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DRAFT

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TECHNICAL EVALUATION REPORT

INSIGHTS INTO PALISADES PORV AND BLOCK VALVE TESTS

R. Steele, Jr.
K. G. DeWall

Prepared for the
U.S. NUCLEAR REGULATORY COMMISSION

EG&G Idaho

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ABSTRACT

In December 1989, a power-operated relief valve (PORV) and a block valve from the Palisades Nuclear Power Plant were removed from the plant and tested at Wyle Laboratories in Norco, California. Earlier, during hydrostatic testing at Palisades, the PORV had opened and the block valve, installed upstream of the PORV, had apparently failed to close on command. The U.S. Nuclear Regulatory Commission asked Idaho National Engineering Laboratory researchers to observe the testing performed at Wyle Laboratories and to provide an analysis of the test results. This report presents the results of that analysis. The analysis determined that the block valve and operator were mechanically capable of operating at all test conditions; however, the margin of safety is small. In addition, the report recommends that guidance be provided to utilities preparing to respond to Generic Letter 89-10.

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SUMMARY

This report presents the analysis performed to date by the Idaho National Engineering Laboratory (INEL) on power-operated relief valve (PORV) and block valve tests conducted by Palisades Nuclear Power Plant staff at Wyle Laboratories in Norco, California. The analysis was conducted for and sponsored by the United States Nuclear Regulatory Commission (USNRC), Division of Engineering, Office of Nuclear Regulatory Research. Two 4-in. valves, namely a Target Rock Y Pattern globe valve (the PORV) and an Edwards split-wedge motor-operated gate valve (the PORV system block valve), were removed from the Palisades primary coolant system following a PORV lift and an apparent failure of the block valve to close during a hydrostatic test of recently installed valves and piping. The event occurred during hot standby and apparently presented no danger to the plant. The valves were installed in a test loop at the Wyle Norco test facilities in Southern California in a configuration that simulated their installation in the plant. The tests consisted of opening and closing the valves against high energy steam loadings while measuring important parameters. Testing started on December 6, 1989, and was completed December 8, 1989.

The PORV testing was apparently designed to address plant operations and pressures, whereas the block valve was tested, within the capability of the test facility, at design basis conditions. For the later PORV tests the Palisades staff rotated the PORV 135 degrees, from its position with the valve operator standing vertical up, to a position with the operator near vertical down. We infer that this was done to provide a better understanding of condensation getting trapped in the pilot assemblies and causing slower valve operation than desired.

The test facility capacity was marginal for the block valve testing. Valve inlet pressure could not be maintained throughout the full closure of the block valve. This deficiency required the Palisades staff to characterize the full valve closure in steps. They performed block valve closures from the 25, 60, and 100% open positions. During the 60 and

100% closings, the valve inlet pressures dropped well below the design basis 2500 psig. The valve successfully closed during all of the test runs.

The onsite data acquisition system and the technical information available at the site prevented the qualification of the data during the test program. Palisades provided the magnetic data and the paper plots from Wyle Laboratories to the INEL for post test evaluation. The INEL processed the data in an attempt to determine if the step test process could be used to determine the margin of safety in the operation of the block valve. The data examination and post test analysis determined that the validity of thrust data taken by Palisades is suspect; however, other data, presented in the body of this report, provided sufficient information to show that the block valve may have a small margin of safety at near design basis conditions. This margin of safety will be larger at normal operating pressures.

Mechanical limitations make the block valve and motor operator marginal for the Palisades application, based on a design basis qualification. The block valve as purchased was limited to 14,000 lb thrust based on ASME code allowables for the stem material. Reevaluation of the stem material based on actual chemical physical material certifications allowed the 14,000-lb limit to be increased to 18,000 lb. The Limitorque SMB-00 motor operator is also qualified for 14,000 lb thrust. However, Limitorque is requalifying the SMB-00 motor operator for 18,900 lb thrust. (Limitorque told us that their participation in the NRC Generic Issue 87 valve tests conducted in 1988 had shown them the need to increase the qualification levels of the SMB series of motor operators.) With these two recalculations, the no-load valve closing thrust can be set high enough to accommodate the loss in thrust at load without exceeding the design limits of either component. The recalculated higher no-load thrust capability will allow the maximum margin that can be developed for this valve-operator combination at load.

Careful review of the data shows that the motor operator torque spring deflection did not exceed the spring preload before the valve closed to the point of flow isolation or before the disc made contact with the wedging portion of the seat during any of the valve loadings experienced at Wyle Laboratories.

Review of the motor current plots shows that throughout the closures, the currents are in the efficient portion of the motor torque curve; thus, the motor also has margin. Details of these analyses are provided in the body of this report.

The pressure plots show that the PORV is the flow limiting orifice until the block valve is between 30 and 40 percent closed, where the choke plane starts to shift from the PORV to the block valve. This indicates that the differential pressure across the block valve will remain fairly constant until the valve is over 40 percent closed. Thus test 13 (from the Palisades test list), which was started at 40 percent closed at an inlet pressure of 2100 psig, is probably a representative test of valve operation at plant operating pressure. Test 14, which was started at 25 percent open, is too short a test to allow for motor heatup and a loss of motor operator momentum. However, it does provide some assurance that if the block valve tripped out on a long closure, plant personnel could restart it and be fairly sure it would close. This test was run at an inlet pressure very near the design basis pressure of 2500 psig.

In other NRC-sponsored testing, the Generic Issue 87 (GI-87) test program, we have subjected seven gate valve designs to full scale, high energy testing. (GI-87 addresses the failure of the high-pressure coolant injection steam line without isolation.) Analysis of results from Phase II of that program are underway. Results from the GI-87 testing indicated marginal motor operator performance and nonlinear disc friction in some of the valves. We compared the GI-87 data to the data from the Palisades testing at Wyle Laboratories and found none of those characteristics in the data recorded for the block valve at Wyle Laboratories.

On the whole, we agree with the conclusions of the Palisades staff that the valve and operator are mechanically marginal for the design basis loading; however, there is sufficient margin for credible valve operation at plant operating conditions, provided the operator is not expected to run on degraded voltage.

INSIGHTS INTO PALISADES PORV AND BLOCK VALVE TESTS

INTRODUCTION

In November 1989, a power-operated relief valve (PORV) and a block valve were subjected to hydrostatic testing at Palisades Nuclear Power Plant. Both valves had been recently installed in the plant. The plant was at hot standby conditions during the tests. The PORV opened when the block valve was opened, and the block valve apparently failed to close on a subsequent command. Palisades personnel removed both valves and sent them to Wyle Laboratories in Norco, California, for testing. The U.S. Nuclear Regulatory Commission asked researchers from the Idaho National Engineering Laboratory to participate in the testing at Wyle. We observed the tests as they were conducted, gave advice when asked, and conducted a separate analysis of the test results.

We have found, through our valve testing for the NRC, that a large number of design features can affect the ability of a gate valve to open and close against high thermal hydraulic loadings. The following list groups those features as to those affecting the valve alone, those affecting the motor operator, and those affecting the assembled unit. (This list is for ac motor-operated valves (MOVs) and does not include maintenance items.)

Valve

1. Higher than calculated valve disc to guide friction.

2. Valve disc loadings exceeding the material properties of the valve guides and seats, resulting in nonlinear friction caused from yielding and tearing.

3. Excessive packing load.

Motor Operator

1. Undersized motor operator because of nonconservative sizing calculations.

2. Torque switch set too low because of miscalculated valve loadings or torque spring aging.

*3. Undersized power cables, resulting in excessive voltage drop.

*4. Voltage drop (item 3 above) aggravated by low voltage conditions.

5. Operating the motor near the knee of the motor speed/torque curve.

Assembled Unit

1. Higher than calculated stem to stem nut friction.

*2. Torque switches set too low because of high thrusts obtained during no-load testing.

Several of these design features (identified in the table with an asterisk) are in-plant features, and the technical information is not available for us to include them in this analysis. Additionally, several can be affected on reinstallation in the plant. Those design features that are not plant features are addressed in this analysis as the valve was configured at Wyle Laboratories.

A great deal of the recorded data taken at Wyle Laboratories can be used only for trending. The data cannot be qualified for a number of reasons. Wyle Laboratories used a pen recorder to record the pressure data, and the magnitude of the response is too small for accurate extrapolation. Two independent thrust measurements were taken by the Palisades staff. One was incorrectly calibrated, and the other is suspect because of offset irregularities and drift. The recorded information that can be qualified appears to be motor current, torque spring pack deflection, the various switch responses, and valve closure under all loadings as verified by stem position recordings and visual observations of the downstream exhaust stack. We believe from our test experience that there are sufficient qualified data, supported by trending data, to determine that with a properly lubricated valve stem, a torque switch setting high enough to produce in excess of 15,000 lb thrust unloaded, and large enough power cables, the block valve would have a sufficient safety margin to close at all credible plant conditions except degraded voltage. The degraded voltage analysis requires technical information we do not currently have available to us. These conclusions are based on the following technical review of the data.

TEST CONFIGURATION

Figure 1 shows a simplified schematic of the Wyle test loop. It is our understanding from the Palisades personnel that the pipe sizes in the test loop and the distances between the valves are representative of the actual plant layout. The block valve and PORV are actual valves removed from the plant and reinstalled in the Wyle test facility. The PORV was a 4-in. Target Rock solenoid-operated Y pattern globe valve. The block valve was a 4-in. motor-operated split wedge Edward gate valve. The motor operator was a Limitorque Model SMB-00-25. The valve would function much like a flexible wedge gate valve. However, the internal design of the valve was different from the flexible-wedge designs. The gate to body guide arrangement uses a tongue on the gate and a groove in the body. Both sides of the guide surfaces, as well as the gate and body sealing surfaces, were hardfaced. The clearances on the gate to body guide surfaces were also quite close compared to the flexible-wedge designs. The valve stem was 1 in. in diameter for most of its length except in one area where the diameter was reduced. This small-diameter portion of the stem established the maximum stem load the valve could sustain. Using normal material strengths, the maximum thrust allowable was 14,000 lb, and the calculated target thrust for the valve was 12,600 lb. This is a very narrow thrust window when one considers that thrust is always higher in an unloaded valve. We understand that the manufacturer has recalculated the maximum allowable thrust at 18,000 lb based on the actual material test strengths. This will provide a greater margin for allowable thrusts.

Measurement responsibilities were split between Wyle and the Palisades staff. Wyle measured and recorded on hard copy the pressures, temperatures, and valve stem positions. Palisades measured valve responses and valve switch responses with two VOTES plant-type diagnostic test machines, designated B&W system and Liberty system on Table 1. Two VOTES thrust sensors were mounted on the block valve yoke. Each of the diagnostic machines monitored one of the thrust sensors. It was later found that the B&W system was improperly calibrated, and we have not used those results in our analysis. The other machine, Liberty system (A1026), monitored the

VOTES thrust sensor, motor current, and switch positions, and also monitored the response of a MOVATS TMD mounted on the motor operator. The TMD measured the motor operator spring pack response. The responses measured by this second machine are the basis for our analysis of the block valve performance.

ANALYSIS OF TEST DATA

Table 1, provided by Palisades, is a list of the tests performed at Wyle Laboratories. The tests of interest for our analysis are those tests identified as 13, 14, and 15 in the column labeled Liberty System (A1026). After their return to Palisades, the staff provided the INEL with the test measurements in magnetic format for the Palisades measurements and copies of the hard copy from the Wyle measurements. Through the use of a plot reader, we digitized the hard copy plots. There was no common trigger between the Wyle data and the Palisades data, so we did not try to match time bases; however, the data can be roughly compared through the stem position plots. The magnetic data was in a canned proprietary code, so access to the raw data was difficult. However, computer experts at the INEL, working together with experts from Liberty, were able to make the data compatible with our analysis tools.

Figures 2 through 11 are the data plots for test 15, the 100% closure test; Figures 12 through 21 are for test 13, the 60% closure test, and Figures 22 through 31 are for test 14, the 25% closure test. These figures are presented at the end of the body of the report. Supplemental data are presented in Figures A-1 through A-13 in Appendix A.

Spring Pack Deflection

The first figure in each set is the spring pack deflection history. Observe in Figure 2 the small jog in the history at 7-1/2 s; this is the start of the valve's approximate 19-s closure. The valve travels all the way to the seating point on spring pack preload (no spring pack deflection). This gives a good indication that at this valve inlet pressure (1800 psig), the valve would have started to seat with a torque switch setting of only 1. In Figure 12, the spring pack deflection history for test 13 (60% closure) shows the same type of response at an average valve inlet pressure of 2000 psig. Figure 22 is the plot for Test 14 (25% closure), where the average valve inlet pressure was near 2500 psig. The spike at 4 s marks the beginning of valve closure. From that point through the 8 s point, a very slight increase in spring pack deflection is evident. From 8 s through final seating at 9 s, the slope of the trace shows that a larger amount of torque was required to move the disc to final seating. The other two plots make this transition in about 1/4 s. This would indicate that in tests 13 and 15 (100 and 60%, closures), the valve was fully seated on motor operator spring pack preload alone, while in test 14 (25% closure), the motor operator exceed spring pack preload for the last 3 or 4% of travel, which would be well after flow isolation.

Motor Operator Torque

The next plot in each set is a motor operator torque history. This plot was derived from the spring pack deflection history and from the Limitorque motor operator dynamometer calibration performed during final testing at Limitorque. (The Limitorque calibration record is Figure A-1 in Appendix A.) This torque history plot is our most useful tool in understanding the operational safety margin.

To understand the derivation and the usefulness of the torque history, one must first understand that the common Limitorque motor operator is a torque controlled device. The torque switch and torque spring combination determine the torque delivered to the worm gear. Figure A-2 in Appendix A is a simplified model of the torque transfer portion of the Limitorque motor operator. The motor turns a set of helical reduction gears, which turn the worm shaft, which, in turn, turns the worm. The worm is free to slide axially on the worm shaft, which is splined. The worm turns the worm gear, and the worm gear assembly contains the stem nut. As the worm gear assembly turns on the stem, which is threaded, it drives the stem into the valve (during closing). When the load in the valve stem is high enough that the load on the worm gear exceeds the preload in the torque spring, the rotation of the worm gear slows or stops, but the worm continues to turn, sliding axially up the worm shaft and compressing the torque spring as it climbs the worm gear. The torque switch setting determines how far the torque spring must be compressed before the torque switch is tripped, dropping out the motor controller contactor and breaking the current flow to the motor.

Rising-stem valves do not open and close on torque. The torque must be converted to thrust. This is done where the rotary motion of the stem nut is converted to the linear motion of the stem. Industry uses a standard calculation for this conversion: $F = T/\mu_s$ where F is stem force, T is operator torque, and μ_s is the stem factor. Stem factor is a function of stem diameter, thread pitch and lead, and the coefficient of friction between the operator stem nut and the valve stem. The only variable in this equation that cannot be effectively calculated is the coefficient of friction. Figure A-3 in Appendix A is a graphical depiction of the Limitorque calibration data shown on Figure A-1. This graphical format allows interpretation of the data and is used digitally to create plots that show calculated motor operator torque and predicted stem thrust. The torque switch on the Palisades block valve during the Wyle tests was set at two, which, as can be seen from Figure A-3, corresponds to about 132 ft-lb torque. The block valve had a 1-in. stem with 1/6 pitch and lead. Using the standard Limitorque tables for calculating stem factors at various coefficients of friction for this combination, we have calculated the thrust that one could expect at credible stem factors and coefficients of friction for the assumed 132 ft-lb torque at torque switch trip. These calculations are shown in Figures A-4 and A-5. This type of analysis is useful for checking the reliability of measured data. By comparing calculations to measured data, one can identify which data are suspect.

Figure A-6 presents a more consolidated picture of coefficient of friction versus torque switch setting for this operator. At the worst case friction factor and with a torque switch setting of two, the operator should deliver the target closing thrust.

A review of the torque history plots from each of the tests (Figures 3, 13, and 23) shows that the final torque at apparent full seating was the same in all three tests; we have created a comparison plot from the torque plots (Figure A-7) where one can see the effects of ΔP on the motor operator seating torque and get a better idea of the apparent safety margins available. The common point is at 2 s, where all torque spring motion had ceased. The preload and final torques line up within the error band of the instrumentation. Test 15 (100% closure) has the lowest ΔP (1800 psig) with test 13 (60% closure) the second lowest (2000 psig), and with test 14 (25% closure) the highest ΔP at near 2500 psig. We can assume that as the torque traces take on a very steep vertical slope, the motion of the valve stem has stopped. The time axis of the plot can be used to determine where the disc was in relation to the valve seat if we assume that the valve was seated at the end of the torque trace. (From all of the other evidence, this is a safe assumption.) The most conservative way to determine the location of the disc at any given time before full seating would be to assign all of the operator motion (per unit of time) to valve stem motion and none to compressing the torque spring. Test 14 shows the most ΔP effect, where the torque spring comes out of preload at about 1 s on the time line. The valve stem speed is 12 in. per minute. One second is equal to 0.2 in. stem travel. Disc travel from flow isolation to full seating is approximately 0.2 in. This would indicate that in the highest pressure test the disc had isolated flow before the torque spring was compressed beyond preload and had completed hard seating at about 146 ft-lb torque. The difference between the torque at hard seating (146 ft-lb) and the final torque (159 ft-lb) consists of spring pack compression; this is the margin for this particular closure. Thus, the valve would isolate flow and partially seat even if it experienced very high disc friction losses.

In the Generic Issue 87 (GI-87) test program (a separate NRC-sponsored test program addressing the failure of the high pressure coolant injection steam line without isolation), we subjected seven gate valve designs to full scale, high energy testing. We also compared partial closure to full closure under otherwise identical conditions. The results showed that full closure and partial closure of valves do not always produce the same results, even with other test parameters the same. A comparison of Figures A-8 and A-9 shows this phenomenon for the GI-87 valves. Figure A-8 is a stem force history for a 6-in. valve undergoing a 100% closure. This is an extreme case, as the valve did not completely seat, as indicated by the relaxation in measured force after the torque switch trips and the stem quits moving. Figure A-9 is a 30% reopening and reclosing of the same valve a few seconds later. The final seating force is 1500 lb more than it was in the 100% closing test, while the force necessary to get the valve in the seat is significantly less, at about 12,000 lb. At this stage of our GI-87 analysis, we are not sure of all of the factors that contribute to this phenomenon; however, it is real.

Test 13 is probably the most representative of an actual use of a motor-operated block valve in conjunction with a PORV lift and failure to close at this plant's operating conditions. The closure is made at 2000 psig, and the closure begins just as the block valve starts to become the flow limiter, as we will see later in the examinations of the pressure plots. The torque history for test 13 (Figure A-7) shows that the valve was seated at about 130 ft-lb torque. The valve appears to have at least a margin of torque at these conditions.

Figure A-10 (from the GI-87 testing) shows how careful one must be when using torque alone to determine valve seating. The torque trace at 31 s appears to have the same vertical component as the traces from tests of the Palisades valve (Figure A-7). However, this is the torque trace for the 100% closing shown in Figure A-8. The valve did not seat and just barely isolated flow. This lack of seating was verified by readings of valve stem position and stem force and by visual observation; all of these same observations in the Palisades case show the valve had closed.

Motor Current

The next important analysis is to determine how much margin is available in the motor operator electric motor. How close are we to stalling the motor at the highest torque demands? The final torques at torque switch trip are nearly identical, so we would expect to find the current traces nearly identical. The third plot in each of the Palisades figure sets (Figures 4, 14, and 24) is the current trace (Figure A-11 shows the three traces on one plot). We can see the average torque out current is 5.7 amp, which is about 22% of the locked rotor current as determined from Figure A-12, a typical motor torque speed curve for LRA type motors. According to Limitorque, they developed these LRA motors especially for high load applications such as line break isolation. Notice in Figure A-12 that the motor speed is very flat through most of the rated torque. This motor type is less likely to stall with a small load change at high torques than a more conventional motor operator motor. Figure A-13 is a more conventional motor speed curve. Notice the much sharper motor speed curve knee for this type of motor, which is much more likely to stall with a small load change out on the knee of the curve, where a large amount of motor speed is lost for a small amount of power gain. This loss of momentum is important in a marginally powered motor. It appears that the Palisades motor has a good margin for a torque switch setting of 2.

Valve Stem Position

The next plot in each Palisades data set (Figures 5, 15, and 25) is the valve stem position. (These plots were digitize from hard-copy plots, and the small nonlinearities are probably more indicative of that process than of the valve closing in a nonlinear manner.) The plots do show that the block valve closed completely in every case.

Pressure, ΔP, and Temperature

The next two plots in each Palisades data set (figures 6, 7, 16, 17, 26 and 27) are the upstream block valve and upstream PORV pressure history plots (these plots were also digitized from hard-copy and must be considered to show only trend). It can be seen in the first set (test 15, Figures 6 and 7) that in both plots the pressure drops linearly with system pressure decay through about 5 s. The small jog in the traces at 5 s is believed to be where Wyle cut the boiler back in to help sustain the accumulator pressure. At about 6 to 7 s the PORV pressure starts to drop and the block valve pressure remains fairly constant. This is the point where the choke plain transfers to the block valve and the ΔP across the block valve starts to increase. This supports Palisade contention that somewhere between 60 and 70% open the block valve becomes the system orifice.

The plots from test 13 (Figures 16 and 17, 60 percent closure) show that the ΔP across the valve increases linearly. Based on our GI-87 experience, the stroke time is marginally long enough to discount the performance differences between full closure and partial closure that we saw with the GI-87 valves.

In the test 14 set (Figures 26 and 27), we see the PORV upstream pressure drop very quickly, while the block valve pressure remains rather constant. We see the value of this test (test 14) being that if the block valve trips out on a full closure, a restart on the valve would probably assure valve closure.

The rest of the pressure and temperature plots (Figures 8 through 10, 18 through 20, and 28 through 30) support the other plots used in the analysis and are included for completeness. The temperatures indicate that the steam in some cases was probably superheated, slightly lowering its density, which may or may not influence the disc loading. The question is density versus velocity and which one produces the highest loading. Our GI-87 work in this area is not complete; however, it has been our experience to date that the ΔP has the most effect on the loading, and density and velocity are much less important effects.

Stem Force

The final plot in each set is the force trace (Figures 11, 21, and 31). Palisades staff electronically zeroed the offsets in the traces at the stem rejection load for the valve inlet pressure. The variability of the initial offsets of the transducer before the forced zeroing was too great for us to put any faith in the results. There were other evidences of the unreliability of the stem force data. Figure 11 (test 15, 100% closure) is a good example, where the general trend of the plot is positive (less force) until final torque out. In our experience, with a constantly increasing ΔP across the disc, the force required to close a valve does not decrease.

CONCLUSIONS AND RECOMMENDATIONS

The technology used in this analysis is our own. We have stated publicly that we and anybody else can do a better job in eliminating assumptions when both torque and thrust are available for use in analyzing a valve's performance. The procedures we used are fairly standard industry practices. The basic difference between this analysis effort and many other uses of the same practices is that we had full scale test results to work with. The valve was not damaged by the loading and appeared to have linear disc friction. These facts justify the use of the standard practices in this analysis.

The valve, as configured at Wyle Laboratories, closed at all of the loads at which it was tested. Although the valve was not tested at design basis loadings (for example, full closure at 2500 psig), the results of the Wyle tests indicate that the valve would close at credible plant conditions. During reinstallation of the valve, care should be given to the following points to ensure that the valve will perform as well as or better than at the test site:

- The torque switch must be set high enough to produce in excess of 15000 lb thrust at torque switch trip unloaded.

- The stem and stem nut must be well lubricated.

- Power cables must be sized for torque out currents, not running currents.

- Packing loads must not be increased significantly.

The difficulty and less-than-straight-forwardness of this analysis are directly proportional to the previously stated hardware, test facility, and measurement problems. The valve and motor operator, as designed, are marginal for the application. The target closing thrust was within 10% of the maximum thrust allowed for the motor-operator/valve combination. The test facility could not maintain the required upstream pressure throughout a full valve closure; this deficiency necessitated a step procedure to characterize the valve closing response. Previous test results show this procedure does not always produce the same results as a full design basis closure. The measurements provided by Wyle were not qualifiable and at best can be used only for trending. The measurements taken by Palisades are more useful; however, the Palisades analysts put all of their confidence in the thrust measurements for test control and acceptability, and those measurements appear to be suspect.

