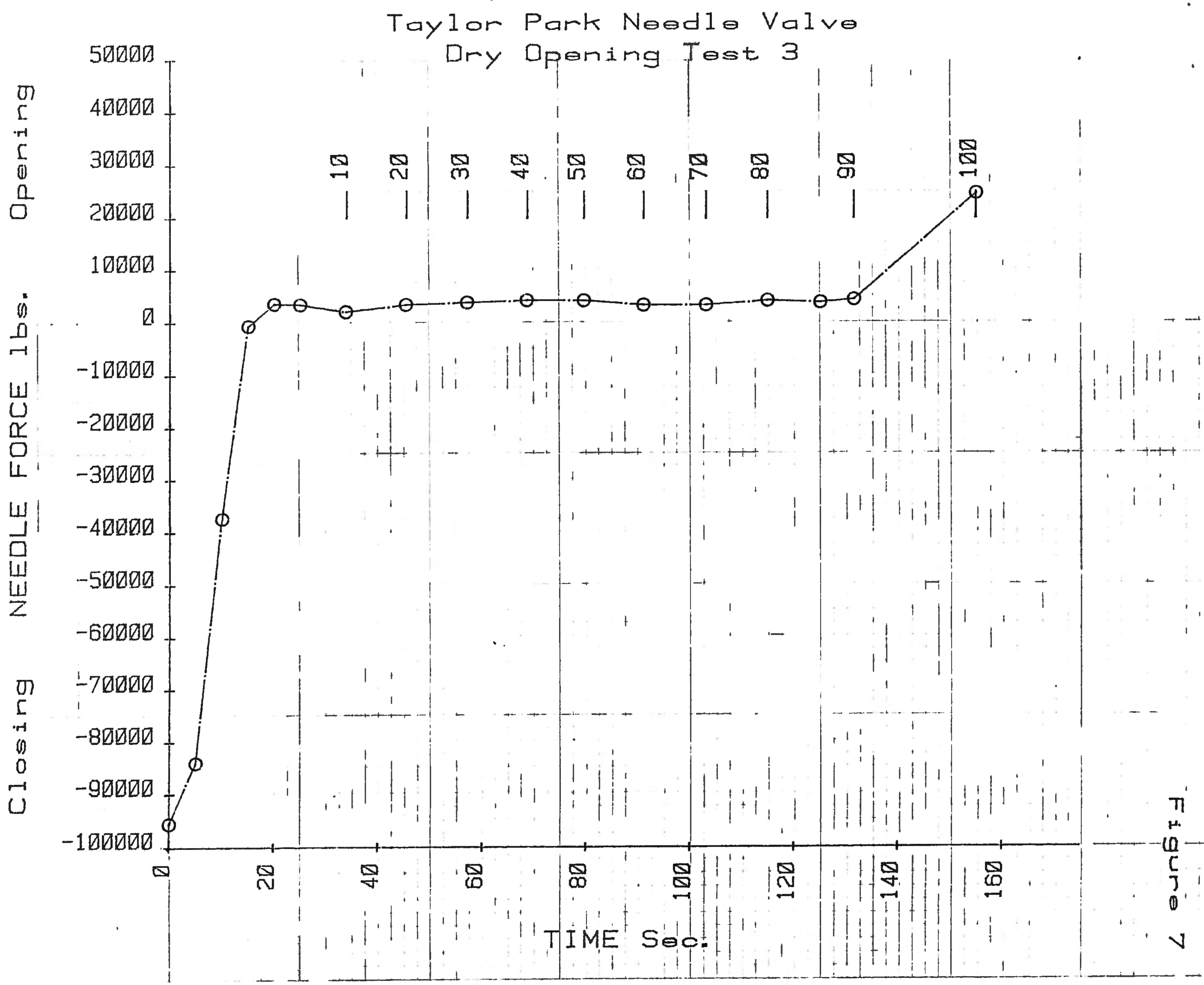
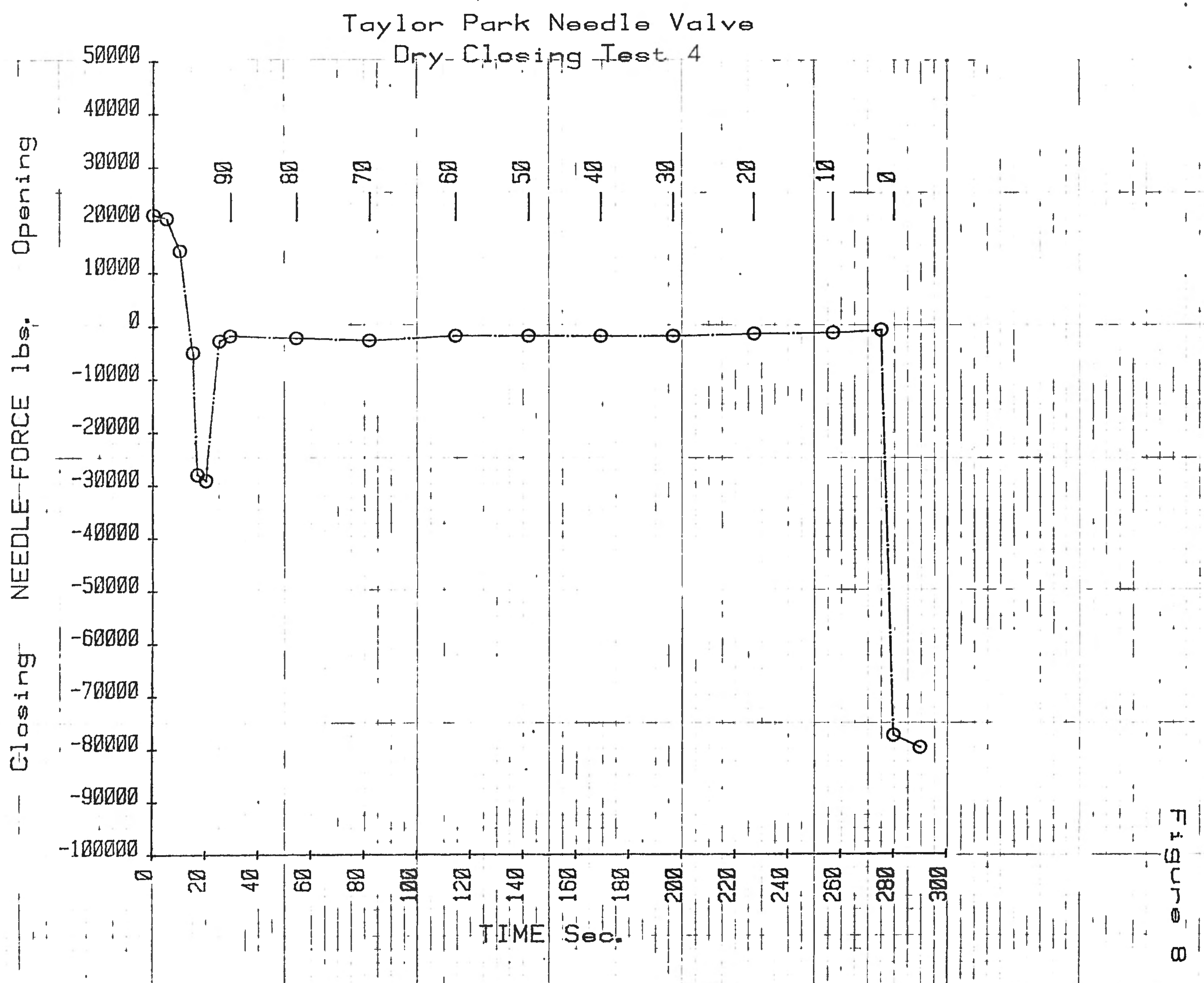

Taylor Park Needle Valve
Dry Closing Test 2
NEEDLE FORCE lbs.
Opening
Closing
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-100000
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
TIME Sec.

Figure 6



Taylor Park Needle Valve
Dry Opening Test 3
Opening
NEEDLE FORCE lbs.
Closing
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-100000
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
TIME Sec.

Figure 7



Taylor Park Needle Valve
Dry Closing Test 4
Opening
NEEDLE FORCE lbs.
Closing
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-100000
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
TIME Sec.

