Thiokol

CHEMICAL CORPORATION

E110-70
MAY 8, 1970

FINAL REPORT

DESIGN AND TESTING OF SQUIB-ACTUATED VALVE

PURCHASE ORDER FK-505624

Elkton Division • Elkton, Maryland

E110-70

THIOKOL CHEMICAL CORPORATION
ELKTON DIVISION
ELKTON, MARYLAND

FINAL REPORT

DESIGN AND TESTING OF SQUIB-ACTUATED VALVE

PREPARED FOR:

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA 91103

PURCHASE ORDER FK-505624

MAY 8, 1970

Jack Buchanan
for H. G. Jones
Vice President and General Manager

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

FOREWORD

This report has been prepared by the Elkton Division of Thiokol Chemical Corporation for the Jet Propulsion Laboratory in fulfillment of the requirements of Purchase Order FK-505624.

Jet Propulsion Laboratory direction of this program was provided by Mr. R. Weiner. Principal Thiokol contributors to the performance of this program include:

E. A. Martino - Senior Project Engineer

R. Bourdon - Design Engineer

J. Smoyer - Test Engineer

L. Deckers - Stress Analyst

Overall program management was provided by E. C. Oosterom.

TABLE OF CONTENTS

I. INTRODUCTION

This Final Report summarizes the results of the design and test program conducted by Thiokol Chemical Corporation for a squib-actuated valve.

The overall scope of the program was to:

- Design a 3/4-inch, normally closed (NC), hermetically sealed, explosive valve.
- Design a 3/4-inch, normally open (NO), hermetically sealed, explosive valve.
- Test a reusable, normally closed, prototype valve with replaceable Rolldex and shear-cup elements.

II. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The following conclusions were reached after evaluating the test data.

1) The normally closed (NC) prototype valve (Appendix C, Figure C-3) can be actuated with the JPL supplied squib (ref: JPL P/N 10000029).

2) The actuated Rolldex assembly of the normally closed prototype valve provides a hermetic seal between the pressure cartridge combustion products and working fluid.

3) The tests conducted on the prototype valve verify the analytically established operational margins and performance.

B. RECOMMENDATIONS

Although the tests described herein complete the program requirements, it is recommended that at least three additional tests at -320°F be performed prior to initiating the design effort for Phase II, Delivery of Functional Ordnance Valves. The test data from this program revealed that redesign of the shear cup from the present 90-degree V-groove to a narrow slotted configuration would result in:

1) An appreciable reduction in the energy level required to initiate fracture of the shear cup element.

2) A reduction in axial travel of the Rolldex seal element prior to shear fracture.

3) Improved long-time secondary and tertiary creep characteristics of the alloy forming the groove.

The components for the prototype valve for the additional test should therefore consist of new Rolldex assemblies and the new slotted configuration shear cup.

III. TECHNICAL DISCUSSION

A. TECHNICAL APPROACH

The design of the Thiokol squib valves was primarily based on an approach which emphasized meeting the critical requirements of extreme reliability of operation and minimal leakage. Careful consideration was also given to the secondary requirement of confining the combustion products (generated during valve actuation) in order to preclude contamination of the controlled working fluid and downstream system components.

Thiokol's design incorporated a rolling metal diaphragm, or Rolldex, to provide a continuous hermetic seal between the working media, or fluid, and the squib cavity in the valve body; this hermetic seal exists before, during, and after valve operation. This design approach eliminates the major problem of leakage during and after operation which is common to conventional dynamic sealing elements.

In the normally closed valve configuration, internal leakage is eliminated by the shear cup hermetic seal which provides a solid metal barrier to flow until the prescored section is sheared off during actuation.

Ordnance valves identical in function have been designed and developed for Condor. These valves are integral with the propellant supply manifold and comprise NC and NO valves in a series arrangement with 1/4-inch porting. The valves were rated for 1000 psi operating pressure.

The shear-cup hermetic seal used is directly related to the Bullpup programs for which Thiokol supplied the packaged liquid powerplants. Each engine was equipped with multiple shear cups which provided hermetic seals for the fuel and oxidizer supply to the engine. To start the engine the shear cups are sheared by a pyrotechnically actuated slide in much the same manner as the NC valve design. Thiokol has manufactured and delivered more than 1,000,000 shear cups.

Rolldex was developed for packaged liquid rocket engines in which pyrotechnic actuation devices are rather common. In much the same way as it is used for these valves, Rolldex has been used as a dynamic hermetic seal to separate the pyrotechnic hot gases from the primary service fluids. Thiokol has developed Rolldex in diameters ranging from 1/2 inch to 30 inches.

B. VALVE DESCRIPTION

The normally open explosive valve design is shown in Figure C-1. The normally closed explosive valve design is shown in Figure C-2. The designs provide a NO valve with a wedging closure seal and a NC valve with a hermetic-throughout seal respectively. Valve porting is 3/4-inch tube size throughout with a right angle flow path for the NO valve and a straight-through flow path for the NC valve.

The NO valve comprises a Rolldex coupling assembly and a shear slide substituted for the flow terminator. The shear cup is fabricated as an integral part of the inlet tubing.

C. DESCRIPTION OF OPERATION

To terminate flow, the squib for the NO valve is electrically triggered. The firing of the initiator develops a high pyrotechnic gas pressure in the controlled volume of the gas chamber above the Rolldex element. This pressure acting against the effective area of the piston overcomes the fluid pressure against the effective area of the Rolldex thereby forcing the spherically contoured flow terminator into a tapered section of the flow passage. The flow terminator is held in place by the differential pressure and the deformed Rolldex.

In the NC valve the squib pressure acting against the effective area of the piston forces the shear slide up into the valve body. With the initial movement of the shear slide, the hermetic seal is sheared at the score mark and the loose end-piece is carried with the shear slide into the upper cavity of the valve where it is retained. Throughout the slide stroke, the Rolldex maintains a full hermetic seal and at the end of the stroke the Rolldex and slide are held in place by the squib pressure, the fluid line pressure, and the deformed Rolldex.

D. PROGRAM PLAN

The technical plan for designing, fabricating and delivering functional ordnance valves was composed of the following steps:

1) Prepare design layouts for NO and NC valves.

2) Prepare drawings and fabricate a prototype reusable valve together with replaceable Rolldex and Shear-Cup Elements.

3) Test reusable valve as described in Section IV of this report.

4) Reflect design evaluation test results on design layouts.

5) Write a final report.

IV. TEST PROGRAM

A. OBJECTIVE

The objective of this program was to conduct tests on a reusable prototype valve to verify the analytically established operational margins and performance. The prototype valve assembly and test arrangement are shown in Figures C-3 and C-4 respectively. The test matrix for these design verification tests included:

- Pneumatic Rolldex Actuation
- Shear Cup Tests
- Helium Leak Checks
- Water Flow Test (pressure drop)
- Proof Tests
- Burst Tests

B. ORIGINAL TEST PROGRAM DETAILS

The original test program submitted to JPL in advance of the scheduled tests is presented in Appendix A. During the course of the program it became necessary to conduct special tests and to deviate from the original test program. These special tests and deviations are covered in Paragraph C.

C. SPECIAL TESTS AND DEVIATIONS TO ORIGINAL TEST PROGRAM

In the first valve operational test, although the squib fired, sufficient pressure was not generated to actuate the valve. The peak pressure generated was only 1,750 psig; design calculations indicated that 3,340 psig minimum should have been achieved for the volume of the prototype valve. The fired squib was removed and without disassembling the valve, the test was repeated using gaseous N_2. The shear slide sheared off the tip of the shear-cup tube and remained in the recess of the shear slide. The Rolldex started to roll; however, a failure of the electron beam weld caused the Rolldex to break loose from the inner ring.

In a special test, a new Rolldex assembly was installed in the prototype valve. A plug was installed in the inlet port in place of the shear-cup tube. Hydraulic pressure was then applied to the outlet port. The Rolldex started to roll at 1300 psig; approximately 1100 psig was required to maintain the rolling action. After completion of the rolling action the hydraulic pressure was increased to 4000 psig with no evidence of leakage (i.e. loss in pressure). The Rolldex assembly was then manually returned to its original position (i.e. re-rolled). The piston was blocked to prevent movement and hydraulic pressure was applied through the squib port. The pressure was applied at 1000 psig increments and turned off between applications to determine any loss in pressure due to leakage. At 3000 psig leakage occurred in the parent metal of the Rolldex because of cracks in the rolled area. The electron beam weld areas did not fail.

In order to determine the adequacy of the weld on units prior to actuation, a high pressure test was incorporated. In this test the piston was blocked to prevent movement and the system was pressurized through the squib port. The first unit tested failed at 1500 psig at the electron beam weld between the inner ring and the Rolldex.

In a later test on a rewelded Rolldex assembly (electron beam weld penetration was between 0.025 and 0.030) the piston was blocked to prevent movement and pressurized to 6000 psi through the exhaust port. The Rolldex assembly did not leak at this pressure.

This Rolldex assembly was then placed in the valve assembly with the other components for a valve operational test. In the modified test arrangement, an accumulator was pressurized to 4000 psi and sealed off. A hand valve between the accumulator and squib port was opened to permit pressurization of the test valve. The first trial at an accumulator pressure of 4000 psi did not actuate the valve; a second trial at an accumulator pressure of 4500 psi also did not actuate the valve. The system was then continually pressurized through the accumulator until the valve actuated at 4900 psi. An inspection of the disassembled valve showed that the Rolldex had failed in the parent material adjacent to the rolled portion of the Rolldex. The end of the shear-cup tube had been sheared off. A detailed visual examination of the Rolldex components revealed that the inner sleeve (attached to the piston) travelled axially a distance of 0.140 inch prior to fracture of the flexure Rolldex component.

An analysis of the shear-cup and Rolldex elements performed after the test disclosed:

1) The fracture origin experienced a full magnitude of bending reversal (compressive stress followed by tensile stress) prior to fracture.

2) The level of shear force required to initiate fracture of the shear cup element was excessively high (exceeded design requirement by a factor of approximately two as a result of the material's high elongation characteristics.)

3) At the instant of shear-cup fracture, high tensile loading was induced in the Rolldex flexure element (fracture area) by shock resulting from a sudden release of energy sustained by the shear cup. Material stiffness characteristics increase sharply when a high strain rate is imposed at the moment of shear cup separation thereby not allowing the Rolldex to deform as a plastic material.

The initial tests indicated that the V-type shear cup tube could not be actuated by the JPL squib. A reduction in the wall thickness of the V-groove to permit actuation by the JPL squib would weaken the valve so that it would not be able to contain oxygen difluoride, diborane or gaseous helium for three years at 4,000 psig. It is extremely difficult to predict the life expectancy of the valve under those conditions since long term data curves for the selected material with the above propellants are not available.)

The test data revealed that redesign of the shear cup from the present 90-degree V-groove to a narrow slotted configuration would result in:

1) Appreciable reduction in energy level required to initiate fracture of the shear-cup element.

2) A reduction in axial travel of Rolldex seal element prior to shear fracture in the groove zone thereby reducing or entirely eliminating the occurrence of full magnitude of bending reversals (flexural compression followed by flexural tensile stress) occurring within the Rolldex's "knuckle" region prior to fracture.

3) Improved long-time secondary and tertiary creep characteristics of the alloy forming the groove.

The slotted-groove concept was configured because of the design intent that fracture of the shear cup should occur prior to any flexure reversals within the Rolldex. The slotted groove configuration is shown in Figure C-5. As a result of engineering analysis the following additional tests were conducted to provide a basis for continued valve operational tests within the original design parameters.