With the utilities preparing to respond to GL-89-10, it may be useful to provide guidance (workshops, guidelines, etc.) to advise utilities personnel on how to run a good test and what kind of results are acceptable. We have learned over the years that you cannot always depend on test facilities to provide the necessary information on how to run a good test, and they are not always familiar with the latest regulatory requirements, which may dictate how a test is run. This Palisades Test has shown what kind of problems the NRC may anticipate in future GL-89-10 testing.

Table 1. MO-1042A votes data

Date	Test Purpose	Test Number: Liberty System (A1026	Test Number: B&W System (A1007)	Data Obtained: Liberty	Data Obtained: B&W	Comments
12/06/89	As Found at Wyle	1	7	Good	Good	Cold-Static
12/06/89	575 psi Jog Open	2	8	Good	Good	Seated Cold
12/06/89	575 psia Jog Open	3	9	Good	Good	Seated Hot
12/07/89	Verify TMD Wiring	4	N/A	Good (Purged)	N/A	Good Response Connected to Liberty System
12/07/89	1800 psia Static Cycle	5	10	Good	Good	Piston Effect
12/07/89	1800 psia Full Open dP	6	11	Good	Good	
12/07/89	2500 psia Full Open dP	7	12	Good	Good	
12/07/89	1400 psia 5 Sec Static Cycle	8	13	Bad Data (Purged)	Good	Water Damage
12/07/89	1800 psia 5 Sec Static Cycle	9	14	Bad Date (Purged)	Good	Water Damage
12/07/89	Check Sensor & Cables	N/A	15	N/A	Bad Data (Purged)	Trouble Shoot
12/07/89 (Purged)	Check Sensor & Cables	N/A	16	N/A	Bad Data	Bad Date
12/08/89	Op Check of System	10	17	Good	Good	Static-Cold
12/08/89	2500 psia Static Cyle	11	18	Good	Good	
12/08/89	2500 psia 60% Close dP	12	19	Missed Data (Purged)	Good	
12/08/89	2500 psia 60% Close dP	13		Good	Missed Data	Purged
12/08/89	2500 psia 25% Close dP	14	20	Good	Trace/No Sensor	
12/08/89	2500 psia 100% Close dP	15	21	Good	Bad Cable (Purged)	

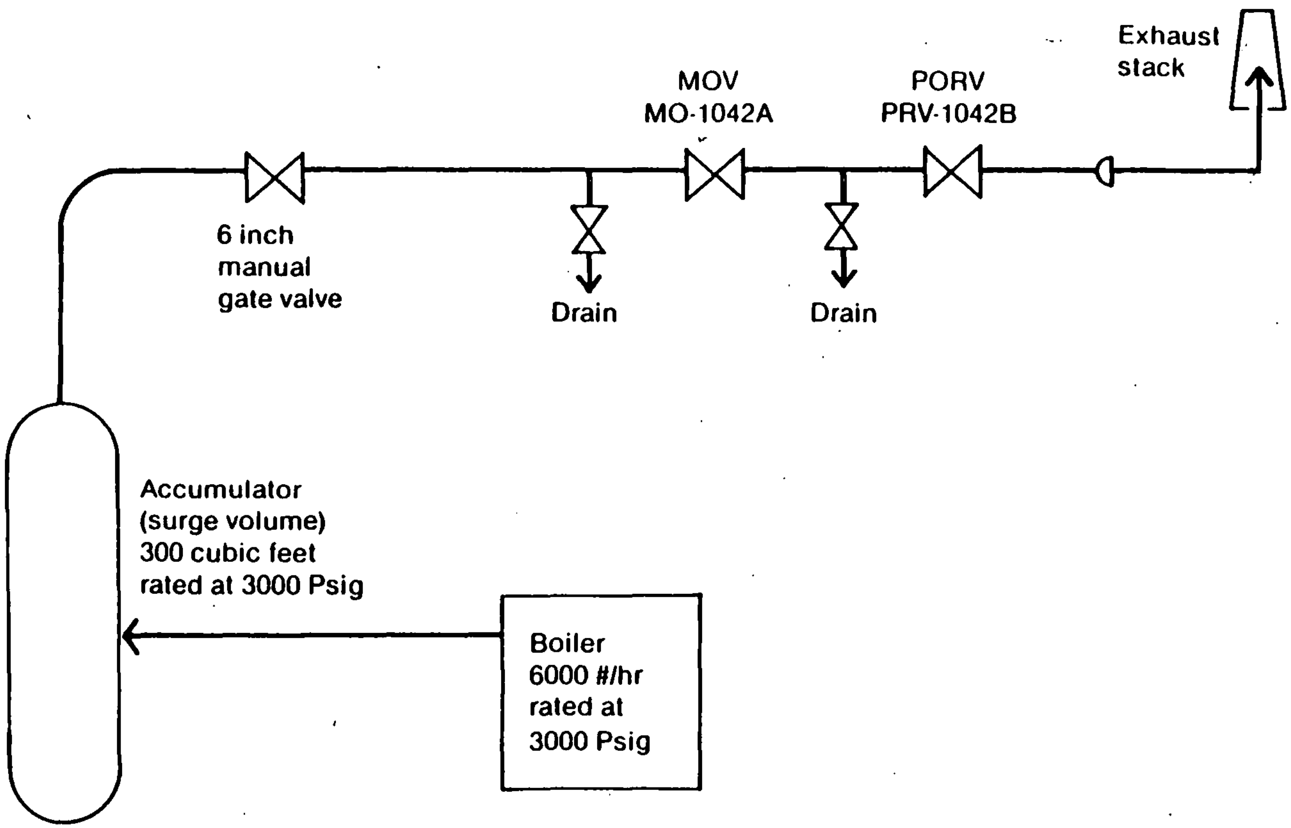

Figure 1. Simplified schematic of the Wyle flow loop.

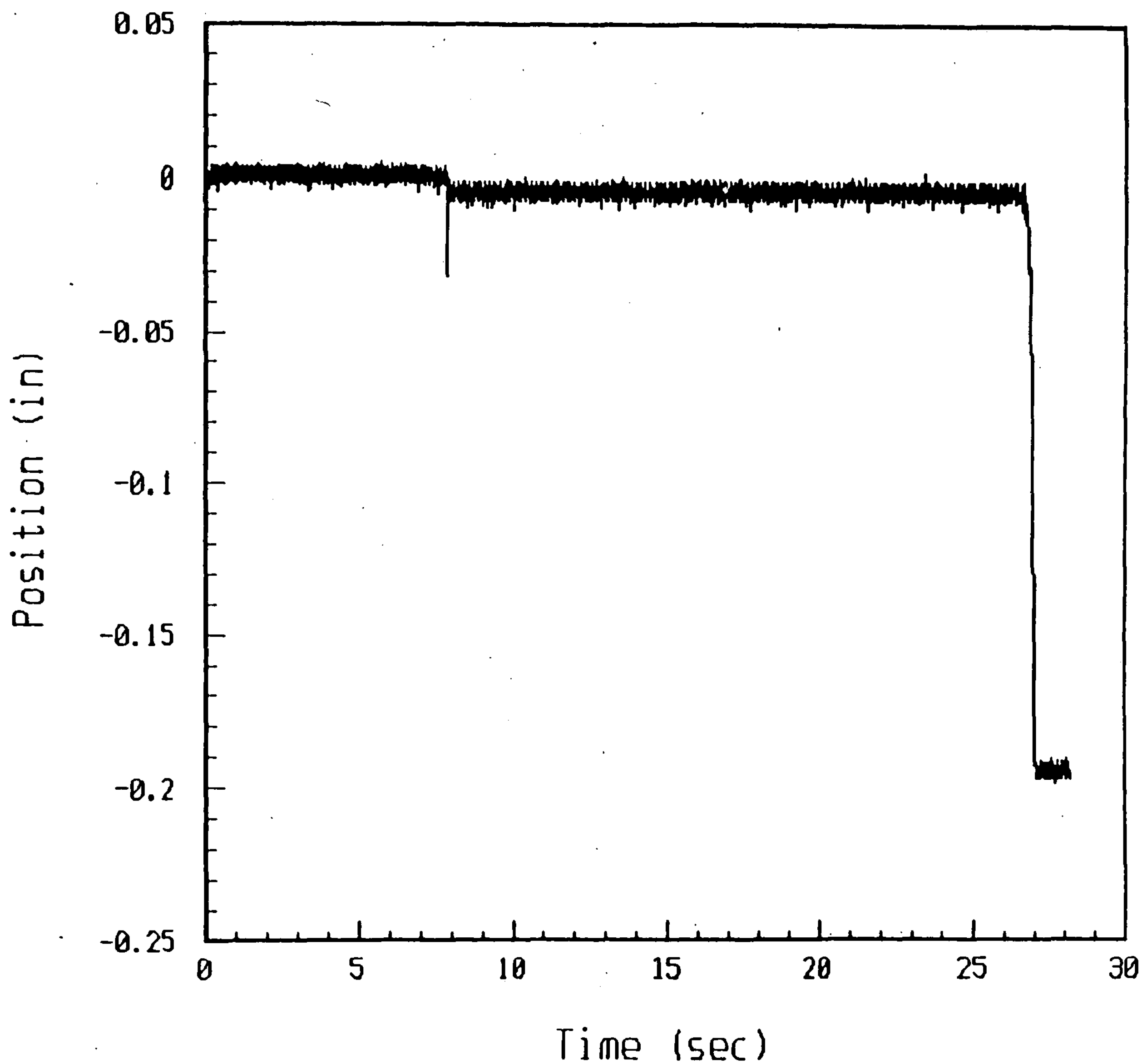

Figure 2. Block valve motor operator spring pack deflection history, test 15 (100% closure)

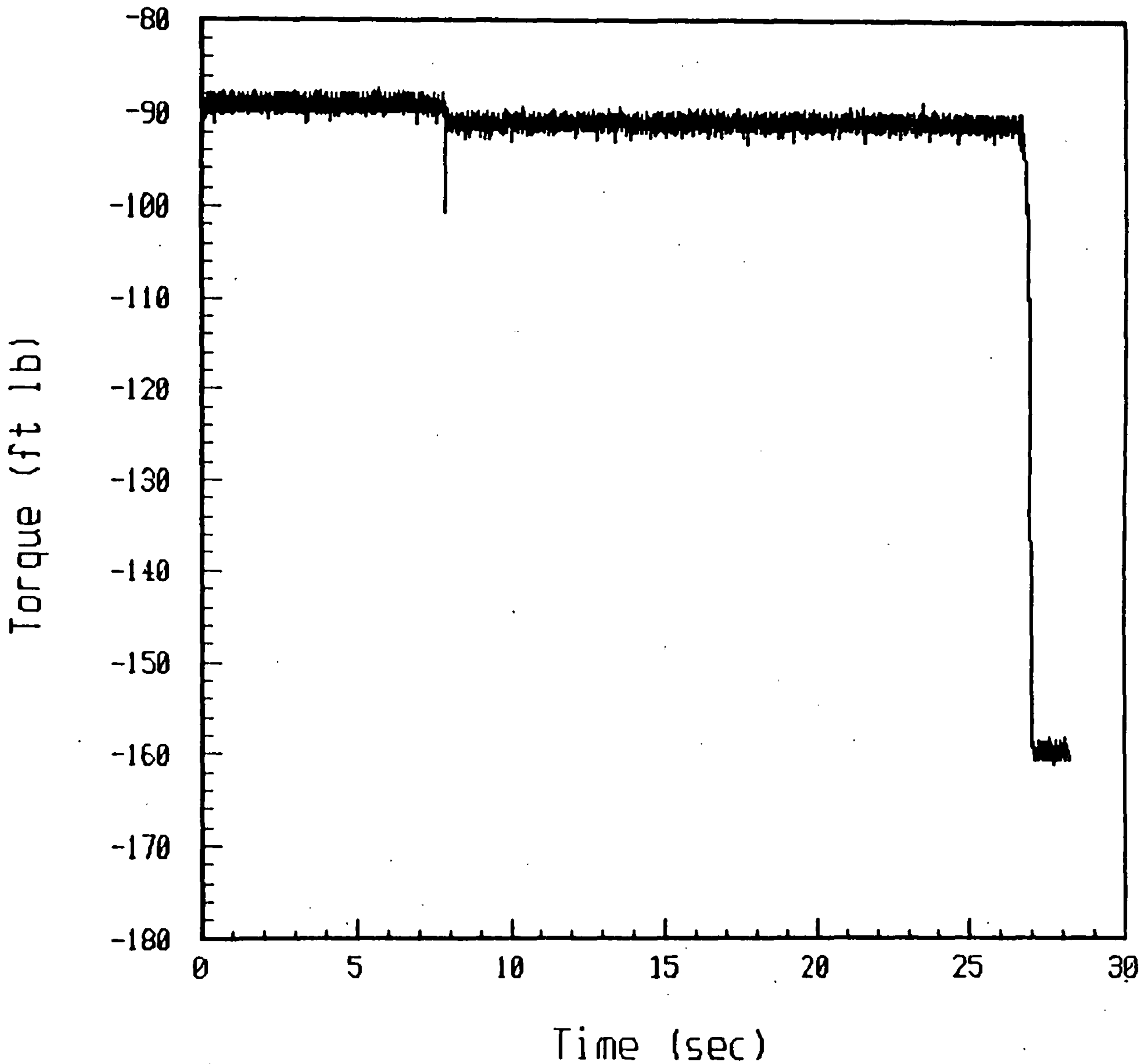

Figure 3. Block valve motor operator torque history, test 15 (100% closure).

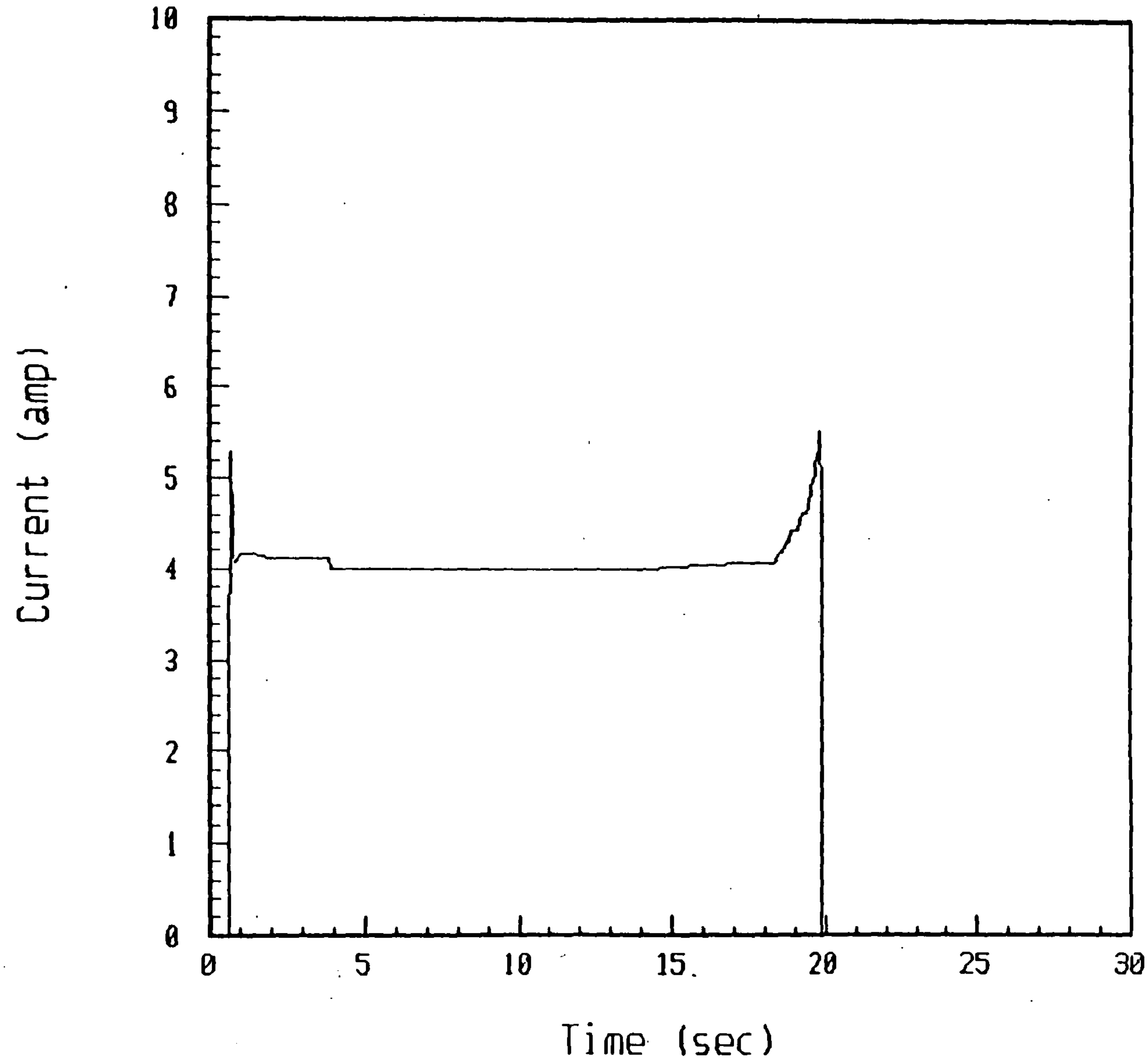

Figure 4. Block valve motor operator motor current history, test 15 (100% closure).

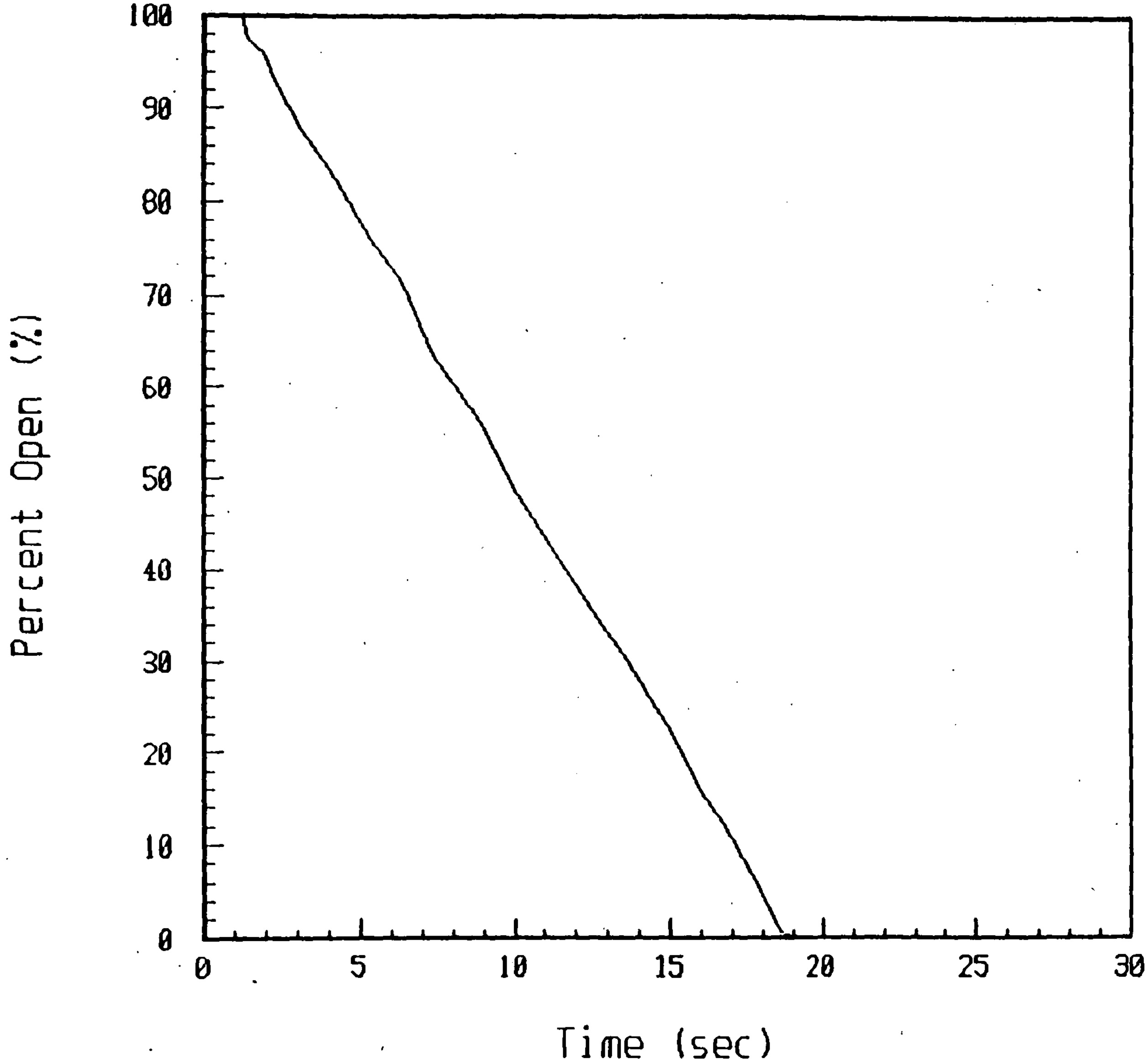

Figure 5. Valve stem position history, test 15 (100% closure).

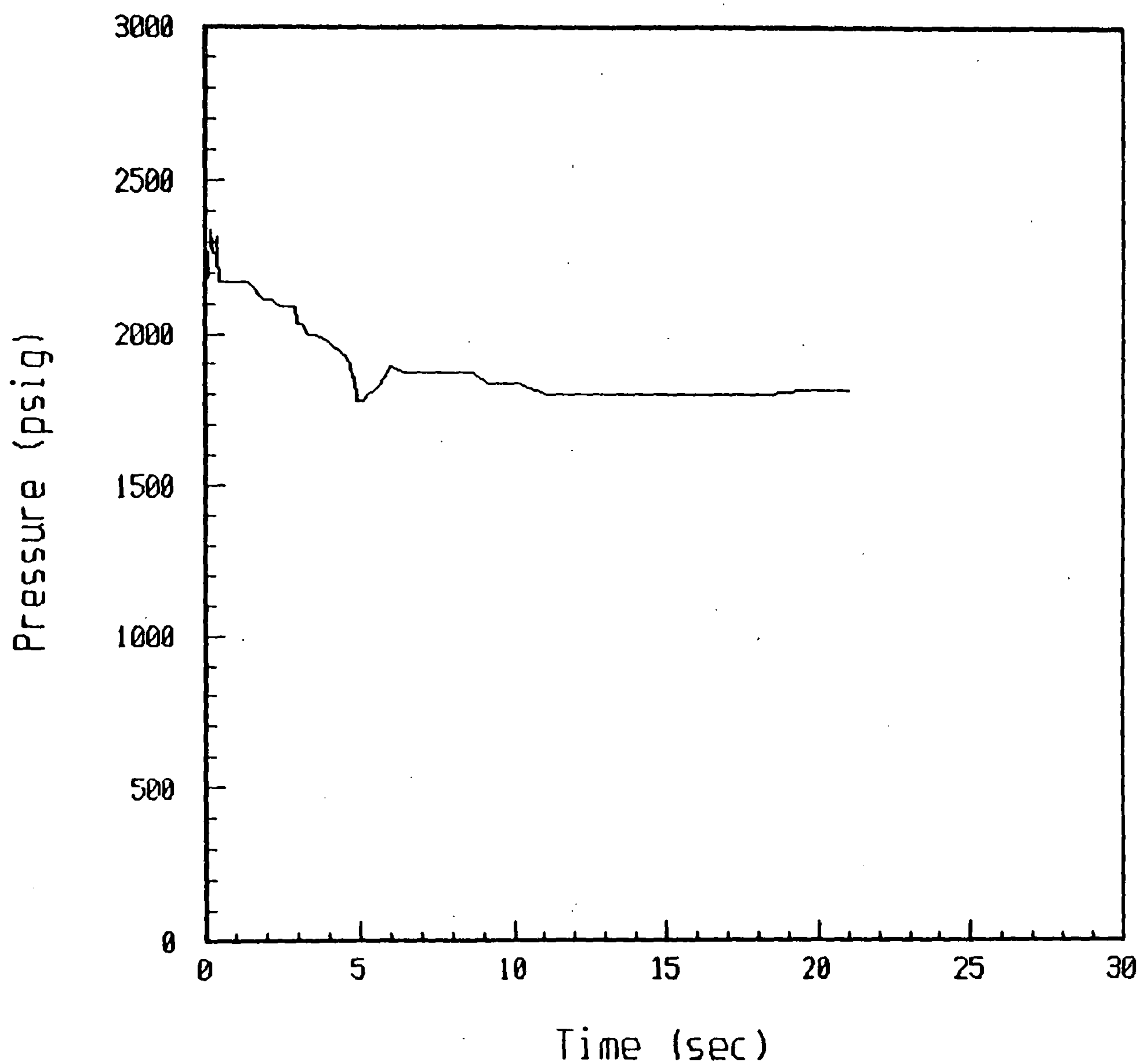

Figure 6. Static pressure history recorded upstream from the block valve, test 15 (100% closure).