Figure 8

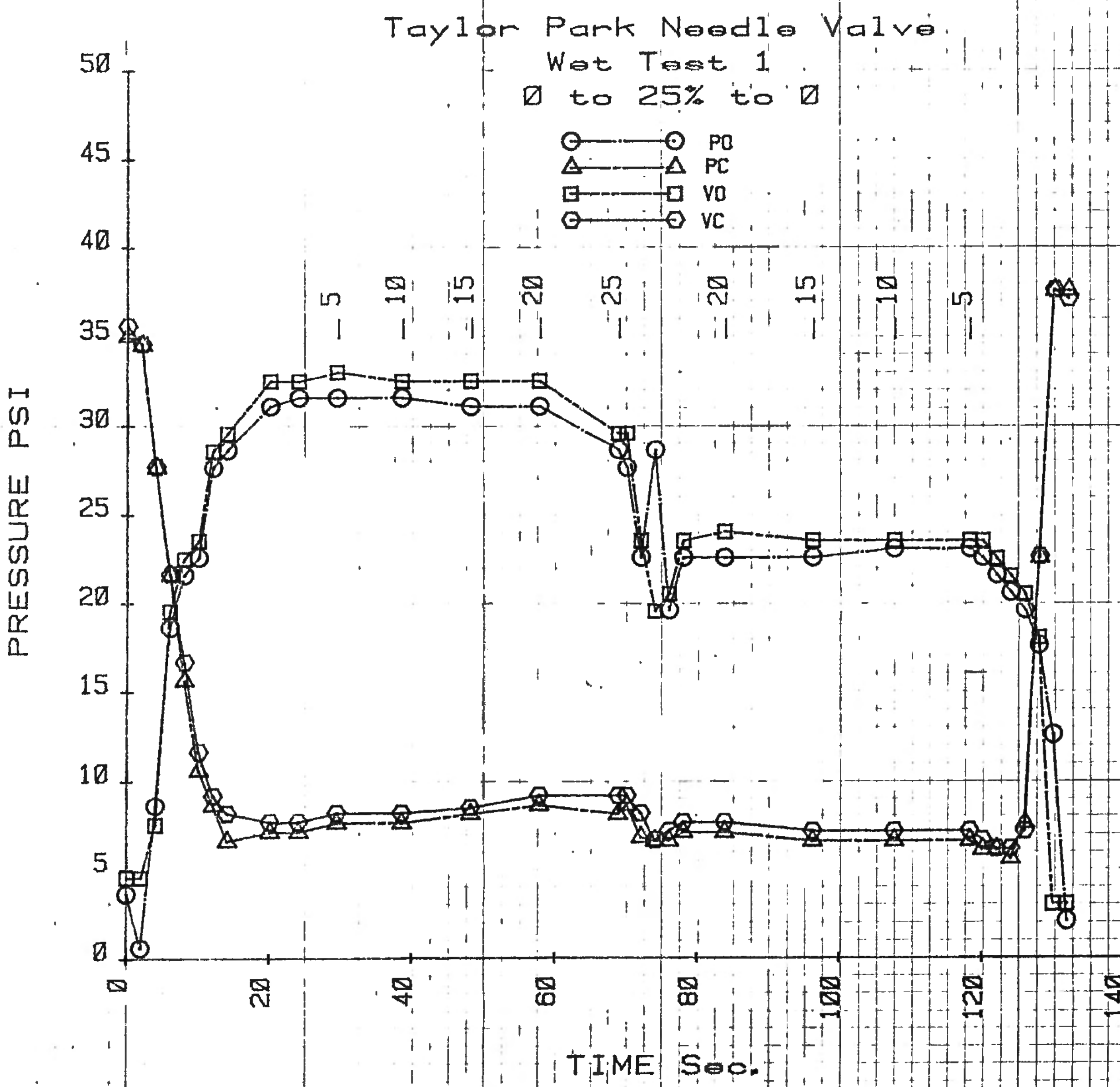
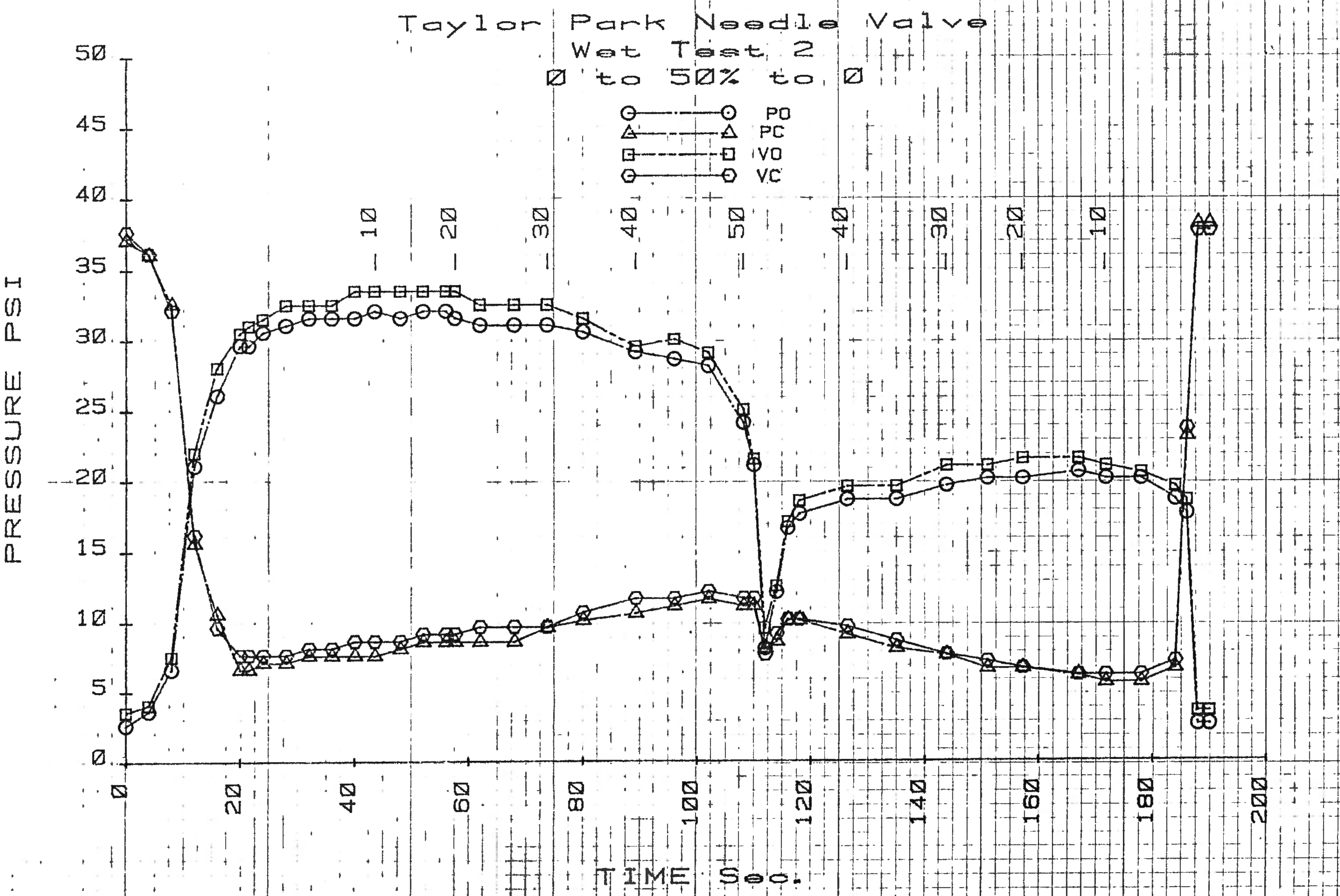
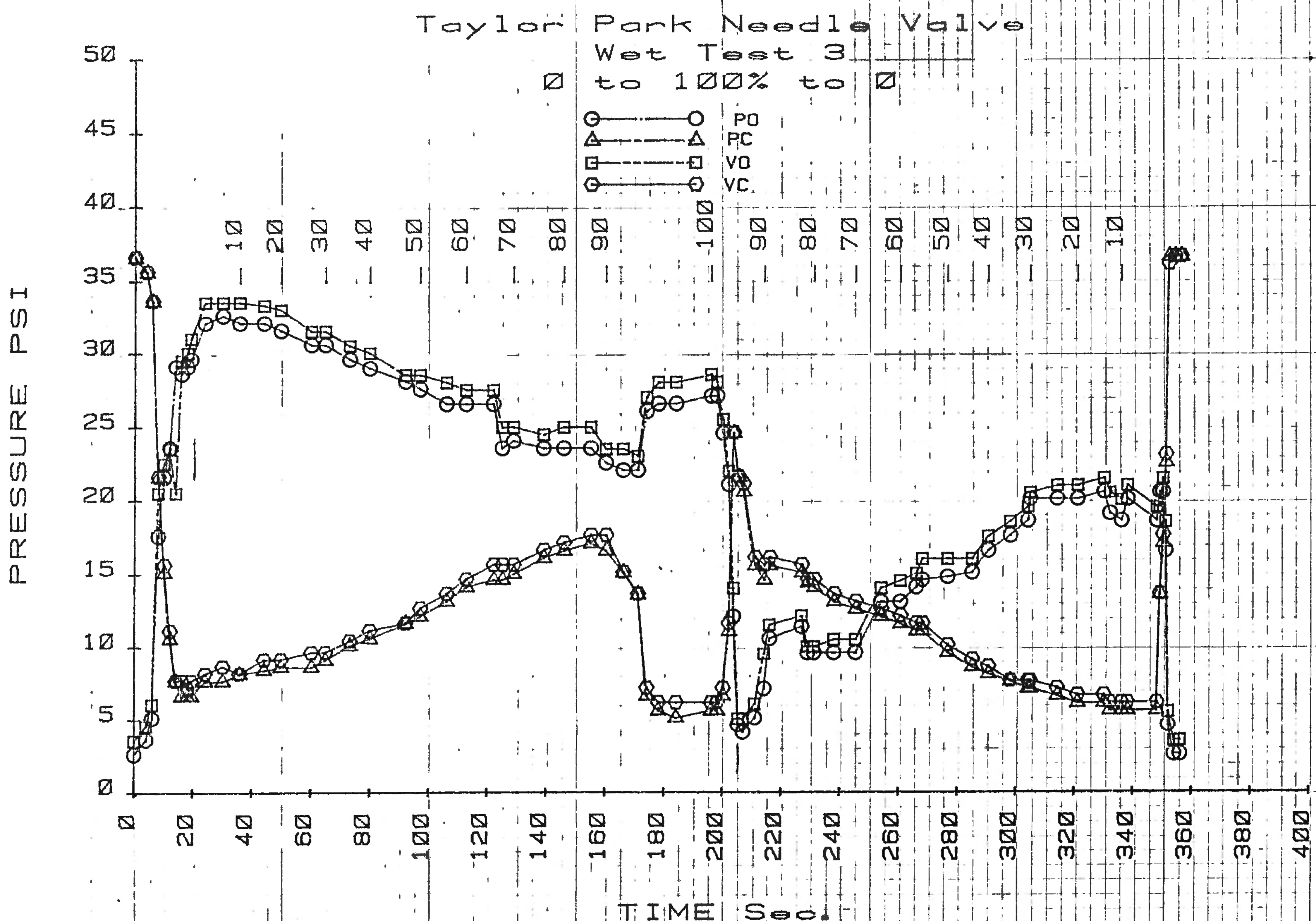

