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TEST REPORT

TR 9302 N990

Test Report for the TITAN Gamma Radiography Exposure Device

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Test Report for the TITAN Gamma Radiography Exposure Device

TR 9302 N990

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NORDION
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1 Introduction

1.1 Scope

This document describes the tests performed on the Nordion TITAN Gamma Radiography Exposure Device. The purpose of the tests was to demonstrate that the TITAN meets the regulations for the design of gamma radiography Exposure Devices and the regulations for the safe transport of radioactive material.

The testing of the TITAN was performed in accordance with IS/DS 0055 N990 revision B, "Test Plan for the Titan Gamma Radiography Exposure Device" [1]. The Test Plan describes the test requirements and contains details of the purpose and procedures for each test.

Table 1 summarizes the tests that were performed on the TITAN and its peripherals.

1.2 Definitions

Most terms used in this report are defined in the Test Plan. Many other terms are defined in the TITAN Gamma Ray Projector User's Manual [2].

1.3 Quality Assurance and Test Data

The Quality Assurance requirements are defined in the Test Plan. All tests were recorded on videotape and witnessed by a Quality Assurance Representative. The test data is stored in Nordion's Central Records Department file No. 8925 "TITAN Licensing and Marketing Test Data". All high magnification photographs are filed in Nordion's Metallurgy Laboratory (file reference No. 93-19).

1.4 Prototype Configuration

The fabrication of prototypes S/N 002 and 003 is documented in the Nordion Central Records Department file No. 8925 "TITAN Prototype Unit History File". The modifications made to prototype S/N 002 are documented in the Deviation Disposition Requests included in Appendix A.

Table 1. Summary of Tests

Device Under Test	Test	Notes	Result
Entire Apparatus	Projection Under Stress Test	Initial test: peak torque = 24 in-lb	Pass
		Final test: peak torque = 28 in-lb	Pass
	Endurance Test	20,000 cycles. 11 problems, all related to Remote Control.	Pass
Exposure Device	Radiation Shielding Test	Initial test: shielding too thin in spots.	Fail
		Final test: no significant increase in fields.	Pass
	Horizontal Shock	6 orientations. Push-button lock deforms	Fail
		Retest with bumpers. Outer Plate deforms.	Fail
		Retest with new Cover Plate. No deformation.	Pass
	Vertical Shock	100 impacts. No significant damage.	Pass
	Handle Wrench	1.1 m drop snatch. No significant damage.	Pass
	Penetration Test	4 impacts. No significant damage.	Pass
	Puncture Resistance	2 prototypes tested. No significant damage.	Pass
	Accidental Drop	2 prototypes, 3 orientations tested. No excessive increase in fields. No loss of containment.	Pass
Remote Control	Kinking	10 trials performed without incident.	Pass
	Crushing	10 trials performed without incident.	Pass
	Tensile	10 trials on sheath without incident.	Pass
		12 trials on cable. 1 failure of Source Assembly at 133%.	Pass
Projection Sheath	Kinking	10 trials performed without incident.	Pass
	Crushing	10 trials performed without incident.	Pass
	Tensile	19 trials performed in total 4 tests to failure: a) crimp failed at 113% b) crimp failed at 175% c) crimp failed at 165% d) crimp failed at 182%	Pass
Source Assembly	Tensile	20 trials performed on each of two source assemblies without incident.	Pass

2 Tests on the Entire Apparatus

2.1 Projection Under Stress Test

2.1.1 Equipment

The Projection Under Stress Test was performed before and after the tests for conditions of normal use. The initial test was performed using a new TITAN projector (S/N 002), a new Remote Control Assembly, a new Projection Sheath, and a new Source Assembly (S/N 0003).

The final projection under stress test was completed after the TITAN projector had been subjected to the Endurance Test, the Horizontal Shock Test, the Vertical Shock Test, the Handle Wrench Test and the Puncture Resistance Test. In addition, the Projection Sheath had been subjected to the Endurance Test, the Kinking Test, the Crushing Test and Tensile Test. Because of a failure during the Projection Sheath Tensile Test, only four trials of this test were completed prior to the final Projection Under Stress Test.

The Remote Control Assembly had been subjected to the Endurance Test and the Crushing Test and part of the Tensile Test. Because of a failure of the Source Assembly during the Tensil Test on the Remote Control Cable, only eight trials of this test were performed prior to the final Projection Under Stress Test. Also because of this failure, a new Source Assembly (S/N 0002) was used for the final Projection Under Stress Test.

The torque meter used for the test was a Snap On torque wrench, model number TQS2FUA. It had an analog readout and was equipped with a follow-up needle which indicated the highest torque reading.

The torque meter was fitted with an adaptor and attached to the Remote Control Pistol Grip Assembly.

2.1.2 Results

The Projection Under Stress Test Data Sheets are included in Appendix B.

The torque meter was read at regular intervals and the torque was recorded. The follow-up needle was reset after each data point. Data for each cycle was grouped into four phases: Source Assembly leaving the Exposure Device, Source Assembly travelling forward in the Projection Sheath, Source Assembly travelling backward, and Source Assembly entering the Exposure Device. The four groups of data for each cycle are separated by square brackets on the data sheets.

2.1.3 Analysis

The peak torque required to drive the source out of the Exposure Device increased from 24 in-lb (2.7 N-m) during the initial test to

28 in-lb (3.2 N-m) during the final test. This increase is less than 25%.

The drive torque required to retract the Source Assembly into the S-tube decreased.

The torque required to drive the source forward and backward through the Projection Sheath did not change over the course of the tests for conditions of normal use.

Regardless of the variations in the actual measurements, it is important to note that all of the measured torques are considered to be low from a human engineering perspective. Test exposures completed manually showed that the C990 Source Assembly exposed easily, retracted easily and secured easily before and after the tests for the conditions of normal use.

2.2 Endurance Test

2.2.1 Equipment

The setup and final adjustment of the automated endurance test apparatus was performed using the TITAN Demonstration Unit (S/N 001). Preliminary testing was also performed using the Demonstration Unit.

The Endurance Test was performed on the entire apparatus that had been subjected to the initial Projection Under Stress Test. The TITAN and its peripherals were laid out as shown in the Test Plan.

The automated operation of the TITAN was accomplished using a pneumatically controlled wrist mechanism, an electrically/pneumatically controlled drive mechanism and a variety of feedback sensors. This equipment was controlled by a microcomputer. A listing of the software used to control the equipment is included in Appendix C.

The wrist mechanism used to turn the Exposure Device's Selector Ring into the operate position is shown in Figure 1. It consisted of two fingers mounted on a pivot plate. In order to turn the Selector Ring into the operate position, the pivot plate was driven forward by two pneumatic cylinders. This action caused the two fingers to engage against two pins on a band clamped on the Selector Ring. A third pneumatic cylinder rotated the pivot plate and Selector Ring counterclockwise. With the Selector Ring in the operate position, the wrist mechanism was reset by retracting the fingers and rotating the pivot plate back to its clockwise position.

The drive mechanism was used to push the Source Assembly to the end of the Projection Sheath and then pull it back again. This was accomplished using a 1.5 hp 3 phase motor with a motor controller and a pneumatically controlled clutch. The motor and clutch were coupled to the pistol grip assembly. The drive mechanism turned the gear wheel inside the pistol grip assembly, driving the Source

Assembly forward. When the Source Assembly reached the end of the Projection Sheath and the torque on the gear wheel reached a pre-defined limit, the clutch disengaged and the motor was shut off. The appropriate clutch torque setting was determined experimentally. (See Appendix D.) Once the clutch was reset, the motor was reversed and the Source Assembly was retracted into the Exposure Device. When the Source Assembly reached the secure position and the clutch disengaged, the motor was turned off and the clutch was reset again.

An exposure cycle was broken down into eight sequential steps:

1. Push fingers forward to engage on pins on Selector Ring
2. Rotate pivot plate and Selector Ring counterclockwise
3. Retract fingers from Selector Ring
4. Return pivot plate to clockwise position
5. Drive motor forward until clutch disengaged
6. Reset clutch
7. Drive motor backward until clutch disengaged
8. Reset clutch

The status of the system was checked prior to each step. This feedback was accomplished using seven mechanical limit switches and one optical sensor. A cycle was considered to be successfully completed only after all eight steps were completed and confirmed by the limit switches and optical sensor.

Error messages were printed if the system was not in the appropriate configuration or if a step was not completed. When an error was detected, testing was interrupted immediately.

Data was output in three ways. For each of the eight steps of a cycle, a single-line description of the action was written to the computer monitor. At the end of every perfect cycle a message with the number of completed cycles and the time and date was written to the computer monitor and to a file on the hard disk. When the testing was interrupted because of a problem detected by a limit switch or the optical sensor, an error message was printed to the monitor, to the hard disk and to the printer. A message also was written to the printer every tenth cycle.

In this manner, a description of the current operation being performed was displayed on the monitor. A list of every cycle performed and every error message generated was recorded on the hard disk. As a backup, a list of every tenth cycle and every failure message was output to the printer.

The printer data was reviewed periodically by a Quality Assurance Witness and compared with the Endurance Test Log Sheets.

After 20,000 cycles were completed, the TITAN and its peripherals were moved to the Canadian Marconi Company for thermal testing. The equipment was installed in a Sexton Espec environmental chamber model number WC-T34-15-15.

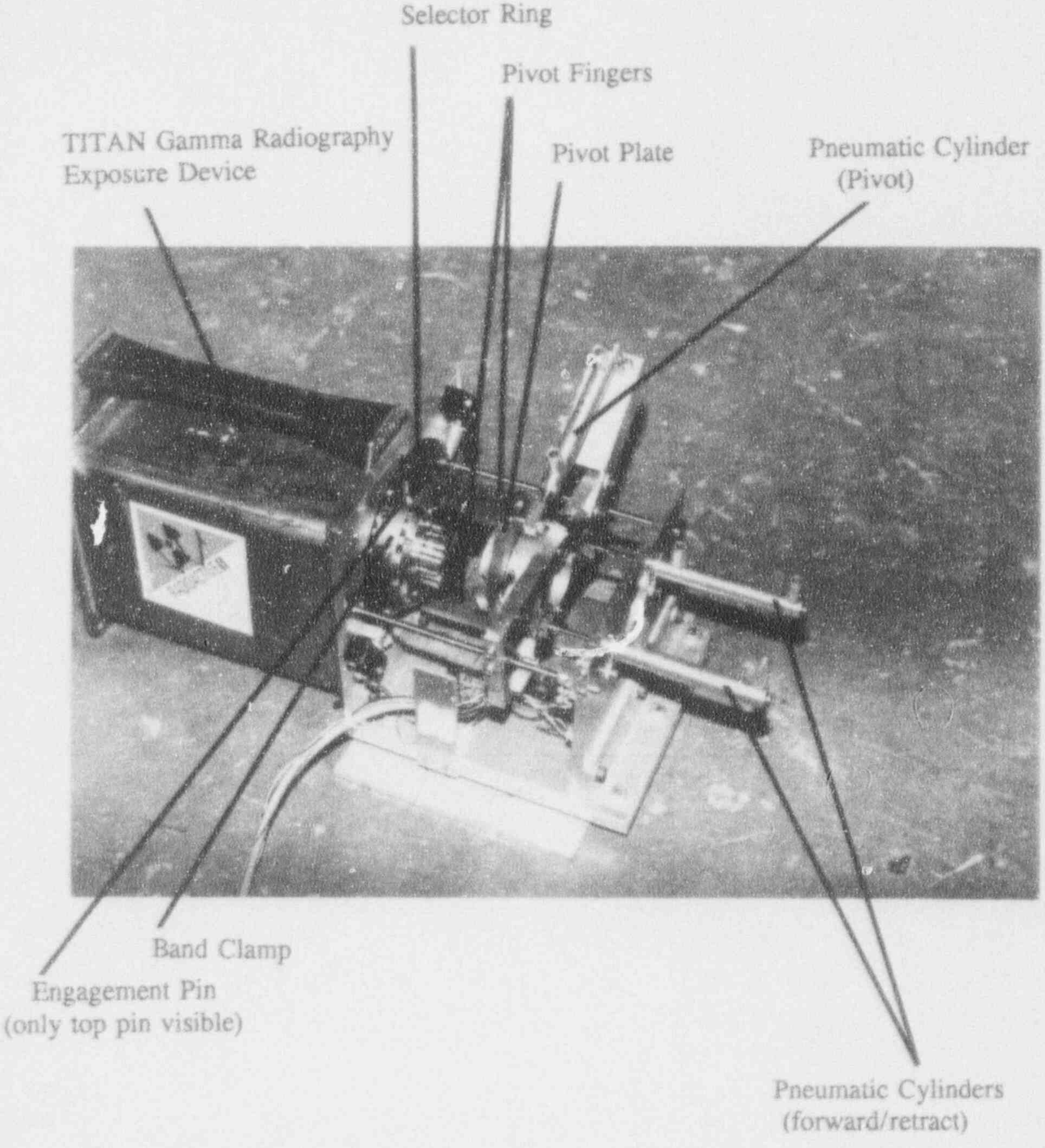


Figure 1. Pneumatic Wrist Mechanism

2.2.2 Results

Prior to the start of the Endurance Test, preliminary testing was performed on the TITAN Demonstration Unit (S/N 001). The Demonstration Unit was subjected to 1000 cycles. As a result of the preliminary test, the design of the TITAN was improved and modifications were made to S/N 002. These changes are documented in DDR-N990-033 in Appendix A.

The Source Assembly and Selector Ring Assembly were dimensionally inspected prior to the start of the Endurance Test. This data is presented in Appendix E. The Source Assembly was also photographed and checked with a Go/No-Go gauge. An impression of the interior of the Exposure Device's S-tube was made using Dow Corning Mold Making Compound HS II.

After the Endurance Test, the Selector Ring was removed and a new impression of the S-tube was made. A small spine was worn on the inside of both curves in the S-tube. This spine was examined microscopically and determined to be approximately 0.005 inches (0.1 mm) deep.

Prior to the start of testing each day, and at other periodic occasions, the test setup and operation was inspected by a Quality Assurance witness. These inspections were documented on the TITAN Endurance Test QA Witness Check Sheets and are included in Appendix E. These are held on file at Nordion along with the printer output and are available for inspection.

During the Endurance Test, 290 interruptions occurred due to problems. Most problems were related to the test equipment, and not the equipment under test. For example there were 14 limit switch failures and 265 problems associated with resetting the clutch. Only 11 problems were attributed to the equipment under test. The discussion of the test results will focus only on these problems.

One problem was a failure of a crimped fitting on the Remote Control Sheath. During cycle number 1314, when the source reached the end of the Projection Sheath, a fitting disengaged from the Remote Control Sheath. The sheath was reversed end-for-end and switched with the reserve sheath. Testing was then resumed.

The other 10 of the 11 problems with the equipment under test were premature disengagements of the clutch caused by kinks in the Teleflex Cable. These occurred at cycle numbers 456 (twice), 678, 1848, 1923 (four times), 5984 and 6485. The Teleflex Cable was replaced after cycle number 1923 and again after cycle number 6485.

After the Endurance Test, the Source Assembly was checked with a Go/No-Go gauge and found to pass. It was then photographed at high magnification.

100 cycles were performed manually with the TITAN thermally stabilized at +55°C without incident. 100 cycles were performed with the TITAN thermally stabilized at -40°C. At this temperature the Selector Ring was stiff to turn. Once the source was returned to the storage position at the end of a cycle, the Selector Ring snapped back automatically, but travelled slowly. The Selector Ring fully secured the Source Assembly every cycle, however.

2.2.3 Analysis

In order to fasten the Remote Control Sheaths and the Projection Sheath to the floor in the predefined layout shown in Figure 2 of the Test Plan, nylon tie-wraps were used with adhesive mounts. It was found however, that the tie wraps were breaking because of the energy dissipated in the Remote Control Sheath immediately before the clutch disengaged. In order to further restrain the Remote Control Sheaths, six 100 lb patio stones were placed against the sheaths. The patio stones were later replaced with a 1.5 inch diameter conduit which defined the path of the sheaths, yet still allowed some freedom of movement when the clutch disengaged.

Rigidly restraining the sheaths caused excessive stress on the Remote Control Sheath and Teleflex Cable that would not be encountered during normal use. This stress forced the crimped fitting off the Remote Control Sheath during cycle number 1314.

It was later demonstrated (refer to paragraph 4.3) that the Remote Control Sheaths are capable of withstanding tensile forces of 500 N for 30 seconds, as required by ANSI N432. The failure of the crimped fitting is therefore attributed to excessive stresses generated by the automated Endurance Test apparatus and not to a design or manufacturing problem with the Remote Control Sheath.

The Teleflex Cable that was replaced after cycle 1923 had two kinks in it. One kink was located 1.1 m from the end of the cable opposite the male connector. The other was located near the mid point of the cable. The cable that was replaced after cycle 6485 also had a kink located 1.1 m from the end of the cable opposite the connector. These locations correspond to the position of the Teleflex Cable on the Remote Control Gear Wheel when the source is fully exposed and fully retracted respectively. The kinks near the end of the cables were caused by the excessive force transferred to the cable by the gear wheel when the Source Assembly reached the end of the Projection Sheath. The other kink was caused by the same excessive force transmission when the source reached the storage position inside the gamma Exposure Device. Since these high forces would not be encountered during normal use, the failure is attributed to the excessive test conditions.

3 Tests on the Exposure Device

3.1 Radiation Shielding Test

3.1.1 Equipment

The initial Radiation Shielding Test was performed on the TITAN prototypes S/N 002 and 003. The shields had not yet been potted in the shells with epoxy foam, so a jig was used to secure them. Figure F-1 in Appendix F shows how the Model C-337 Source Assembly used for the test was secured.

The final Radiation Shielding Test was performed on the prototypes after the Puncture Resistance Test and the Accidental Drop Test. The Lock Assembly was removed from each prototype and a C-337 Source Assembly was installed in an adaptor. (See Figure F-2.)

The survey instruments used for the tests were a Bicron Surveyor 2000 GM Tube, a Bicron Model RSO-5 Ion Chamber, and a Victoreen Model 471 Ion Chamber.

3.1.2 Results

The results of the initial Radiation Shielding test are discussed in the report "TITAN Radiation Survey Results" included in Appendix F.

The results of the Radiation Shielding Tests completed after the drop tests are shown in Figures F-3 and F-4. These illustrations are included in Appendix F.

After the drop tests, the maximum radiation level at the surface of S/N 002 was 900 mrem/h on contact using a 2.66 TBq (72 Ci) source. The maximum radiation level at the surface of S/N 003 was 1.3 rem/h on contact using a 3.96 TBq (107 Ci) source.

3.1.3 Analysis

The prototype units require additional shielding to satisfy the ANSI N432 requirement for a field of 50 mrem/h at 50 mm from the surface of the Exposure Device. It is estimated that the additional shielding will increase the weight of the Exposure Device by 6.7 N (1.5 lbs).

Extrapolating to the maximum allowable source activity of 4.44 TBq (120 Ci), the maximum radiation level would be 15.0 mSv/h (1.50 rem/h) at the surface of the Exposure Device S/N 002 after the accidental drop tests. Similarly, the radiation level would be 14.6 mSv/h (1.46 rem/h) for S/N 003. The increase in radiation level is due to the poor fit of the adaptor used to secure the source assembly for the radiation shielding test. The poor fit is a result of the impact against the face of the exposure device.

After the tests for accident conditions of transport, and with its maximum radioactive contents, the TITAN contained sufficient shielding to keep the radiation level at 1 m from the package less than 10 mSv/h (1 rem/h).

3.2 Horizontal Shock Test

3.2.1 Equipment

The test was setup as described in the Test Plan using TITAN S/N 002. The Exposure Device had been subjected to the Endurance Test and the Projection Under Stress Test. Because the prototype weighs less than the production design of the TITAN, the release height for the impacts was increased to 105 mm.

3.2.2 Results

The Exposure Device was tested in the six orientations described in the Test Plan.

The impacts against the side and bottom of the Exposure Device did not cause any significant damage, nor did the impacts against the side and the face of the Exit Port.

The 20 impacts against the face of the Selector Ring caused the push-button lock to deform. The design was therefore changed to include two bumpers to protect this lock. The prototype was modified accordingly and 20 impacts were repeated against the face of the Selector Ring. The prototype modification is described in DDR-N990-034 which is included in Appendix A.

After this test, the push-button lock was undamaged but the Selector Ring was difficult to turn.

The problem was found to be that the standoffs of the Inner Plate (K122213-203) had been forced into the Outer Plate (K122213-201). This deformation caused the Inner and Outer Plates to pinch the web of the Outer Ring (K122213-202). In order to prevent this problem, the design was changed so that the standoffs bear on the stainless steel Cover Plate (K122213-204) rather than on the titanium Outer Plate. (See Appendix P for copies of the above engineering drawings).

The prototype was modified accordingly and 20 impacts were repeated against each the face and the side of the Selector Ring. The modification to the prototype is described in DDR-N990-035 which is included in Appendix A.

Following each of these two sets of 20 impacts, three exposure cycles were performed on the Exposure Device in order to demonstrate that it was in working order. After the impacts against the face of the Selector Ring, the Exposure Device performed perfectly. Following the impacts against the side of the Selector Ring, the Selector Ring was slightly stiff to rotate, but it returned to the "Lock" position automatically.

The tests were recorded on videotape and photographed. The Horizontal Shock Test Data Sheets are included in Appendix G.

3.2.3 Analysis

The design of the TITAN was improved and is resistant to the Horizontal Shock Test. The stiffness in rotating the Selector Ring after the final 20 impacts was the result of burrs on the edge of the Selector Ring. This condition does not pose a safety problem, and the removal of any such burrs is addressed as a standard maintenance procedure in the TITAN Users' Manual.

3.3 Vertical Shock Test

3.3.1 Equipment

The equipment was setup as described in the Test Plan using TITAN S/N 002. The Exposure Device had been subjected to the Horizontal Shock Test, the Endurance Test and the Projection Under Stress Test. Because the prototype weighs less than the production design of the TITAN, the height of the drops was increased to 160 mm.

3.3.2 Results

No damage to the prototype was observed. The test was recorded on videotape and photographed.

3.3.3 Analysis

The Exposure Device suffered no damage during the Vertical Shock Test.

3.4 Handle Wrench Test

3.4.1 Equipment

The equipment was setup as described in the Test Plan using TITAN S/N 002. The Exposure Device had been subjected to the Vertical Shock Test, the Horizontal Shock Test, the Endurance Test and the Projection Under Stress Test. Because the prototype weighs less than the production design of the TITAN, the height of the drop was increased to 1.1 m.

3.4.2 Results

The test was recorded on videotape and photographed. After the test, the four screws fastening the handle were slightly loose.

4.3.3 Analysis

The Exposure Device suffered no significant damage during the Handle Wrench Test.

3.5 Penetration Test

3.5.1 Equipment

The equipment was setup as described in the Test Plan using TITAN S/N 003.

3.5.2 Results

The Exposure Device was struck four times as described in the Test Plan. The test was recorded on videotape and photographed. The Penetration Test Data Sheet is included in Appendix H. After the test the Selector Ring was difficult to turn.

3.5.3 Analysis

Because this test is a transport requirement, the Exposure Device is not required to be operational afterwards. The damage caused to the Selector Ring is therefore acceptable.

3.6 Puncture Resistance Test

3.6.1 Equipment

The test was setup as described in the Test Plan using TITAN S/N 002 and 003. Because the prototypes weigh less than the production design of the TITAN, the height of the drop was increased to 1.05 m.

3.6.2 Results

Both prototypes were released in an upright orientation so that the pin struck the Selector Ring. On the first attempt using S/N 003, the pin did not strike its target properly. The test was therefore repeated. The impacts caused no significant damage. The observations are included in Appendix I.

The tests were recorded on videotape and the prototypes were photographed after each impact.

3.6.3 Analysis

The 1.05 m drop onto the pin did not cause any damage that adversely affected the prototypes' ability to satisfy the transport requirements. The dummy sealed source was retained and no significant deformation was observed.

3.7 Accidental Drop Test

3.7.1 Equipment

The test was setup as described in the Test Plan using TITAN S/N 002 and 003. The prototypes had been previously subjected to the

Puncture Resistance Test. Because the prototypes weigh less than the production design of the TITAN, the height of the drop was increased to 9.45 m.

3.7.2 Results

S/N 002 was released in an upright orientation. The impact caused the end plates to bend. A tear occurred in one end plate below the belly of the Exposure Device, but there was no breach of the Exposure Device's shell.

S/N 002 was released in an oblique orientation as shown in Figure 8 of the Test Plan. The Exposure Device rotated before striking the target, however, and landed at an oblique angle on its side. The impact orientation and a description of the deformation are included in Appendix I.

S/N 003 was released with the Selector Ring facing downward. The Exposure Device rotated slightly before landing. Examination of the prototype after impact suggests that it struck with approximately a 20° slant toward a bottom corner.

The tests were recorded on videotape and the prototypes were photographed after each impact.

Once the prototype Exposure Devices were returned to Nordion, the Selector Rings were removed. At this time it was determined that the radiation shield in S/N 002 had shifted approximately 5 mm toward the Exit Port. There was no measurable shift in the radiation shield in S/N 003.

3.7.3 Analysis

The Radiation Shielding Test performed after the drop tests (paragraph 3.1) demonstrated that the Exposure Devices satisfy the transportation requirements for accidental conditions.

Examination of the C-990 Source Assembly showed no damage to the sealed capsule. The containment system was intact.

4 Tests on the Remote Control Device

4.1 Kinking Test

4.1.1 Equipment

The Remote Control Sheaths used for the Kinking Test had been subjected to the Tensile Test.

The apparatus was setup as described in the Test Plan. It was found however that the Ametek digital tachometer was not suitable for measuring the speed of the Remote Control Sheath. Instead the time required to manually pull the sheath until the loop had disappeared was recorded. A time of 0.76 seconds or less was required to achieve an average speed of at least 2.0 m/s.

4.1.2 Results

The test was recorded on videotape and the times were recorded on the Remote Control Kinking Test Data Sheet which is included in Appendix J.

4.1.3 Analysis

The Remote Control suffered no damage and was later demonstrated to pass the Projection Under Stress Test (paragraph 2.1).

4.2 Crushing Test

4.2.1 Equipment

The apparatus was setup as described in the Test Plan. The Remote Control Sheath had been subjected to the Projection Under Stress Test and Endurance Test. The Remote Control Cable had been subjected to over 13,000 cycles of the Endurance Test.

4.2.2 Results

The test was recorded on videotape and photographed. The Crushing Test Data Sheet is included in Appendix K.

4.2.3 Analysis

The Remote Control suffered no damage and was later demonstrated to pass the Projection Under Stress Test (paragraph 2.1).

4.3 Tensile Test

4.3.1 Equipment

The apparatus was setup as described in the Test Plan. Because the Remote Control Sheaths used for the Endurance Test had been over stressed and damaged, the Tensile Test on the Remote Control Sheath was performed using new sheaths. The Teleflex Cable used for the Tensile Test on the drive cable was the same cable used for the last 15,000 cycles of the Endurance Test.

An Omega Bending Beam Load Cell model No. LCCB-300 was used to measure the force. Later, because this transducer became damaged, it was replaced with an Omega Bending Beam Load Cell model No. LCCA-500. The data was collected using a Fluke Hydra Data Logger.

4.3.2 Results

The test was recorded on videotape and photographed. The data was plotted and is included in Appendix L. The plots for the Tensile Test on the Remote Control sheath are labelled "rctest trial #1" through "rctest trial #10".

During trial #7 of the Tensile Test on the Remote Control Sheath, the bolt restraining the crank handle failed. The impact that ensued damaged the force transducer. This is evident from the 90 lb offset after 17 seconds in the plot "RC Cable Trial #7" in Appendix L.

Because the damage to the transducer was not observed immediately, testing continued. During the next trial, a significant over test resulted. The force applied to the Teleflex Cable reached 265 lb (1179 N) before the C990 Source Assembly failed. This trial is plotted in "RC Cable Trial #8" in Appendix L.

With a new force transducer, the testing was resumed. Four new trials were completed. These are labelled "RC Cable Trial #9" througn "RC Cable Trial #12".

At the conclusion of the tests, the male connector on the drive cable was checked with a Go/No-Go gauge and passed.

4.3.3 Analysis

The Teleflex Cable was demonstrated to meet and exceed the test requirements.

5 Tests on the Projection Sheath

5.1 Kinking Test

5.1.1 Equipment

The apparatus was setup as described in the Test Plan. Rather than using a pneumatic cylinder however, the force was applied to the Projection Sheath by hand. An Omega Bending Beam Load Cell model No. LCCB-300 was used to measure the force. The data was collected using a Fluke Hydra Data Logger. The Projection Sheath used for the test had been subjected to the Projection Under Stress Test and the Endurance Test.

5.1.2 Results

No damage to the Projection Sheath was observed. The test was recorded on videotape and photographed. The Projection Sheath Kinking Test Data Sheet is included in Appendix M.

5.1.3 Analysis

The Projection Sheath suffered no damage and was later demonstrated to pass the Projection Under Stress Test (paragraph 2.1).

5.2 Crushing Test

5.2.1 Equipment

The apparatus was setup as described in the Test Plan. The Projection Sheath used for the test had been subjected to the Kinking Test, the Projection Under Stress Test and the Endurance Test.

5.2.2 Results

No significant damage to the Projection Sheath was observed. The test was recorded on videotape and photographed. The Crushing Test Data Sheet is included in Appendix K.

5.2.3 Analysis

The Projection Sheath suffered no damage and was later demonstrated to pass the Projection Under Stress Test (paragraph 2.1).

5.3 Tensile Test

5.3.1 Equipment

The apparatus was setup as described in the Test Plan. An Omega Bending Beam Load Cell model No. LCCA-500 was used to measure the force. The data was collected using a Fluke Hydra Data Logger. The Projection Sheath used for the first four trials of the test had been subjected to the Crushing Test, the Kinking Test, the Projection Under Stress Test and the Endurance Test. For the subsequent trials, new Projection Sheaths were used.

5.3.2 Results

The test was recorded on videotape and photographed. During trial #4, a crimped fitting pulled off of the middle section of the Projection Sheath. The applied force reached 126 lbs (560 N) before the sheath failed. The plot is labelled "PS Tensile #4" and is included in Appendix N with the test data.

Because the force at which the Projection Sheath failed during trial #4 was considered to be low, the crimping procedure used for the manufacture of the Projection Sheaths was improved.

Three new sections were fabricated including one termination section and the testing was repeated. During the first trial of the re-test, the applied force reached 196 lbs (872 N) and a crimped connection failed again. The plot of the force profile is labelled "PS Tensile Trial #5".

The failed Projection Sheath extension was replaced with one used in trials #1 through #4. Testing resumed and eleven successful trials were completed. These are labelled "PS Tensile #7" through "PS Tensile #17 and are included in Appendix N. Note that trial #6 was rejected.

The Projection Sheath was then tested until failure. During trial #18, a crimped connection failed at 185 lbs (823 N). This sheath had been crimped according to the old procedure. During trial #19, failure occurred at 204 lbs (907 N). This failure was at a fitting crimped using the new procedure.

The Projection Sheath subjected to the first four trials was later demonstrated to pass the Projection Under Stress Test (paragraph 2.1). A C-990 Source Assembly was shown to freely pass through all six of the Projection Sheath sections after the Tensile Test.

5.3.3 Analysis

With the improved fabrication procedure, the Projection Sheath was demonstrated to exceed the Tensile Test requirement. The improved crimped fittings failed at 175% and 182% of the 500 N (112 lb) rated strength. The fittings crimped prior to the change in the fabrication failed at 113% and 165% of the rated strength.

6 Test on the Source Assembly

6.1 Tensile Test

6.1.1 Equipment

The apparatus was setup as described in the Test Plan. An Omega Bending Beam Load Cell model No. LCCA-500 was used to measure the force. The data was collected using a Fluke Hydra Data Logger. Because the Source Assembly used for the Endurance Test had been over stressed and failed during the Remote Control Cable Test, a new source was used for this test.

6.1.2 Results

The Source Assemblies were dimensionally inspected prior to the testing. The C-990 Source Assembly Data Sheets are included in Appendix O.

Source Assembly S/N 0005 was subjected to ten trials of 1000 N (225 lbs) applied to each of the capsule and lock ball. The duration of the applied force was only 5 seconds, however. The force profiles are plotted in "Source Capsule #1" through "Source Capsule #10" and "Source Ball #1" through "Source Ball #10". These figures are included in Appendix O.

The test was repeated with Source Assembly S/N 0004, with the applied force held for 30 seconds. This data is presented in "Capsule Pull #21" through "Capsule Pull #30" and "Lock Ball Pull #31" through "Lock Ball Pull #40". This data is also included in Appendix O.

After the Tensile Tests, the Source Assemblies were dimensionally re-inspected.

6.1.3 Analysis

The Source Assemblies met the Tensile Test Requirements. The Source Assembly (S/N 0003) that failed during the Remote Control Cable Tensile Test (paragraph 4.3) was subjected to a force that exceeded its rated strength.

7 References

1. Nordion Document IS/DS 0055 N990
"Test Plan for the TITAN Gamma Radiography Exposure Device".

2. Nordion Document IS/OP 0090 N990
"Titan User's Manual".

APPENDIX A

Deviation Disposition Requests

NORDION INTERNATIONAL INC.

DDR
DEVIATION DISPOSITION REQUEST

(INSTRUCTIONS ON REVERSE)

A. P.O./M.O. ____

CONTRACTOR: Nordion, Eng Services

ADDRESS: ____

DDR NUMBER: N990.033

EQUIPMENT: TITAN

PART NAME: Primary Lock Assembly

DWG NO.: K122213200 Issue 4

QTY/SERIAL NO.: Prototype #1 only

B. DESCRIPTION OF DEVIATION

Move actuator spring so that it is no longer concentric with teleflex cable (This will reduce wear on spring). Shim standoffs (K122213203). Lubricate with Fel-Pro C54

Increase depth of ø0.280 flat bottom hole on bayonet connector

C. PROPOSED ACTION WITH REASON(S)

① move ~~CSINK~~ CBORE ø0.44 to 0.812 offset from through hole; 0.04 deep on K122213216 Issue 3.

② K122213215 Issue 1. Change depth of channel from 0.450 to 0.386

③ K122213201 Issue 7 change left hand ø0.250 flat bottom hole from 0.250 Deep to 0.290 Deep

④ K122213208 Issue 5 change depth of ø280 flat bottom hole from 1.300 ± .001 to 1.381 ± .001

⑤ K122213203 Issue 5 move flat bottom hole ø.375 for actuator spring to .812 offset, ø.375 X .365 Deep

⑥ Shim standoffs on inner plate: .004" for each of bottom standoffs, .008" for top.

⑦ Lubricate all moving parts with Fel-Pro C54

D. SPECIFY REINSPECTION & RETEST TO BE PERFORMED

Dimensionally re-inspected in Cobalt Measurement Lab & subjected to 20,000 cycle endurance test.

F. CONTRACTOR'S REPRESENTATIVE

Blair Menna	Blair Menna	93/07/29
NAME	SIGNATURE	DATE

G. COMMENTS BY MANAGER, QUALITY ASSURANCE

R Goddard	R Goddard	July 29/93
NAME	SIGNATURE	DATE

H. COMMENTS BY ENGINEERING

Mike K. ACCEPT

M. Lyaniel — ENGINEERING REPRESENTATIVE — DATE: 93/07/29

JURISDICTION AUTHORIZATION IF REQUIRED (SPECIFY):

JURISDICTION ____ Q.A. PROGRAM ____

BY ____ FOR ____ DATE ____

I. DISPOSITION

APPROVED ✓ YES ✓ NO ____ AS NOTED ____ MRB MEETING ____

COMMENTS!

R Goddard — MANAGER, QA — DATE: July 30/93

CAR RAISED ____ DATE ____

(QA-F02)

(QA-P-AP2)

NORDION INTERNATIONAL INC.

DDR
DEVIATION DISPOSITION REQUEST

(INSTRUCTIONS ON REVERSE)

A. P.O./M.O. ______

CONTRACTOR Nordion, Eng Services

ADDRESS ______

DDR NUMBER N990.034

EQUIPMENT TITAN

PART NAME Outer Plate

DWG NO. K12221320l

QTY/SERIAL NO. Prototype #1 only

B. DESCRIPTION OF DEVIATION

Add bumper pins to protect push button lock.

C. PROPOSED ACTION WITH REASON(S)

Create "Bumper" (K122213229) and press into outer plate.

D. SPECIFY REINSPECTION & RETEST TO BE PERFORMED

Repeat Horizontal Shock test against face of Selector Ring as per IS/DS 0055 N990 Rev B.

F. CONTRACTOR'S REPRESENTATIVE

Blair Menna	Blair Menna	93/07/29
NAME	SIGNATURE	DATE

G. COMMENTS BY MANAGER, QUALITY ASSURANCE

R Goddard		July 29/93
NAME	SIGNATURE	DATE

H. COMMENTS BY ENGINEERING

Mike K Accept

M. [illegible]	93/07/29
ENGINEERING REPRESENTATIVE	DATE

JURISDICTION AUTHORIZATION IF REQUIRED (SPECIFY):

JURISDICTION	Q.A. PROGRAM		
BY	FOR	DATE	

I. DISPOSITION

APPROVED ✓ YES ______ NO ______ AS NOTED ______ MRB MEETING ______

COMMENTS:

R Goddard	July 30/93
MANAGER, QA	DATE

CAR RAISED ______ DATE ______

NORDION INTERNATIONAL INC.

DDR
DEVIATION DISPOSITION REQUEST

(INSTRUCTIONS ON REVERSE)

A. P.O./M.O. ______ DDR NUMBER N990.035

CONTRACTOR Nordion, Eng Services EQUIPMENT TITAN

ADDRESS ______ PART NAME Cover Plate, Inner Plate

DWG NO. K122213-204, K122213-203

QTY/SERIAL NO. Prototype #1 only

B. DESCRIPTION OF DEVIATION

Fill 3 holes on Cover Plate so that standoffs bear against cover plate and not outer plate. Shave length of standoffs accordingly.

C. PROPOSED ACTION WITH REASON(S)

[K122213204] Open 3 Ø.375 holes to Ø0.500. Press in 3 washers with I.D. = .266" thickness to match cover plate.

[K122213203] Shave height of standoffs down to 0.222".

D. SPECIFY REINSPECTION & RETEST TO BE PERFORMED

Re-inspect dimensionally in Cobalt measurement Lab.
Measure space between Outer Plate & Outer Ring with feeler gauges.
Repeat Horizontal Shock Test as per IS/DS 0055, two orientations against selector Ring

F. CONTRACTOR'S REPRESENTATIVE

Blair Menna (NAME) — [signature] (SIGNATURE) — 93/05/29. (DATE)

G. COMMENTS BY MANAGER, QUALITY ASSURANCE

[signature] (NAME) — ______ (SIGNATURE) — July 29/93. (DATE)

H. COMMENTS BY ENGINEERING

Mike K - Accept

JURISDICTION AUTHORIZATION IF REQUIRED (SPECIFY):

______ JURISDICTION ______ Q.A. PROGRAM

[signature] (ENGINEERING REPRESENTATIVE) — 93/07/29 (DATE) — ______ BY ______ FOR ______ DATE

I. DISPOSITION

APPROVED ✓ YES ✓ NO ______ AS NOTED ______ MRB MEETING ______

COMMENTS:

[signature] (MANAGER, QA) — July 30/93 (DATE) — CAR RAISED ______ DATE ______

(QA-F02) (QA-P-AP2)

APPENDIX B

Projection Under Stress Test Data Sheets

Projection Under Stress Test Data Sheet

Date May 28, 1993

Torque Meter Model TQS2FUA

Calibration Date Nov 24/93

Torque Meter Serial Number 3967

Trial Number	Maximum Torque Reading (~~N.m~~) in.lb
1	16.5 inlb out of S tube, 9 SGT+, 9 in lb SGT-, 12.5 in lb in S, (Blair operating).
2	17 in·lb out of S tube, no SGT measurement, 7.5 SG.T., 16 in lb in S (MK)
3	24 in.lb, 12, ~~14~~, 15 in.lb (MK)
4	21.5 in.lb, 12.5, 13, 20* (MK)
5	18.5 in lb, 8.5, 19*, 17 (BM)
6	20.5 in lb, 8.5, [8.5, 29, 8, 8, 8], [11.5, 17, coming in @ end] (BM)
7	21 in·lb, [9, 9, 9, 10.5, 10.5, 11], [10.5, 11, 11, 11, 11] [18.5, 18.5] (MK)
8	[10, 21], [9.5, 10, 10, 11.5, 11.5] [9, (18.5), 9, 9.5, 14, 7, 10] [16.5] (MK)
9	[21], [7.5, 8, 8, 8, 9], [8, 8.5, [illegible], 8.5, 9], [12.5, 14] (BM)
10	[17.5, 17], [8, 8, 9] [9, (9.5), 8.5] [16] (BM)

Has the equipment under test been subjected to the tests for conditions of normal use? Y ☐ N ☑

Test By M. Kyzmil Blair Merrer

Witness [signature] 93/05/28

Project Engineer M. Kyzmil

* source bottomed out (i.e. hit stop)

SGT+ = source guide tube forward

SGT- = sgt back

MK note: may have been snapping wrist when turning meter cycles 2, 3, 4

Projection Under Stress Test Data Sheet

Date 93/07/15 Torque Meter Model TQ 52FUA

Calibration Date Nov 24/92 Torque Meter Serial Number 3967

operator	Trial Number	Maximum Torque Reading ~~(N·m)~~ (in.lb)
BM	1	[24 in·lb] [16.5, 12, 8] [8, 11, 8] [14.5, 17.5]
BM	2	[28] [8.5, 7.5, 8, 8, 8, 9.5, 9] [9, 8.5, 8, 9.5, 8, 14.5, 12]
MK	3	[28 15.5] [13.5, 9.5, 9.5, 9.5, 9.5] [9, 10, 9, 11, 9] [10, 15.5]
MK	4	[16, 25] [8.5, 9.5, 9, 8.5, 11, 9, 9] [11, 10.5, 10.5, 10, 9.5, 9.5] [12, 12]
BM	5	[16, 24.5] [12, 14, 11, 7, 8, 7, 7, 11] [8.5, 8.5, 9, 8, 13.5, 9, 11] [12]
BM	6	[25, 22.5, 21, 16] [6.5, 7.5, 7, 7, 20*, 24] [9, 9, 9, 9, 7] [14.5]
MK	7	[8, 27] [8, 9.5, 9, 9.5, 10.5] [9, 9, 9, 9, 8.5] [10.5, 13]
MK	8	[24] [9.5, 9, 9.5, 10, 9.5] [12.5*] [9.5, 9.5, 12, 10, 10] [12, 12, 12]
BM	9	[18.5, 15.5] [15, 8, 8.5, 8.5, 7] [8, 8.5, 8, 12, 7.5] [11, 11]
BM	10	[21.5, 19] [11, 12, 12.5, 11.5, 11, 11, 12, 12, 13, 11] [7, 7, 7, 7.5, 12, 6.5] [8, 12.5]

(every rev) →

every 10 turns

* @ source stop.

* source at end.

Has the equipment under test been subjected to the tests for conditions of normal use? Y [✓] N [ ]

Test By [signatures] Witness [signature]

Project Engineer [signature]

APPENDIX C

TITAN Endurance Test Software
Document Number K122215-001 Revision D

```
/*                                                                   */
/*      Document No:    K122215-001  Rev D                           */
/*      Title:          TITAN GAMMA PROJECTOR TEST SOFTWARE          */
/*                                                                   */
/*       Compiled:  A Anderson / B Menna                             */
/*                                                                   */
/*       Drafting Approval:  M.F.                                    */
/*                                                                   */
/*       Project Eng:  M.K.                                          */
/*                                                                   */
/*       Eng Approval:  G.A.B.                                       */
/*                                                                   */
/*                                                                   */
/* REV   WO/DCR   DATE       AUTHOR    APPROVAL    DESCRIPTION       */
/* ***************************************************************** */
/* A     6290     93june01   AA/BM     AA          original issue    */
/* B     2729     93june09   AA/BM     BM          DCR No. 2729      */
/* C     2730     93june11   BM        BM          DCR No. 2730      */
/* D     2739     93june25   AA/BM     BM          DCR No. 2739      */
/*                                                                   */
/*                                                                   */


[illegible]nclude "inc.c"

        char time_string[26];

        FILE * fp_file;
void main()
{
        int                     cycle_count,num_times,num,num1,cycle_start;
        num_times    =          0;
        cycle_count =           0;
        cycle_start =           0;

        if((fp_file = fopen("titan.dat","a")) == NULL)
        {
                printf(" Cannot open file titan.dat");
                fclose(fp_file);
        }
        opto_reset();
        start();
        initial();
        clear_screen();
        while(num_times <= 0 || num_times > MAX_CYCLES)
        {
                fflush(stdin);
                clear_line_5();
                POS(5,5);
                printf("How many cycles would you like to run: ");
                num = scanf("%d",&num_times);
        }
        while(cycle_start <= 0 || cycle_start > 19999)

                /*4 [illegible] digit
```

```
            printf("Resume counting at what cycle number : ");
            num = scanf("%d",&cycle_start);
      }

/*      check date and time      */

            fflush(stdin);
            system("time");
            system("date");

      fprintf(fp_file,"%s%d\n"," The number of cycles to run is : ",num_times)
      fprintf(fp_file,"%s%d\n"," Resuming count at cycle number : ",cycle_star

      cycle_count = cycle_start;
      num_times = cycle_start + num_times;

      do
      {

            step_1();
            waitsec(0.0);

            step_2();
/*    wait for camera to engage in operate position  */
            waitsec(0.5);

            step_3();
            waitsec(0.0);

            step_4();
            waitsec(0.0);

            step_5();
/*    wait for motor to stop spinning    */
            waitsec(2.0);

            step_6();
            waitsec(0.0);

            step_7();
/*    wait for motor to stop spinnirg    */
            waitsec(0.7);

            step_8();
            waitsec(0.0);

      tt_time(time_string);
      fprintf(fp_file,"%s%d%s%s"," Cycle count = ",cycle_count," - ",time_stri
      if((num1 = cycle_count%10) == 0)
            {
             fprintf(stdprn,"%s%d%s%s"," The cycle count is : ",cycle_count,
             fflush(stdprn);
            }
      printf("%s%d%s%s"," Cycle count = ",cycle_count," - ",time_string);
      cycle_count++;
      }
      while(cycle_count < num_times);
      if(num1 = cycle_count%10 != 0)
```

```
            {

             tm_time(time_string);
             fprintf(stdprn,"%s%d%s%s"," Cycle count = ",--cycle_count," - "
             fflush(stdprn);
            }
      fclose(fp_file);

}


int engage_clutch_at_end()
{
      long     start_to_engage,current_time;
      int      flag = 1;

      if(clutch_engaged())
      {
               printf("\n Clutch is engaged");
      }
      if(!clutch_engaged())              /* clutch is not engaged          */
      {
               high_press_to_clutch();
               motor_cw_slow();
               time(&start_to_engage);
               do
               {
               } while((time(&current_time)  - start_to_engage < CLUTCH_TIMEOUT
               if(current_time - start_to_engage >= CLUTCH_TIMEOUT)
               {
                        flag = 0;
               }
               motor_cw_ccw_off();
               motor_slow_fast_off();
               waitsec(0.3);
               no_press_to_clutch();
      }
      return flag;
}

int engage_clutch_at_begin()
{
      long     start_to_engage,current_time;
      int      flag  = 1;

      if(clutch_engaged())
      {
               printf("\n Clutch is engaged");
      }
      if(!clutch_engaged())              /* clutch is not engaged          */
      {
               motor_cw_slow();
               waitsec(3.0);
               high_press_to_clutch();
               time(&start_to_engage);
               do
               {
               } while((time(&current_time)  - start_to_engage < CLUTCH_TIMEOU
```

```
                if(current_time - start_to_engage >= CLUTCH_TIMEOUT)
                {
                        flag = 0;
                }
                motor_cw_ccw_off();
                motor_slow_fast_off();
                waitsec(0.3);
                /*  releave residual clutch torque  */
                no_press_to_clutch();
                motor_ccw_slow();
                waitsec(0.7);
                motor_cw_ccw_off();
                motor_slow_fast_off();
        }
        return flag;
}

int cw_until_disengage()
{
        long    start_to_turn,current_time;
        int     flag = 1;

        if(!clutch_engaged())
        {
                POS(10,5);
                printf("Clutch is disengaged");
        }
        if(clutch_engaged())                    /* clutch is engaged            */
        {
                motor_cw_fast();
                time(&start_to_turn);
                do
                {
                } while((time(&current_time)  - start_to_turn < TURN_TIMEOUT) &&
                if(current_time - start_to_turn >= TURN_TIMEOUT)
                {
                        flag = 0;
                }
                motor_cw_ccw_off();
                motor_slow_fast_off();
        }
        return flag;
}

int ccw_until_disengage()
{
        long    start_to_turn,current_time;
        int     flag = 1;

        if(!clutch_engaged())
        {
                POS(10,5);
                printf("Clutch is disengaged");
        }
        if(clutch_engaged())                    /* clutch is engaged            */
        {
                motor_ccw_fast();
                time(&start_to_turn
```

```
                do
                {
                } while((time(&current_time)  - start_to_turn < TURN_TIMEOUT) &&
                if(current_time - start_to_turn >= TURN_TIMEOUT)
                {
                        flag = 0;
                }
                motor_cw_ccw_off();
                motor_slow_fast_off();
        }
        return flag;
}

void motor_cw()
{
        out_2_off();
        out_1_on();
}
void motor_ccw()
{
        out_1_off();
        out_2_on();
}

void motor_cw_ccw_off()
{
        out_1_off();
        out_2_off();
}
void motor_enabled()
{
        out_3_off();
}
void motor_disabled()
{
        out_3_on();
}
void speed_slow()
{
        out_5_off();
        out_4_on();
}
void speed_fast()
{
        out_4_off();
        out_5_on();
}
void motor_slow_fast_off()
{
        out_4_off();
        out_5_off();

void motor_cw_slow()
{
        motor_disabled();
        speed_slow();
        motor_cw();
        motor_enabled();
```

```
void motor_cw_fast()
{
        motor_disabled();
        speed_fast();
        motor_cw();
        motor_enabled();
}
void motor_ccw_slow()
{
        motor_disabled();
        speed_slow();
        motor_ccw();
        motor_enabled();
}
void motor_ccw_fast()
{
        motor_disabled();
        speed_fast();
        motor_ccw();
        motor_enabled();
}
void forks_fwd()
{
        out_11_off();
        out_10_on();

void forks_back()
{
        out_10_off();
        out_11_on();
}

void pivot_cw()
{
        out_13_off();
        out_12_on();
}

void pivot_ccw()
{
        out_12_off();
        out_13_on();
}
void low_press_sel_on()
{
        out_9_on();
}
void low_press_sel_off()

        out_9_off();
}
void high_press_sel_on()
{
        out_14_on();
}
void high_press_sel_off()
```

```
        out_14_off();
}
void no_press_to_clutch()
{
        low_press_sel_off();
        high_press_sel_off();
}
void high_press_to_clutch()
{
        low_press_sel_on();
        high_press_sel_on();
}

/*      High level input routines                       */

int clutch_engaged()
{
        if(in_1())
                return 0;
        else
                return 1;
}
int is_cable_at_camera()
{
        if(in_7())
                return(1);
        else
                return(0);
}
int is_cable_at_end()
{
        if(in_8())
                return 0;
        else
                return 1;
}



int are_forks_back()
{
        if(in_2())
                return 1;
        else
                return 0;
}

int are_forks_fwd()
{
        if(in_3())
                return 1;
        else
                return 0;
}

int is_pivot_cw()
```

```
        if(in_4())
                return 1;
        else
                return 0;
}

int is_pivot_ccw()
{
        if(in_5())
                return 1;
        else
                return 0;
}

int is_camera_locked()
{
        if(in_6())
                return 1;
        else
                return 0;
}

int is_camera_in_operate()
{
        if (in_9())
                return 1;
        else
                return 0;
}

void waitsec(double secs)
{
        unsigned long   count0,count;
        count0 = t_counts();
        count = count0 + (unsigned long) (secs * 18.2);
        while(t_counts() < count)
                ;
}
unsigned long t_counts(void)
{
        union REGS      rin,rout;
        unsigned long   tc;
        rin.h.ah = 0;
        int86(INT_TIME,&rin,&rout);
        tc = ((long) rout.x.cx) << 16;
        tc += rout.x.dx;
        return tc;
}
void opto_reset()
        {
         outp(0x1e0,01);
        }

void opto_on(unsigned int mask,unsigned int address)
        {
         int old_value;
         old_value = inp(address);
         mask = mask | old_value;
```

```
        outp(address,mask);
       }

void opto_off(unsigned int mask,unsigned int address)
       {
        int old_value;
        old_value = inp(address);
        mask = mask & old_value;
        outp(address,mask);
       }

int opto_in(unsigned int mask,unsigned int address)
{
        unsigned int temp;
        temp = inp(address);
        return(temp & mask);
}

/*      Opto routines to turn off frist 8 outputs          */
/*      Address hex 100. Outputs 1 to 8                    */

void out_1_off(void)
        {
         opto_off(OUT_0_OFF,OUT_100);
        }
void out_2_off(void)
        {
         opto_off(OUT_1_OFF,OUT_100);
        }
void out_3_off(void)
        {
         opto_off(OUT_2_OFF,OUT_100);
        }
void out_4_off(void)
        {
         opto_off(OUT_3_OFF,OUT_100);
        }
void out_5_off(void)
        {
         opto_off(OUT_4_OFF,OUT_100);
        }
void out_6_off(void)
        {
         opto_off(OUT_5_OFF,OUT_100);
        }
void out_7_off(void)
        {
         opto_off(OUT_6_OFF,OUT_100);
        }
void out_8_off(void)
        {
         opto_off(OUT_7_OFF,OUT_100);
        }

/*      Opto routines to turn on the first 8 outputs       */
/*      Address 100 hex. Outputs 1 to 8                    */

void out_1_on(void)
```

```
        {
        opto_on(OUT_0_ON,OUT_100);
        }
void out_2_on(void)
        {
        opto_on(OUT_1_ON,OUT_100);
        }
void out_3_on(void)
        {
        opto_on(OUT_2_ON,OUT_100);
        }
void out_4_on(void)
        {
        opto_on(OUT_3_ON,OUT_100);
        }
void out_5_on(void)
        {
        opto_on(OUT_4_ON,OUT_100);
        }
void out_6_on(void)
        {
        opto_on(OUT_5_ON,OUT_100);
        }
void out_7_on(void)
        {
        opto_on(OUT_6_ON,OUT_100);
        }
void out_8_on(void)
        {
        opto_on(OUT_7_ON,OUT_100);
        }

/*      Opto routines to turn off the second bank of outputs    */
/*      Address 101 hex. Outputs 9 to 16.                        */

void out_9_off(void)
        {
        opto_off(OUT_0_OFF,OUT_101);
        }
void out_10_off(void)
        {
        opto_off(OUT_1_OFF,OUT_101);
        }
void out_11_off(void)
        {
        opto_off(OUT_2_OFF,OUT_101);
        }
void out_12_off(void)
        {
        opto_off(OUT_3_OFF,OUT_101);
        }
void out_13_off(void)
        {
        opto_off(OUT_4_OFF,OUT_101);
        }
void out_14_off(void)
        {
        opto_off(OUT_5_OFF,OUT_101);
```

```
        }
void out_15_off(void)
        {
         opto_off(OUT_6_OFF,OUT_101);
        }
void out_16_off(void)
        {
         opto_off(OUT_7_OFF,OUT_101);
        }

/*      Opto routines to turn on the second bank of outputs.      */
/*      Address 101. Outputs 9 to 16.                             */

void out_9_on(void)
        {
         opto_on(OUT_0_ON,OUT_101);
        }
void out_10_on(void)
        {
         opto_on(OUT_1_ON,OUT_101);
        }
void out_11_on(void)
        {
         opto_on(OUT_2_ON,OUT_101);
        }
void out_12_on(void)
        {
         opto_on(OUT_3_ON,OUT_101);
        }
void out_13_on(void)
        {
         opto_on(OUT_4_ON,OUT_101);
        }
void out_14_on(void)
        {
         opto_on(OUT_5_ON,OUT_101);
        }
void out_15_on(void)
        {
         opto_on(OUT_6_ON,OUT_101);
        }
void out_16_on(void)
        {
         opto_on(OUT_7_ON,OUT_101);
        }



/*      Opto input routines      */

int in_1(void)
{
        return(opto_in(OUT_0_ON,IN_102));
}
int in_2(void)
{
```

```
        return(opto_in(OUT_1_ON,IN_102));
}
int in_3(void)
{
        return(opto_in(OUT_2_ON,IN_102));
}
int in_4(void)
{
        return(opto_in(OUT_3_ON,IN_102));
}
int in_5(void)
{
        return(opto_in(OUT_4_ON,IN_102));
}
int in_6(void)
{
        return(opto_in(OUT_5_ON,IN_102));
}
int in_7(void)
{
        return(opto_in(OUT_6_ON,IN_102));
}
int in_8(void)
{
        return(opto_in(OUT_7_ON,IN_102));
}
int in_9(void)
{
        return(opto_in(OUT_0_ON,IN_103));
}
int in_10(void)
{
        return(opto_in(OUT_1_ON,IN_103));
}
int in_11(void)
{
        return(opto_in(OUT_2_ON,IN_103));
}
int in_12(void)
{
        return(opto_in(OUT_3_ON,IN_103));
}
int in_13(void)
{
        return(opto_in(OUT_4_ON,IN_103));
}
int in_14(void)
{
        return(opto_in(OUT_5_ON,IN_103));
}
int in_15(void)
{
        return(opto_in(OUT_6_ON,IN_103));
}
int in_16(void)
{
        return(opto_in(OUT_7_ON,IN_103));
```

```
void    clear_screen()
{
        unsigned short far       *v;
        unsigned                 i;
        v = (unsigned short far *) (0xb000L << 16);
        for(i= 0; i < (80*43); i++)
                *v++ = 0x1f20;
}
void set_curs(unsigned char x,unsigned char y,unsigned char page)
{
        union REGS       inreg,outreg;
        inreg.h.ah = 2;
        inreg.h.dh = x;
        inreg.h.dl = y;
        inreg.h.bh = page;
        int86(0x10,&inreg,&outreg);
}
void start()
{
        forks_back();
        waitsec((double) 2.0);
        pivot_cw();
        waitsec((double) 2.0);
}
void initial()
{
        int      flag = 1;
        if(!is_pivot_cw())
        {
                flag = 0;
                printf("\n Pivot is not CW");
        }
        if(!are_forks_back())
        {
                flag = 0;
                printf("\n Forks are not back");
        }
        if(!clutch_engaged())
        {
                flag = 0;
                printf("\n Clutch is not engaged");
        }
        if(!is_camera_locked())
        {
                flag = 0;
                printf("\n Camera is not locked");
        }
        if(!flag)
        {
                printf("\n System is not in proper starting configuration");
                exit(1);
        }
        if(flag)
                printf("\n System checked and ready to do a run.");
}
void step_1()
{
```

```
        long    start_time,current_time;
        initial();
        printf("\n Step 1.  Move forks forward.");
        time(&start_time);
        forks_fwd();
        do
        {
        }while((time(&current_time) - start_time < TIMEOUT) && (!are_forks_fwd())
        if(current_time - start_time >= TIMEOUT)
        {
                tt_time(time_string);
                printf("%s%s","Timeout moving forks fwd step 1 - ",time_string);
                fprintf(fp_file,"%s%s"," Timeout moving forks fwd step 1 - ",time
                fprintf(stdprn,"%s%s"," Timeout moving forks fwd step 1 - ",time_
                fflush(stdprn);
                fclose(fp_file);
                exit(1);
        }

}
void step_2()
{
        long    start_time,current_time;
        if(!are_forks_fwd())
        {
                tt_time(time_string);
                printf("%s%s"," Forks are not forward at the start of step 2 - ",
                fprintf(fp_file,"%s%s"," Forks are not forward at the start of s
                fprintf(stdprn,"%s%s"," Forks are not forward at the start of ste
                fflush(stdprn);
                fclose(fp_file);
                exit(1);
        }
        printf("\n Step 2.  Pivot forks CCW.");
        time(&start_time);
        pivot_ccw();
        do
        {
        }while((time(&current_time) - start_time < TIMEOUT) && (!is_pivot_ccw()))
        if(current_time - start_time >= TIMEOUT)
        {
                tt_time(time_string);
                printf("%s%s"," Timeout moving pivot CCW in step 2 - ",time_strin
                fprintf(fp_file,"%s%s"," Timeout moving pivot CCW in step 2 - ",
                fprintf(stdprn,"%s%s"," Timeout moving pivot CCW in step 2 - ",ti
                fflush(stdprn);
                fclose(fp_file);
                exit(1);
        }

}
  d step_3()

        long    start_time,current_time;
        if(!is_pivot_ccw())
        {
                tt_time(time_string);
                printf("%s%s"," Pivot is not ccw at the start of step 3 - ",time
```

```
            fprintf(fp_file,"%s%s"," Pivot is not ccw at the start of step 3
            fprintf(stdprn,"%s%s"," Pivot is not ccw at the start of step 3 -
            fflush(stdprn);
            fclose(fp_file);
            exit(1);
    }

    printf("\n Step 3.  Retract forks.");
    time(&start_time);
    forks_back();
    do
    {
    }while((time(&current_time) - start_time < TIMEOUT) && (!are_forks_back(
    if(current_time - start_time >= TIMEOUT)
    {
            tt_time(time_string);
            printf("%s%s"," Timeout moving forks back in step 3 - ",time_str
            fprintf(fp_file,"%s%s"," Timeout moving forks back in step 3 - "
            fprintf(stdprn,"%s%s"," Timeout moving forks back in step 3 - ",
            fflush(stdprn);
            fclose(fp_file);
            exit(1);
    }
}
d step_4()

    long    start_time,current_time;
    if(!are_forks_back())
    {
            tt_time(time_string);
            printf("%s%s"," Forks are not back at the start of step 4 - ",ti
            fprintf(fp_file,"%s%s"," Forks are not back at the start of stec
            fprintf(stdprn,"%s%s"," Forks are not back at the start of step
            fflush(stdprn);
            fclose(fp_file);
            exit(1);
    }

    printf("\n Step 4.  Pivot forks CW.");
    time(&start_time);
    pivot_cw();
    do
    {
    }while((time(&current_time) - start_time < TIMEOUT) && (!is_pivot_cw())
    if(current_time - start_time >= TIMEOUT)
    {
            tt_time(time_string);
            printf("%s%s"," Timeout moving pivot CW in step 4 - ",time_strin
            fprintf(fp_file,"%s%s"," Timeout moving forks back in step 4 - "
            fprintf(stdprn,"%s%s"," Timeout moving forks back in step 4 - "
            fflush(stdprn);
            exit(1);
    }

}

void step_5()          /* Push cable to the very end.  */
```

```
{
        int     flag;
        if(!is_camera_in_operate())
        {
                tt_time(time_string);
                printf("%s%s"," Camera is not in operate mode step - 5 - ",time_s
                printf("%s\n","Relieve tension in drive cable and restart (repea
                fprintf(fp_file,"%s%s"," Camera is not in operate mode step - 5 -
                fprintf(fp_file,"%s\n","Relieve tension in drive cable and restar
                fprintf(stdprn,"%s%s"," Camera is not in operate mode step - 5 -
                fprintf(stdprn,"%s\n","Relieve tension in drive cable and restar
                fflush(stdprn);

                motor_cw_slow();
                waitsec(.5);
                motor_cw_ccw_off();
                step_1();
                step_2();
                step_3();
                step_4();
        }
        if(!is_camera_in_operate())
        {
                tt_time(time_string);
                printf("%s%s"," Camera is not in operate mode - ",time_string);
                fprintf(fp_file,"%s%s"," Camera is not in operate mode - ",time_s
                fprintf(stdprn,"%s%s"," Camera is not in operate mode - ",time_st
                fflush(stdprn);
                fclose(fp_file);
                exit(1);
        }

        printf("\n Step 5.  Push source to end.");
        flag = cw_until_disengage();
        if(!flag)
        {
                tt_time(time_string);
                printf("%s%s"," Timeout disengaging clutch ccw in step 5 - ",time_
                fprintf(fp_file,"%s%s"," Timeout disengaging clutch cw in ste, 5 -
                fprintf(stdprn,"%s%s"," Timeout disengaging clutch cw in step 5 -
                fflush(stdprn);
                exit(1);
        }
}
void step_6()              /* Engage clutch after source is the expose position    *
{
        int     flag;
        if(!is_cable_at_end())
        {
                tt_time(time_string);
                printf("%s%s"," Cable is not at the end at the start of step 6 -
                fprintf(fp_file,"%s%s"," Cable is not at the end at the start of
                fprintf(stdprn,"%s%s"," Cable is not at the end at the start of s
                fflush(stdprn);
                fclose(fp_file);
                exit(1);
        }
```

```
        if(clutch_engaged())
        {
                tt_time(time_string);
                printf("%s%s"," Clutch is engaged at the start of step 6 - ",time
                fprintf(fp_file,"%s%s"," Clutch is engaged at the start of step 
                fprintf(stdprn,"%s%s"," Clutch is engaged at the start of step 6 
                fflush(stdprn);
                fclose(fp_file);
                exit(1);
        }

        printf("\n Step 6.  Re-engage clutch.");
        flag = engage_clutch_at_end();
        if(!flag)
        {
                tt_time(time_string);
                printf("%s%s"," Timeout engaging clutch cw in step 6 - ",time_st
                fprintf(fp_file,"%s%s"," Timeout engaging clutch cw in step 6 - 
                fprintf(stdprn,"%s%s"," Timeout engaging clutch cw in step 6 - "
                fflush(stdprn);
                exit(1);
        }
}

void step_7()              /* Pull cable into the camera.  */

        int     flag;
        if(!clutch_engaged())
        {
                tt_time(time_string);
                printf("%s%s"," Clutch is not engaged at the start of step 7 - "
                fprintf(fp_file,"%s%s"," Clutch is not engaged at the start of s
                fprintf(stdprn,"%s%s"," Clutch is not engaged at the start of st
                fflush(stdprn);
                fclose(fp_file);
                exit(1);
        }

        printf("\n Step 7.  Pull source back.");
        flag = ccw_until_disengage();
        if(!flag)
        {
                tt_time(time_string);
                printf("%s%s"," Timeout disengaging clutch ccw in step 7 - ",time_
                fprintf(fp_file,"%s%s"," Timeout disengaging clutch ccw in step 7
                fprintf(fp_file,"%s%s"," Timeout disengaging clutch ccw in step 7
                exit(1);
        }
        motor_cw_slow();
        waitsec(0.5);
        motor_cw_ccw_off();


void step_8()
{
        int     flag;
        if(clutch_engaged())
        {
```

```
                tt_time(time_string);
                printf("%s%s"," Clutch is engaged at the start of step 8 - ",time
                fprintf(fp_file,"%s%s"," Clutch is engaged at the start of step (
                fprintf(stdprn,"%s%s"," Clutch is engaged at the start of step 8
                fflush(stdprn);
                fclose(fp_file);
                exit(1);
        }

        printf("\n Step 8.  Re-engage clutch.");
        flag = engage_clutch_at_begin();
        if(!flag)
        {
                tt_time(time_string);
                printf("%s%s"," Timeout engaging clutch cw in step 8 - ",time_str
                fprintf(fp_file,"%s%s"," Timeout engaging clutch cw in step 8 - '
                fprintf(stdprn,"%s%s"," Timeout engaging clutch cw in step 8 - ",
                fflush(stdprn);
                exit(1);
        }
}

void clear_line_5()
{
        POS(5,0);
        printf("%80c",' ');
}


        struct   tm *newtime;
        time_t   aclock;
void tt_time(char time_string[])
{
        time(&aclock);
        newtime = localtime(&aclock);
        strcpy(time_string,asctime(newtime));
}
```

APPENDIX D

Determination of Endurance Test Torque.