— Test A - Determine the pressure required to cause failure of the original V-type shear-cup tube.

— Test B - Determine the squib output pressure for a known volume.

Test A showed that the shear-cup tube, P/N-23105-01, failed at 9,500 psi, which is well above the operating pressure of 4,000 psi and the proof pressure of 6,000 psi. As a result, the V-type shear-cup tube wall thickness (originally 0.012 + 0.002 inch) was reduced to 0.006 + 0.001 inch. The shear forces required for the slotted groove shear-cup tube could now be simulated by this thinner V-type shear-cup tube.

Test B was conducted by tapping the bottom of the aluminum housing in which the squib is shipped for pressure transducer installation. The transducer cavities (two) and attachment fittings were filled with grease to eliminate a compressible volume of unknown magnitude. The internal volume of the aluminum housing was determined to be 0.49 cubic inch. Test B results indicated that the squib has sufficient pressure (i.e. peak pressure approximately 6,000 psi in aluminum housing) to operate the valve provided that:

— Excessive pressure drop does not occur within the valve due to the tortuous path that the gas must travel to pressurize the piston.

— Heat losses within the valve body do not cause an excessive pressure drop.

Thiokol then performed a valve operational test using a V-groove shear cup with a wall thickness of 0.007 and a rewelded Rolldex assembly. The valve was successfully actuated with the JPL squib. The shear slide sheared off the tip of the shear-cup tube and the Rolldex rolled as designed.

The valve operational test was successfully repeated with another rewelded Rolldex assembly and V-groove shear cup (wall thickness 0.007). The actuated Rolldex assemblies from these two valve tests were then welded into the pressure test fixture and subjected to the helium leak test. The Rolldex assemblies had a helium leak rate at 4,000 psig of less than 1.0×10^{-7} standard cubic centimeter/second.

In addition to the ambient valve operational tests Thiokol conducted the following verification tests:

- Three actuated shear-cup tubes (i.e. shear-cup end-plug welded) were pressurized to 15,500 psig without bursting the tubes.
- A water flow test in an actuated valve which showed a pressure drop of 0.5 psi caused by the valve.

One operational test was to be conducted at -320°F. The purpose of this test was to demonstrate the operational capabilities of the valve under conditions of extreme cold induced by long-term storage of a cryogenic liquid in the valve. For this test, gaseous nitrogen replaced the cryogenic fluid up to the shear cup, and the long-term thermal effects were simulated by immersing the entire assembly in an open Dewar flask of liquid nitrogen (-320°F).

Because of the extreme temperature, the valve was assembled with split Teflon seals and Teflon O-rings in place of the standard O-rings used for the ambient temperature tests. Significant leakage through these seals was anticipated, and the assembly was leak tested with gaseous nitrogen at 50 psig prior to immersion in the liquid nitrogen. Pressurization through the valve exhaust port showed a 10-psig-per-minute leak measured at the 50 psig-gaseous nitrogen source. A similar leak rate was indicated when the assembly was pressurized to 50 psig through the squib port. Because the squib produces such a steep pressure pulse (4,400 psi in less than 0.001 second), it was felt that the squib might operate the valve.

The valve was assembled to the Figure C-3, (-02) configuration and immersed in liquid nitrogen. Twenty minutes later, the accumulator tank on the valve inlet was pressurized to 2000 psig and the squib activated. The valve failed to actuate, although the squib operated properly.

The test was then repeated with the squib replaced by a gaseous nitrogen source, and the assembly again immersed in liquid nitrogen. The source consisted of a 130-cubic-inch accumulator initially charged to 4500 psig and an 18-foot x 0.210-inch ID line from the accumulator to the squib port. A hand-operated ball valve at the accumulator was opened to apply actuation pressure to the squib port. The resulting pressure against the piston was approximately 4370 psig (neglecting temperature effects), based on a 4500-psig accumulator pressure, the line volume and the volume of the appropriate flow passages in the test valve. The valve did actuate, but a Rolldex failure was indicated by the immediate equalization of the squib chamber and valve inlet pressures at approximately 4300 psig. Disassembly and examination of the test valve revealed a Rolldex failure and leakage past the Teflon retaining rings around the valve body evidenced by burned squib material from the first actuation attempt on the threads of the valve body retaining nut.

The Rolldex was removed from the valve and inspected. The following observations were noted:

1) The failure occurred at the outer ring of the Rolldex in tension.

2) The heat-affected zone, as a result of rewelding the Rolldex, was excessive and was located within approximately 0.030 inch of the point of failure.

3) The material was quite grainy at the fracture zone with no visual evidence of elongation.

4) This Rolldex was not rewelded in the same time period as the two earlier Rolldex assemblies that had operated successfully.

5) Weld penetration on the outer sleeve was 0.030 inch deep while weld penetration on the inner sleeve varied from 0.050 to about 0.100 inch.

It is Thiokol's conclusion that the Rolldex failed as a result of the excessive heat from rewelding. The excessive heat is indicated by the discoloration extending to about 0.030 inch from the fracture zone. Since the heated zone was approximately 1/8 inch long (over six times the length of the weld) the embrittled area adjacent to the heat-affected zone was positioned at the tangent point of the annulus of the Rolldex to the outer cylinder. This is a highly stressed area due to bending and requires that the material be plastic; since embrittlement occurred the material was not plastic and failure occurred.

APPENDIX A

EXPLOSIVELY ACTUATED VALVE
TE-V-569

TEST PROGRAM

1.0 OBJECTIVE

The objective of this test program will be to conduct tests on a reusable prototype valve to verify the analytically established operational margins and performance.

2.0 VALVE DESCRIPTION

The reusable prototype valve will be constructed of stainless steel and have provisions for mounting a shear cup tube, which will thread into the valve housing and be sealed with an o-ring. The shear slide and piston will be separate parts and reusable for each valve test. The Rolldex will be welded to two cylinders to form an assembly. The outer cylinder will be sealed by an o-ring and clamped into the body of the valve. The inner cylinder will be clamped between the shear slide and piston, with an o-ring used to seal the joint between the piston and the inner cylinder of the Rolldex assembly. The squib will be installed into the valve and sealed by means of an o-ring. The dynamic seal on the piston is a teflon seal with stainless steel expander spring. All other seals for the ambient tests will be o-rings. For the -320°F test split teflon back-up rings or solid teflon o-rings will be used.

The reason for using o-rings and mechanical fastening for the valve components is to provide for versatility.

3.0 TEST DESCRIPTION

3.1 Test No. 1 - Shear Cup Tube Hydrotest

3.1.1 Six shear cup tubes, P/N E-23105 are hydrotested to $6000 \, {}^{+0}_{-100}$ psig for three (3) minutes. With the pressurization system valved off, there shall be no discernible pressure drop within the three minute period.

3.1.2 No special fixturing, other than a floor covering to prevent damage of the tubes' exterior surfaces, is required.

3.1.3 Fitting and o-rings will be required for the open end of the tube, which has a 3/4-16 internal thread.

3.1.4 No procedures will be written for these tests.

3.2 Test No. 2 - Valve Body Hydrotest

3.2.1 One valve body assembly will be hydrotested to $6000 \, {}^{+100}_{-0}$ psig for one (1) minute. With the pressurization system valved off, there shall be no discernible pressure drop within the one-minute period.

3.2.2 The test configuration is per E-23130, with the following items removed: (Reference Dwg. E-23189)

a) Item 3 - Shear Cup Tube
b) Item 4 - Jam Nut
c) Item 5 - Rolldex Assembly
d) Item 6 - Retainer
e) Item 7 - Shear Slide
f) Item 8 - Piston
g) Item 11 - Bal-Seal
h) Item 12 - Piston o-ring
i) Item 13 - Rolldex o-rings

3.2.3 The assembly should be dogged to the floor through the Item 14 mounting plate (E-23119). No other fixturing is required.

3.2.4 A fitting, E-23183-01, will be used in the squib port. A plug, E-23169-01) will be used at the shear cup tube inlet. Test pressure is applied through the E-23183-01 fitting. The pressure transducer port will be sealed with an AN-4 bolt and a Stat-o-seal.

3.2.5 No procedures will be written for the test. See Dwg. E-23189 for test arrangement.

3.3 <u>Test No. 3 - Low Pressure Nitrogen Leak Test</u>

3.3.1 Test operations will make six valve assemblies per Dwg. E-23130.

3.3.2 Install an AN-919-10 fitting in the valve exhaust port which will have a 7/16-16 male fitting through which the gaseous N_2 pressure will be applied. The unactuated shear cup will seal the shear cup tube port. The squib port will not be sealed, the squib pressure transducer (a Dynisco PT-110) planned for use in the static test will be installed. The squib port is left open to permit an escape path for otherwise un-detectable leaks past the Rolldex.

3.3.3 The leak test consists of pressurizing the assembly through the exhaust port to 50 $\pm$ 10 psig. The Pressurization system is then valved off. During a five minute period, no discernible pressure drop is permitted. Check all interfaces with "Leak-Tek" fluid.

3.3.4 No procedure will be written for these tests.

3.3.5 No additional fixtures are required.

3.3.6 After the test, install the exhaust port plug and o-ring; do not remove the squib pressure transducer.

3.4 Test No. 4 - Valve Operational Test

3.4.1 The test assembly is shown in E-23130, with the following items:

3.4.2.1 Accumulator: Accumulator, nominally 3-inch I. D. x 4-inch long will be attached to the shear cup tube to prevent an excessive pressure drop within the valve during the piston stroke.

3.4.2.2 Fittings: A fitting AN-919-10 will be installed in the valve exhaust port and a fitting AN 815-8 will be installed in the shear cup tube. No other fittings will be required in the valve.

3.4.2.3 Instrumentation: Pressure transducers will be installed as follows: (Note-all lines dry)

3.4.2.3.1 Shear Cup Tube Pressure: 0-5000 psig; Y-Block configuration; 2 channels; install in accumulator.

3.4.2.3.2 Outlet tube pressure: 0-5000 psig; Y-Block configuration; 2 channels; assemble to fitting in outlet tube.

3.4.2.3.3 Squib Pressure: 0-3000 psig; single Dynisco PT-110; install in 1/4-28 tapped hole on valve body; single channel.

3.4.2.3.4 Squib Current: Record squib current.

3.4.2 Assembly will be dogged to the floor. No other fixtures required.

3.4.3 Take FASTAX movies of the first test only, to be developed only in event of failure. Take B/W stills, pre-and post-test for documentation of each test.

3.4.4 A test procedure will be written for these tests.

3.4.5 Test consists of applying 4000 $\pm$ 50 psig gas pressure to accumulator and shear cup tube, then explosively actuating valve by means of squib. The procedure will define the sequence in which internal valve pressures are to be relieved after the test.

3.4.6 Data Reduction will plot pressures versus time, indicating pre-actuation conditions and all parameters through actuation until transients have ceased.

3.5 Test No. 5 - Rolldex Hi-Pressure Gaseous N_2 and Helium Leak Test

3.5.1 The Rolldex assembly (Item 5 on E-23130) is removed from four valves after test No. 4 by Test Operations and welded into a pressure test fixture per E-23136 by the Weld Shop.

3.5.2 This assembly is then returned to Test Operations for a gaseous N_2 leak test. The gaseous N_2 leak test consists of pressurizing the E-23136 assembly to 1000 ± 50 psig for one minute with the assembly immersed in water. Leaks at the weld joints of the Rolldex sleeves detected here will be repaired and the test repeated until the welds show no leaks.

3.5.3 When the gaseous N_2 leak test has been successfully completed, the E-23136 assembly is installed per the leak test arrangement drawing E-23152.