Taylor Park Needle Valve
Wet Test 1
Ø to 25% to Ø
PO
PC
VO
VC
PRESSURE PSI
TIME Sec.
5
10
15
20
25
20
15
10
5
0
5
10
15
20
25
30
35
40
45
50
Ø
20
40
60
80
100
120
140

Figure 6



Taylor Park Needle Valve
Wet Test 2
Ø to 50% to Ø
PO
PC
VO
VC
PRESSURE PSI
TIME Sec.

Figure 1Ø



Taylor Park Needle Valve
Wet Test 3
0 to 100% to 0
PO
PC
VO
VC
PRESSURE PSI
TIME Sec.
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
10
20
30
40
50
60
70
80
90
100
90
80
70
60
50
40
30
20
10

Figure 11

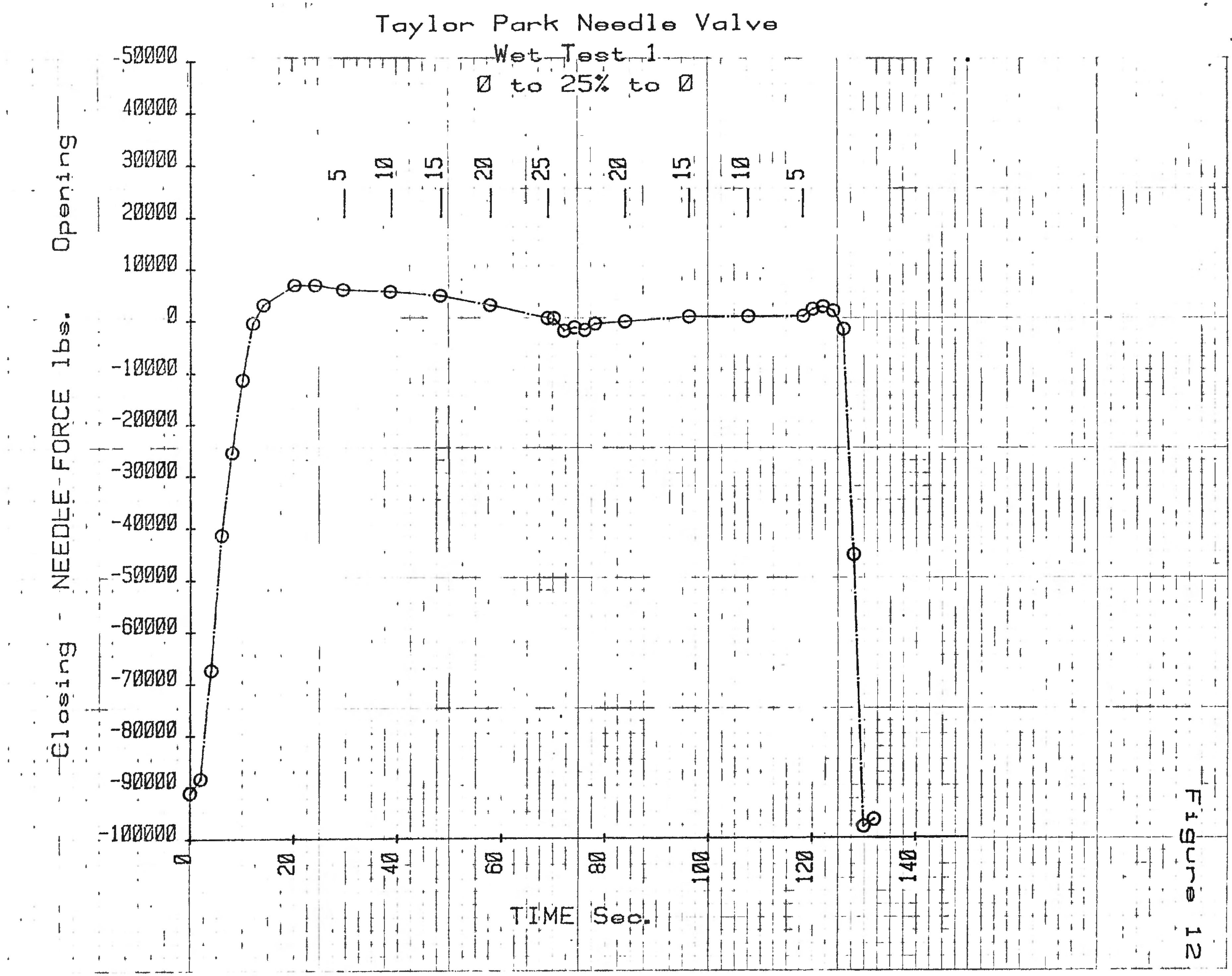

Taylor Park Needle Valve
Wet Test 1
Ø to 25% to Ø
Opening
Closing - NEEDLE FORCE lbs.
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-100000
5
10
15
20
25
20
15
10
5
Ø
20
40
60
80
100
120
140
TIME Sec.