Background

ANSI N432 states that during the Endurance Test, a torque of T = 500 X L N-m must be exerted on the crank shaft at both extremities of its normal movement, where L is the length, in meters of the crank lever.

The length of the crank lever for the Remote Control used with the TITAN is 0.103 m (4.063 in). The torque requirement is therefore 51.6 N-m (38.1 ft-lbs).

This torque is transferred to the Remote Control drive cable via the control cable gear wheel which has a radius of 4.0 cm (1.6 in). The corresponding force on the drive cable is therefore 1276 N (287 lb). This force exceeds the rated strength of Teleflex Cable, however.

It was therefore necessary to determine experimentally a realistic torque setting.

Equipment

An experiment was designed to measure what torque would be exerted on the Remote Control by a human operator. The Remote Control was connected to a rigidly mounted bracket. The Teleflex Cable was projected through this bracket and secured to another bracket rigidly mounted 3 m away. In order to measure the tension on the Teleflex Cable, a force transducer was connected in series with the projected section of Teleflex Cable. The force transducer used was Omega Model LCCB-300.

The excitation voltage for the force transducer was provided by a Triple Output DC Power Supply, BK Precision Model No. 1660.

The signal from the force transducer was input into a Dual Channel Signal Conditioner, Gould Electronics Model No. 56-2400-00. The output from the signal conditioner was captured using a Gould Digital Storage Oscilloscope Model No. 4050.

The oscilloscope was then directly output to a Hewlett Packard plotter Model :470A.

Results

Data was first collected for human operators in a dynamic situation. The Teleflex Cable was retracted quickly by hand. The oscilloscope was triggered manually just before the slack in the cable was taken up. Figures D-1 through D-3 are representative samples of the profile of the impact when the cable became taught. Note that 1mV corresponds to 29 N (6.5 lb).

Next data was collected for human operators in a static situation. With no slack in the cable, the operator pulled back on the crank as hard as possible. Figures D-4 through D-6 show three profiles for the static test. Note that two plateaus are shown in Figure D-6. The second and lower plateau is the result on the operator placing the pistol grip assembly against his thigh in order to brace it to achieve a higher torque.

In order to determine the force profiles produced by the automated test equipment described in paragraph 2.2.1, the gear shaft of the Remote Control assembly was coupled to the pneumatic clutch of the Endurance Tester. The drive cable was wound back at 180 RPM with the air pressure to the clutch set at different pressures ranging from 15 to 24 psi. Figures D-7, D-8 and D-9 show the forces profiles recorded for clutch air pressures of 15 psi, 16 psi and 17 psi respectively.

Analysis

By comparing the force profiles for the manual operation against those for the automated operation, it was determined that a clutch air pressure setting of 16 psi would provide a release torque that safely represented the torque encountered in reality. As discussed in paragraph 2.2.3, the air pressure chosen caused excessive stresses not encountered during normal use.

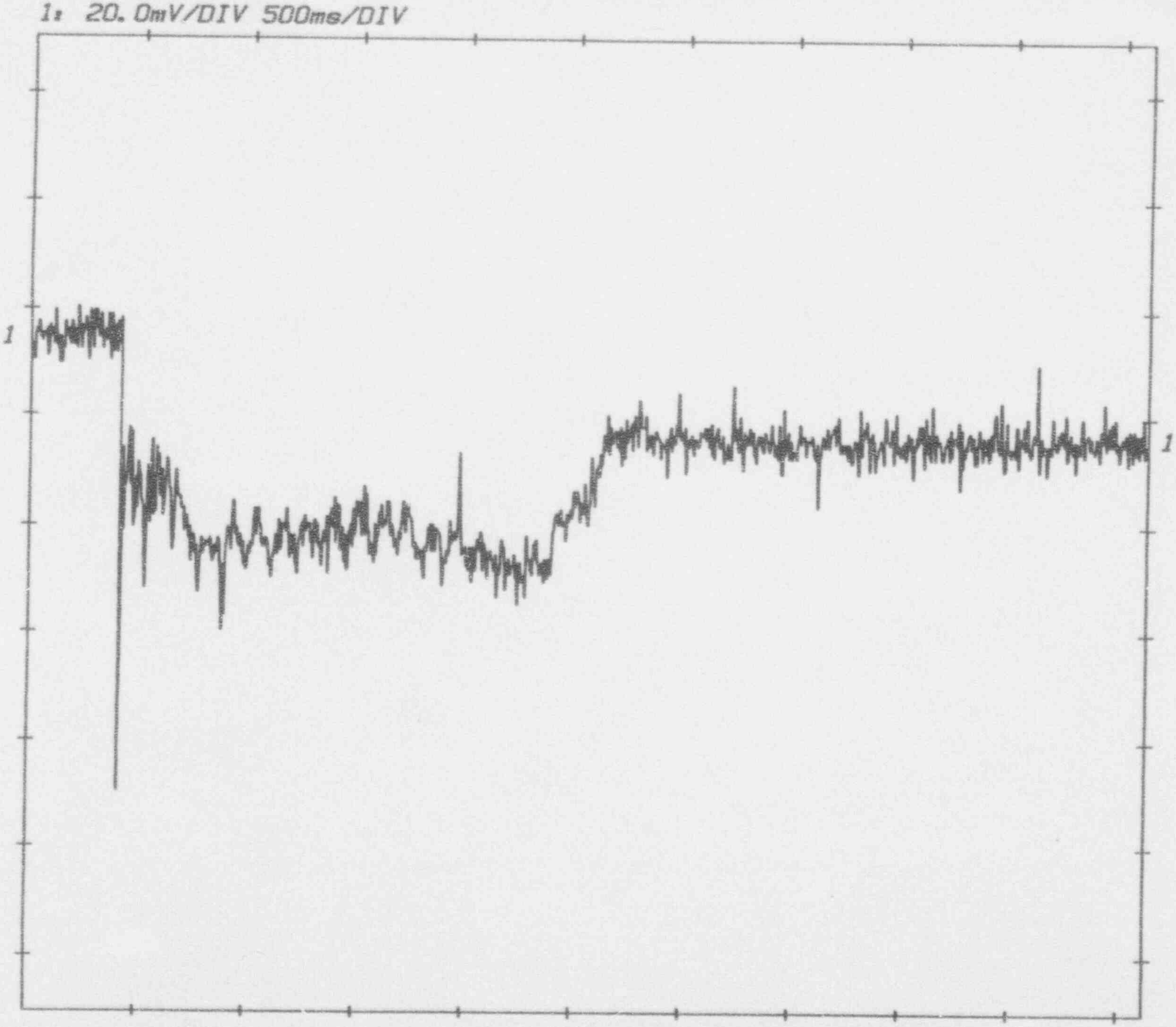


Figure D-1. Impact Profile, Manual Operator #1, Dynamic

Manual -Mike
9. /31

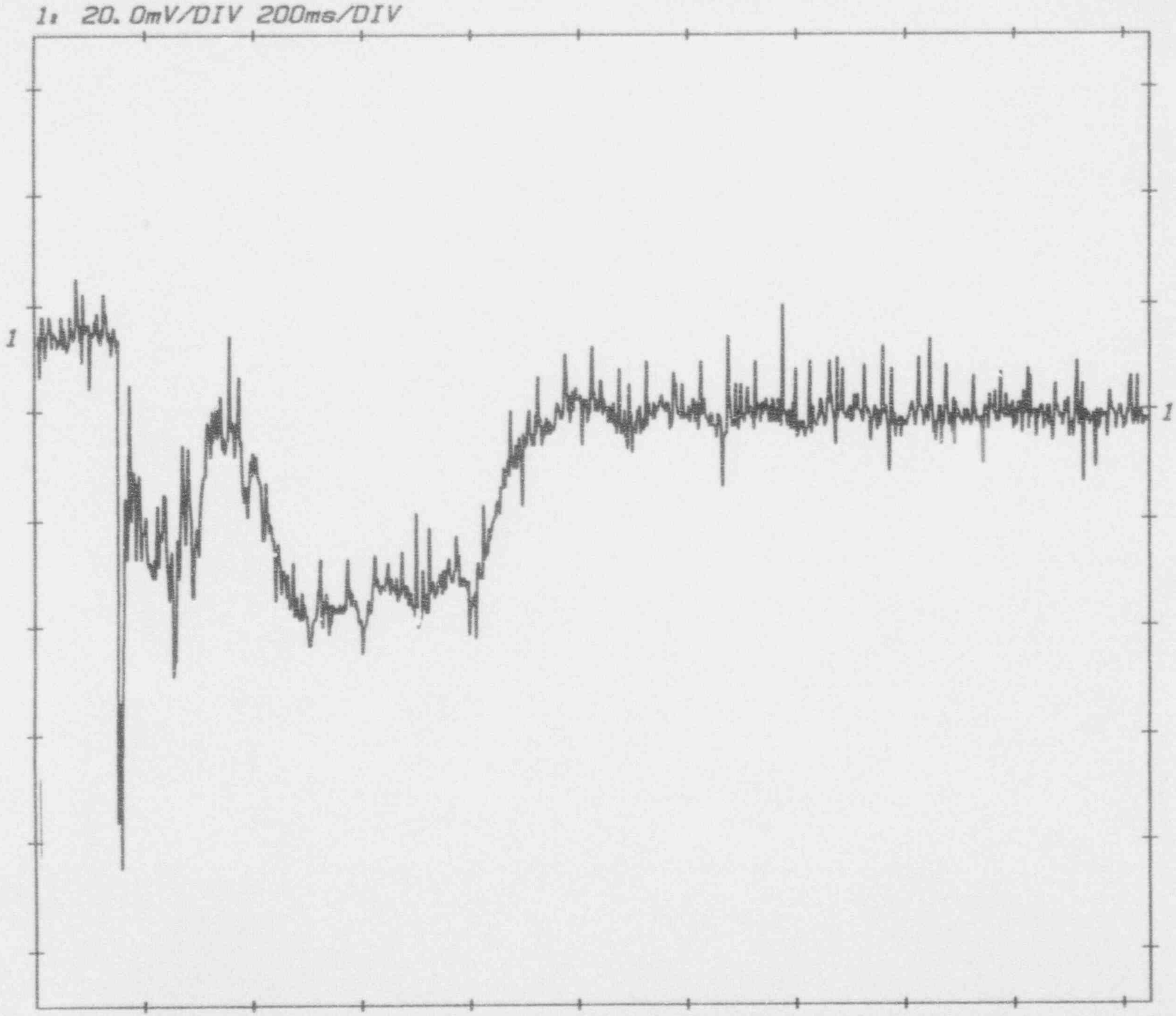


Figure D-2. Impact Profile, Manual Operator #2, Dynamic

Manual - Blair
93/051.

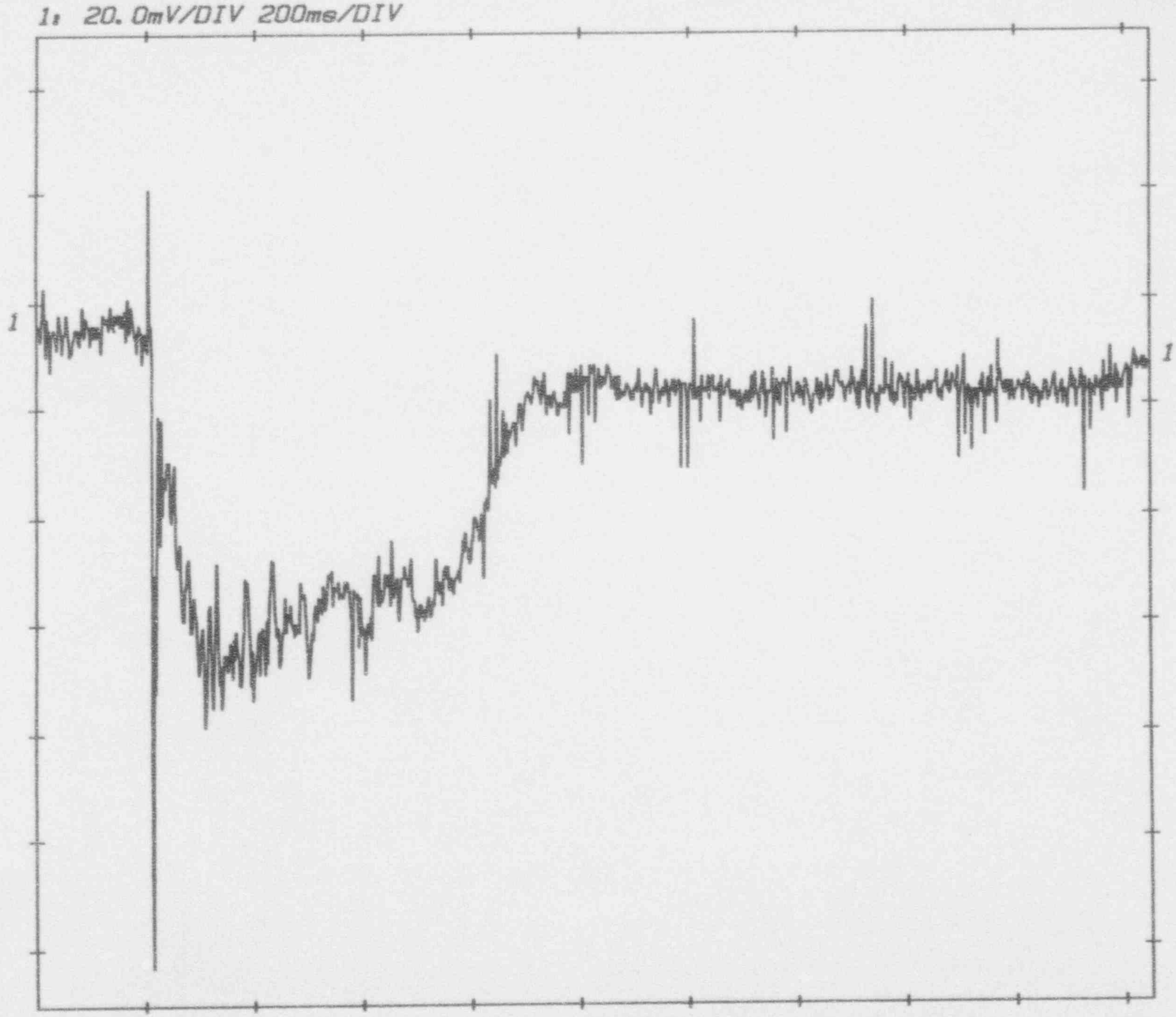


Figure D-3. Impact Profile, Manual Operator #3, Dynamic

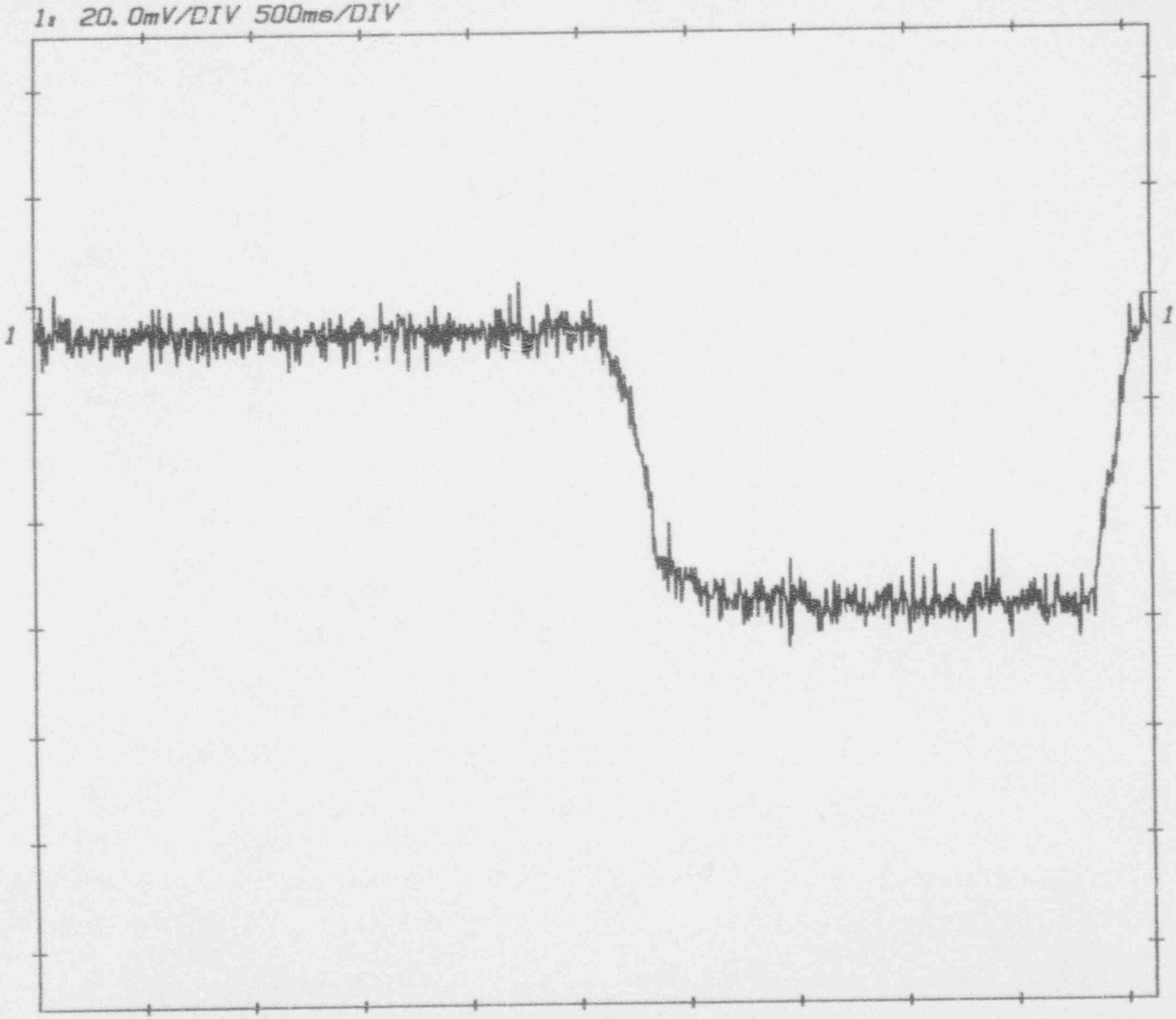


Figure D-4. Impact Profile, Manual Operator #1, Static

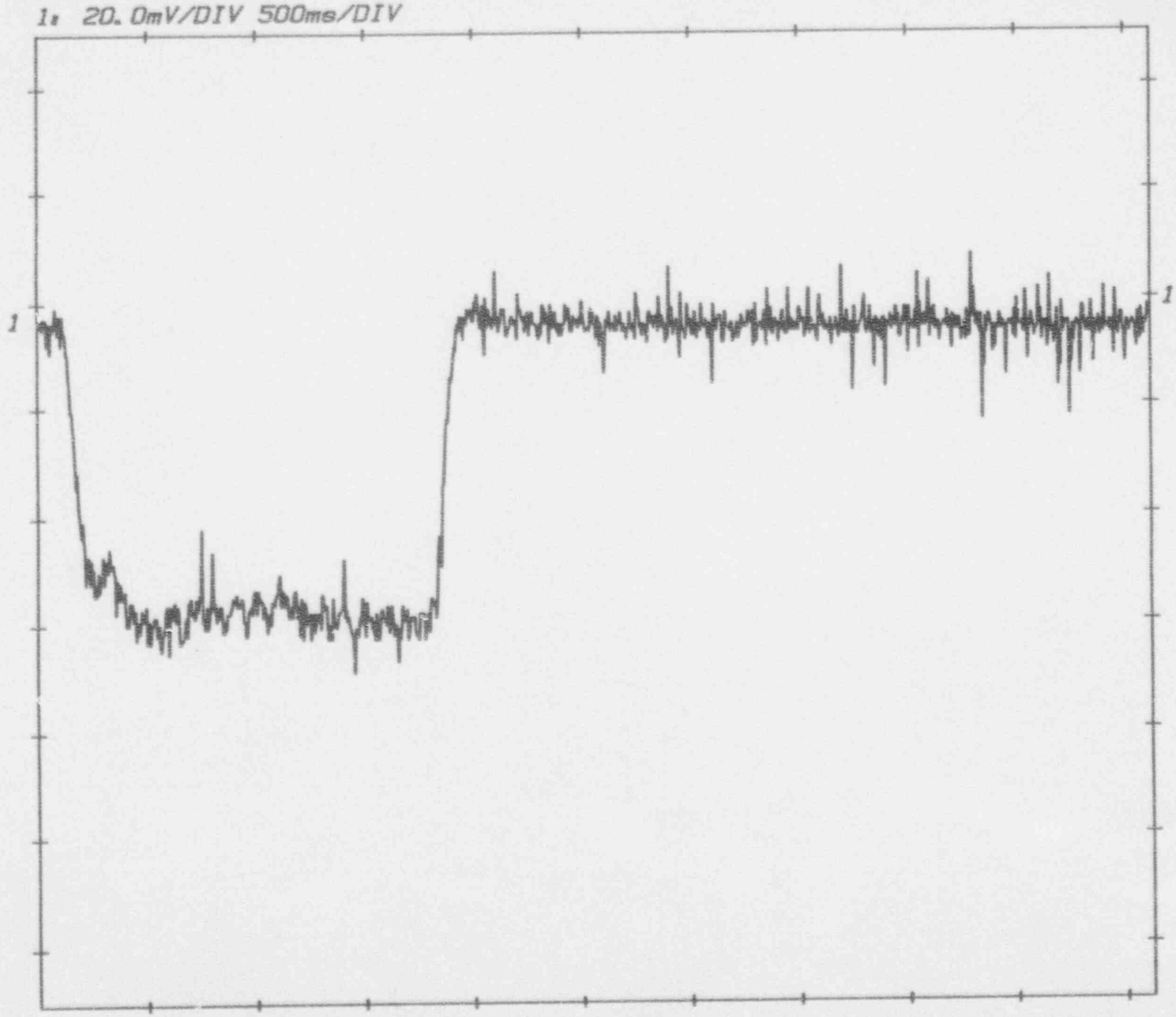


Figure D-5. Impact Profile, Manual Operator #2, Static

AIR
[illegible]
95/05/31

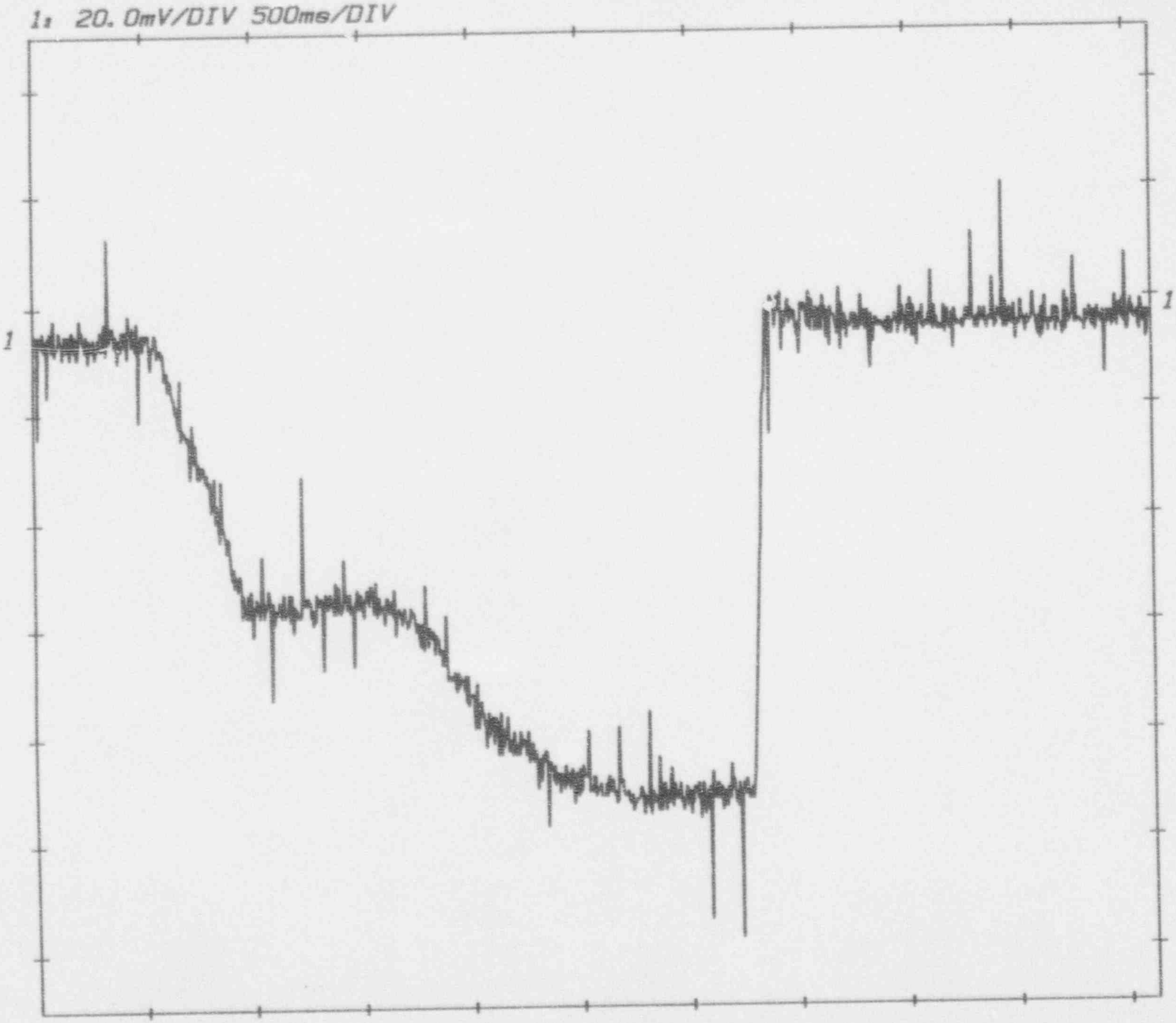


Figure D-6. Impact Profile, Manual Operator #3, Static

Automatic - 15psi
93/05/31

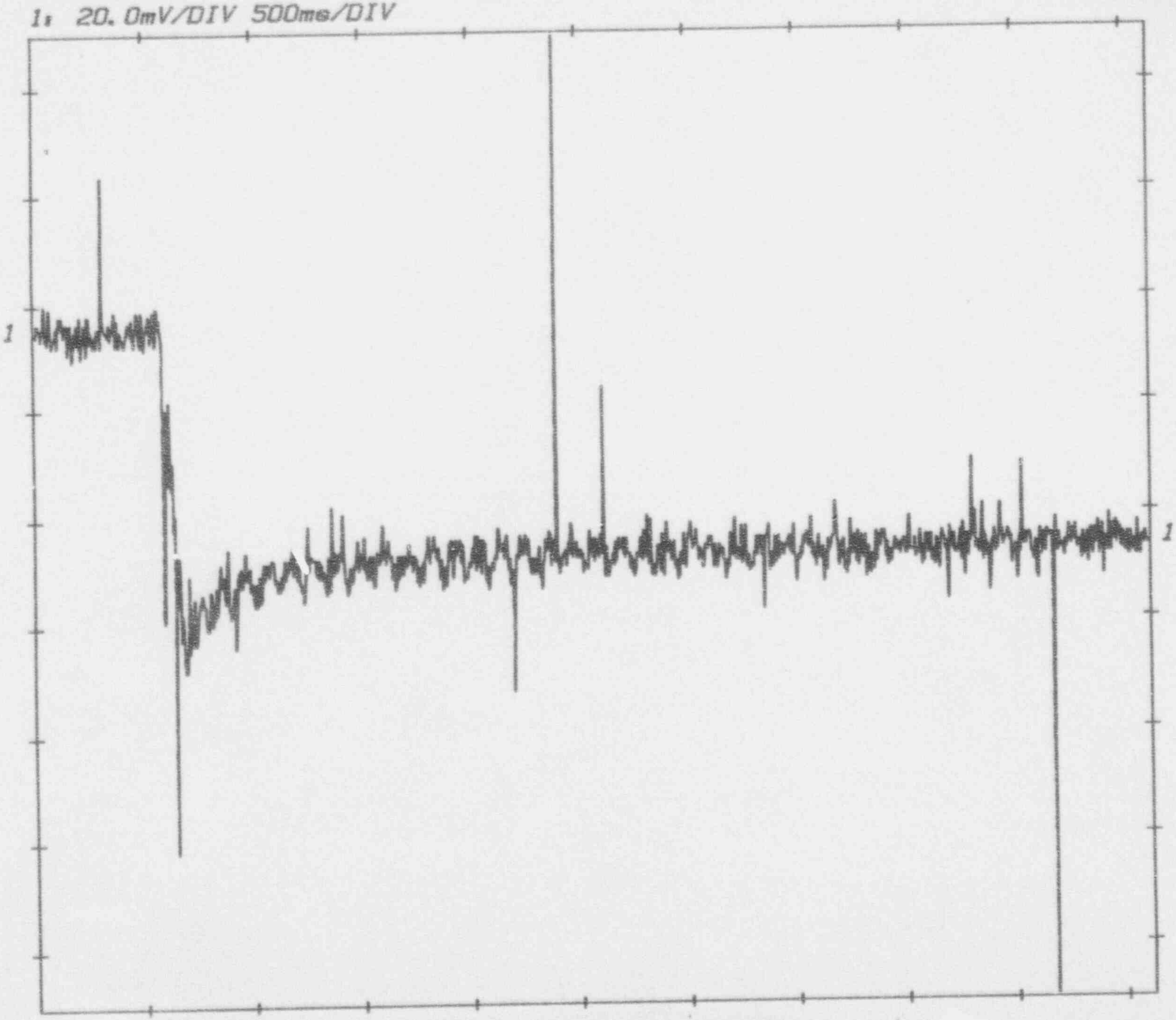


Figure D-7. Impact Profile, Automatic Operation
15 psi Clutch Air Pressure

93/05/31

automatic [illegible] psi

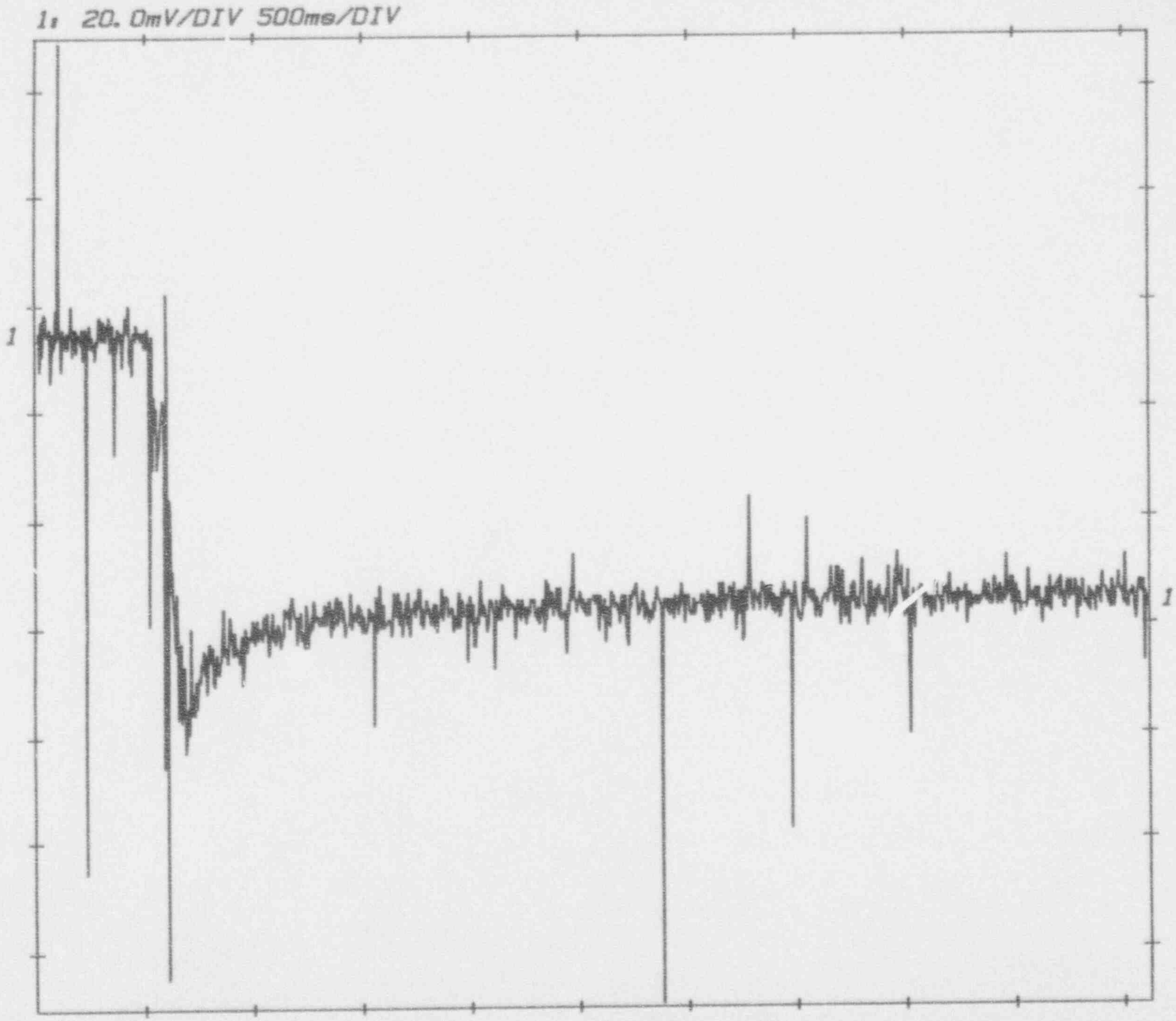


Figure D-8. Impact Profile, Automatic Operation
16 psi Clutch Air Pressure

93/05/31
automatic 17psi

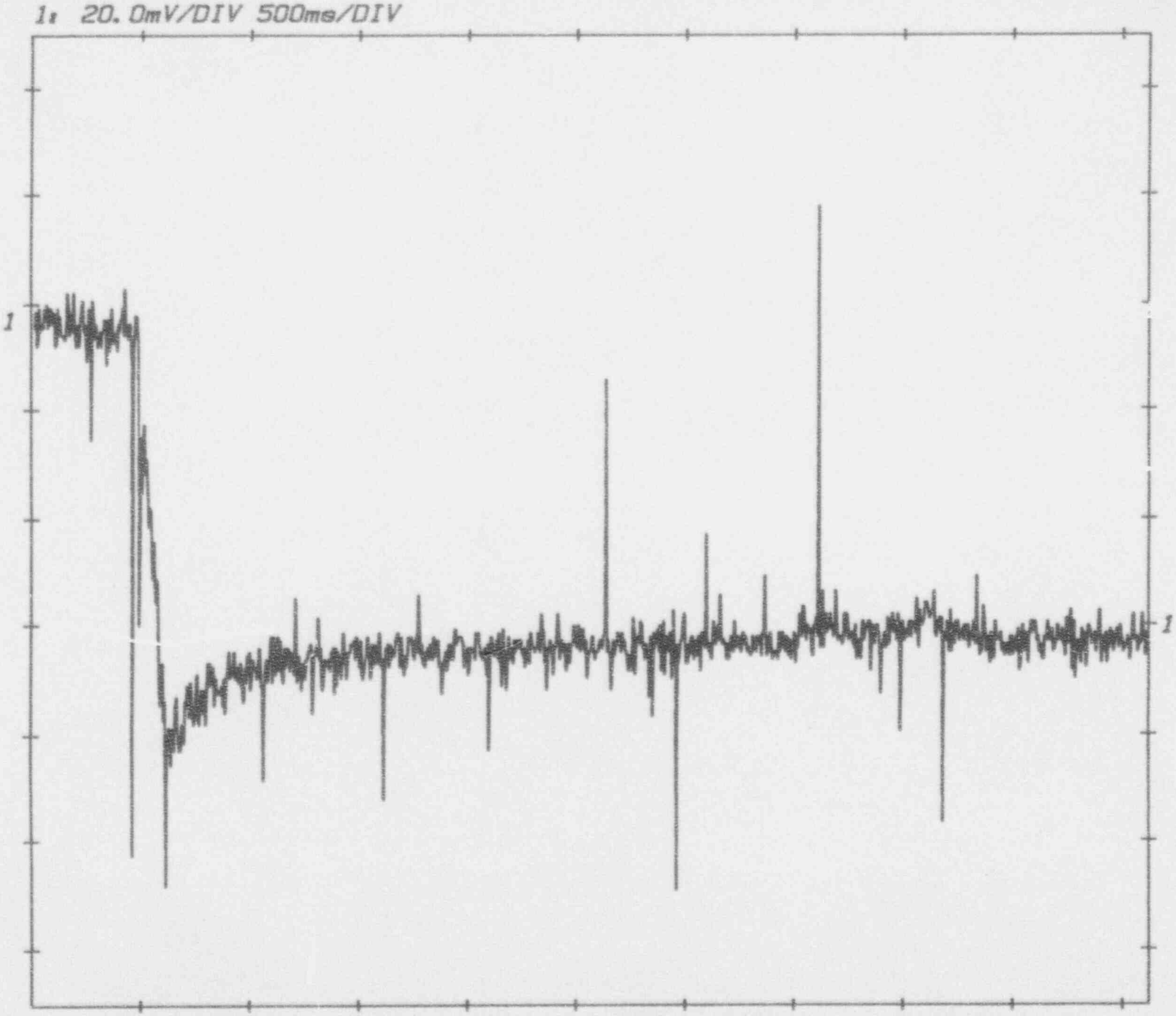


Figure D-9. Impact Profile, Automatic Operation
17 psi Clutch Air Pressure

APPENDIX E

Endurance Test Log Sheets

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
1	93/06/04	2:30	Begin Endurance Test	BM	RG	
1	"	2:31	Failure: lock did not rotate ccw	BM	RG	1
1	"	2:33	— " —	BM	RG.	2
38	93/06/04	3:06	Motor did not stop when source reached end	BM	RG	3
40	"	3:07	— " —	BM		4
100	93/06/04	16:00	shutdown	BM		
101	93/06/06	9:35	startup	BM	Gm	
104	93/06/06	9:38	failure - lock did not snap back completely; action - resume test.	BM	Gm	5
104	93/06/06	9:44	same - lock stopped ~5° short	BM	Gm	6
104	"	9:53	same. See log book p.200	BM	Gm.	7
128	—"—	12:15	no action taken. See log book p.199	MK	Gm	8
162	"	14:05	did not pivot completely ccw	BM	Gm	9
166	"	14:40	same	BM	Gm	10
170	"	14:46	"	BM	Gm	11
206	"	15:13	same - limit switch needed adjustment	BM	Gm	12
240	"	15:42	same - pivot did not turn much at all	BM	G	13
240	"	15:45	same - pivot turned most of way	BM	G	14
325	"	16:40	timeout moving pivot ccw	BM	G	15
325	"	16:50	— " —	BM	Gm	16
358	—"—		—"—	MR	RG	17
373	93/06/07	8:30	~~Start~~ Pivot was slow to turn	BM	RG	18
402	"	9:06	"	BM	RG	18
456	"	9:42	at start of cycle: clutch not engaged. camera not locked.	BM	[illegible]	19
456	"	10:14	camera did not stay in operate	BM	RG	20

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
456	93/06/07	10:16	same as failure #19	BM	[illegible]	21
456	93/06/07	11:35	Startup	BM		
470	93/06/07	11:45	patched hole in airline to camera pivot	BM	[illegible]	
604	93/06/07	13:02	pivot was slow to turn [illegible]	BM	[illegible]	
631	93/06/07	13:20	Problem A - restart	BM	[illegible]	
678	93/06/07	13:51	Cable did not wind at (expose)	BM	[illegible]	22
742	93/06/07	14:56	Camera is not in the operate mode	BM		23
1131	93/06/07	unattended	Timeout rotating pivot ccw (~5° short of operate)	BM	[illegible]	24
1131	93/06/08	8:44	Startup	BM	[illegible]	
1131	"	8:50	Timeout rotating ccw	BM	[illegible]	25
1314	"	10:57	Timeout disengaging clutch at PS end. Sheath disengaged from crimp fitting	BM	[illegible]	26
1314	"	15:27	Start-up after repair	BM	[illegible]	
1393	"	16:15	No action, lock pin did not engage but did not fail by hand, restart	MK	[illegible]	27
1464	"	17:05	Same as #27	MK	BA	28
1473	"	18:05	"	MK	BA	29
1473	"	18:05	" restart.	MK	BA	30
1484	"	18:11	"	MK	BA	31
1505	"	18:26	"	MK	BA	32
1549	"	19:10	"	MK	BA	33
1549	"	19:10	"	MK	BA	34
1586	"	19:35	"	MK		35
1586	"	19:35	"	MK		36
1586	"	19:35	" SEE NOTES	MK	—	37
1586	"	19:41	"	MK		38
1586	"	19:43	"			39

NORDION INTERNATIONAL INC.

BY______ DATE______ PROJECT ENDURANCE TEST LOG SHEET JOB NO.______

CHKD______ DATE______ PAGE NO.____ OF____

	Cycle	Date	Time	Action	Test Eng	Witness
40	1600	-"-	20:01	restart	MK	[illegible]
41	1600	-"-	20:01	rotate motor & restart	MK.	[illegible]
	1669	93/06/09	13:48	Startup with software RevB	BM	
42	1694	"	13/14:03	camera did not stay in op.	BM	GLM
43	1699	"	14:11	"	BM	GLM
44	1719	"	14:24	same error s/w change	BM	
45	1735	"	14:52	forced failure	BM	
	1737	"	15:16	Problem A	BM	
	1741	"	15:32	startup with new Rev B	BM	
46	1775	"	16:25	camera did not stay in op.	BM	
	1784	"	16:35	"	BM	
	1785	"	16:56	"	BM	
47	1836	-"-	17:07	PROBLEM A reset	MK	
48	1848	-"-	17:17	-"-	MK	← MK
49	1848	-"-	17:20	Cable is not at end at start of step 6		← [illegible]
50	1879	-"-	17:53	cam not in operate	MK	

transfer to proper data sheet.

N990

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
1880	93/06/09	17:56	Problem B	MK		51
1891	— "	18:04	Problem B	MK		52
1923	— "	18:24	Problem A	MK		53
1923	— "	18:24	Same as 49	MK		54
1923	— "	18:25	See lab book #55	MK.	BM	55
1923	— "	18:53	— — " #56	MK.	BM	56
1923	93/06/10	8:40	source did not reach end	BM	[illegible]	57
1923	93/06/10	10:50	Replaced teleflex drive cable	BM	GLM	
1928	93/06/10	10:59	restart after 5 cycle test	MK		
1932	"	11:04	Problem B rotate clutch fwd by hand	BM		
1940	"	11:11	Problem B. "	BM		
1958	"	11:26	Problem B "	BM		
1980	"	11:36	Problem B "	BM		
1981	"	11:38	" "	BM		
2077	"	12:34	" "	BM		
2214	— "	unad. 13:54	— " —	MK.		
2304	"	14:58	Clutch not engaged @ step?	BM		58
2316	"	15:08	Problem B - rotate clutch fwd	BM		
2317	"	15:10	— " ———— by hand & restart	BM		
2322	"	15:14	"	BM		
2341	"	15:26	"	BM		
2386	"	15:52	"	BM		
2415	"	16:10	"	BM		
2482	"	16:50	"	BM		59

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
2557	93/06/10	17:38	Problem B - rotate clutch fwd & restart	BM		
2584	"	18:21	"	BM	see QA data sheet.	
2629	"	18:47	see log book	BM		60
2673	"	19:13	Problem B - turn clutch & restart	BM		
2675	"	19:15	"	BM		
2685	"	19:21	"	BM		
2819	"	20:39	"	BM		
2827	"	20:45	"	BM		
2835	"	20:50	"	BM		
2962	"	22:04	"	BM		
3005	"	22:31	leave aparatus run unattended	BM.		
3010	"	22:33	Problem B	BM	[illegible]	
3010	93/06/11	8:16	turn clutch fwd, Startup.	BM		
3018	"	8:22	Problem B, turn clutch fwd ~1/8 turn	BM		
3035	"	8:33	"	BM		
3037	93/06/11	8:35	"Camera is not locked"	BM	BL.	61
3048	"	8:49	Problem B, turn clutch fwd ~1/8 turn	BM		
3058	"	8:55	"	BM		
3064	"	8:59	"	BM		
3069	"	9:03	"	BM		
3076	"	9:08	"	BM		
3078	"	9:10	"	BM		
3091	"	9:18	"	BM		
3093		9:19	"	BM		

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
3096	93/06/11	9:22	Problem B - rotate clutch fwd 1/8 turn, Restart	BM		
3097	"	9:23	"	BM		
3098	"	9:24	"	BM		
3108	"	9:31	"	BM		
3109	"	9:32	"	BM		
3111	"	9:34	"	BM		
3113	"	9:36	"	BM		
3115	"	9:37	"	BM		
3116	"	9:39	"	BM		
3119	"	9:42	"	BM		
3121	"	9:44	"	BM		
3123	"	9:45	"	BM		
3126	"	9:48	"	BM		
3128	"	9:50	"	BM		
3129	"	9:51	"	BM		
3130	"	9:52	"	BM		
3133	"	9:54	"	BM		
3133	"	10:02	Modified software, restart	BM		62
3191	"	10:46	Problem B - rotate clutch fwd 1/8, restart	BM		63
3275	"	11:40	"	BM		64
3654	"	15:55	Camera not in operate Mode (Prob B)	BM		65
3837		17:46	Prob B	NK		66
3849	—"—	17:56	—"—	NK		67
3981		19:14	—"—			68

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
3991	93/06/11	19:22	Prob B	MK		69
3998	—"—	19:27	—"—	MK		70
4056	—"—	20:02	—"—	MK		71
4102	—"—	20:31	—"—	MK		72
4271	June 11/93	22:11	Problem B (unattended)	BM		73
4271	June 13	09:13	Startup.	BM	BM	
4343	June 13	9:55	Problem B - 1/8 turn Fwd & restart	BM		74
4454	"	11:03	"	BM		75
4762	"	1404	"	BM		76
4800	"	14:28	"	BM		77
4951	"	15:57	"	BM		78
4980	"	16:16	"	BM		79
5061	93/06/14	17.07 13th unattended	Problem B	MK		80
5080		8:25	Prob A	MK		81
5080		8:25	Prob A	MK		82
5080		8:25	Prob B retracted too far	MK		83
5080		8:25	Prob B	MK		84
5082		8:40	Prob A	MK		85
5083		8:46	Prob A	MK		86
5085		8:50	Prob A (switch? see notes)	MK	[illegible]	87
5141		9:33	Prob B	MK		88
5241		unatt. 10:45	Prob B	MK		89
5462		12:56	Prob B	MK		90
5519		13:31	—"—	MK		91

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
5773		16:01	Prob B	MK.		92
5888	93/06/14	17:10	Problem B	BM		93
5972 (5972)	"	18:00	"			94
5984	"	18:07	"Clutch not Engage", "Camera Not Locked"	BM	[illegible]	95
5999	"	19:49	Problem B	BM	[illegible]	96
6026	"	20:06	"	BM		97
6039	"	20:15	"	BM		98
6104	"	20:53	"	BM		99
6169	"	21:33	"	BM		100
6224	"	22:11	"	BM		101
6259	"	2235	"	BM		102
6269	"	2241	"	BM		103
6390	"	2354	"	BM		104
6485	93/06/15	01:11	Prob B (unattended)	MK		105
6485	—"—	08:01	cam not locked - teleflex bend	MK	[illegible]	106
6504	—"—	09:10	Prob B	MK		107
6618	—"—	unatt 11:21	Prob B	MK		108
6629	—"—	11:32	—"—	MK		109
—"—	—"—	11:32	—"— (did not move motor far enough)	MK		110
6652	—"—	11:47	Prob B	MK		111
6658	—"—	11:54	Prob B	MK		112
6666	—"—	12:00	unattented (Prob B)	MK		113
6704	"	13:09	Problem B	BM		114
6872	"	14:49	Problem B	BM		115

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
6930	93/06/15	15:24	Problem B, rotate clutch fwd 1/8 turn	BM		116
7067	"	16:10	"	BM		117
7188	"	17:56	"	BM		118
7268	"	18:44	"	BM		119
7285	"	18:54	"	BM		120
7381	"	19:51	"	BM		121
7382	"	19:52	"	BM		122
7413	"	20:11	"	BM		123
7573	"	21:46	" (unattended)	BM	[illegible]	124
7573	93/06/16	08:34	Startup	BM		—
7599	"	8:49	Problem B - Rotate clutch fwd by hand	BM		125
7602	"	8:57	"	BM		126
[illegible]617	"	9:06	"	BM		127
[illegible]	"	9:13	"	BM		128
7648	"	9:26	"	BM		129
7649	"	9:28	"	BM		130
7654	"	9:31	"	BM		131
7668	"	9:40	"	BM		132
7698	"	9:59	"	BM		133
7720	"	10:12	"	BM		134
7774	"	10:51	" (unattended)	BM		135.
7804	"	12:08	" (unattended)	BM		136
7817	"	12:53	"	BM		137
7840	"	13:00	"	BM		138

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
7862	93/06/16	13:22	Problem B - advance clutch by hand and restart.	BM		139
7973	"	14:29	"	BM		140
8094	"	15:45	"	BM		141
8138	"	16:14	"	BM		142
8360	"	18:31	" (unattended)	BM		143
8361	93/06/17	08:35	Startup	BM	[illegible]	
8427	"	9:14	Problem B. Rotate clutch fwd by hand	BM		144
8485	"	9:49	"	BM		145
8683	"	11:46	"	BM		146
9060	"	15:29	"	BM		147
9079	"	15:57	"	BM		148
9112	"	16:17	"	BM		149
[illegible]594	"	21:02	Prob B (21:16 unattended)	MK		150
9872	"	23:59	(Unattended) Clutch did not re-engage in step 8	BM	[illegible]	151
9873	93/06/18	9:05	Startup with R Goddard	BM		
10008	"	10:24	Problem B	BM		152
10048	"	10:49	Problem B	BM		153
10064	"	10:59	"	BM		154
10120	"	11:33	"	BM		155
10123	"	11:36	"	BM		156
10172	"	12:06	"	BM		157
10223	"	12:36	" (unattended)	BM		158
10224	"	12:39	Problem B	BM		159

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
10224	June 18	12:40	(forgot to rotate clutch fwd)	BM		160
10412	"	14:31	Problem B (unattended)	BM		161
10443	"	15:12	Problem B - rotate clutch fwd	BM		162
10448	"	15:15	"	BM		163
10473	"	15:30	timeout turning pivot ccw	BM		164
10549	June 19	16.18	unattended prob B and startup @ 7:50	MK	///.C.	165
10557	June 20	07:56	Prob B	MK		166
10602	—"—	08:27	Prob B	MK		167
10759	—"—	10.11 unatt	Prob B	MK		168
10762	—"—	11.25 unatt	Prob B	MK		169
10805	—"—	11.59	Prob B	MK		170
10904	—"—	12:58	Prob B	MK		171
10921	—"—	13:10	Prob B	MK		172
10926	—"—	13:14	Prob B	MK		173
10979	—"—	13:46	Prob B	MK		174
10995	—"—	13:55	Prob A	MK		175
10995	—"—	13:56	Prob B (retracted too far)	MK		176
10996	—"—	13:59	Prob A } SEE	MK		177
10996	—"—	14:01	restart w/o incident } LOG	MK		178
10997	—"—	14:04	Prob B } BOOK	MK		179
11007	—"—	14:11	Prob A (timeout) LOCK IS OPERATE ~~LOCKED~~	MK		180
11007	—"—	14:15	Prob A (—"—) —"—	MK		181
11016	—"—	14:24	Prob B	MK		182
11158	—"—	15.49	Prob A (timeout, switch did not indicate full ccw of forks but unit OK)	MK		183

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
11205	93/06/20	16:36	Camera not in op mode (Prob B) unattended	MK		184
11205	93/06/21	07:45	startup	MK	[illegible]	
11207	— " —	07:47	Prob B	MK		185
11245	— " —	08:10	Prob B	MK		186
11252	— " —	08:33	unattended came @ 9:07 Prob A incl CCW limit switch	MK		187
11276		09:23	Prob B	MK		188
11326	— " —	09:53	Prob B	MK		189
11334	— " —	10:01	Prob B restart @ 10:23	MK		190
11391	— " —	10:56	Prob B unatt. checked @ 11:12	MK		191
11421	— " —	11:31	— " —	MK		192
11451		11:50	— " —	MK		193
11461	— " —	11:57	Prob B (checked @ 12:02)	MK		194
11544	"	12:52	Problem B	BM		195
11549	"	12:55	Camera not locked	BM		196
11634	"	13:46	Timeout moving pivot CCW	BM		197
11643	"	"	Camera is not locked	BM	[illegible]	[illegible]
11653	"		10 test cycles complete - resume	BM		
11702	— " —	15:00	Prob B	MK		199
11718	"	15:10	Problem B	BM		200
11811	"	16:05	Problem B	BM		201
11909	"	17:15	Problem B	BM		202
12062	"	18:45	Problem B.	BM		203
12173	"	19:51	Problem B	BM		204
12191	"	20:03	Problem B	BM		205

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
12242	93/06/21	20:35	Camera not inoperate (Problem B)	BM	[illegible]	206
"	93/06/22		Startup	BM	[illegible]	/
12320	"	09:07	Problem B	BM		207
12338	"	9:19	Problem B	BM		208
"	"	9:21	Shut down for Mech Room Mntnce	BM		/
"	"	11:20	Restart after overhead steam valve			—
			was replaced.	BM		—
12501		12:59	pivot not ceed - broken microswitch replaced	MK	JLM	209
12510		13:30	10 test cycles completed normally	MK.		—
12511	–"–	13:33	Prob B	MK	[illegible]	210
12662	–"–	15:03	Shutdown to do tensile test	MK	[illegible]	—
12677	–"–	16:41	Prob B	MK.		211
12908	–"–	18:57	Prob B	MK		212
12936	–"–	19:17	Prob B	MK		213
13069	"	20:41	Prob B (unattended)	BM		214
13069	93/06/23	08:16	Start up 13069.	BM	JLM	/
13658	–"–	14:05	Problem B	MK		215
14097	–"–	18:25	Problem B	MK		216
14192	–"–	19:22	Prob B (unatt)	MK		217
14193	–"–	19:31	Prob B * [Mistyped as 1494] *	MK		218
1601	–"–	20:35	1601 = 14301 Prob B	MK		219
14352	–"–	21.11	unattended Prob B	MK		220
14352	~~–"–~~ 93/06/24	07:50	startup	MK	JLM	—
14422	93/06/24	08:30	Prob B	MK		221

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
1484	93/06/24	10:04	Prob. B	MK		222
14808	— "	1410	Prob B	MK		223
14910	"	15:10	Problem B, started new data file (TITAN 94 DAT)	BM		224
15095	"	17:06	Problem B.	BM		225
15113	"	17:18	Problem B	BM		226
15139	"	17:35	Problem B	BM		227
15241	"	18:43	Problem B	BM		228
15464	— "	20:59	unattended Prob B	MK		229
15464	9306/24	07:40	startup	MK	[illegible]	/
15597	"	09:00	Problem B	BM		230
15738	"	10:22	Problem B	BM		231
15805	"	11:03	Problem B	BM		232
15865	"	11:39	Problem B	BM		233
15929	"	12:40	Problem B	BM		234
15938	"	12:49	Problem B	BM		235
15942	"	12:49	Forced Failure (pressed clutch limit switch)	BM		236
*	"	12:58	variety of failures during debug cycle Nos.	HO BM	[illegible]	/
15942		14:02	Startup with Software Rev D	BM	[illegible]	/
15946		14:06	Interrupt to change title block on S/W	BM		237
"	"	14:15	Resume	BM		/
16522	— "	19:55	Unattended ~~Prob B~~ (Lock Bounce)	MK		238
18082	93/06/25	14:27	CCW switch did not trigger (RAN OVERNIGHT)	MK.		239
	93/06/27	07:40	startup	MK.	[illegible]	
19998			normal completion			

Endurance Test Log Sheet

Cycle No.	Date	Time	Action (e.g., startup/maintenance)	Test Engineer Initials	QC Initials	Failure No.
			startup (2 cycles)	MK		
20,000			normal completion			

APPENDIX F

Radiation Shielding Test Data

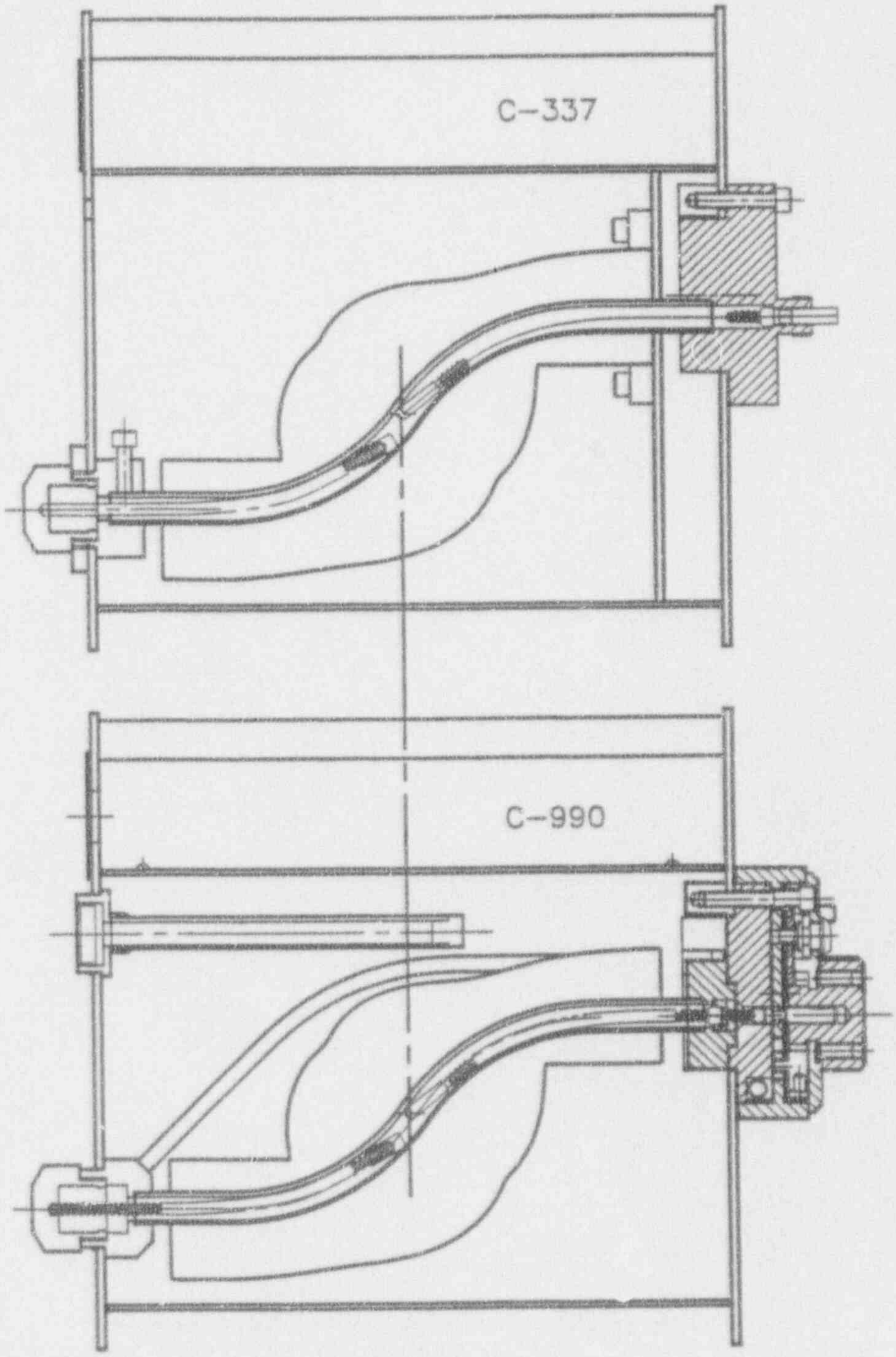


Figure F-1. Shield Jig and C-337 Source Assembly for Initial Radiation Shielding Test.

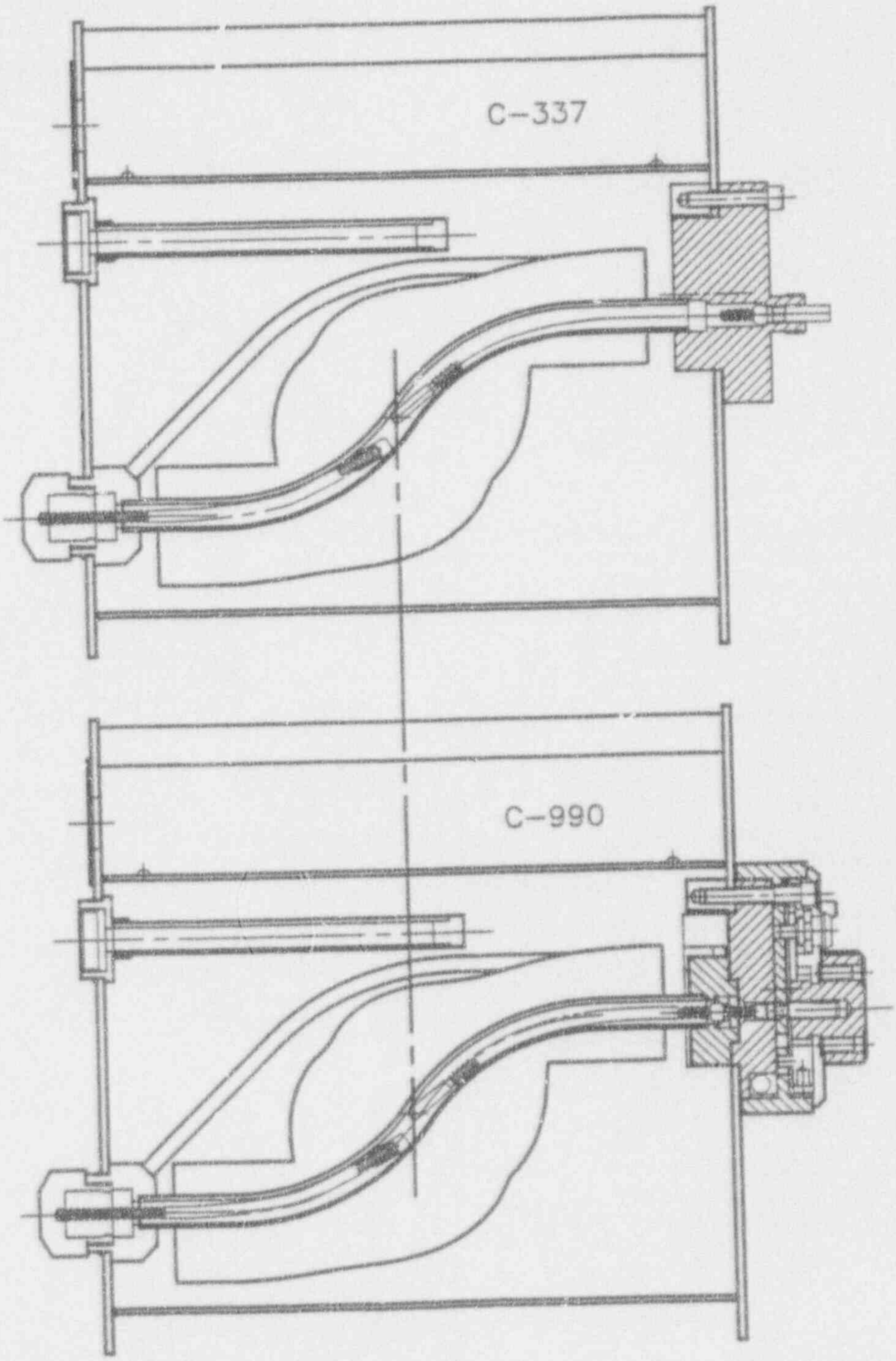


Figure F-2. Shield Jig and C-337 Source Assembly for Final Radiation Shielding Test.