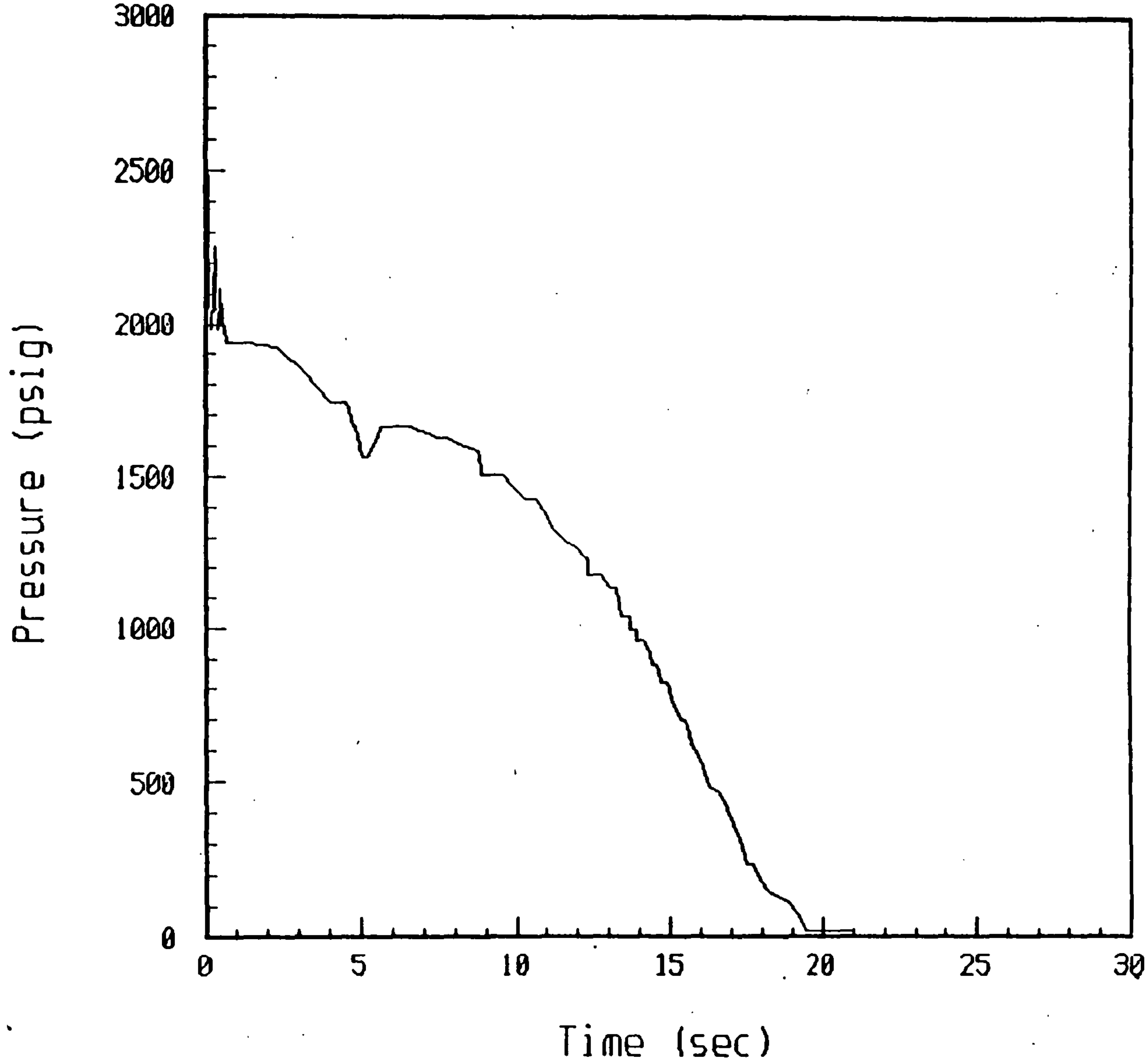

Figure 7. Static pressure history recorded upstream from the PORV, test 15 (100% closure).

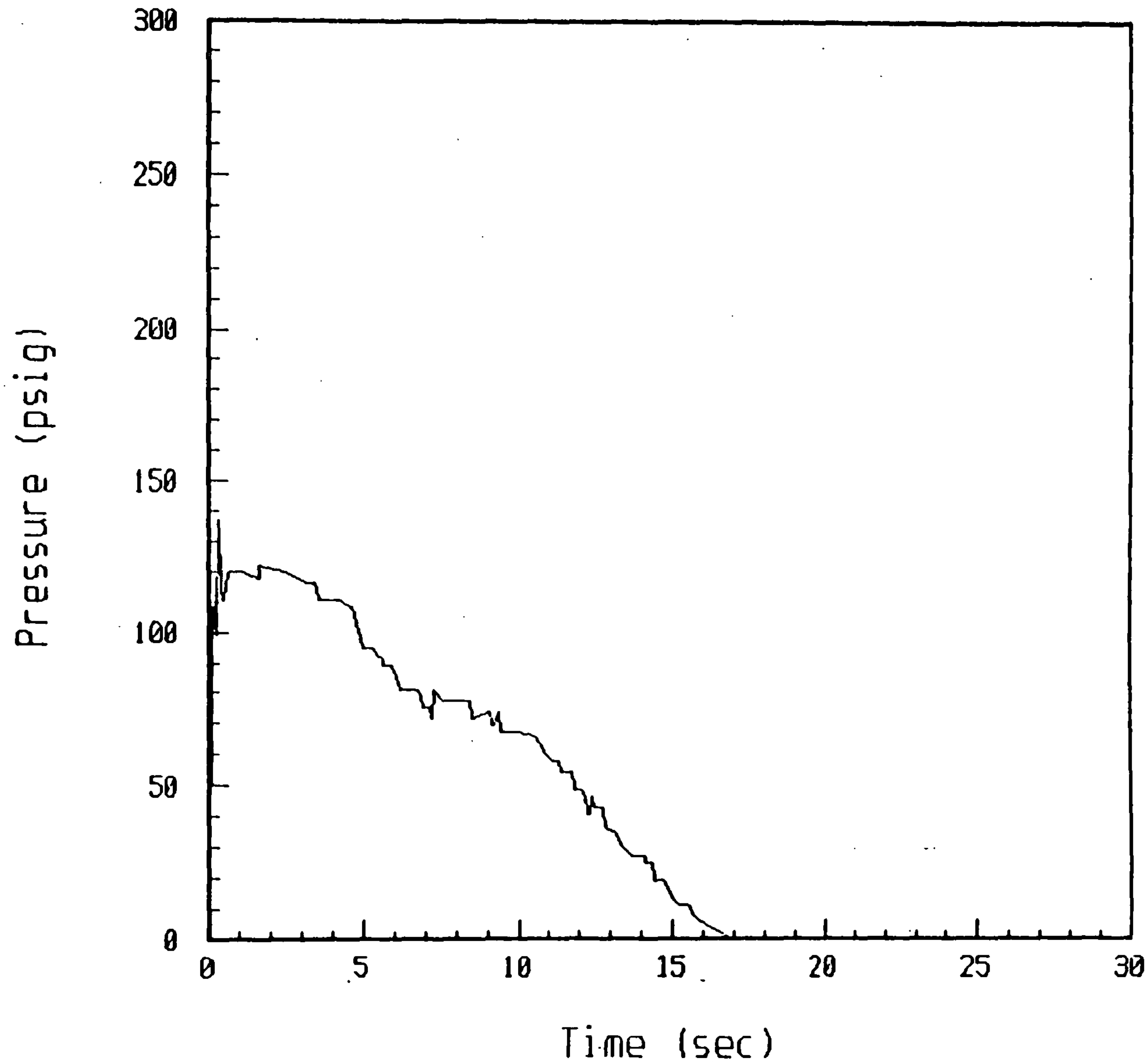

Figure 8. Dynamic pressure history recorded upstream from the block valve, test 15 (100% closure).

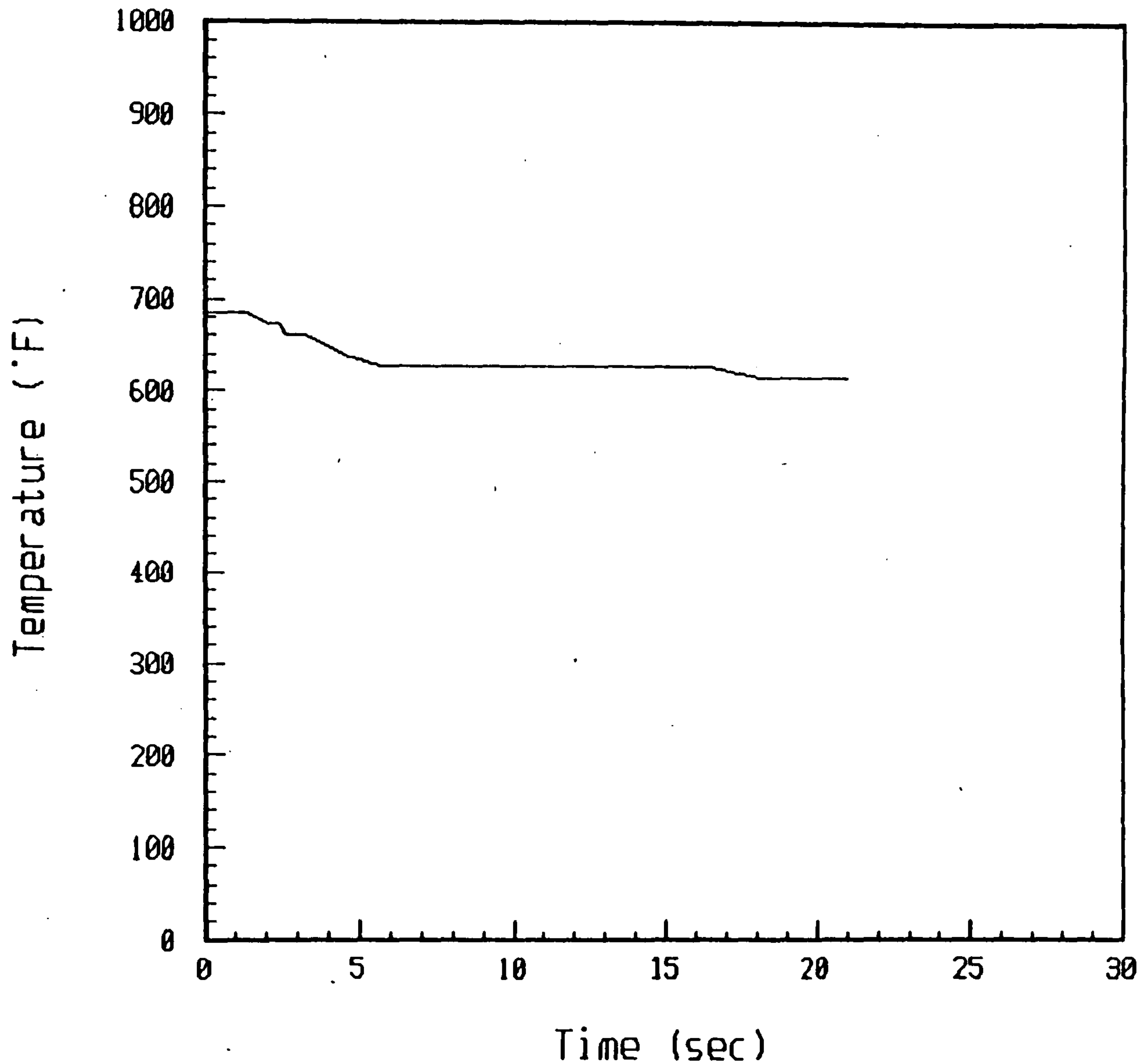

Figure 9. Temperature history recorded upstream from the block valve, test 15 (100% closure).

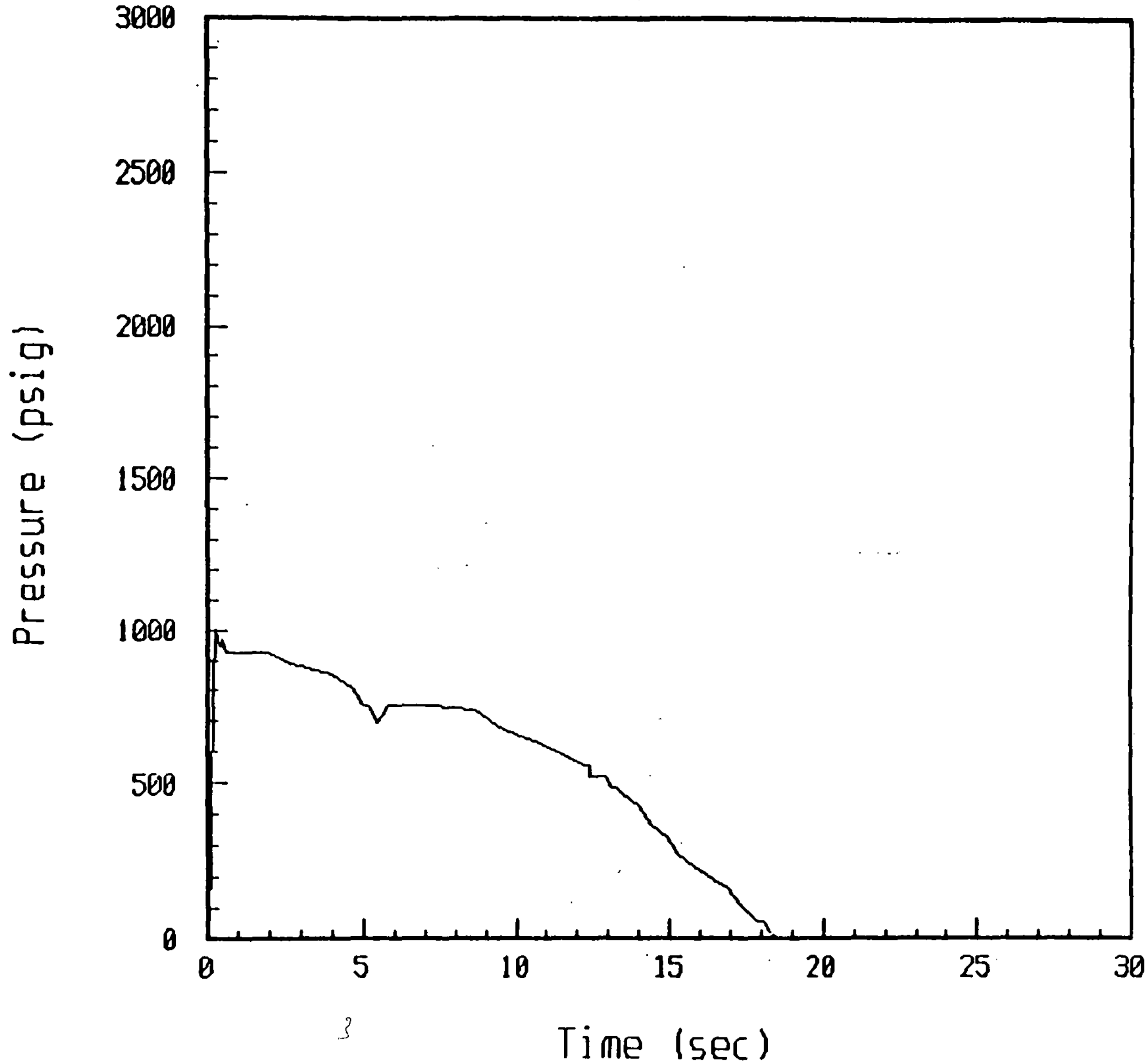

Figure 10. Static pressure history recorded downstream from the PORV, test 15 (100% closure).

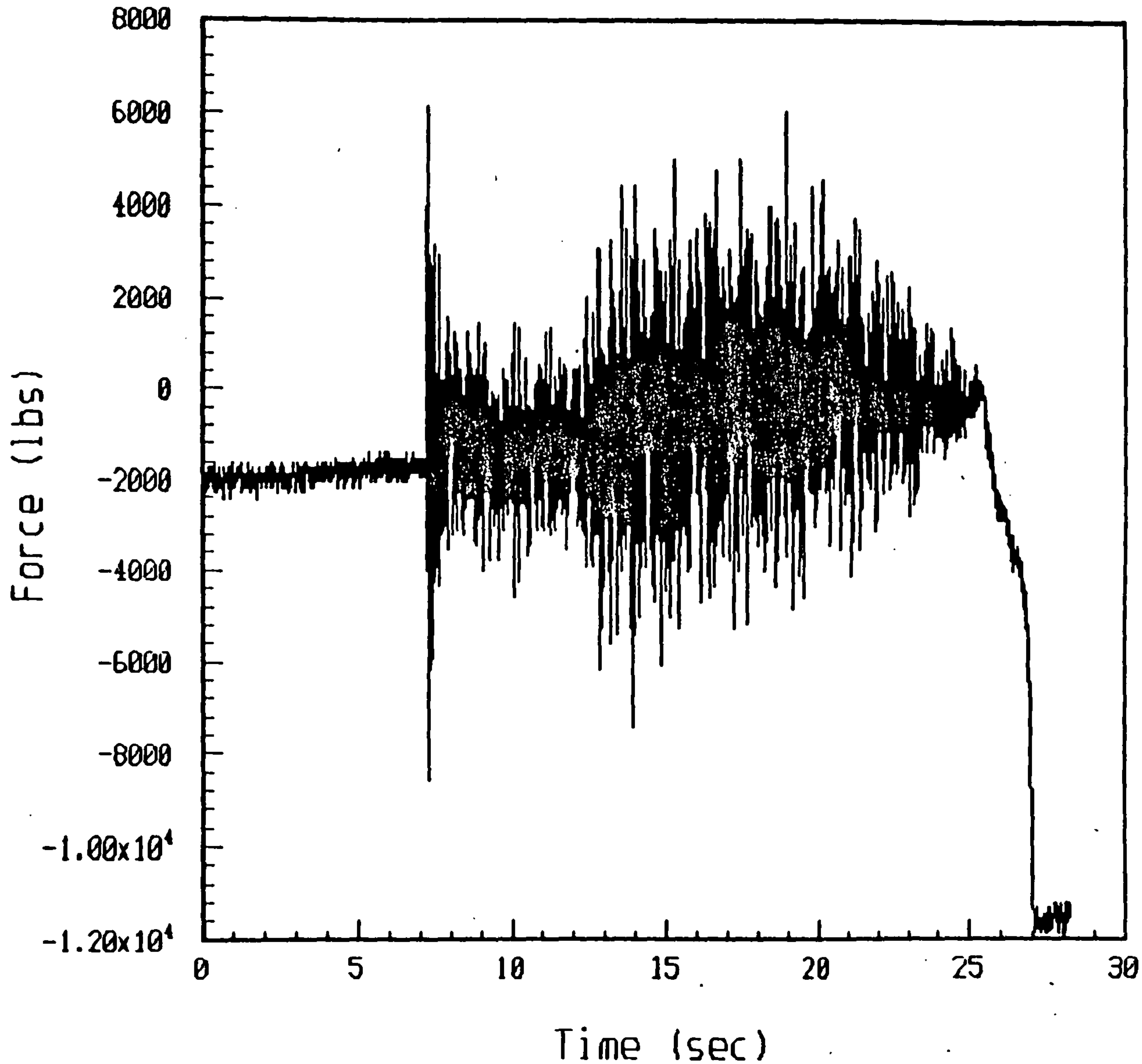

Figure 11. Block valve stem force history, test 15 (100% closure).

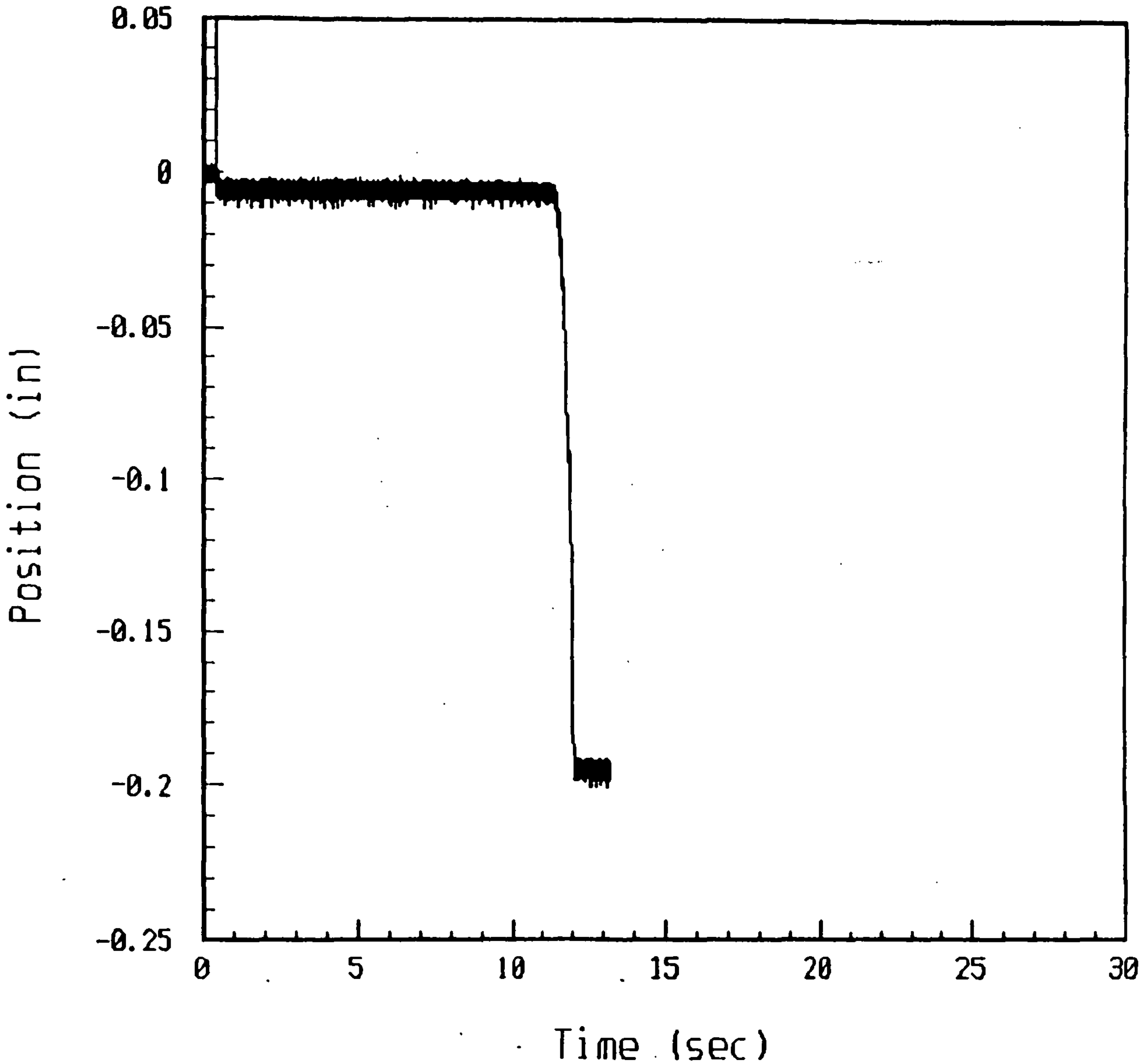

Figure 12. Block valve motor operator spring pack deflection history, test 13 (60% closure).