Figure 12

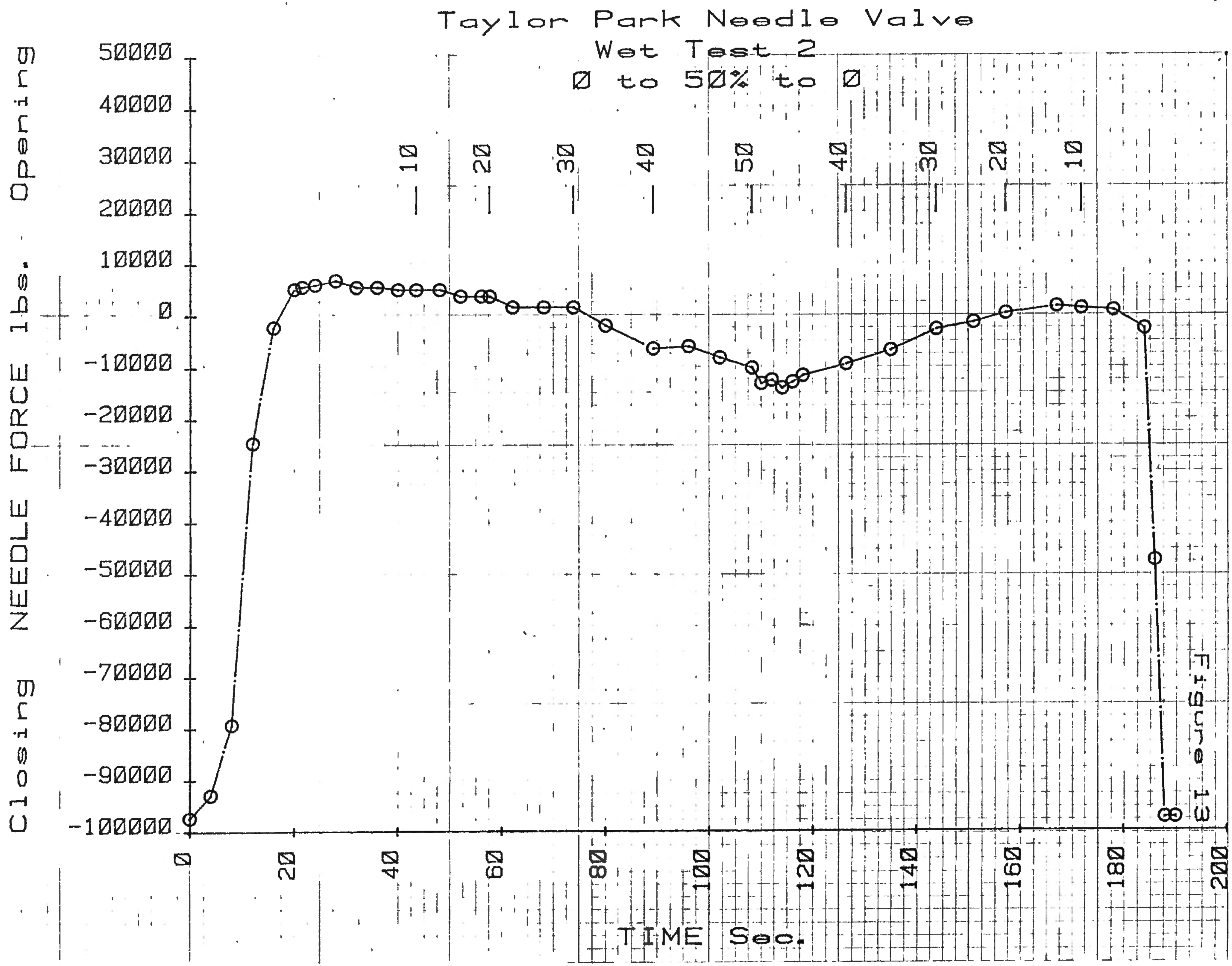
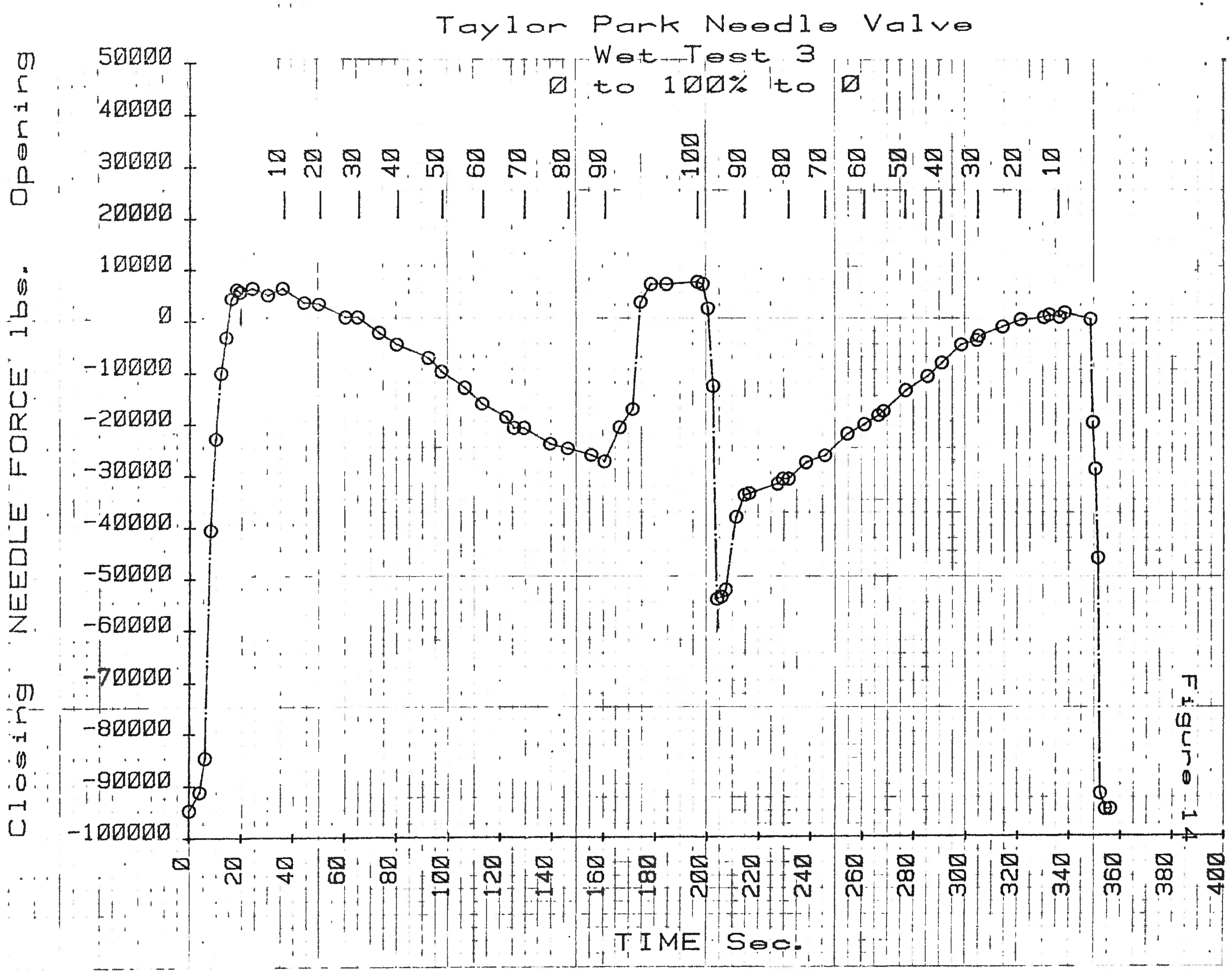

Taylor Park Needle Valve
Wet Test 2
0 to 50% to 0
Closing NEEDLE FORCE lbs. Opening
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-100000
10
20
30
40
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200
TIME Sec.

Figure 13



Taylor Park Needle Valve
Wet Test 3
0 to 100% to 0
Closing NEEDLE FORCE lbs. Opening
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-100000
10 20 30 40 50 60 70 80 90 100 90 80 70 60 50 40 30 20 10
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400
TIME Sec.
Figure 14