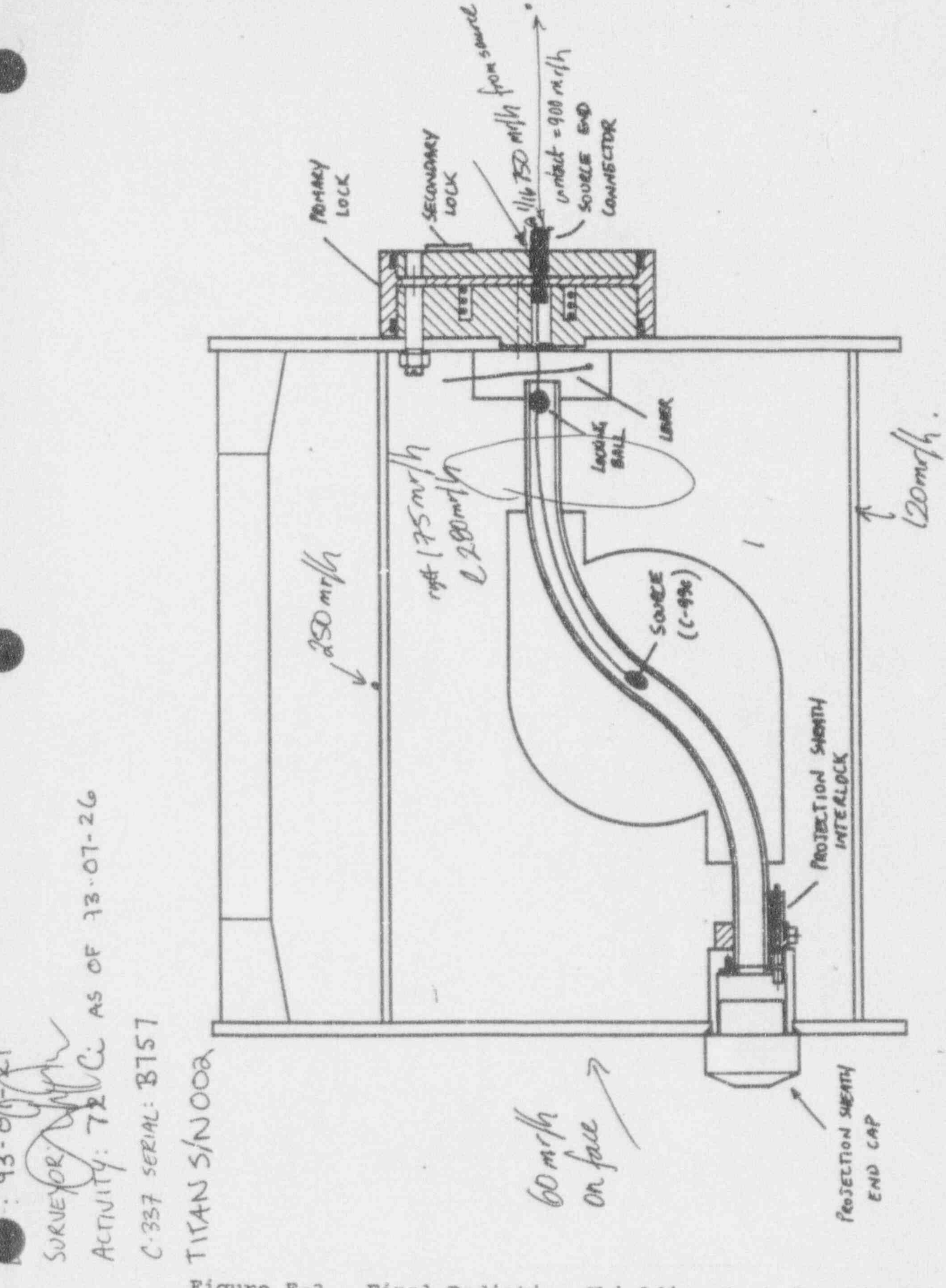


Figure F-3. Final Radiation Shielding Test for S/N 002.

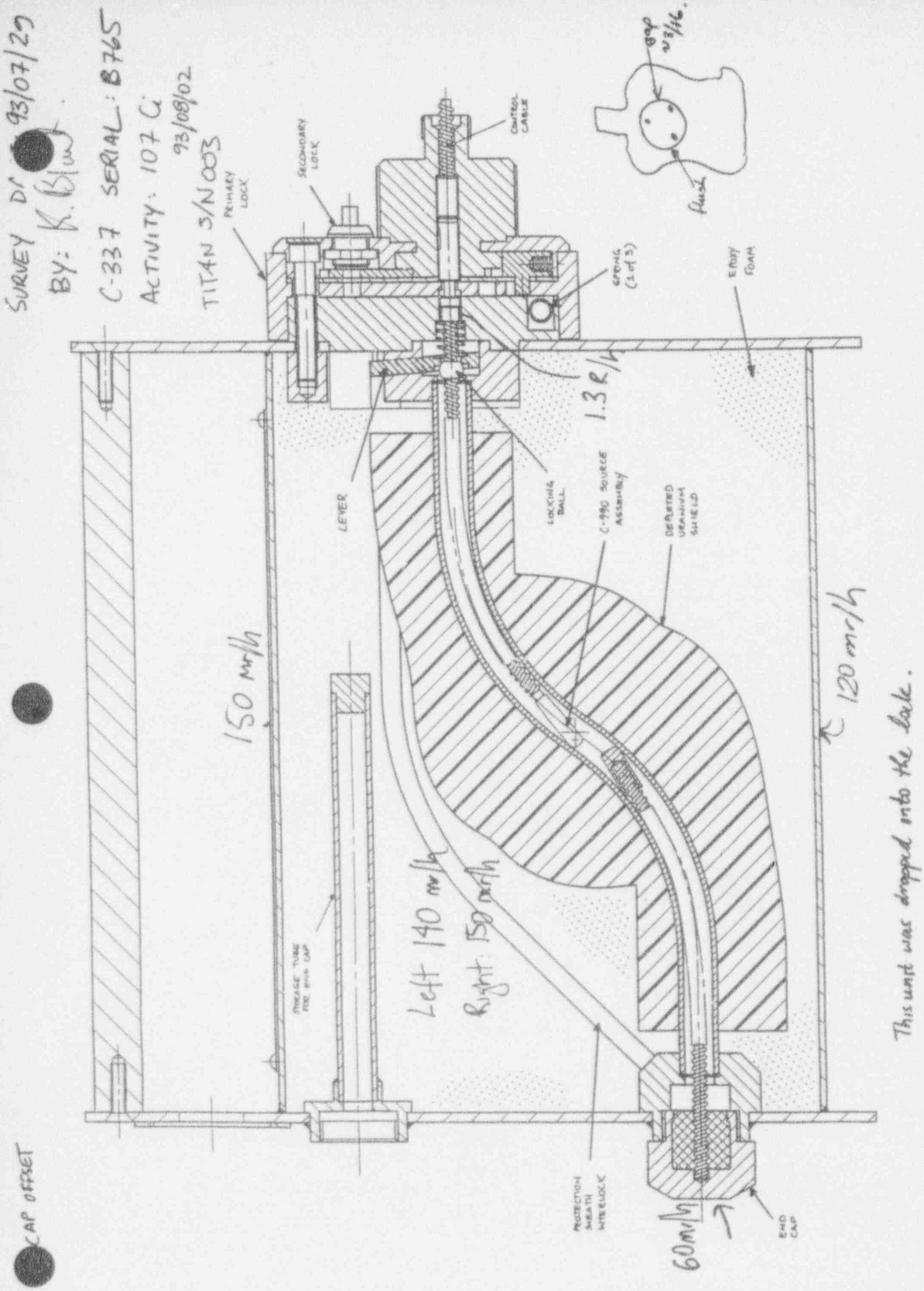


Figure F-4. Final Radiation Shielding Test for S/N 003.

TITAN RADIATION SURVEY RESULTS

Kevin P.J. O'Hara
March, 1993

One Titan shield was surveyed on 1993 March 02; both Titan shields were surveyed on 1993 March 05. The effect of source position on external radiation fields and the effect of depleted uranium (DU) shrinkage on external radiation fields were investigated in greater detail.

Measurement Geometry and Instrumentation

The distance between the shield's surface and the geometric centre of the instrument's sensitive volume was 50 mm. The measurement of the exposure rate at this distance from the surface shall be averaged over an area of 10 cm^2 with no linear greater than 5 cm. This field shall no exceed 50 mR/h (3.583 aA/kg). If this field requirement is achieved, the field requirments at the surface and 1 meter from the surface will be achieved.

Three instrument's were used for the survey. Instrument (1) is a GM tube which detects crack leakage more easily than an ion chamber because of its smaller sensitive volume. Instruments (2) and (3) are ion chambers which are closer to the requirements required by ANSI for radiation survey measurements.

(1) Bicron Surveyor 2000 GM Tube

S.N. 6-144-060
Calibrated on 93 Jan 26
Active Length 6 cm

(2) Bicron RSO-5 Ion Chamber

S.N. 6-144-107
Calibrated on 93 Jan 26
200 cubic cm volume

(3) Victoreen 471 Ion Chamber

S.N. 6-144-266
Calibration Due Date 93 March 24
485 cubic cm volume with an equilibrium cap

Instruments (1) and (3) were used for the first survey on 1993 March 02; Instruments (1) and (2) were used for the second survey on 1993 March 05.

Source Activity

The Ir-192 source activity was 119 Ci on 1993 March 01, using Nordion's exposure rate constant of 0.54 $R \cdot m^2/h \cdot Ci$. (ANSI uses an exposure rate constant of 0.48 $R \cdot m^2/h \cdot Ci$.)

Radiation Survey Results

The grid pattern used for the radiation surveys is illustrated in Figure 1. Each surface has been divided into a number of incremental areas. The radiation survey results for shield 1 on 1993 March 02 are summarized in Figure 2; the radiation survey results for shields #1 and #2 on 1993 March 02 are summarized in Figures 3 and 4 respectively.

Effect of Shrinkage on Measured Radiation Fields

Figure 5 shows the measured shrinkage in thousands of an inch (and mm) for Shield #2. (These measurements were performed by QNDE.)

Figure 6 shows the vertical plane of the Titan through the S-tube for Shield #2. The exposure rate measurements (mR/h) for a number of field points, the measured DU shrinkage (mm) and the estimated increase in DU (mm) to reduce fields to 50 mR/h are summarized for a number of points in that plane.

Figures 7 and 8 show the estimated increase in DU to reduce the fields at 50 mm to 50 mR/h for all measurement points for Shields #1 and #2 respectively.

TECHNICAL NOTE

For estimating the DU necessary to reduce fields to 50 mR/h, it is very important to distinguish the transmission of ^{192}Ir in depleted uranium from the transmission of ^{192}Ir in depleted uranium after transmission through about 40 mm of depleted uranium.

This is important since most low energy photons have been filtered out with this thickness of shield; the energy spectrum has become quite hard. (It will take more depleted uranium to reduce the fields after transmission through 40 mm DU.) For example, the half-value layer of Ir-192 in DU is approximately 1.5 mm; after transmission through 40 mm, the half-value layer is approximately 3 mm. Table 1 summarizes the transmission factors for a number of thicknesses of DU <u>after</u> transmission through about 40 mm of DU.

Table 1

Transmission of ^{192}Ir in DU after Transmission through 40 mm DU

Thickness of Depleted Uranium (mm)	Transmission Factor	Field Reduction (%)
0.5	0.90	10
1.0	0.82	18
1.5	0.75	25
2.0	0.67	33
2.5	0.62	38
3.0	0.55	45
3.5	0.51	49
4.0	0.46	54

The half-value layer of ^{192}Ir in stainless steel after transmission through 40 mm DU was measured to be 20 mm.

Effect of Source Position on Radiation Fields

For Shields #1 and Shield #2, the entire surface of the Titan was scanned using the Bicron Surveyor 2000 for a number of known source positions. (The Surveyor 2000 is better suited for detecting localized radiation fields due to its smaller sensitive volume.) The results are shown in Figures 9 and 10.

Figure 9 illustrates the maximum exposure rate at 50 mm as a function of source position for each surface. Figure 10 shows the same data except that the fields have been normalized to the field measurement with the source in the optimum position.

Summary

Radiography film will be used to map all six Titan surfaces. This is particulary important for mapping the riser of Shield #2. 100 mR/h could be measured with the GM tube while only 50 mR/h could be measured with the ion chamber.

In general there was a good correlation between the ion chamber measurements and the GM tube which indicates good field uniformity over the cross-sectional area of the ion chamber.

Shrinkage has accounted for some of the high field measurements. The original shield design assumed 0.7% linear shrinkage; some of the shrinkage measurements performed by QNDE show shrinkage much greater than 0.7%. A larger shrinkage factor can be used in the model; however, this will mean overshielding a large portion of the surface. The shield's manufacturer has estimated that the shrinkage is about 2.5%. Nordion must be certain that the shrinkage is reproducible; if not, it must be accounted for.

Overall, the radiation field measurements show a good degree of optimization. Depleted uranium will have to added in some areas due to shrinkage.

The position of the S-tube within the DU shield must be determined.

Lastly, it must be verified that the shields which have been produced are the shields which were calculated (with the exception of shrinkage). One method is to check the estimated DU thickness based on the digitized surface with the calculated DU thicknesses based on Nordion's model.

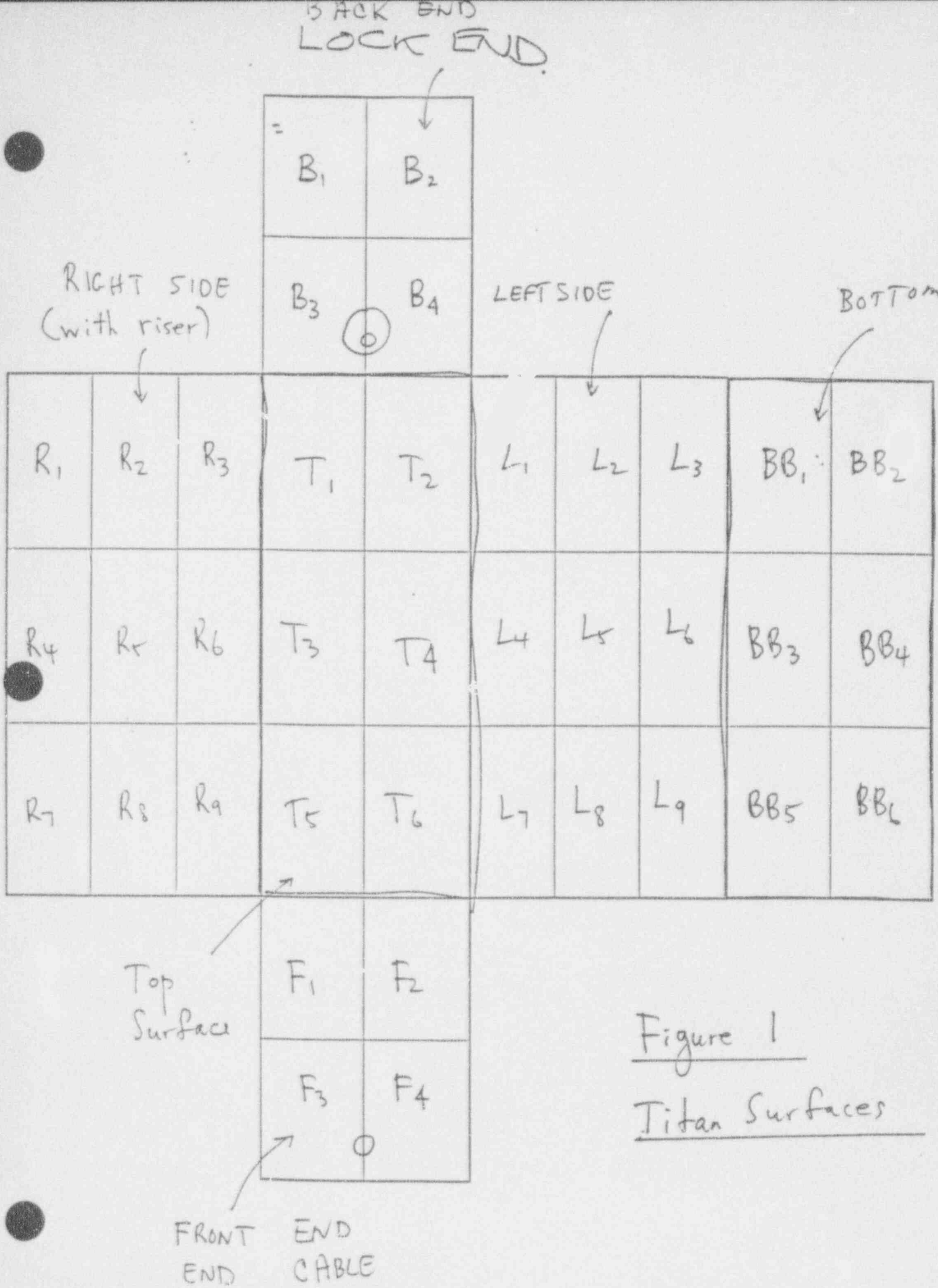


Figure 1

Titan Surfaces

LOCK END

Shield # 1
93 Mar 02

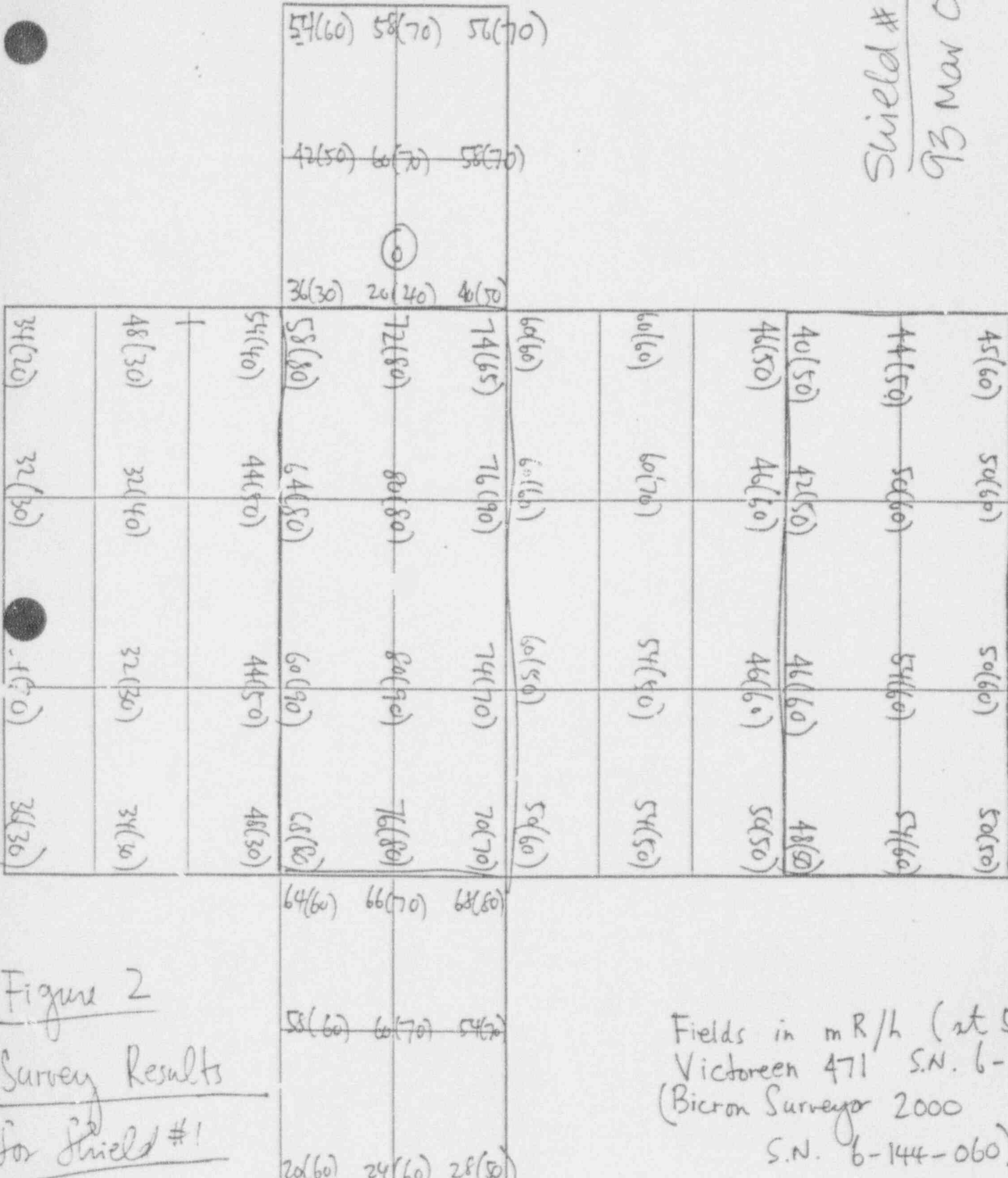


Figure 2
Survey Results
for Shield #1

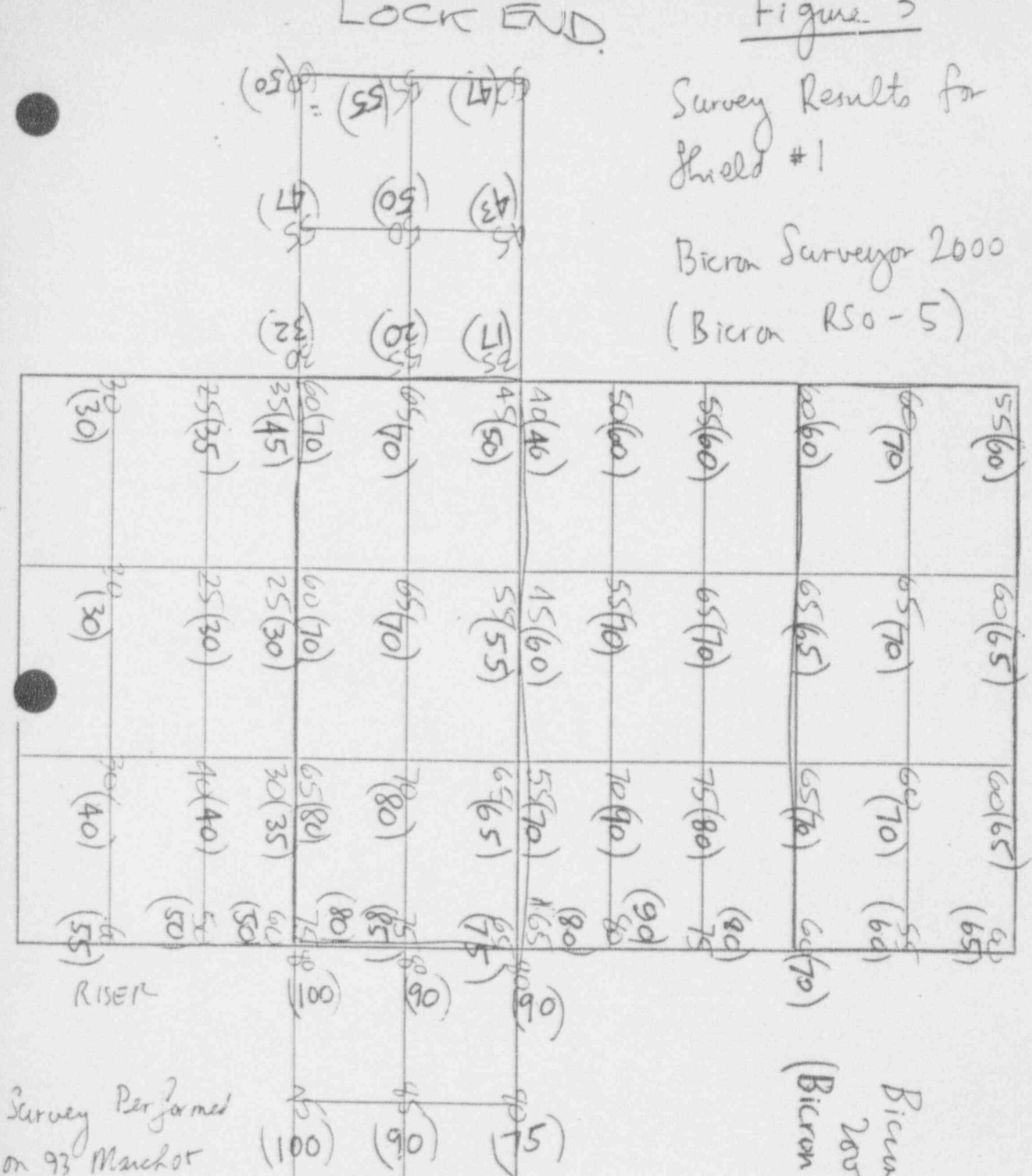
Fields in mR/h (at 50mm)
Victoreen 471 S.N. 6-144-266
(Bicron Surveyor 2000
S.N. 6-144-060)

A = 119 Ci ^{192}Ir (93 Mar 01)

Figure 3

Survey Results for Shield #1

Bicron Surveyor 2000 (Bicron RSO-5)



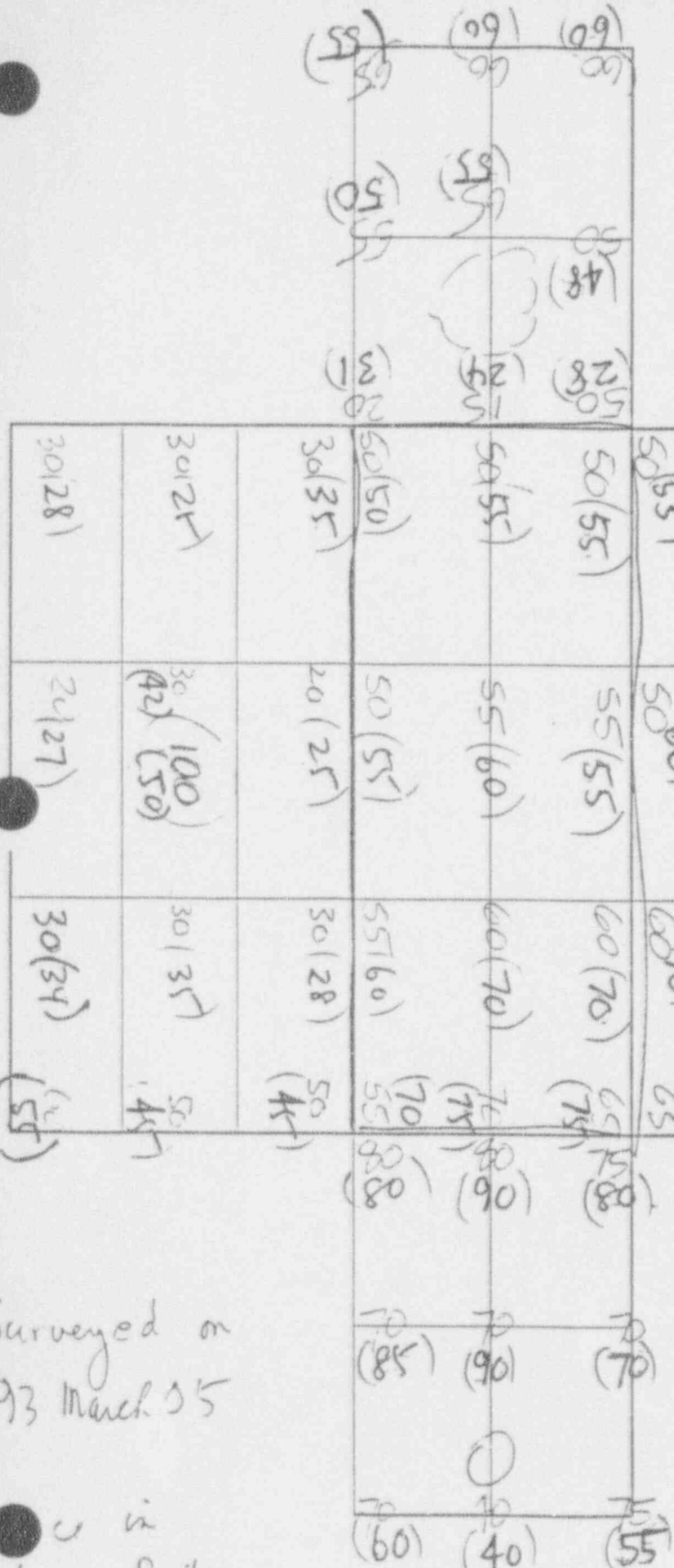
Survey Performed on 93 March 04

Source in Operation Position

Bicron Surveyor 2000™ (Bicron RSO-5)

Figure 4

LOCK END.



Survey Results for Shield #2

Bicron Surveyor 2000 (Bicron RSO-5)

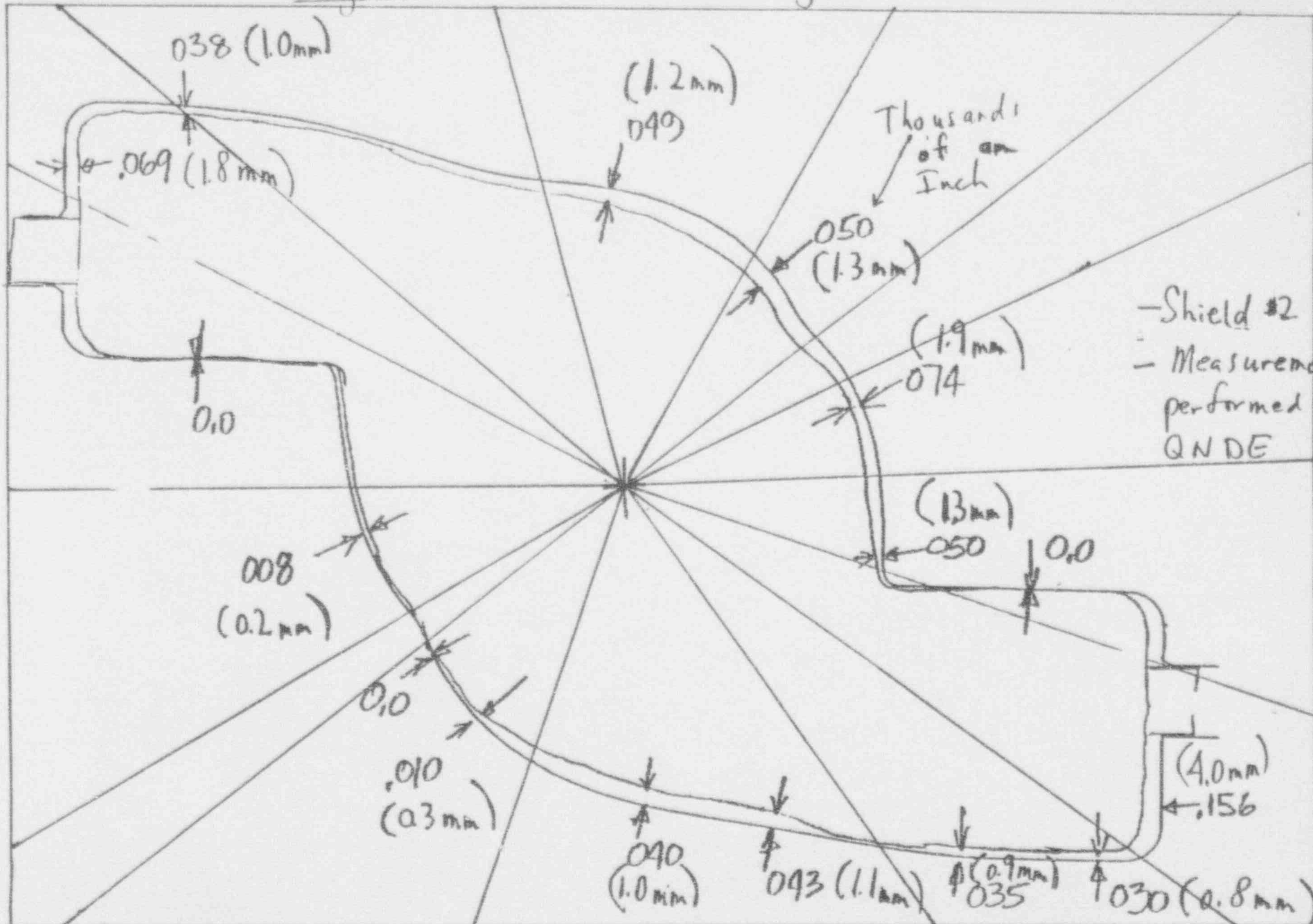
Fields at 50mm (mR/h)

Surveyed on 93 March 15

S... in Optimum Position

Measured DU Shrinkage (Vertical Plane Through the S-tube) — 93 Mar 08 / K. Olson

Figure 5



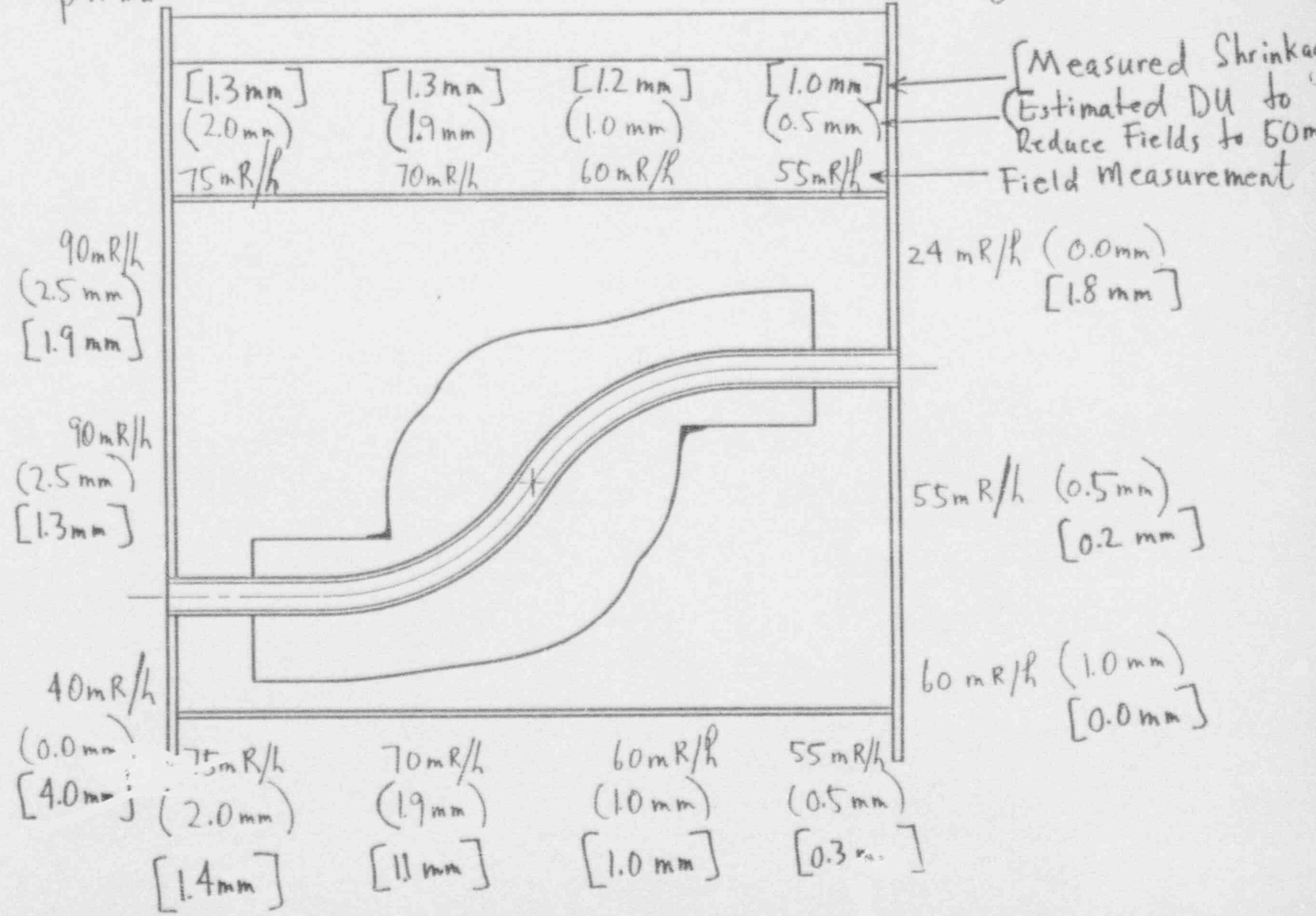
93 Mar. 11
K. Hara

Estimated DU thickness to reduce fields to 50 mR/h at 50 mm

Figure

Measurements with Bicron RSO-5 Ion Chamber
119 Ci ^{192}Ir (93 March 01)
Source in Optimum Position

Vertical Cross-Section through the S-tube



LOCK END

Source is in Optimum Position

			0.0	0.5	0.0						
			0.0	0.0	0.0						
			0.0	0.0	0.0						
0.0	0.0	0.0	1.9	1.9	0.0	0.0	1.0	1.0	1.0	1.9	1.0
0.0	0.0	0.0	1.9	1.9	0.5	1.0	1.9	1.9	1.3	1.8	1.3
0.0	0.0	0.0	2.3	2.3	1.3	1.9	3.0	2.3	1.9	1.9	1.3
0.5	0.0	0.0	2.3	2.7	2.0	2.3	3.0	2.3	1.9	1.0	1.3
			3.6	3.0	3.0						
			3.6	3.0	2.0						
			1.9	2.3	1.9						

Figure 7

Estimated DU (mm) to Reduce Fields to 50 mR/h

Bicron RSO-5 Measurements

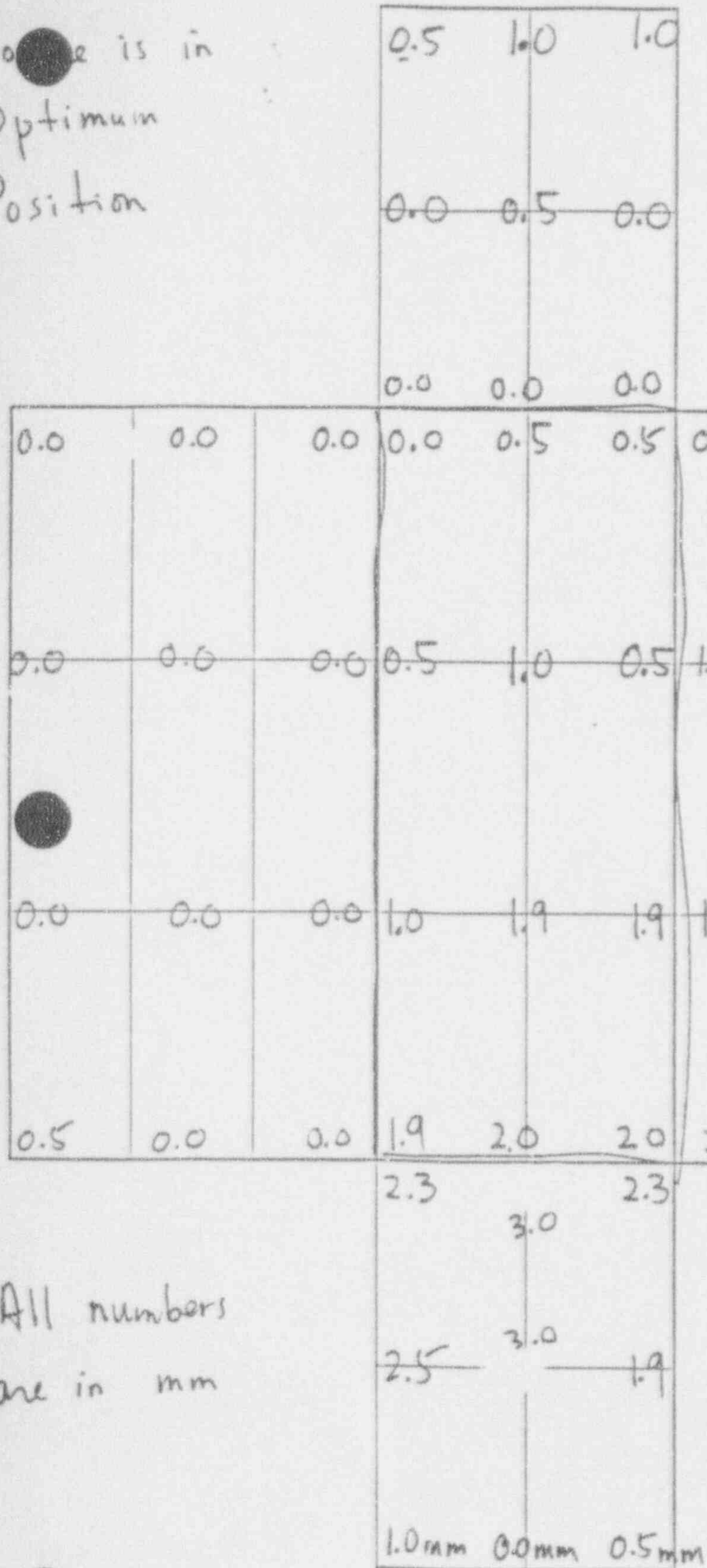
Shield #1

93 March 09

K. O'Hara

LOCK END

Source is in Optimum Position



END CABLE

All numbers are in mm

Figure 8

Estimated DU to Reduce Fields to 50 mR/h

Bicron RSO-5 Measurements

Shield #2

93 March 09

K. Ostara

Figure 9

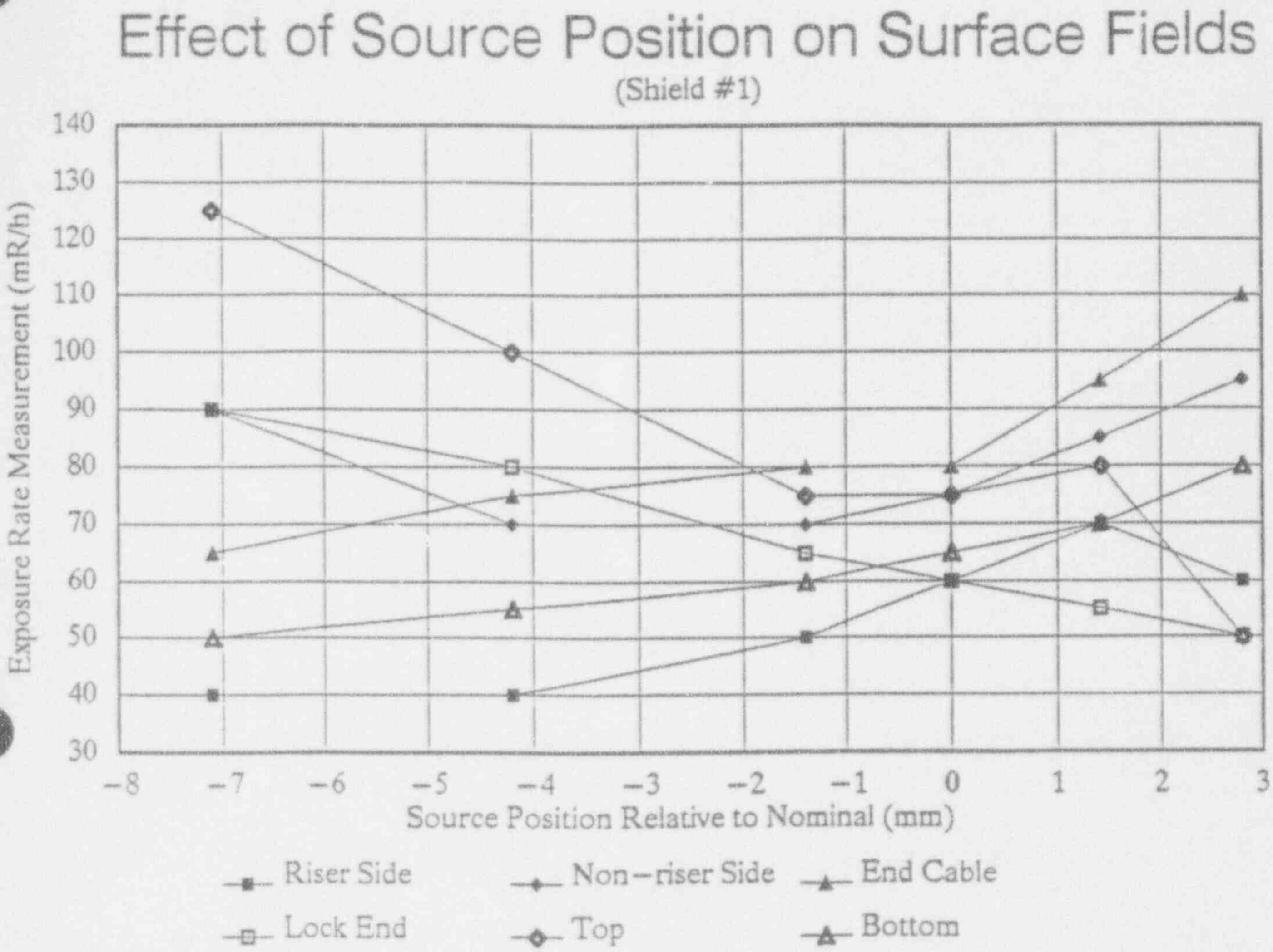
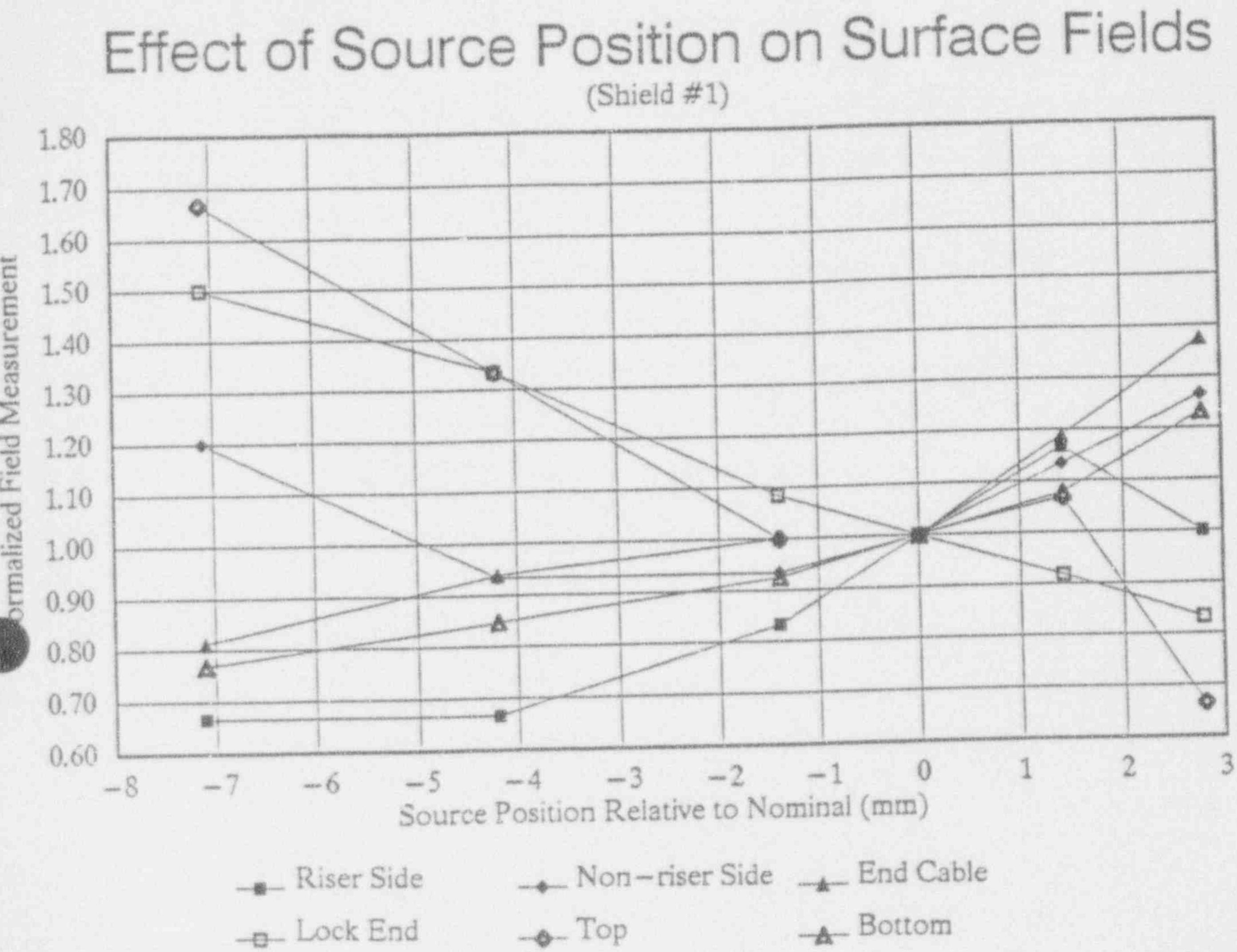

Effect of Source Position on Surface Fields
(Shield #1)
Exposure Rate Measurement (mR/h)
140
130
120
110
100
90
80
70
60
50
40
30
−8
−7
−6
−5
−4
−3
−2
−1
0
1
2
3
Source Position Relative to Nominal (mm)
Riser Side
Non−riser Side
End Cable
Lock End
Top
Bottom

Figure 10



Effect of Source Position on Surface Fields
(Shield #1)
Normalized Field Measurement
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
−8
−7
−6
−5
−4
−3
−2
−1
0
1
2
3
Source Position Relative to Nominal (mm)
Riser Side
Non−riser Side
End Cable
Lock End
Top
Bottom

APPENDIX G

Horizontal Shock Test Data Sheets

Horizontal Shock Test Data Sheet

Titan Serial Number 002 Date 93/07/07

Orientation against side of TITAN (left side when viewed from lock end)

Trial Number	Observations
1	
2	
3	
4	
5	
6	
7	Δh = 10.5 cm minimum.
8	
9	
10	No significant damage
11	very small dents inside only.
12	
13	Photos afterwards.
14	Video of all impacts
15	
16	
17	present Phil L
18	Mike K
19	Gord M
20	

Test Engineer Blair [signature] QA Witness [signature]

Project Engineer [signature]

Horizontal Shock Test Data Sheet

Titan Serial Number 002 Date 93/07/07

Orientation Face of lock, striking 2ndary (push-button) lock

Trial Number	Observations
1	Δh = 10.5 cm minimum
2	push-button lock deformed after each
3	impact.
4	Cannot insert key after 8 impacts.
5	Complete 20 impacts.
6	
7	
8	
9	present: M Krzaniak
10	Phil L
11	Paul Q
12	Bob M
13	Gord M
14	
15	
16	
17	
18	
19	
20	

Test Engineer Blair Menard QA Witness [signature]

Project Engineer M Krzaniak

Horizontal Shock Test Data Sheet

Titan Serial Number 002 Date 93/07/07

Orientation side of outerring (right side)

Trial Number	Observations
1	
2	
3	
4	Δh = 10.5 cm minimum
5	
6	
7	20 impacts
8	small dents & burrs
9	Scallop at 90° from vertical is rounded
10	from impacts.
11	Cannot test TITAN for operation because
12	GRED is locked, and key won't fit.
13	
14	
15	
16	
17	
18	
19	
20	

Test Engineer ______ QA Witness ______

Project Engineer ______

Horizontal Shock Test Data Sheet

Titan Serial Number 002 Date 93/07/08

Orientation side of projection sheath connector

Trial Number	Observations
1	
2	
3	
4	
5	
6	
7	
8	20 impacts, several discounted ∴ many
9	repeated. $\Delta h = 10.5cm$ minimum
10	Connector is burred, but still threads out.
11	All impacts on videotape.
12	
13	
14	
15	
16	
17	
18	
19	
20	

Test Engineer Blaine [signature] QA Witness [signature]

Project Engineer [signature]

Horizontal Shock Test Data Sheet

Titan Serial Number 002 Date 93/07/08

Orientation front of projection sheath connector

Trial Number	Observations
1	
2	20 impacts Δh = 10.5cm minimum
3	connector is slightly burred
4	but still threads out.
5	
6	Photos taken afterwards
7	Videotapes taken, but cassette full &
8	stopped before end of test.
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

Test Engineer [signature] QA Witness [signature]

Project Engineer [signature]

Horizontal Shock Test Data Sheet

Titan Serial Number 002 Date 93/07/08

Orientation impact against bottom of projector.

Trial Number	Observations
1	
2	
3	
4	
5	
6	
7	20 impacts
8	Δh = 10.5 cm minimum.
9	bottom of camera is dented.
10	No cracks, tears or significant damage
11	videotaped all trials.
12	Photos before & after.
13	
14	
15	
16	
17	
18	
19	
20	

Test Engineer [signature] QA Witness [signature: G. Murphy]

Project Engineer [signature]

Horizontal Shock Test Data Sheet

Serial Number 002 Date 93/07/14

Orientation face of lock, against bumper pin.

Trial Number	Observations
1	
2	
3	
4	
5	
6	20 impacts, some hit 1 pin, some hit both pins,
7	Δh = 10.5 cm (all on video tape).
8	photos before
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

Test Engineer [signature] QA Witness [signature]

Project Engineer [signature]

Horizontal Shock Test Data Sheet

Serial Number 002*   Date 93/07/26

Orientation against side of selector ring

Trial Number	Observations
1	20 impacts
2	
3	Δh = 10.5 cm.
4	test recorded on video tape.
5	
6	M. Krzaniak, B Menna, G Murphy present
7	
8	Projector tested afterward.
9	Selector ring slightly stiff to turn at
10	first. Locks automatically.
11	Stiffness caused by burrs on outer ring.
12	
13	
14	
15	
16	
17	
18	
19	
20	

Test Engineer Blair Menna   QA Witness G Murphy

Project Engineer M Krzaniak

* inner plate and shield from S/N 003.

Horizontal Shock Test Data Sheet

1 Serial Number 002* Date 93/07/26

Orientation against face of selector ring (push-button lock bumpers).

Trial Number	Observations
1	20 impacts
2	Δh = 10.5cm
3	test recorded on videotape
4	set up photographed
5	M. Krzaniak, B Menna, G Murphy present
6	
7	Projector tested afterwards. Selector Ring turns
8	smoothly & lock automatically.
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

Test Engineer Blair Menna QA Witness G Murphy

Project Engineer Mkrzaniak

* shield & inner plate traded from S/N 003

APPENDIX H

Penetration Test Data Sheet

Penetration Test Data Sheet

TITAN S/N 003

Impact Area	Observations
bottom of the exposure device	solid hit. Shell dented (TITAN balanced up side down on handle)
side of the exposure device	solid hit. shell dented.
front of lock	SGT end cap removed. TITAN balanced on end struck first on end cap. 2NDary hit on face of lock.
side of lock	2 trials req'd. 2ND hit good. dents on 2 scallops.

Date 93/07/14 Test Engineer Blair [signature]

QA Witness [signature] Project Engineer [signature]

AECL EACL

AECL Research EACL Recherche

Engineering and Design Division Design Document

Classification/ Designation: Proprietary/Nordion

[X] Chalk River Laboratories
Chalk River Ontario
Canada K0J 1J0

[ ] Whiteshell Laboratories
Pinawa, Manitoba
Canada R0E 1L0

DOCUMENT TITLE: Summary of Test Results

PROJECT/JOB TITLE: Titan GRED Drop Testing

DOCUMENT TYPE: Technical Note

Prepared By	R.J. Lesco (signature)	Date	93/08/01
Reviewed By		Date	
Approved By	E.W. Butterworth (signature)	Date	93 8 12
Accepted By		Date	
Accepted By		Date	

(Signatories for Rev. 0 only)

Design Job No. 13,324

Document No. A-13324-TN-1

Revision No. 0

Alternate Document No.

CRL-3554-1-Rev.2

AECL EACL

Document Status and Revision History

AECL Research EACL Recherche

TITLE: Titan Gred Drop Testing Summary of Test Results	Job No. 13,324 Document No. A-13324-TN-1 Sheet No. 1 of

Rev. No. / Date	Revision History and ECN reference	Prepared / Reviewed	Approved / Accepted

Iss. No.	Rev. No.	DTS No.	Date	ISSUE/STATUS	By
1	0	1	93.7.19	Issued for Information	RJL

SUMMARY OF TEST RESULTS

TITAN GRED DROP TESTING

TECHNICAL NOTE

TEST SUMMARY

This technical note summarizes the drop testing conducted on the Titan Gamma Radiography Exposure Device (GRED) developed by Nordion for Quality NDE of Montreal.

Two prototype devices (serial numbers 002 and 003) were tested as follows:

TEST 01	1.05 m Puncture Test onto Lock Assembly of S/N 003
TEST 02	1.05 m Puncture Test onto Lock Assembly of S/N 003 (Repeat of TEST 01)
TEST 03	1.05 m Puncture Test onto Lock Assembly of S/N 002
TEST 04	9.45 m Upright (Flat Bottom) Drop Test of S/N 002
TEST 05	9.45 m Oblique Drop Test onto Handle of S/N 002
TEST 06	9.45 m Vertical Drop Test onto Lock of S/N 003

The drop height was increased by 5% from normal regulatory drop heights to compensate for the differences in weight between the prototype devices (42.5 lbs) and the production devices.

The results of each test are recorded on the attached drop test record sheet. A visual record of the testing can also be found on the following films and photographs:

- High Speed Films AVC No.
- Normal Speed Video AVC No.
- Photographs, 9307-21627-1 to 40

Identification No. TEST 01.

TITAN GRED DROP TEST RECORD SHEET

page 1-1

TEST COMPONENTS:

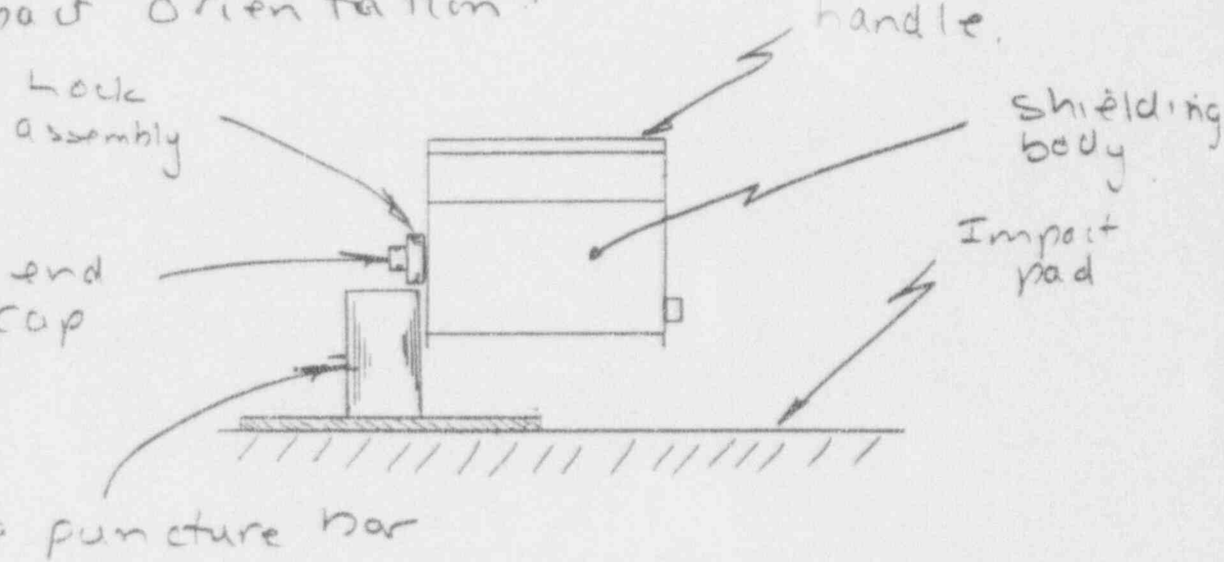
GRED S/N 003

TEST DESCRIPTION:

TEST 01 - 1.05 m Puncture Test onto Lock assembly of S/N 003

TEST OBSERVATIONS:

Impact Orientation*



* On impact it appeared that the puncture bar miss the lock assembly and impacted the end cap

Prepared By: R [signature]

Date: 93/07/16

Identification No. TEST 01

TITAN GRED DROP TEST RECORD SHEET (Cont'd)

Page 1-2

TEST OBSERVATIONS: (Continued)

Condition of Package after Test

- there was a slight marking of the end cap
- one foot was slightly bend outwards
- no visible damage to main body welds

Prepared By: [signature]

Date: 93/5/16

Identification No. TEST 02

TITAN GRED DROP TEST RECORD SHEET

Page 2-1

TEST COMPONENTS:

GRED S/N 003

TEST DESCRIPTION:

TEST 02 - Repeat of Test 01
(1.05 m puncture test onto lock assembly of S/N 003)

TEST OBSERVATIONS:

Impact orientation
- same as Test 01

Condition of package
- no significant damage
- slight marking of end cap
- no visible damage to body welds

Prepared By: [signature]

Date: 93/07/16

Identification No. TEST 03

TITAN GRED DROP TEST RECORD SHEET

page 3-1

TEST COMPONENTS:

GRED S/N 002.

TEST DESCRIPTION:

Test 03 - 1.05m puncture test onto lock assembly of S/N 002.

TEST OBSERVATIONS:

Impact orientation

- same as Test 01

Condition of package.

- no significant damage.
- slight marking of end cap.
- no visible damage to body welds.

Prepared By: [signature]

Date: 93/07/16

Identification No. Test 04.

TITAN GRED DROP TEST RECORD SHEET

Page 4-1.

TEST COMPONENTS:

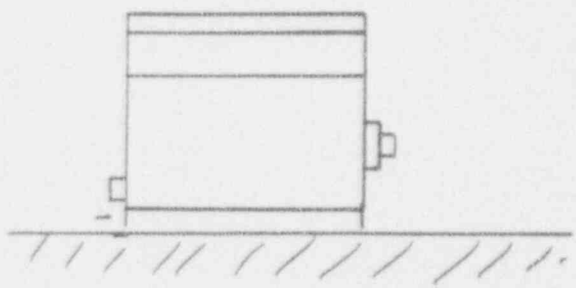
GRED S/N 002.

TEST DESCRIPTION:

TEST 04 - 9.45 m. Upright Test
(Bottom Impact).

TEST OBSERVATIONS:

Drop Test orientation (Impact orientation)



Condition of Package After Test

- two feet on one side were significantly bent (this would indicate that these two feet impacted first).
- One foot had a tear (1½" sector length) at the bend. (see sketch on pg 4-2)

Prepared By: RCsc[illegible]

Date: 93/01/16

Identification No. Test 04

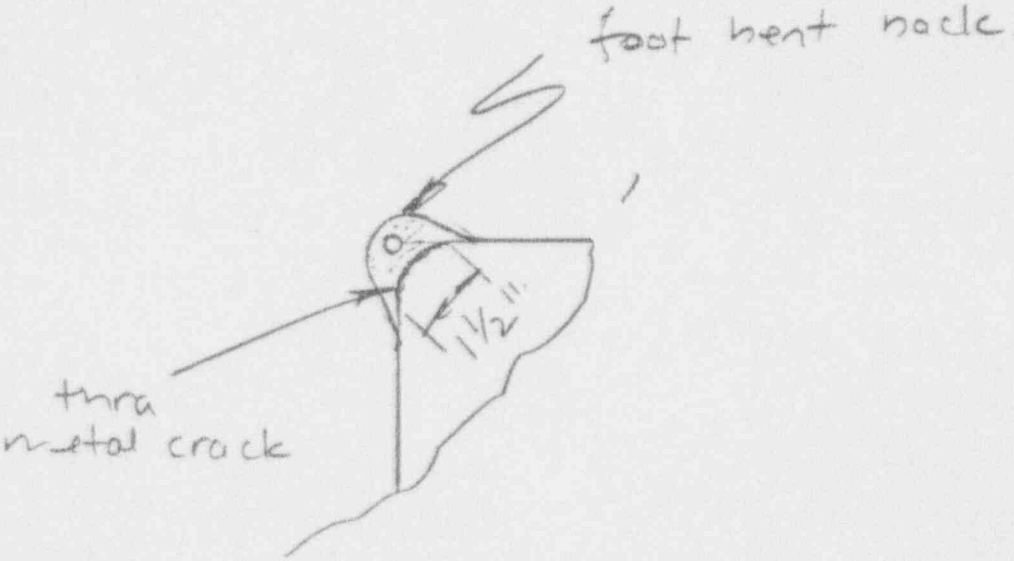
TITAN GRED DROP TEST RECORD SHEET (Cont'd)

Page 4-2

TEST OBSERVATIONS: (Continued)

Condition of Package (continued)

- there was no visible damage to external camera welds



Prepared By: Rw.

Date: 3/07/'6

Identification No. TEST 05

Page 5-1

TITAN GRED DROP TEST RECORD SHEET

TEST COMPONENTS:

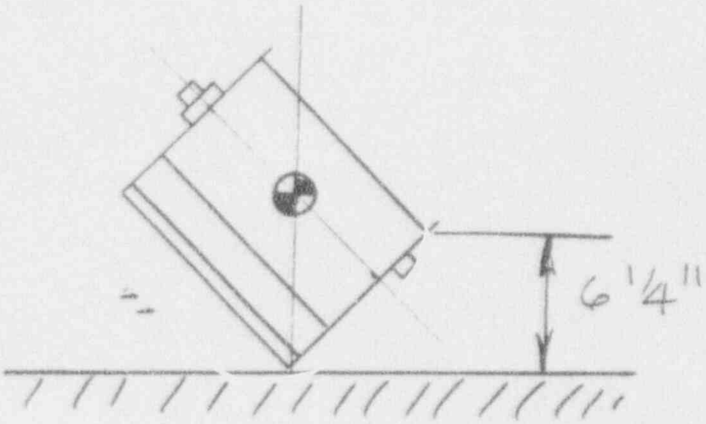
GRED S/N 002

TEST DESCRIPTION:

TEST 05 – 9.45m Oblique Angle Drop onto camera handle.

TEST OBSERVATIONS:

Drop Test Orientation (Impact Orientation)*



* This was the original pre-drop set-up. During the test, it appeared that the camera rotated in such a manner that impacted more to the side of the camera.