3.5.4 At this point coordination is required with Research Laboratory for use of Helium leak detector. Note that the system must be calibrated so as to detect a leak of 2.5×10^{-8} scc/sec of Helium, or less.

3.5.5 When the E-23152 assembly has been completed, connect the E-23136 pressure test fixture to the Helium supply and evacuate the E-23152 assembly through the port in the Item 2 reworked headcap, using the pump in the leak detector to evacuate the E-23152 assembly to a pressure of 1×10^{-4} torr or less. When this vacuum is attained, leaks in the headcap/case vessel should be immaterial since the test will use a Helium tracer gas to detect leaks in the test item. At this point, pressurize the E-23136 pressure test fixture to 4000 ± 100 psig and hold for ten (10) minutes. Manually record the maximum leak rate measured by the detector. Maximum allowable leak rate is 1×10^{-7} scc/sec of Helium. The system can be bled after test through the Helium manifold.

3.5.6 No test procedures will be written for these tests.

3.6 Test No. 6 - Water Flow Test of Actuated Valve

3.6.1 This test will be performed on two (2) units which will have previously completed test No. 4, Valve Operational Test.

3.6.2 The test assembly is shown in E-23189 and consists of the actuated valve assembly, inlet and outlet port pressure transducers, and a Potter 3/4-64C H_2O flow meter. Nominal flowrate is 9 GPM. All assembly performed by test operations.

3.6.3 The following data will be recorded.

3.6.3.1 Valve Inlet Static Pressure: 0-100 psig; single channel; install near shear cup tube in the water inlet line; resolution of 0.5 psi or less.

3.6.3.2 Valve Outlet Static Pressure: 0-100 psig; single channel; install in outlet line upstream of flow meter; resolution of 0.5 psi or less.

3.6.3.3 Valve Flow: Ranges as indicated in 3.6.2, install in outlet line, downstream of valve outlet pressure transducer; resolution of 0.1 GPM or less.

3.6.4 Unit should be dogged to test bay floor for the test.

3.6.5 Test consists of flowing water through the actuated valve at 30-75 psig at a rate of 9.4 GPM. Once this flow is established and maintained, record the two pressures on the oscillograph for approximately five (5) seconds and note the flow rate on the trace, unless a flow channel is recorded.

3.6.6 No procedures will be written for this test.

3.6.7 Data Reduction will report volume flow rate and the two pressures corresponding to that flow.

3.7 Test No. 7 - Hydrotest of Actuated Valve

3.7.1 The test will be performed on 2 units.

3.7.2 Test is performed on an actuated, fully assembled valve following the flow test, No. 6 described above.

3.7.3 The test configuration consists of E-23130 with the exhaust port plugged, fired squib installed, squib pressure transducer removed and its port plugged by a special bolt/washer/o-ring assembly.

3.7.4 This assembly is pressurized through the shear cup tube inlet port with water to $6000\,^{+100}_{-0}$ and the pressure held for one (1) minute with the pressurization system valved off. No discernible pressure drop is permitted during the one (1) minute period.

3.7.5 No procedures will be written for this test (Ref. E-23189).

3.8 Test No. 8 - Hydroburst of Shear Cup Tube

3.8.1 This test to be performed on 2 units from test No. 7.

3.8.2 Test assembly consists of the Shear cup tube with a plug welded in place of the shear cup.

3.8.3 Assembly is pressurized first to 8800 psig for one (1) minute and then to burst or 16,000 psig whichever occurs first.

3.8.4 No procedures will be written for this test (Ref. E-23189).

3.9 <u>Test No. 9 - Operational Test at -320°F</u>

3.9.1 This test to be performed on one valve only, with assembly immersed in Liquid Nitrogen.

3.9.2 The valve will be equipped with Teflon o-rings and split rings; leakage is expected. Accordingly, an ambient-temperature gaseous N_2 leak test will first be conducted on the E-23130 assembly with a dummy squib. Gaseous N_2 at 45 psig is introduced to the exhaust port through a Brooks flow meter, the size of which must be determined at the time of the test. Once the ambient temperature leakage rate has been determined, the cold operational test can proceed after an engineering evaluation.

3.9.3 The operational test configuration is the same as that defined for test No. 4, including accumulator. Tubing will be installed in the fittings for pressure transducers and a 4000 psi gaseous N_2 source connection at the accumulator. The tubing will be of sufficient length to permit connection while the test assembly is immersed in Liquid Nitrogen.

3.9.4 The entire test assembly is then immersed in Liquid Nitrogen. A Dewar type vessel of sufficient size is needed. Connect the inlet and outlet pressure transducers and the high-pressure gaseous N_2 source at the accumulator.

3.9.5 Pressurize the valve through the accumulator to $4000\,^{+50}_{-0}$ psig, and, within one (1) minute, valve off the pressurization system and fire the squib.

3.9.6 Record the same parameters as in test No. 4. Data Reduction requirements are the same as test No. 4.

3.9.7 If the valve does not actuate, the test will be repeated with the squib replaced by a fitting E-23183 through which gaseous N_2 at 4000 psig is introduced to actuate the valve; again, the same parameters will be measured.

3.9.8 A test procedure will be generated for this test.

3.10 <u>Test No. 10 - Hydro/Proof Test of Actuated Rolldex</u>

3.10.1 The Rolldex from one of the operational valve tests will be installed in the valve body after test No. 9.

3.10.2 The test configuration is essentially the same as that for test No. 4, with all ports open except the inlet and outlet ports. Note that the Teflon o-rings used in test No. 9 will be replaced by standard o-rings.

3.10.3 The test consists of plugging the shear cup tube port and pressurizing through the exhaust port to 8800 psig. With the pressurization system valved off, there shall be no discernible system pressure drop within one (1) minute.

3.10.4 No procedures will be written for this test.

3.11 Test No. 11 - Hydro/Proof Test of Valve Body

This test is exactly the same as Test No. 2 except that the test pressure shall be 8800 psig.

4.0 TEST SEQUENCE

Table I indicates the test sequence applicable to each item in the Test Program.

TABLE I

TEST SEQUENCE

ITEM	*TESTS TO BE PERFORMED
Shear Cup Tube (6 units)	#1
Valve Body (1 unit)	#2
Valve #1	#3, #4, #5 (Rolldex only)
Valve #2	#3, #4, #6, #7, #8 (Shear Cup Tube only)
Valve #3	#3, #4, #5 (Rolldex only)
Valve #4	#3, #4, #5 (Rolldex only)
Valve #5	#3, #4, #6, #7, #8 (Shear Cup Tube only)
Valve #6	#3, #9, #5 (Rolldex only)
Valve Body	#11
Rolldex from Valve #5	#10

*Each Item subjected to tests in order shown

DEVIATION TO ORIGINAL TEST PROGRAM

The following deviations to the original test program as outlined in Table I, Test Sequence, were necessary:

Item	DEVIATION
Valve No. 1	Test No. 5, Rolldex Helium Leak Test, was deleted due to Rolldex failure. Test No. 8, Hydroburst of Shear-Cup tube, was added.
Valve No. 2	Test No. 6, Water Flow Test, and Test No. 7, Hydrotest of Actuated Valve, were deleted due to Rolldex failure.
Valve No. 3	This test replaced by equivalent tests: a) Actuation of Rolldex in prototype valve without shear cup. b) Hydroburst of original V- type shear cup tube c) Squib output pressure at ambient and -320°F.
Valve No. 4	No deviations on this test.
Valve No. 5	Test No. 7, Hydrotest of Actuated Valve, was deleted. Test No. 5, Rolldex Helium Leak Test was added.
Valve No. 6	Test No. 5, Rolldex Helium Leak Test, was deleted due to Rolldex failure.

APPENDIX B

DATA SUMMARY

DATA SUMMARY

Figure B-1. First test of prototype valve with JPL squib; shear-cup tube was not sheared.

Figure B-2. Repeat of first test using gaseous N_2 at squib port. Rolldex failed during operation.

Figure B-3. Valve was tested with rewelded Rolldex and was gas-actuated. The Rolldex failed at the time the end of shear-cup tube released. Pressure equalized throughout the valve chamber due to Rolldex failure.

Figure B-4. First successful valve operation in which end of shear-cup tube was sheared and Rolldex performed as designed. Actuation was with JPL squib. Rolldex was subsequently helium leak tested and met design requirements.

Figure B-5. Second successful valve operation in which end of shear-cup tube was sheared and Rolldex performed as designed. Actuation was with JPL squib. Inlet and outlet pressures were at 2, 000 psig nominal at initiation of tests which indicated, that a pin hole leak had occurred in the minimum cross section of the shear cup tube during assembly.

Figure B-6. An actuated valve was assembled to a fluid source with a pressure transducer upstream and downstream of the valve with a venturi at the end to provide the correct flow rate. The graph shows the differential pressure for this system at the indicated flow rate and pressure.

Figure B-7. The test setup was the same as for the valve in Figure B-6, except a smooth tube was placed in the system instead of the valve. This permitted the measurement of the differential pressure in the system without the valve. Thus the pressure drop (0. 5 psig) through the valve was determined by subtracting the pressure drop of the system without the valve from the pressure drop of the system with the valve.

Figure B-8. The JPL squib was installed in a chamber with a 0.49 in.^{3} free volume and actuated to determine actual output pressure at ambient conditions.

Figure B-9. The JPL squib was installed in a chamber with an 0.49 in.^{3} free volume, immersed in liquid nitrogen and actuated to determine actual output pressure at the -320°F condition.