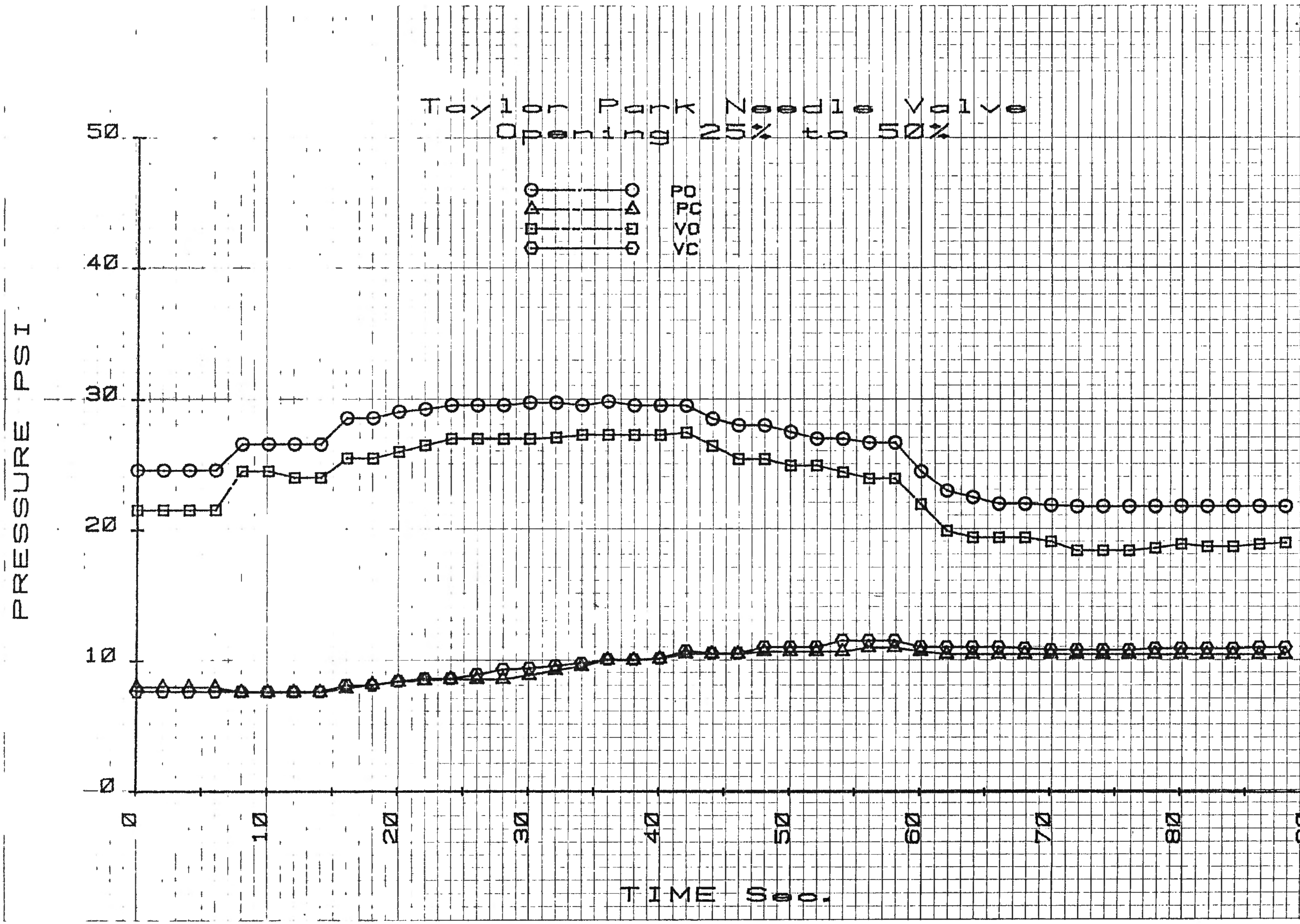
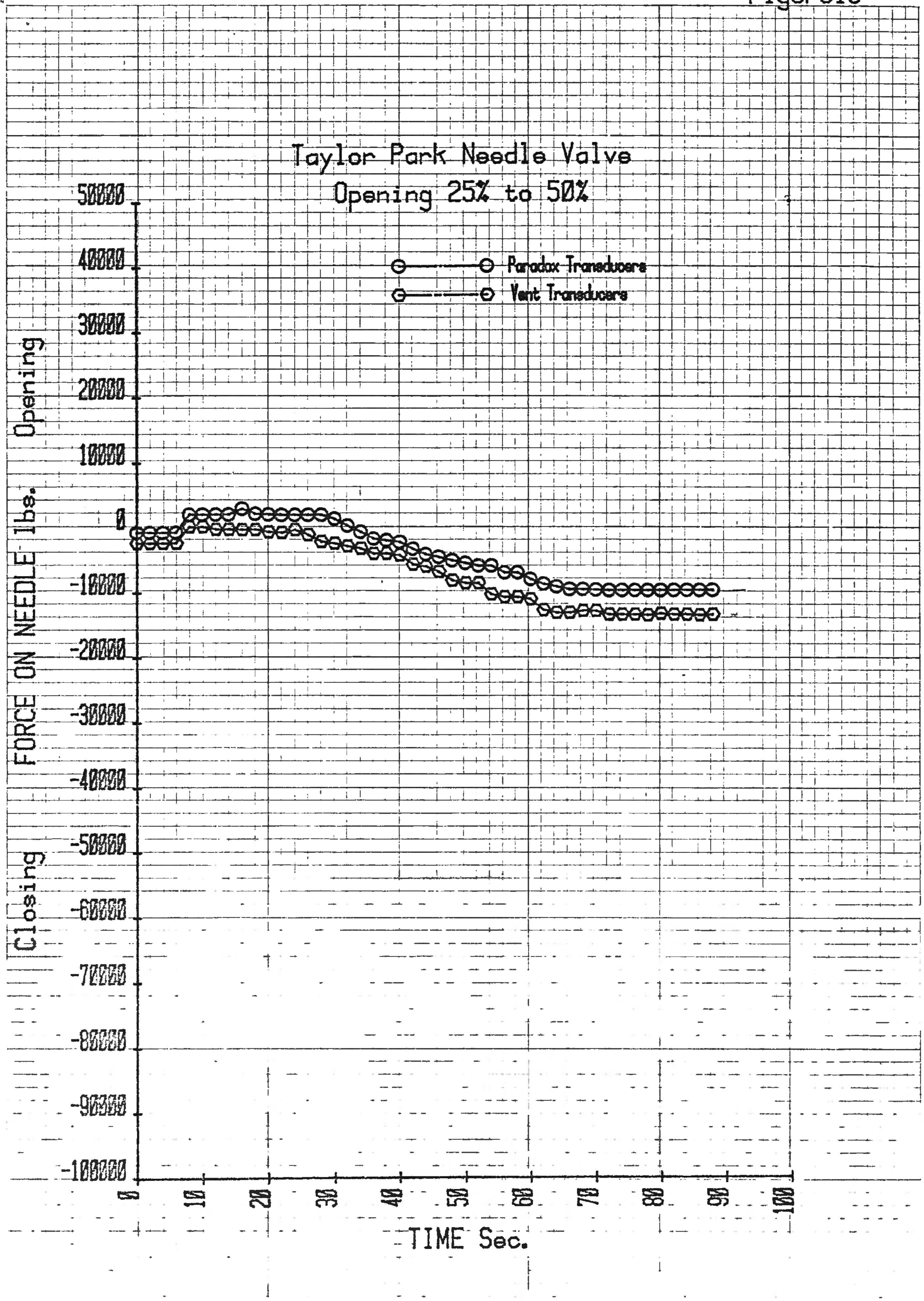
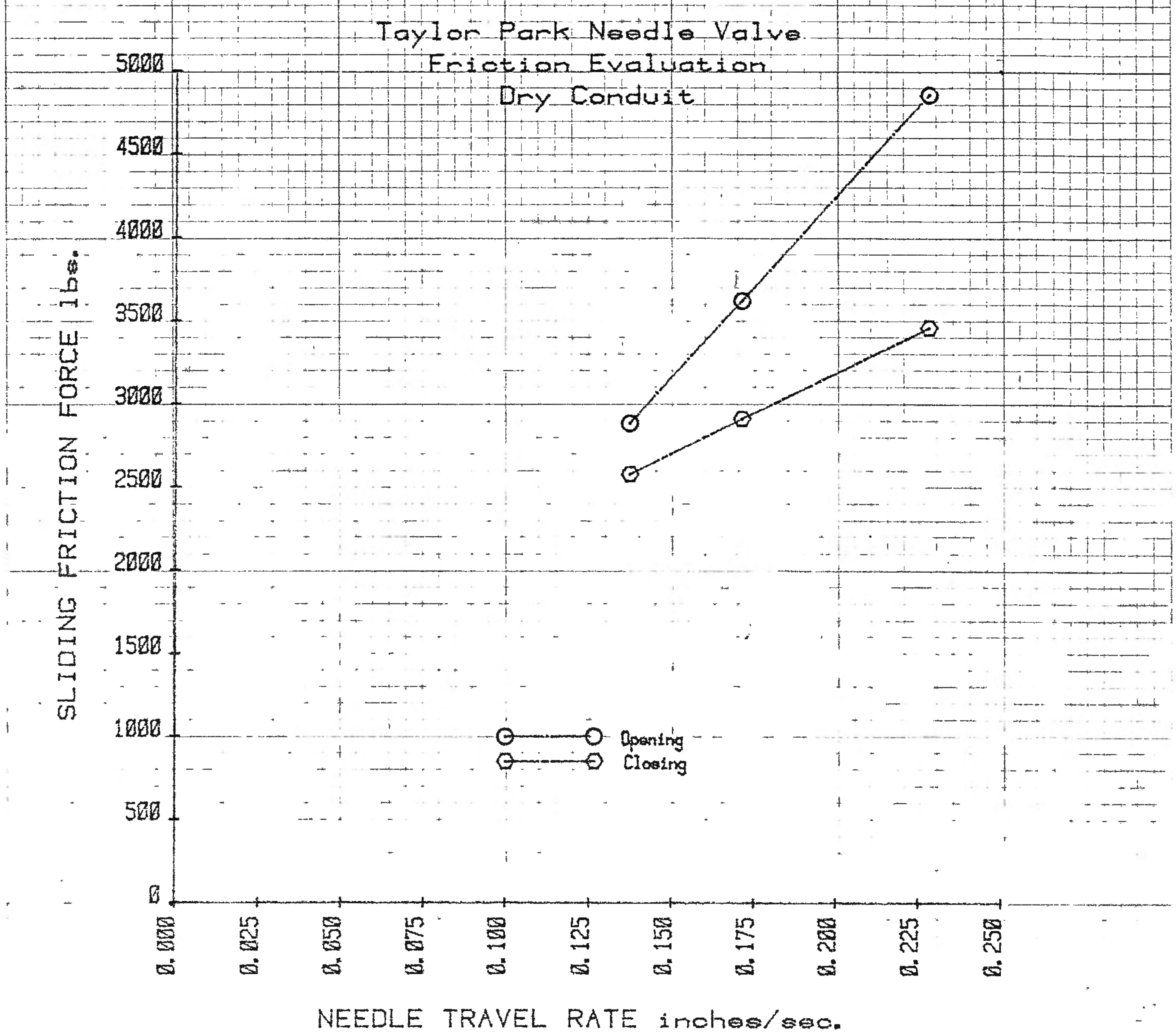