Prepared By: [signature]

Date: 93/01/16

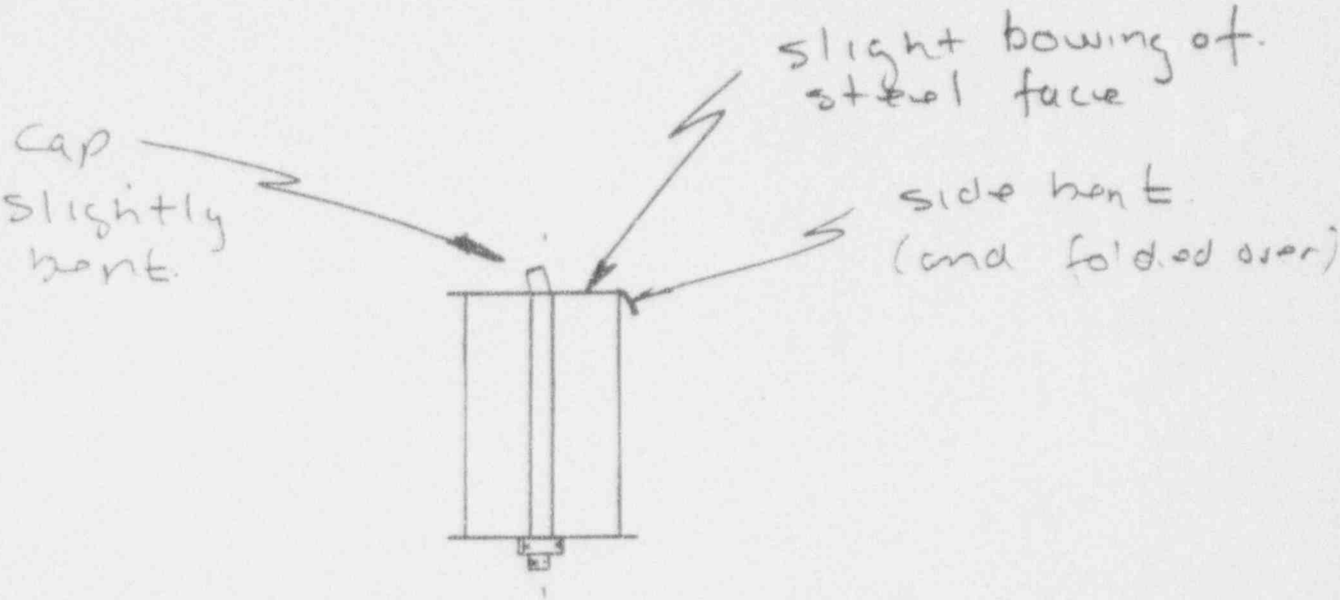
Identification No. TEST05

TITAN GRED DROP TEST RECORD SHEET (Cont'd)

Page 5-2

TEST OBSERVATIONS: (Continued)

Condition of Package After Test



- no damage to external camera welds

see photographs

Prepared By: [signature]

Date: 93/07/16

Identification No. TEST 06.

Page 6-1

TITAN GRED DROP TEST RECORD SHEET

TEST COMPONENTS:

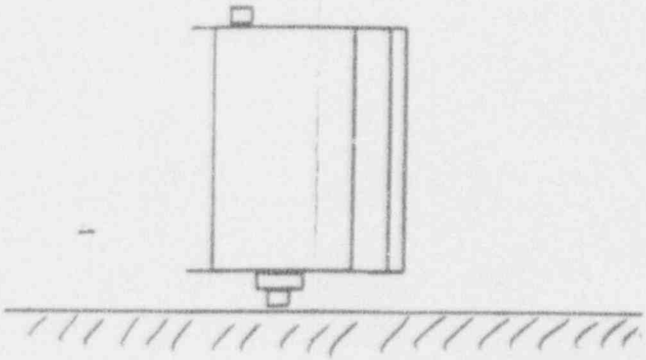
GRED S/N 003

TEST DESCRIPTION:

TEST 06 - 9.45m VERTICAL DROP ONTO CAMERA LOCK.

TEST OBSERVATIONS:

Drop Test orientation.



Condition of Package After test

- no damage to weld areas on body
- slight damage (bending) of one leg on impact side.

Prepared By: R.G.

Date: 97/07/16

Identification No. Test 06

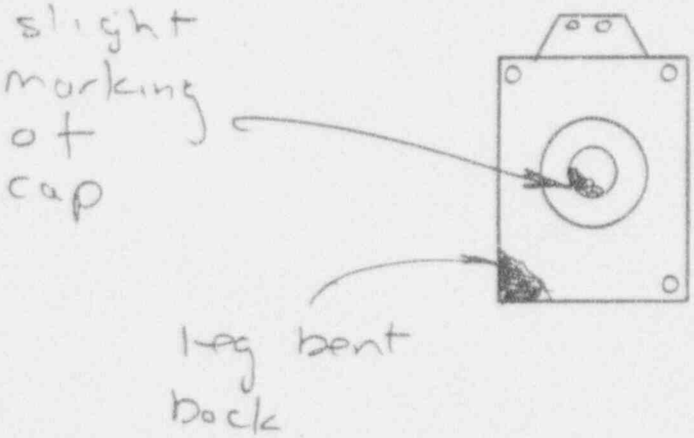
TITAN GRED DROP TEST RECORD SHEET (Cont'd)

pag 6-2

TEST OBSERVATIONS: (Continued)

Condition of Package (continued)

- slight marking of small diameter cap on front



See photographs.

Prepared By: RGW

Date: 93/07/16

[redacted]

TITAN GAMMA RAD[redacted]RAPHY EXPOSURE
DEVICE (GRED) DRO[redacted]STING CHECKLIST

Sheet 1 of [redacted]

APPROVALS		SIGNATURE	DATE	
Prepared by:	R.J. Lesco	R Lesco	93/07/15	Route Sheet No. A-13324-RS-1 Revision No. 0 Date: 93/07/15
Reviewed by:	R.D. Linton	R Linton	93/07/15	Reference Documents: Nordion Test Plan IS/DS 0055W990
Approved by:	E.W. Butterworth	E.W. Butterworth	93. 7. 15.	

NO.	RESPONSIBLE BRANCH	ACTIVITY	SIGNATURE	DATE
1	PMD	Receive two prototype units from Nordion. Record ID nos. S/N 002, SN/003	R Lesco	93/07/16.
2	PMD	Conduct ~~1m~~ 1.05 M 93/07/16 Puncture Test on Prototype No. 002 and 003	R Linton	93/07/16
3	PMD/TIS	Record actual test and record condition of unit after testing.	R Lesco	93/07/16.
4	PMD	Conduct ~~9m~~ 9.45 M Upright Drop Test on Prototype No. 002	R Linton	93/07/16
5	PMD/TIS	Record actual test and record condition of unit after testing.	R Lesco	93/07/16.
6	PMD	Conduct ~~9m~~ 9.45 M Oblique Drop Test on Prototype No. 002	R Linton	93/07/16
7	PMD/TIS	Record actual test and record condition of unit after testing.	R Lesco	93/07/16.
8	PMD	Conduct ~~9m~~ 9.45 M drop test directly onto lock of Prototype No. 003	Randy Linton	93/07/16
9	PMD/TIS	Record actual test and record condition of unit after testing.	R Lesco	93/07/16
10	PMD	Return prototypes to Nordion.	R Lesco	93/07/19
11	PMD	Final sign-off.	R Lesco	93/07/19

TEST 01   1.05 M PUNCTURE TEST ONTO LOCK ASSEMBLY OF S/N 003

PHOTO 1

PHOTO 2

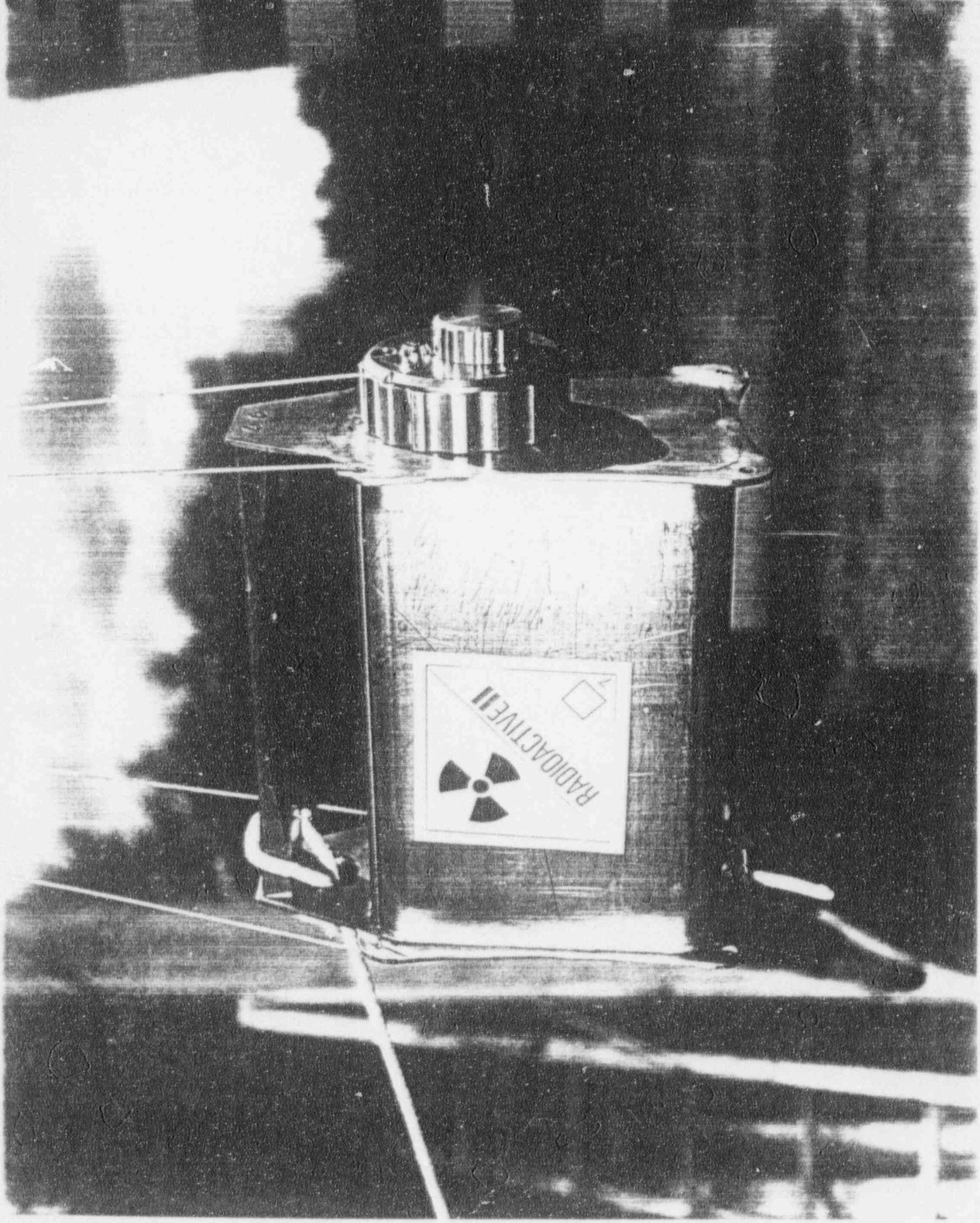


PHOTO 3

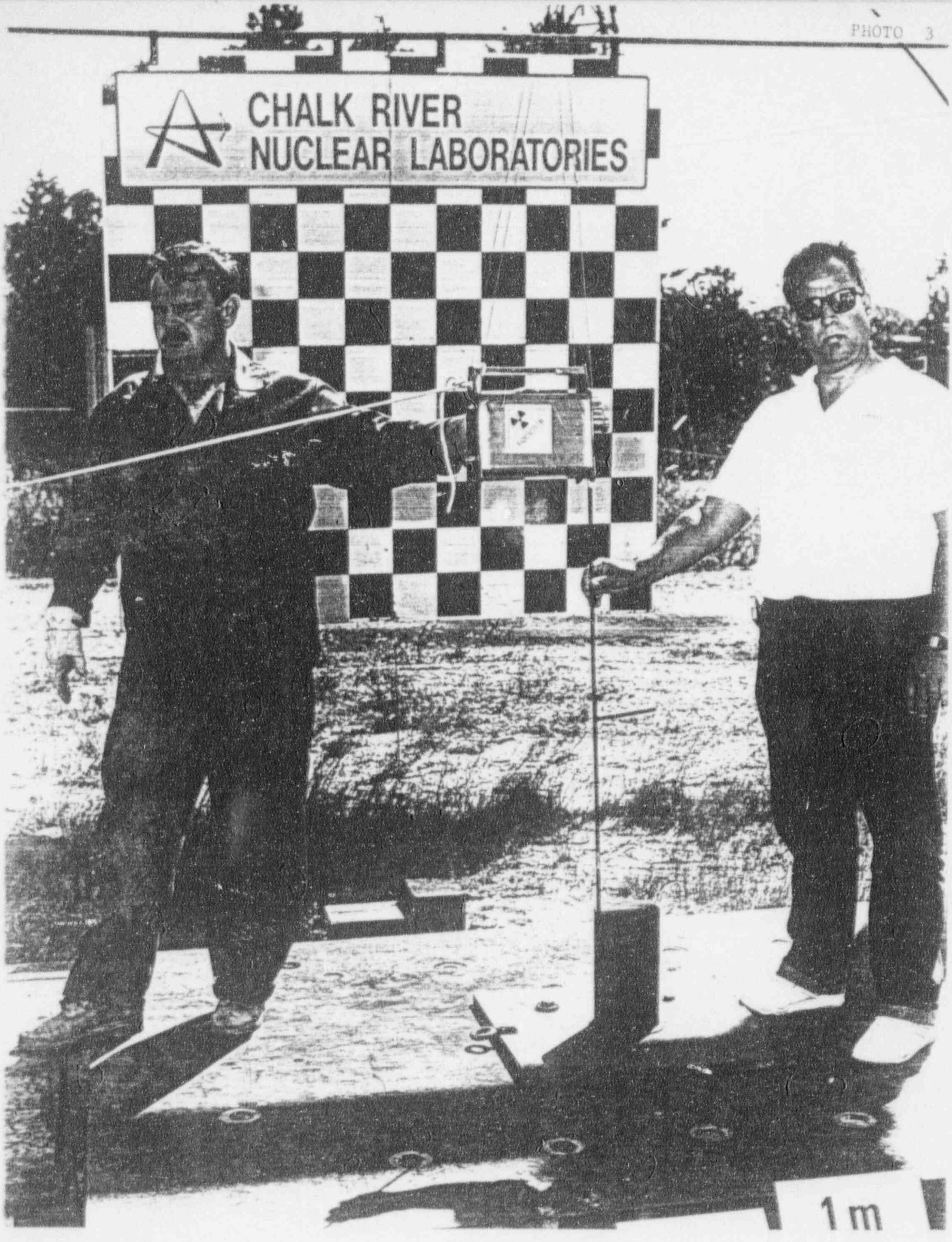


PHOTO 4

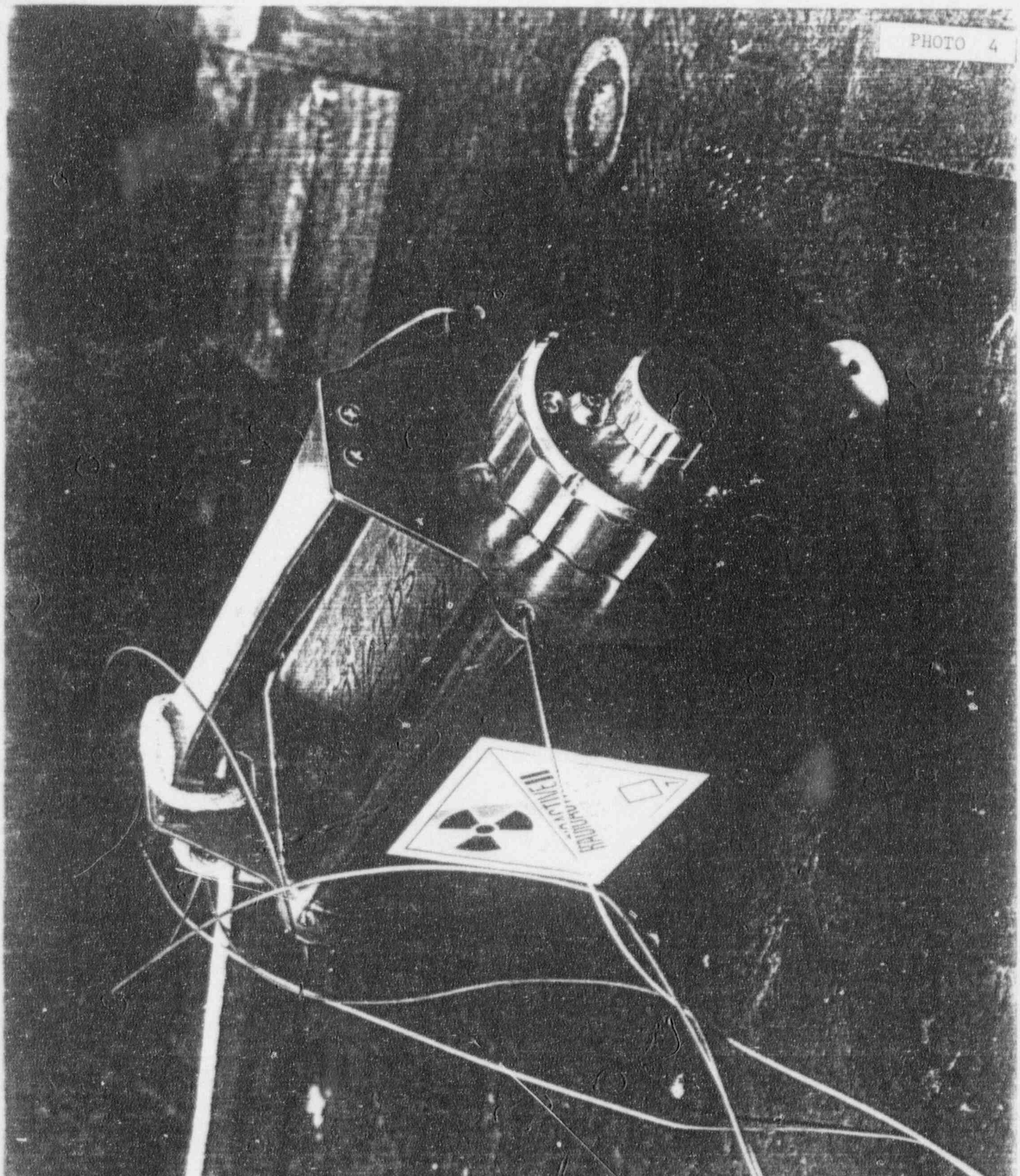
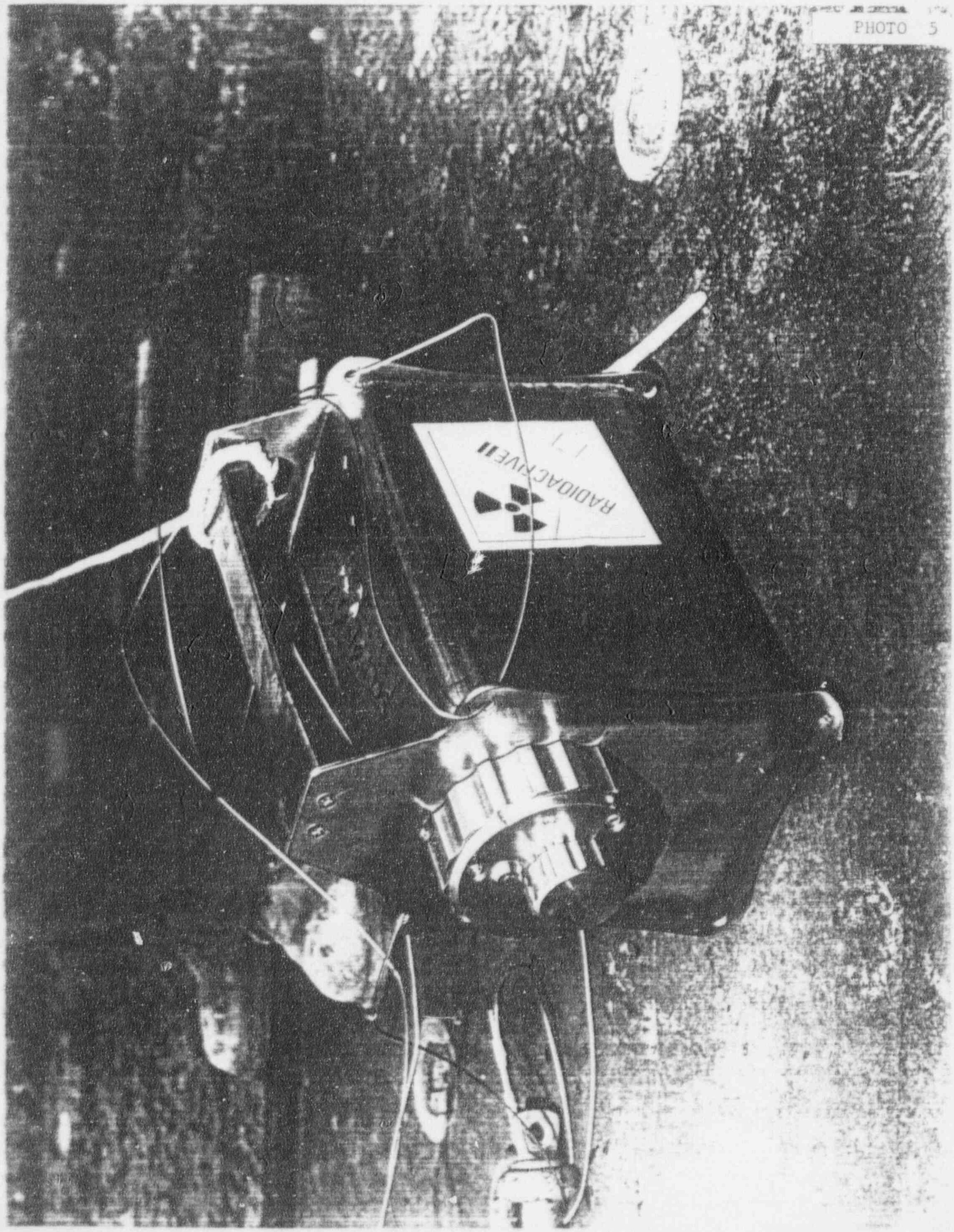


PHOTO 5



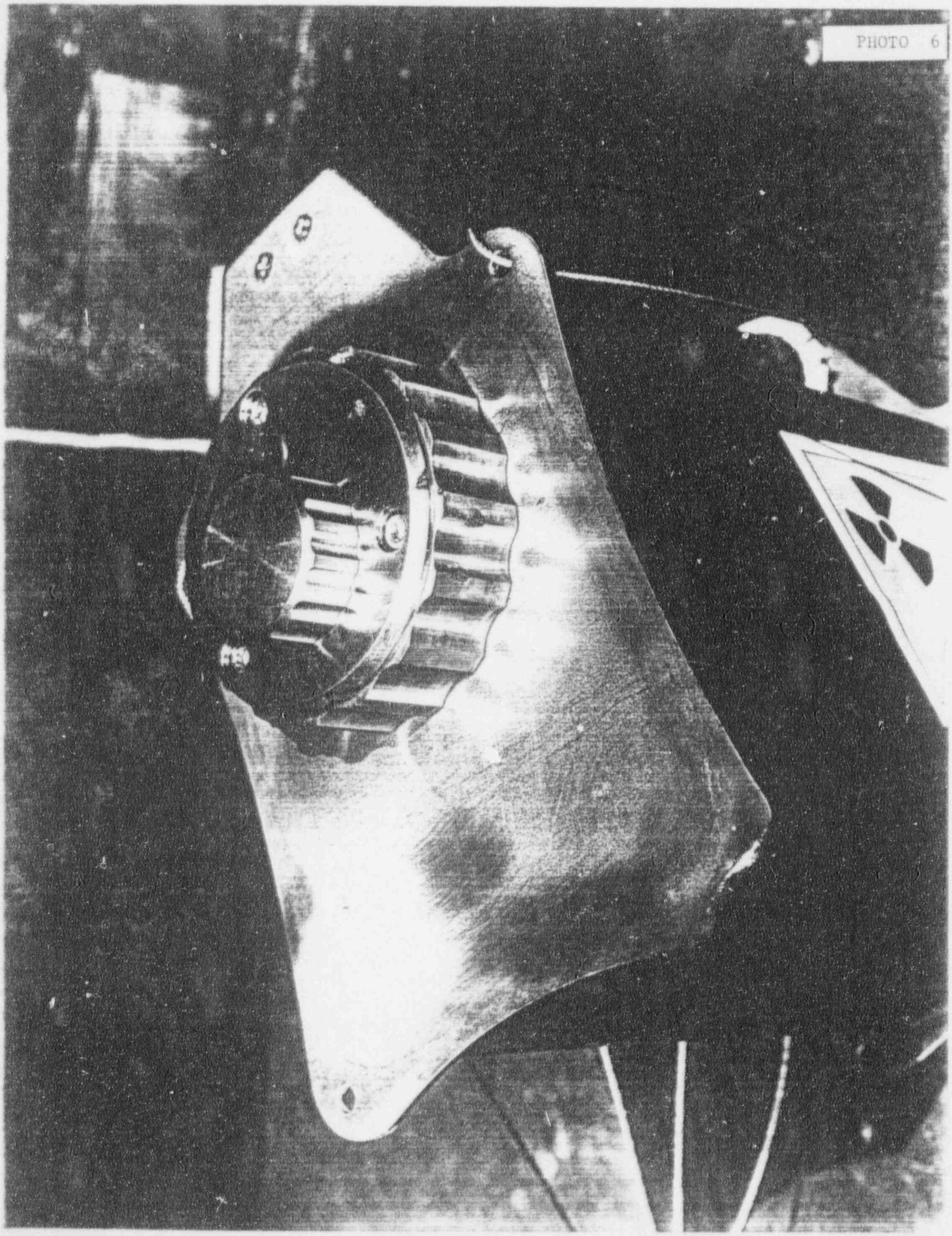


PHOTO 6

PHOTO 7

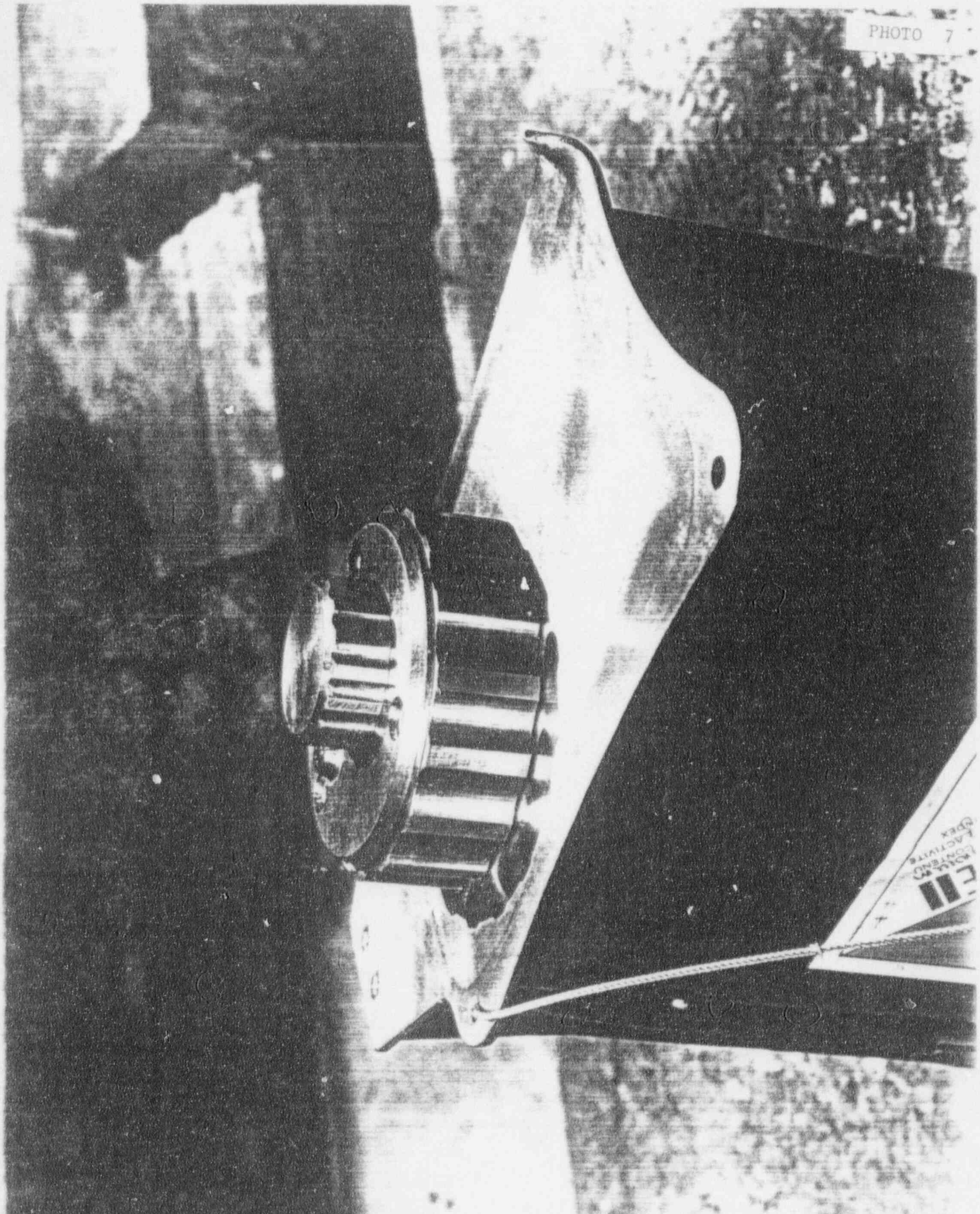
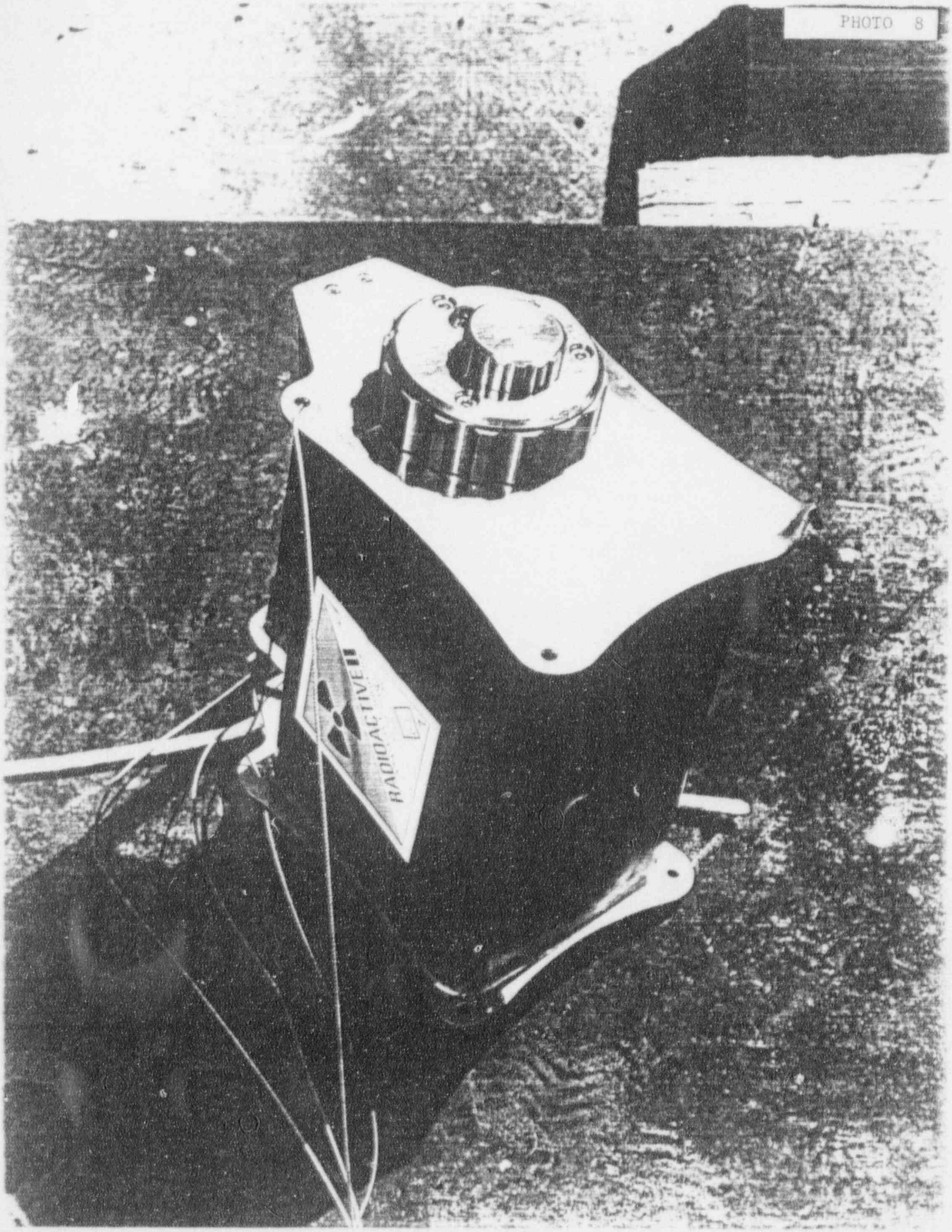


PHOTO 8



TEST 02 1.05 M PUNCTURE TEST ONTO LOCK ASSEMBLY OF S/N 003
(REPEAT OF TEST 01)

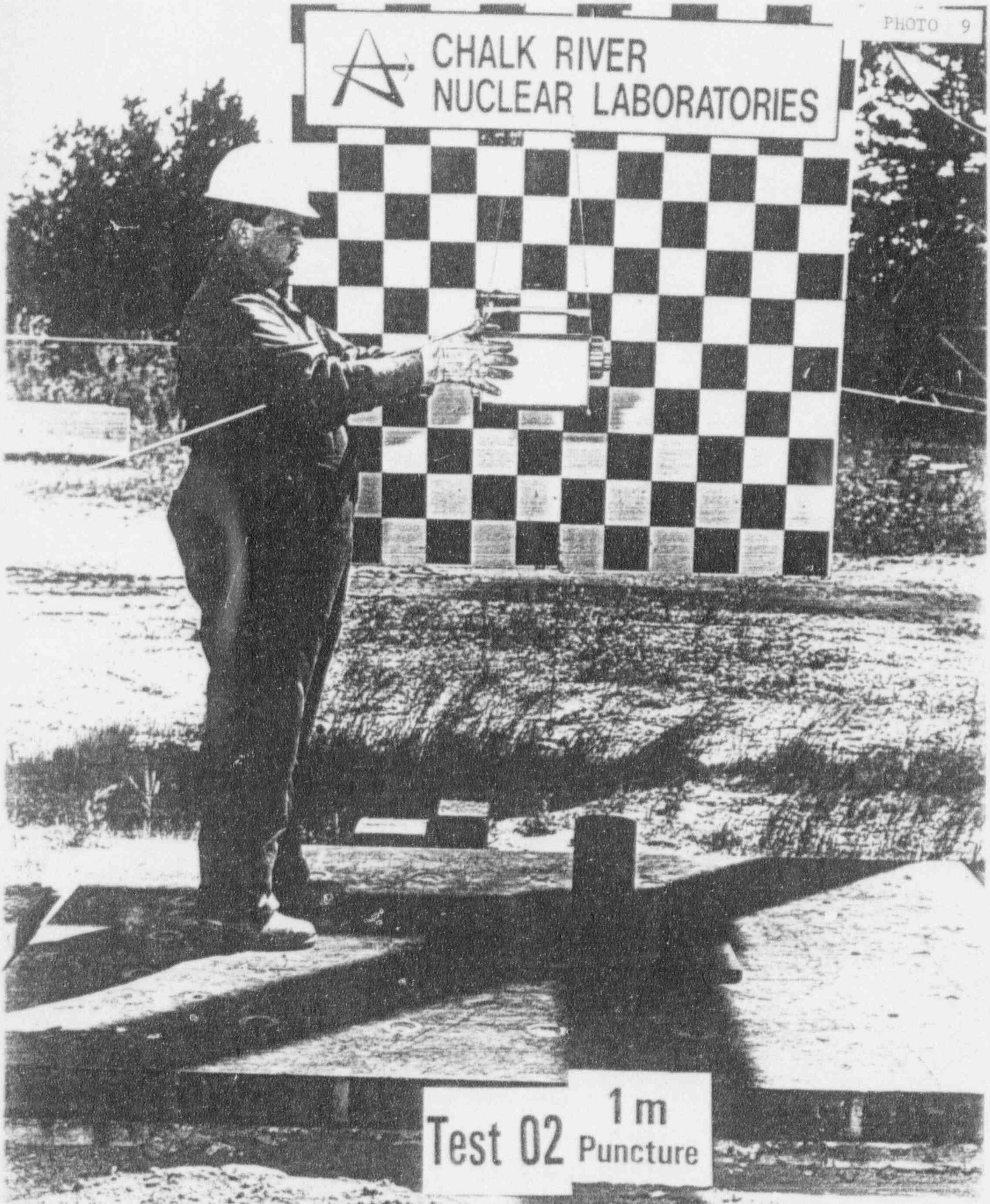


PHOTO 9
CHALK RIVER
NUCLEAR LABORATORIES
Test 02
1 m
Puncture

PHOTO 10

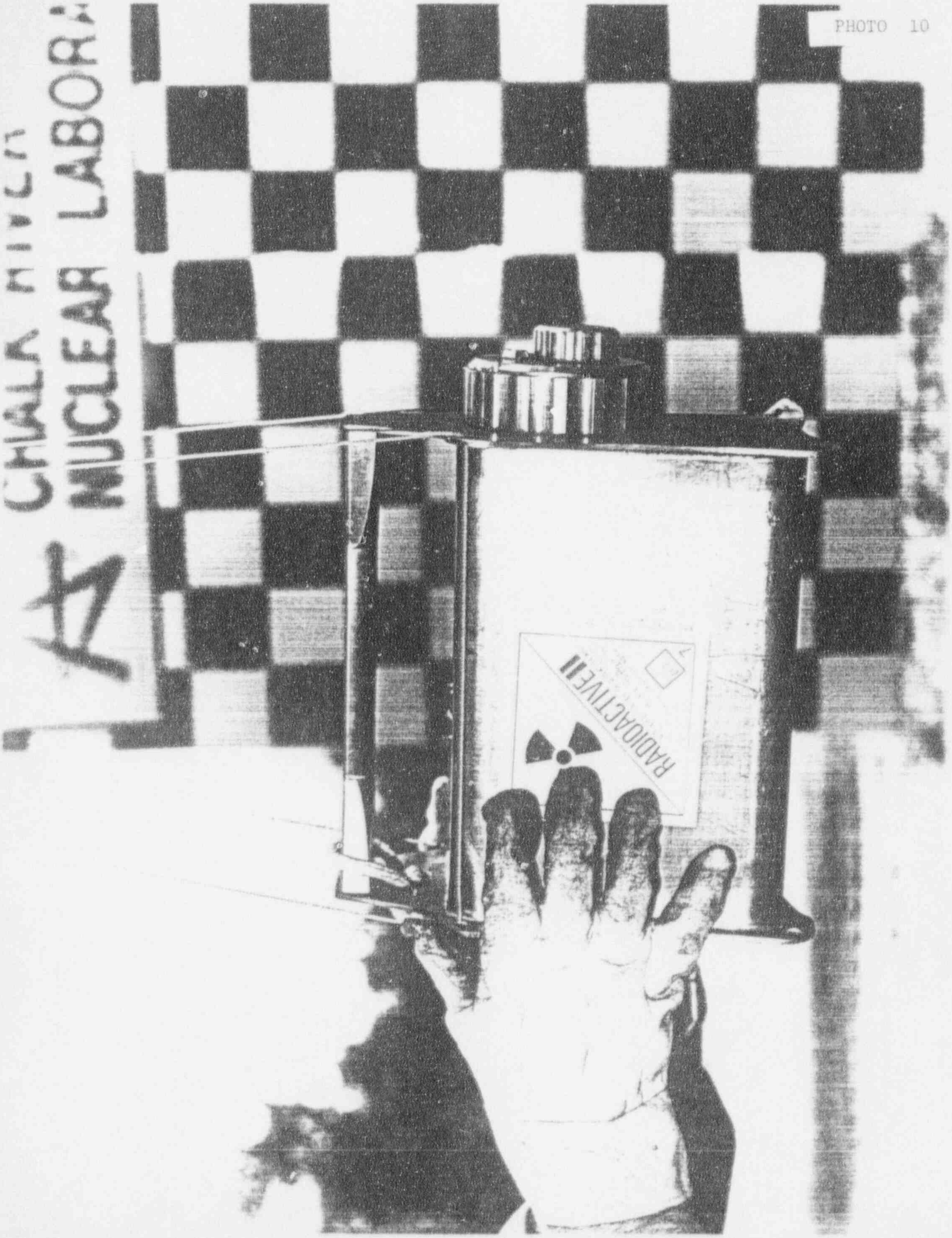
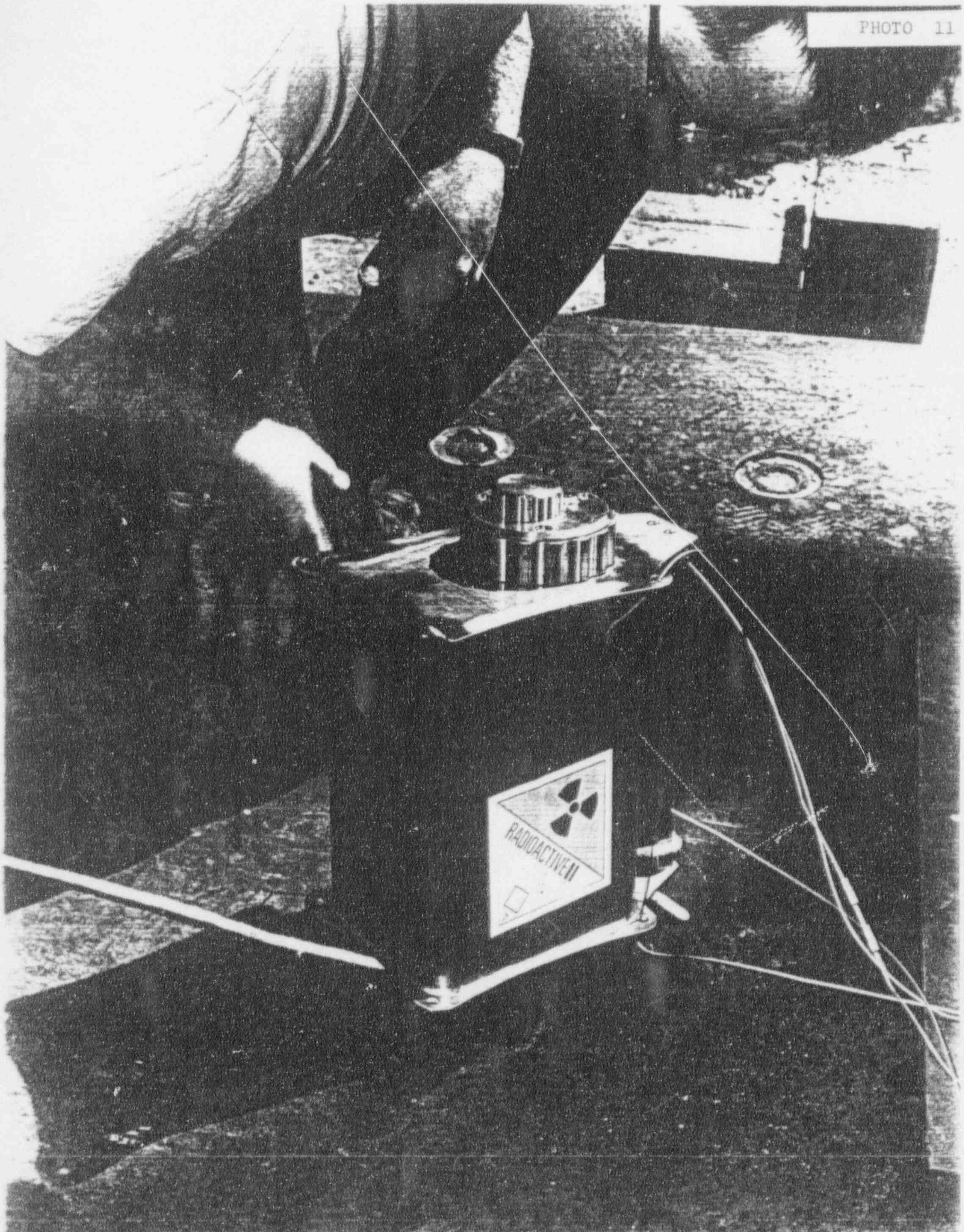


PHOTO 11



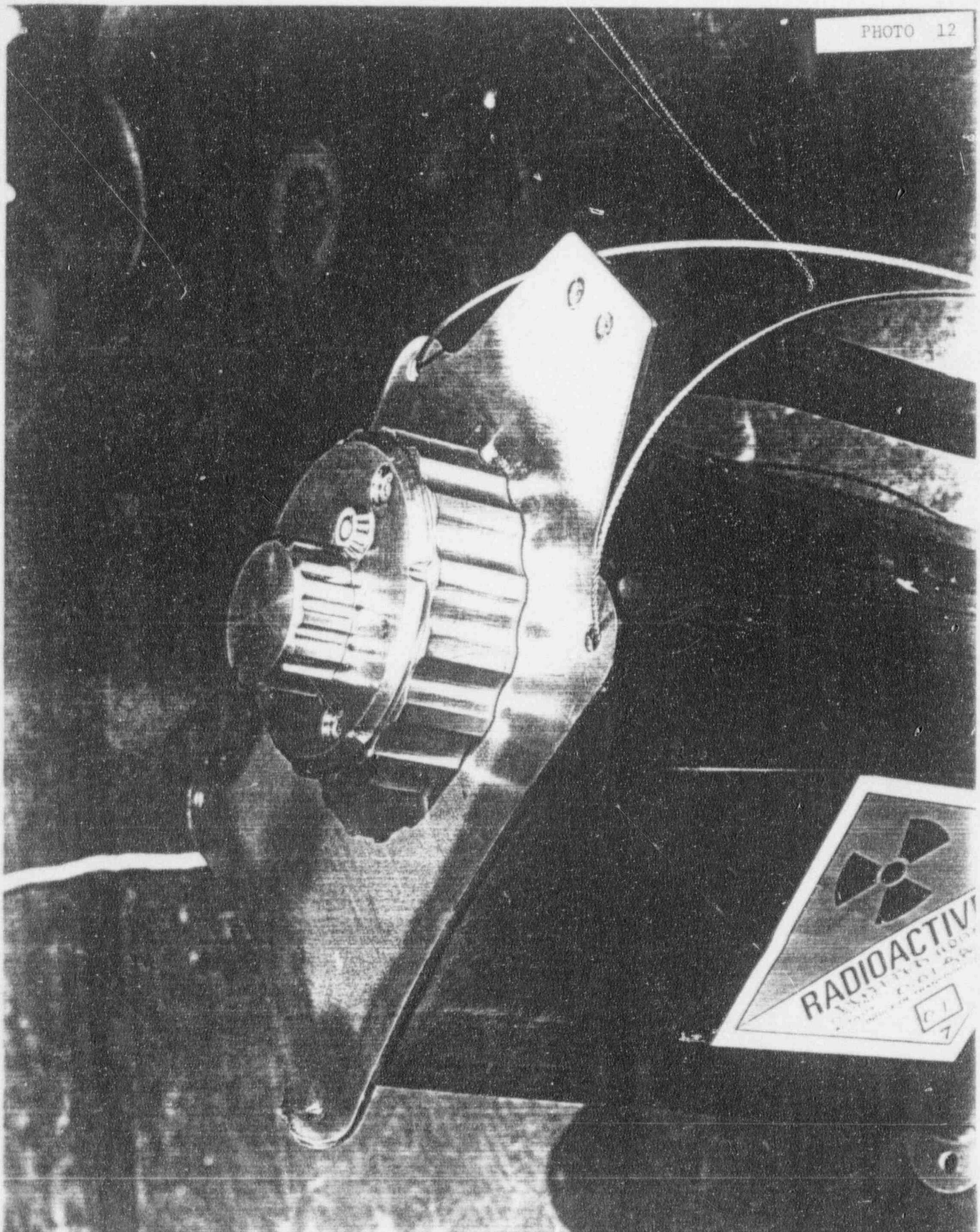


PHOTO 12

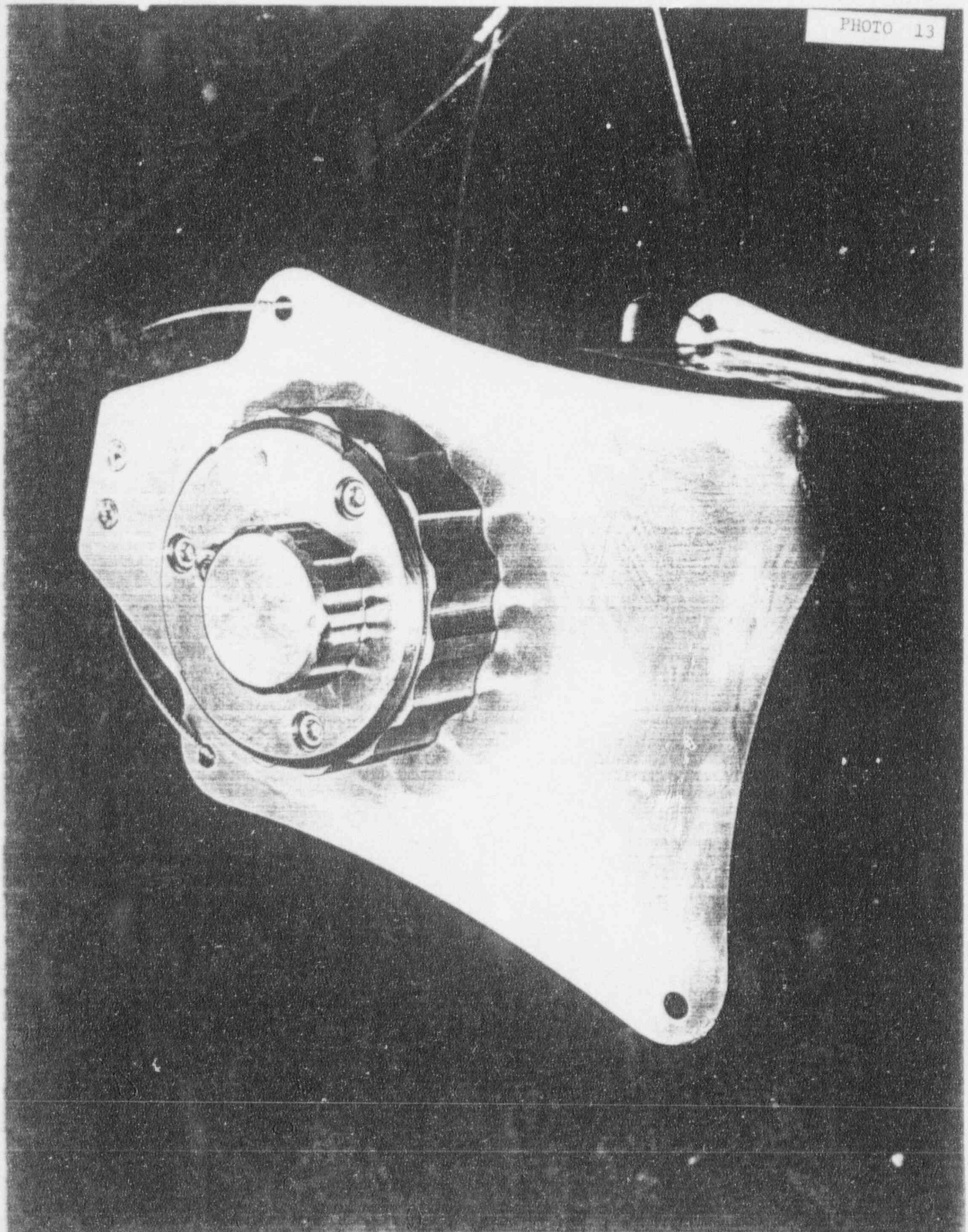
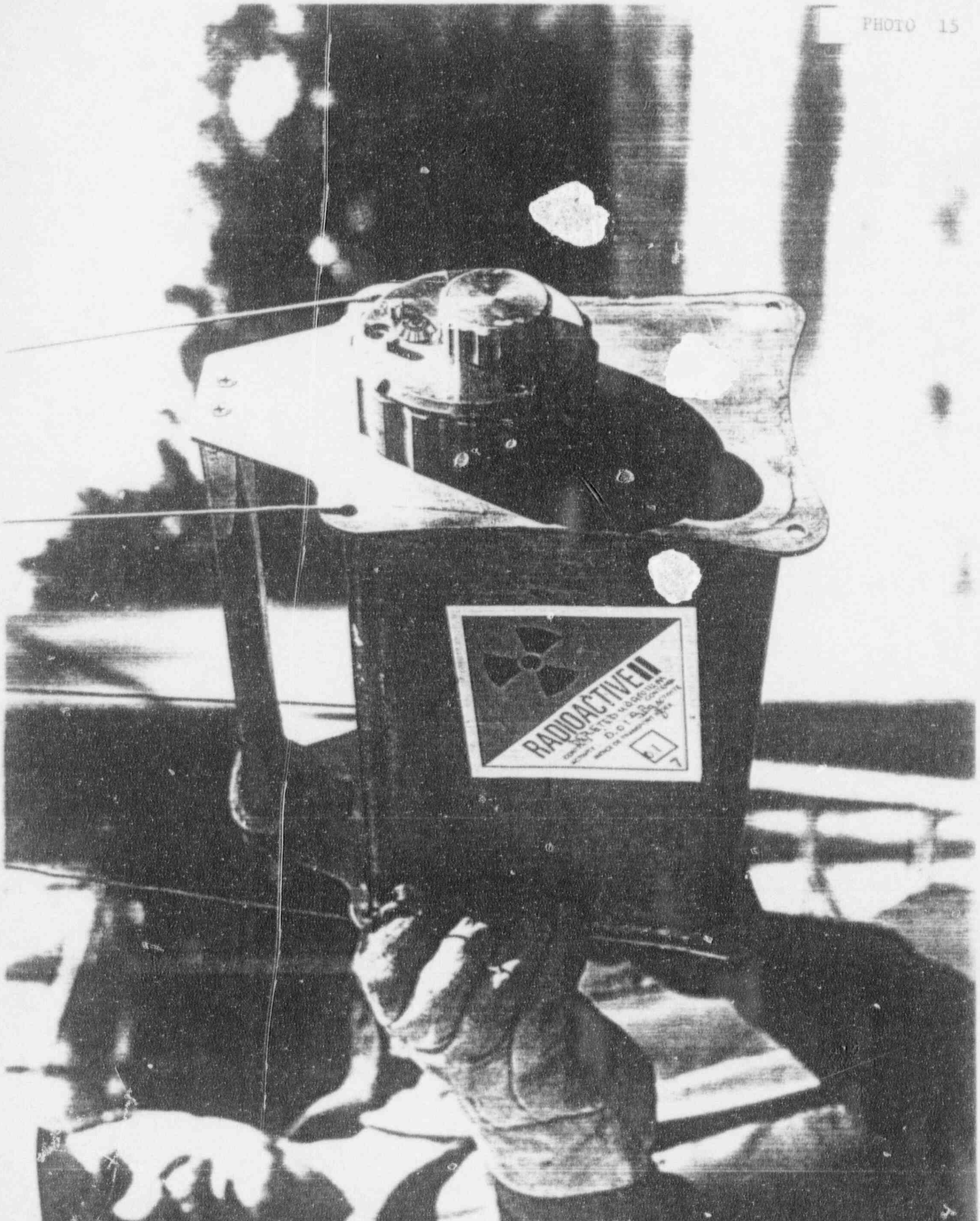


PHOTO 13

TEST 03 1.05 M PUNCTURE TEST ONTO LOCK ASSEMBLY OF S/N 002

PHOTO 14

PHOTO 15



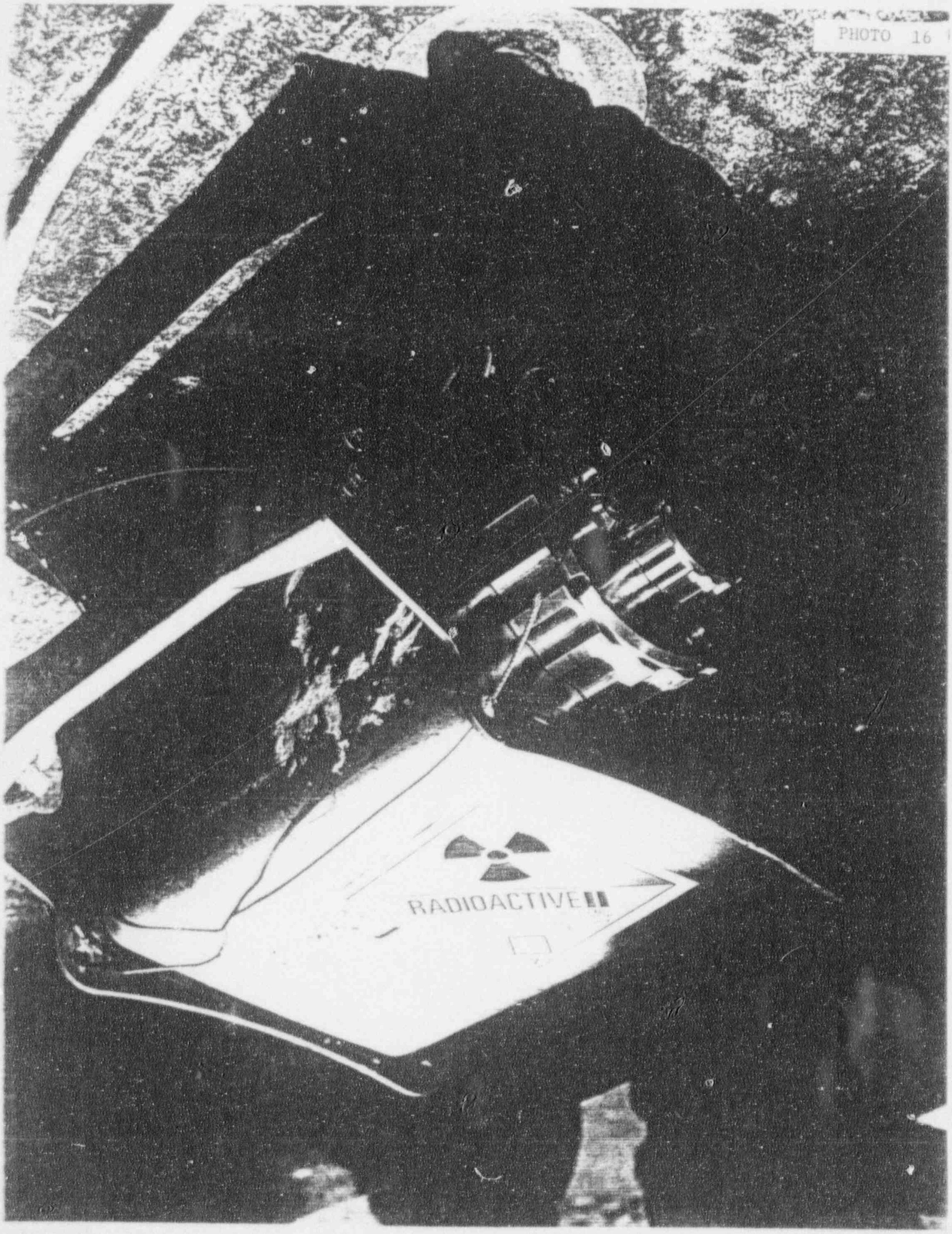


PHOTO 16
RADIOACTIVE

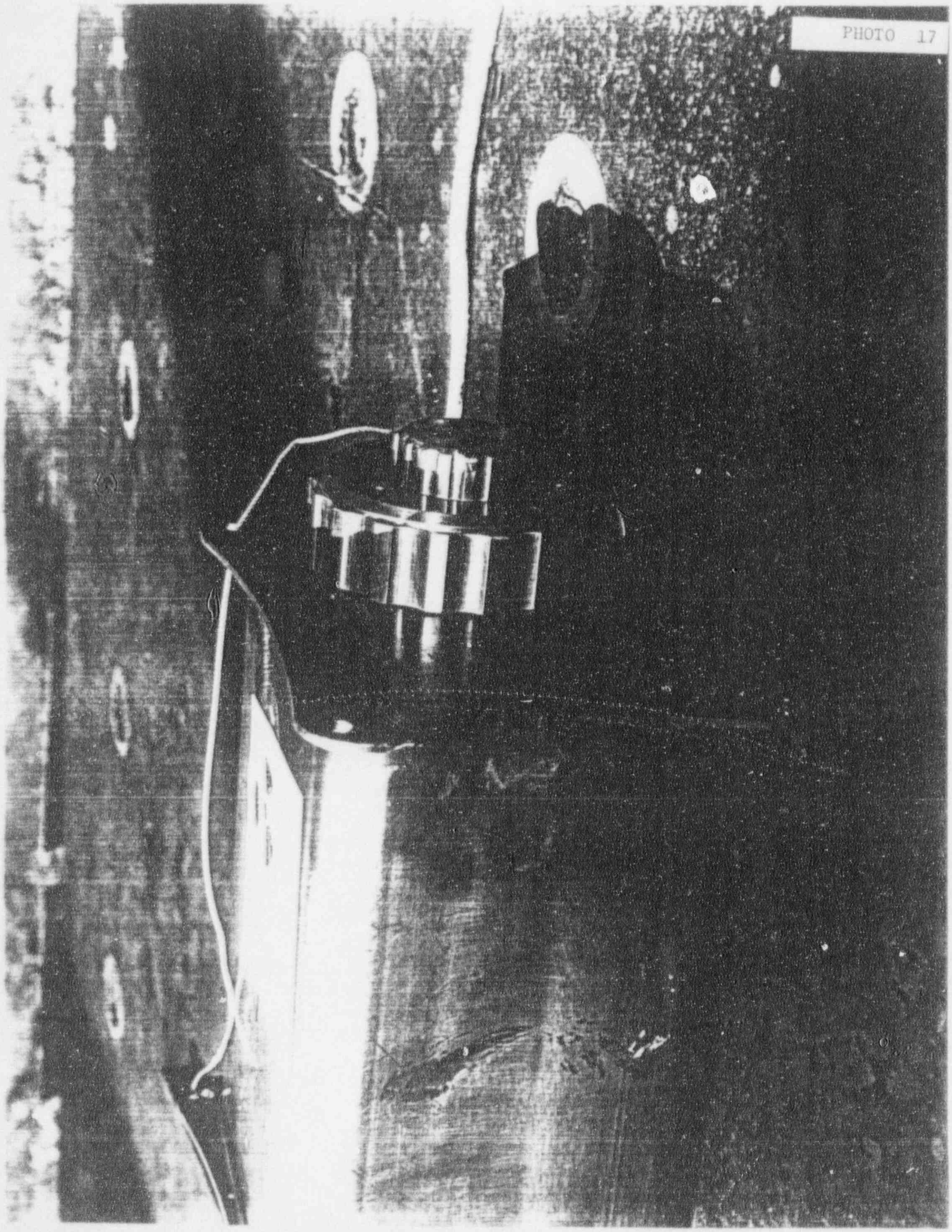


PHOTO 17

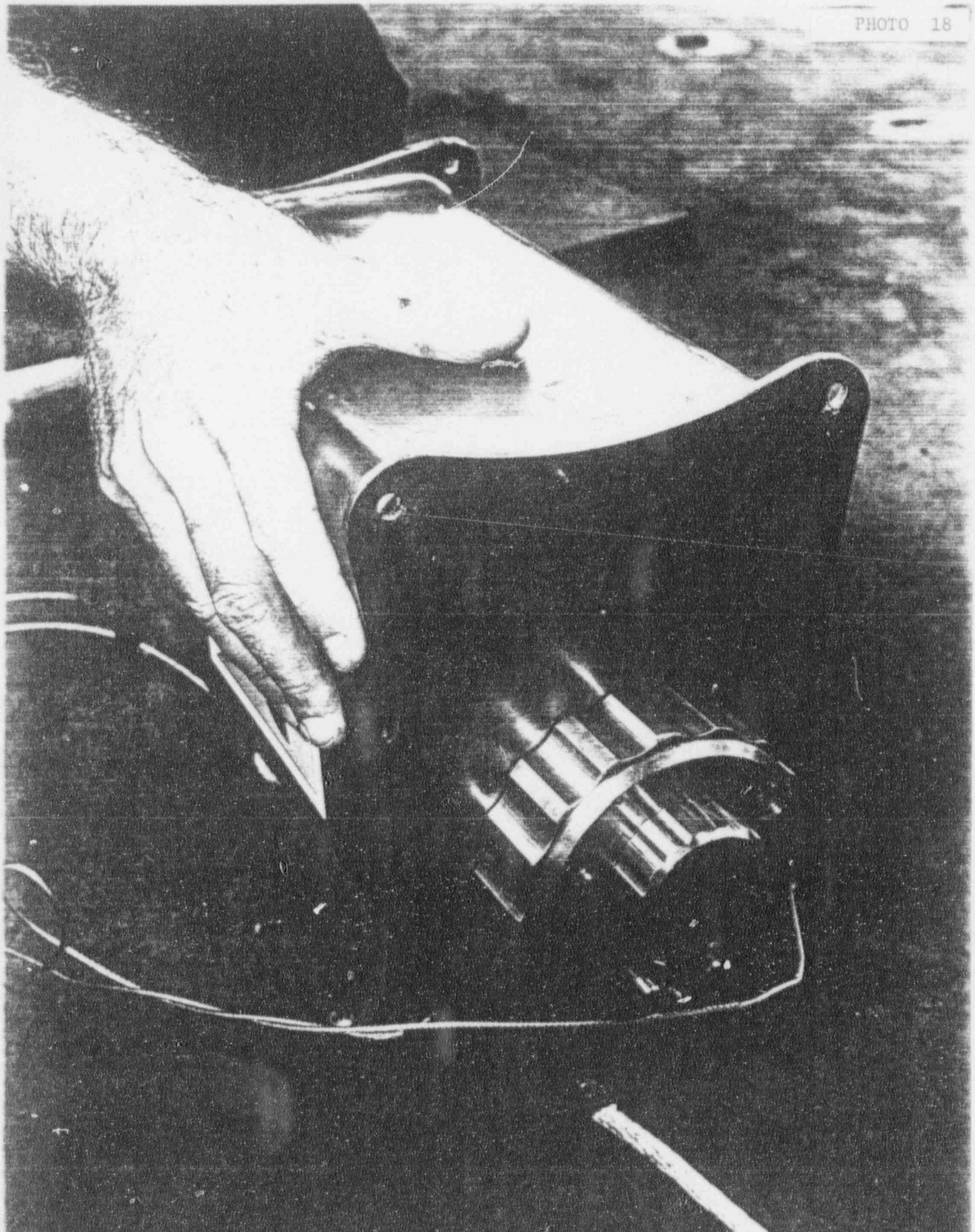


PHOTO 18

TEST 04 9.45 M UPRIGHT (FLAT BOTTOM)
DROP TEST OF S/N 002

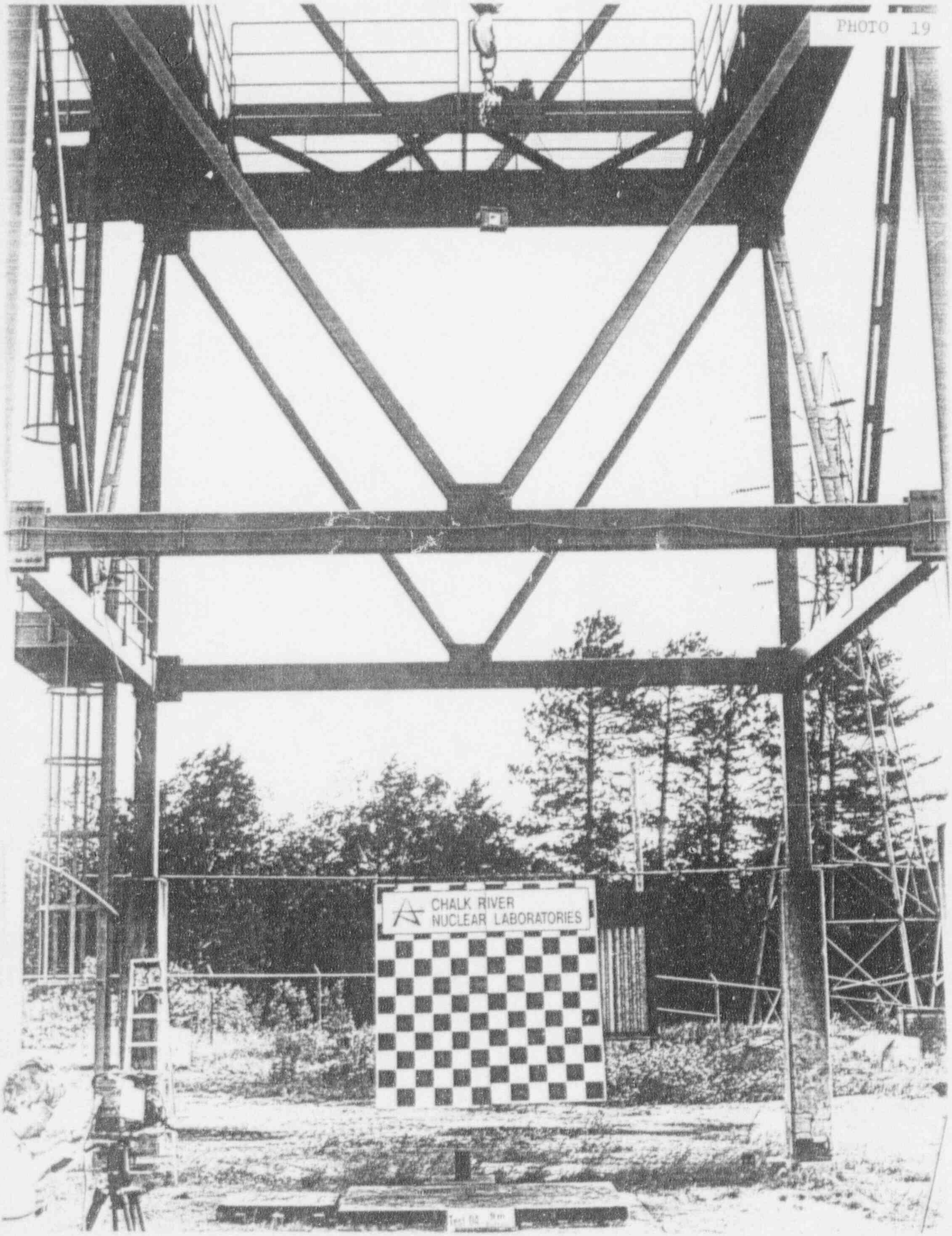
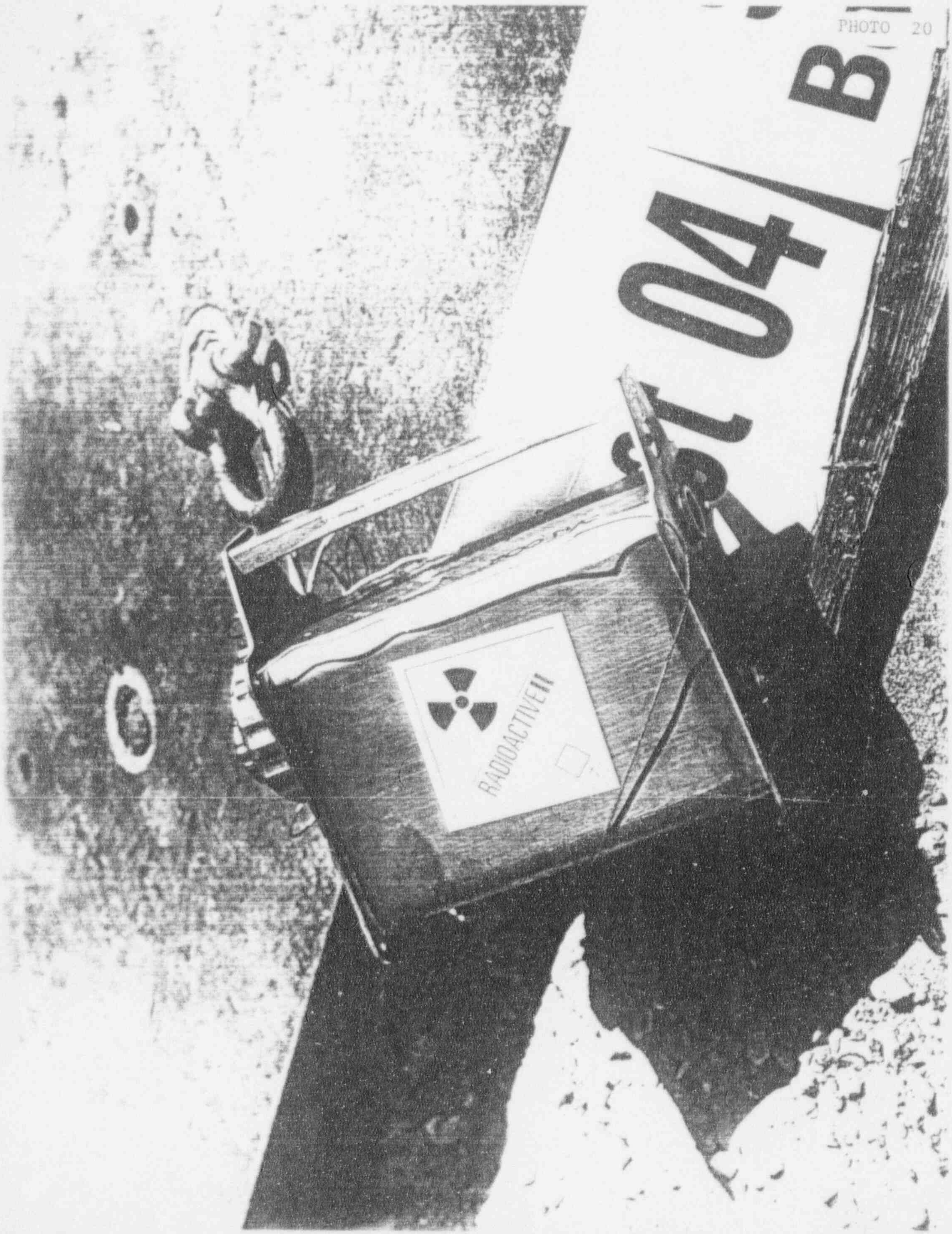