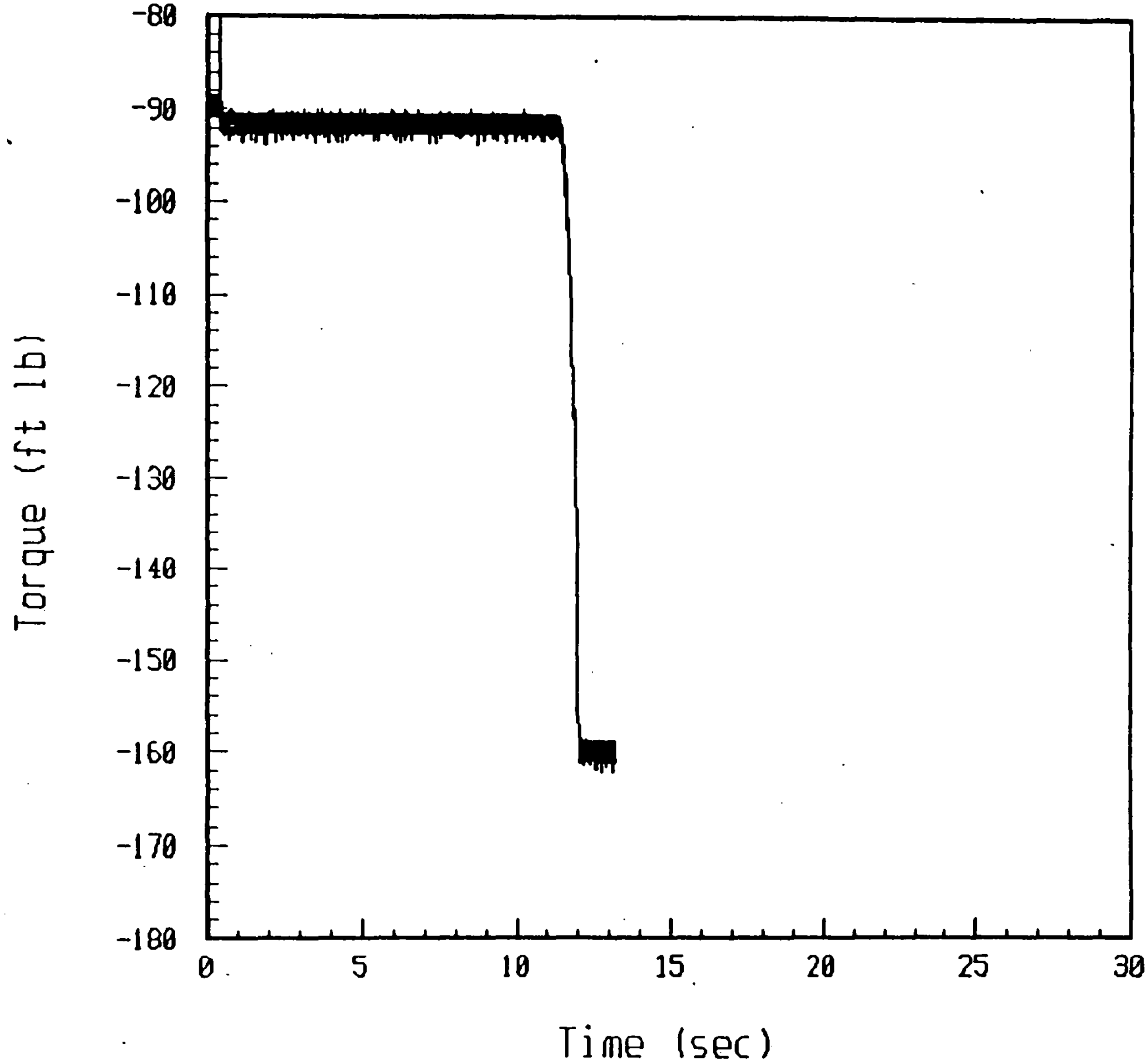

Figure 13. Block valve motor operator torque history, test 13 (60% closure).

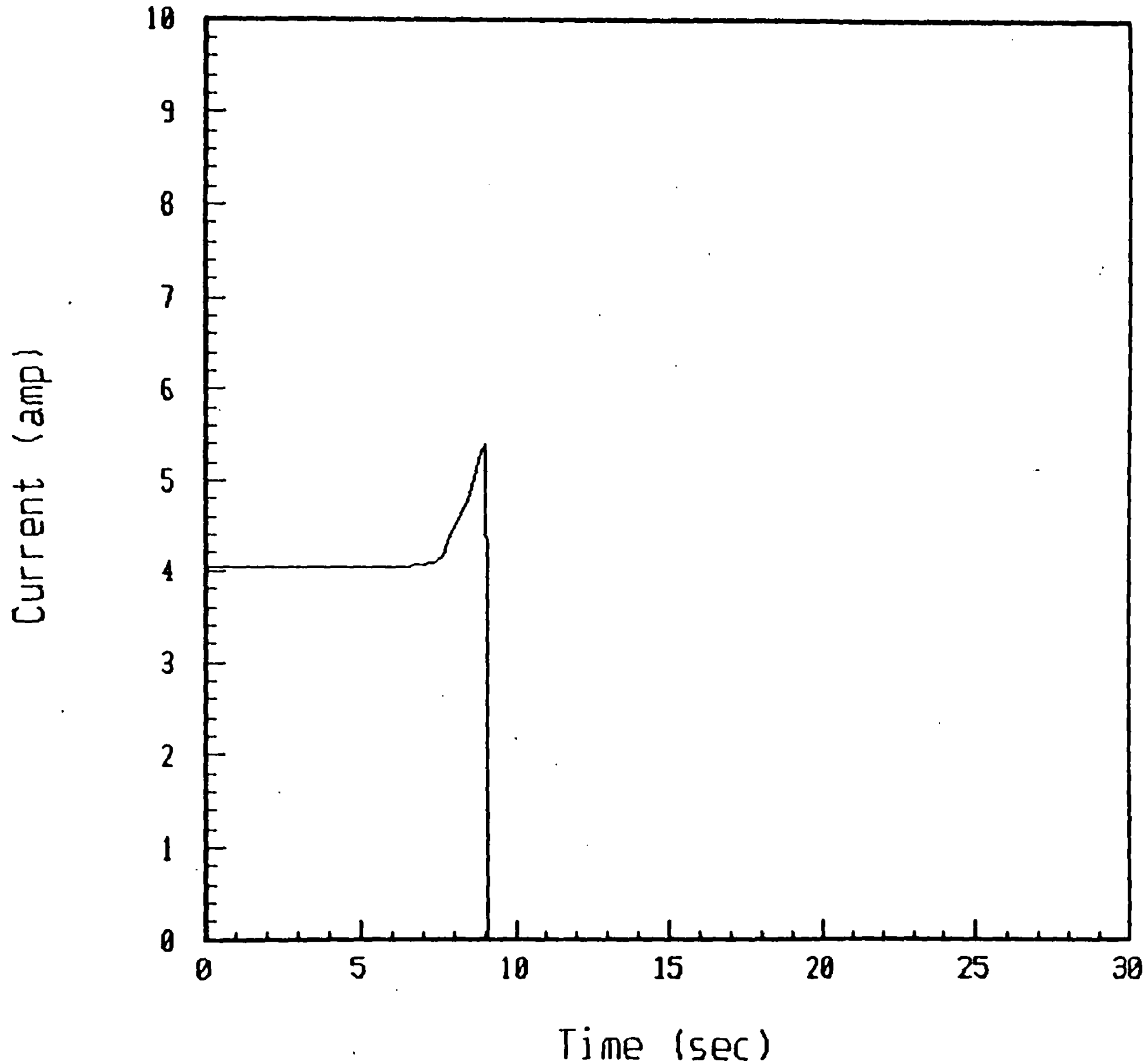

Figure 14. Block valve motor operator motor current history, test 13 (60% closure).

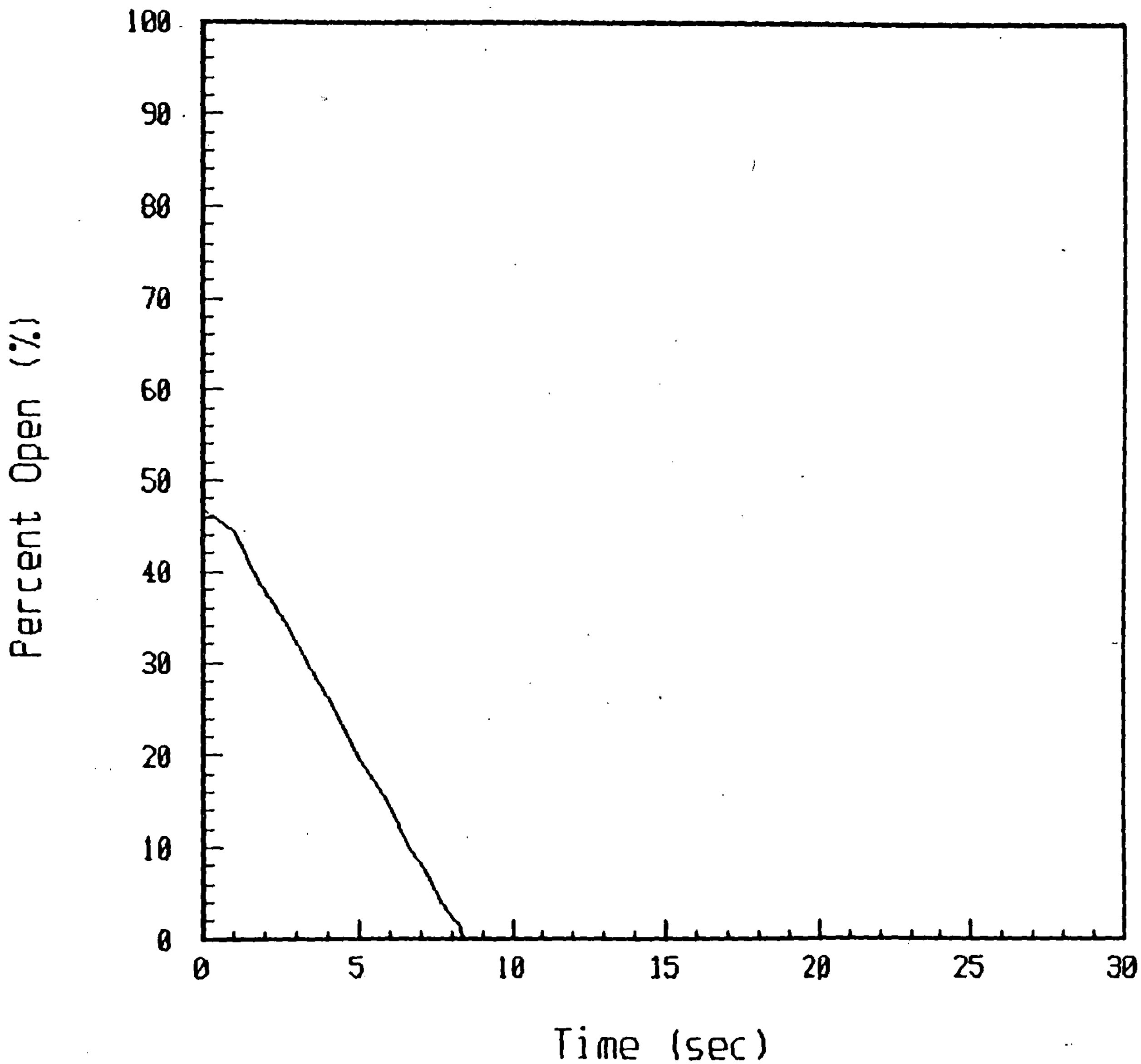

Figure 15. Valve stem position history, test 13 (60% closure).

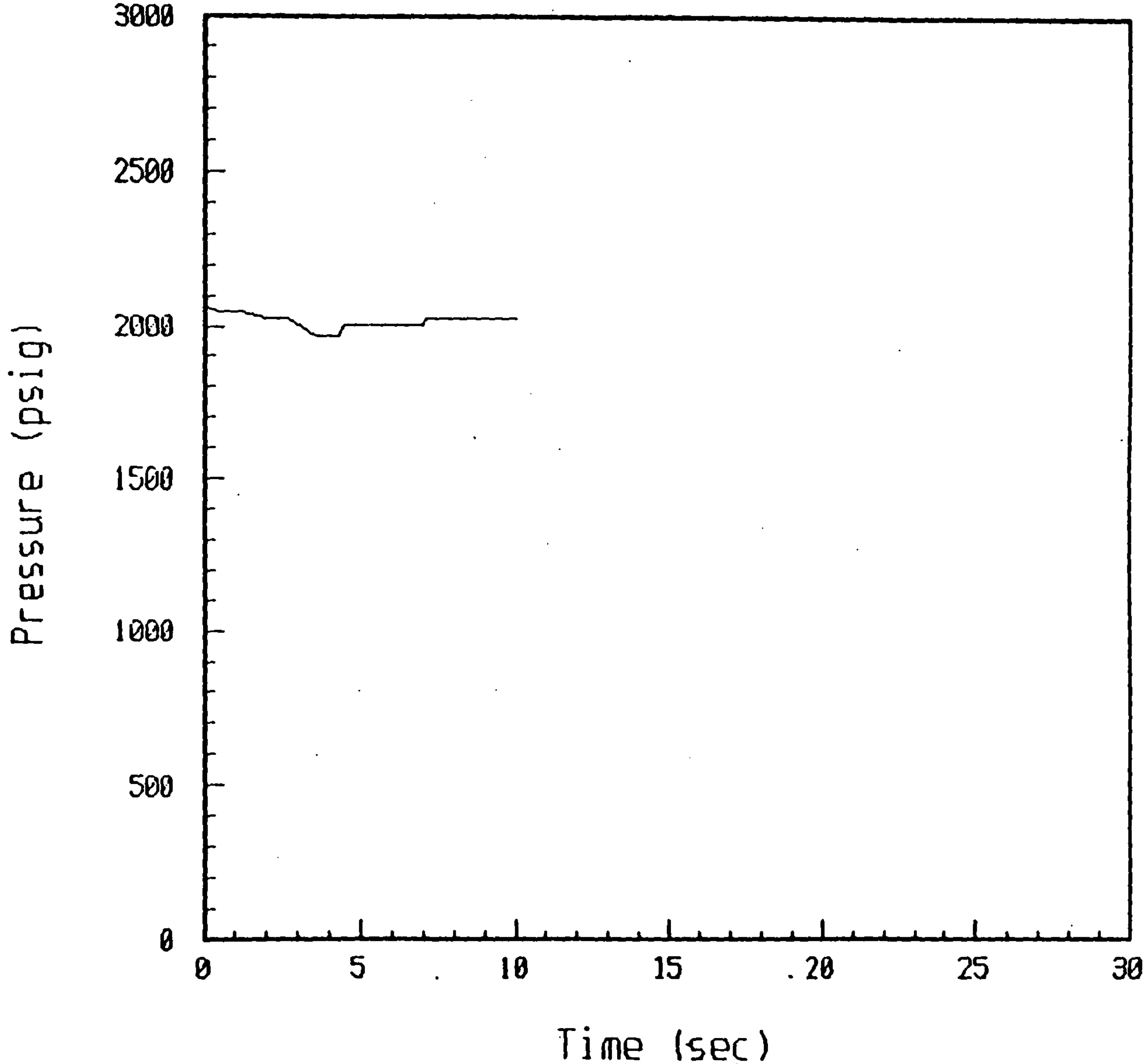

Figure 16. Static pressure history recorded upstream from the block valve, test 13 (60% closure).

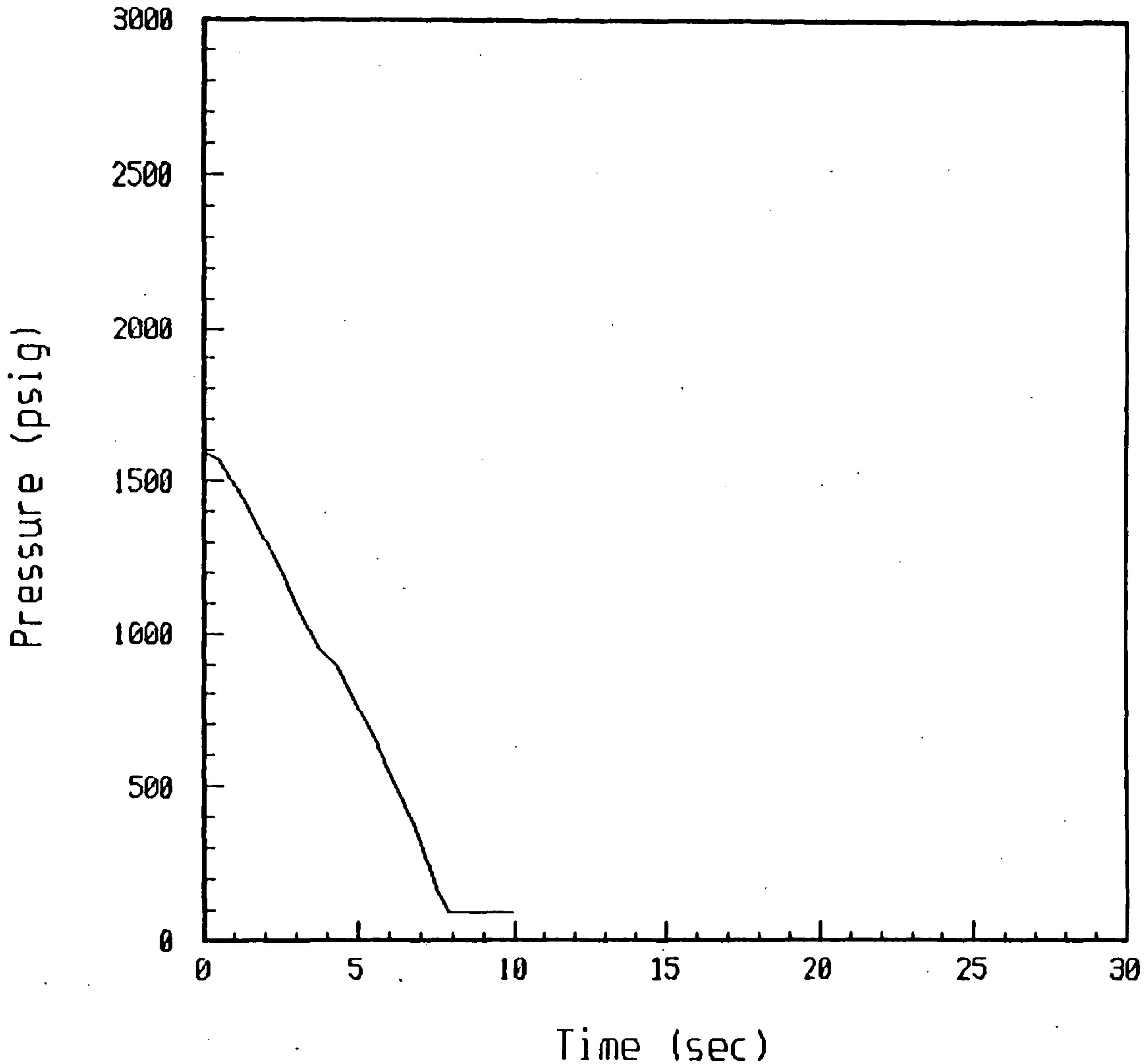

Figure 17. Static pressure history recorded upstream from the PORV, test 13 (60% closure).

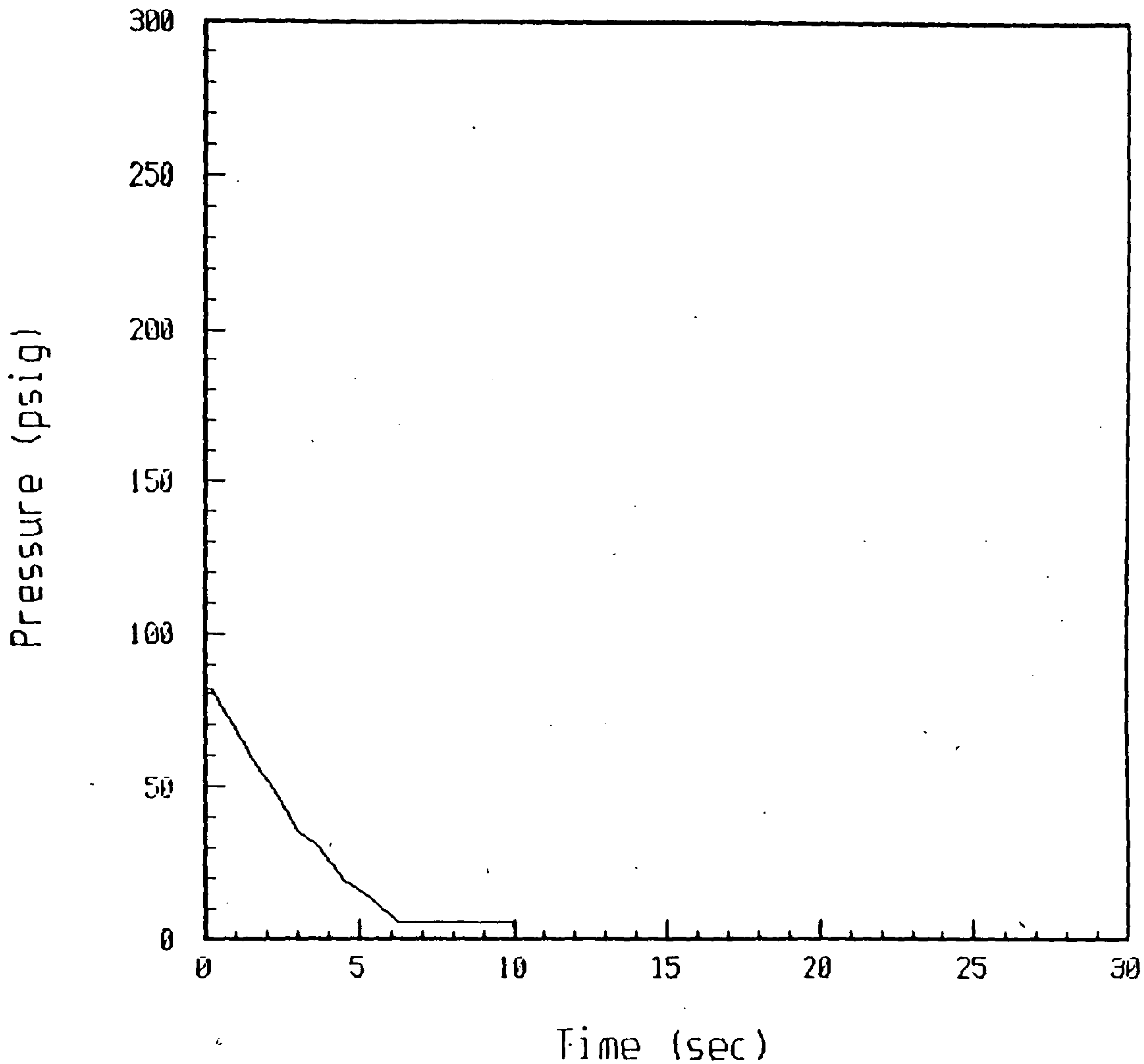

Figure 18. Dynamic pressure history recorded upstream from the block valve, test 13 (60% closure).