Taylor Park Needle Valve
Opening 25% to 50%
PO
PC
VO
VC
PRESSURE PSI
TIME Sec.
0
10
20
30
40
50
60
70
80
90

Figure 15



Taylor Park Needle Valve
Opening 25% to 50%
Paradox Transducers
Vent Transducers
Closing FORCE ON NEEDLE lbs. Opening
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-100000
0
10
20
30
40
50
60
70
80
90
100
TIME Sec.

Figure 17


Taylor Park Needle Valve
Friction Evaluation
Dry Conduit
SLIDING FRICTION FORCE lbs.
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
0.200
0.225
0.250
Opening
Closing
NEEDLE TRAVEL RATE inches/sec.

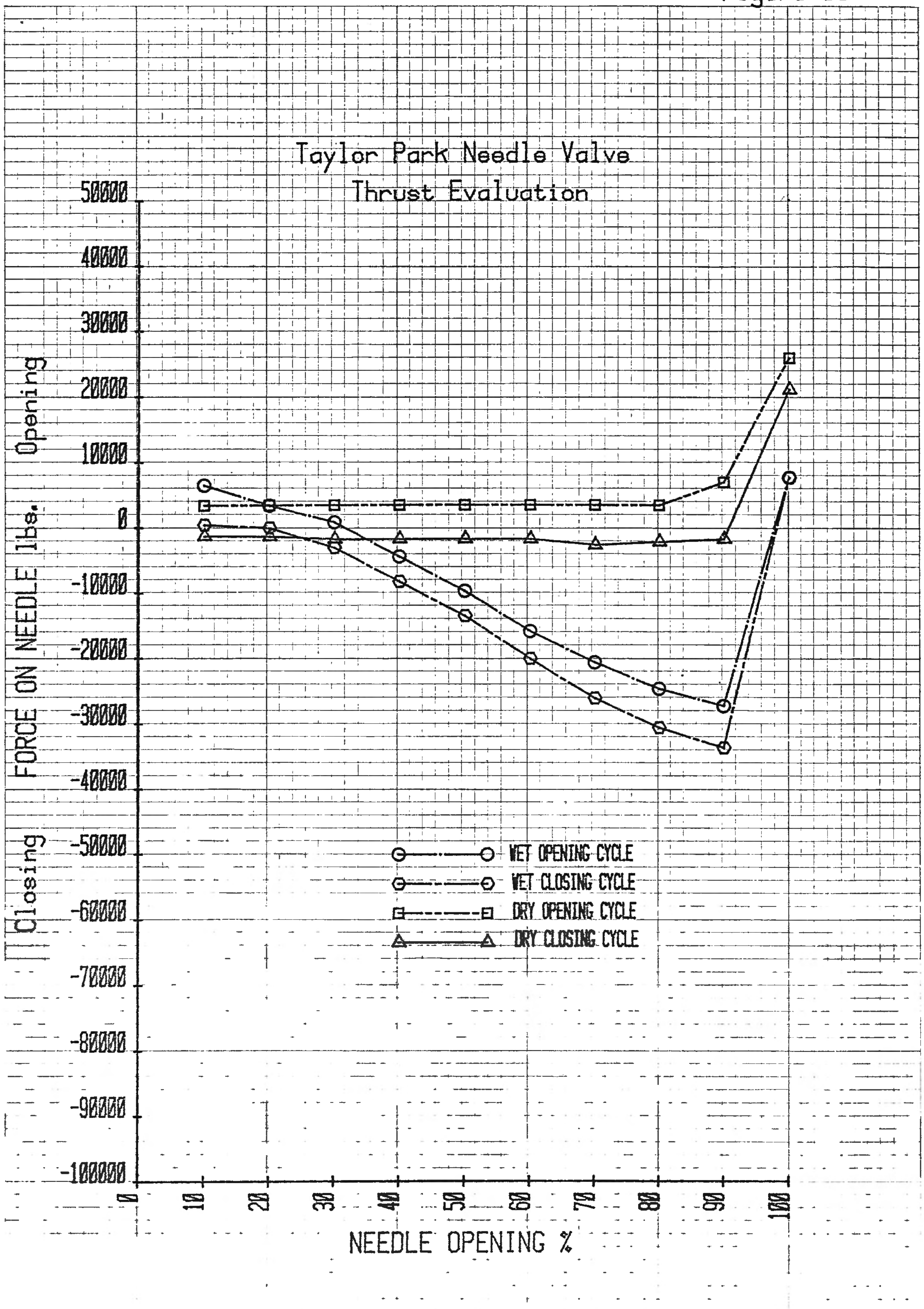
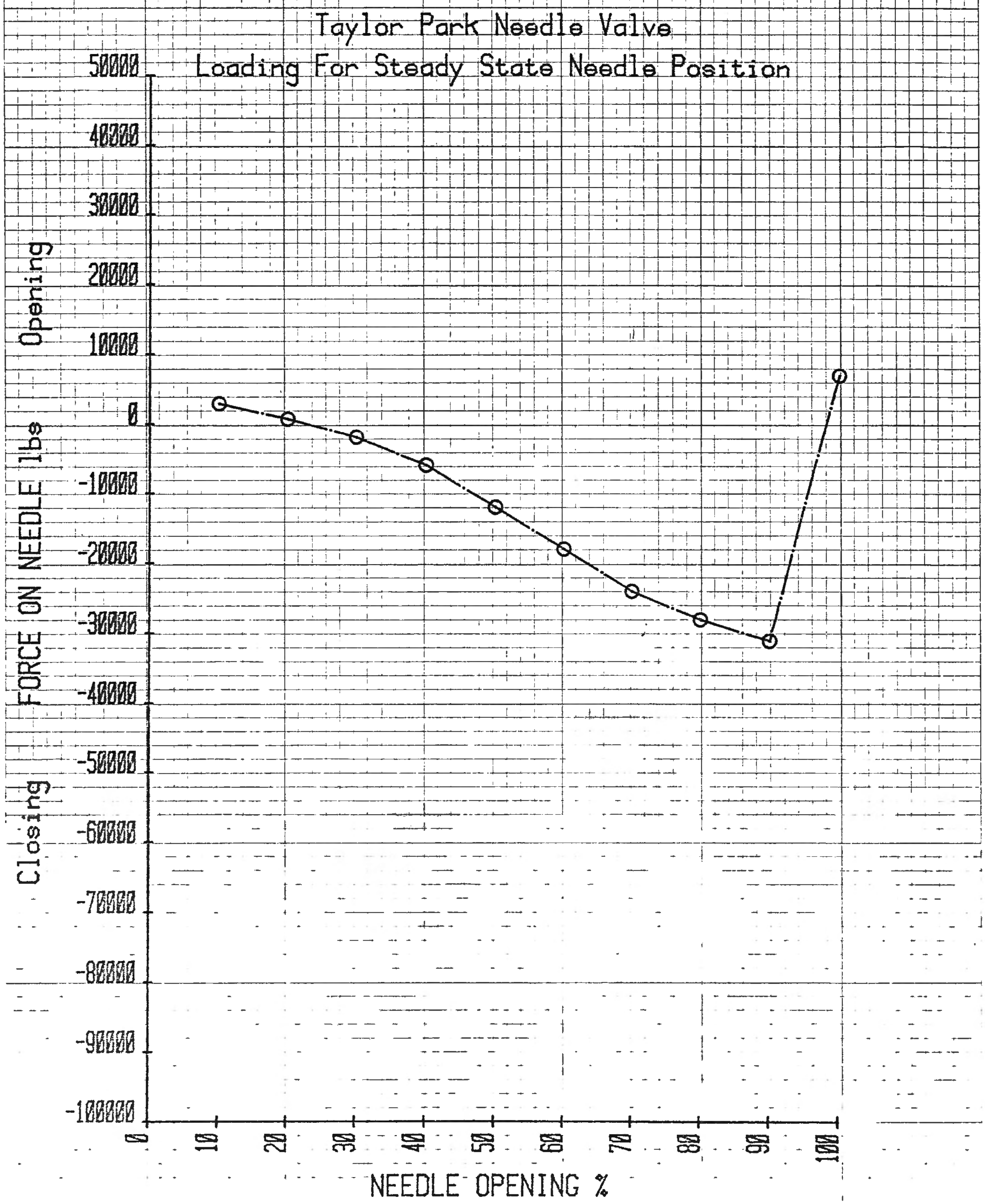
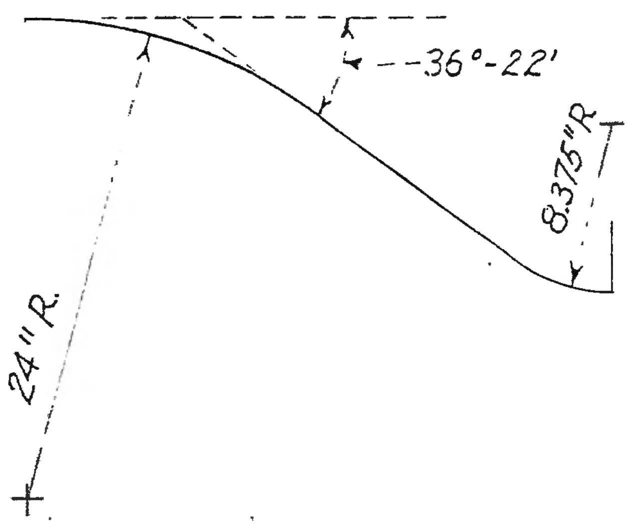