PHOTO 19

PHOTO 20



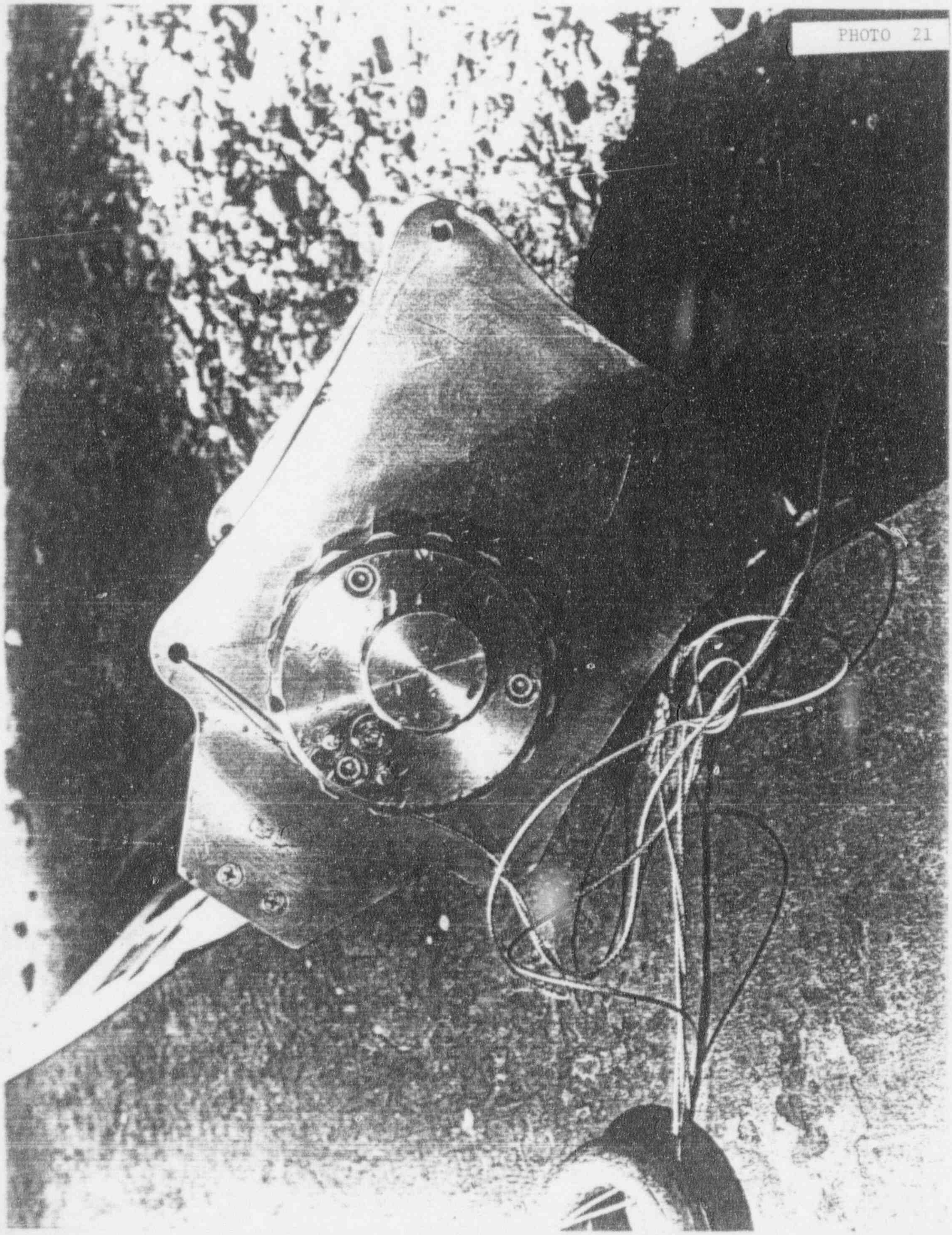


PHOTO 21

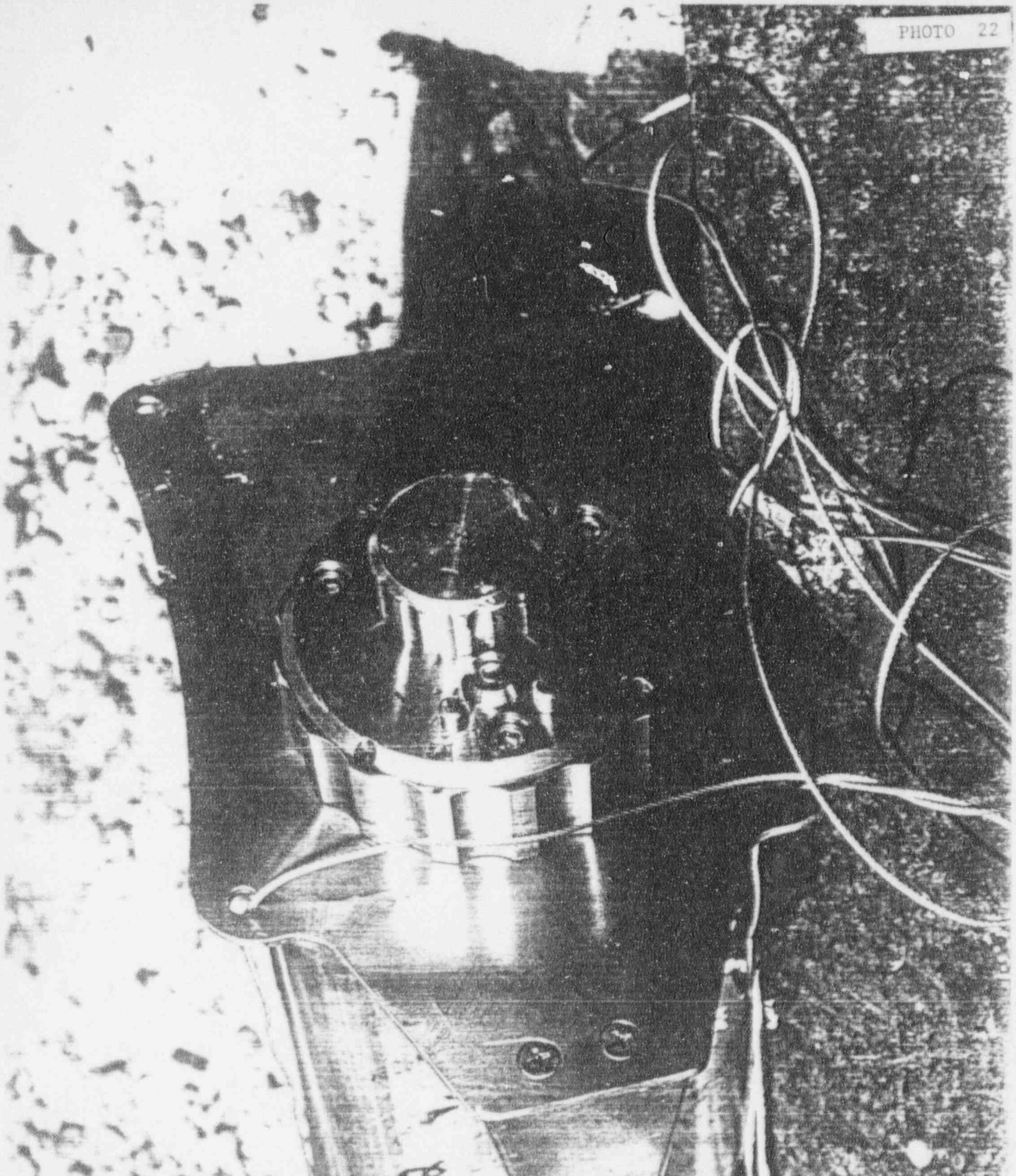


PHOTO 22

PHOTO 23

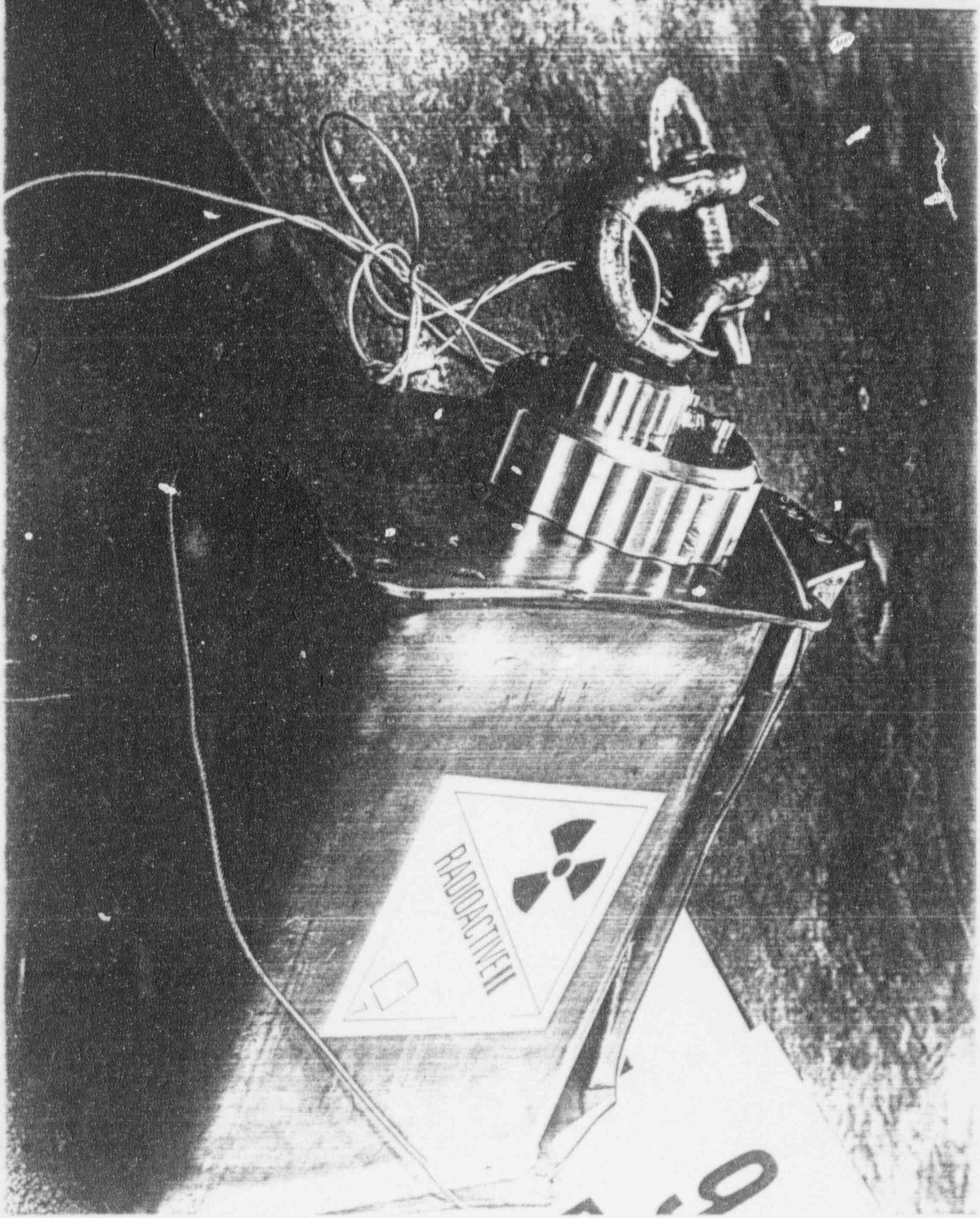
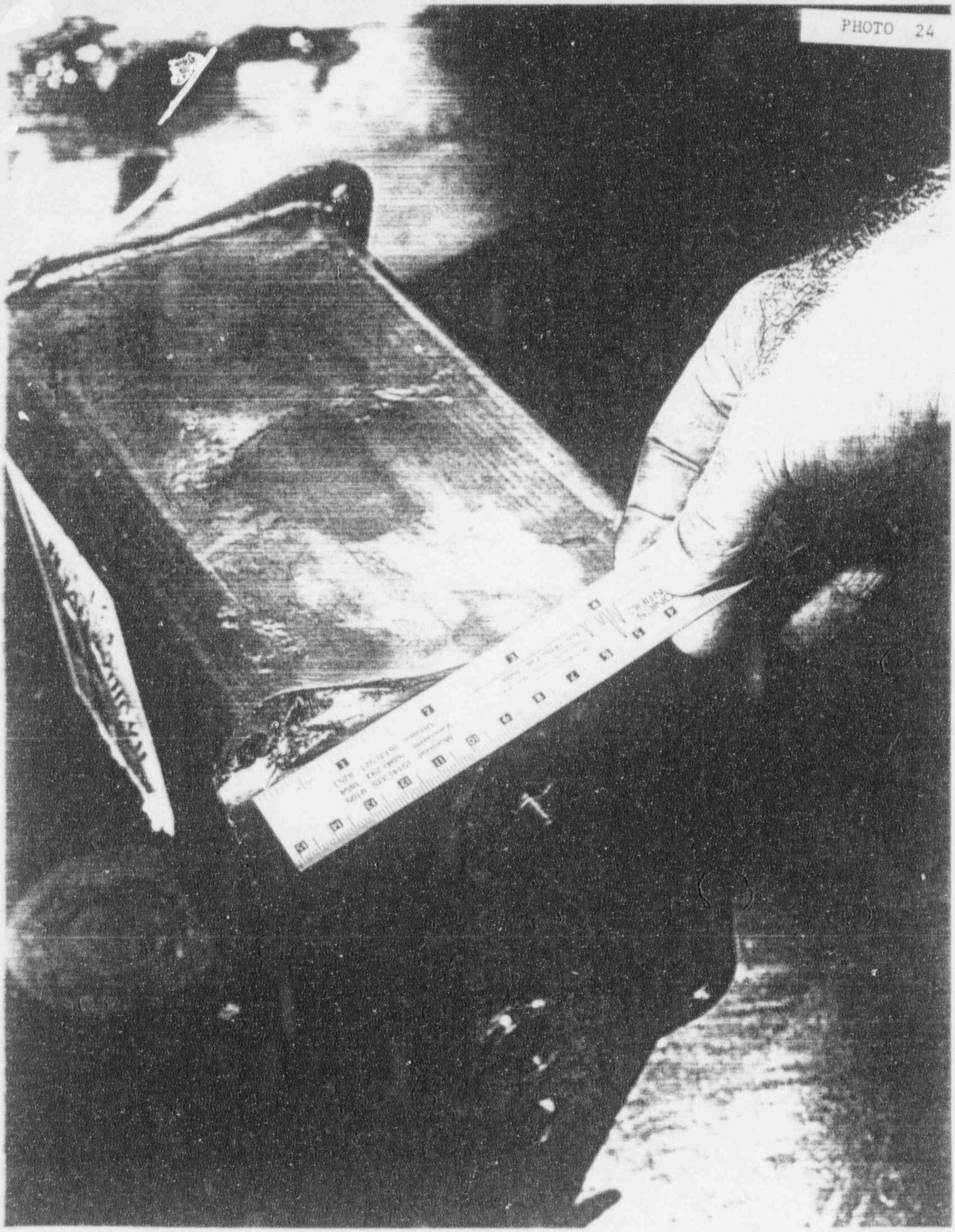


PHOTO 24



TEST 05 9.45 M OBLIQUE DROP TEST ONTO HANDLE OF S/N 002

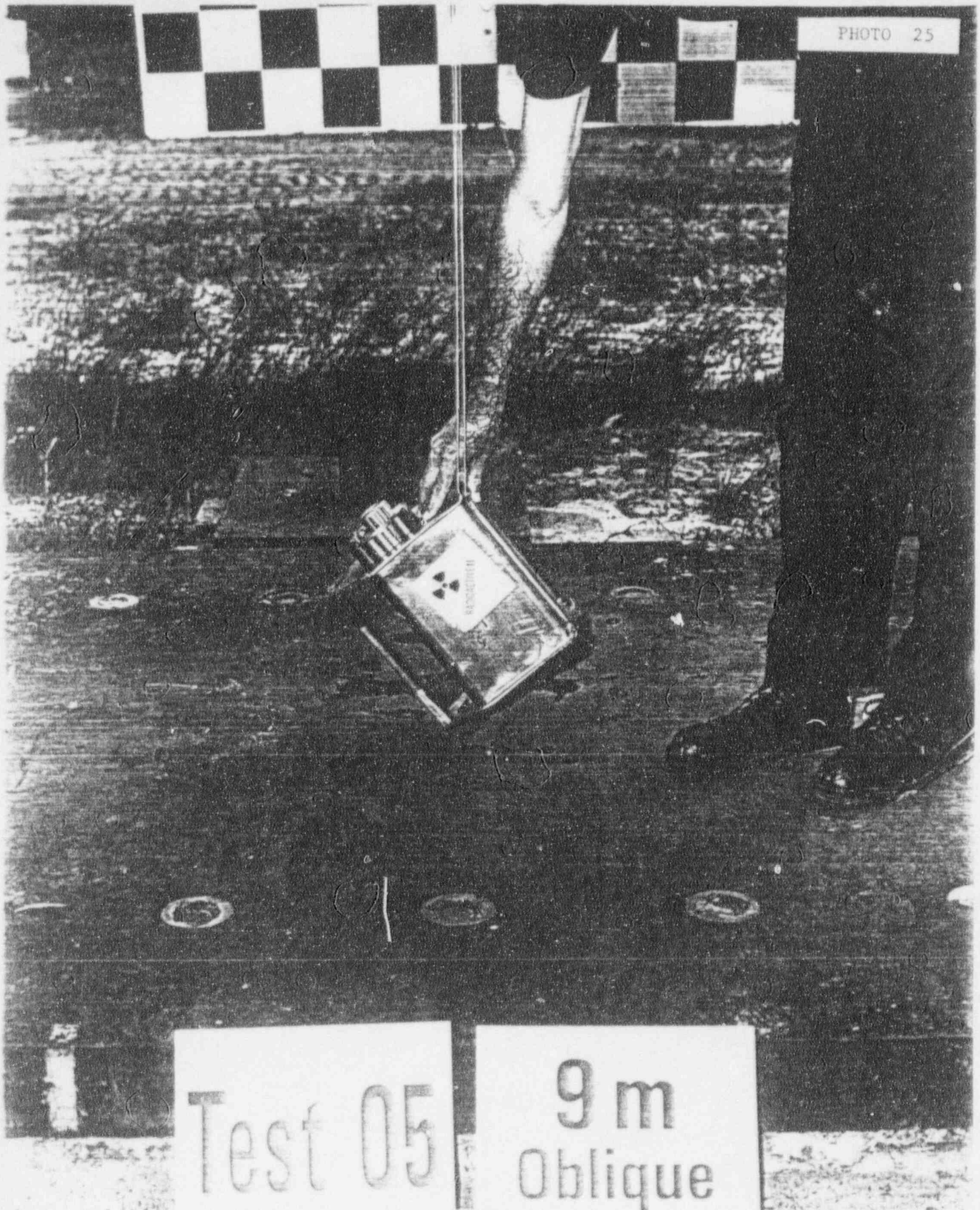


PHOTO 25
Test 05
9m
Oblique

PHOTO 26

PHOTO 27

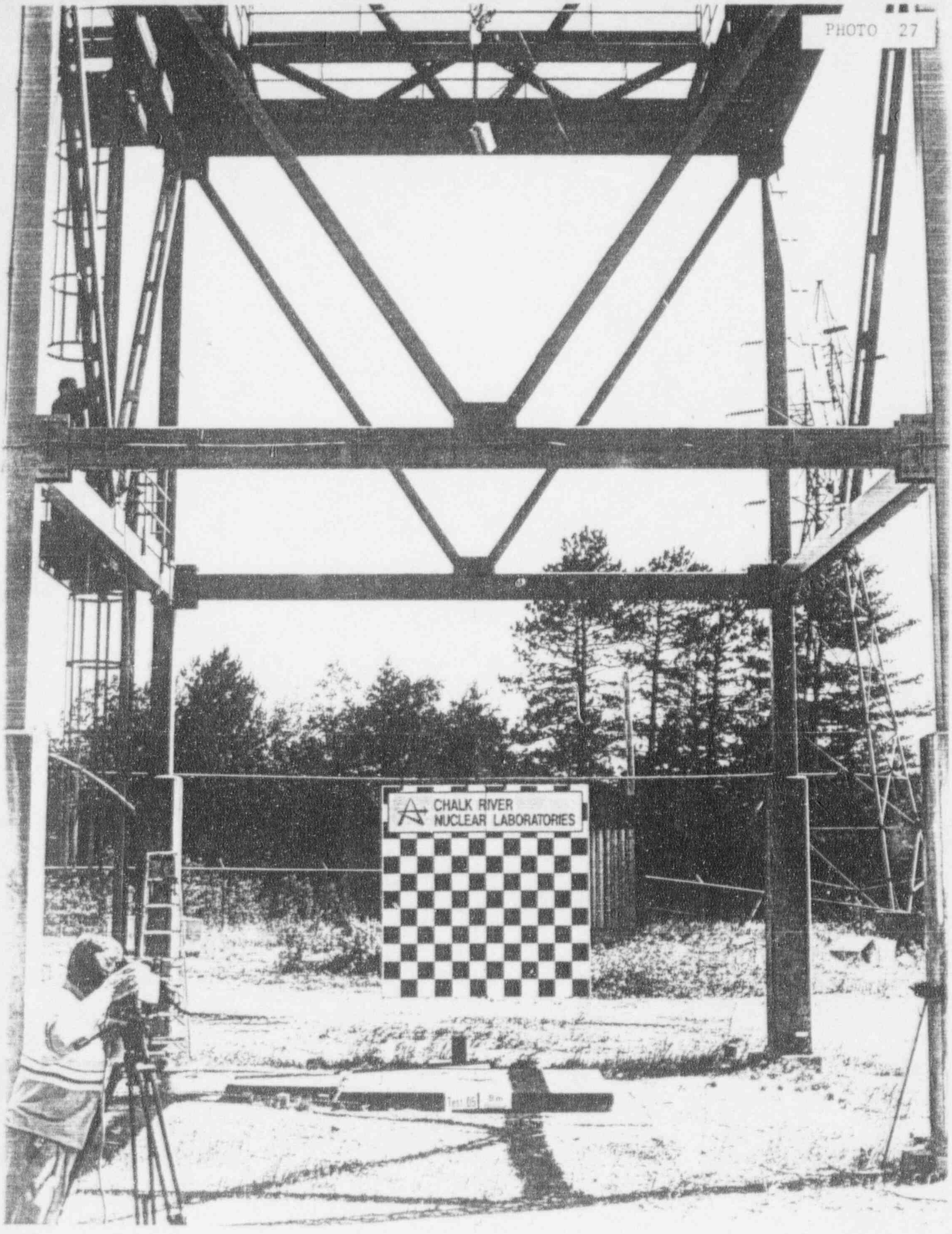


PHOTO 28

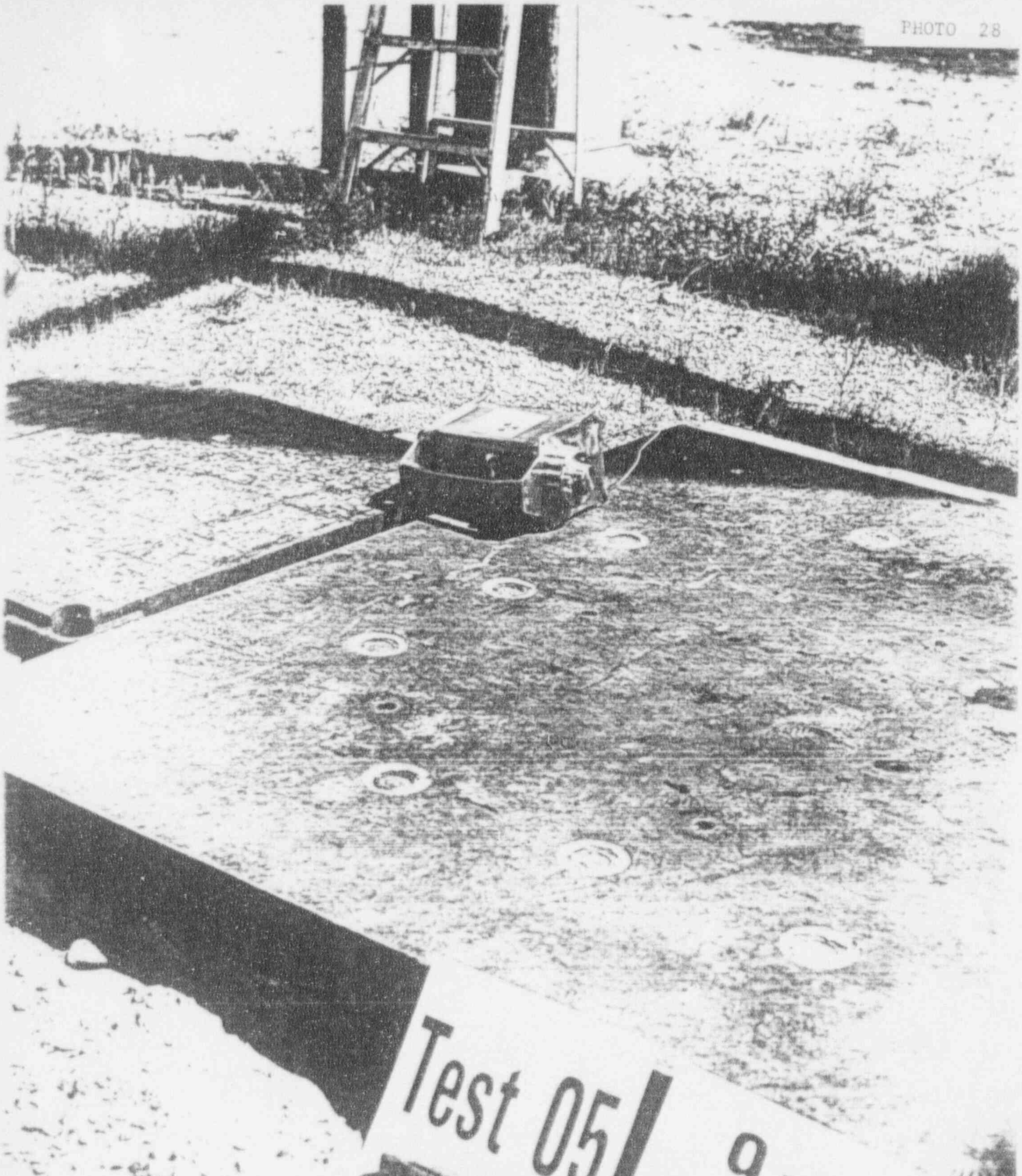


PHOTO 29

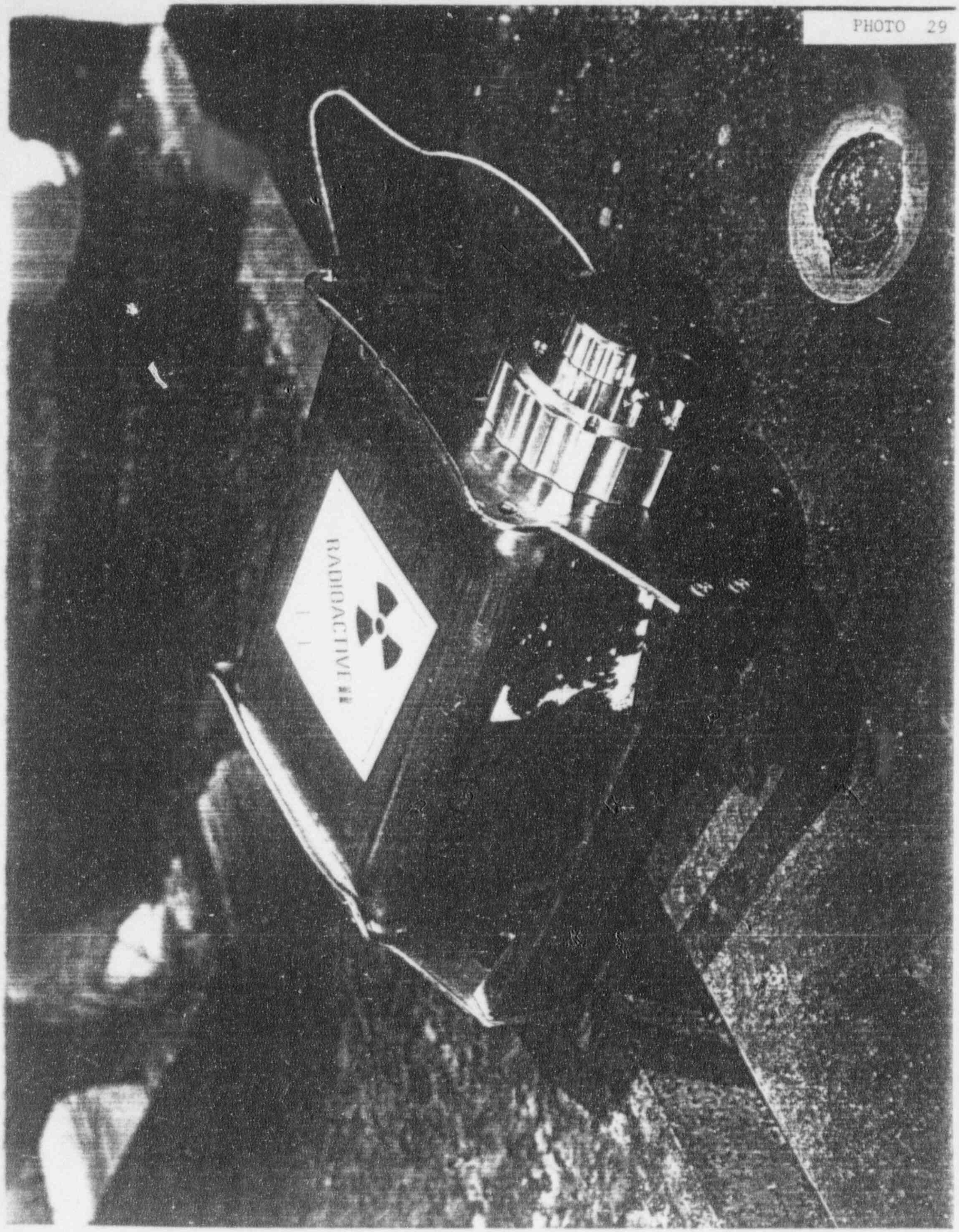


PHOTO 30

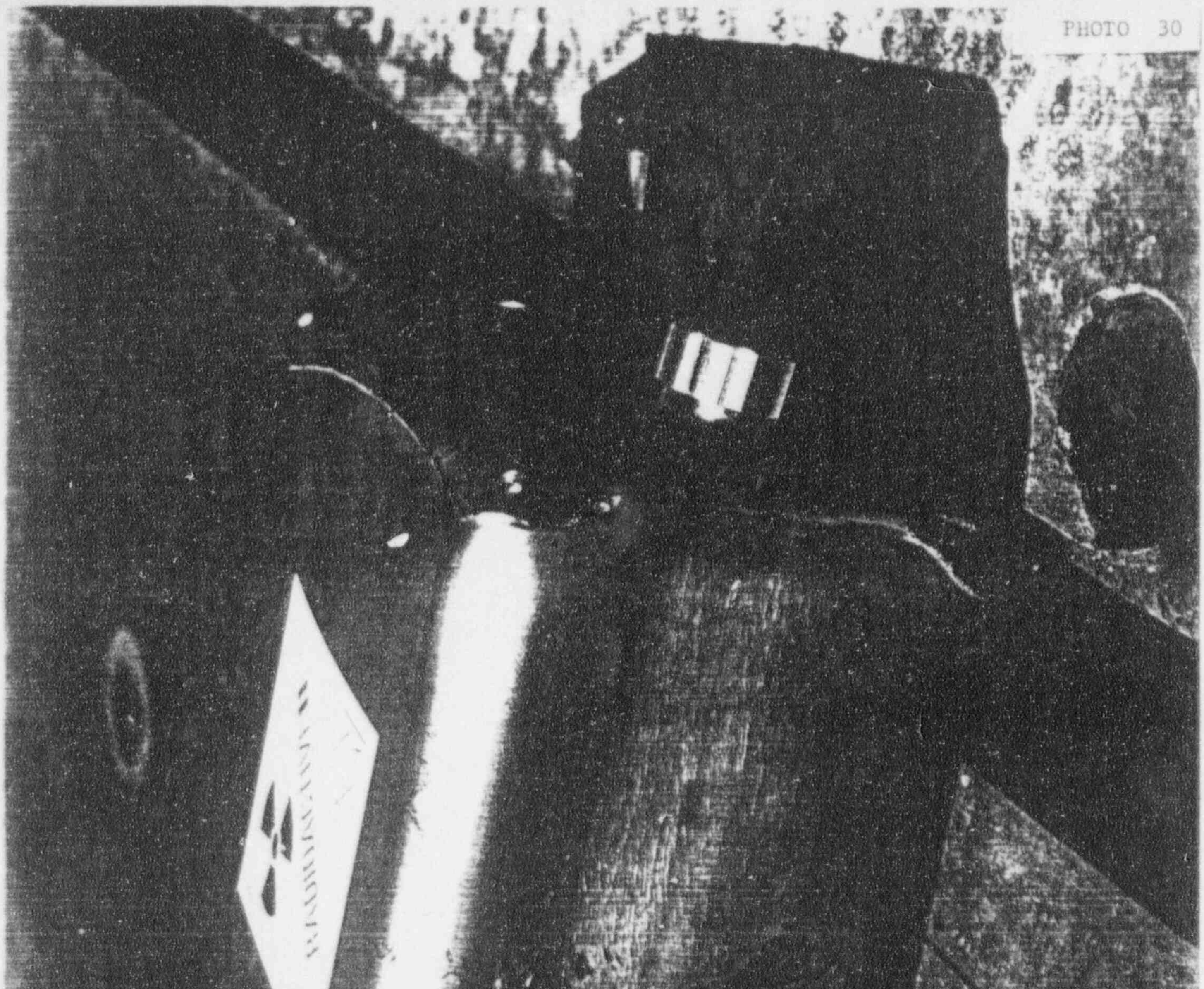
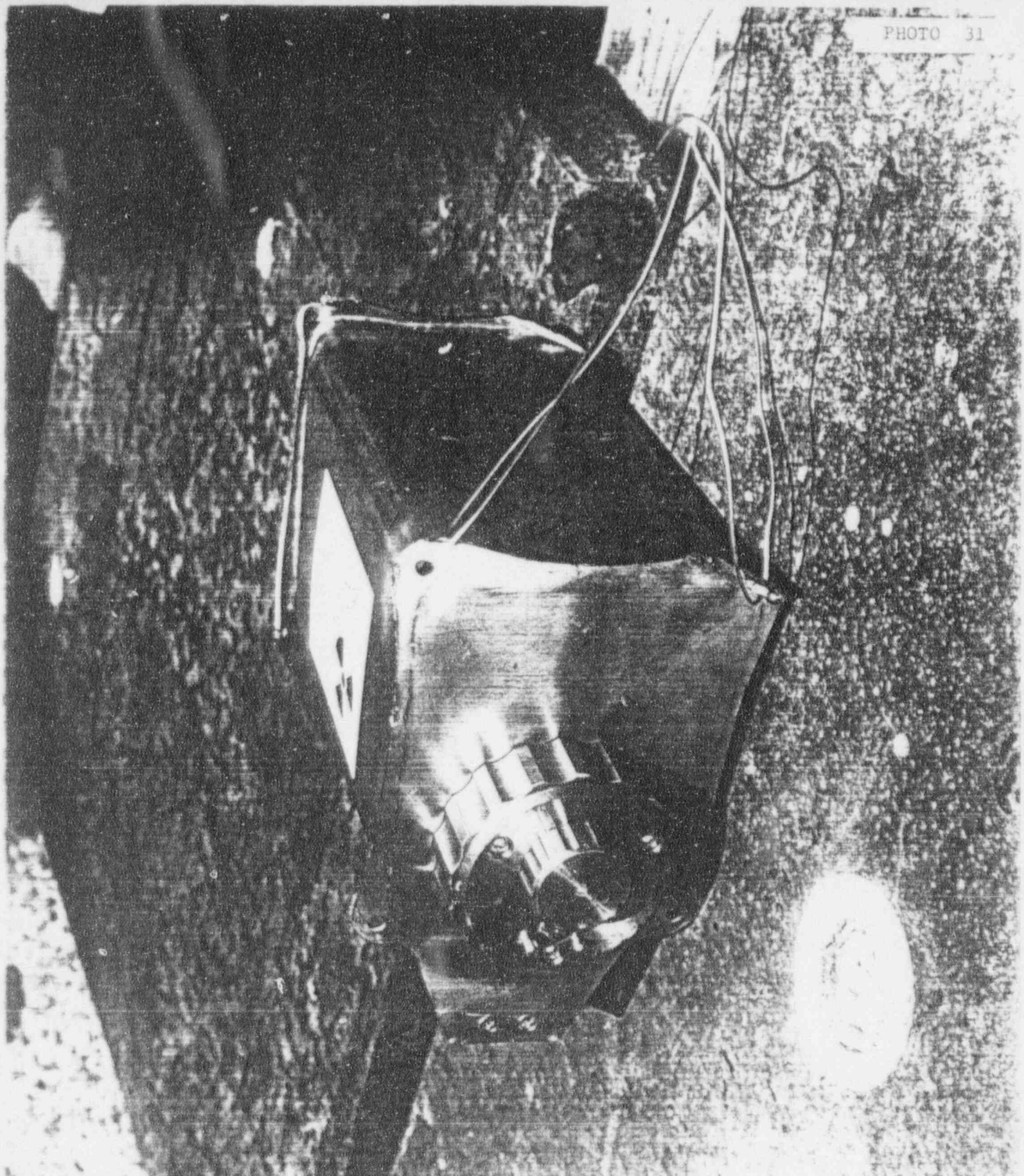


PHOTO 31



TEST 06 9.45 M VERTICAL DROP TEST ONTO LOCK OF S/N 003

PHOTO 32

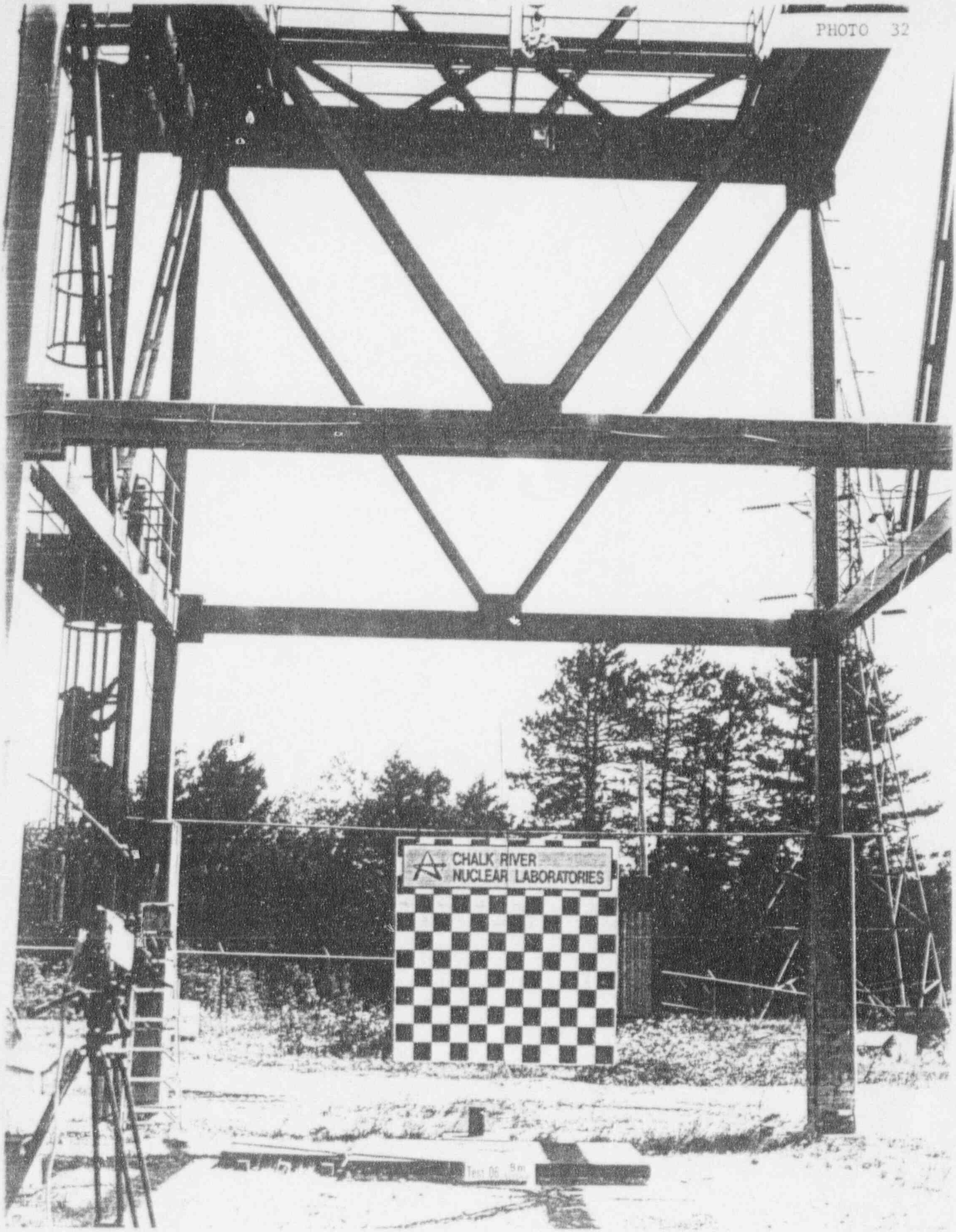


PHOTO 33

PHOTO 34

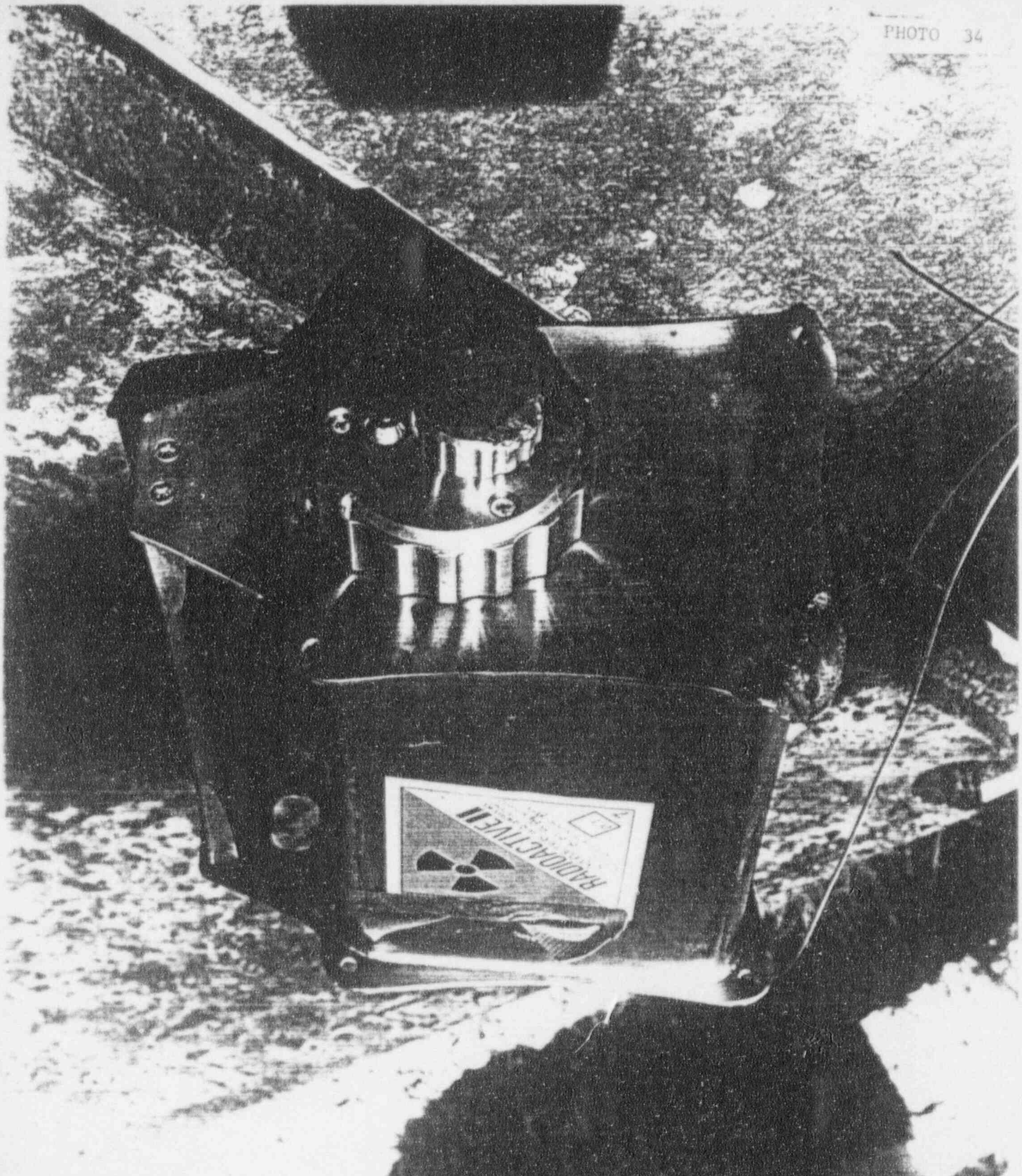


PHOTO 35

PHOTO 36

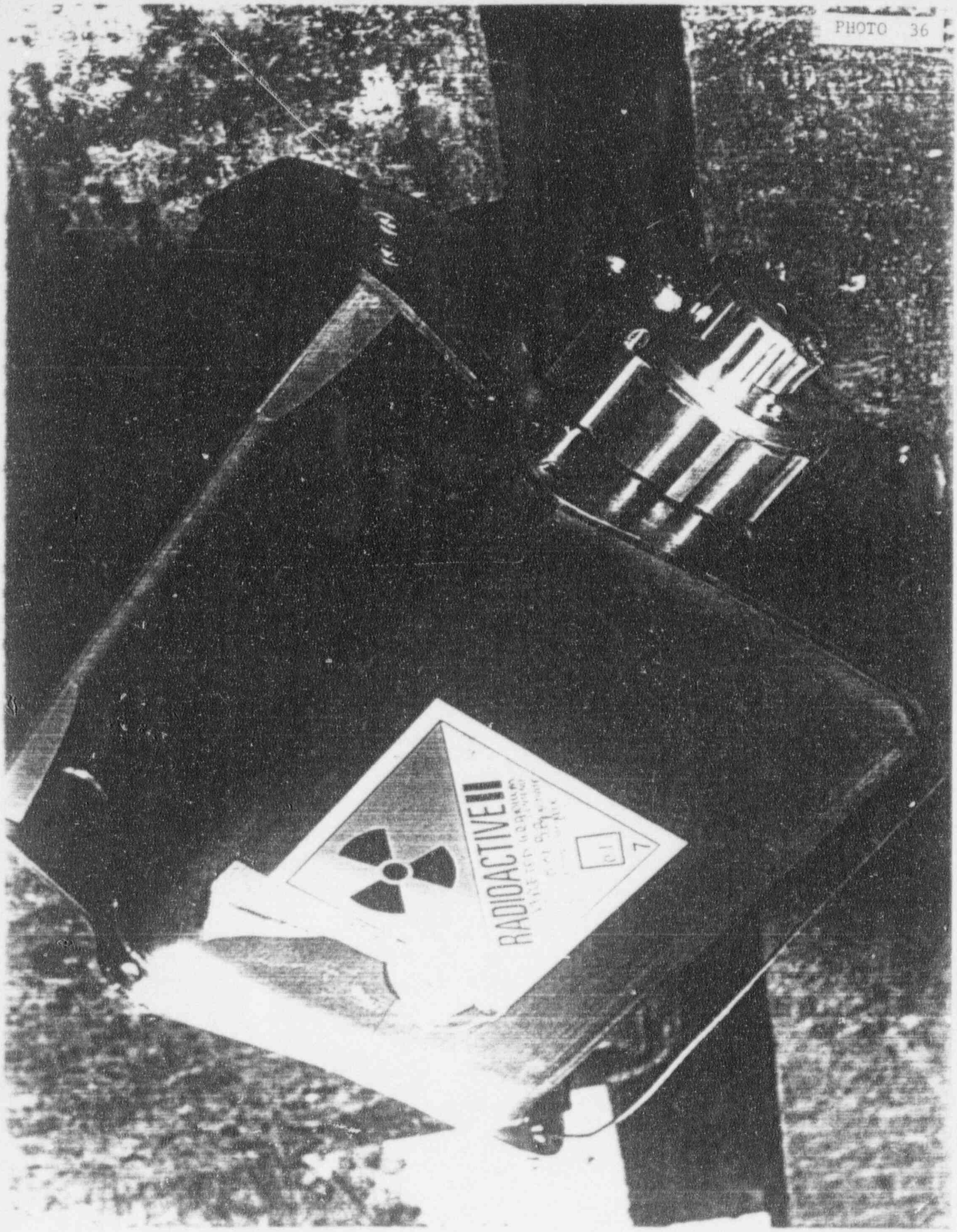


PHOTO 37

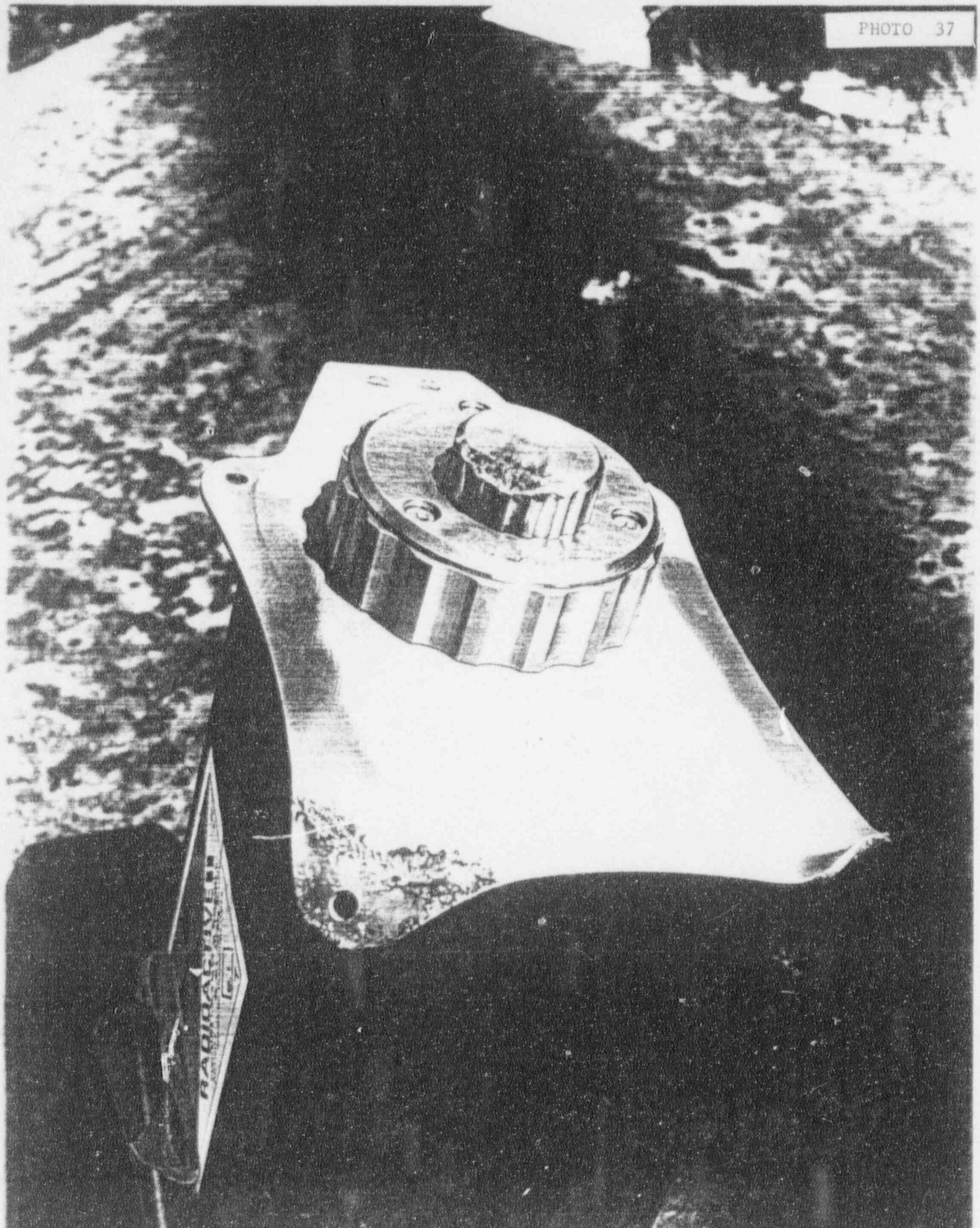
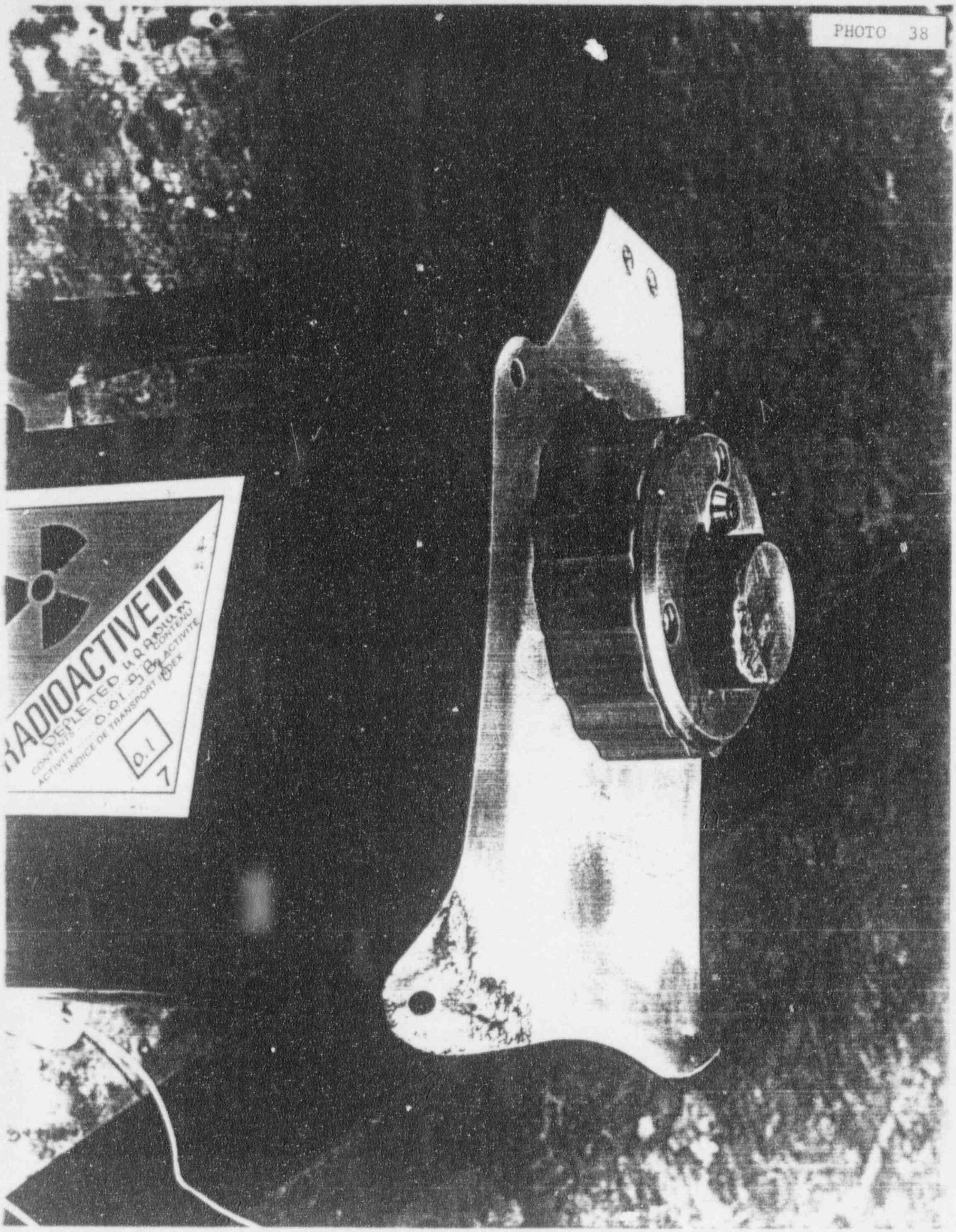
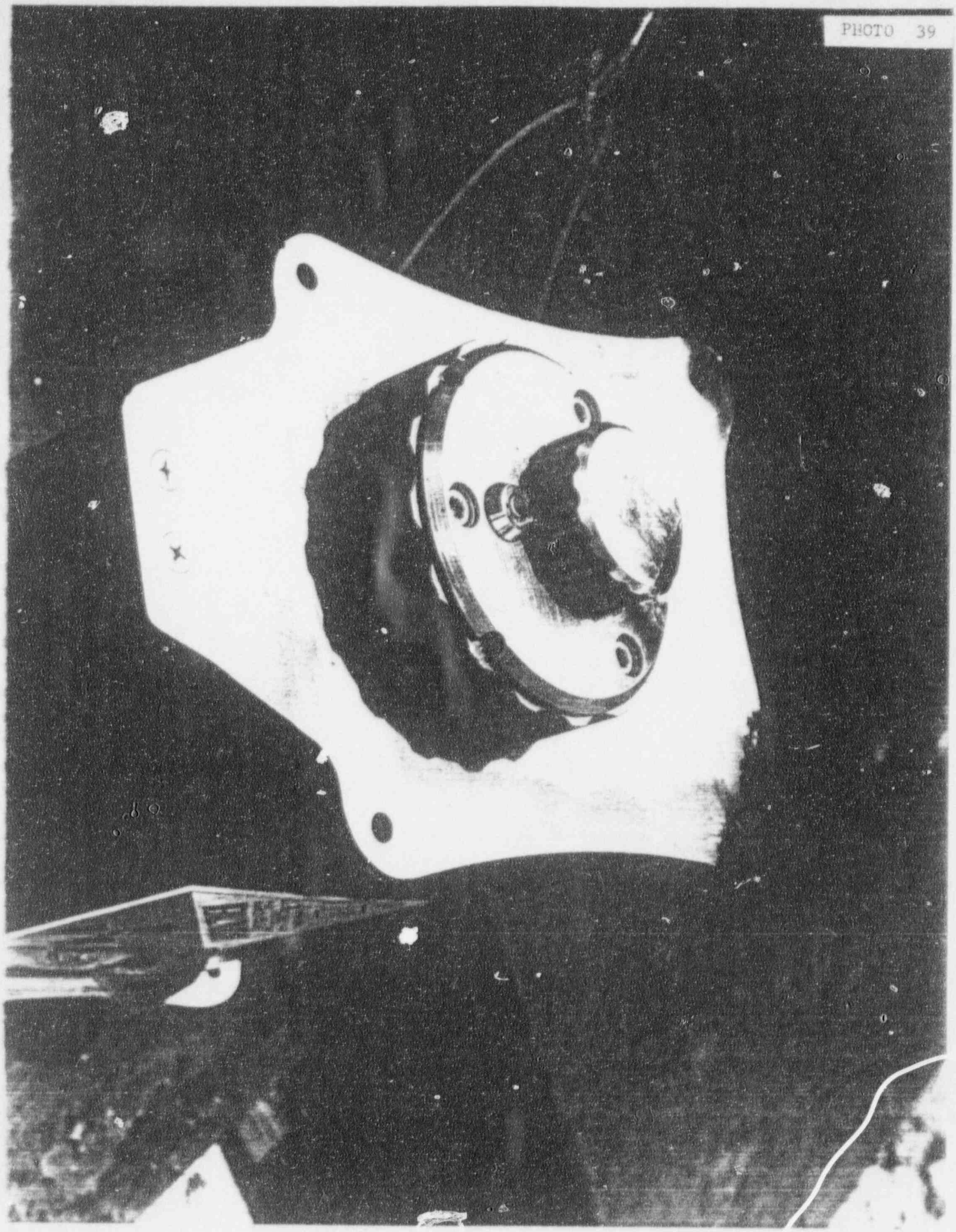


PHOTO 38



RADIOACTIVE II
CONTENTS
CONTENU
ACTIVITY
ACTIVITE
INDICE DE TRANSPORT

PHOTO 39



APPENDIX J

Remote Control Kinking Test Data Sheet

Remote Control Kinking Test Data Sheet

Date 93/07/05

Trial Number	Minimum Speed (ft/s)	Average Speed (ft/s)	Maximum Speed (ft/s)	Observations
1	t=.88 s	d=1.53m.	t_2=.66.	2 trials required
2	t=.64 s.			
3	t=.55 s.			
4	t=.82	t=.52		2 trials required
5	t=.58			
6	t=.53			
7	t=.62			
8	t=.67			
9	t=.57			
10	t=.70			
11				Distance always 152.5cm
12				All trials video taped.
13				No anomalies observed.
14				No problems observed with RC sheath.
15				

Test Engineer Blair M[illegible] Witness Gordon Murphy [signature]

Project Engineer Mike Krmpnich [signature]

APPENDIX K

Crushing Test Data Sheets

Crushing Test Data Sheet

Device under test Remote control.