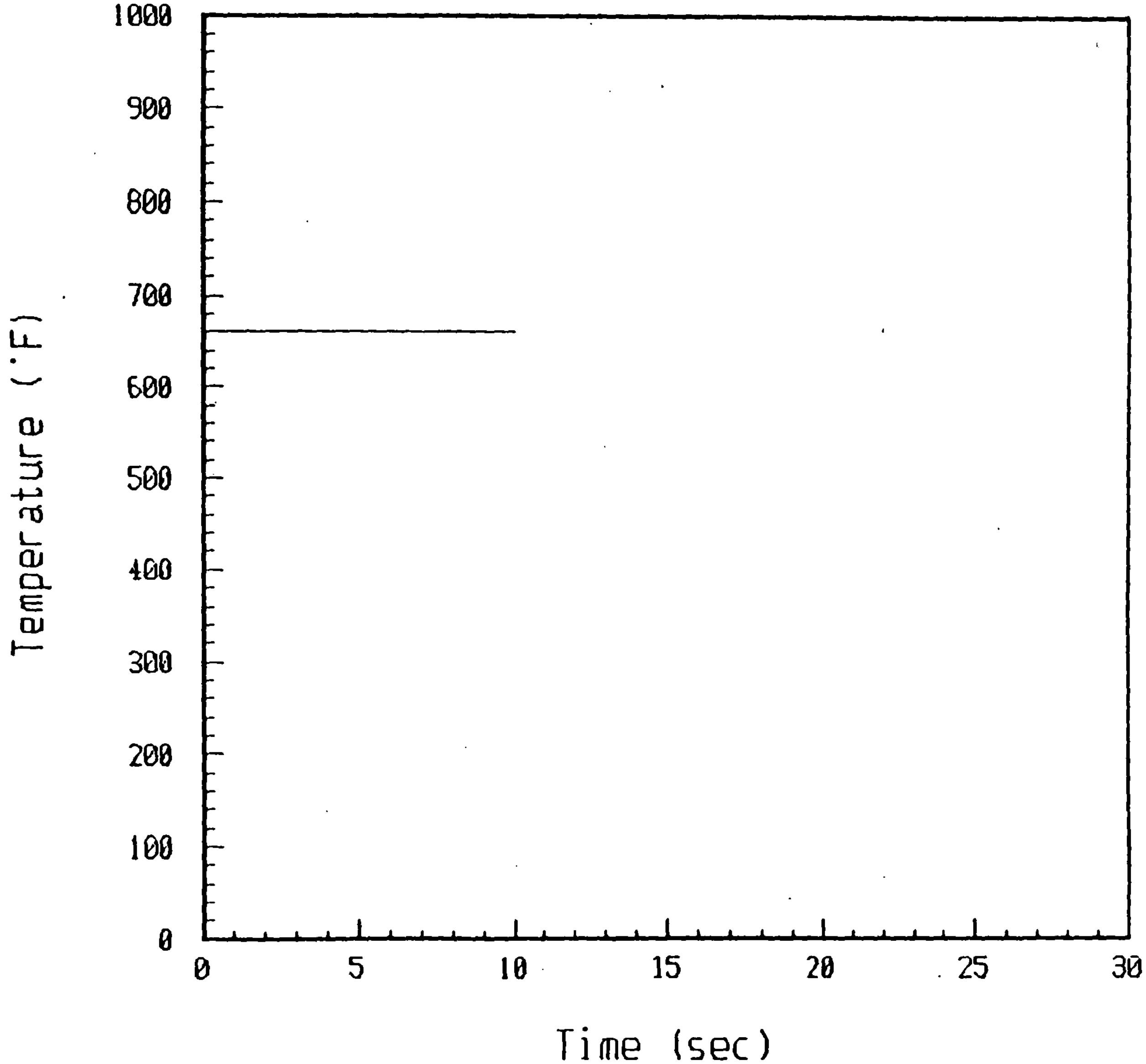

Figure 19. Temperature history recorded upstream from the block valve, test 13 (60% closure).

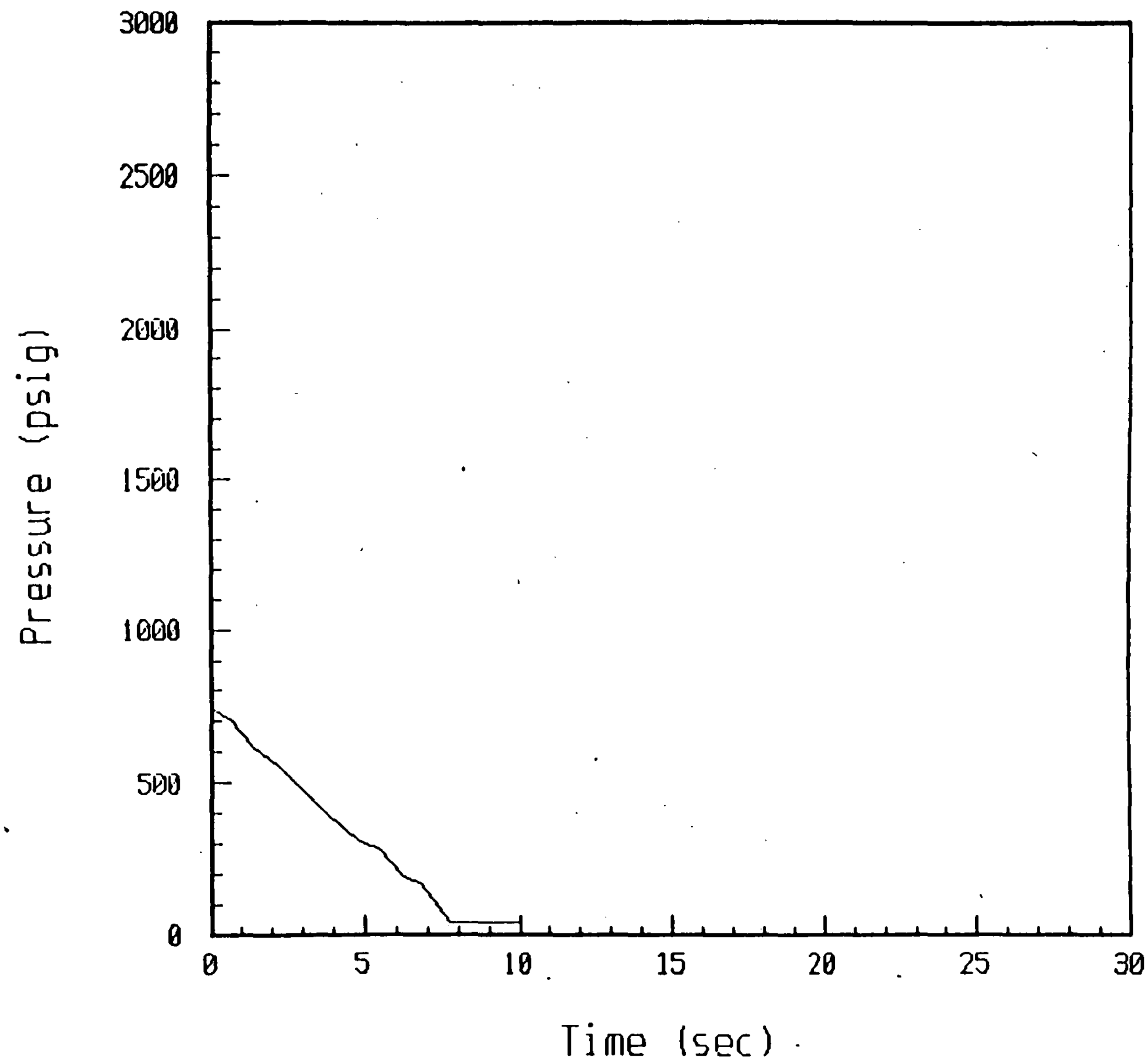

Figure 20. Static pressure history recorded downstream from the PORV, test 13 (60% closure).

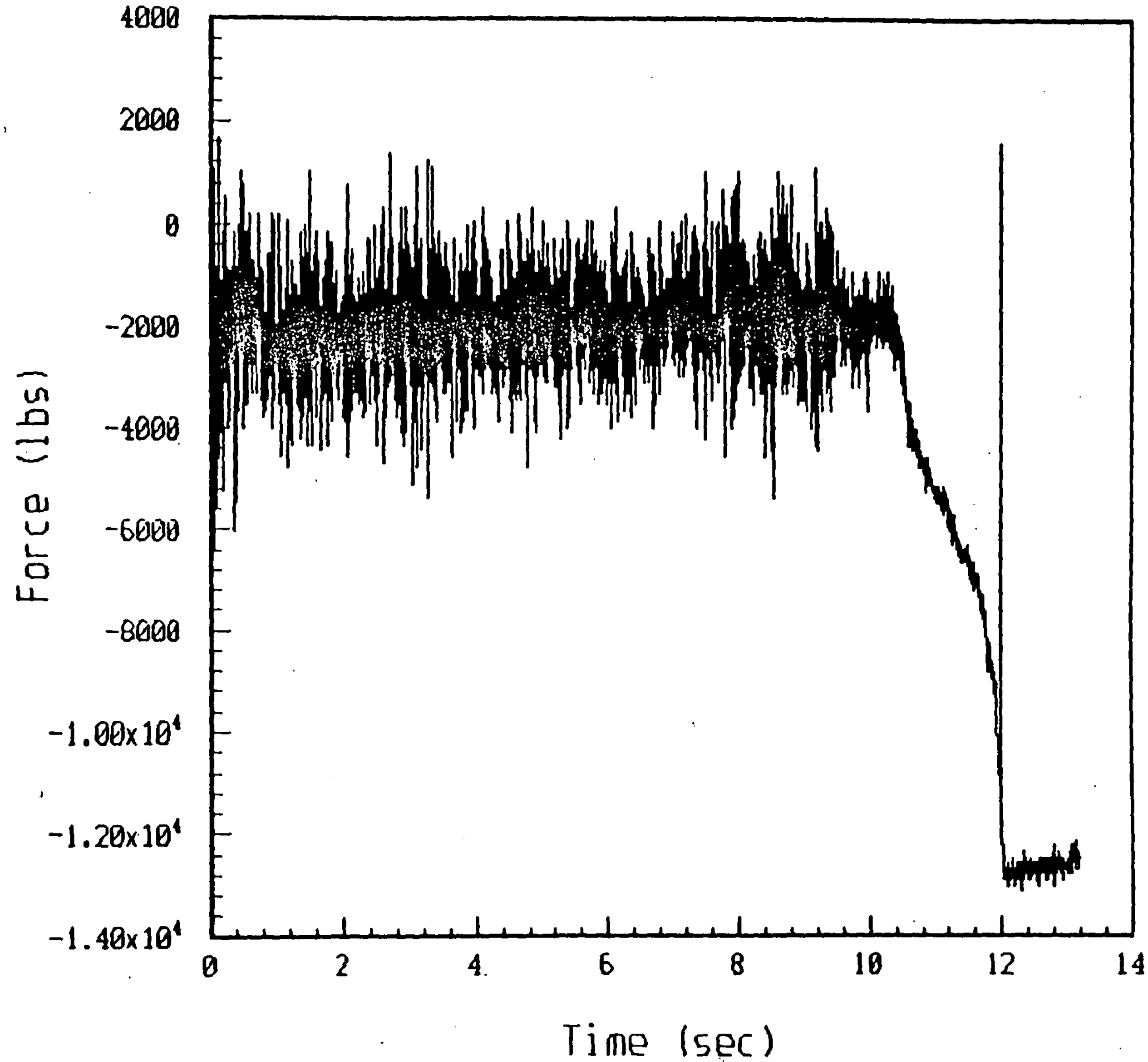

Figure 21. Block valve stem force history, test 13 (60% closure).

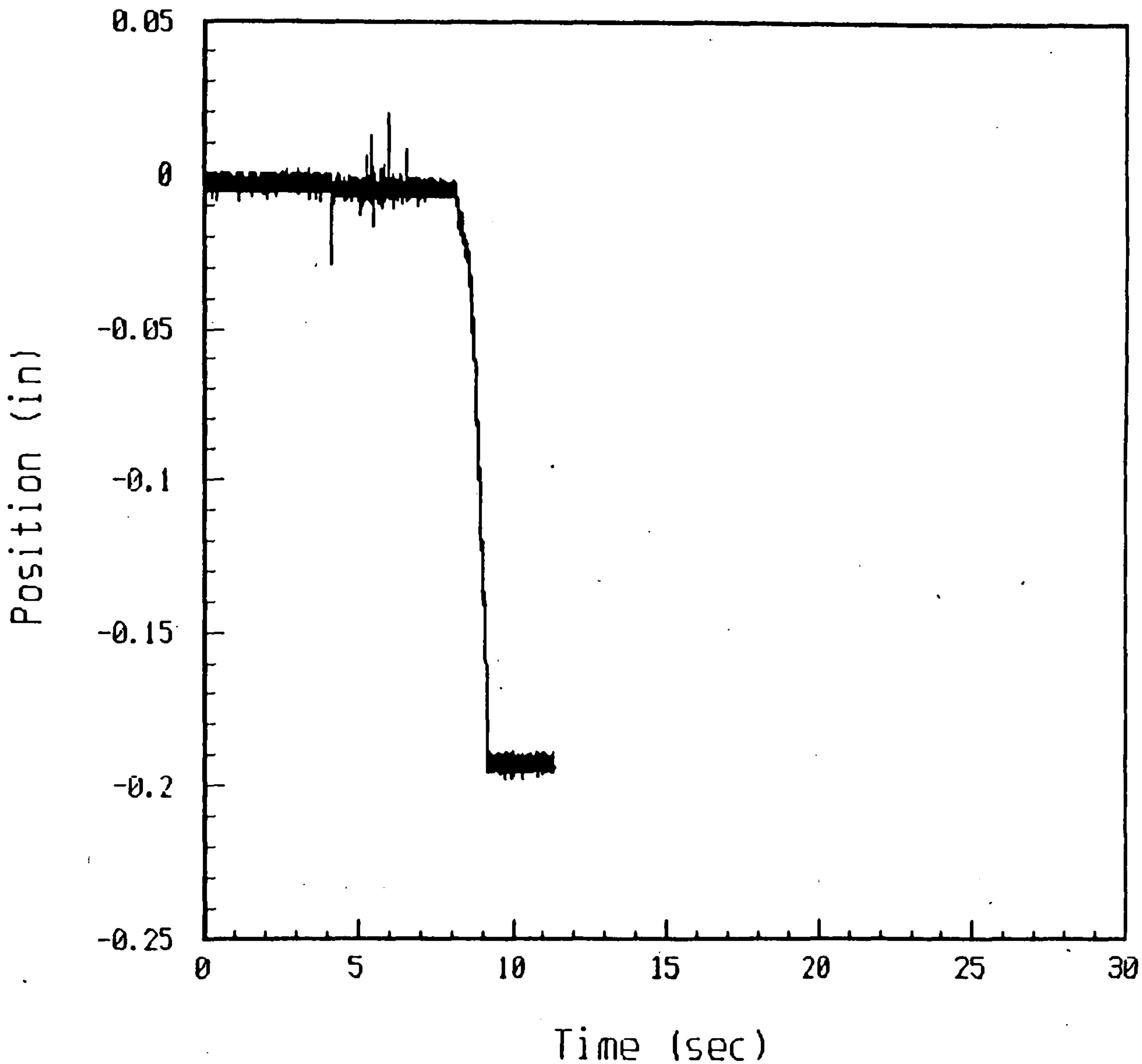

Figure 22. Block valve motor operator spring pack deflection history, test 14 (25% closure).

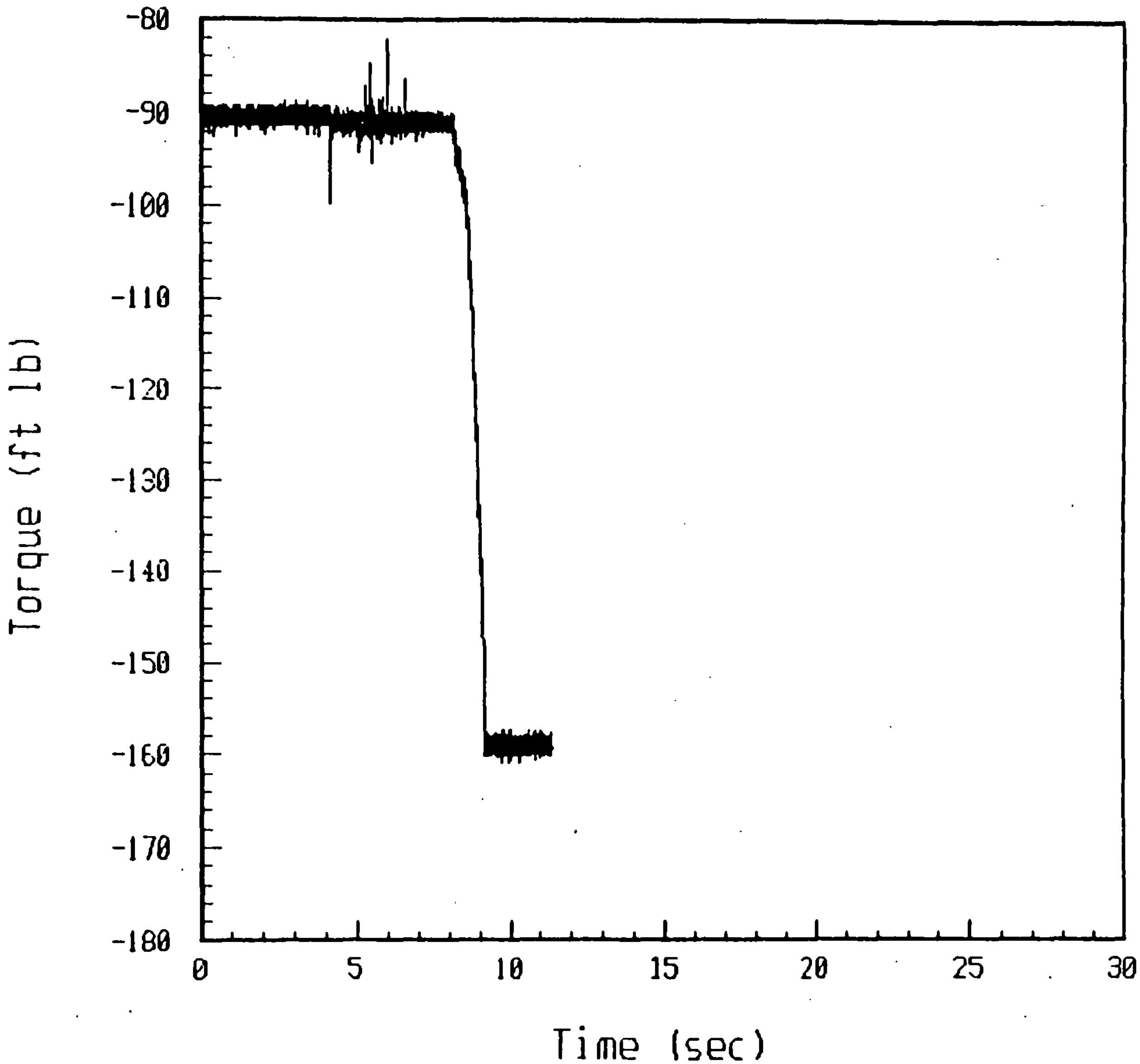

Figure 23. Block valve motor operator torque history, test 14 (25% closure).

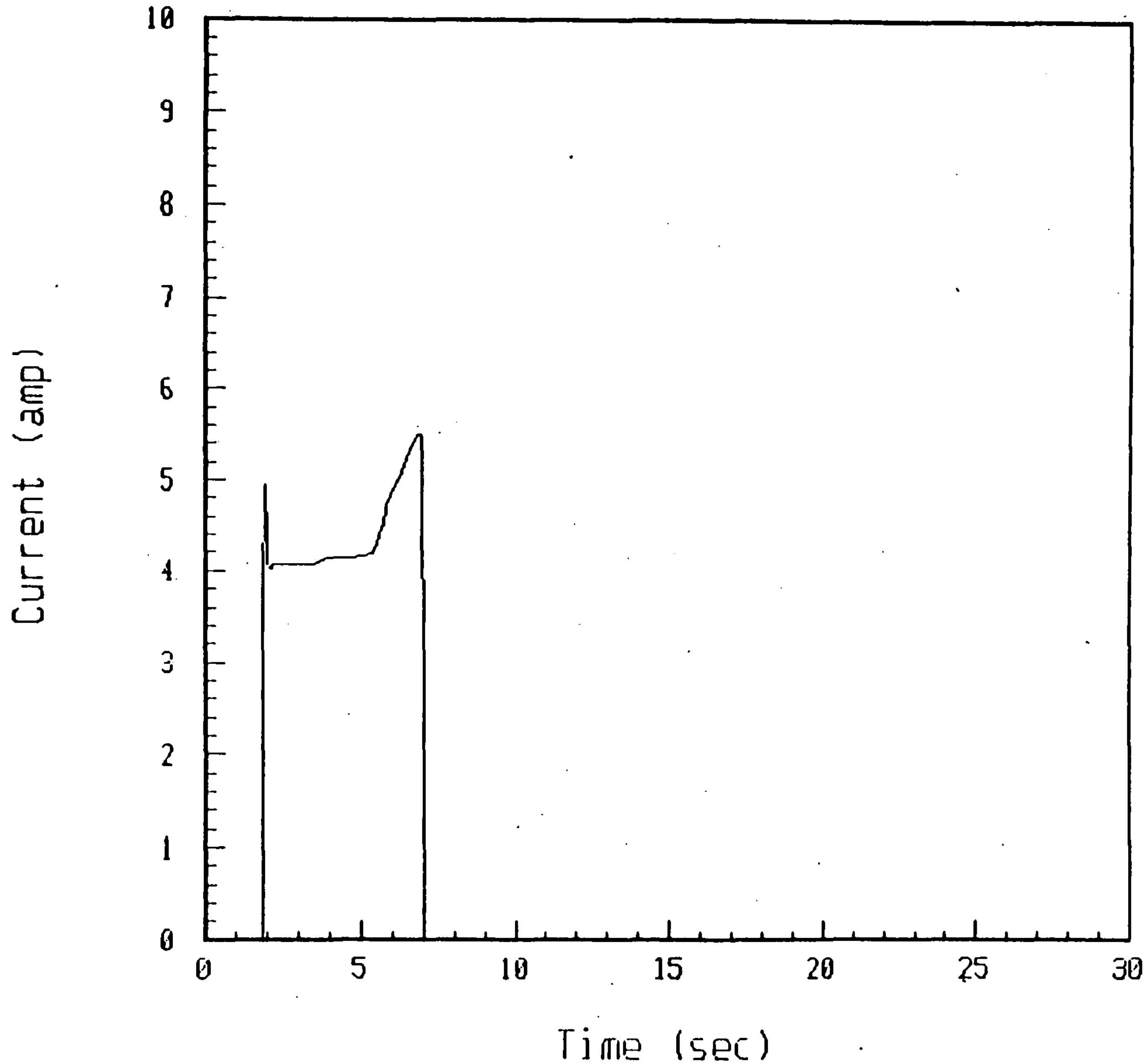

Figure 24. Block valve motor operator motor current history, test 14 (25% closure).

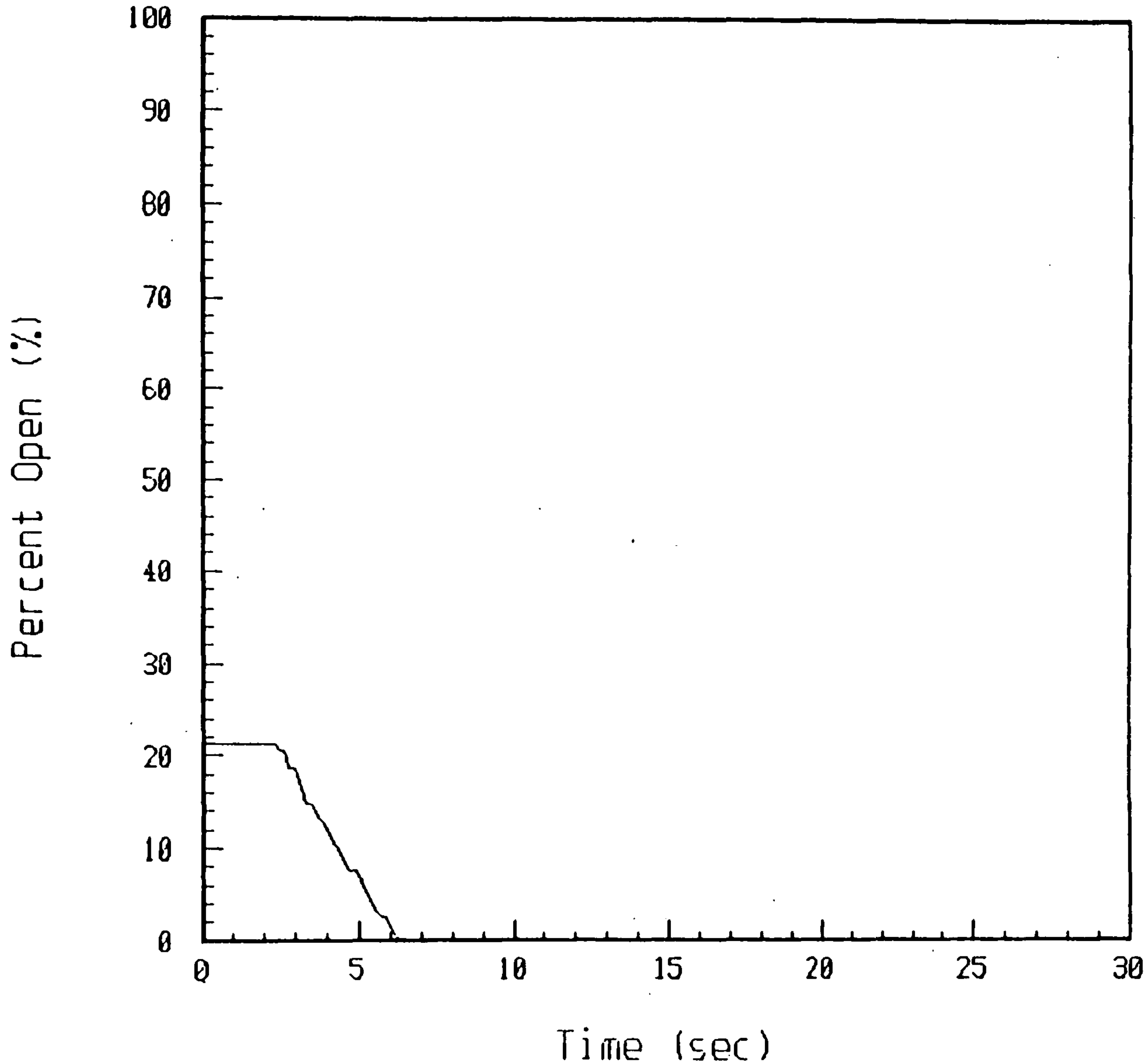

Figure 25. Valve stem position history, test 14 (25% closure).