Taylor Park Needle Valve
Thrust Evaluation
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-100000
Closing FORCE ON NEEDLE lbs. Opening
0
10
20
30
40
50
60
70
80
90
100
NEEDLE OPENING %
WET OPENING CYCLE
WET CLOSING CYCLE
DRY OPENING CYCLE
DRY CLOSING CYCLE

Figure 19

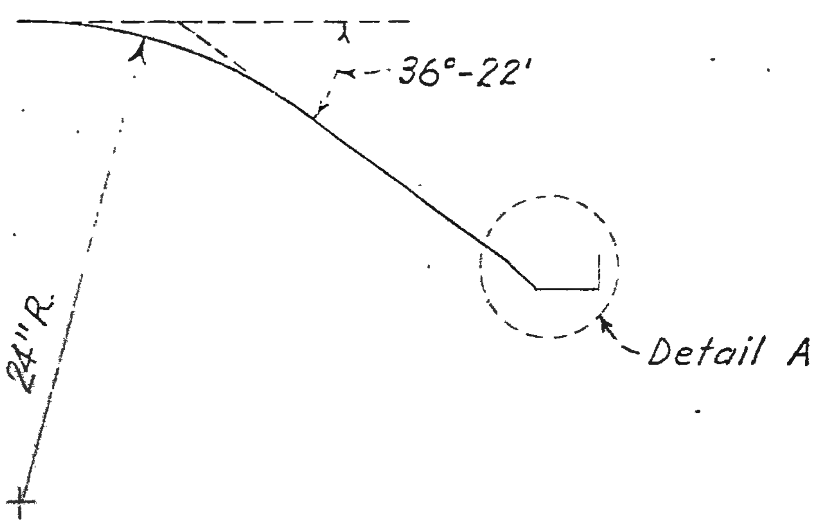


Taylor Park Needle Valve
Loading For Steady State Needle Position
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-100000
Closing FORCE ON NEEDLE lbs Opening
0
10
20
30
40
50
60
70
80
90
100
NEEDLE OPENING %