Trial Number	Location of Impact	Observations
1	vertically opposed C1	both sheaths have teleflex
2	vertical C2	teleflex through both sheaths
3	vertical C3	lower sheath empty, upper has teleflex
4	vertical C4	lower sheath empty, upper loaded
5	vertical C5	empty sheath on top, lower sheath ~~empty~~ loaded.
6	horizontally opposed C6	teleflex on ~~right~~ left
7	horizontal C7	teleflex on ~~right.~~ left
8	horizontal C8	teleflex on ~~left~~ right
9	horizontal C9	teleflex in both
10	horizontal C10	teleflex in both

Date 93/07/06 Test Engineer [signature]

QA Witness [signature] Project Engineer [signature]

No damaged observed after any impact.

Height for all drops = 30 cm. $^{+.5\ cm}_{-0\ cm}$

all impact areas marked C1, C2... C10 on both sheaths

Crushing Test Data Sheet

Device under test Projection sheath

Trial Number	Location of Impact	Observations
1	sheath, section 1	a flatened area was visible after each impact.
2	"	Each impact was labled c1, c2, c3... c9
3	"	
4	sheath section 2	
5	"	
6	"	
7	sheath section 3	
8	"	
9	"	
10	connection 2-3	No damaged observed. Connector unthreads easily.

Date 93/07/06 Test Engineer [signature]

QA Witness [signature] Project Engineer [signature]

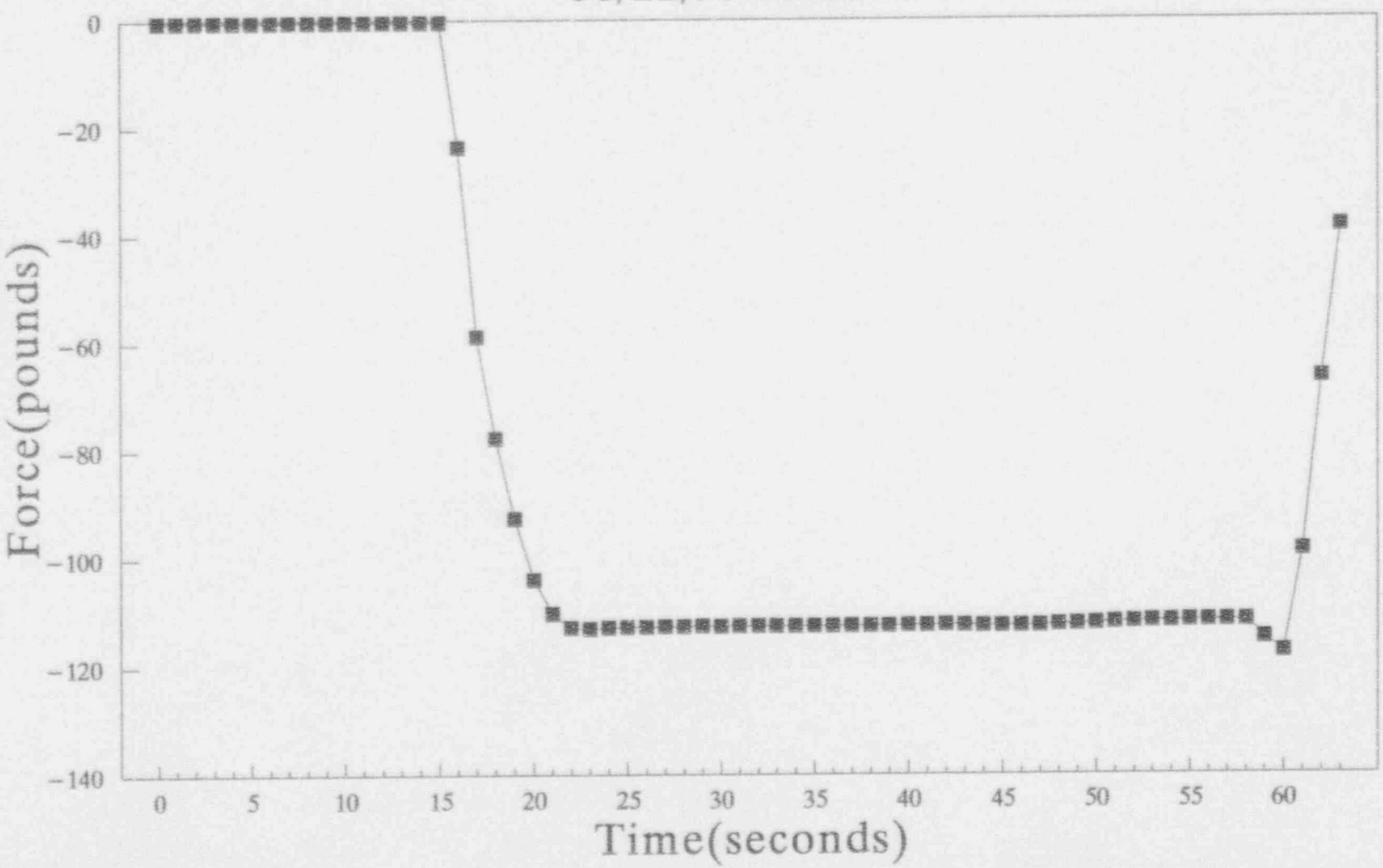
section 1 = section nearest TITAN (extension)
section 2 = middle (extension)
section 3 = nose with tip

APPENDIX L

Remote Control Tensile Test Data

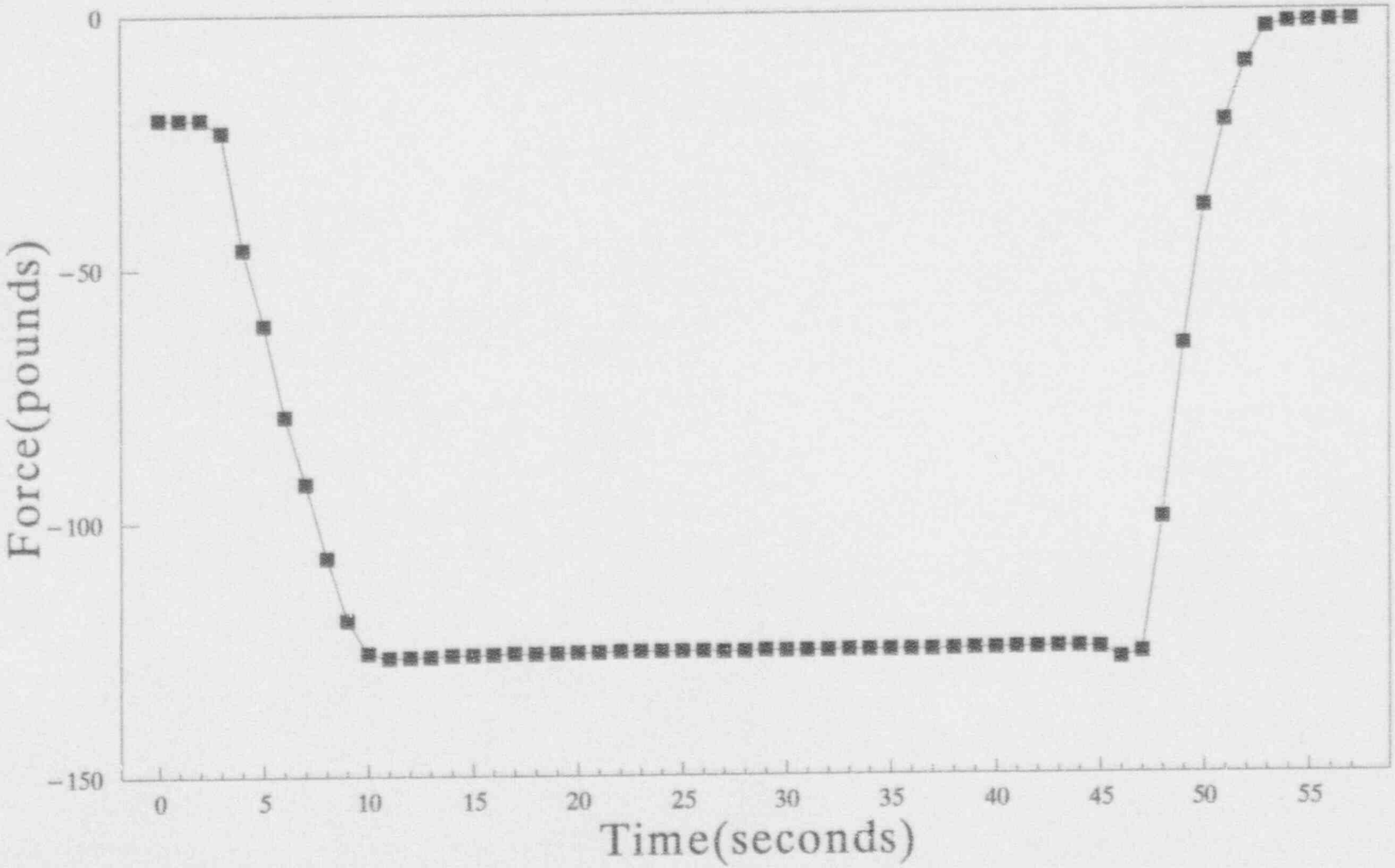
93/06/22 rctest trial #1

06/22/93 15:53:49



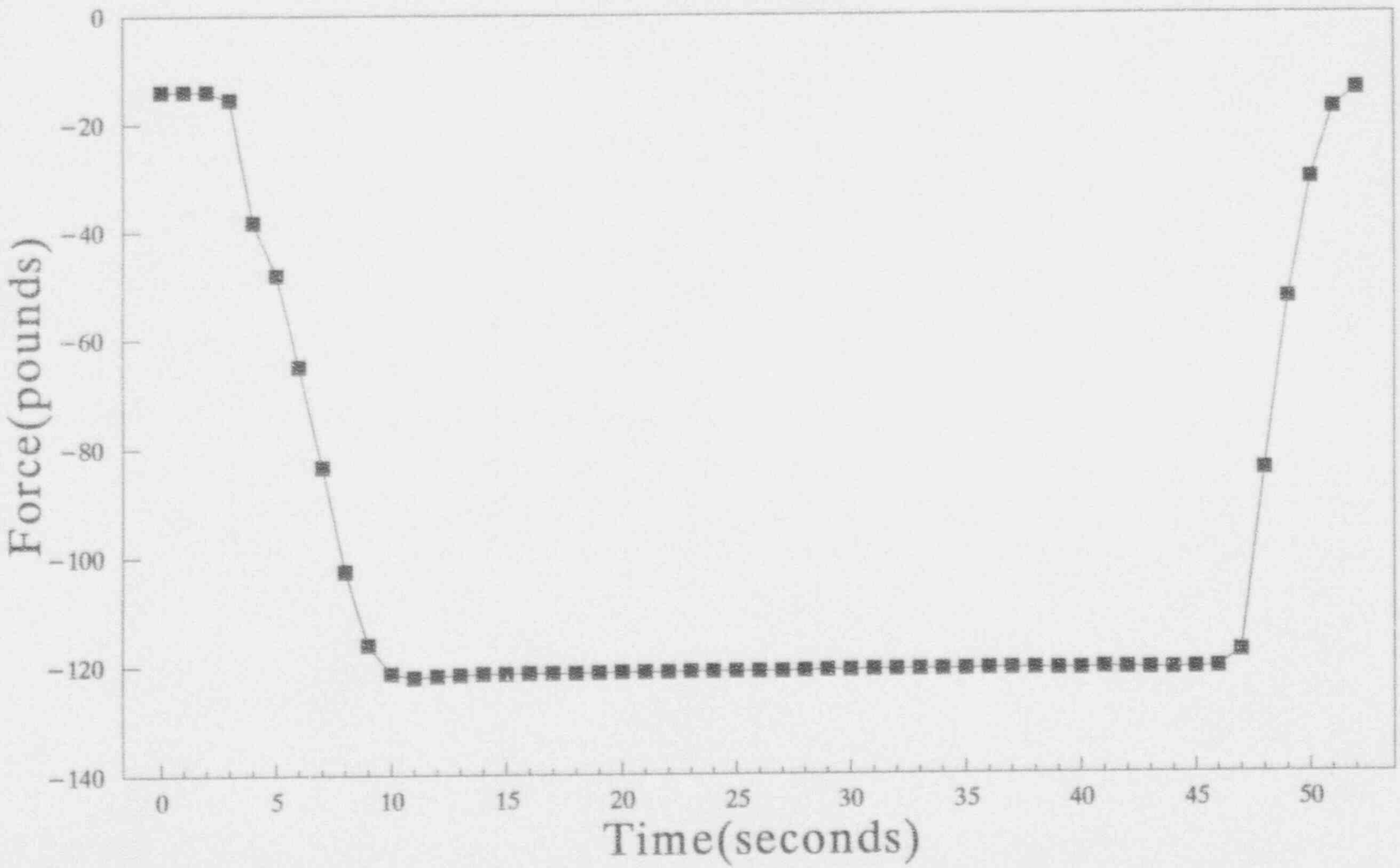
93/06/22 rctest trial #2

06/22/93 16:02:36



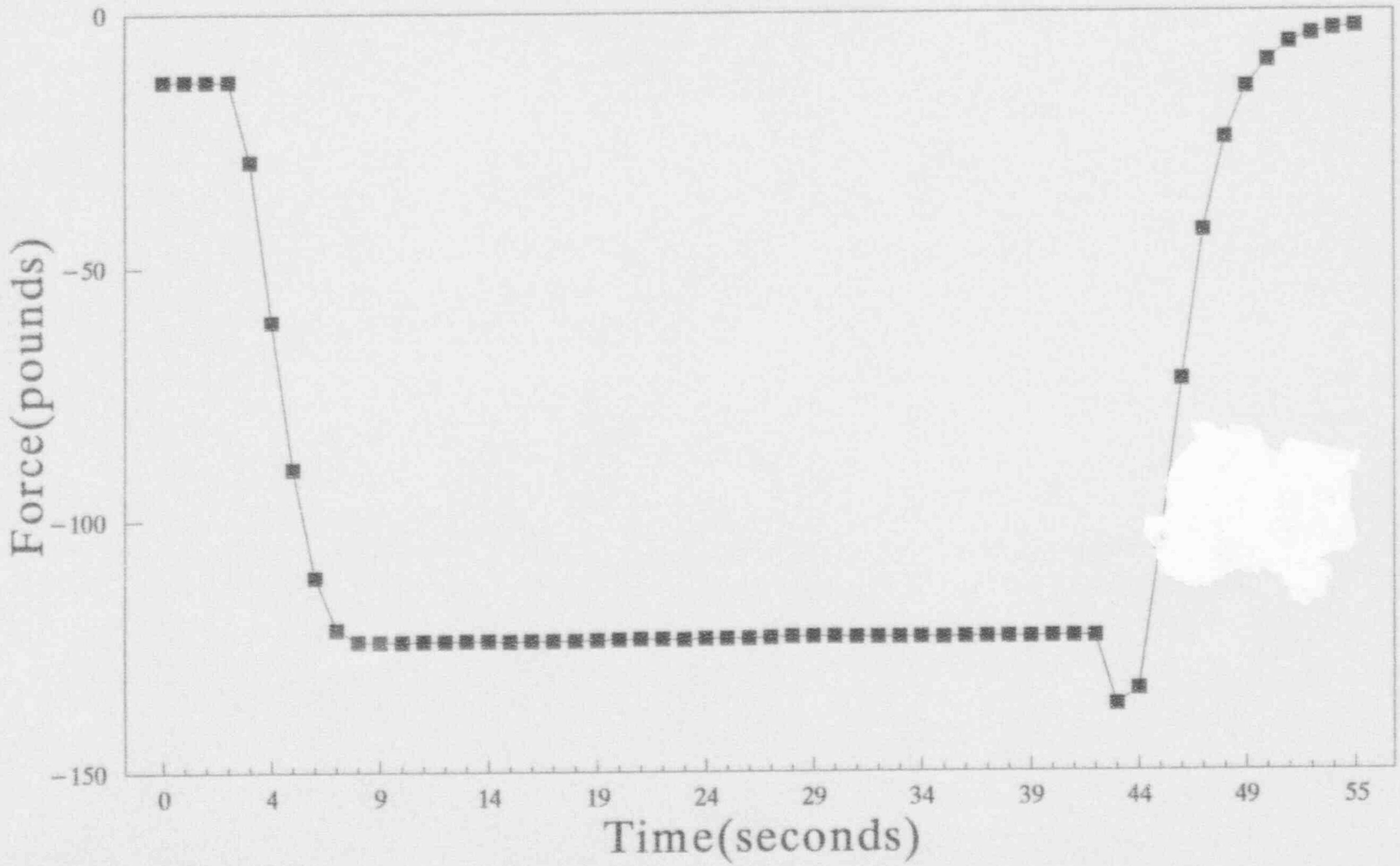
93/06/22 rctest trial #3

06/22/93 16:07:49



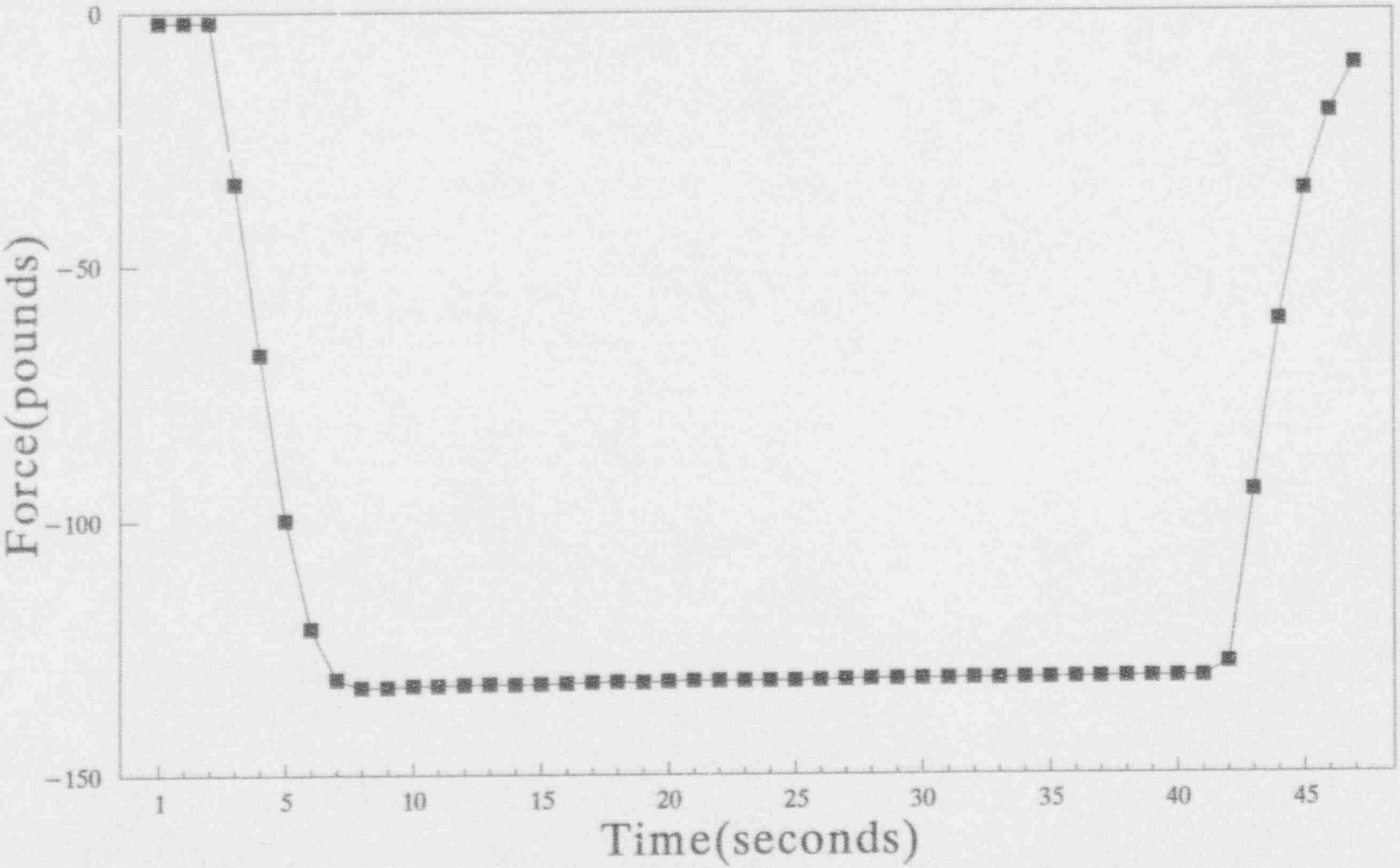
93/06/22 rctest trial #4

06/22/93 16:10:17



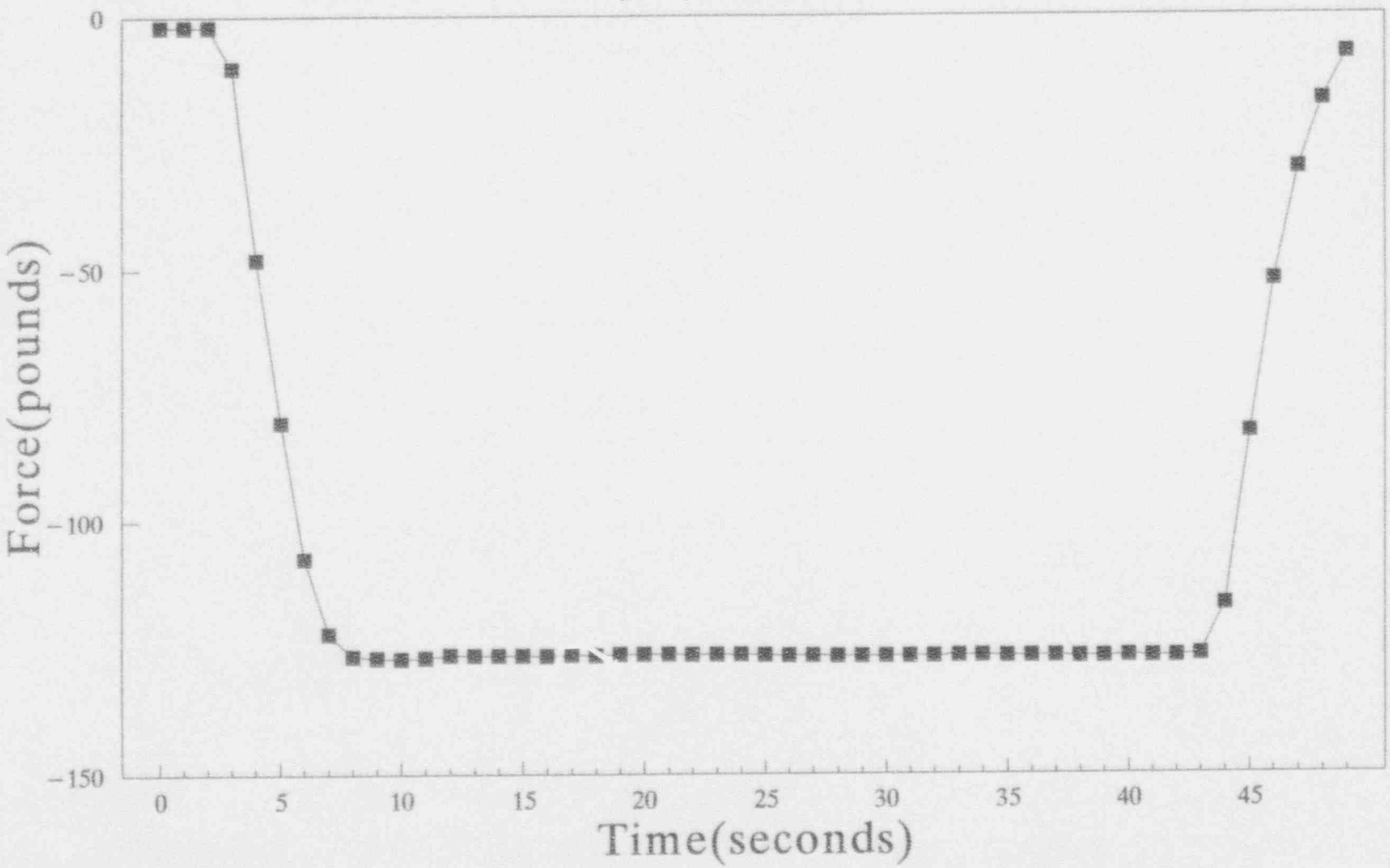
93/06/22 rctest trial #5

06/22/93 16:12:05



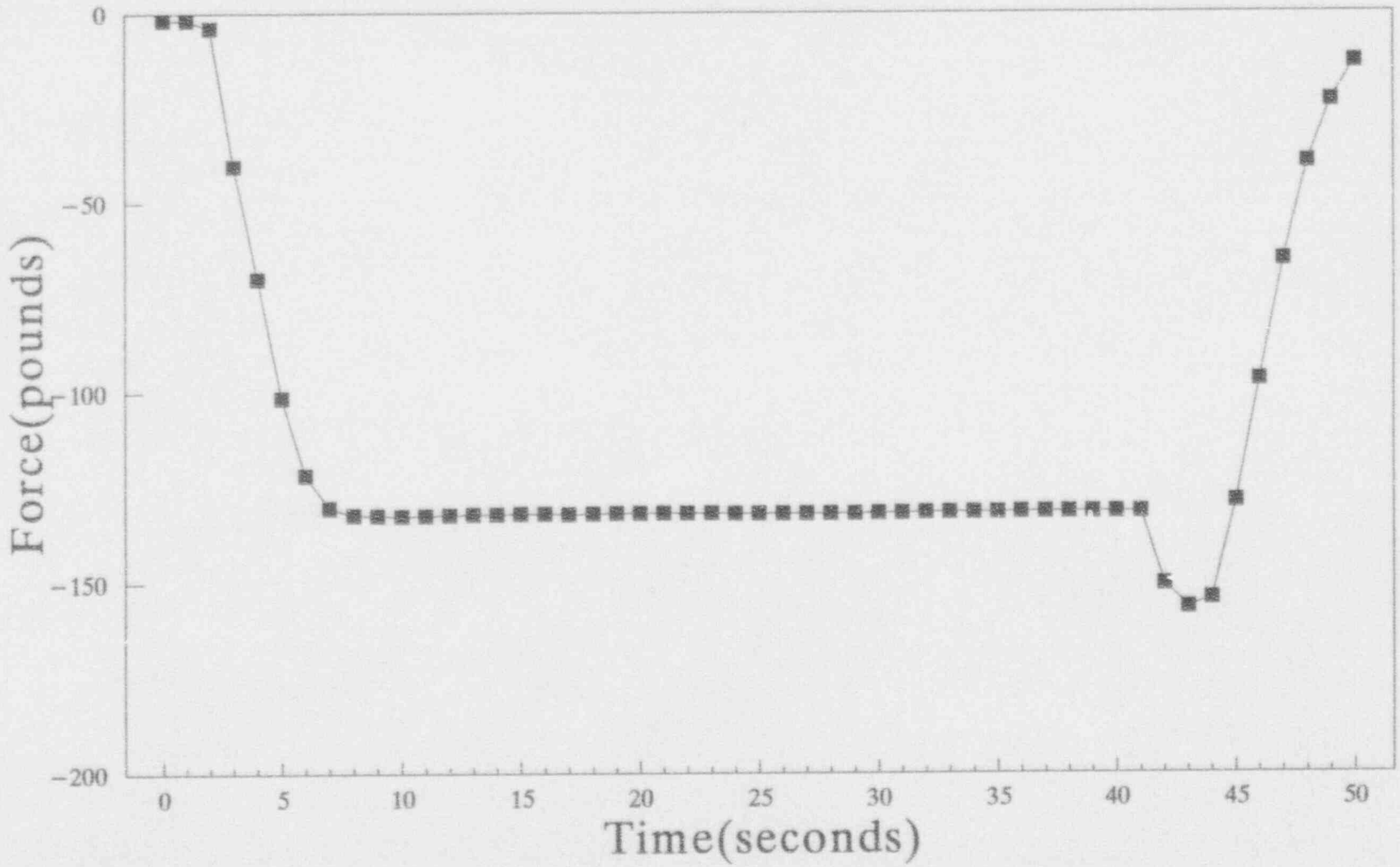
93/06/22 rctest trial #6

06/22/93 16:13:54



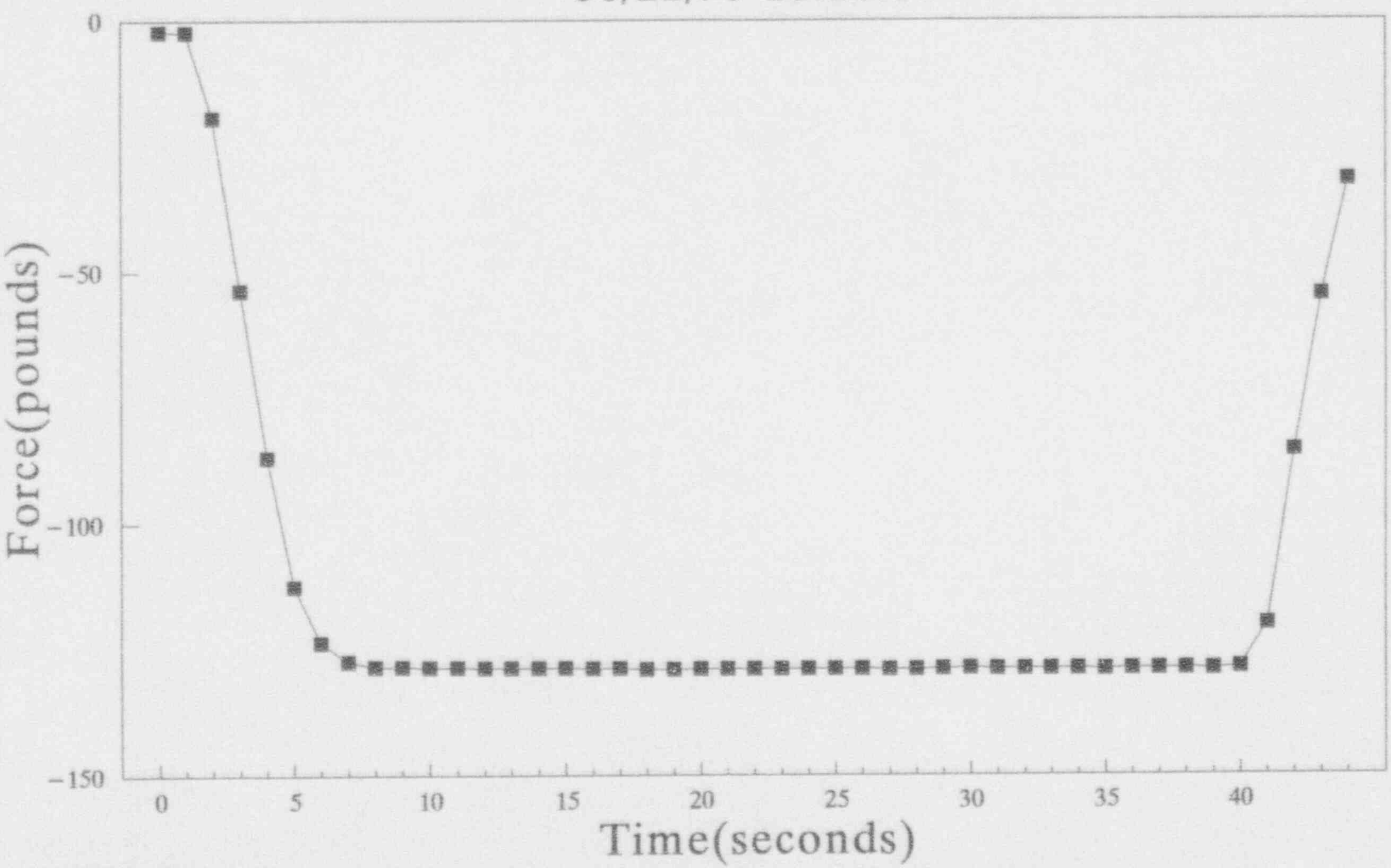
93/06/22 rctest trial #7

06/22/93 16:15:20

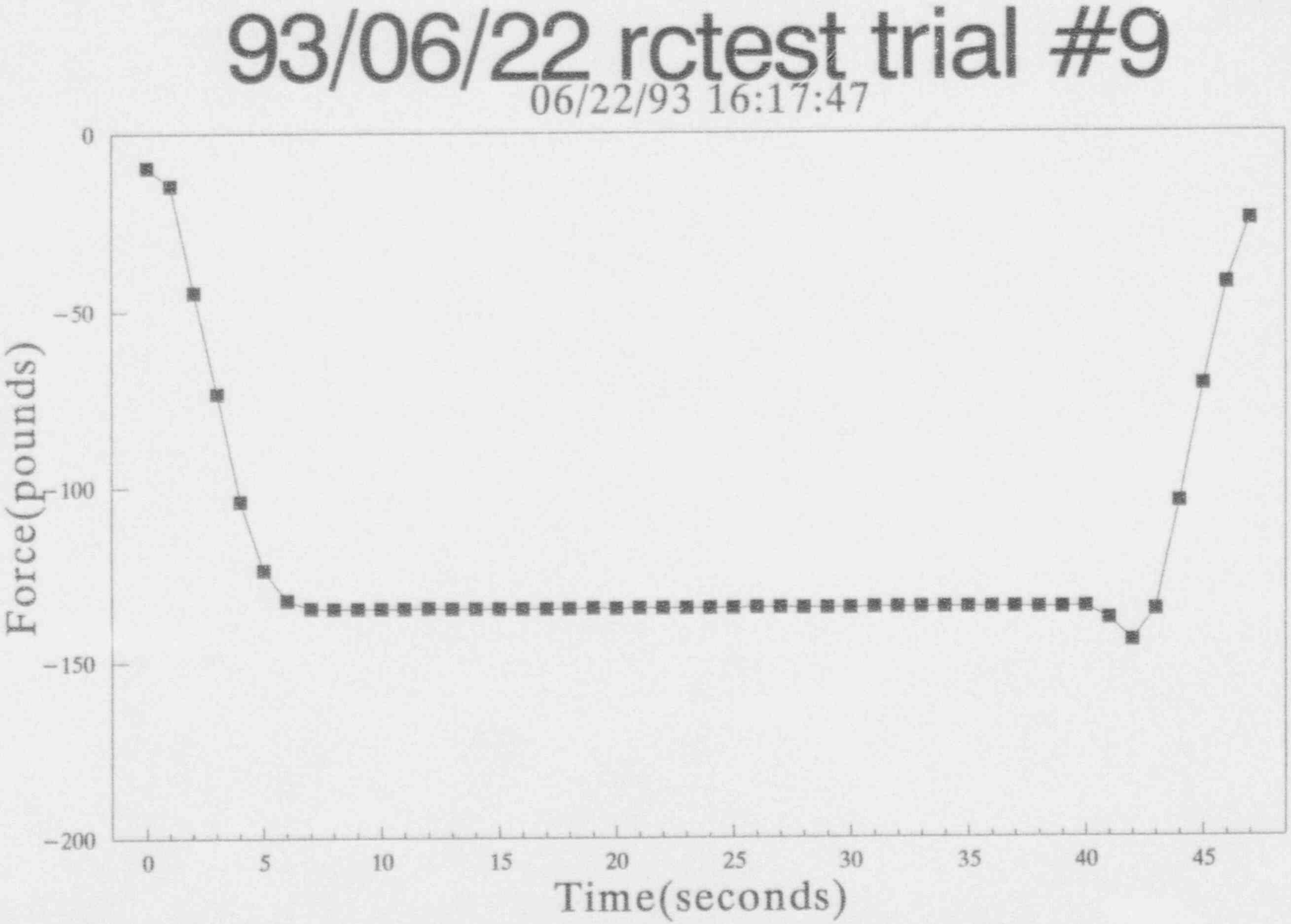


93/06/22 rctest trial #8

06/22/93 16:16:36

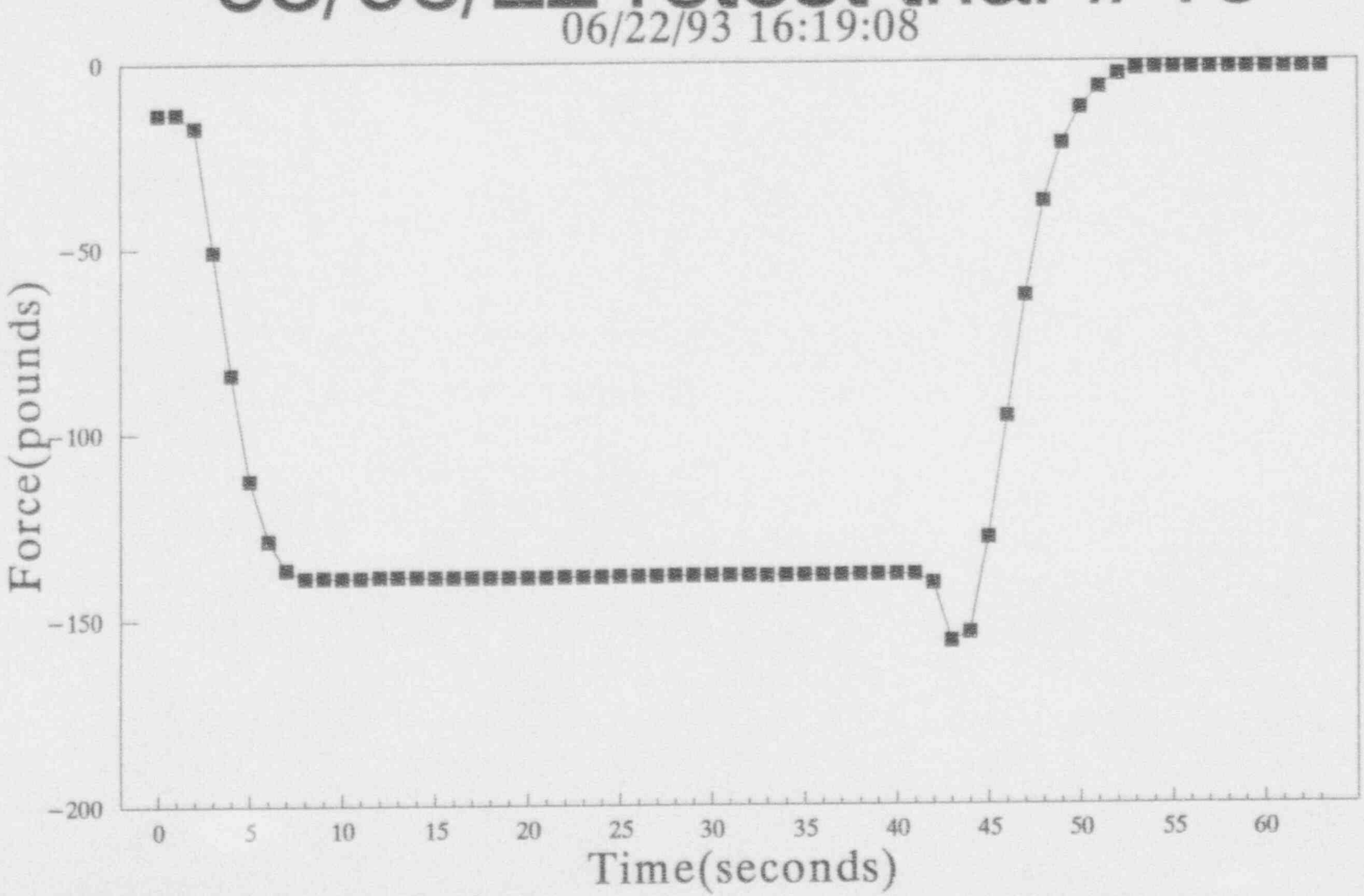


6-7


93/06/22 rctest trial #9
06/22/93 16:17:47
Force(pounds)
0
-50
-100
-150
-200
Time(seconds)
0
5
10
15
20
25
30
35
40
45