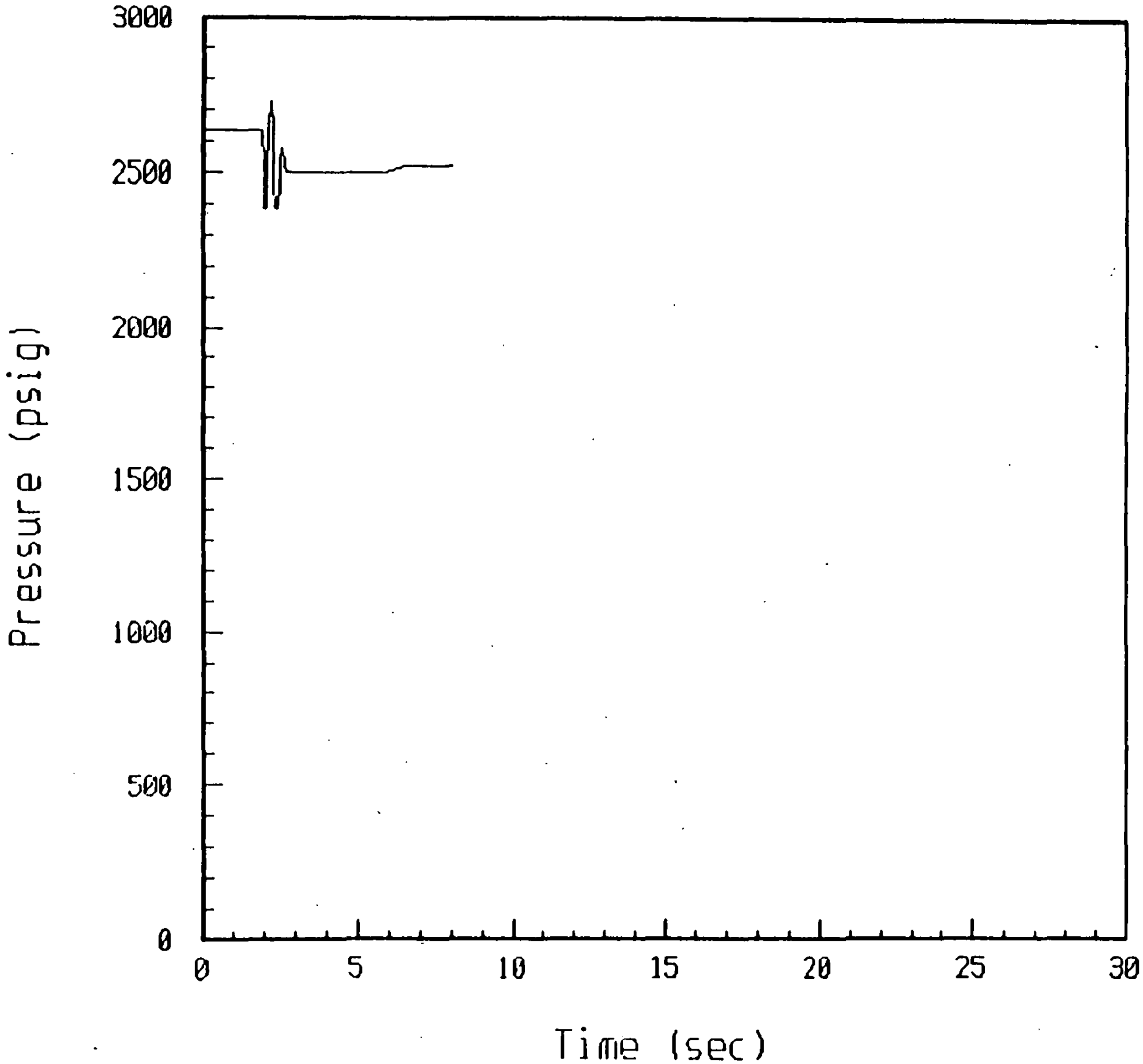

Figure 26. Static pressure history recorded upstream from the block valve, test 14 (25% closure).

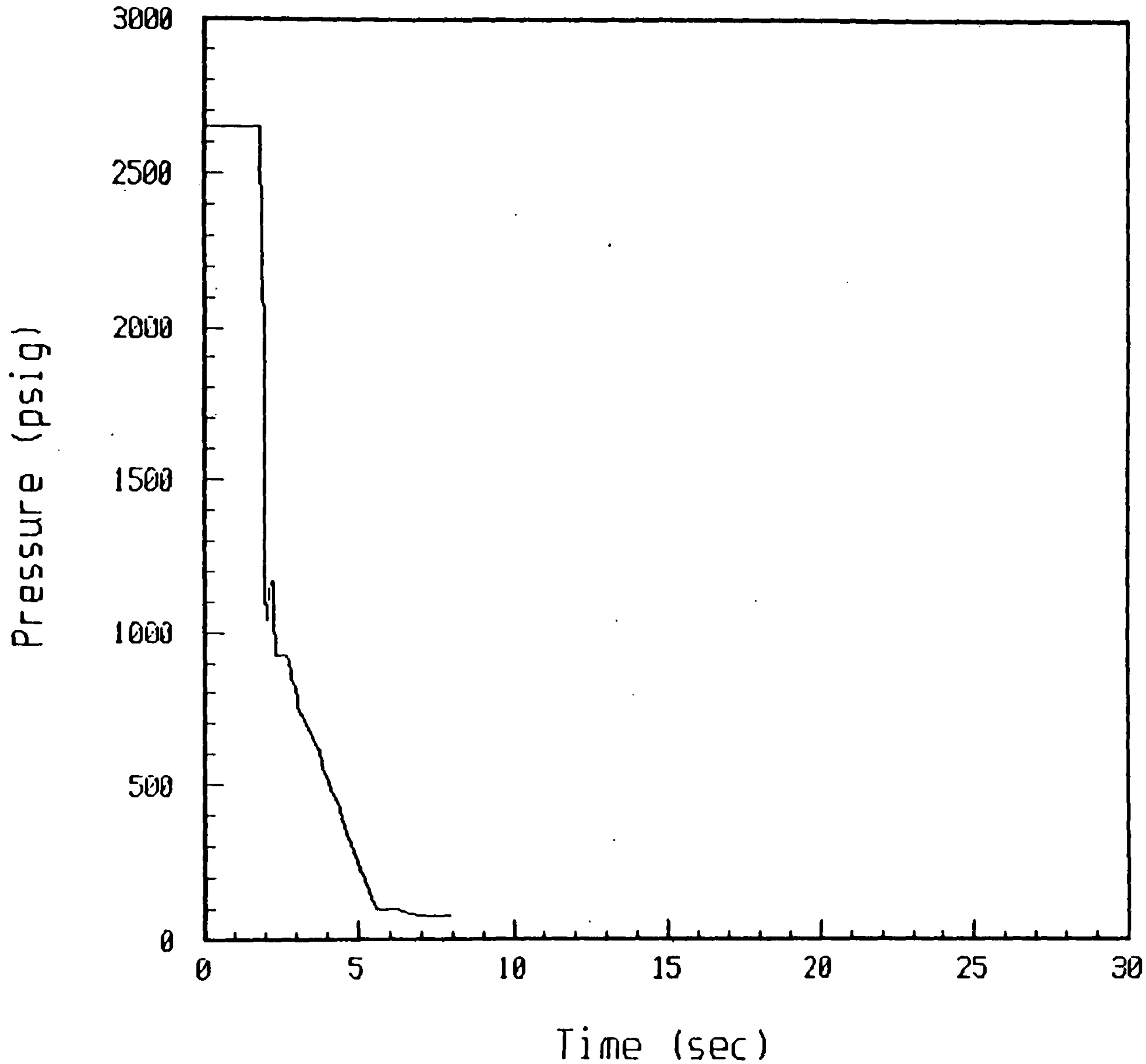

Figure 27. Static pressure history recorded upstream from the PORV, test 14 (25% closure).

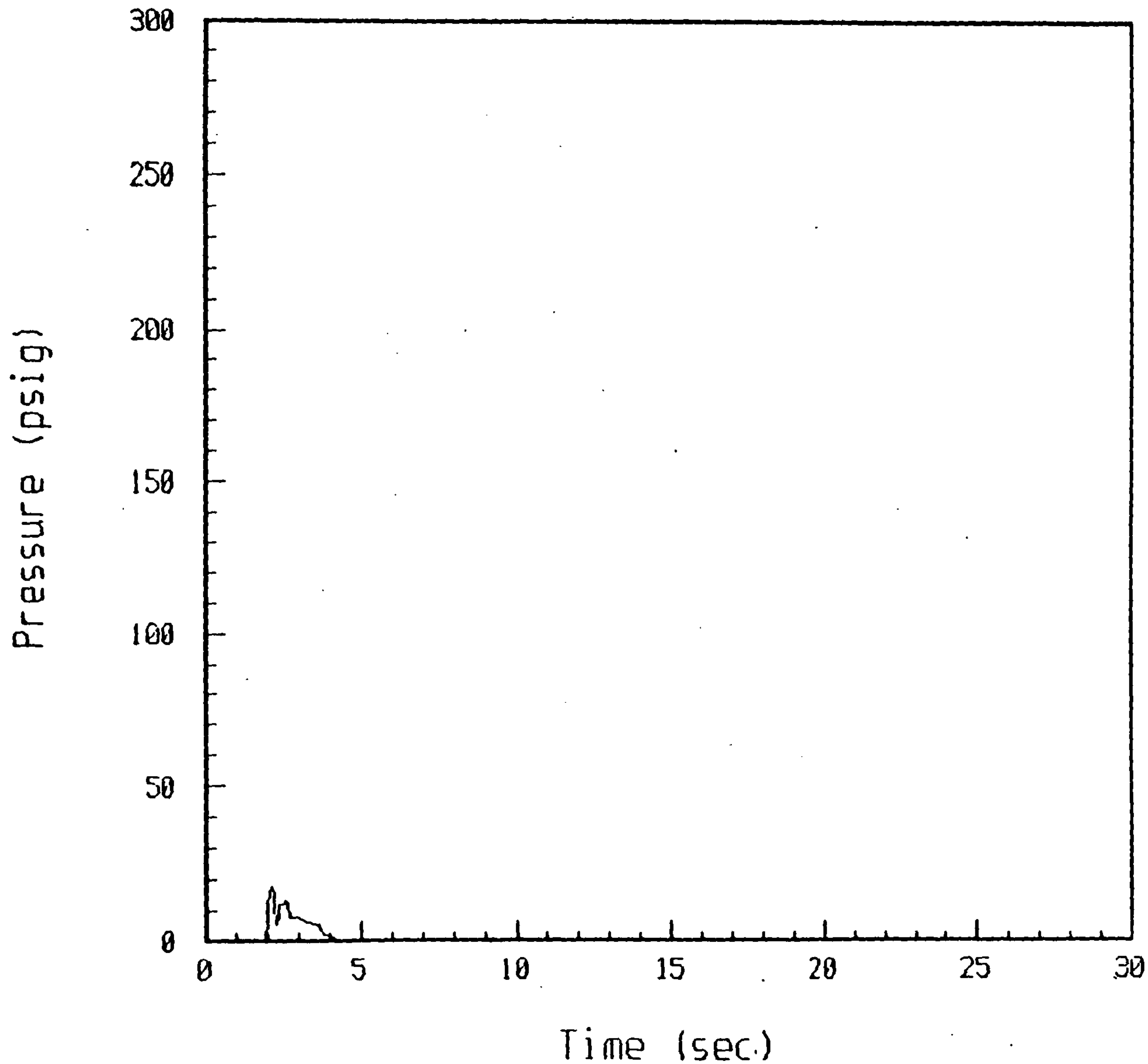

Figure 28. Dynamic pressure history recorded upstream from the block valve, test 14 (25% closure).

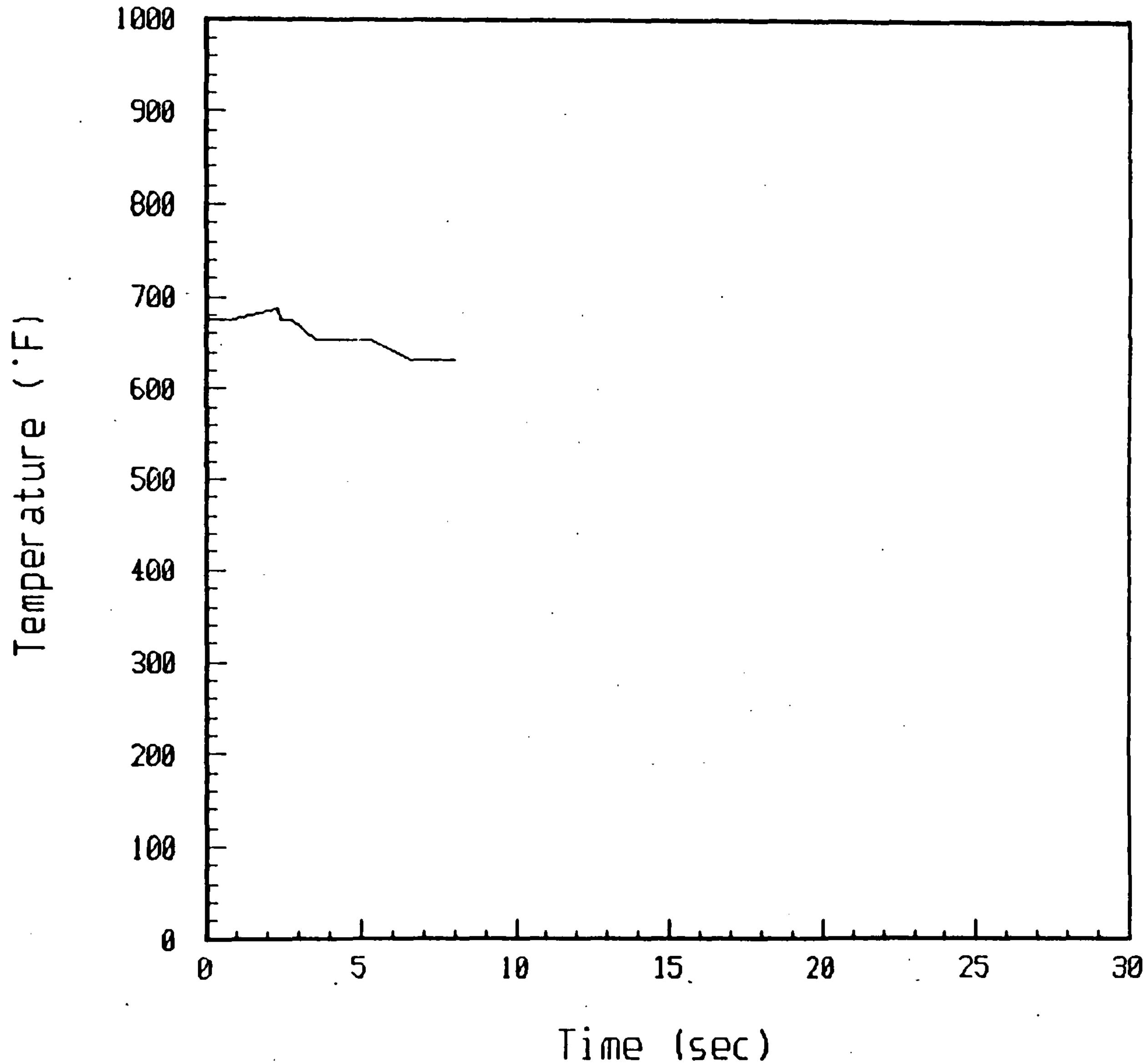

Figure 29. Temperature history recorded upstream from the block valve, test 14 (25% closure).

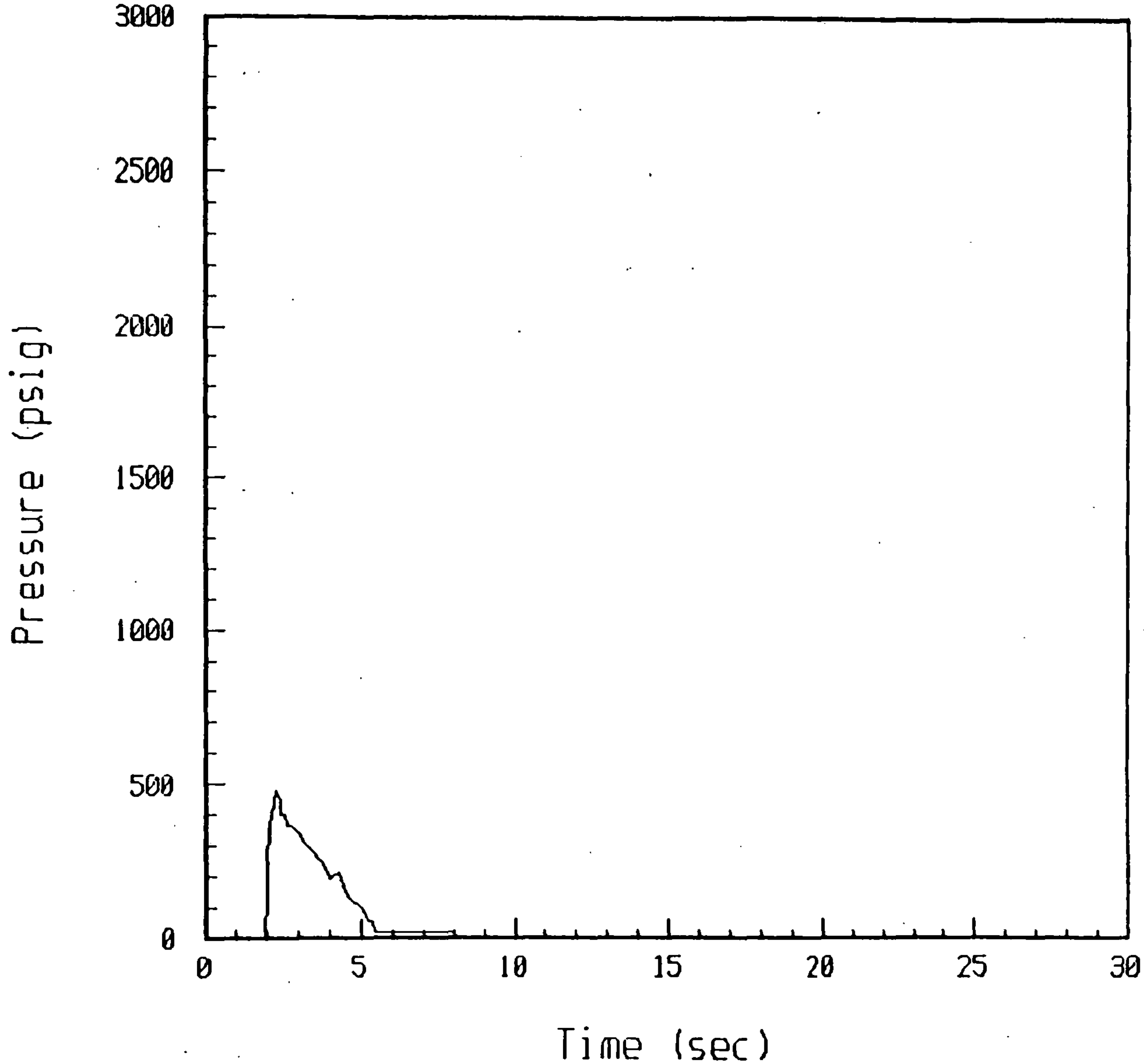

Figure 30. Static pressure history recorded downstream from the PORV, test 14 (25% closure).

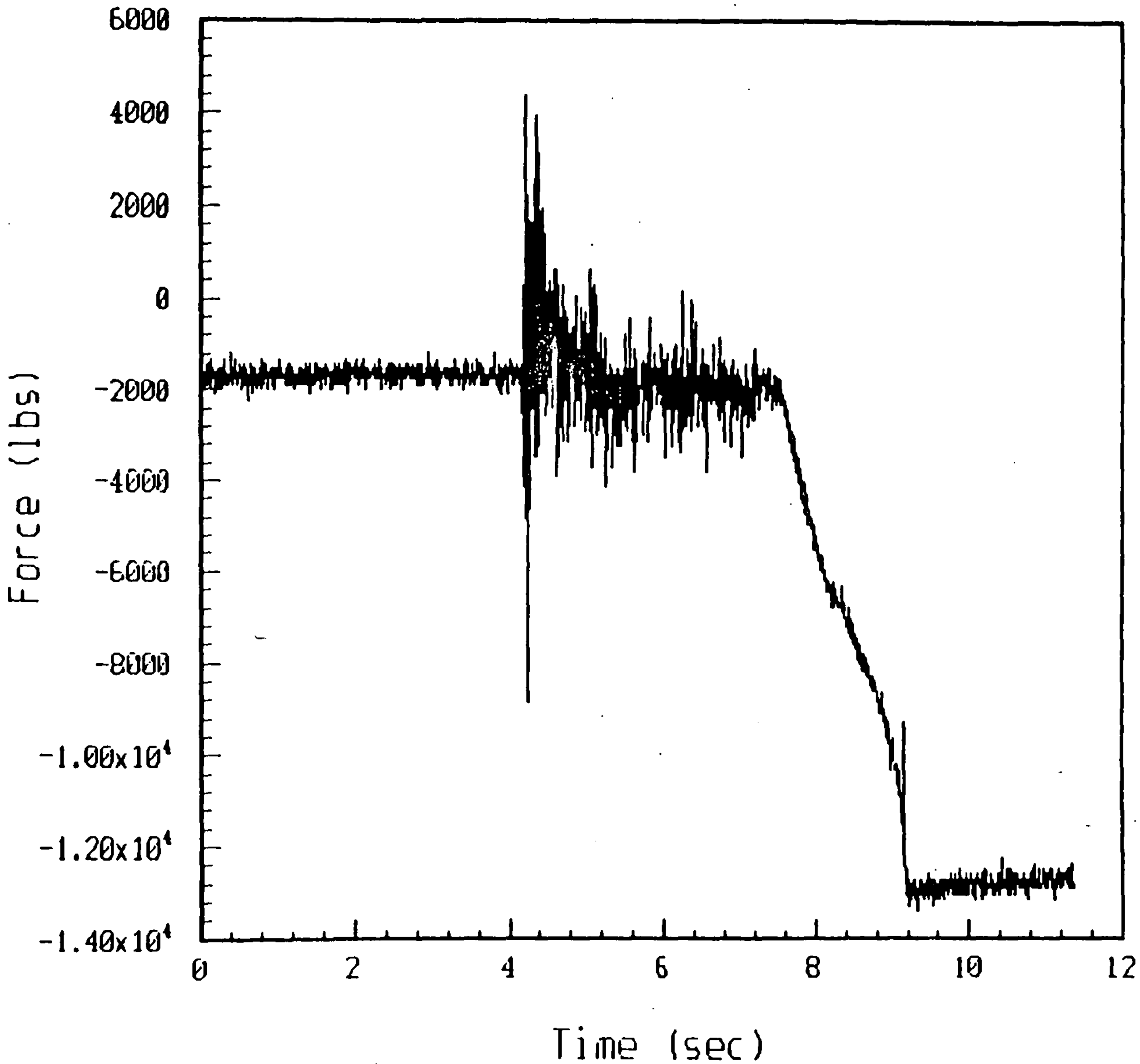

Figure 31. Block valve stem force history, test 14 (25% closure).