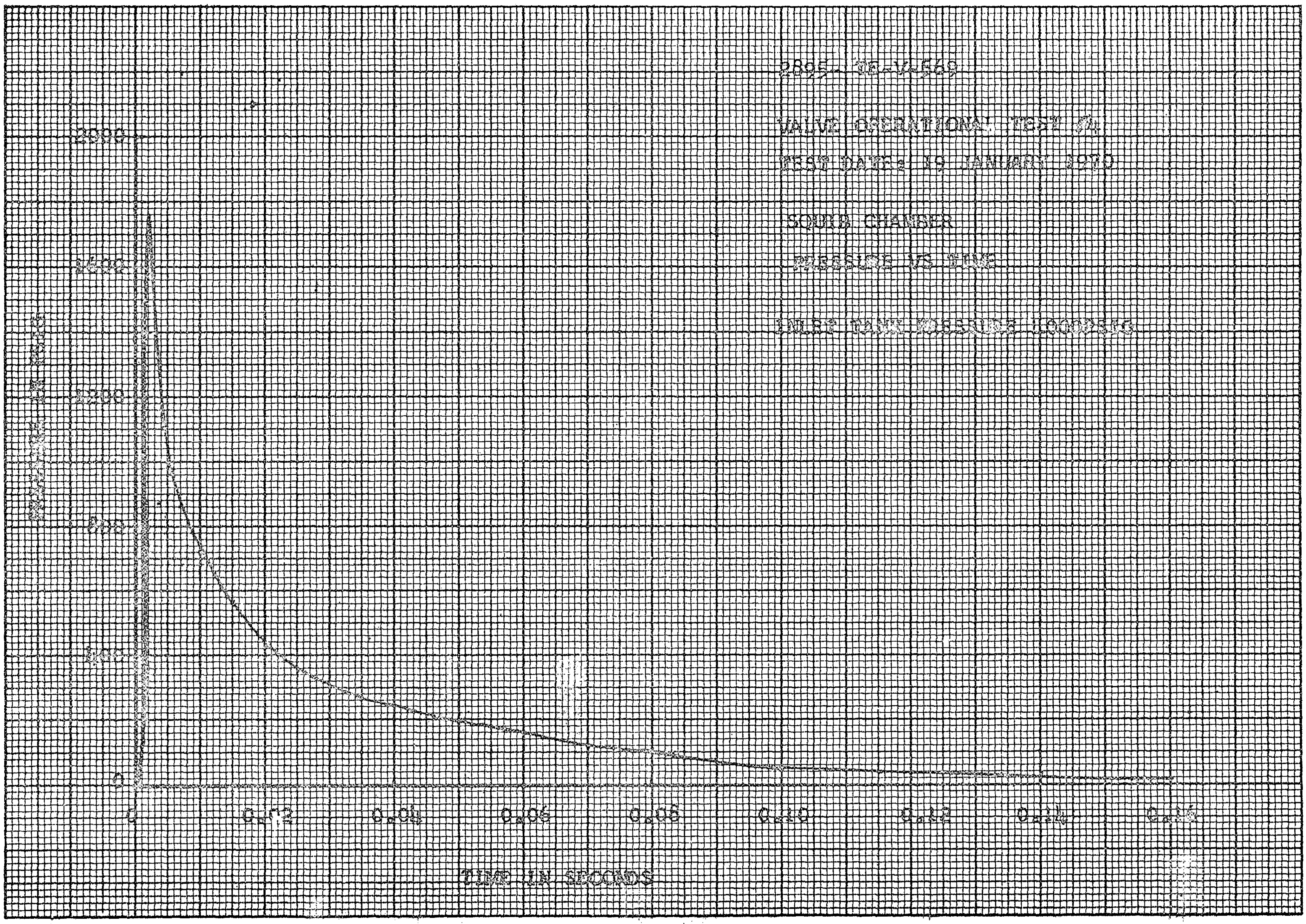

VALVE OPERATIONAL TEST #1
TEST DATE: 19 JANUARY 1970
SQUIB CHAMBER
PRESSURE VS TIME
INLET TANK PRESSURE 1000PSIG
2000
1600
1200
800
400
0
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
TIME IN SECONDS

FIGURE B-1

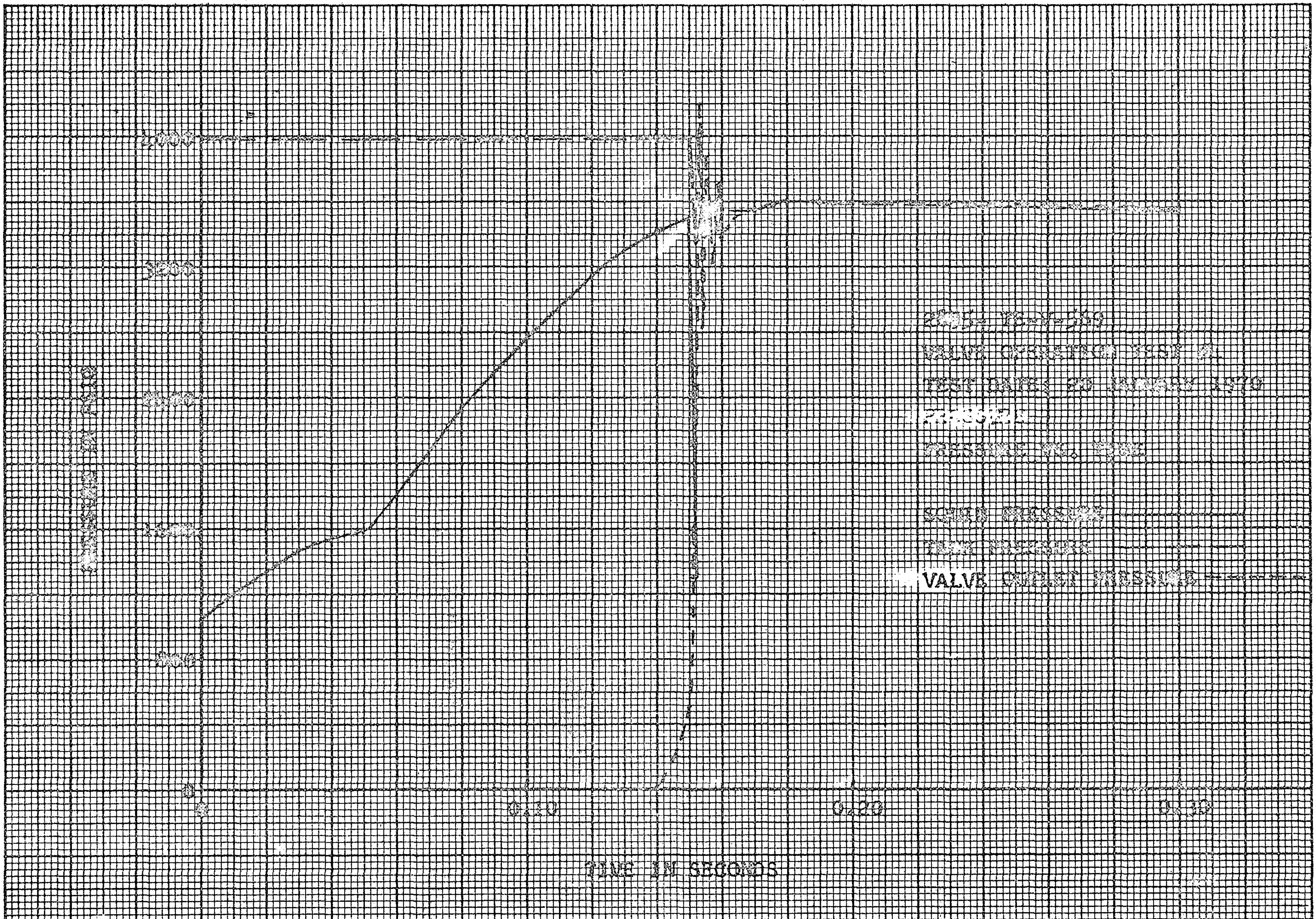


FIGURE B-2

K+E 10 X 10 TO ½ INCH 46 1327
7 X 10 IN. • ALBANENE®
KEUFFEL & ESSER CO.