I-10

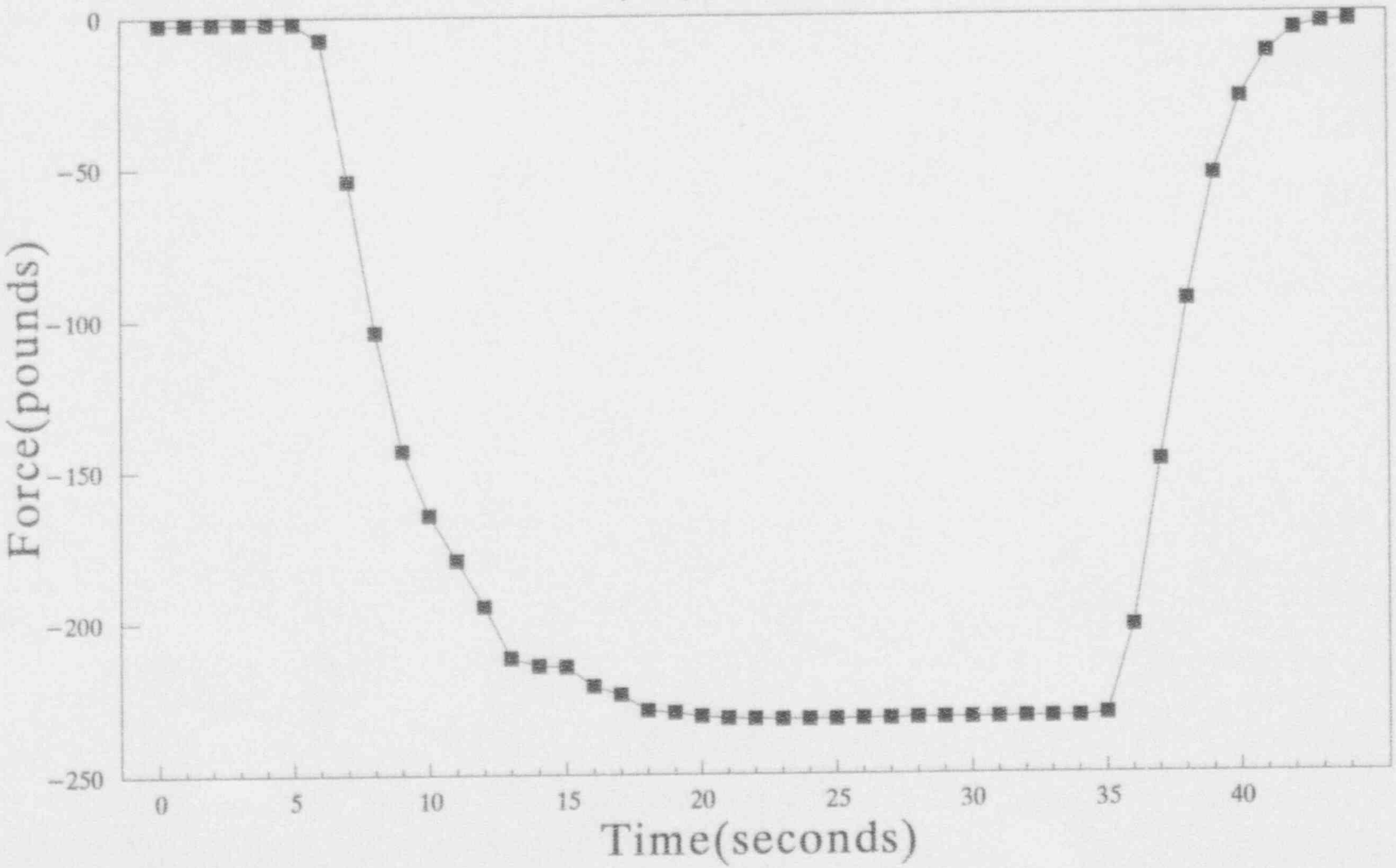
93/06/22 rctest trial #10



II-7

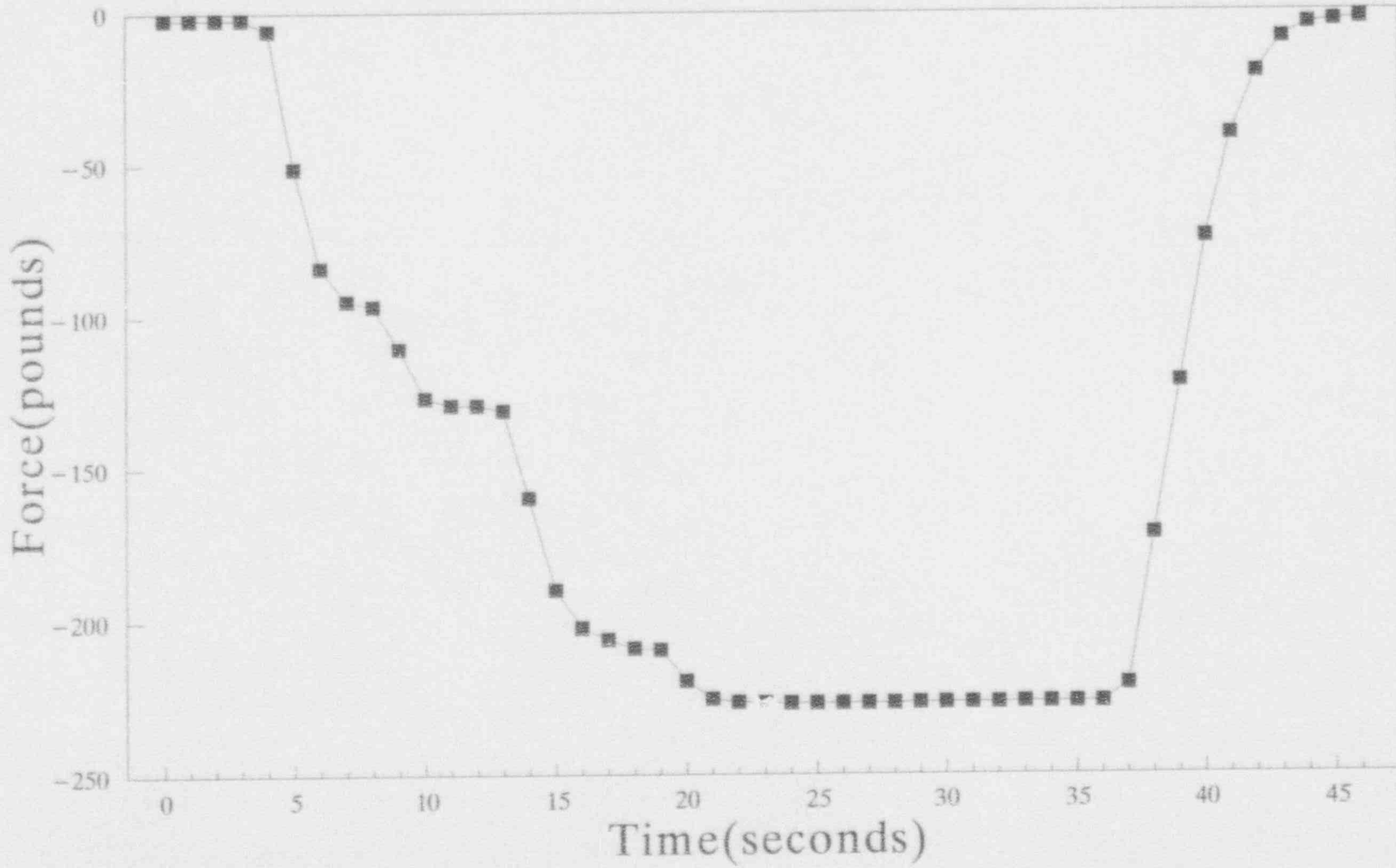
93/07/12 RC Cable Trial #1

07/12/93 11:41:21



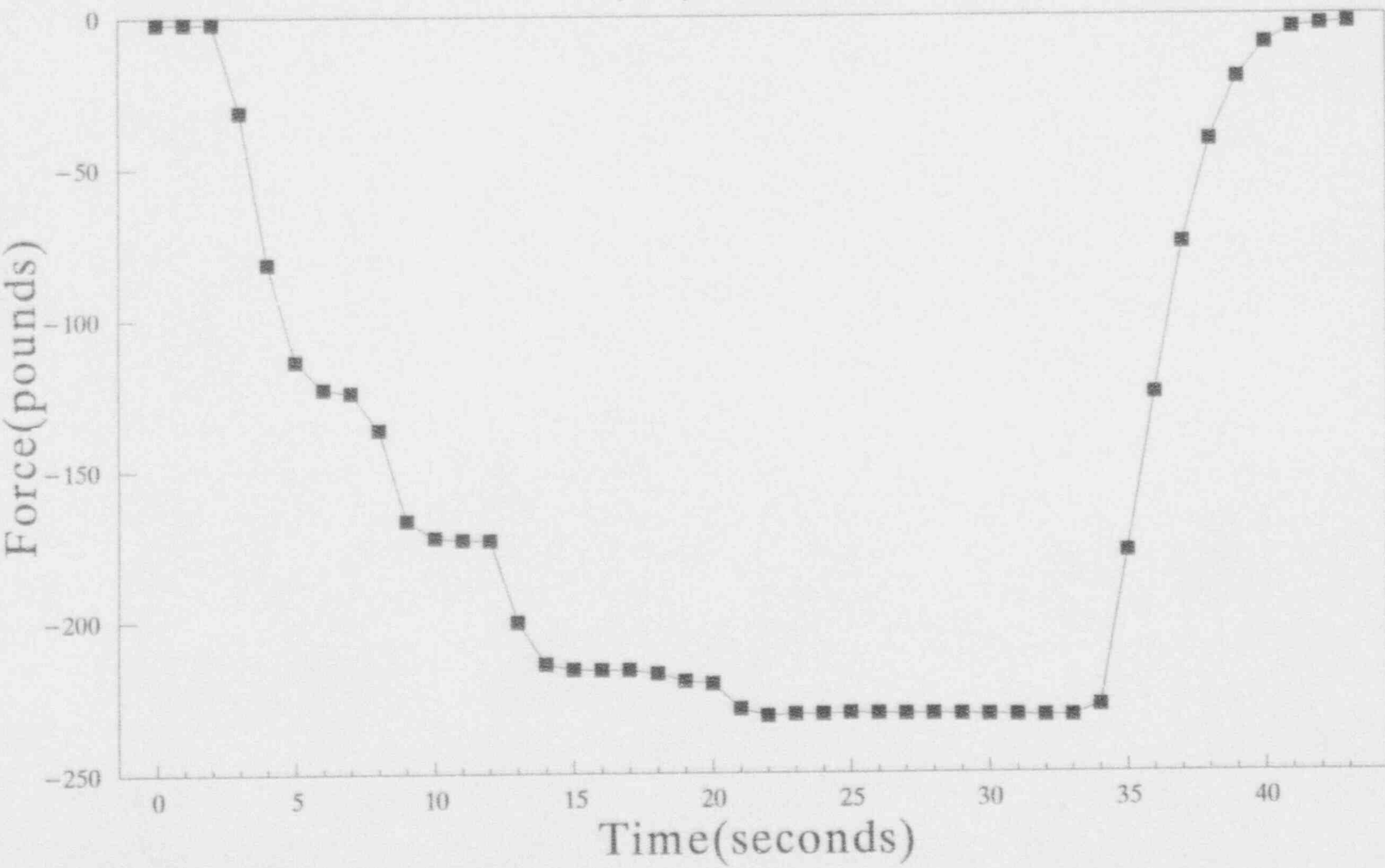
93/07/12 RC Cable Trial #2

07/12/93 11:46:14



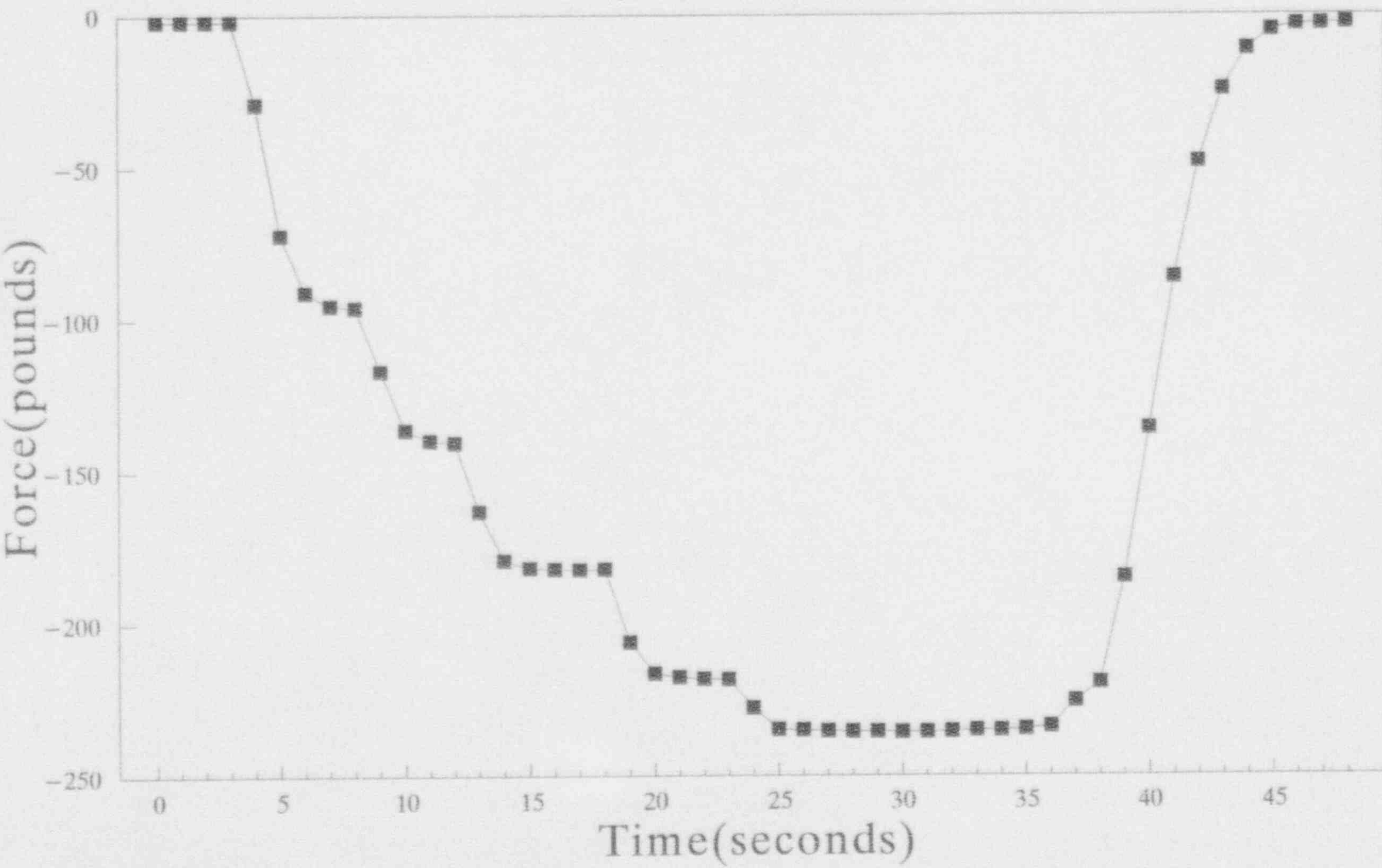
93/07/12 RC Cable Trial #3

07/12/93 11:47:33



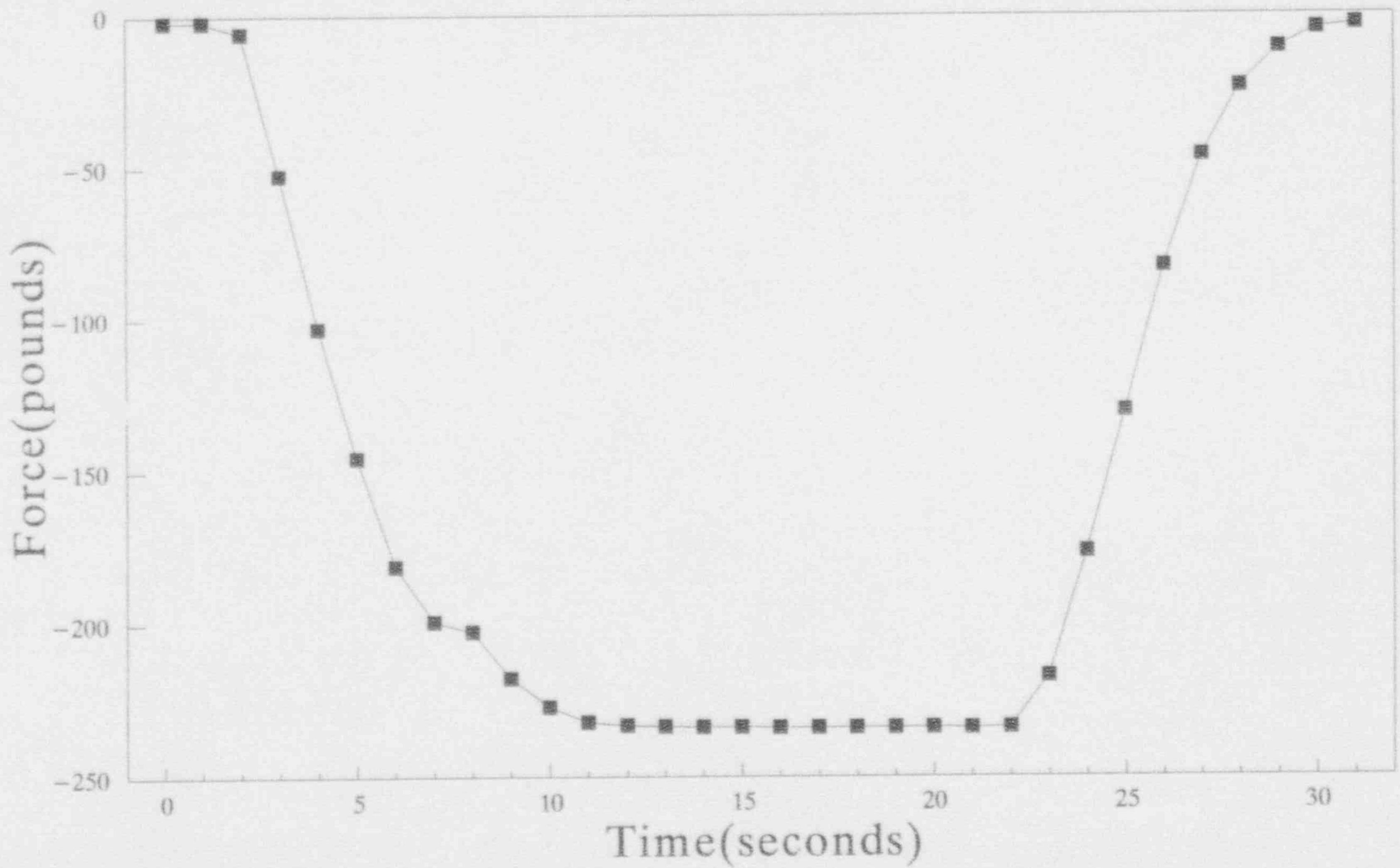
93/07/12 RC Cable Trial #4

07/12/93 11:48:46



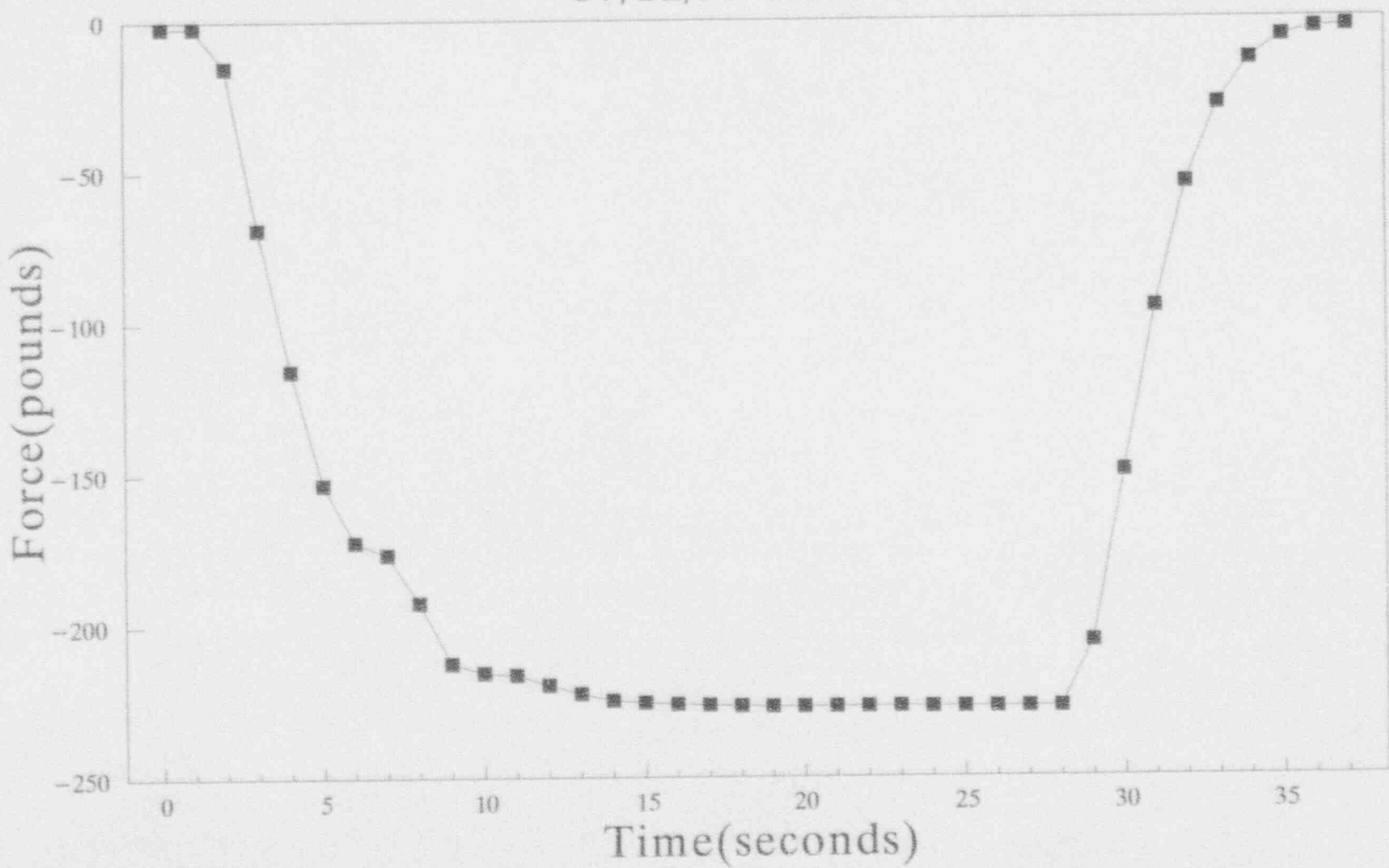
93/07/12 RC Cable Trial #5

07/12/93 11:50:07



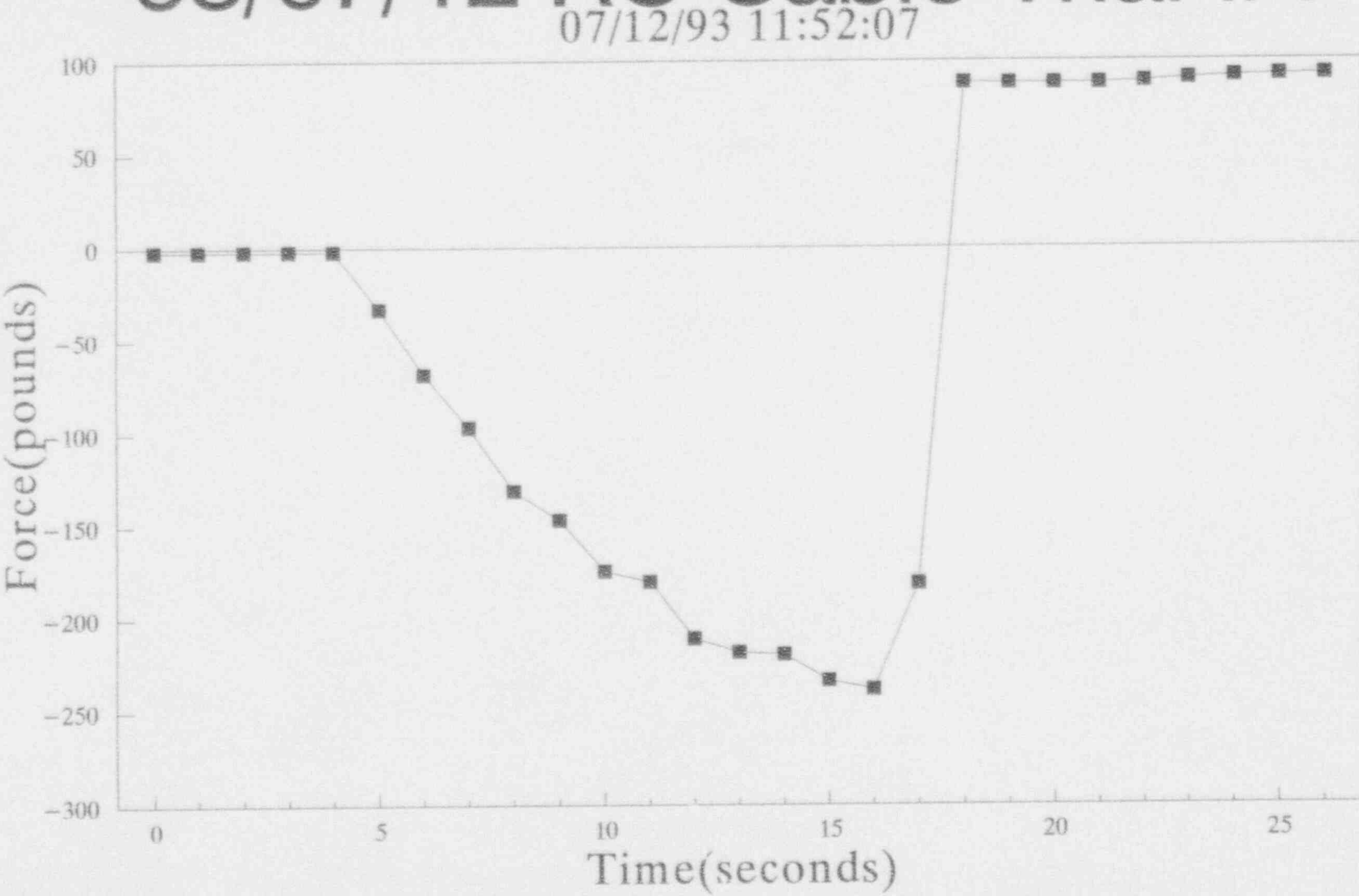
93/07/12 RC Cable Trial #6

07/12/93 11:51:05



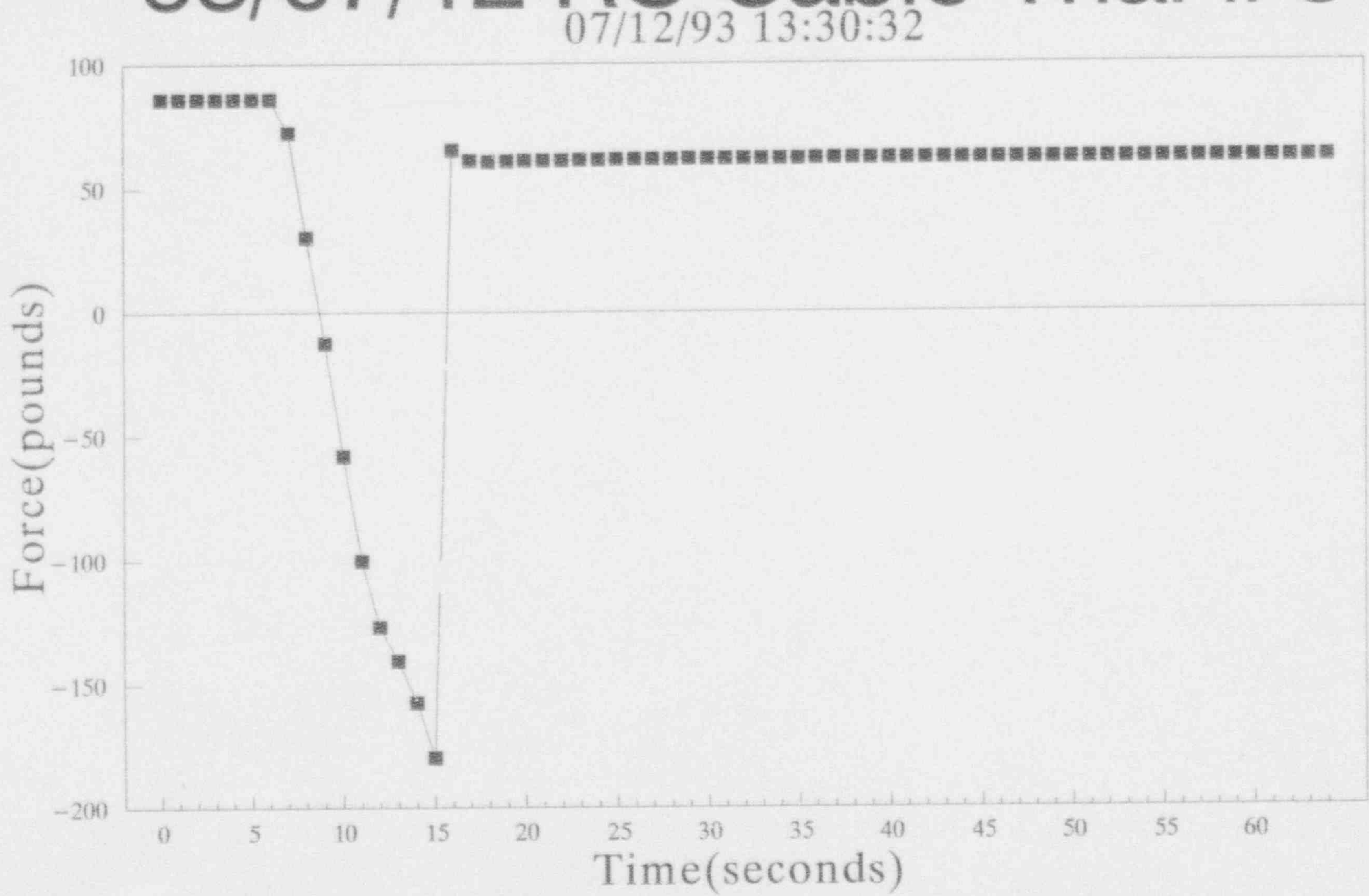
4-13

93/07/12 RC Cable Trial #7

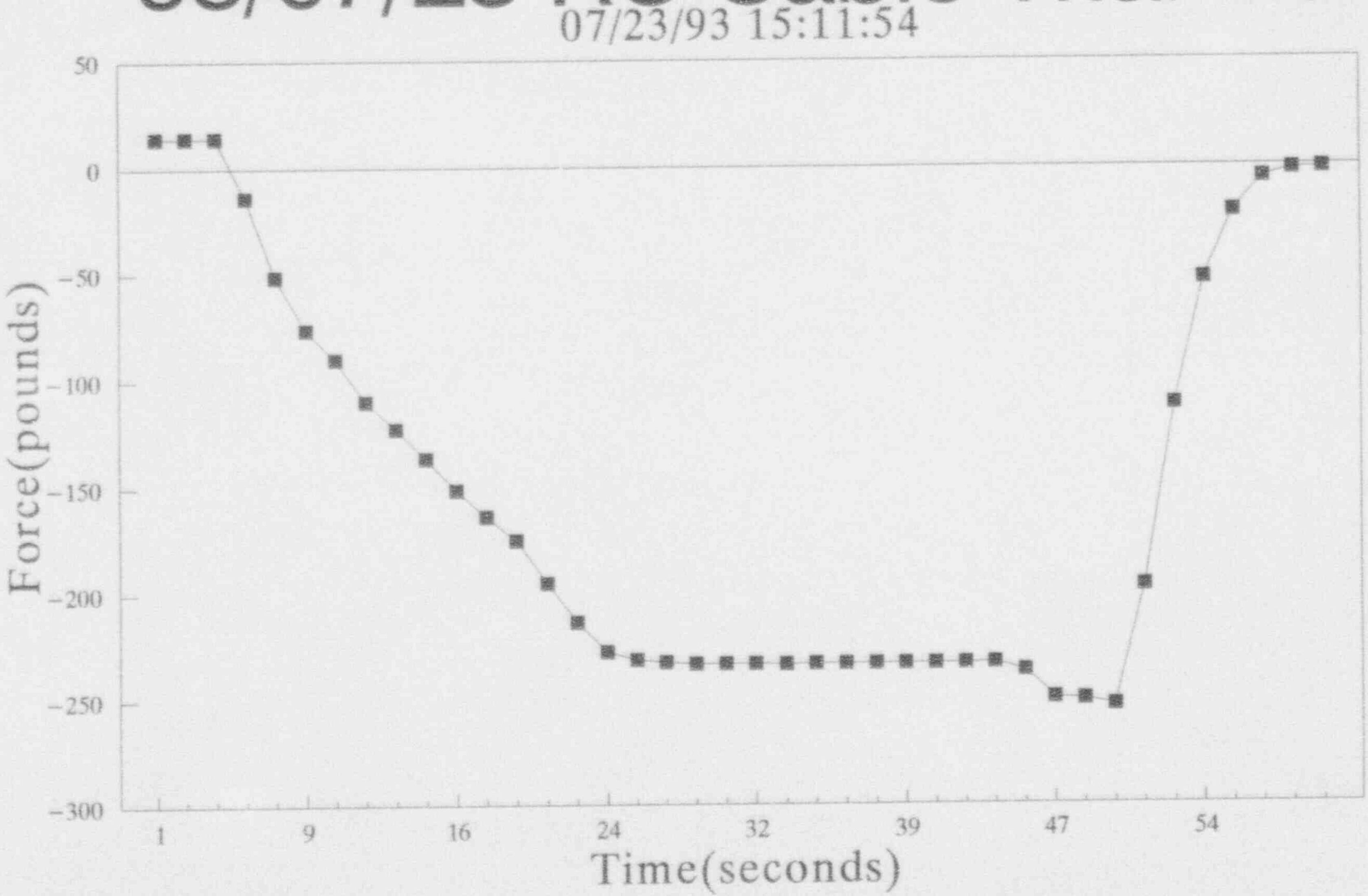


81-7

93/07/12 RC Cable Trial #8

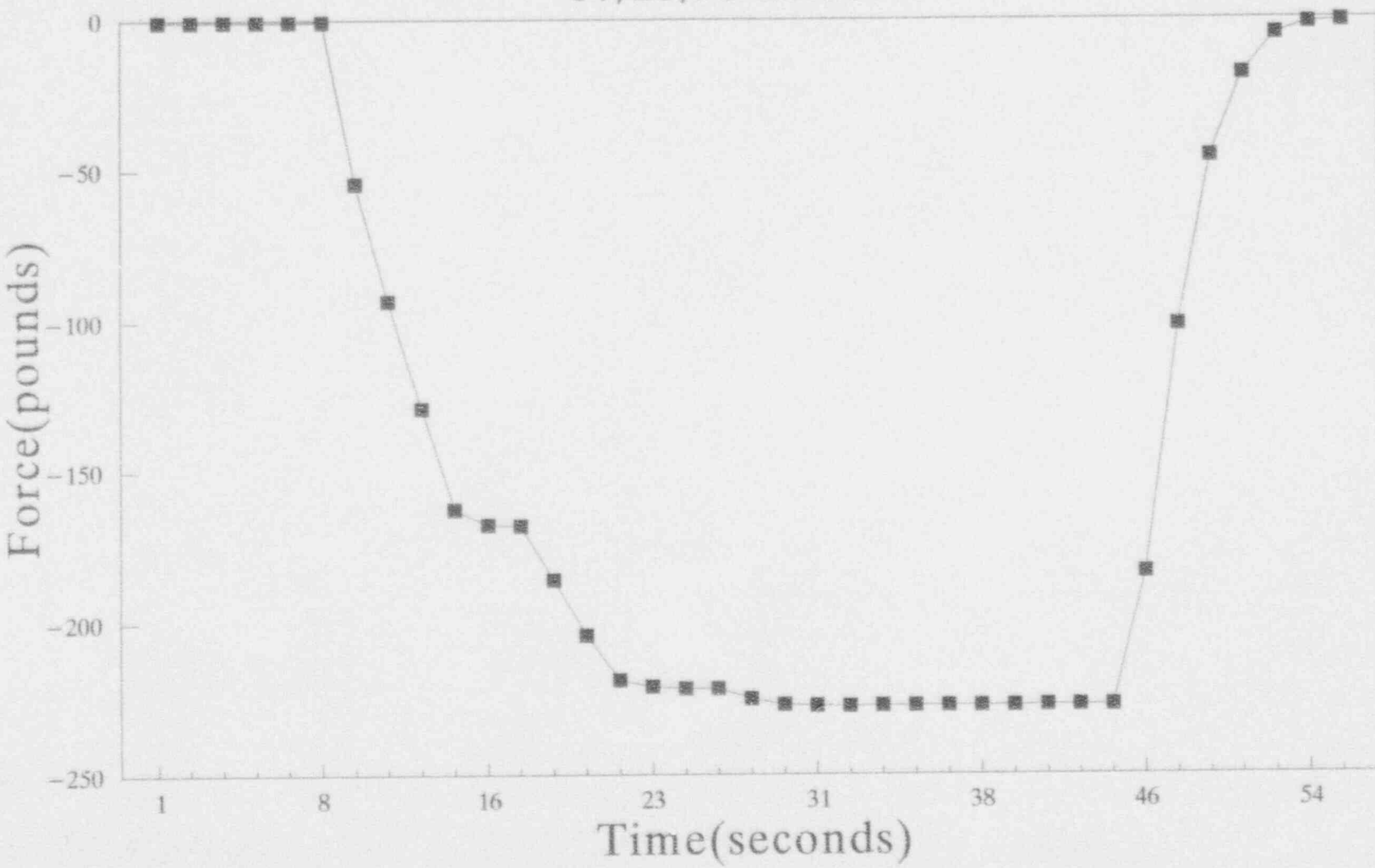


93/07/23 RC Cable Trial #9



93/07/23 RC Cable Trial #10

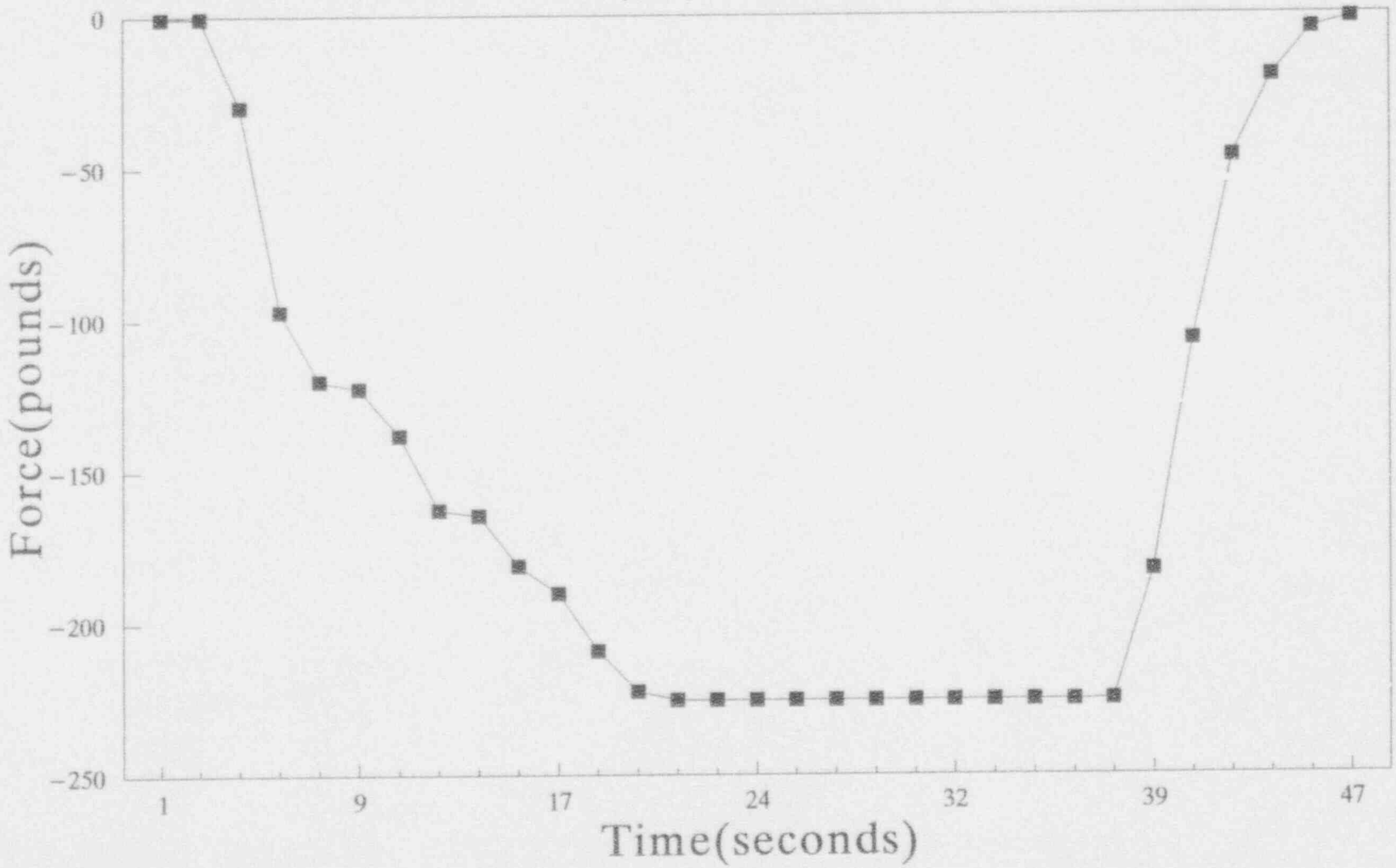
07/23/93 15:13:43



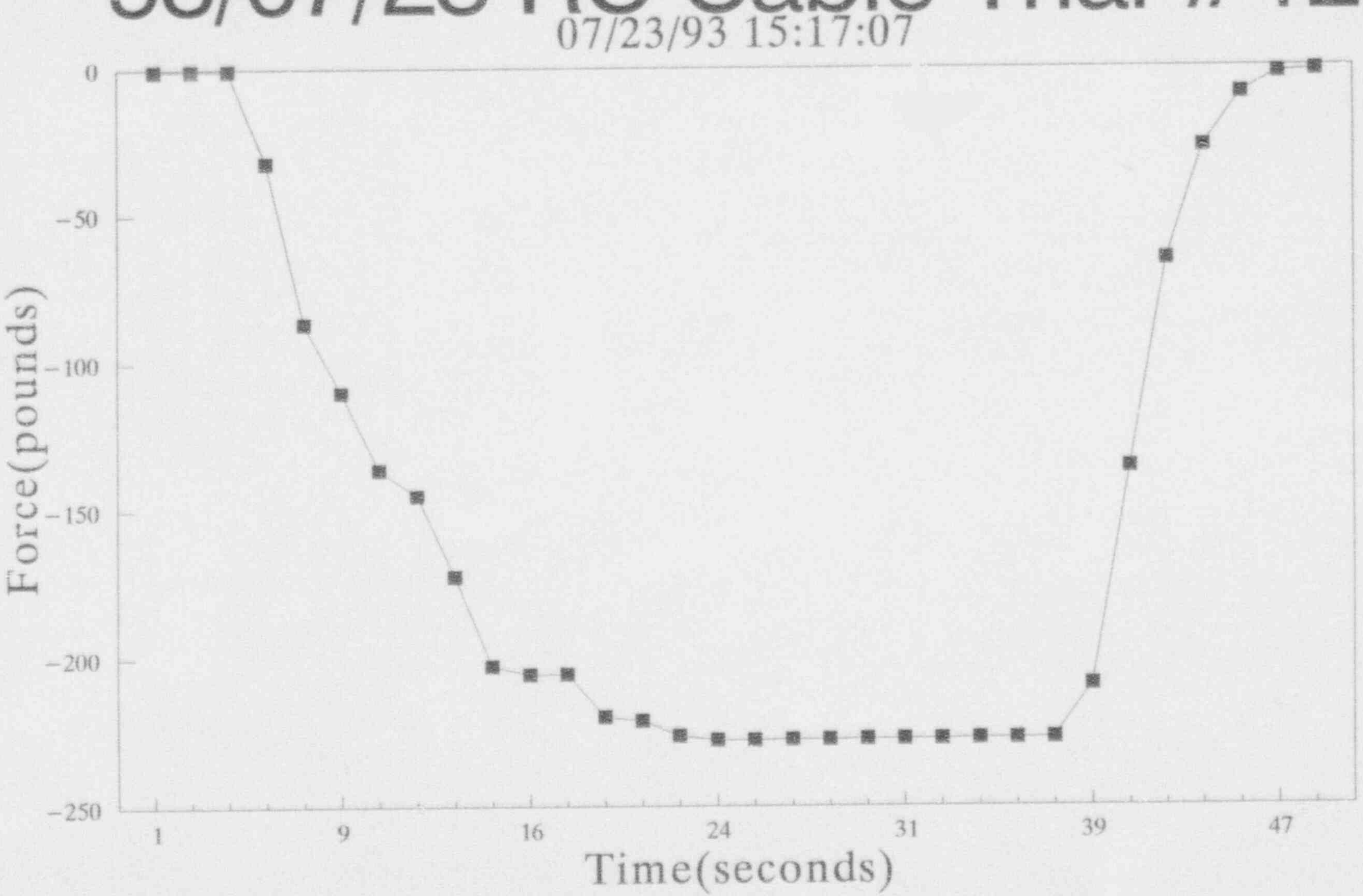
I-21

93/07/23 RC Cable Trial #11

07/23/93 15:15:24



93/07/23 RC Cable Trial #12



APPENDIX M

Projection Sheath Kinking Test Data

Projection Sheath Kinking Test Data Sheet

Trial Number	Observations (attach the force measurement plot)
1	Pulled P.S. manually
2	Video taped all trials
3	still photographs taken
4	Marked position of kink on P.S.
5	No test anomalies observed.
6	Final inside diameter of loop < 2"
7	
8	
9	
10	
11	
12	
13	
14	
15	

Force Transducer Model No. LCCB-300

Serial No. C00030

Calibration Due Date 93/10/31

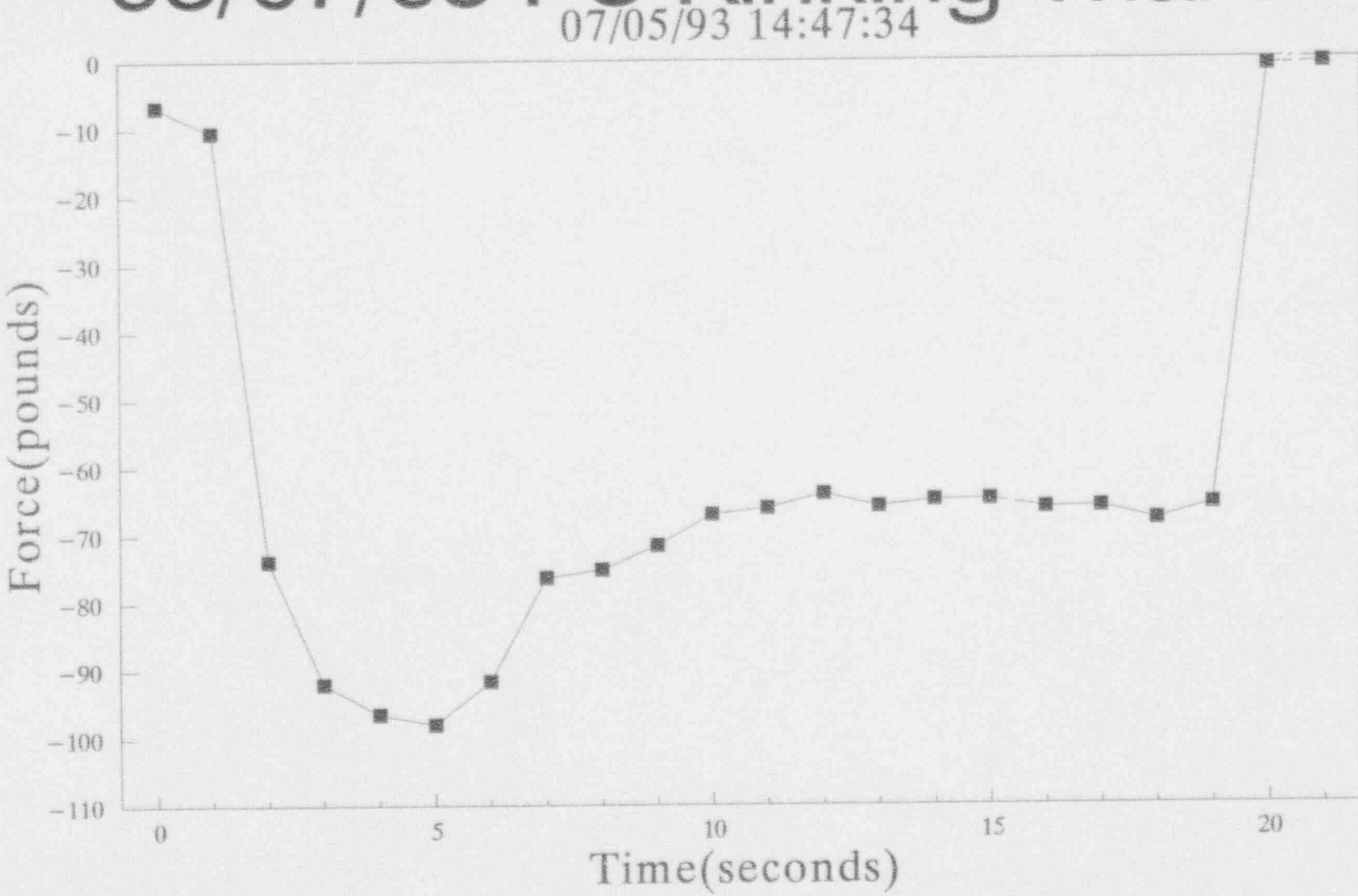
Date 93/07/05

Test Engineer [signature]

QA Witness G.L. Murphy

Project Engineer [signature]