APPENDIX A
SUPPLEMENTARY DIAGRAMS AND DATA PLOTS

APPENDIX A

SUPPLEMENTARY DIAGRAMS AND DATA PLOTS

Data from the Palisades testing at Wyle Laboratories are presented in the main body of this report. Plots of Palisades data manipulated for the INEL analysis are presented in this appendix. The appendix also contains original data from Limitorque and diagrams and data plots from the INEL Generic Issue 87 testing.

LIMITORQUE TEST DATA

DATE: 8/15/89 ORDER NO. 145/155.01

UNIT SIZE: SMB-00-25-4 CUST. P.O. NO. 736-680IFL

PARAMETERS	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	TEST 6	TEST 7	TEST 8	TEST 9	NOTES
TQ. SW. SET.	1	1.5	2	2.5	3	3.5	4	4.5		CLOSE
TORQUE OUTPUT	89	106	139	156						FT. LB.
VOLTAGE	390	390	390	390						VOLTS-AC/DC
CURRENT	5.6	6.9	7.8	8.6						AMPS

FREQUENCY 60 HERTZ

NORMAL SET. 2 LOAD 139 (FT.LB.) VOLTS 390 AMPS 7.8

MAXIMUM SET. 2 1/2 LOAD 156 (FT.LB.) VOLTS 390 AMPS 8.6

STALL VOLTAGE N.A LOAD NA (FT.LB.) VOLTS NA AMPS NA

ONE MINUTE TEST OF 500V DC. ON All wiring .OK

SERIAL NO. L 412 164

TESTED BY M.Tucker & R. Adams

TEST LAB MANAGER W. O. Moo

Figure A-1. Actual Limitorque motor operator calibration sheet, closing direction.

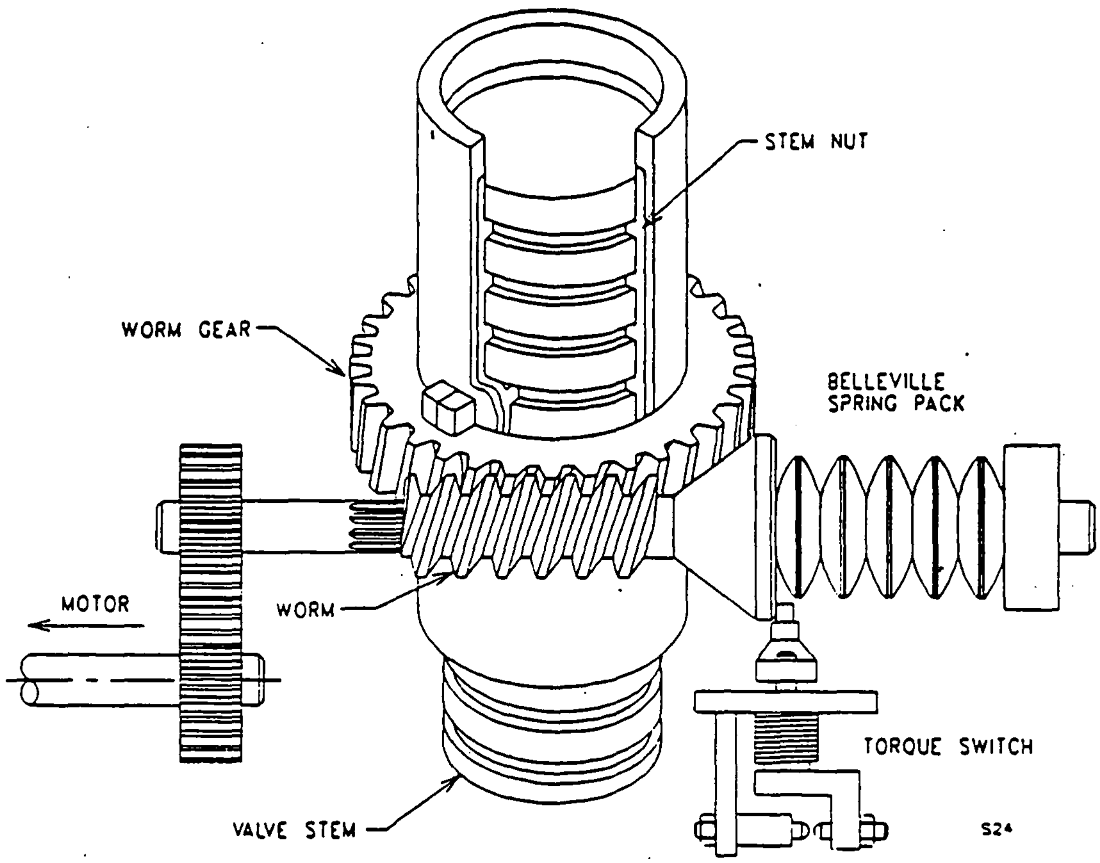

Figure A-2. Simplified model of the torque transfer portion of a Limitorque motor operator.

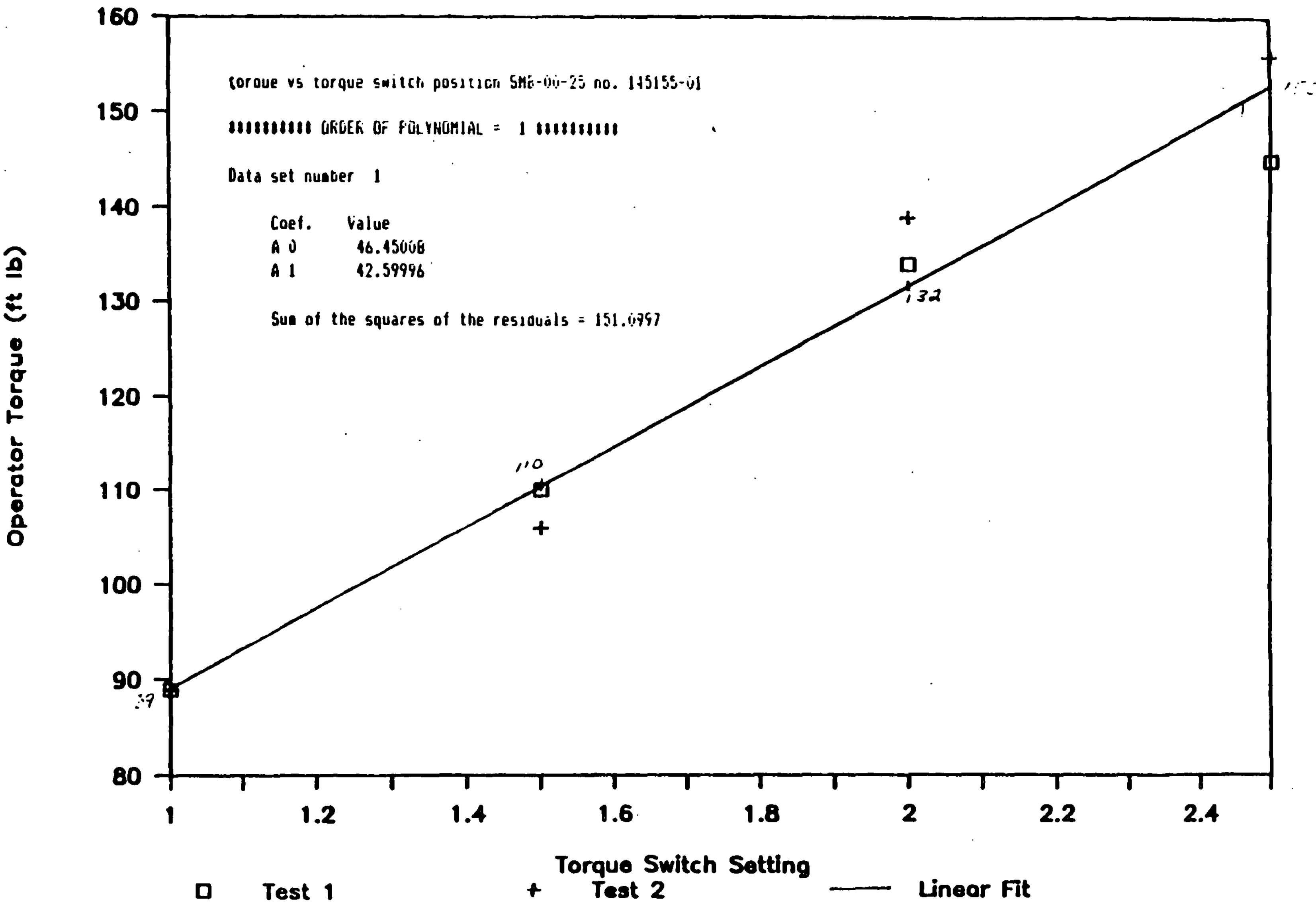

Figure A-3. Torque versus torque switch position based on Limitorque motor operator calibration.

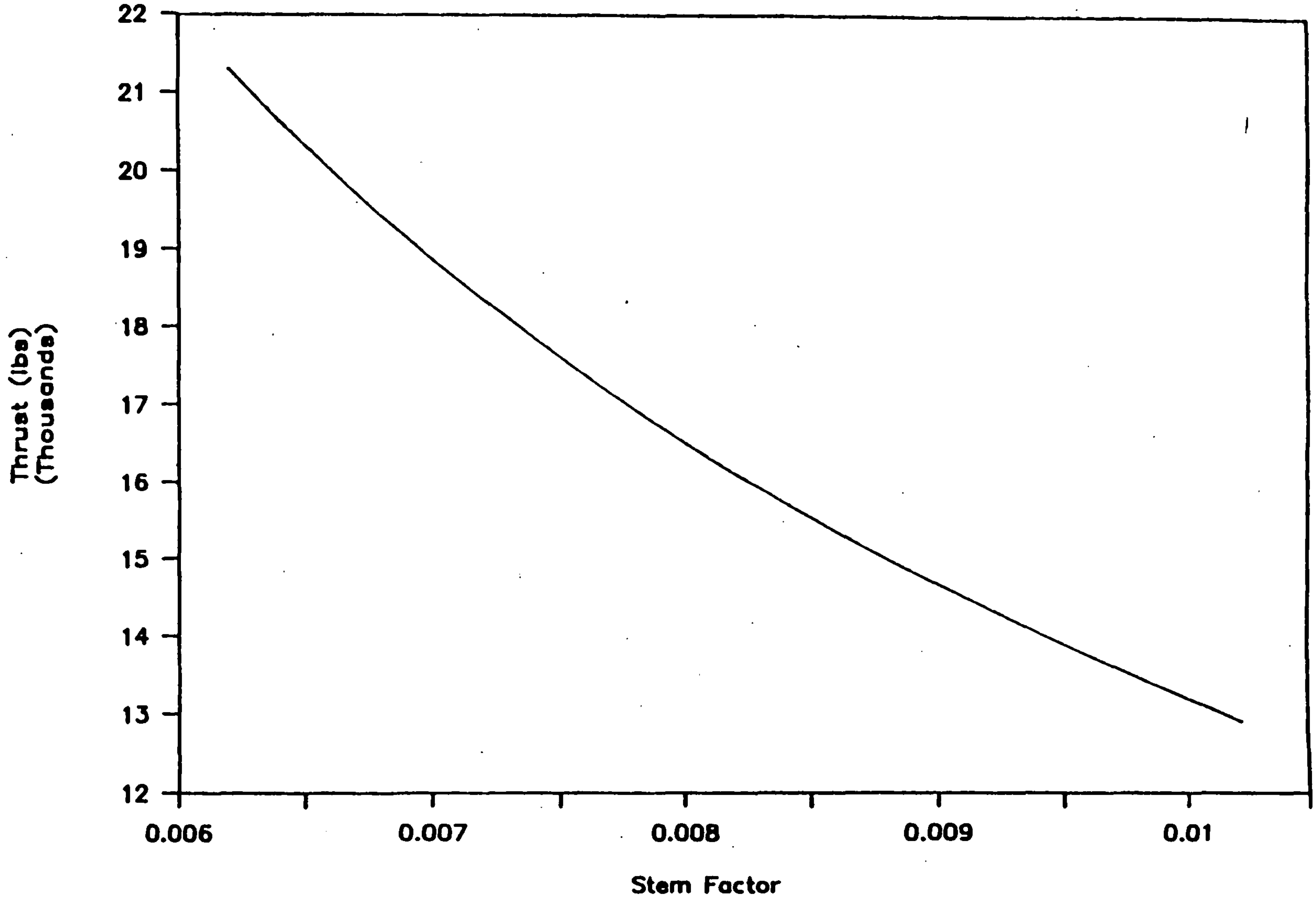

Figure A-4. Thrust versus stem factor at 132 ft-lb torque.

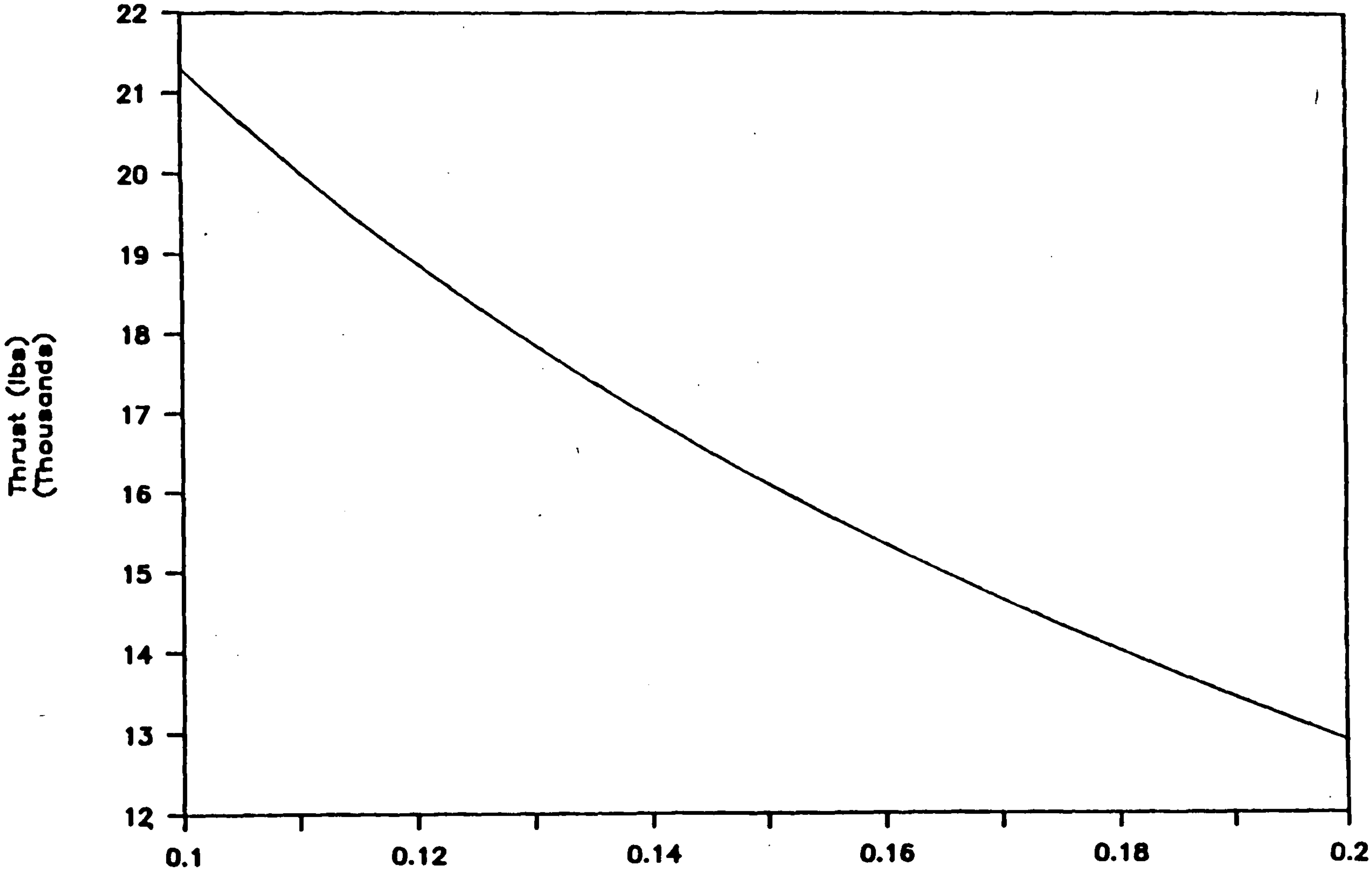

Figure A-5. Thrust versus stem nut coefficient of friction at 132 ft-lb torque.

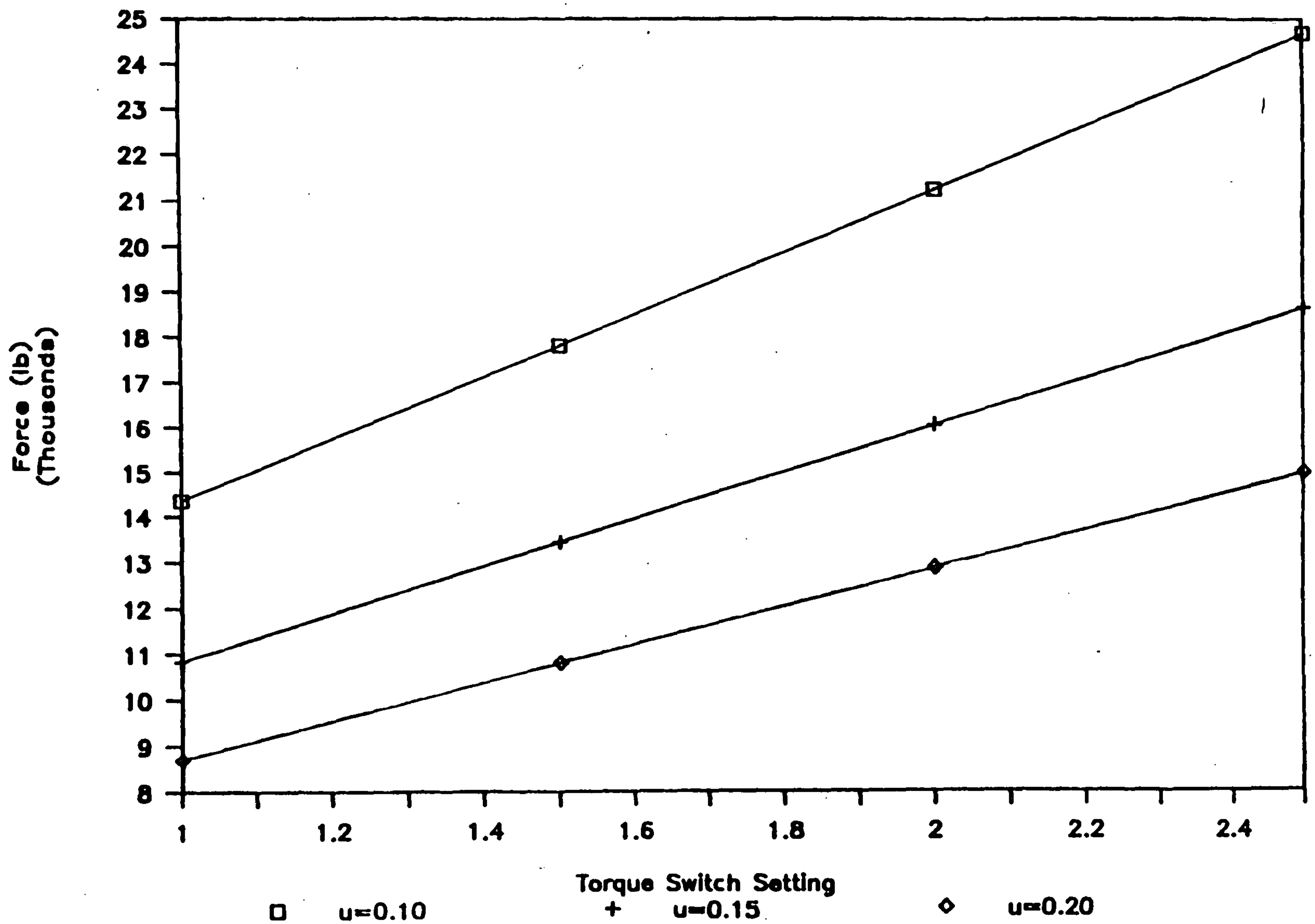

Figure A-6. Calculated stem force versus torque switch position at three stem nut coefficients of friction.

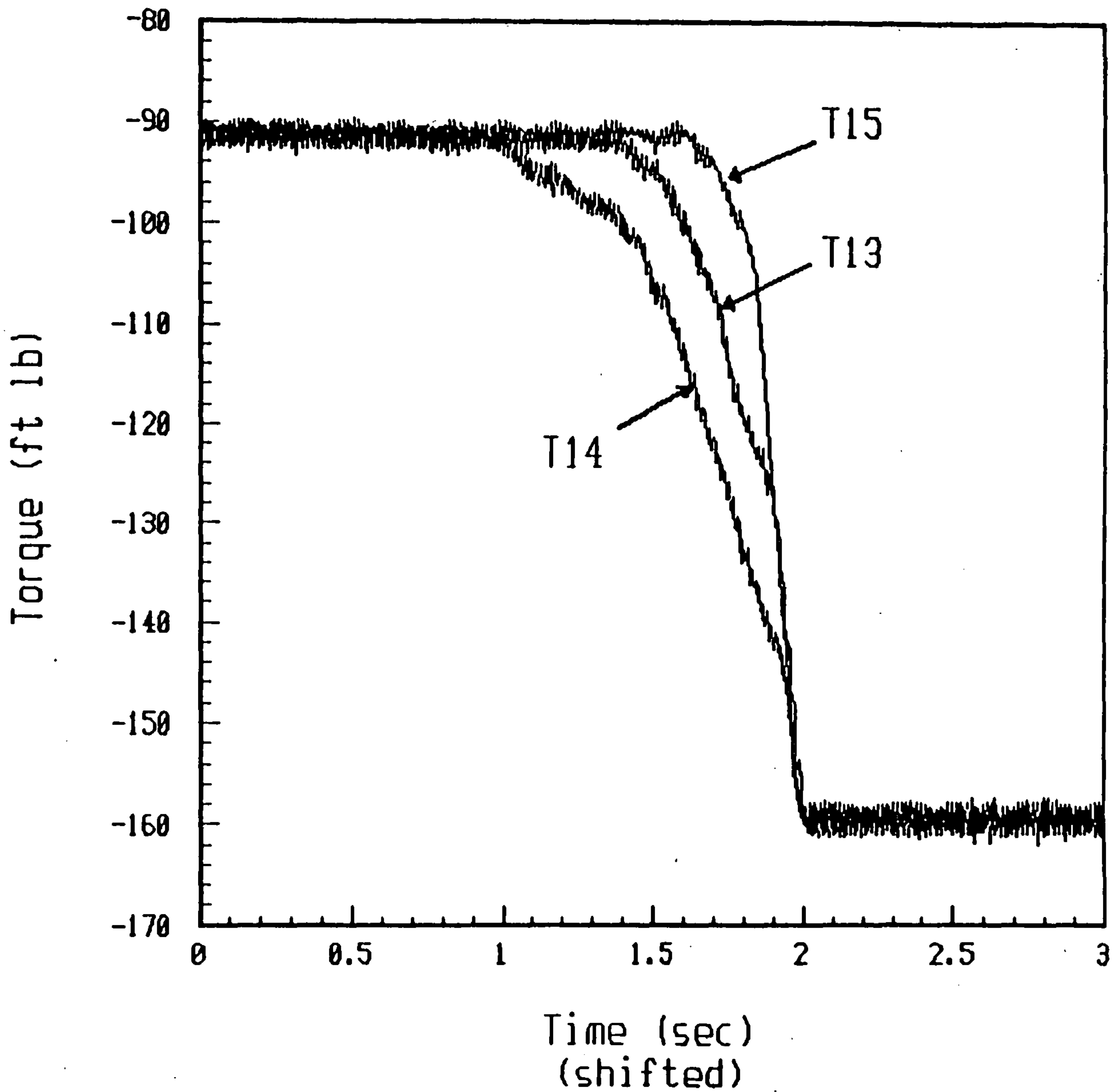

Figure A-7. Comparison of the effects of ΔP on torque curves.