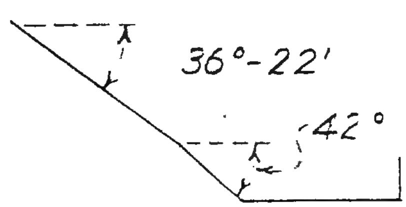
Appendix
Figure 1A



Original Nozzle Shape



Modified Nozzle Shape

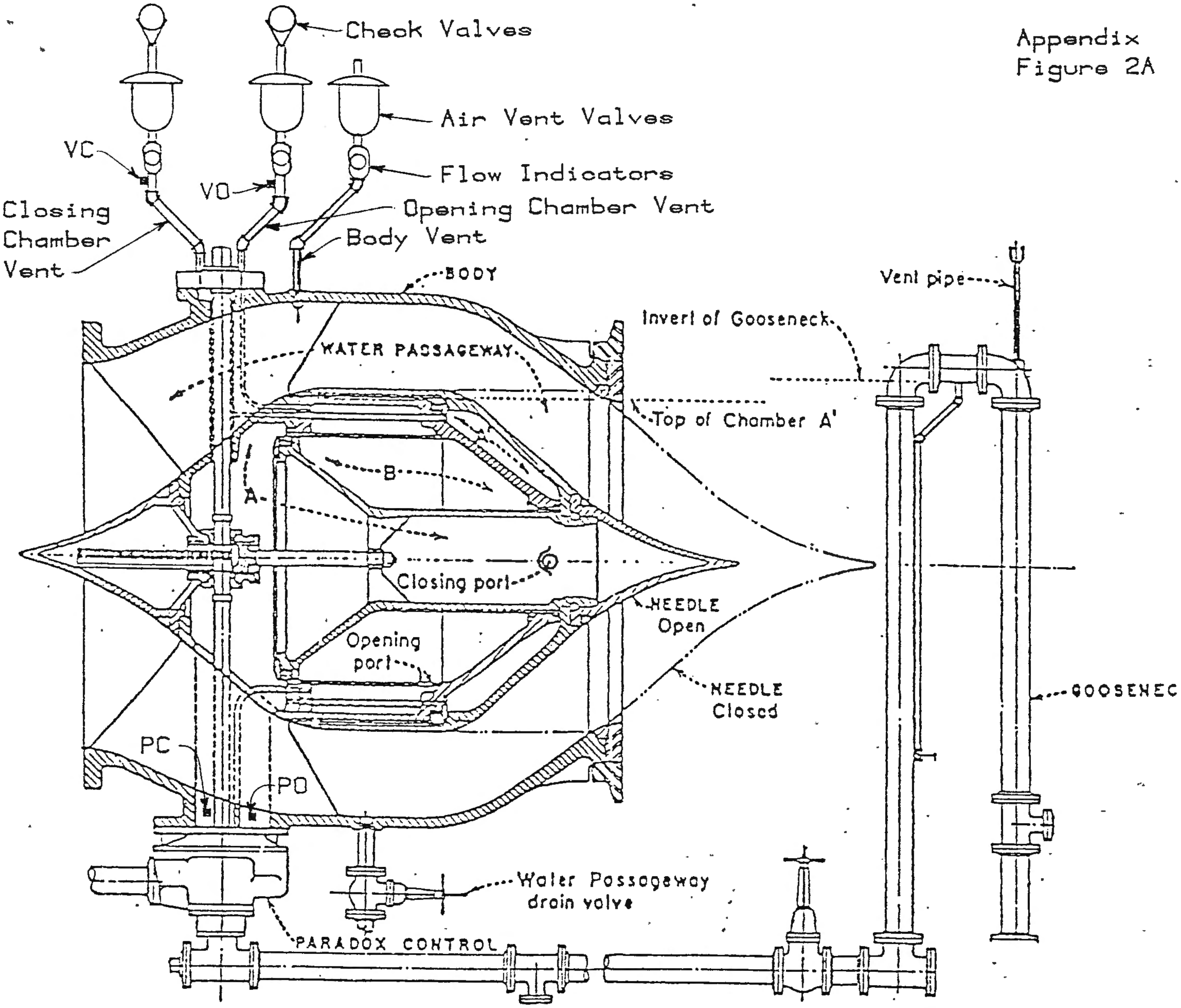


Detail A

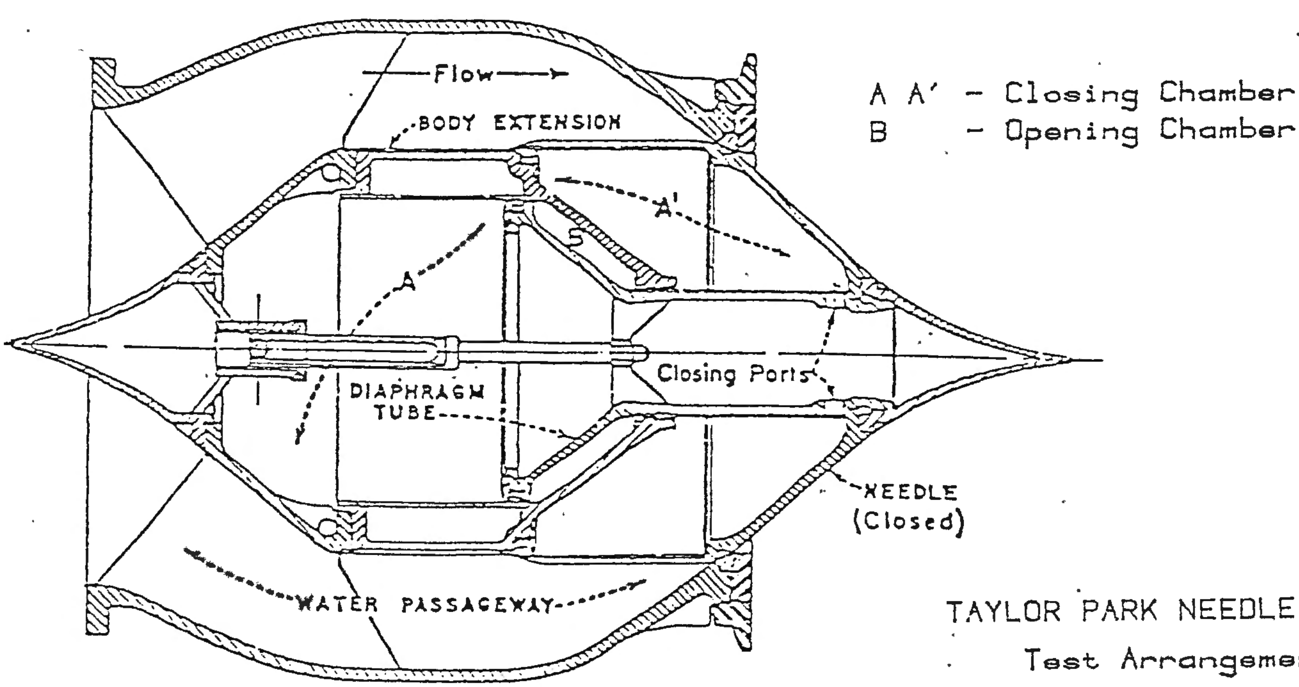
TAYLOR PARK NEEDLE VALVE

Nozzle Shape

Appendix
Figure 2A



NEEDLE VALVE OPEN



TAYLOR PARK NEEDLE VALVE
Test Arrangement

TR-85-8

D-1532
Isbester

BUREAU OF RECLAMATION
Engineering and Research Center
Denver, Colorado

TRAVEL REPORT

Code : D-1532 Date: July 19, 1985

To : Chief, Division of Research and Laboratory Services

From : T. J. Isbester and L. E. Elgin

Subject: Hydraulic Tests of Taylor Park 48-in Interior Differential Needle Valve

1. Travel period: May 20 to May 23, 1985.

2. Places or offices visited: Taylor Park Dam and Gunnison, Colorado.

3. Purpose of trip: To perform hydraulic tests to determine operating chamber pressures on a needle valve at Taylor Park Dam. Reference: Memorandum from Chief, Division of Water and Land Technical Services, Subject: Needle Valve Investigation, dated March 21, 1985.

4. Synopsis of trip:

We departed the Denver Federal Center at 6:00 a.m. on May 20, 1985, in a Government vehicle and arrived at Taylor Park Dam about 11:15 a.m. We transported the equipment necessary to perform the tests. At the dam we met Fred Crabtree from the Grand Junction Projects Office; Jim Hokit and Ken McCracken from the Uncompahgre Water District; and Jess Jenkins, Taylor Park Dam Tender.

After inspecting the valve and piping we began installation of the test equipment. The pipe plugs in the opening and closing flow passages just above the paradox flange had probably not been removed since the valve was installed some 48 years ago and required considerable effort including drilling out and retapping the threads. After this task was completed, the transducer hookup and plumbing for the sight glasses, float type air vent valves, and check valves went smoothly. Mike Pearson (PN-245) arrived shortly after noon.

The following day we continued piping and instrumentation hookup. The internal chambers of the valve were watered up, and with the guard valve closed and main conduit drained a series of opening and closing cycles was performed to bleed the inner chambers of the valve. After this was accomplished, data were recorded for a series of two opening and closing cycles to obtain the friction force for moving the needle at a constant rate.

The conduit was watered up in the evening and a cyclic venting of the automatic air vent on the needle valve closing chamber noted. This continued for a considerable period of time. The conduit was drained overnight.

The morning of May 22, 1985, the needle valve was again watered up, cycled through three full openings and closures and conduit watered up. Cyclic venting reoccurred on the closing chamber air vent accompanied by a surge in the goose neck air vent of the left needle valve (valve No. 1). The only communication between the two conduits was through the filling lines.

The pressure was bled from No. 2 penstock by cracking the needle valve. Large accumulations of air were noted leaving the valve in a rather explosive decompression fashion. Once the pressure was relieved, we went up into the guard gate chamber and noted that the 8-in air vent valve was still seated. In manually unseating the valve, considerable force was required on the counter weight to break the seal. After applying spray lubricant the sticking persisted. By unseating the valve by hand, the conduit was safely watered up and wet tests performed on the valve. Three series were performed consisting of opening the valve to 25 percent of travel and closing, opening the valve to 50 percent and closing, and opening the valve to 100 percent and closing.

After the completion of the flow tests, some additional tests were performed on the valve at preset openings to check for adverse conditions.

The following morning Mike Pearson held a meeting with Jess Jenkins, Fred Crabtree, Elgin, and Isbester to discuss the latest findings in the needle valve program and the operation, maintenance, and problem areas of the paradox valve and needle valve.

After the meeting, the test equipment was removed and packed for the return trip to Denver. We left Taylor Park Dam at 1:45 p.m. and arrived at the Denver Federal Center at 7:00 p.m. on May 23, 1985.

5. Conclusions:

a. A memorandum report will follow detailing the results of the tests.

b. A potentially dangerous situation can result from an air vent which sticks in the closed position and fails to vent conduit air.

c. Vent piping from the chambers of the valve should not contain any horizontal pipe sections to trap air. The sight glasses should be easily visible from the control pedestal hand wheel operator position.

Travelers: T. J. Isbester and L. E. Elgin Date: July 19, 1985

d. The 8-in air vent valve should be disassembled and cause of sticking eliminated, before it is placed back in service. The position of the counter weight should be included on the check list so that the vent is not stuck closed before the conduit filling operation is begun.

T. J. Isbester

L. E. Elgin

CP 7-25-85

7/26/85

Copy to:
Regional Director, Boise, Idaho, Attention: PN-245
Regional Director, Salt Lake City, Utah, Attention: 400
Projects Manager, Grand Junction, Colorado, Attention: 200
Chief, Division of Water and Land Technical Services, E&R Center

Blind to:
D-1500
D-1530
D-1530A
D-1531 (file)
D-1532

TJIsbester:flh

Noted: 7-26-85
H. Walter Anderson
ACTING Chief, Division of Research and Laboratory Services