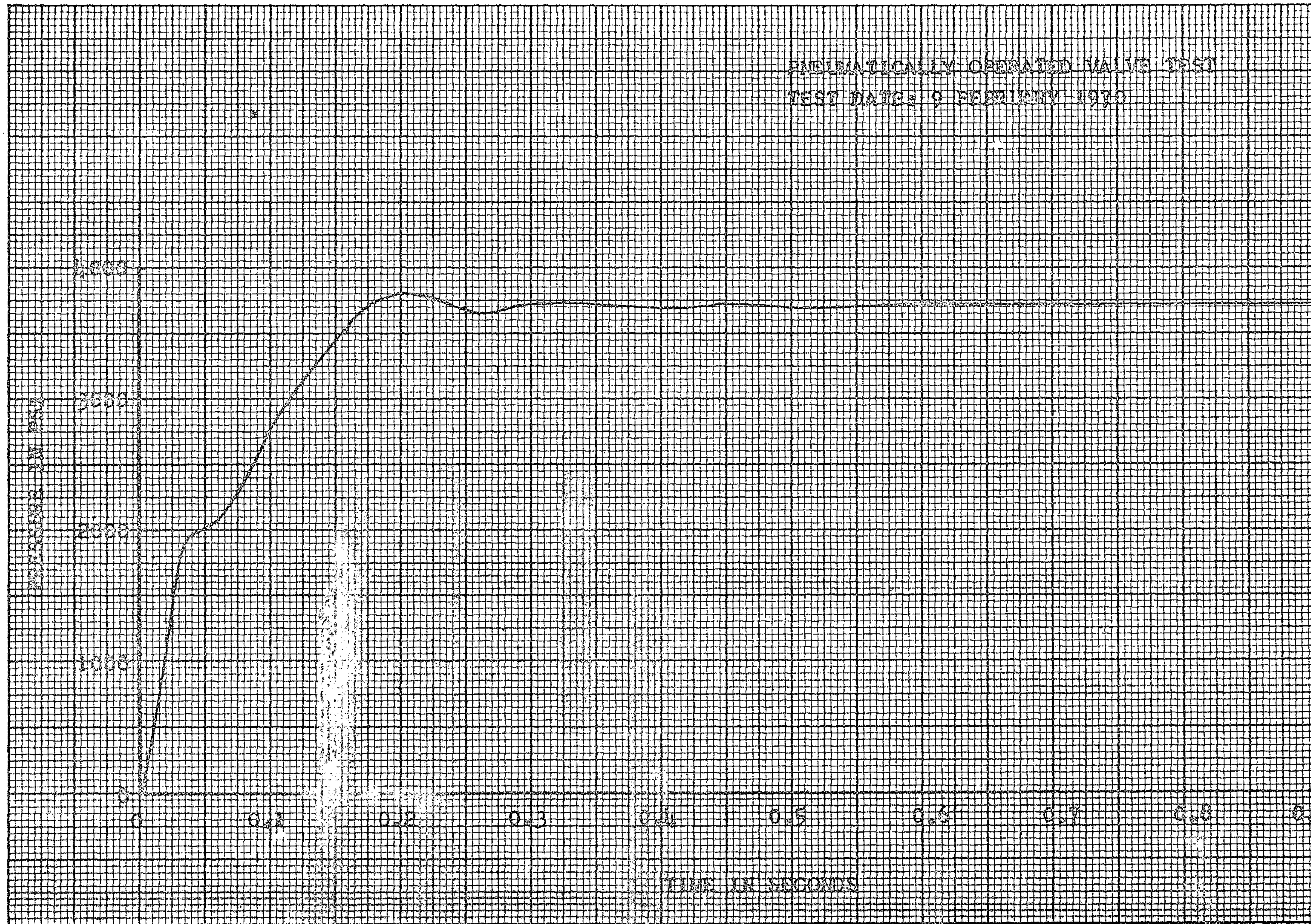


FIGURE B-3

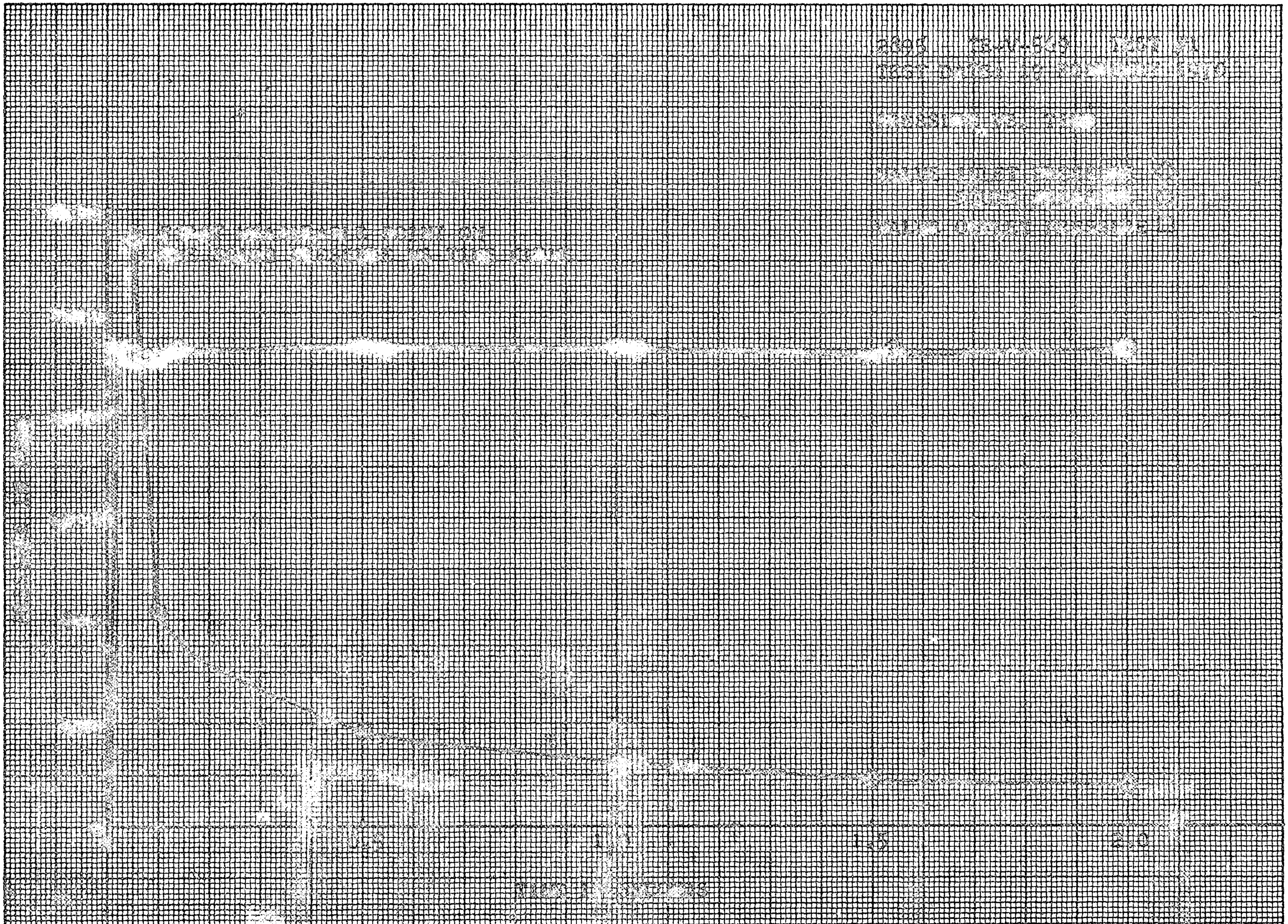


FIGURE B-4

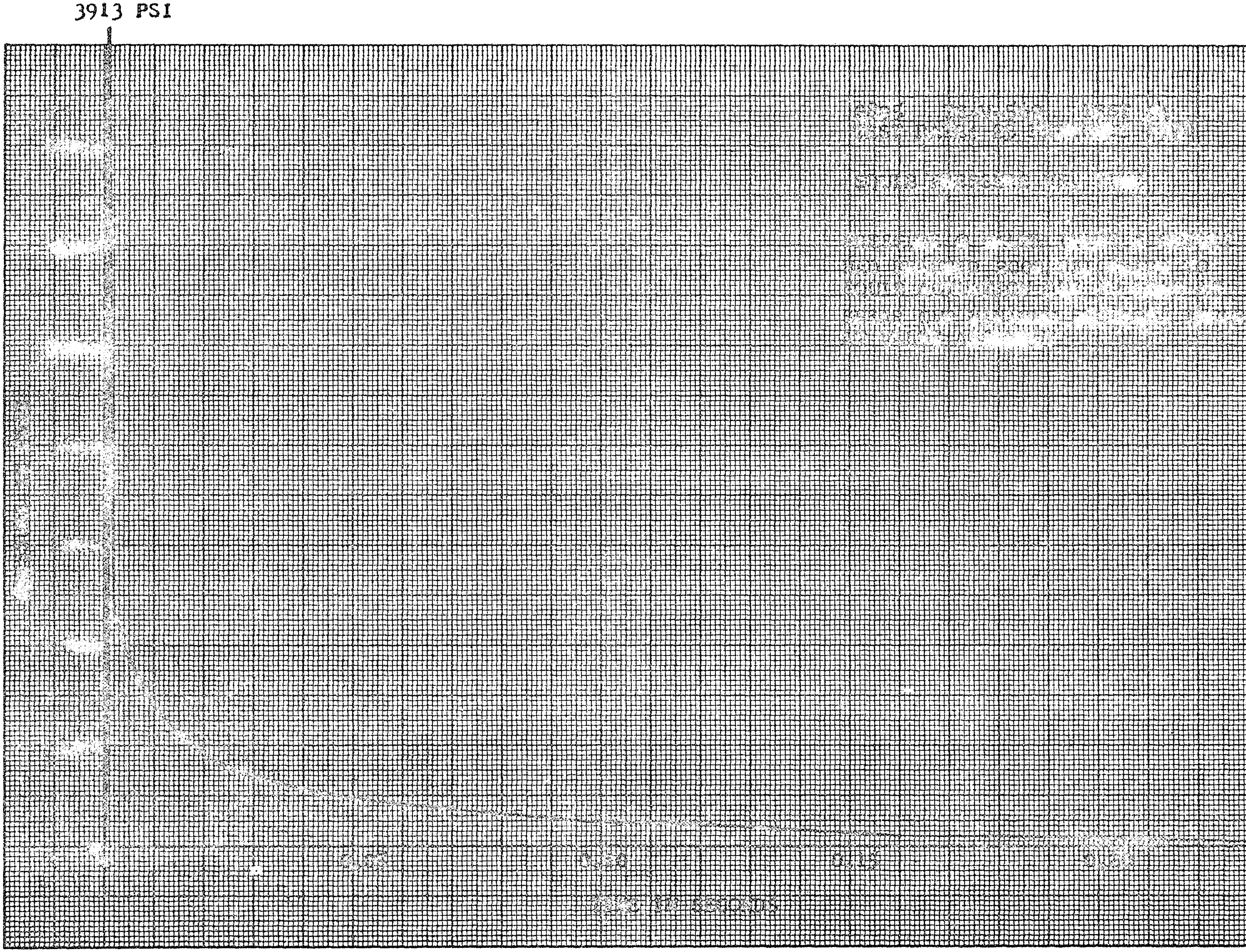


FIGURE B-5

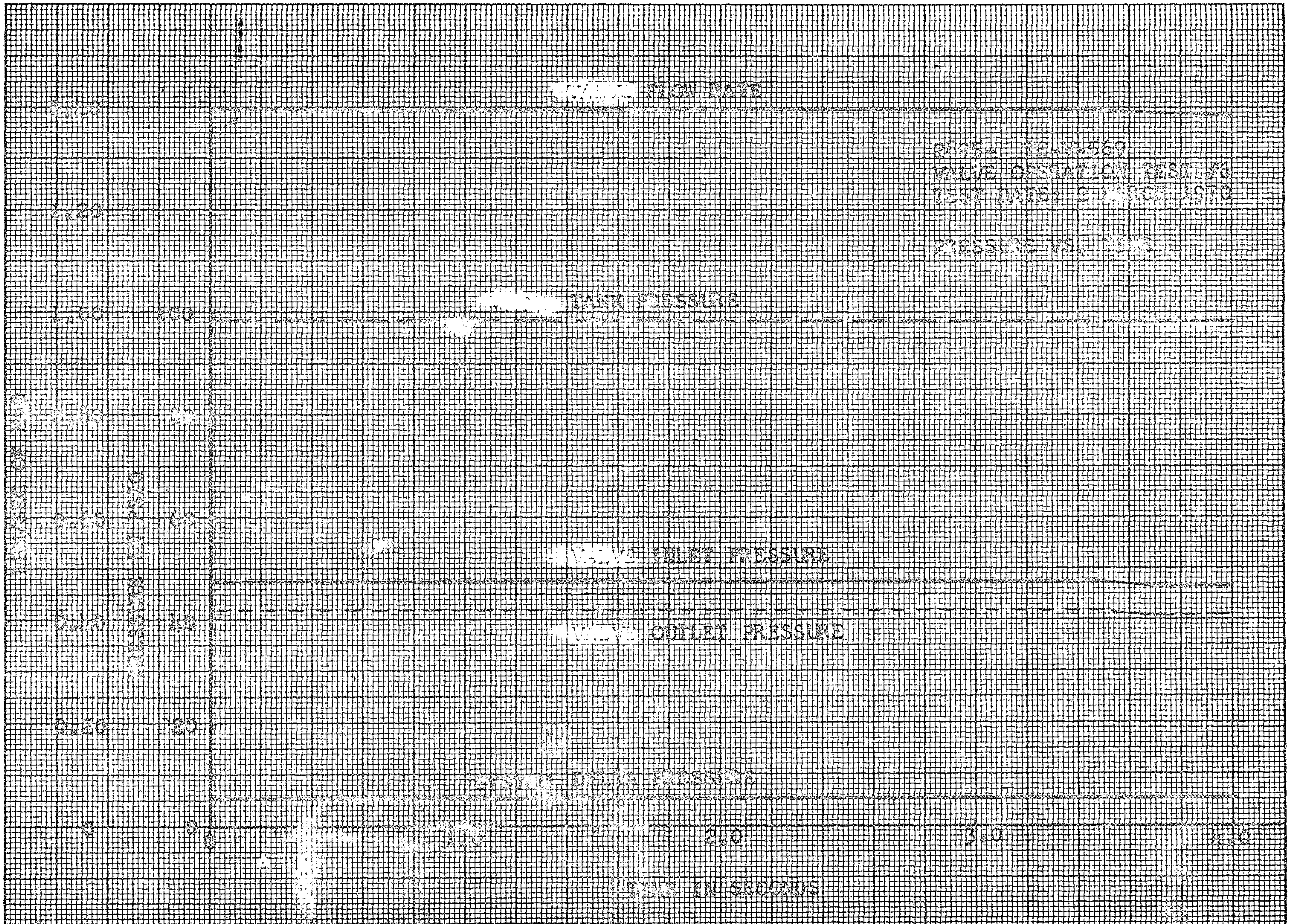


FIGURE B-6

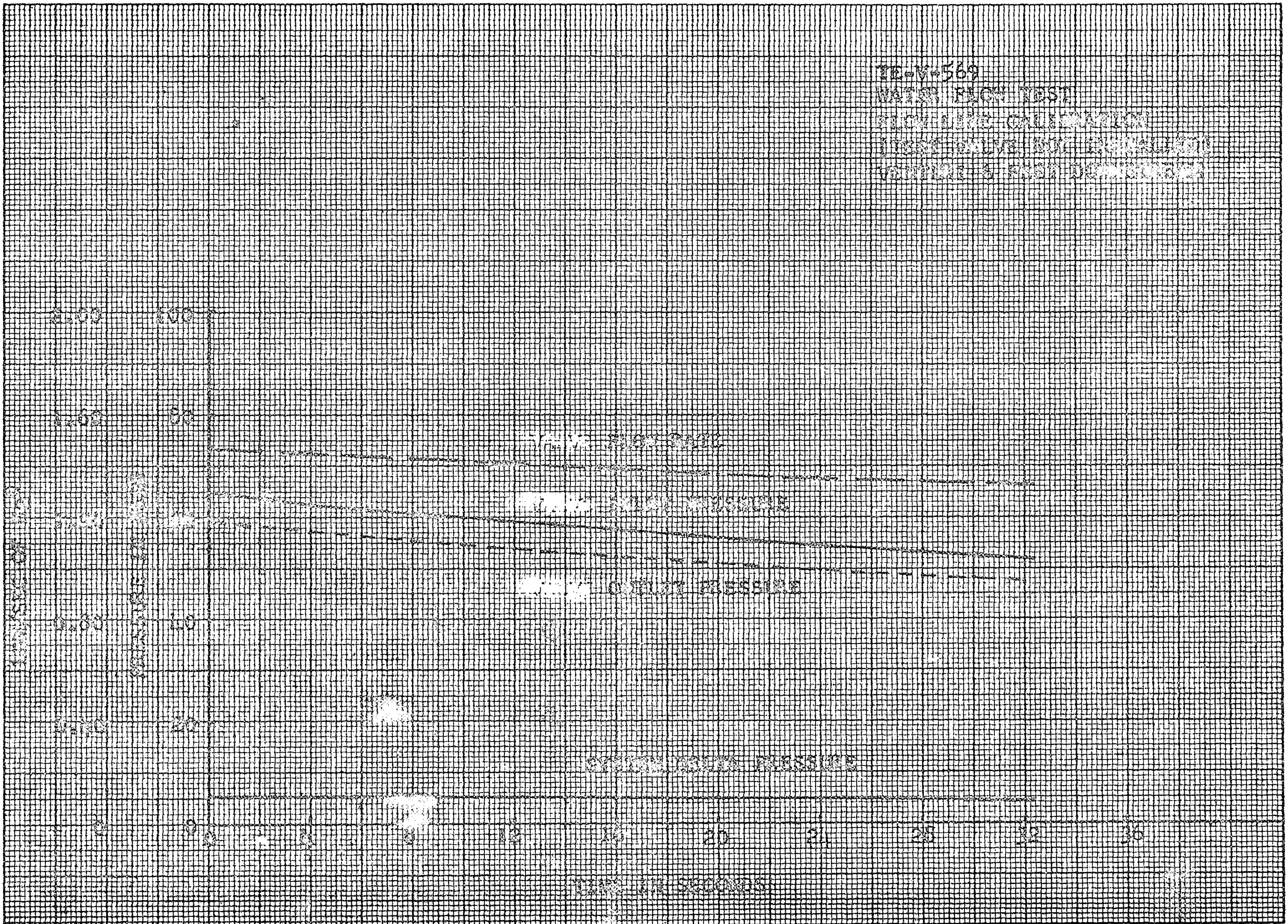

TE-V-569
WATER FLOW TEST
FLOW LINE CALIBRATION
OUTLET PRESSURE
TIME IN SECONDS
0
4
8
12
16
20
24
28
32
36
100
80
40
20
0

FIGURE B-7

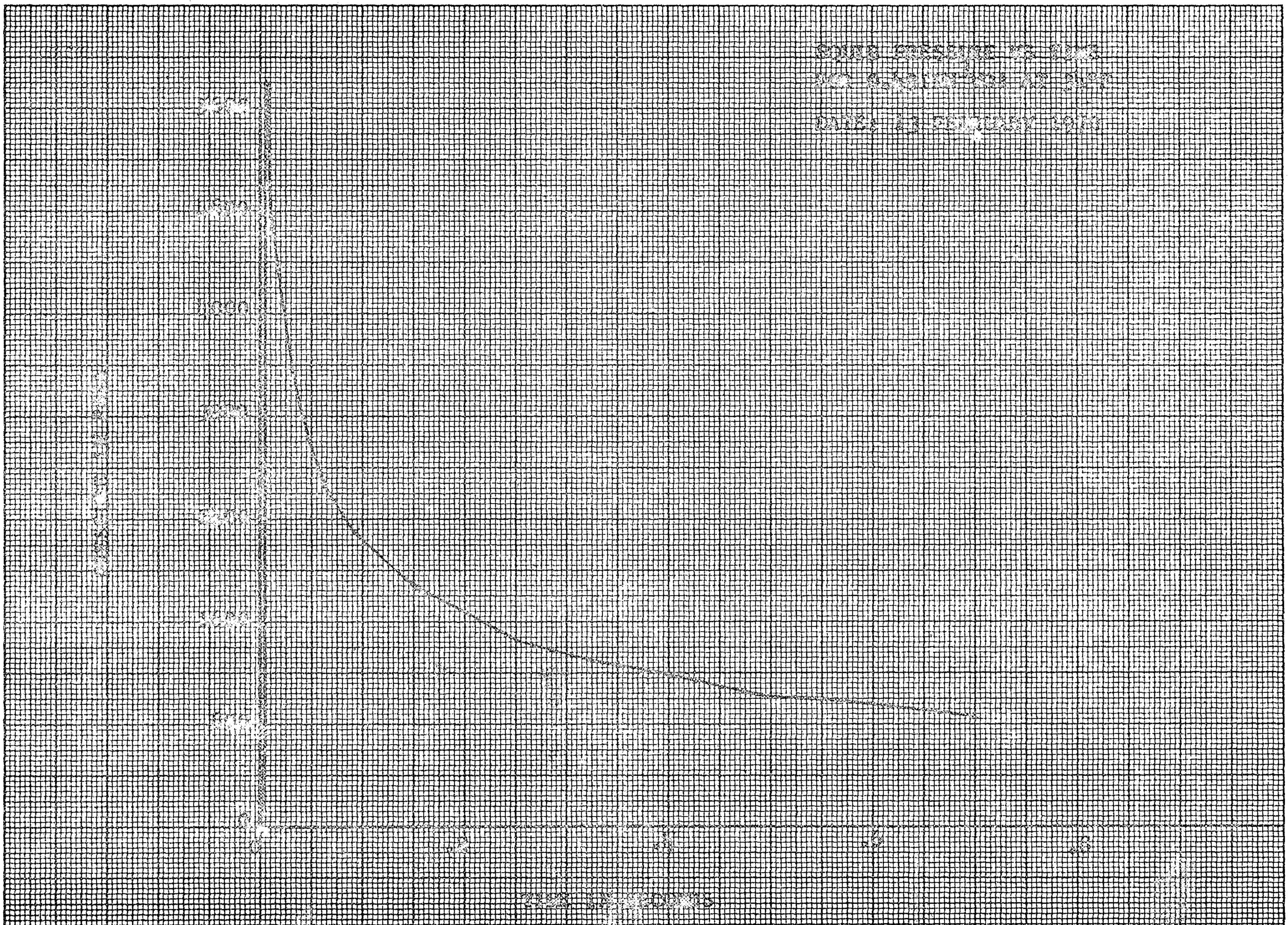


FIGURE B-8

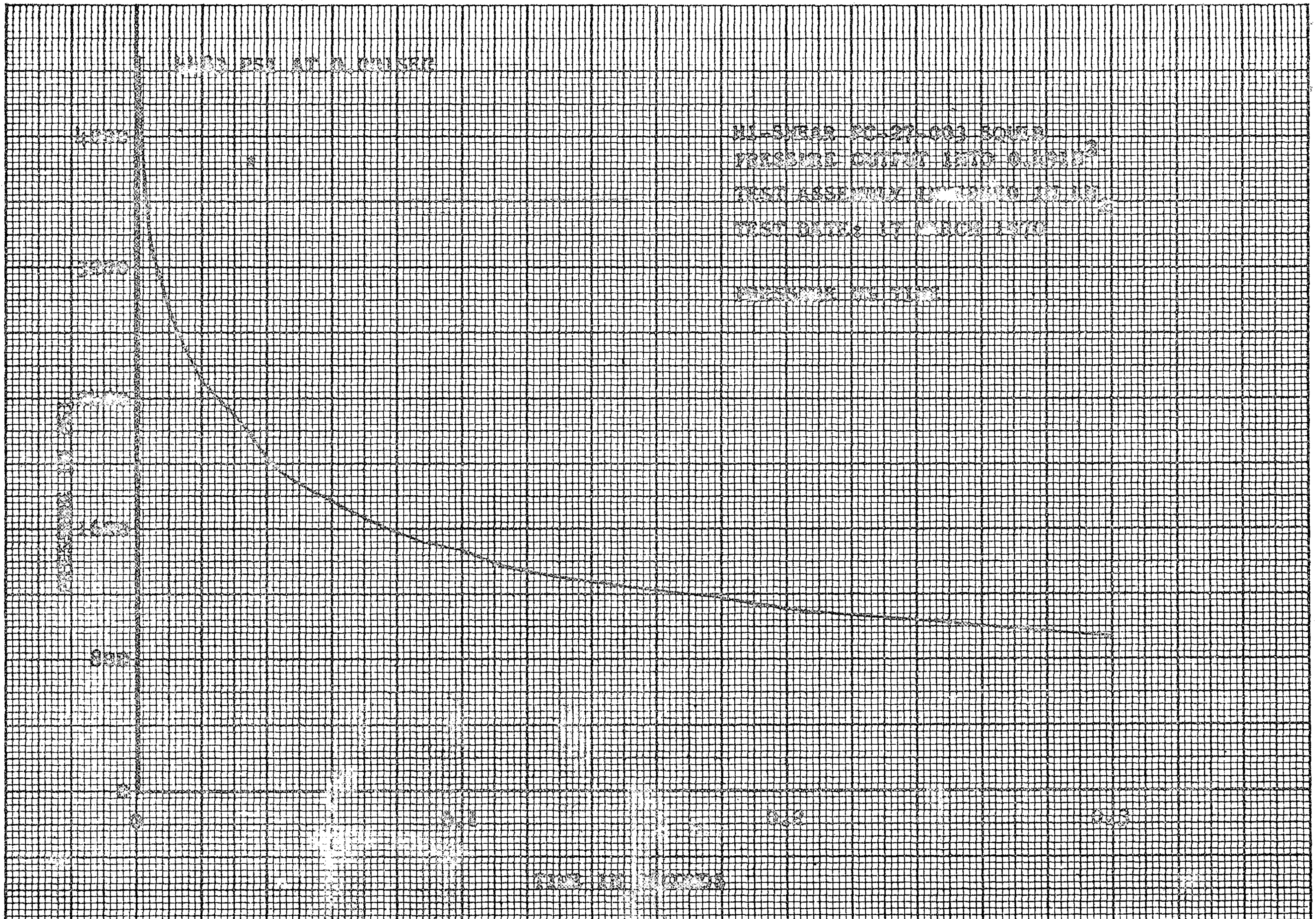


FIGURE B-9

APPENDIX C

ENGINEERING DRAWINGS

LIST OF FIGURES

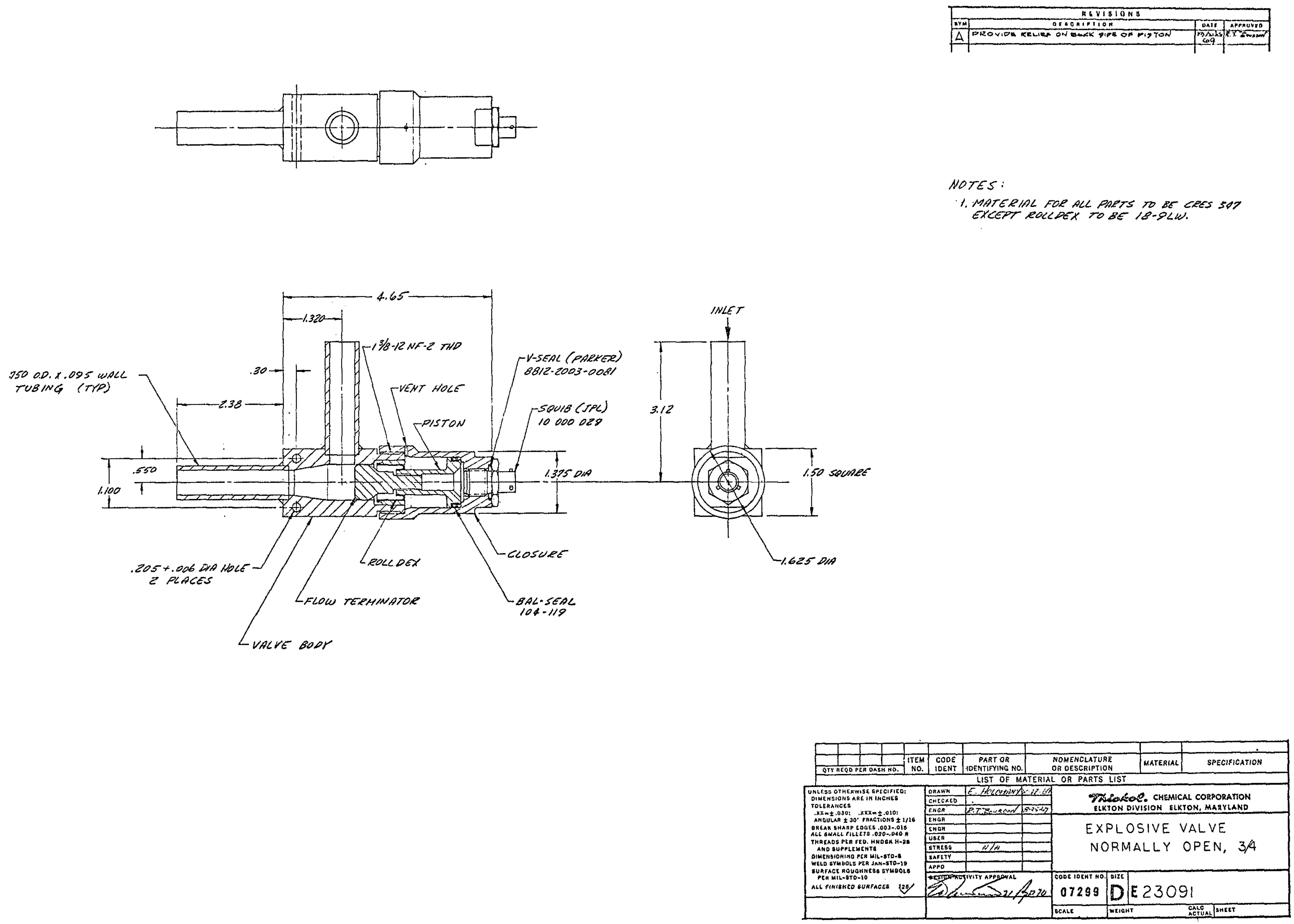


FIGURE C-1. EXPLOSIVE VALVE, NORMALLY OPEN, 3/4

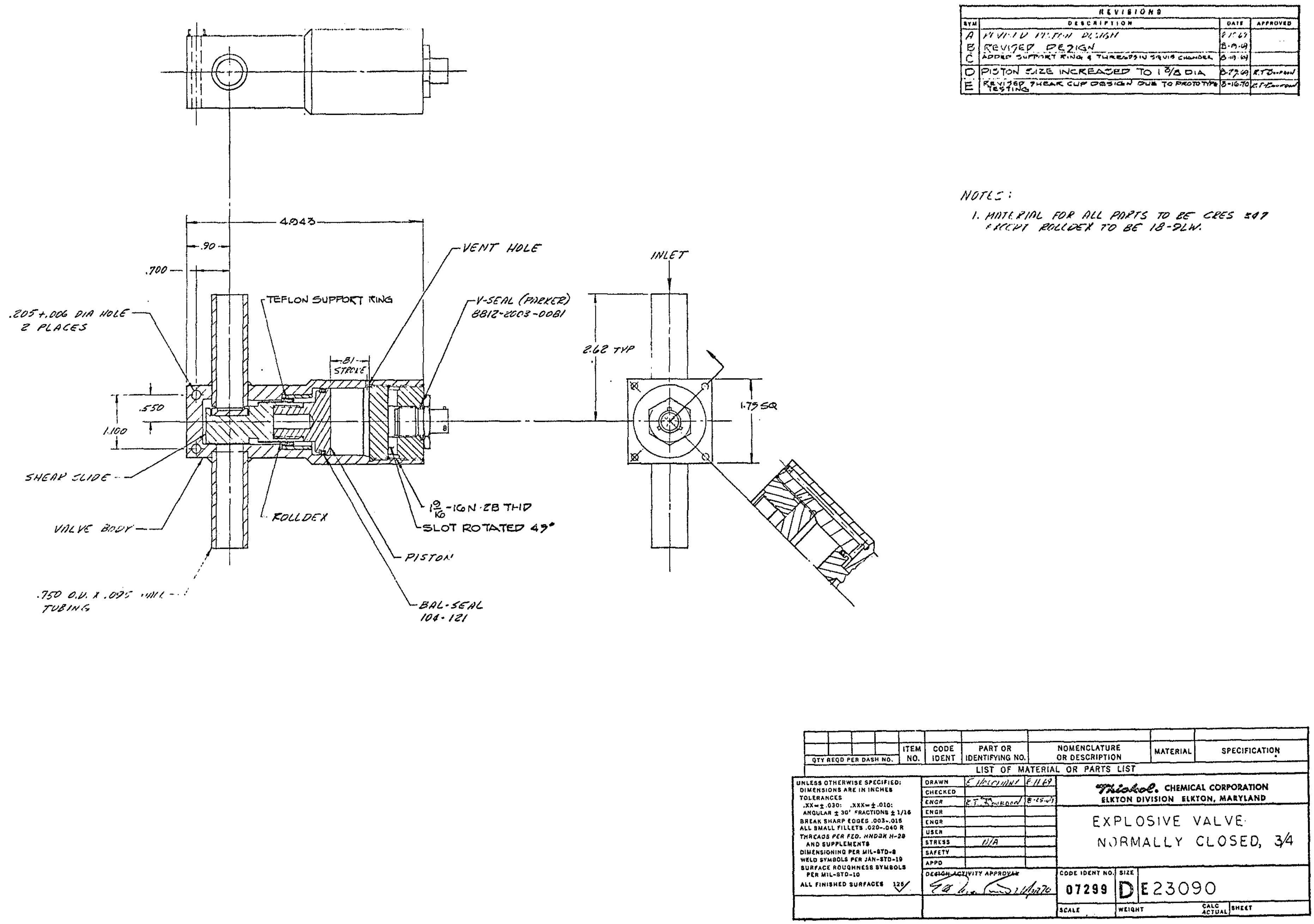