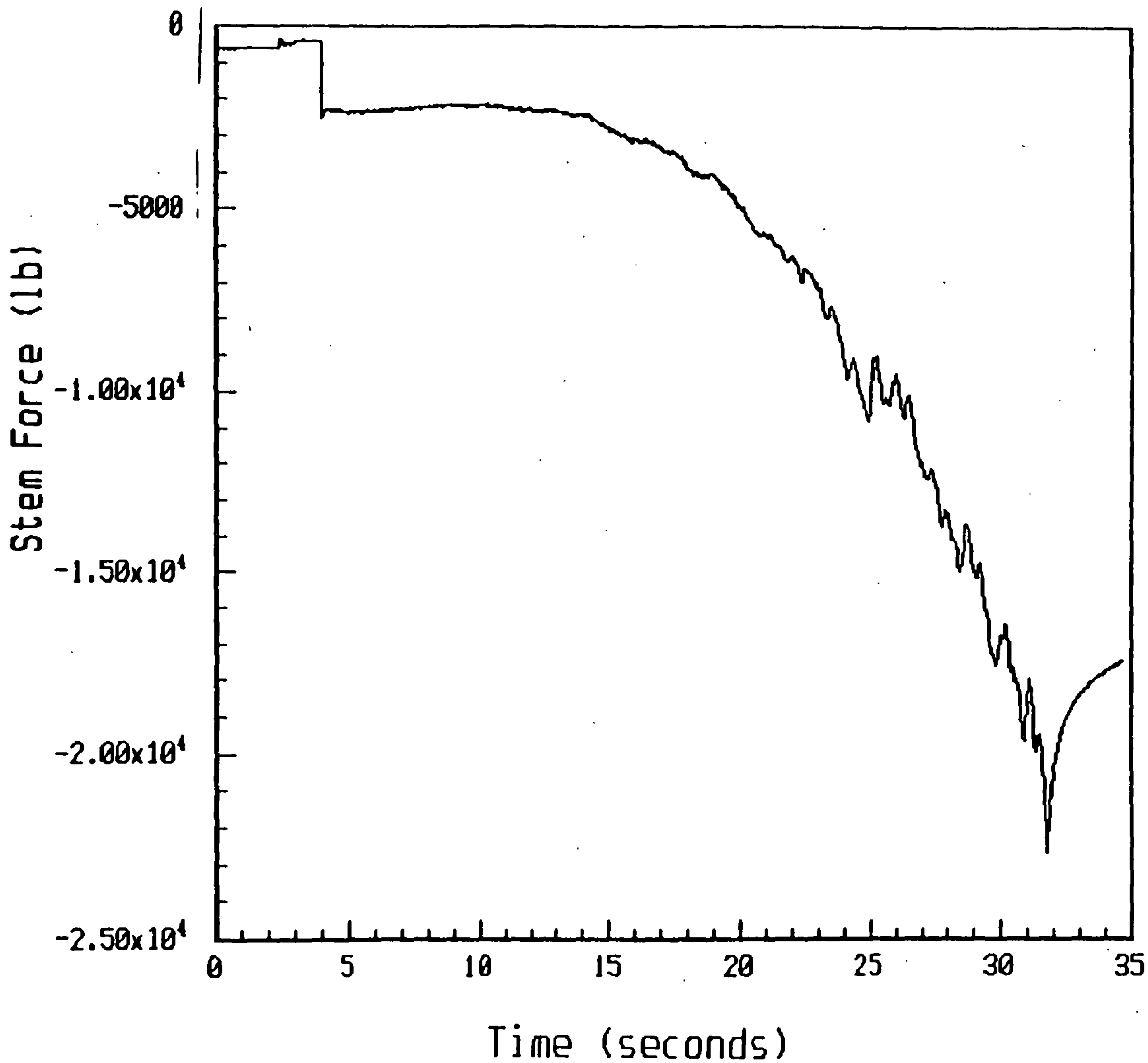

Figure A-8. GI-87 test valve stem force history, full closure.

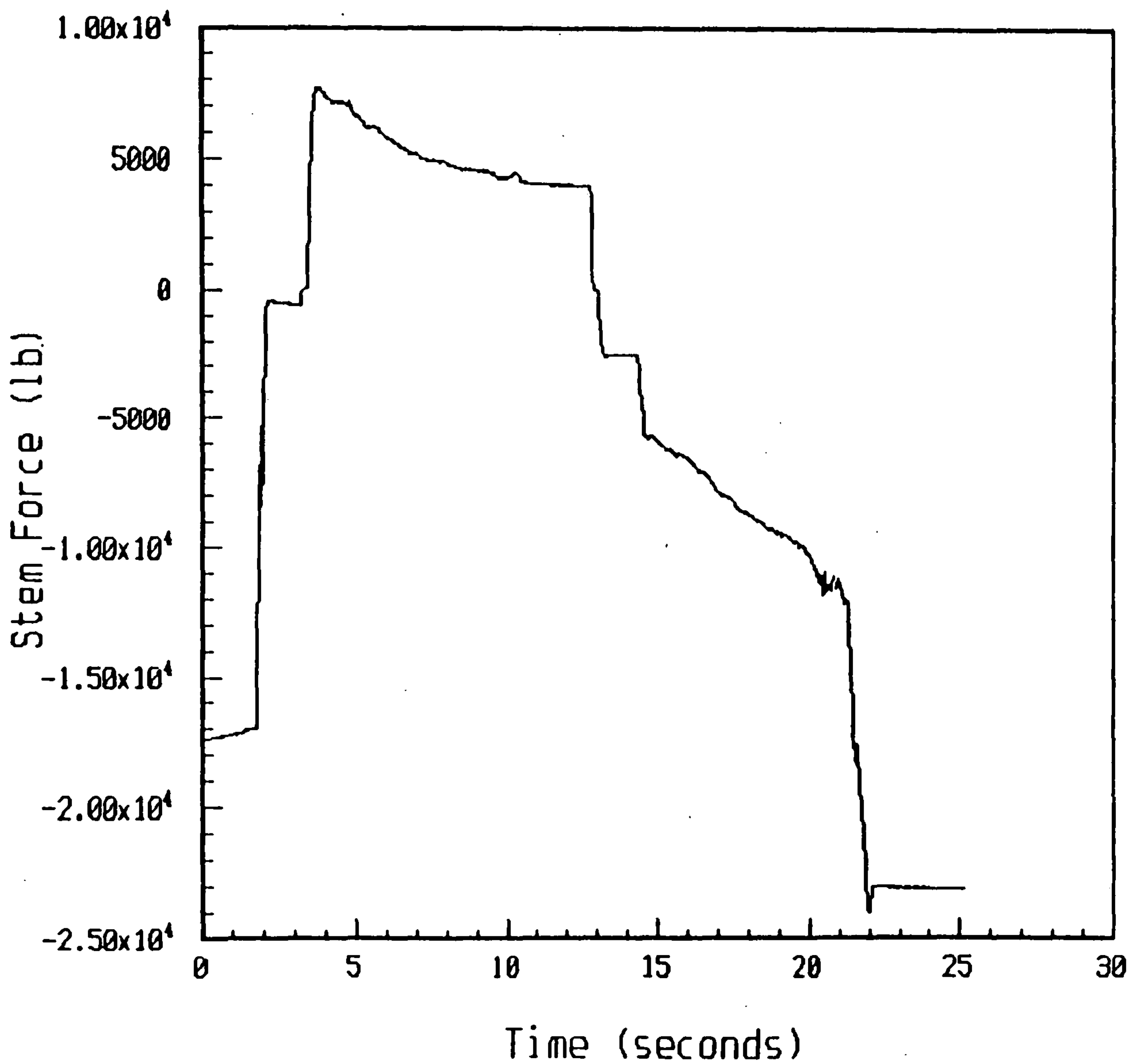

Figure A-9. GI-87 test valve stem force history, 30% reopen followed by reclose.

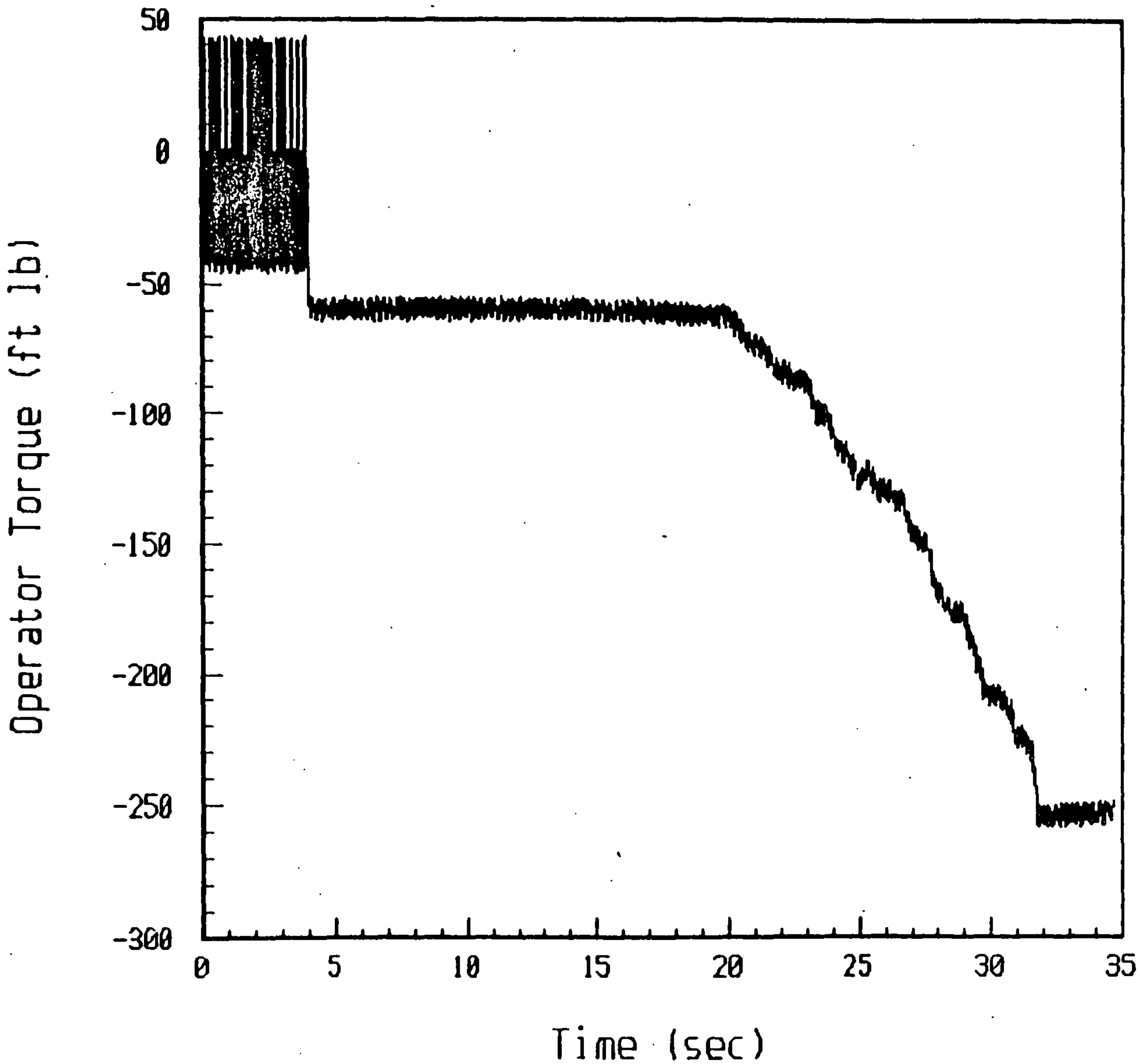

Figure A-10. Closing torque history for the closure shown in Figure A-8.

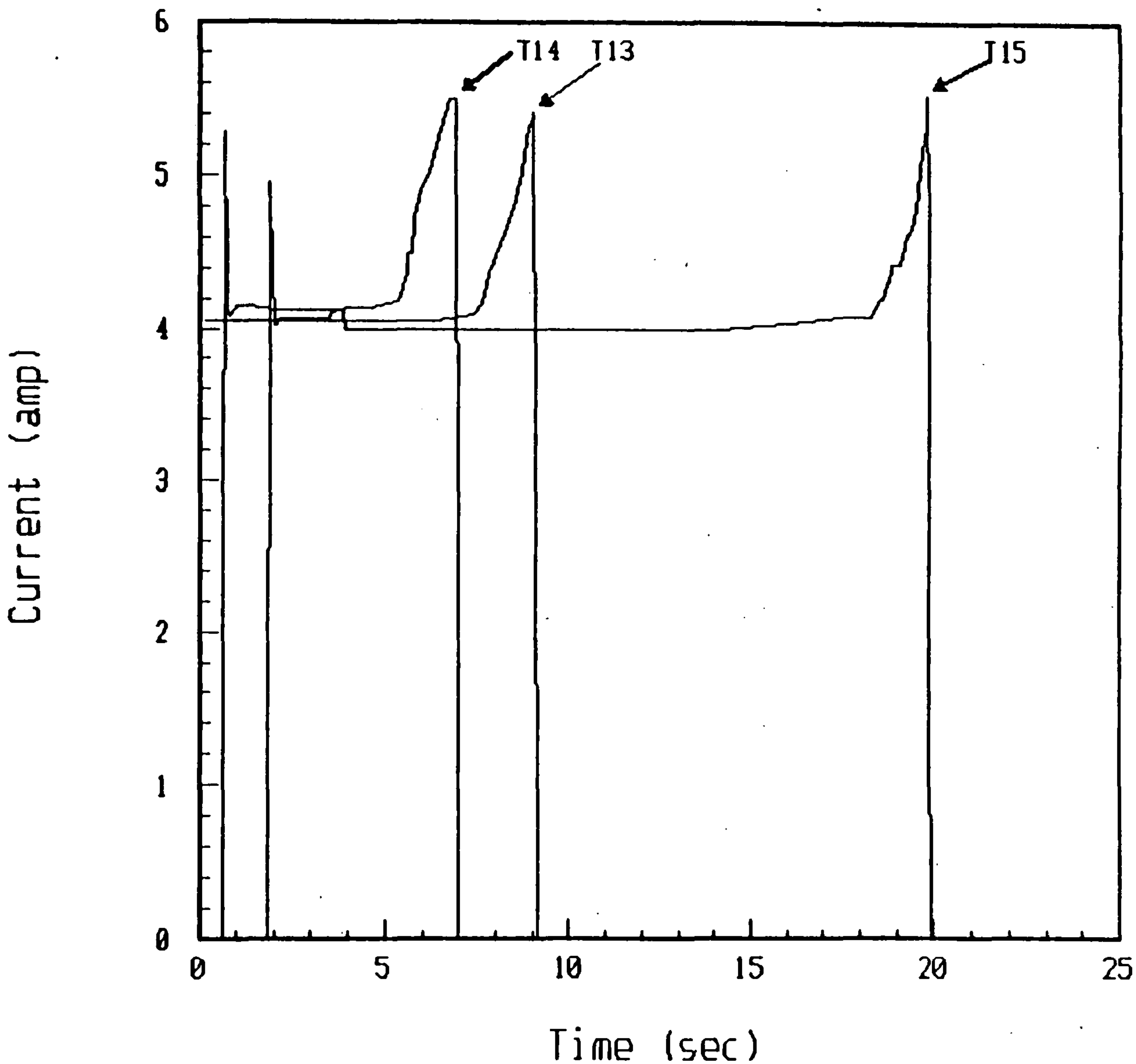

Figure A-11. Motor current histories for tests 13, 14, and 15.

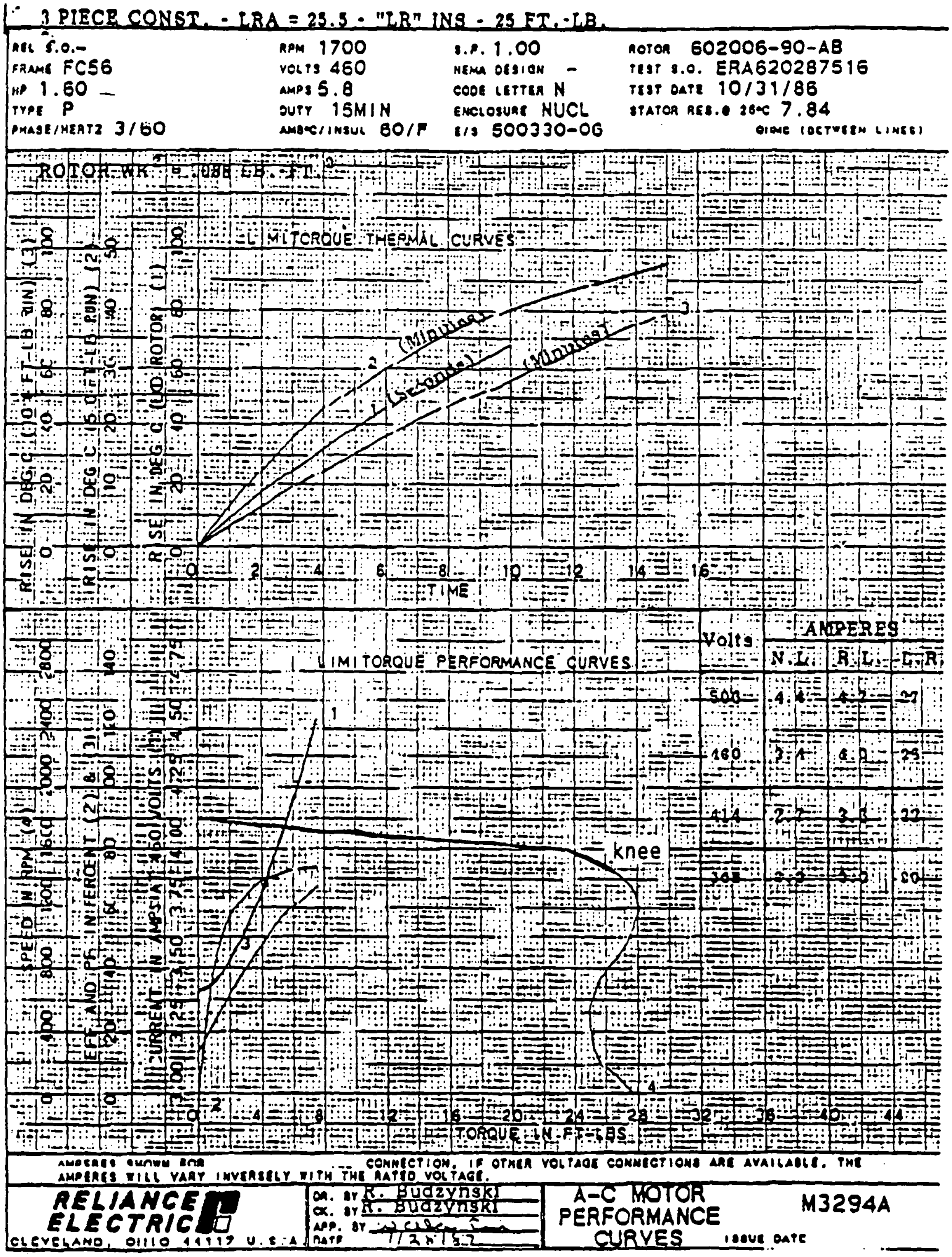

Figure A-12. Typical LRA motor operator motor performances curves provided by Limitorque.

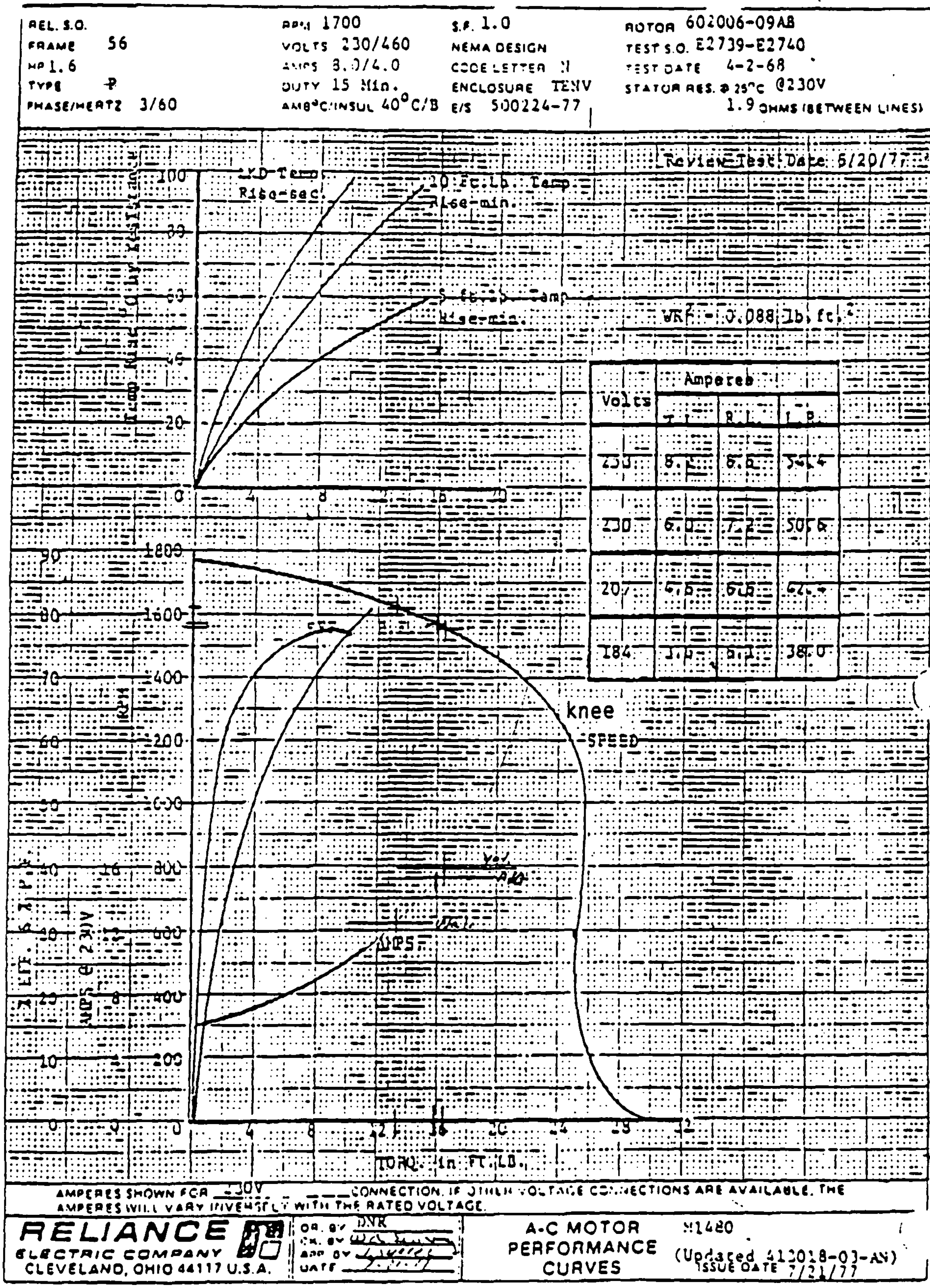

Figure A-13. Conventional motor operator motor performance curves.

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(See instructions on the reverse)

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10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

In December 1989, a power-operated relief valve (PORV) and a block valve from the Palisades Nuclear Power Plant were removed from the plant and tested at Wyle Laboratories in Norco, California. Earlier, during hydrostatic testing at Palisades, the PORV had opened and the block valve, installed upstream of the PORV, had apparently failed to close on command. The U.S. Nuclear Regulatory Commission asked Idaho National Engineering Laboratory researchers to observe the testing performed at Wyle Laboratories and to provide an analysis of the test results. This report presents the results of that analysis. The analysis determined that the block valve and operator were mechanically capable of operating at all test conditions; however, the margin of safety is small. In addition, the report recommends that guidance be provided to utilities preparing to respond to Generic Letter 89-10.

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