FIGURE C-2. EXPLOSIVE VALVE, NORMALLY CLOSED, 3/4

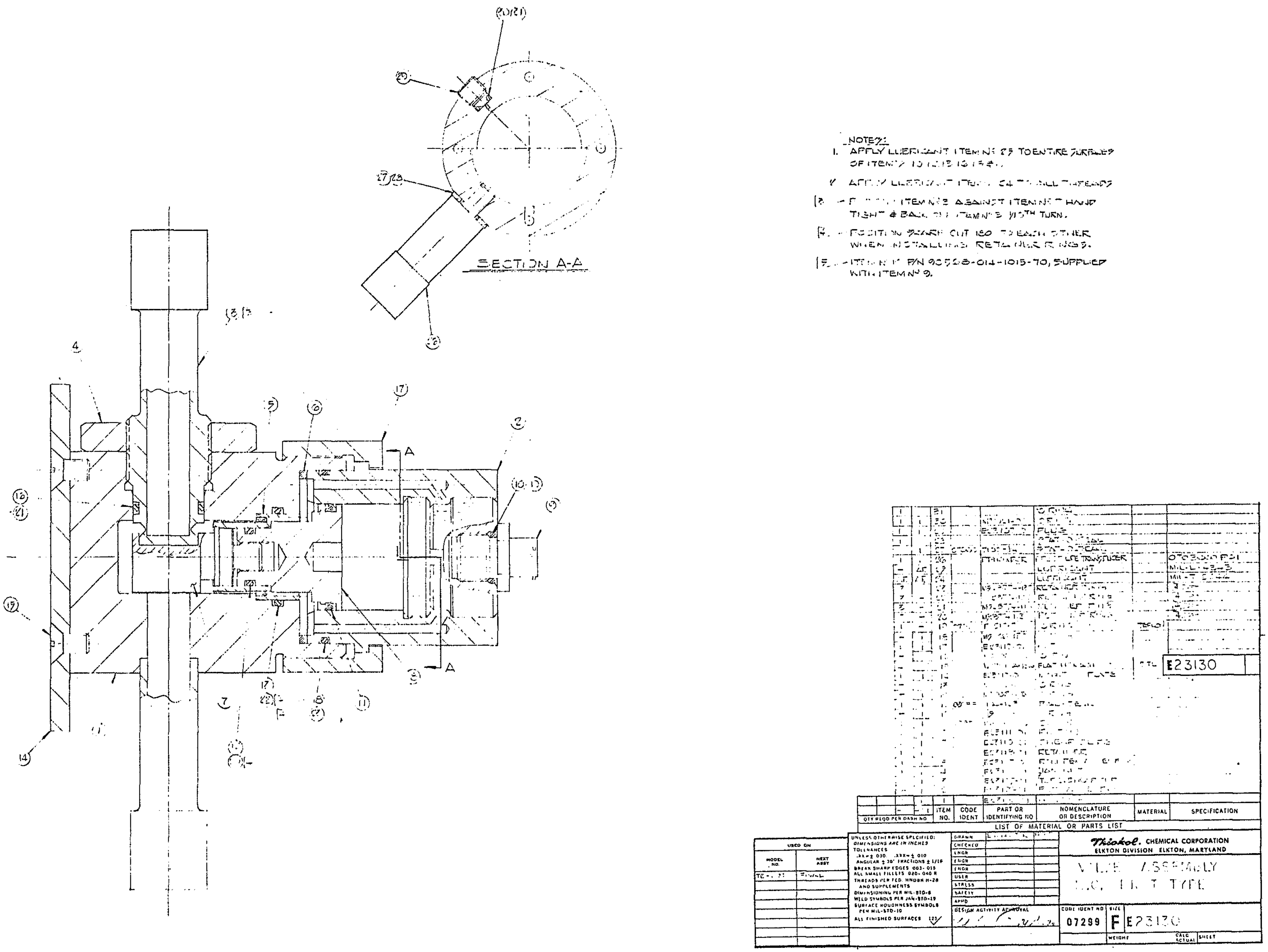


FIGURE C-3. VALVE ASSEMBLY, NORMALLY CLOSED, PROTOTYPE

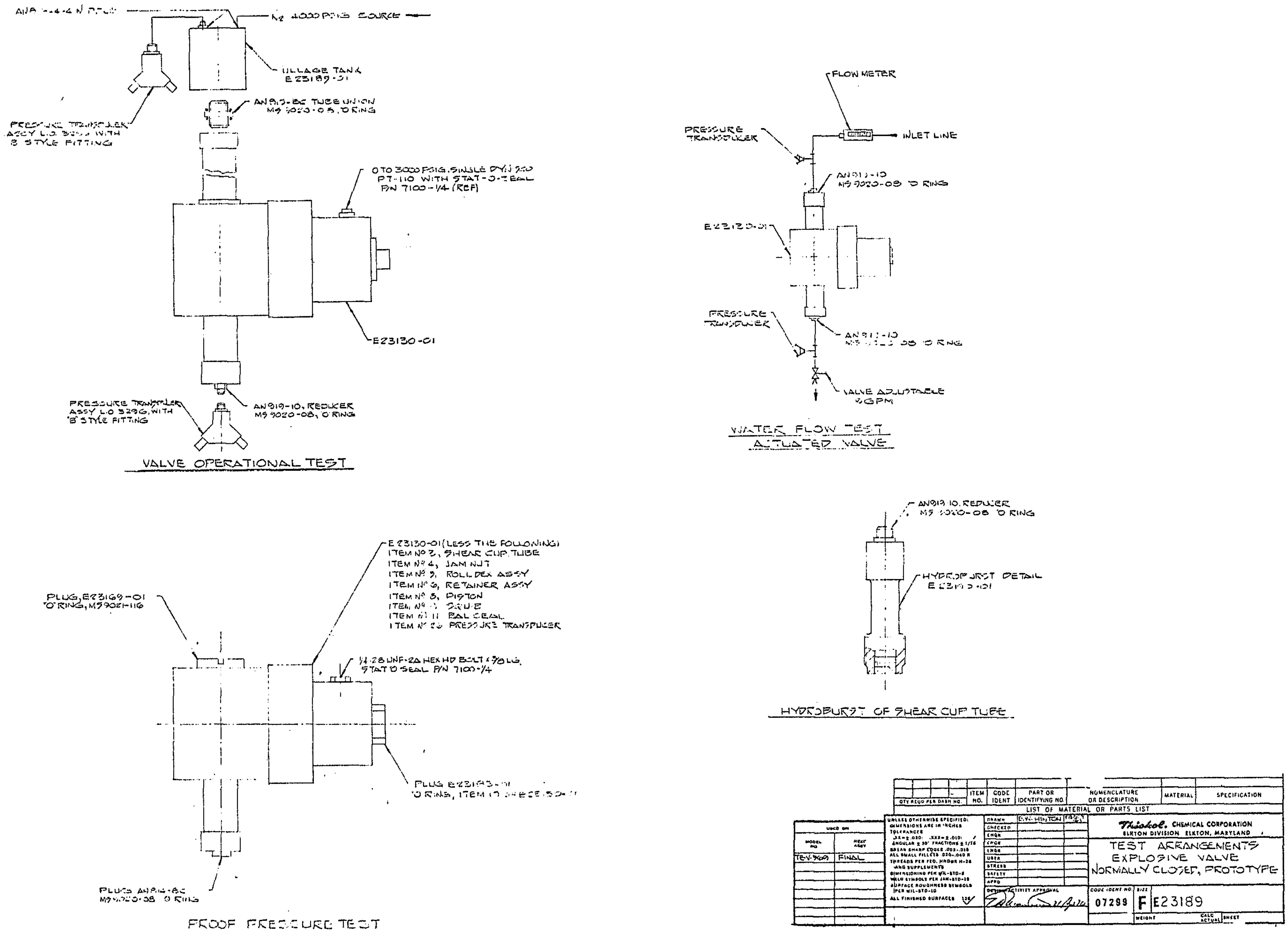


FIGURE C-4. TEST ARRANGEMENTS, EXPLOSIVE VALVE NORMALLY CLOSED, PROTOTYPE

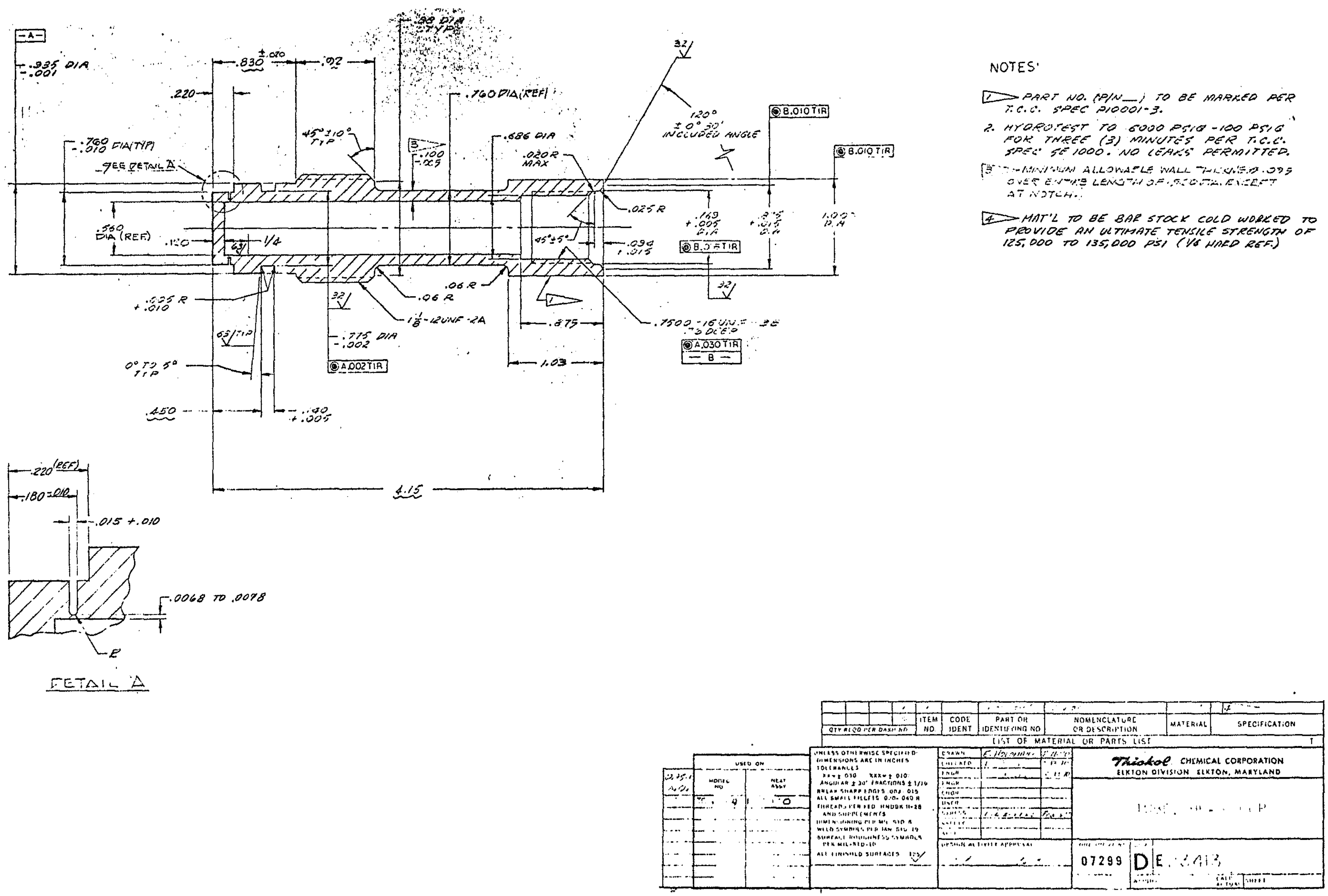
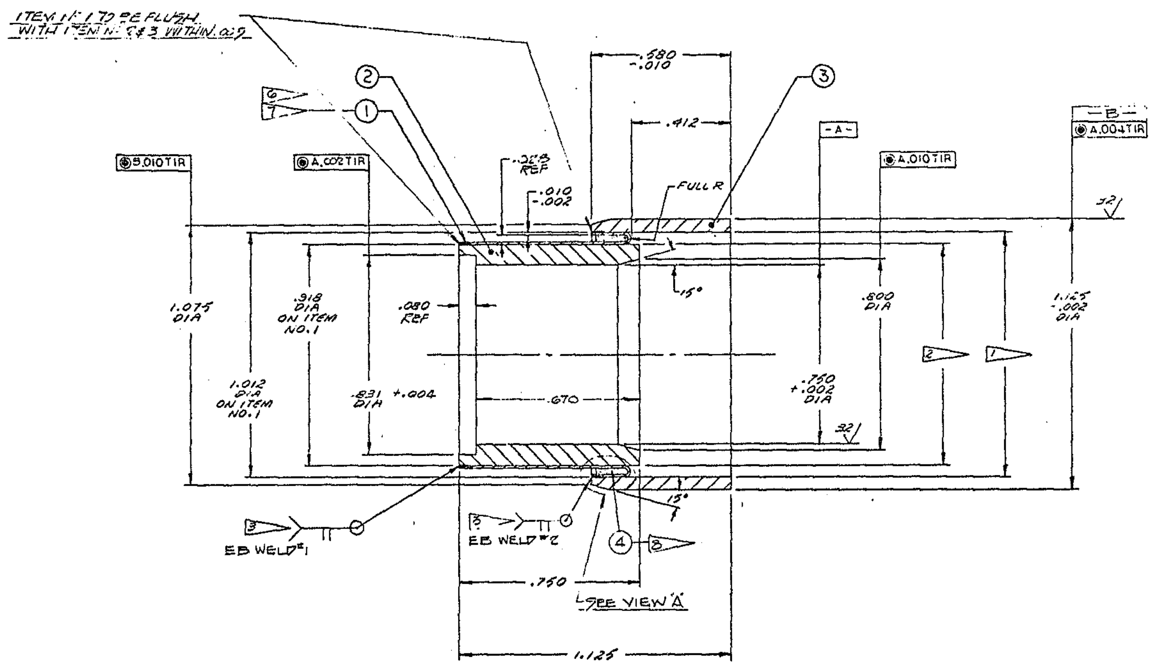
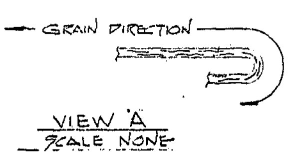


FIGURE C-5. TUBE, SHEAR CUP

EFFECTIVITY	SYM	REVISIONS DESCRIPTION	DATE	APPROVED
	A	UPDATE FOR PROCUREMENT		C.T.J.S.





NOTES:

1. MACHINE TO .0005 TO .0015 LOOSE FIT WITH 1.012 DIA ON ITEM NO. 1.
2. MACHINE TO .0005 TO .0015 LOOSE FIT WITH .918 DIA ON ITEM NO. 1.
3. ELECTRON BEAM WELD PER T.C.C. SPEC P13006, CATEGORY I, (WITHIN PENETRATION) RADIOGRAPHIC INSPECTION NOT REQUIRED.
4. TRUE LENGTH OF ITEM NO. 1 IS .902 REF.
5. PART NO. (P/N__) TO BE MARKED PER T.C.C. SPEC P10001-11.
6. NO NICKS, DENTS OR SCRATCHES PERMISSIBLE ON ITEM Nº 1
7. ITEM Nº 1 TO BE FABRICATED WITH THE GRAIN DIRECTION AS SHOWN IN VIEW 'A'
8. ITEM Nº 4 TO HAVE .001 TO .003 RADIAL LOOSE FIT.

QTY REQD PER DASH NO.				ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION
			1	4		E23110-01	[illegible]		
			1	3		TYPE 321	RING, OUTER	CRES	
			1	2		TYPE 321	RING, INNER	CRES	
			1	1		18-9LW	ROLLDEX	CRES	4
			-01						

LIST OF MATERIAL OR PARTS LIST

DASH NO.	USED ON MODEL NO.	USED ON NEXT ASSY
	TE-V-564	E23130-01

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
TOLERANCES
.XX = ± .030; .XXX = ± .010;
ANGULAR ± 30' FRACTIONS ± 1/16
BREAK SHARP EDGES .003-.015
ALL SMALL FILLETS .020-.040 R
THREADS PER FED. HNDBK H-28 AND SUPPLEMENTS
DIMENSIONING PER MIL-STD-8
WELD SYMBOLS PER JAN-STD-19
SURFACE ROUGHNESS SYMBOLS PER MIL-STD-10
ALL FINISHED SURFACES 125

DRAWN	R.T. DOYLE	
CHECKED		
ENGR		
ENGR		
ENGR		
USER		
STRESS		
SAFETY		
APPD		
DESIGN ACTIVITY APPROVAL		

Thiokol CHEMICAL CORPORATION
ELKTON DIVISION ELKTON, MARYLAND

ROLLDEX ASSEMBLY

CODE IDENT NO. 07299 SIZE D E23107
WEIGHT CALC ACTUAL SHEET

FIGURE C-6. ROLLDEX ASSEMBLY