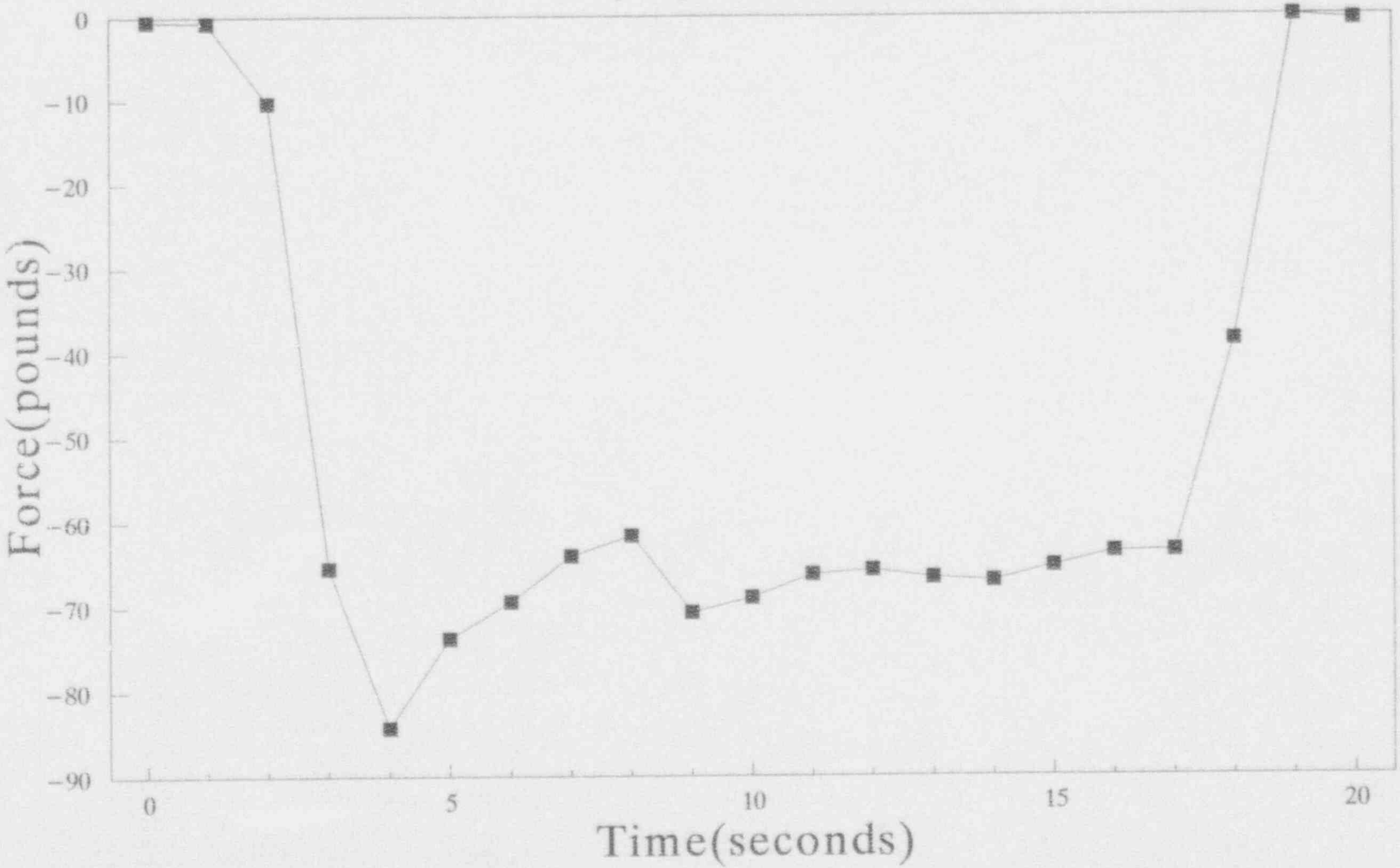
93/07/05 PS Kinking Trial #1



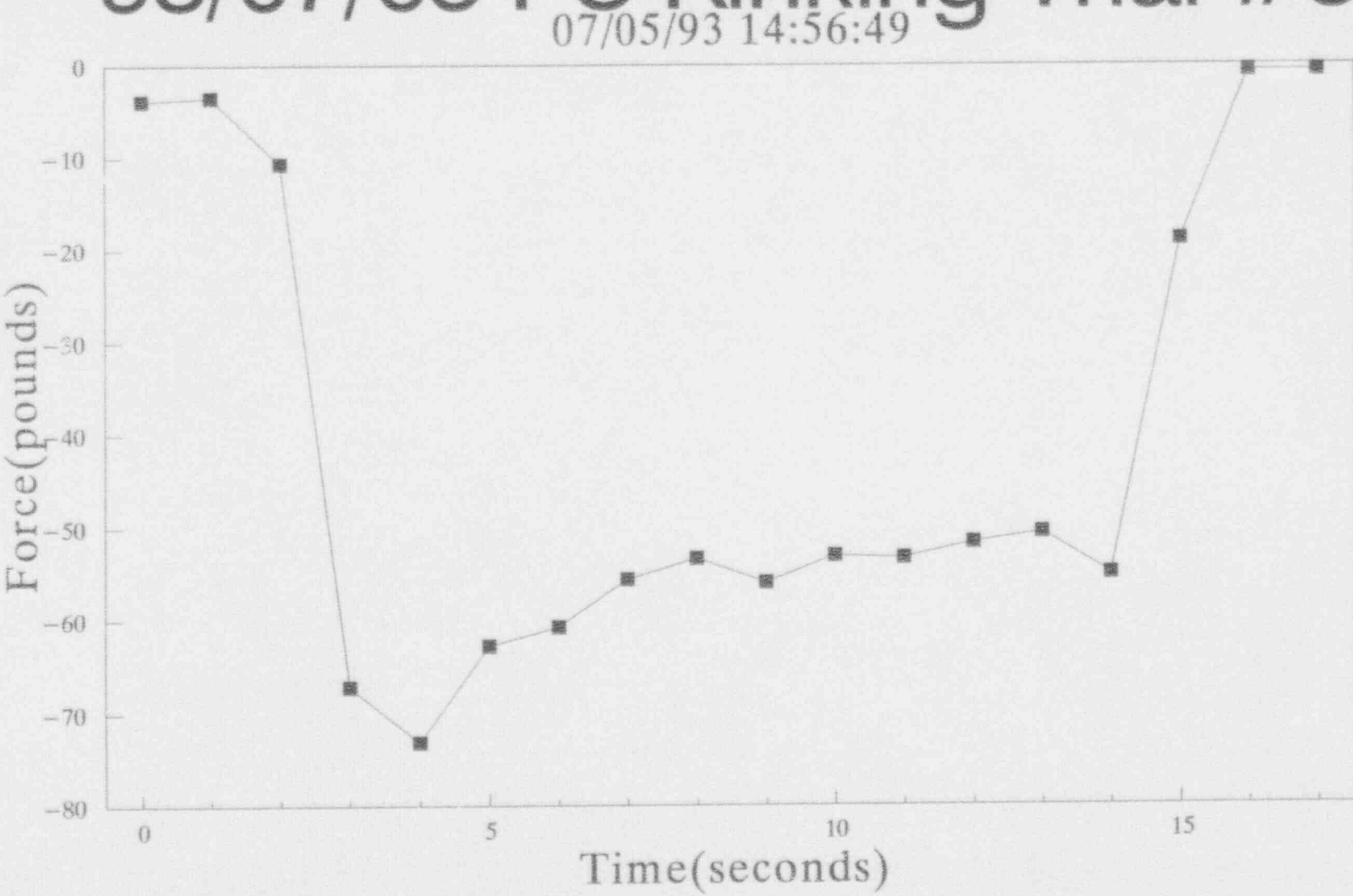
M-3

93/07/05 PS Kinking Trial #2

07/05/93 14:54:56

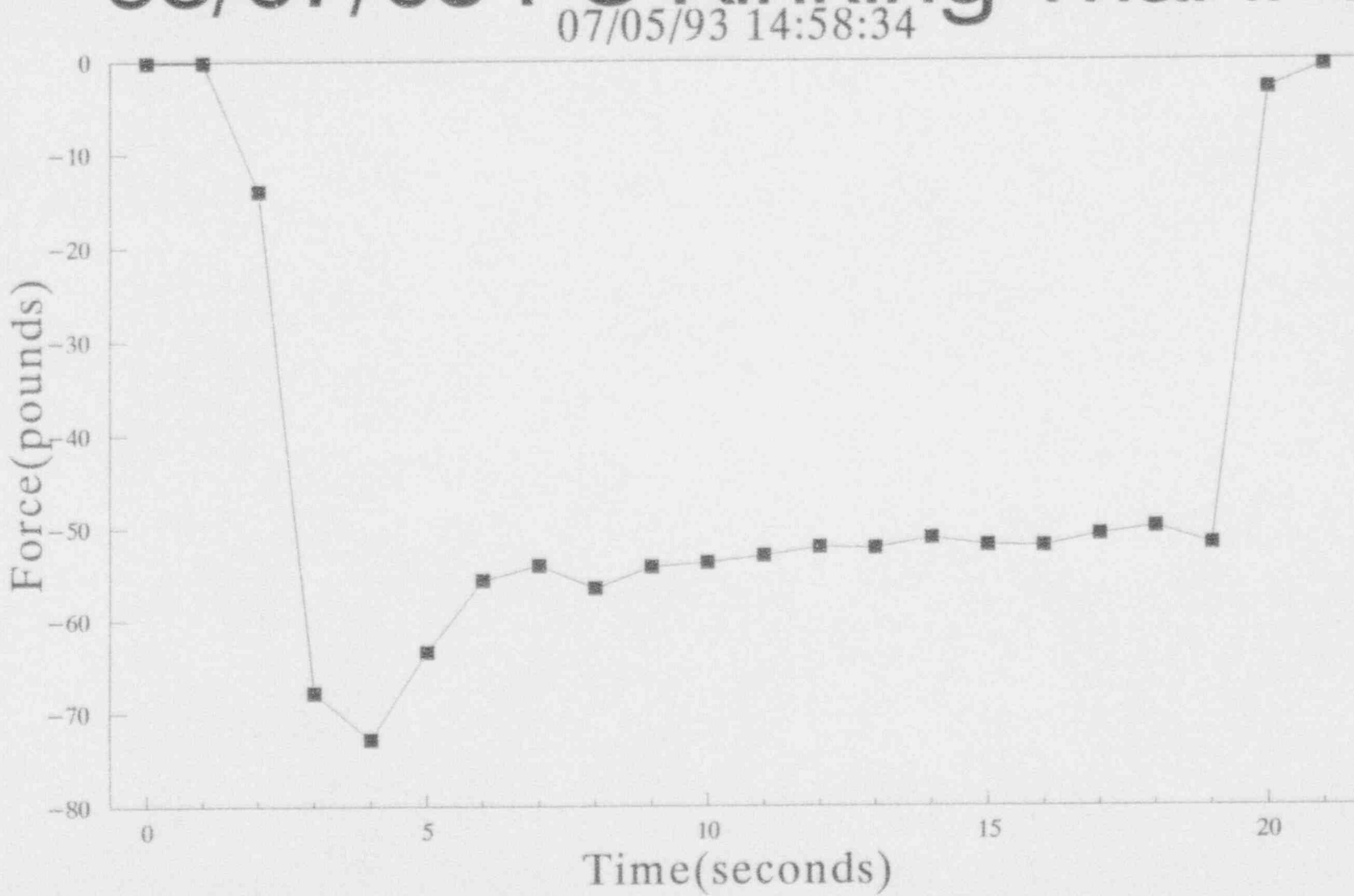


93/07/05 PS Kinking Trial #3



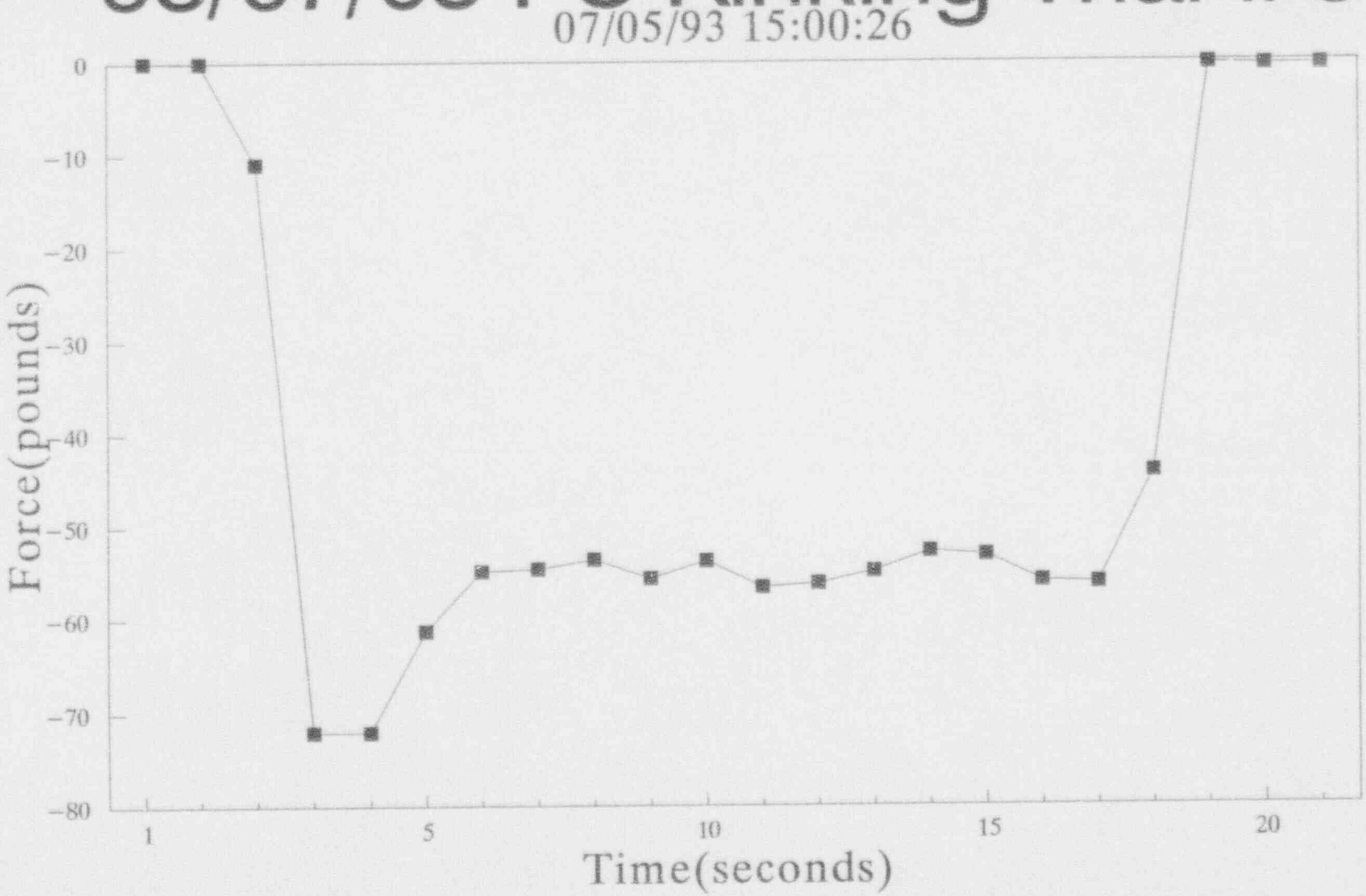
M-5

93/07/05 PS Kinking Trial #4



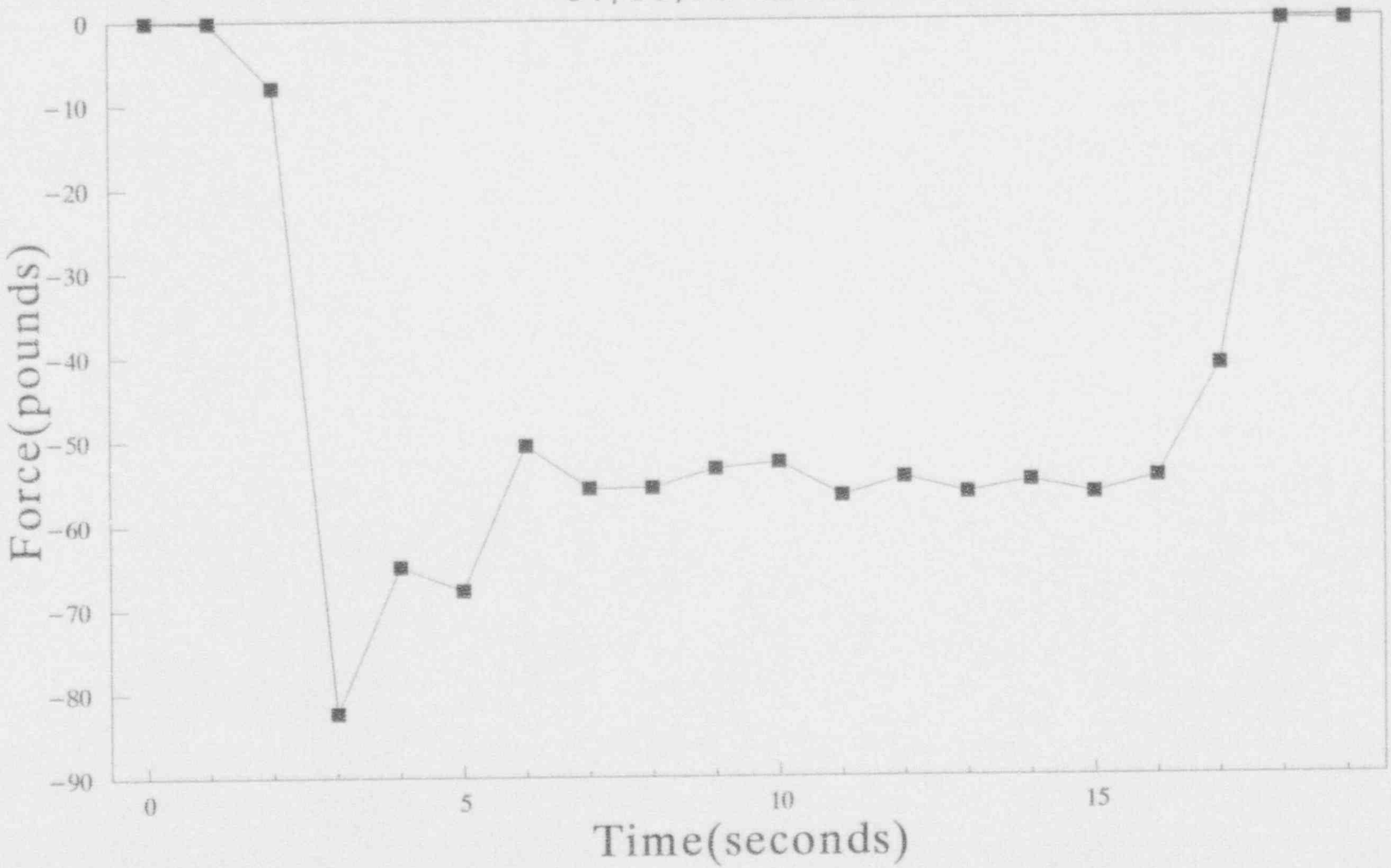
M-6

93/07/05 PS Kinking Trial #5



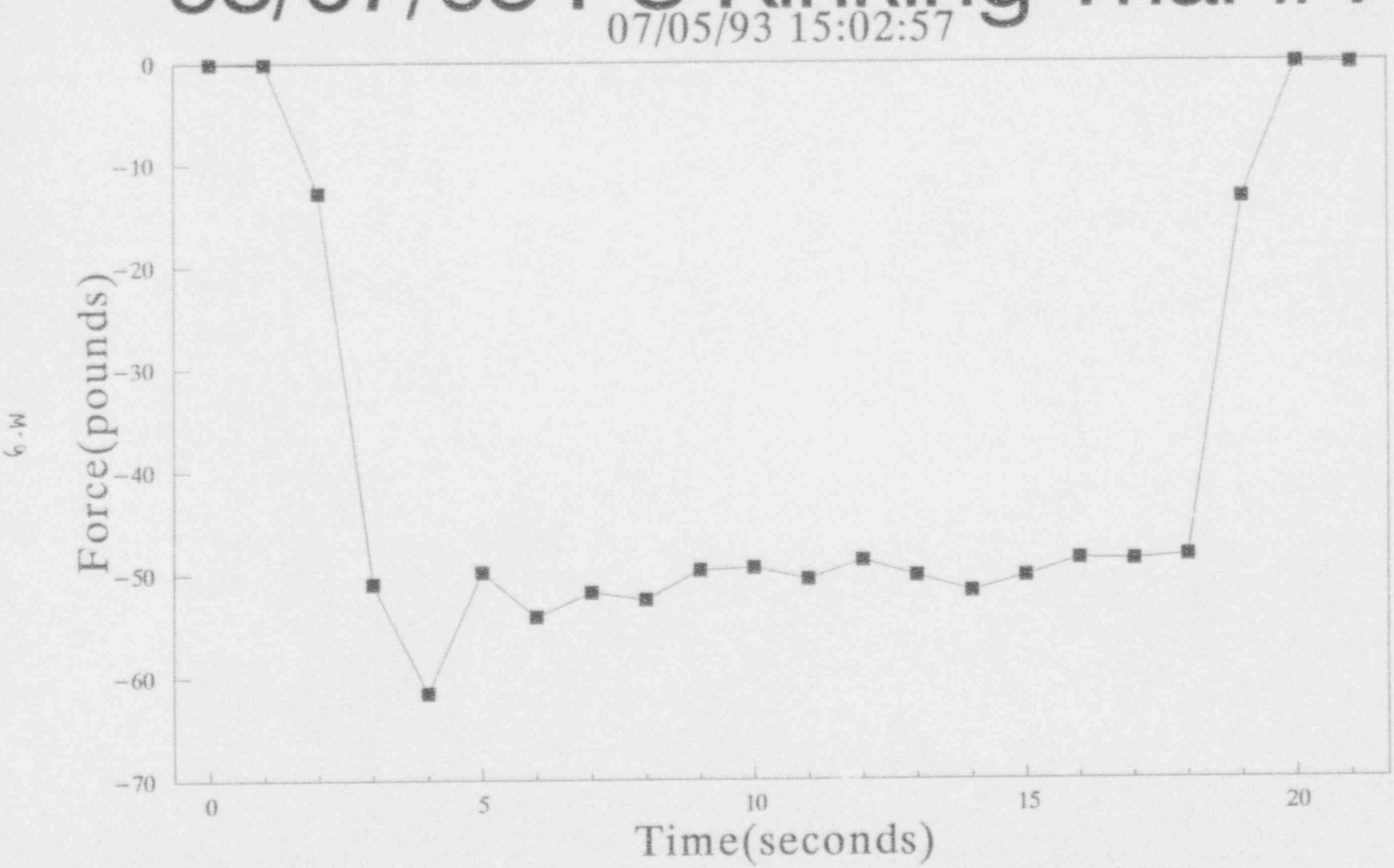
93/07/05 PS Kinking Trial #6

07/05/93 15:01:41

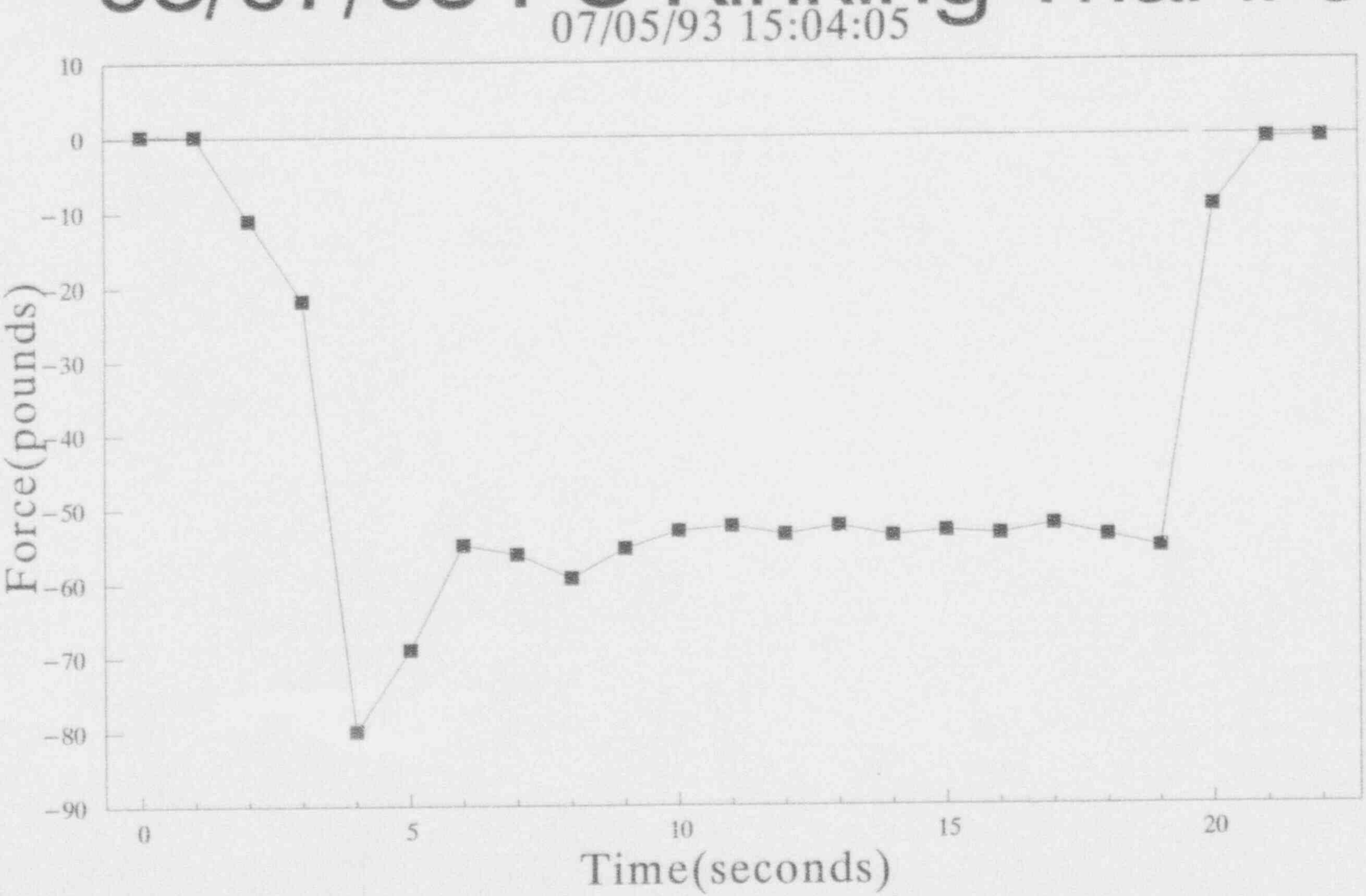


8-W

93/07/05 PS Kinking Trial #7



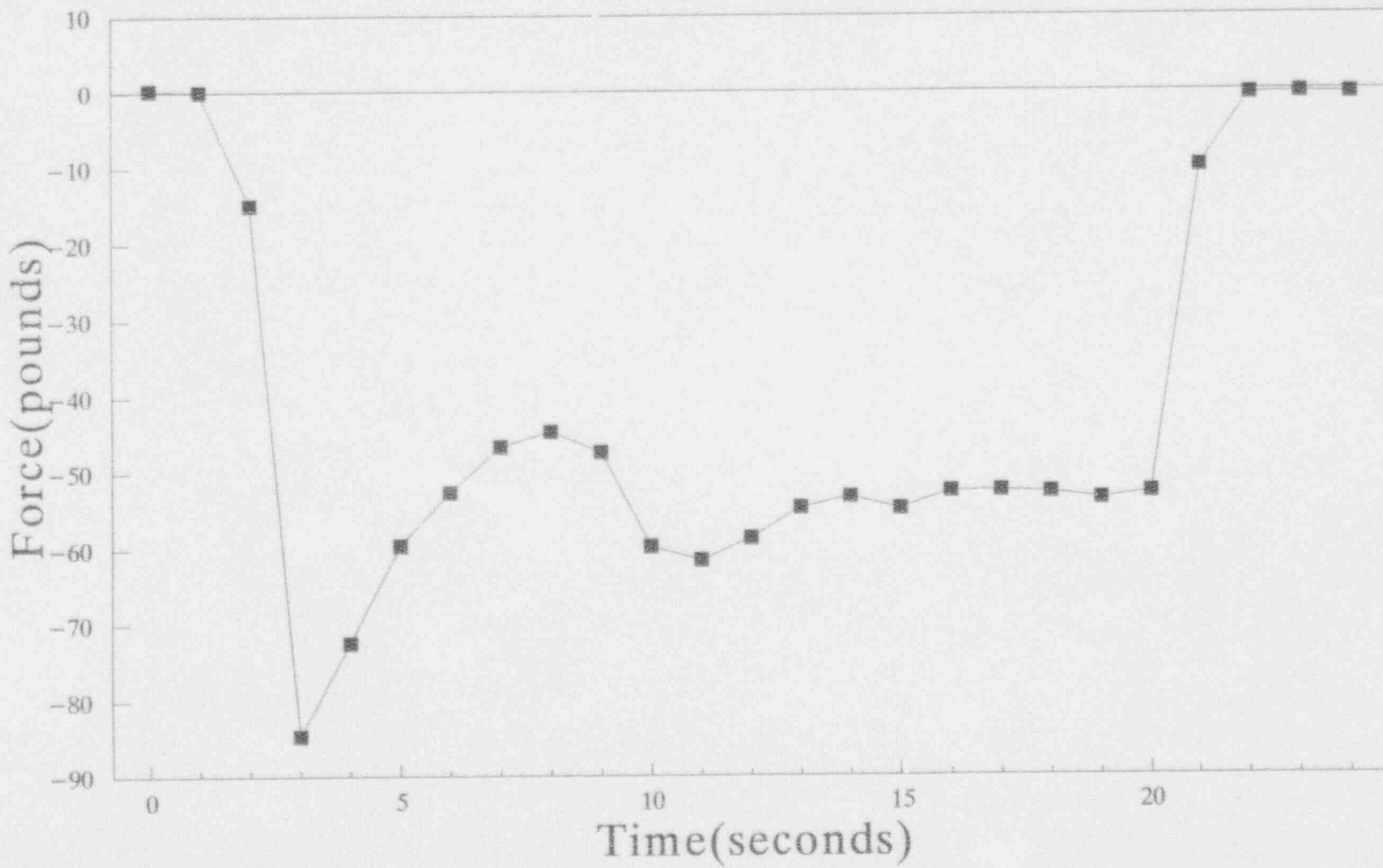
93/07/05 PS Kinking Trial #8



M-10

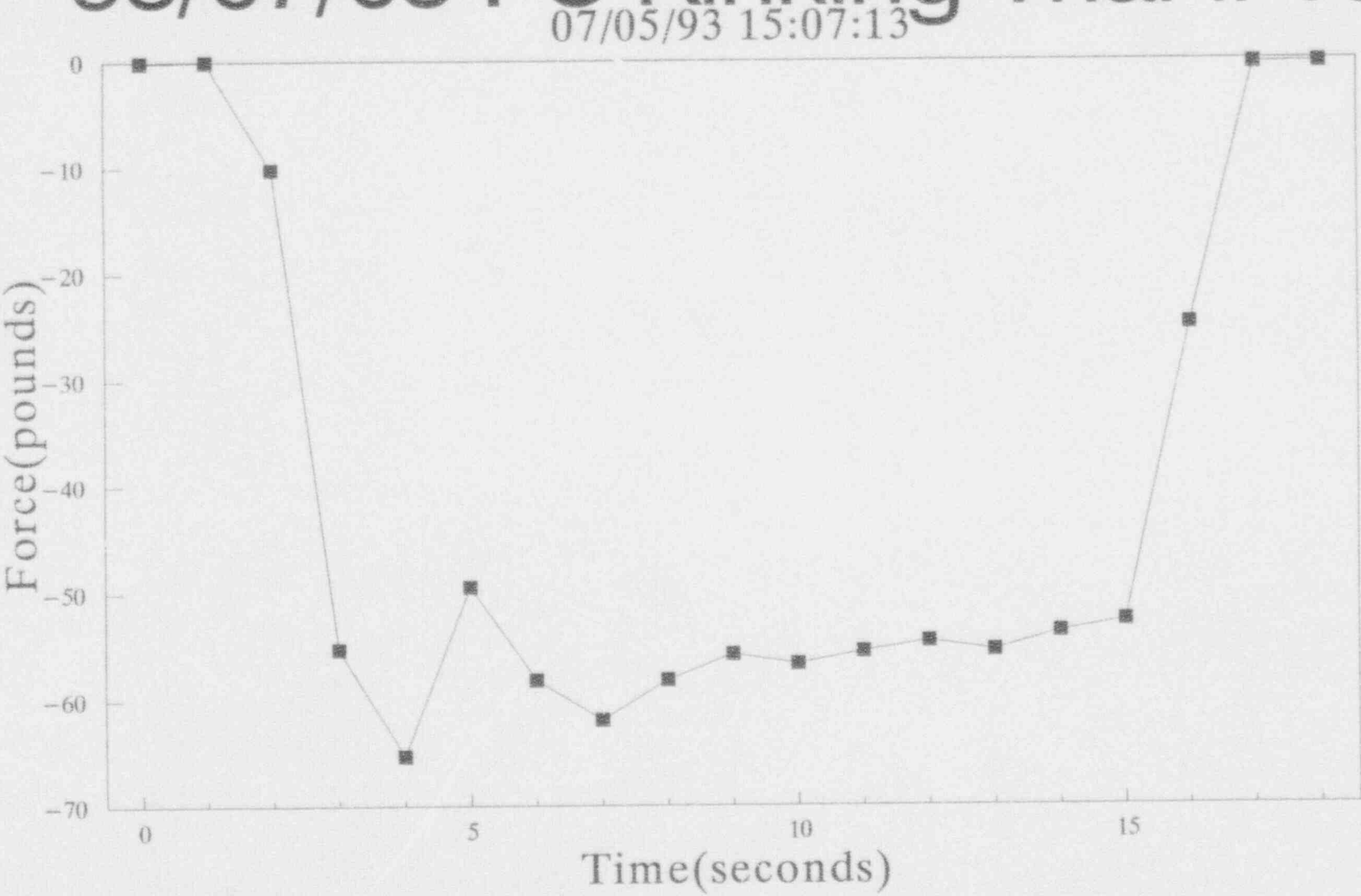
93/07/05 PS Kinking Trial #9

07/05/93 15:05:25



M-11

93/07/05 PS Kinking Trial #10

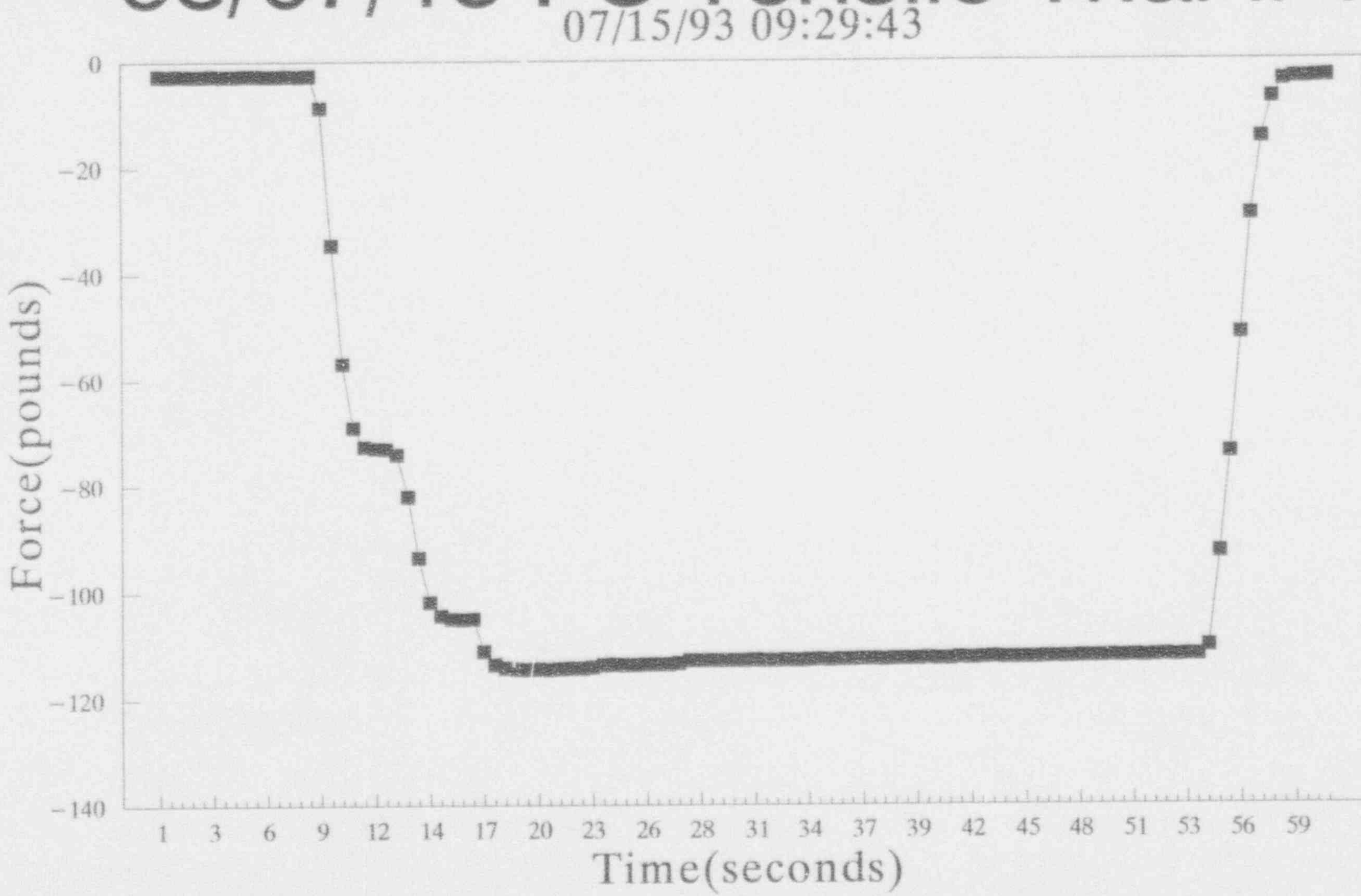


M-12

APPENDIX N

Projection Sheet Tensile Test Data

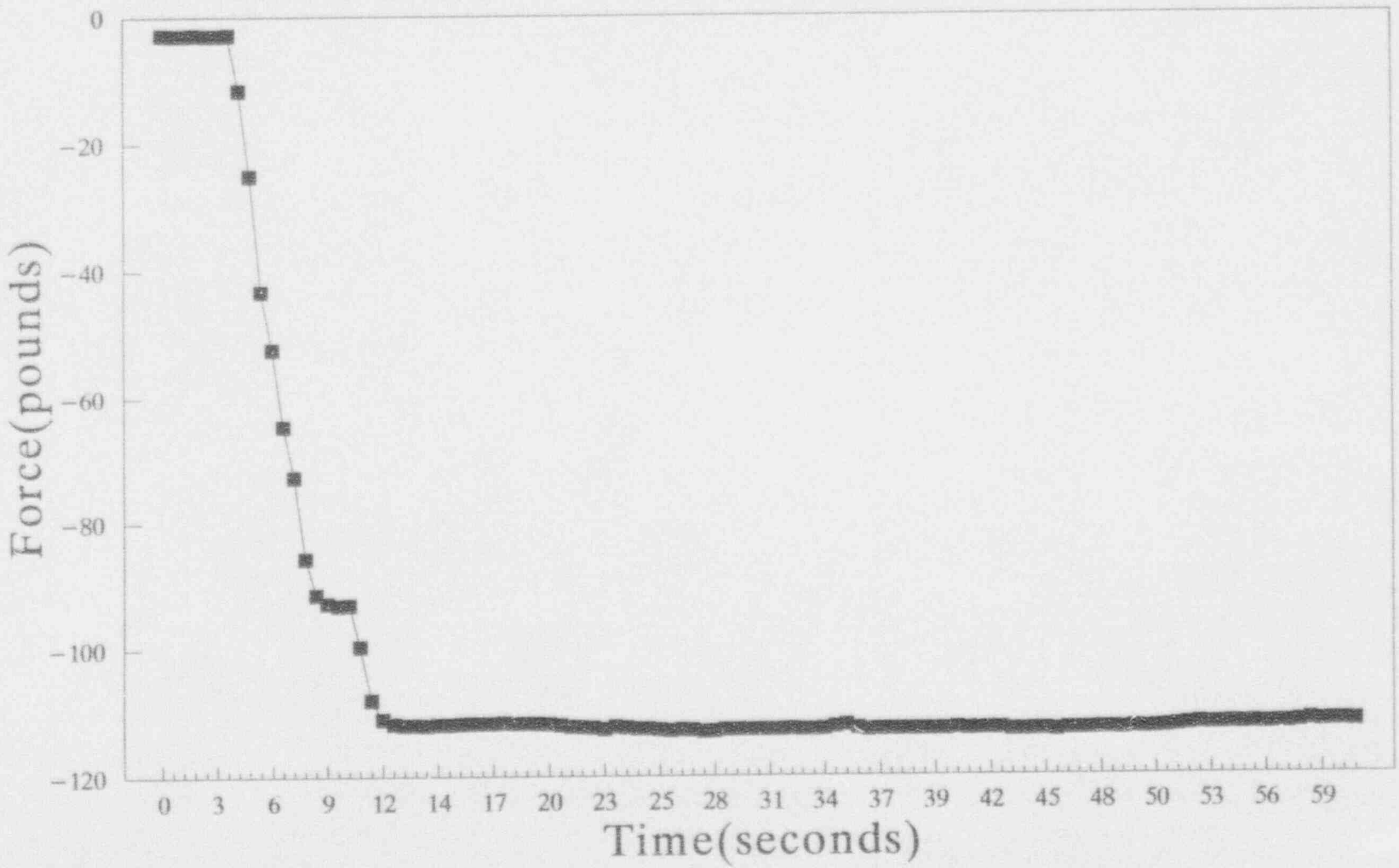
93/07/15 PS Tensile Trial #1



N-2

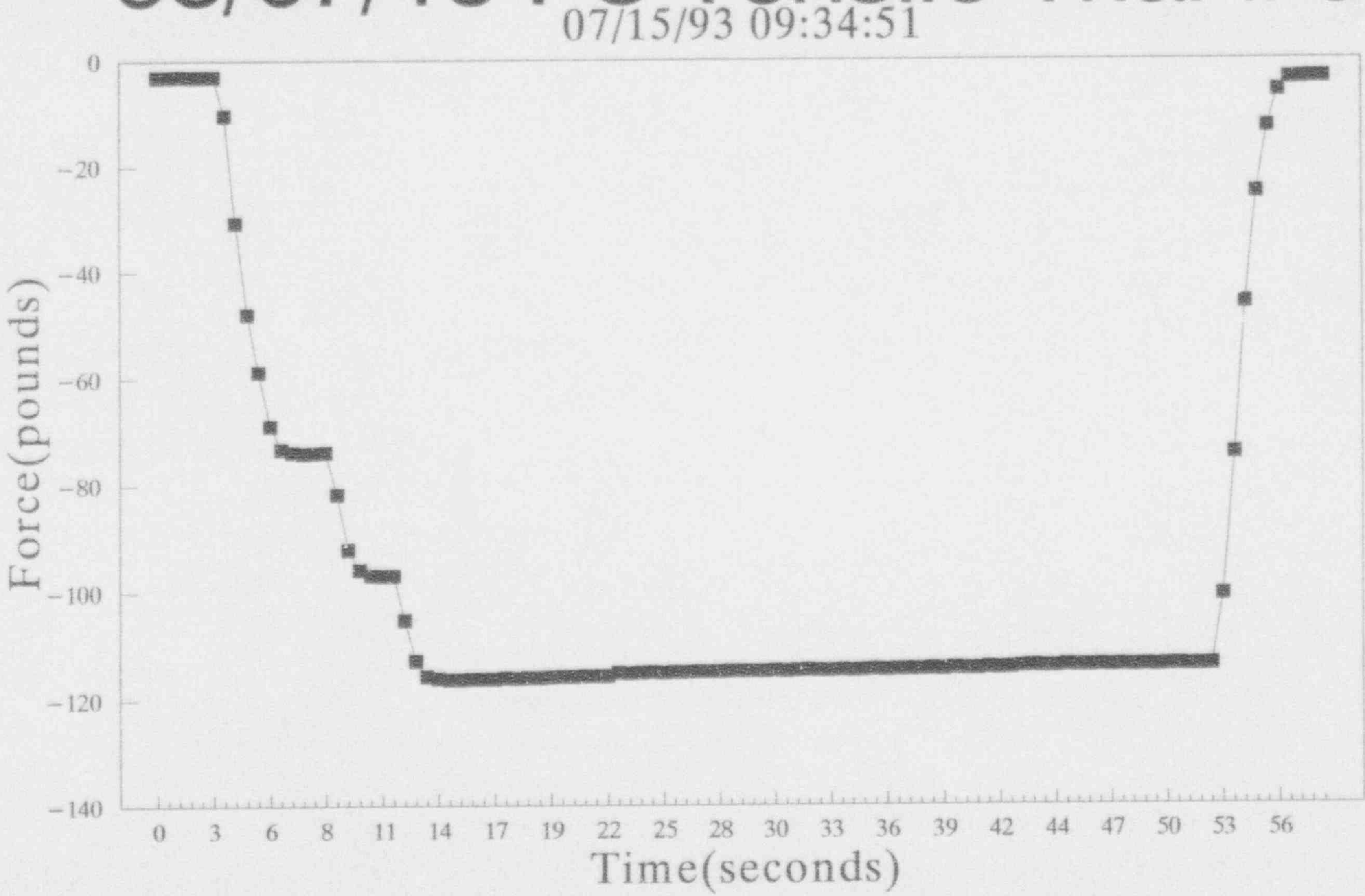
93/07/15 PS Tensile Trial #2

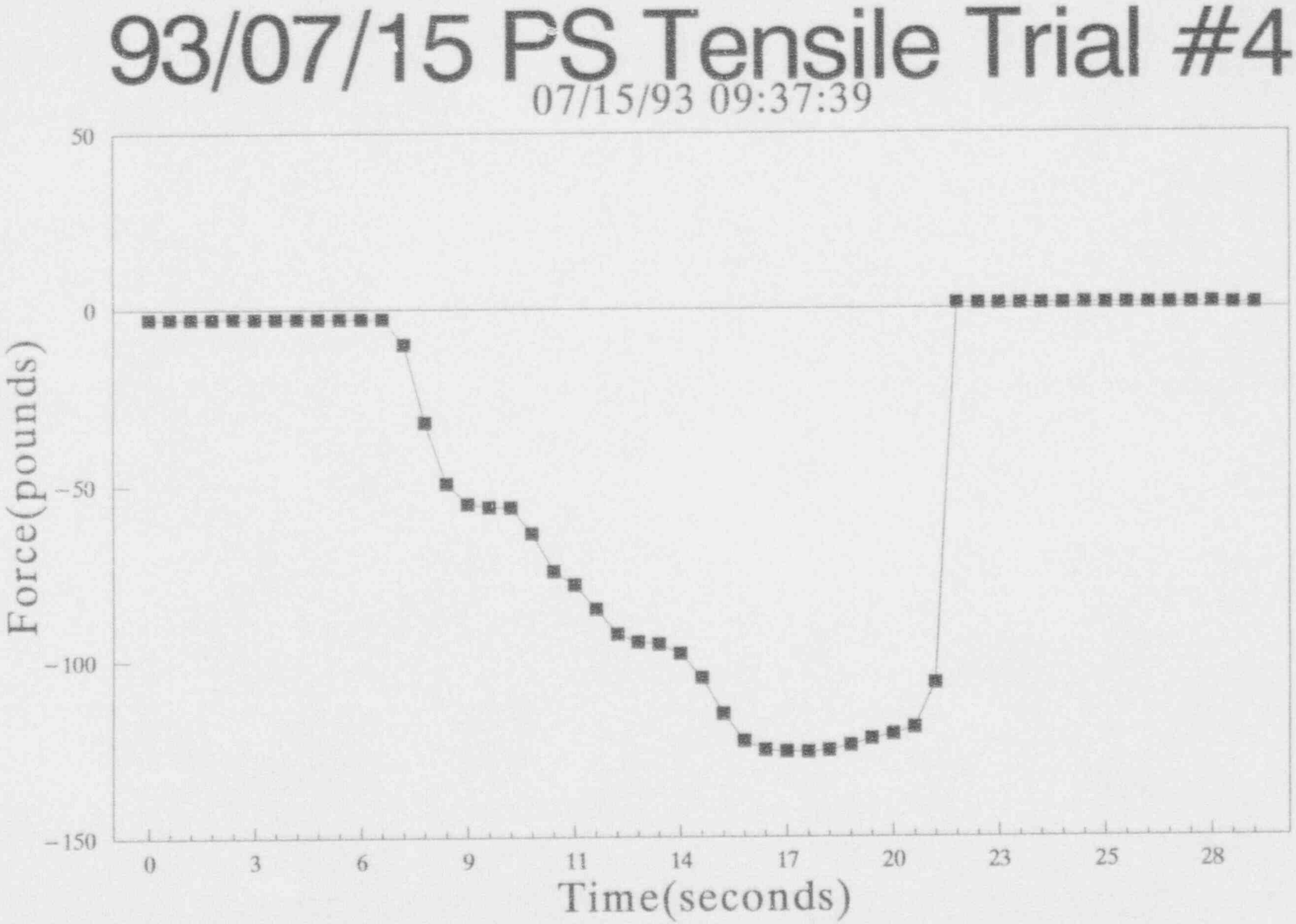
07/15/93 09:33:09



N-3

93/07/15 PS Tensile Trial #3

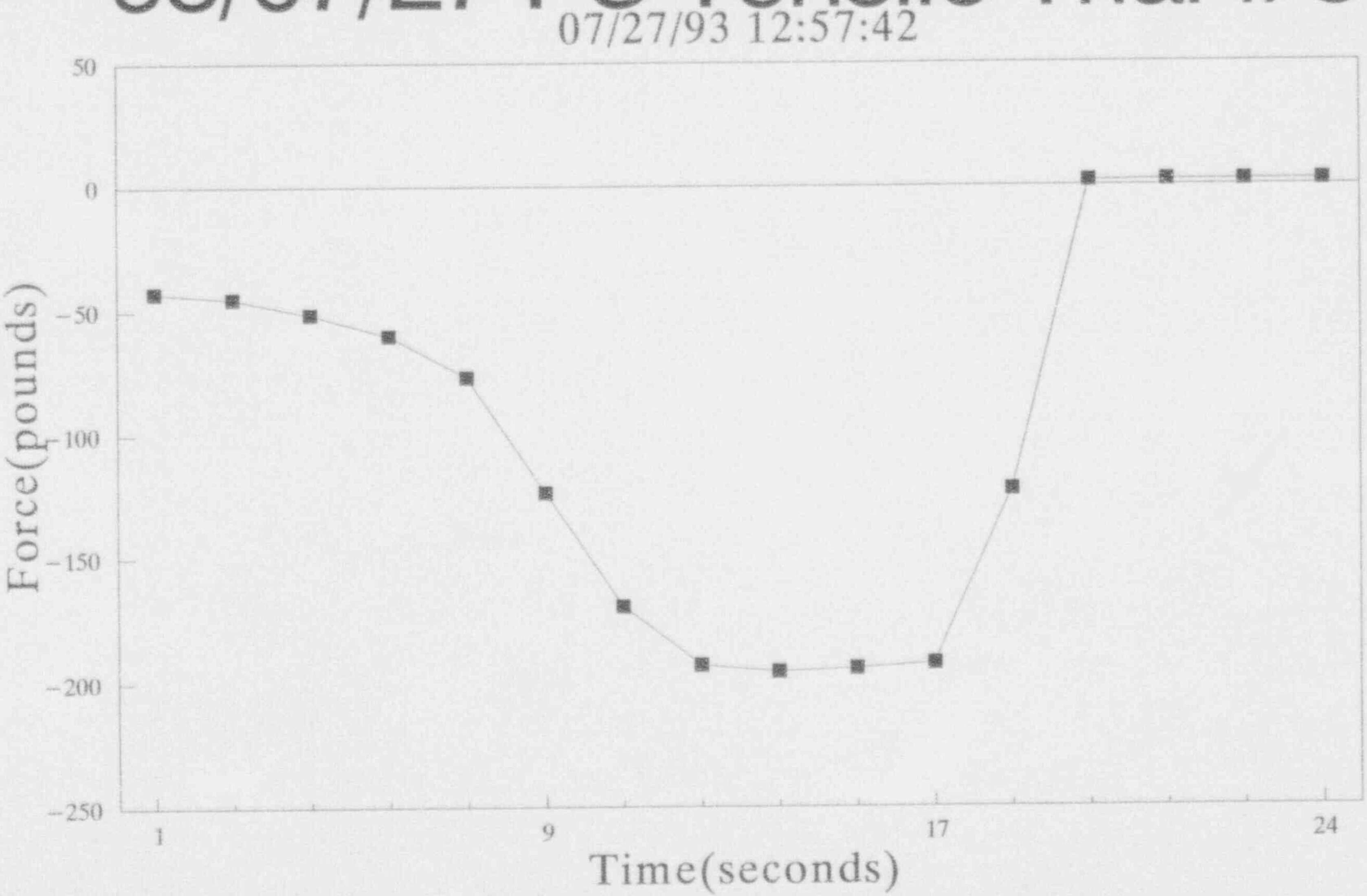




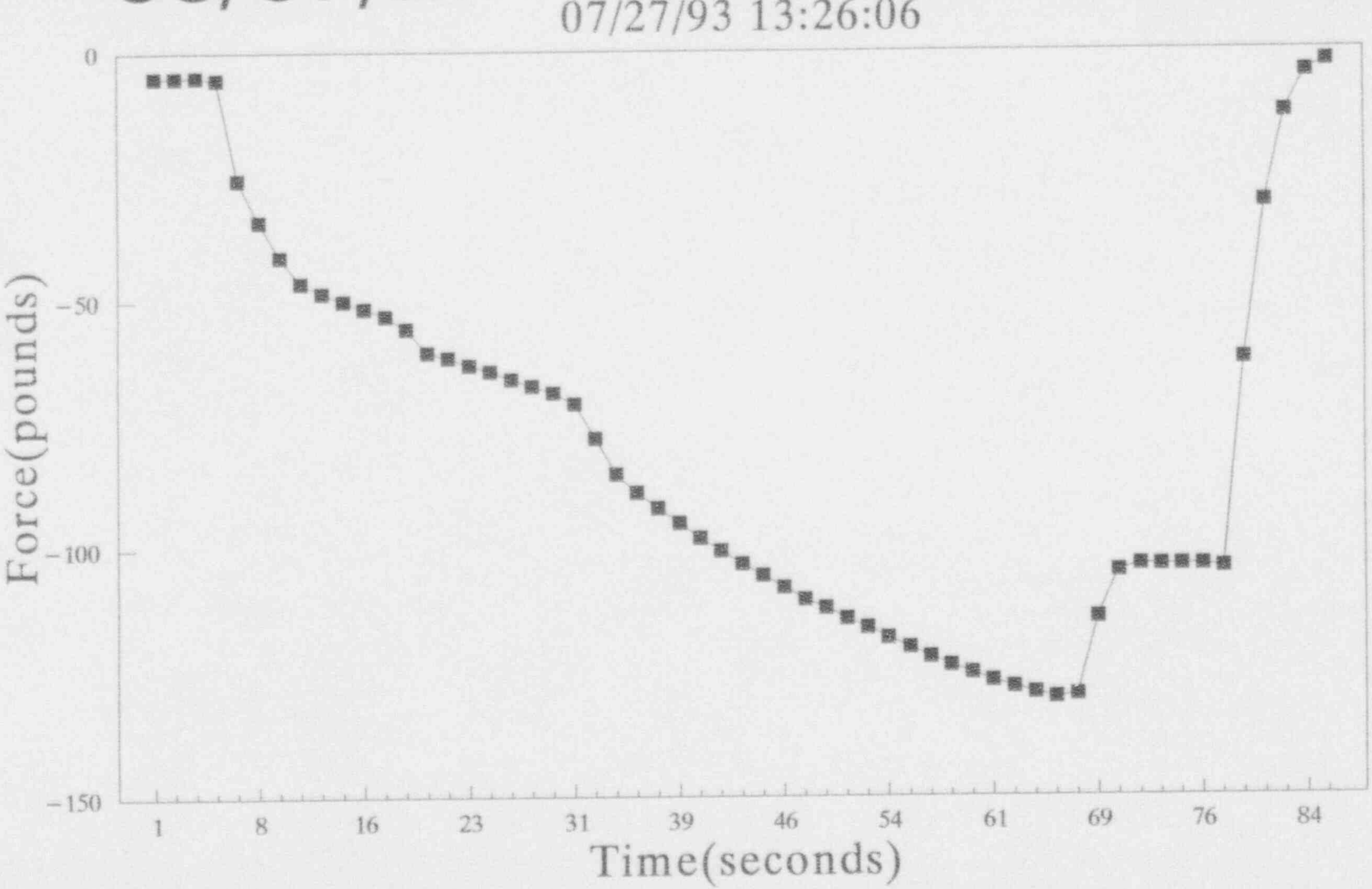
93/07/15 PS Tensile Trial #4
07/15/93 09:37:39
Force(pounds)
50
0
-50
-100
-150
Time(seconds)
0
3
6
9
11
14
17
20
23
25
28

5-N

93/07/27 PS Tensile Trial #5



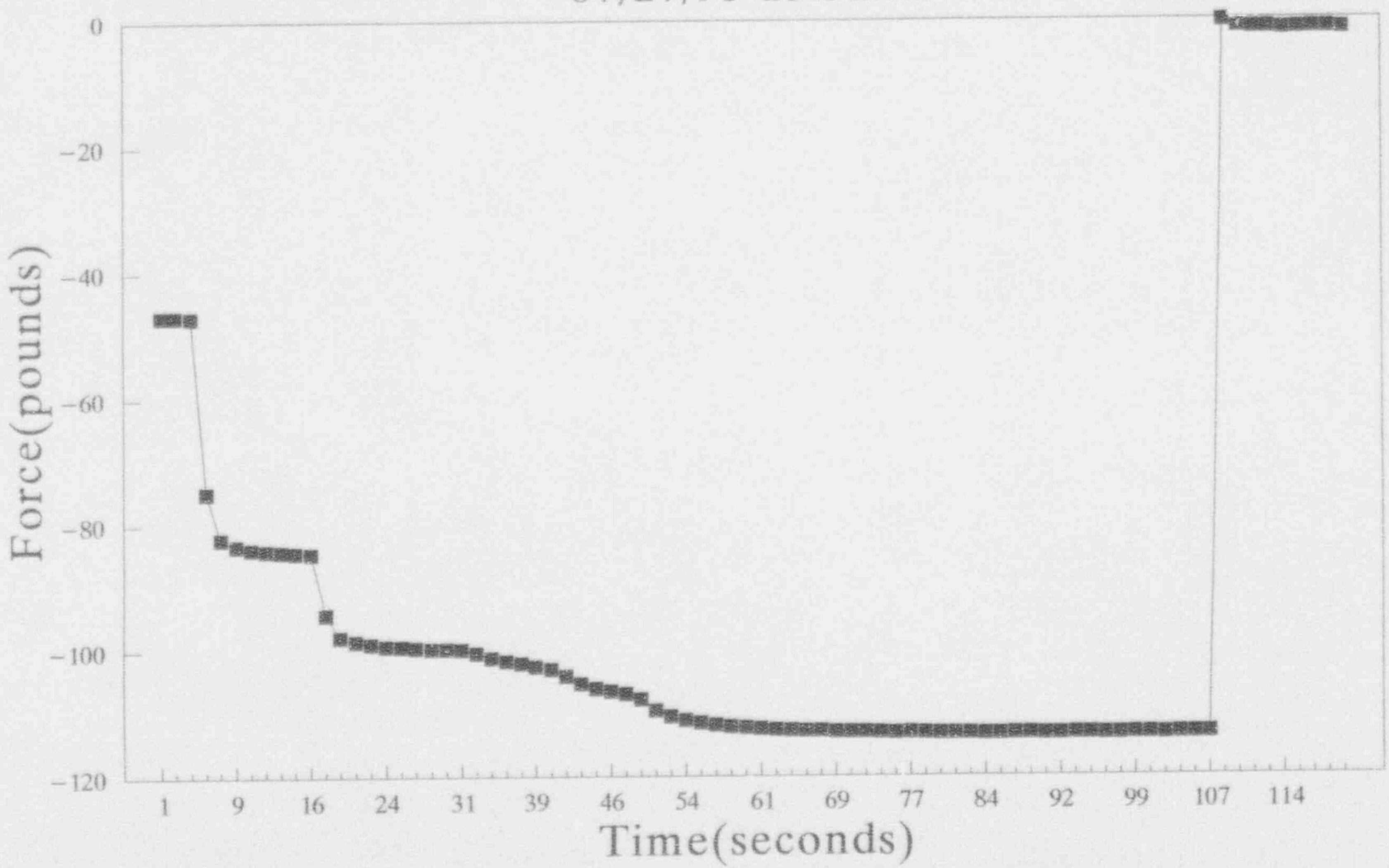
93/07/27 PS Tensile Trial #6



N-7

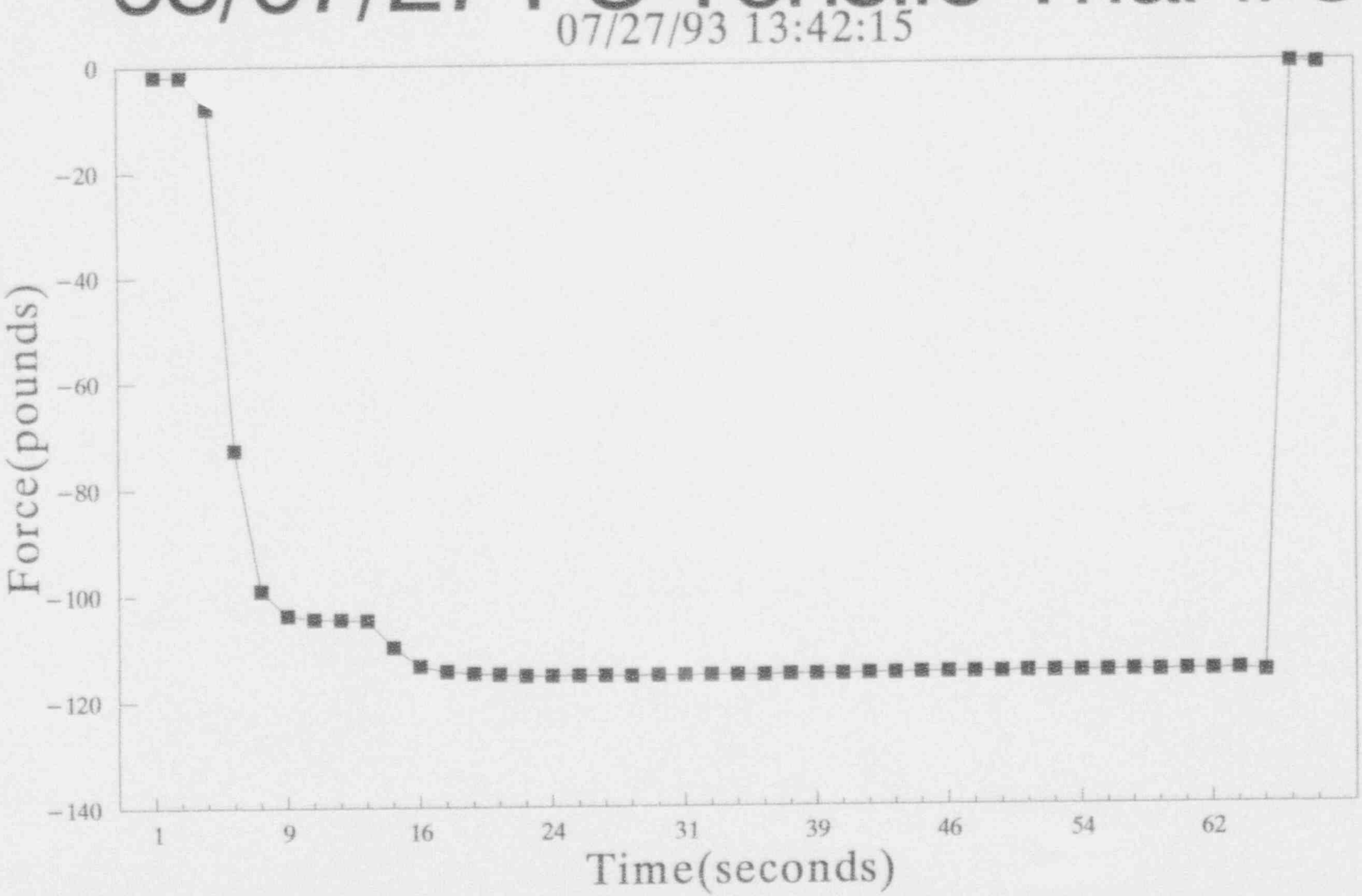
93/07/27 PS Tensile Trial #7

07/27/93 13:32:22



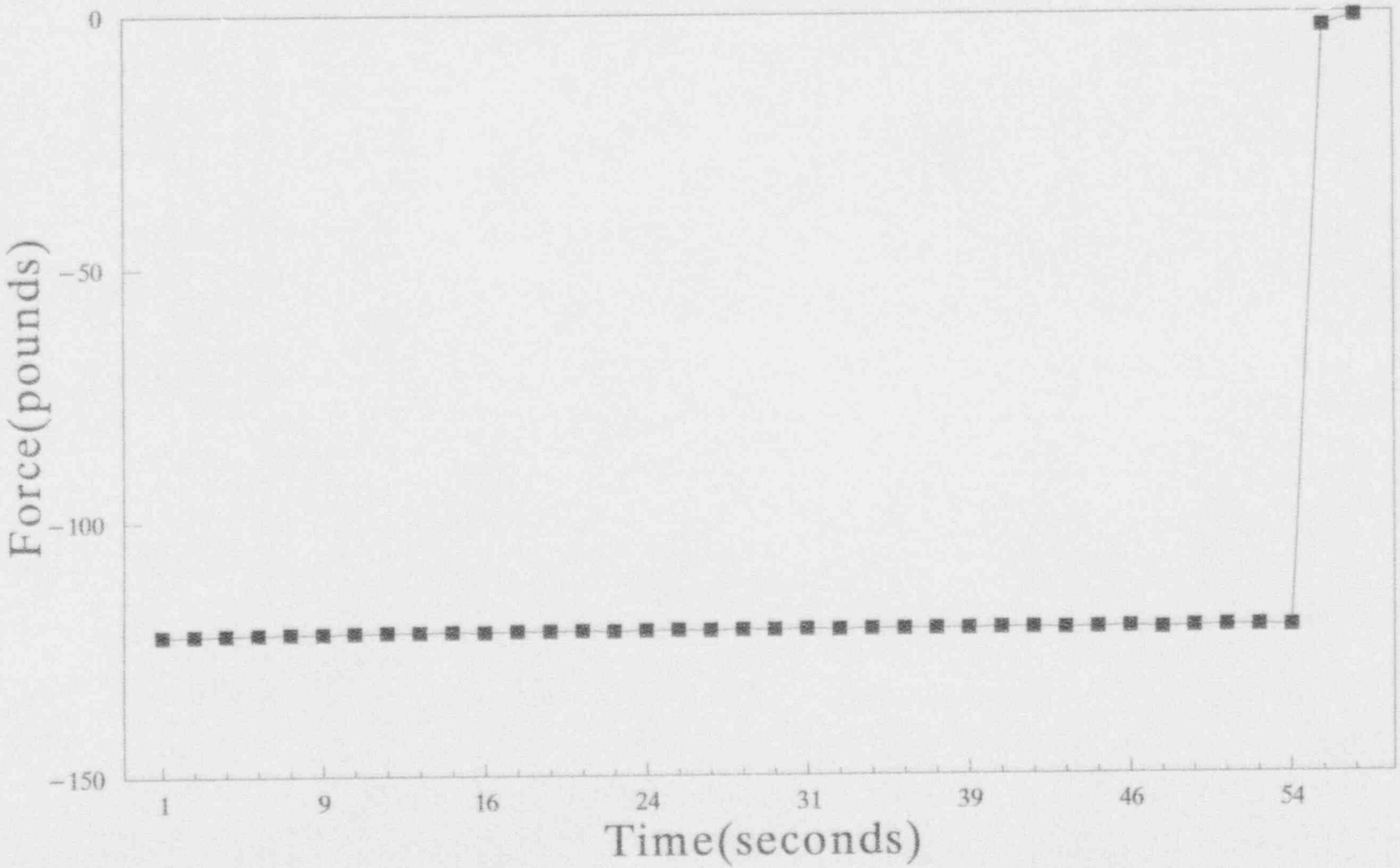
8-N

93/07/27 PS Tensile Trial #8



93/07/27 PS Tensile Trial #9

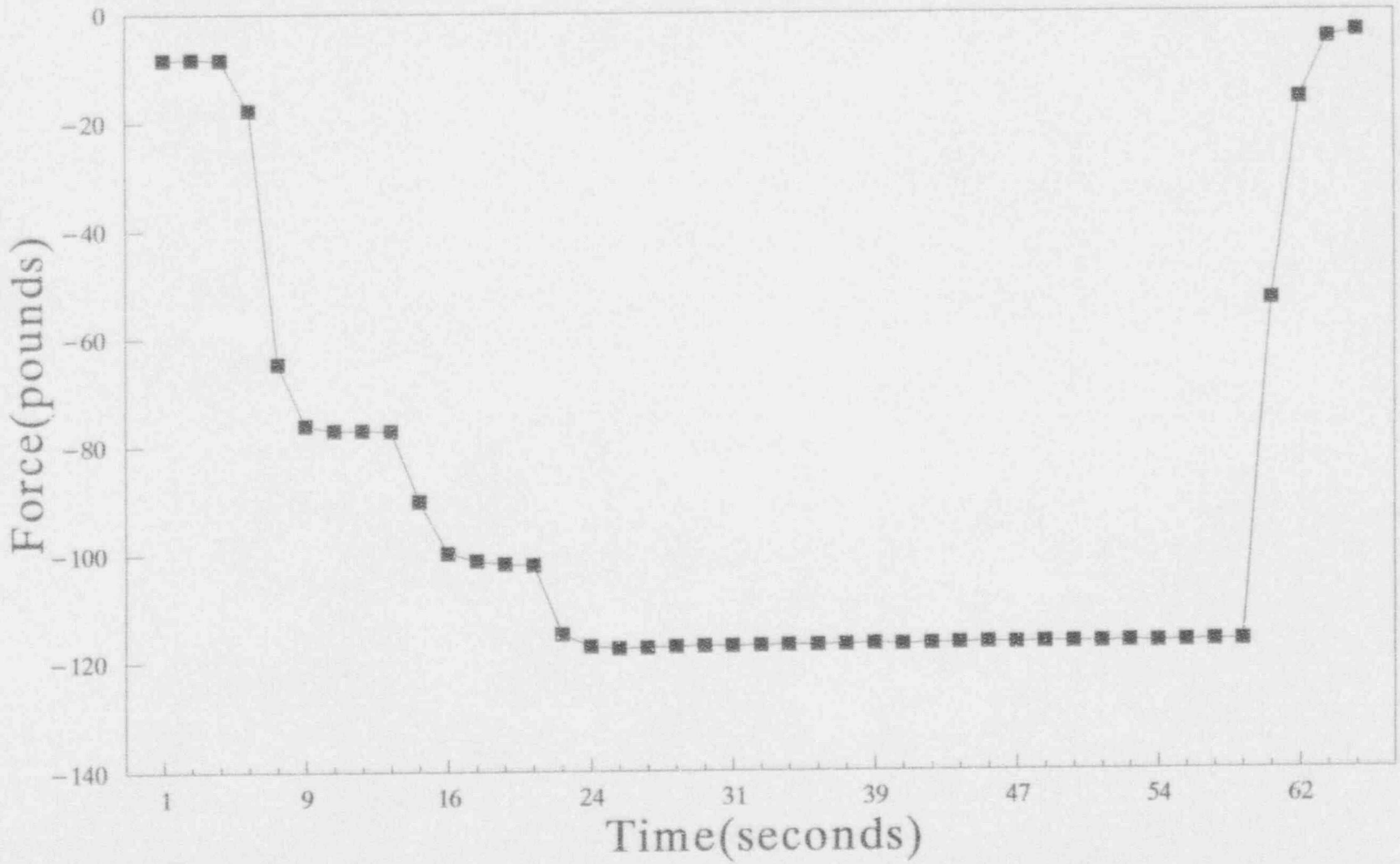
07/27/93 13:44:21



N-10

93/07/27 PS Tensile Trial #10

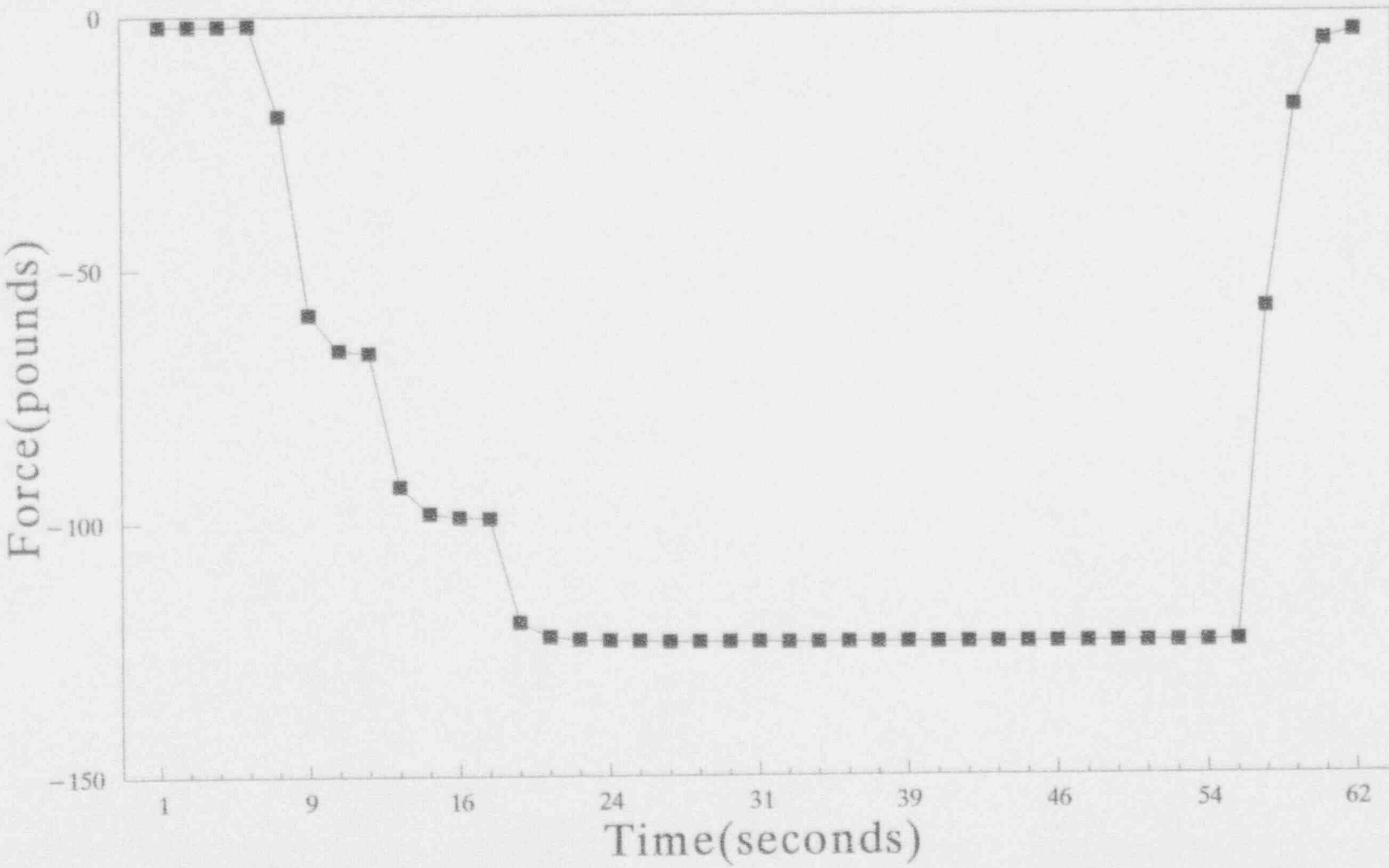
07/27/93 13:46:34



N-11

93/07/27 PS Tensile Trial #11

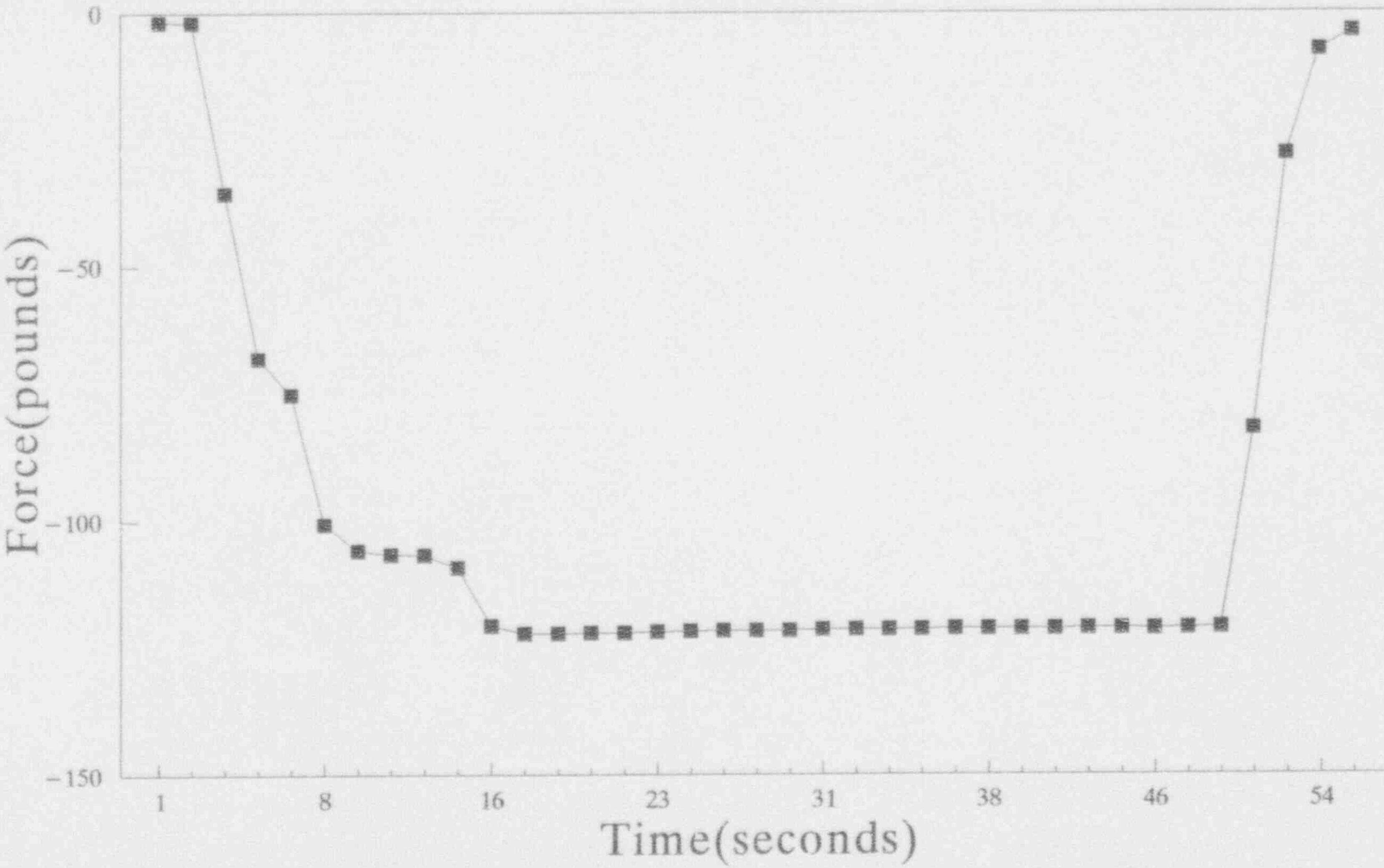
07/27/93 13:48:51



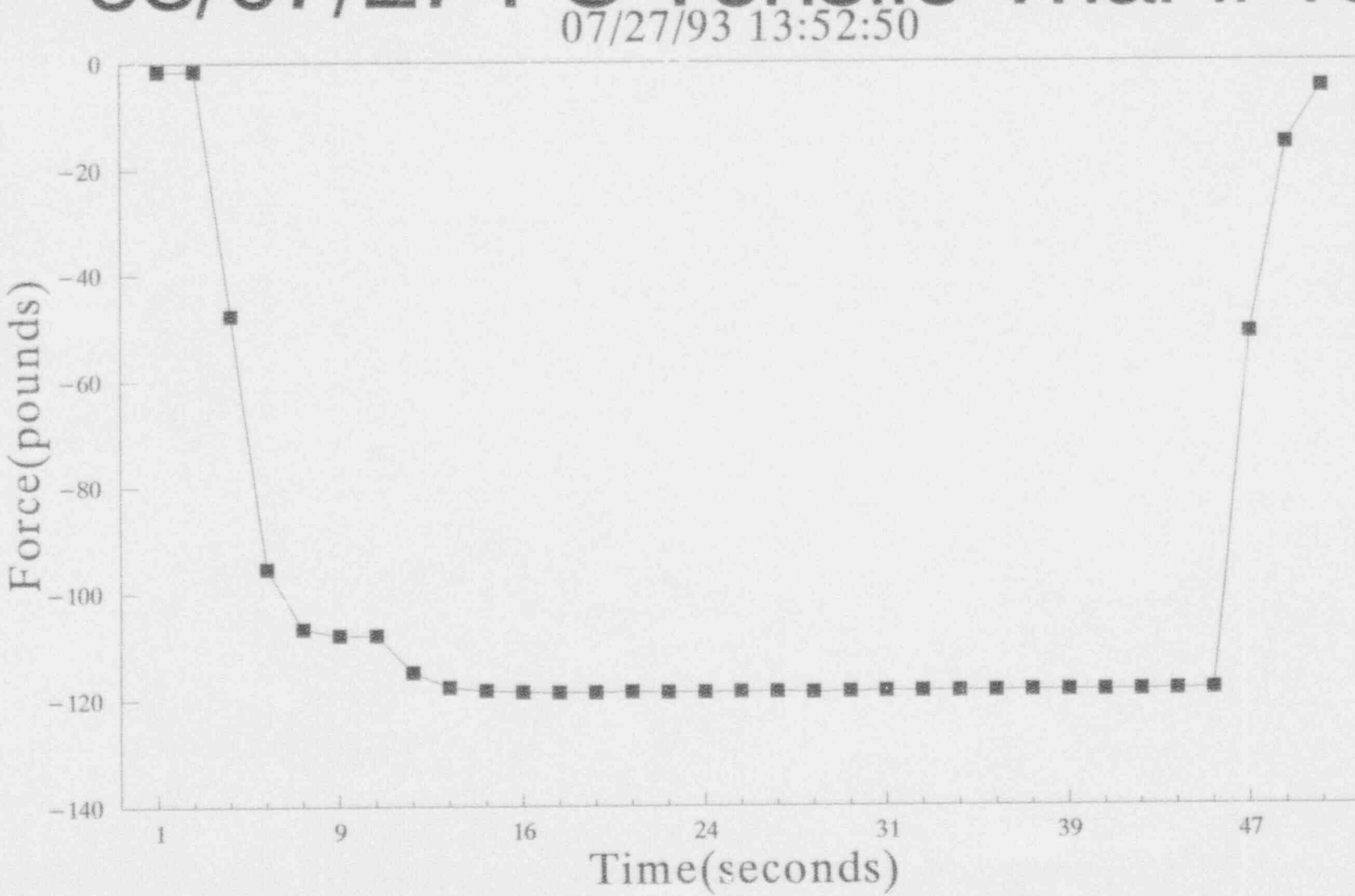
N-12

93/07/27 PS Tensile Trial #12

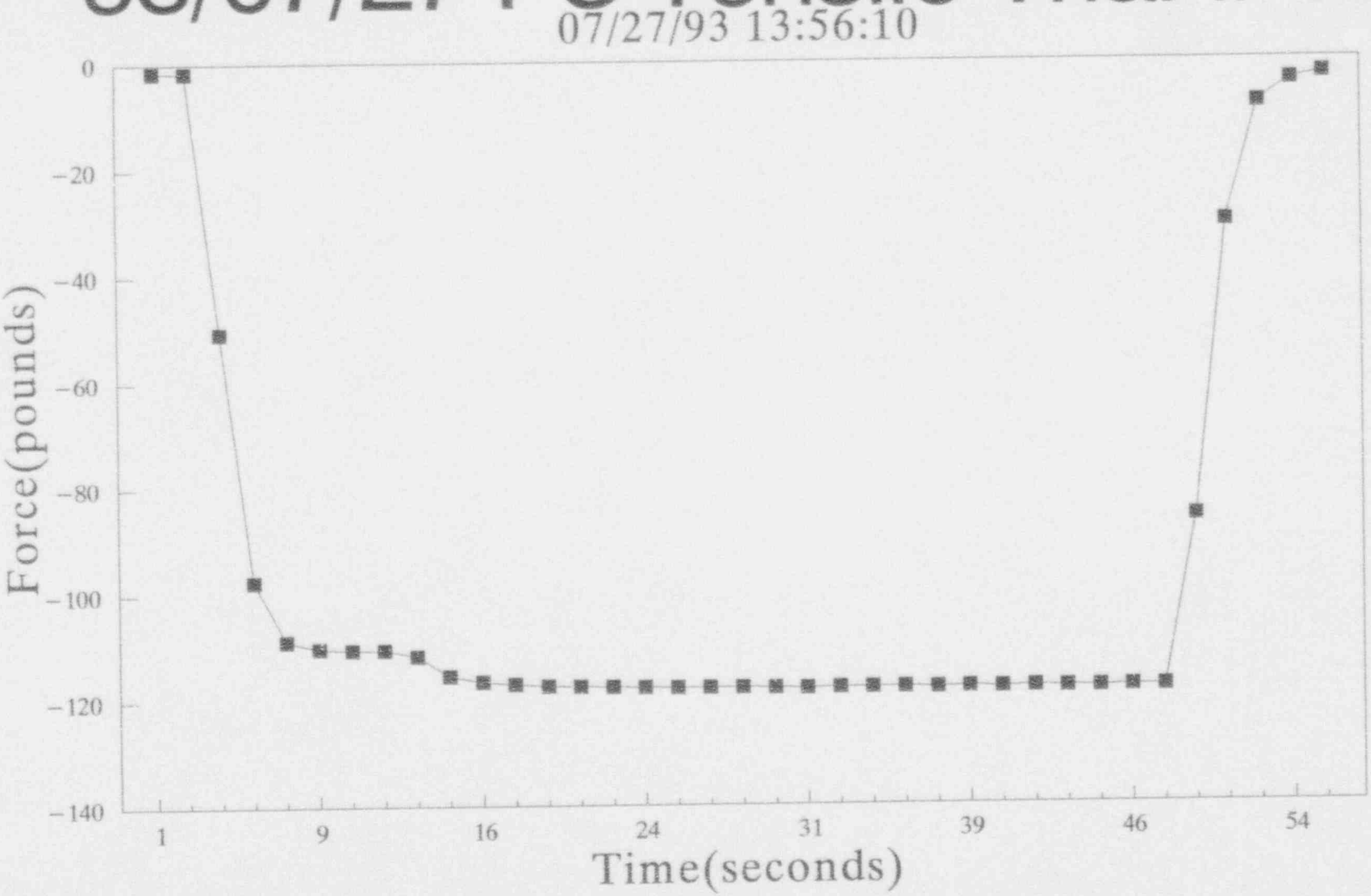
07/27/93 13:50:52



93/07/27 PS Tensile Trial #13



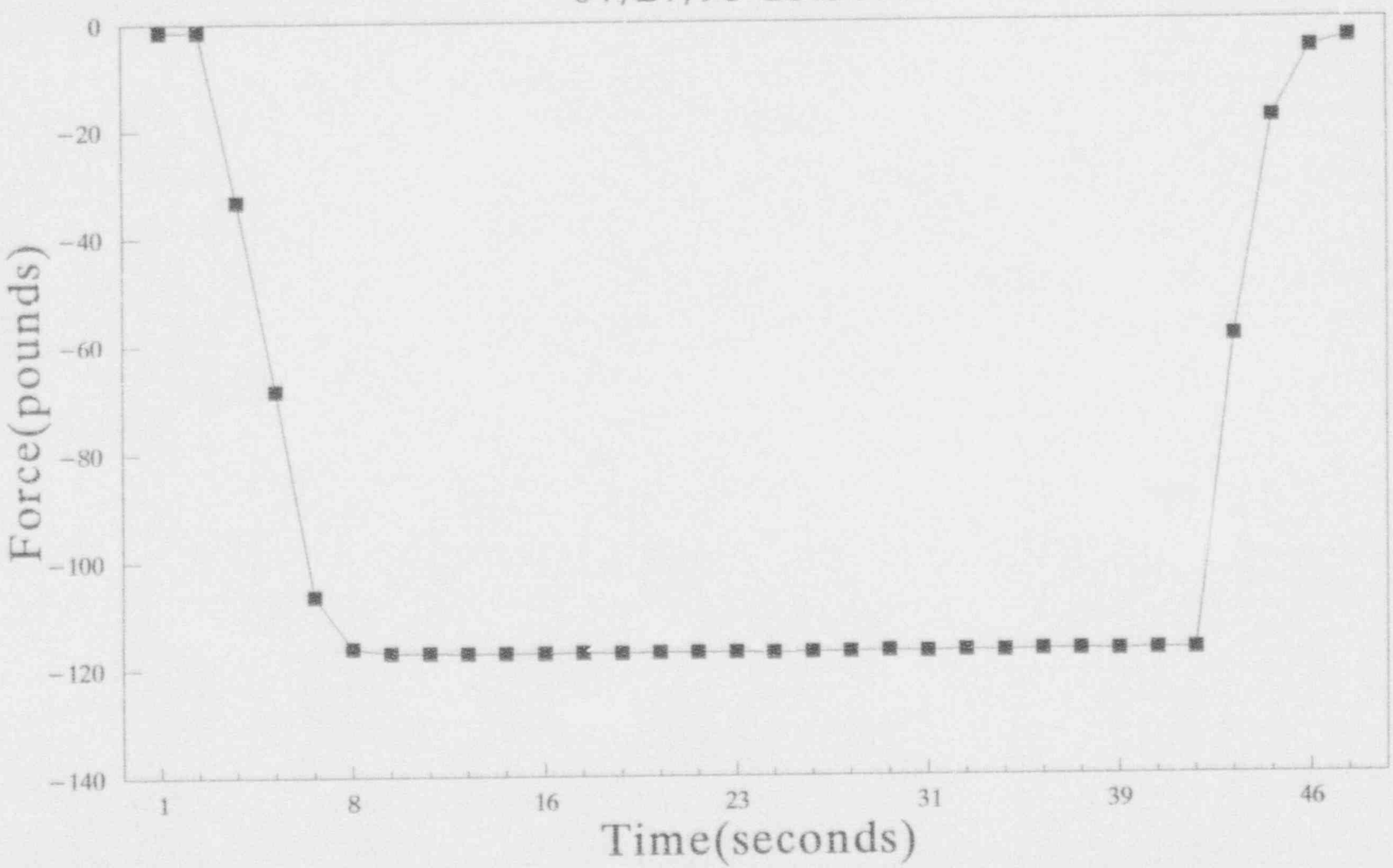
93/07/27 PS Tensile Trial #14



N-15

93/07/27 PS Tensile Trial #15

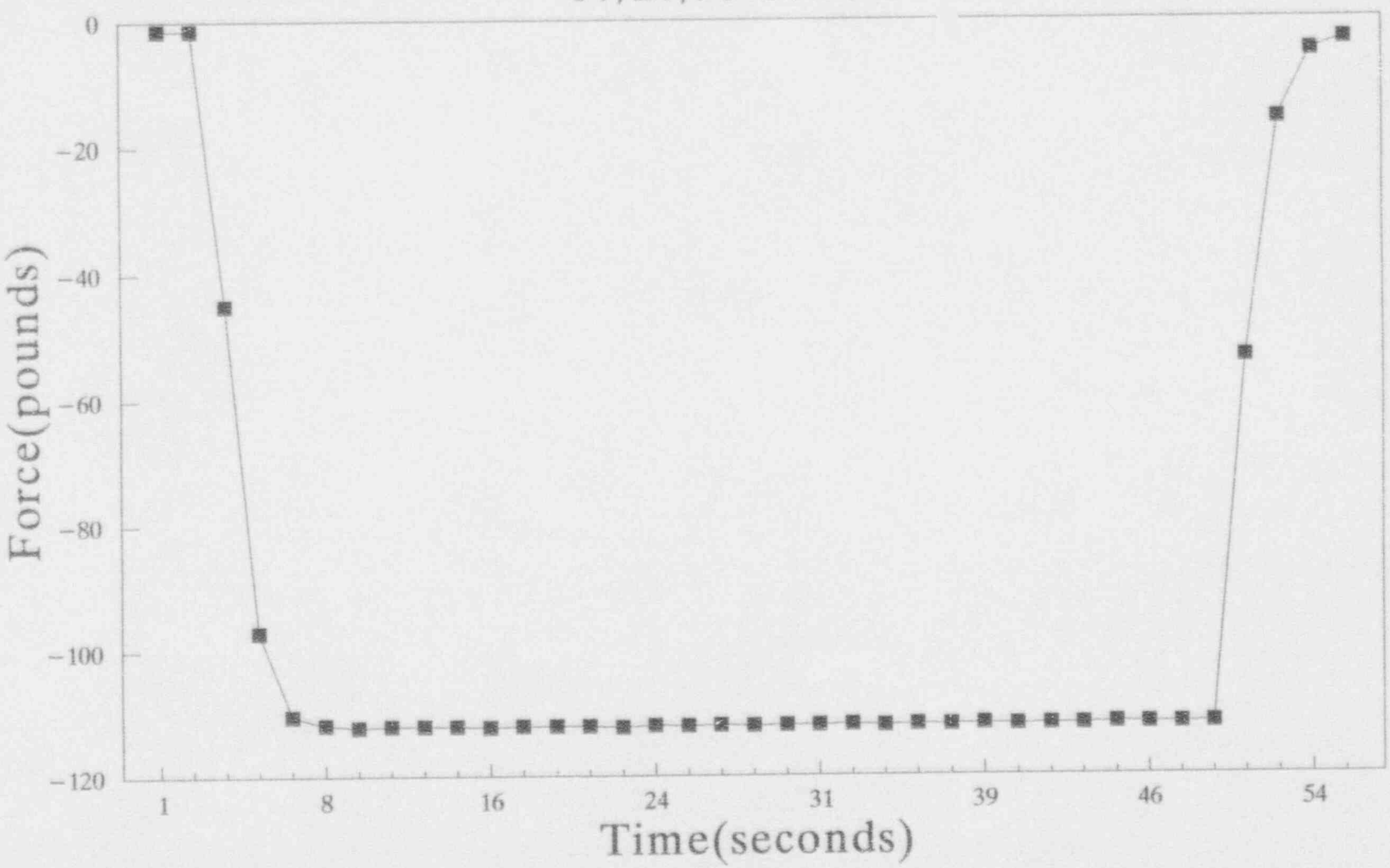
07/27/93 13:57:44



N-16

93/07/27 PS Tensile Trial #16

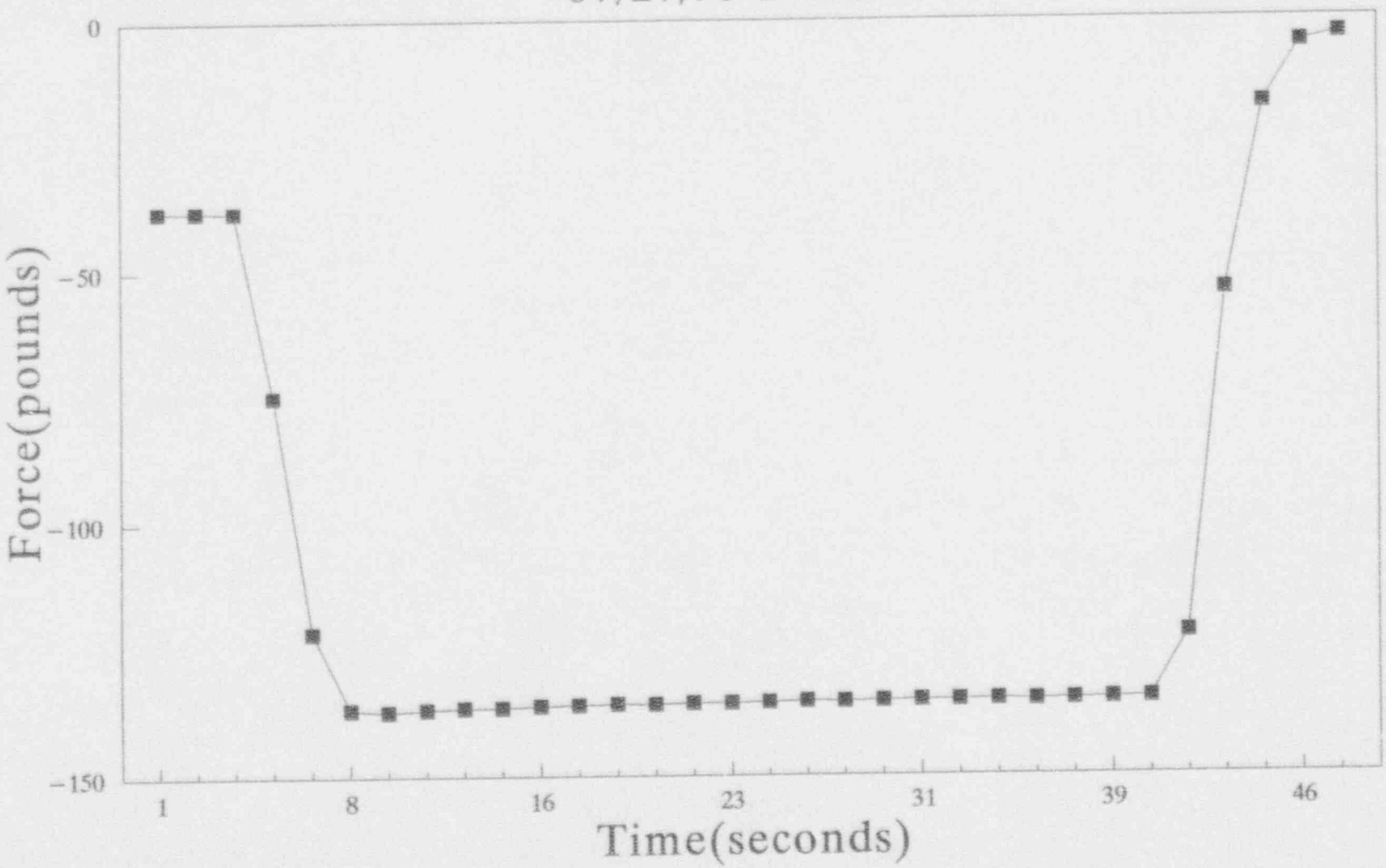
07/27/93 13:59:37



N-17

93/07/27 PS Tensile Trial #17

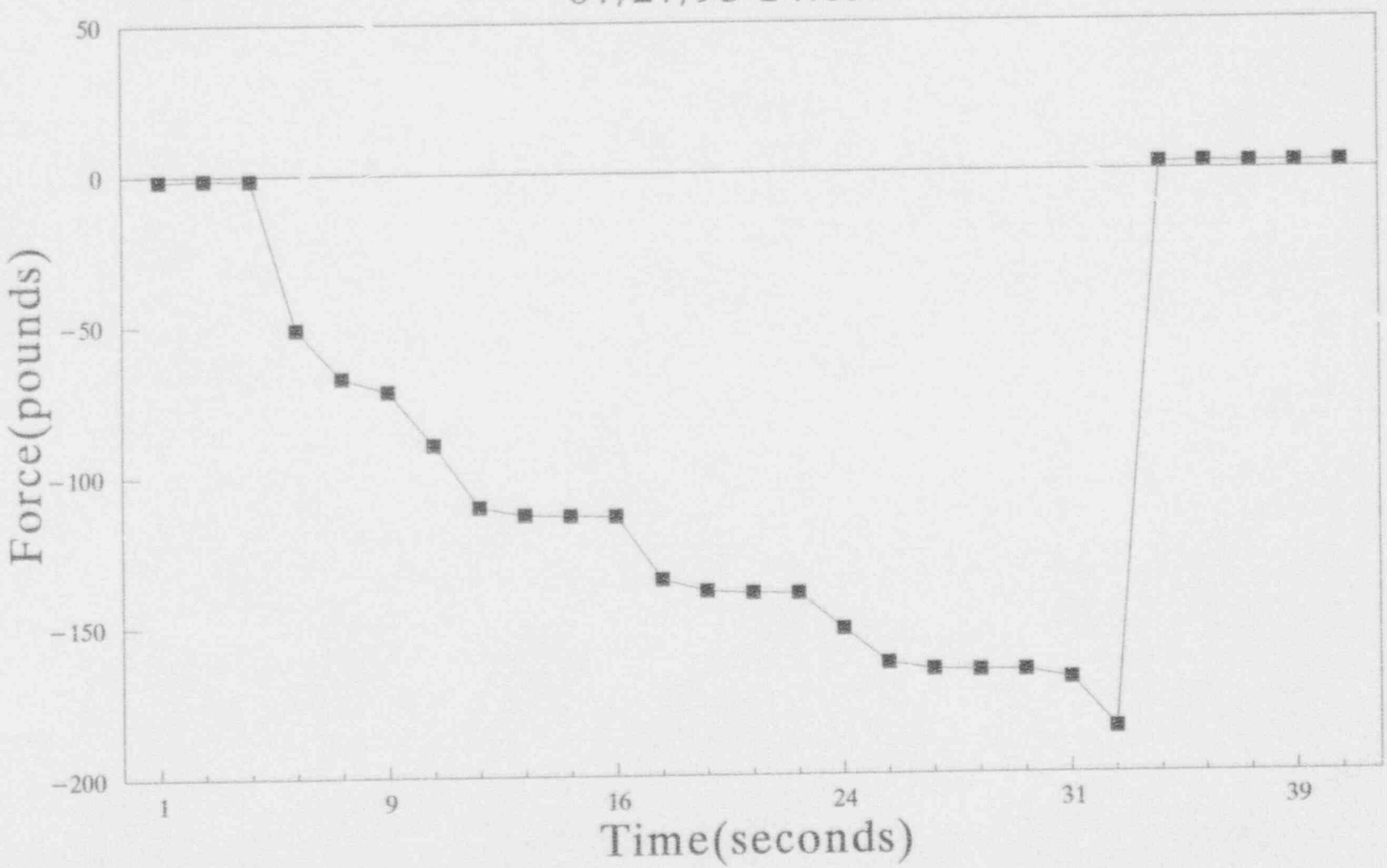
07/27/93 14:01:29



N-18

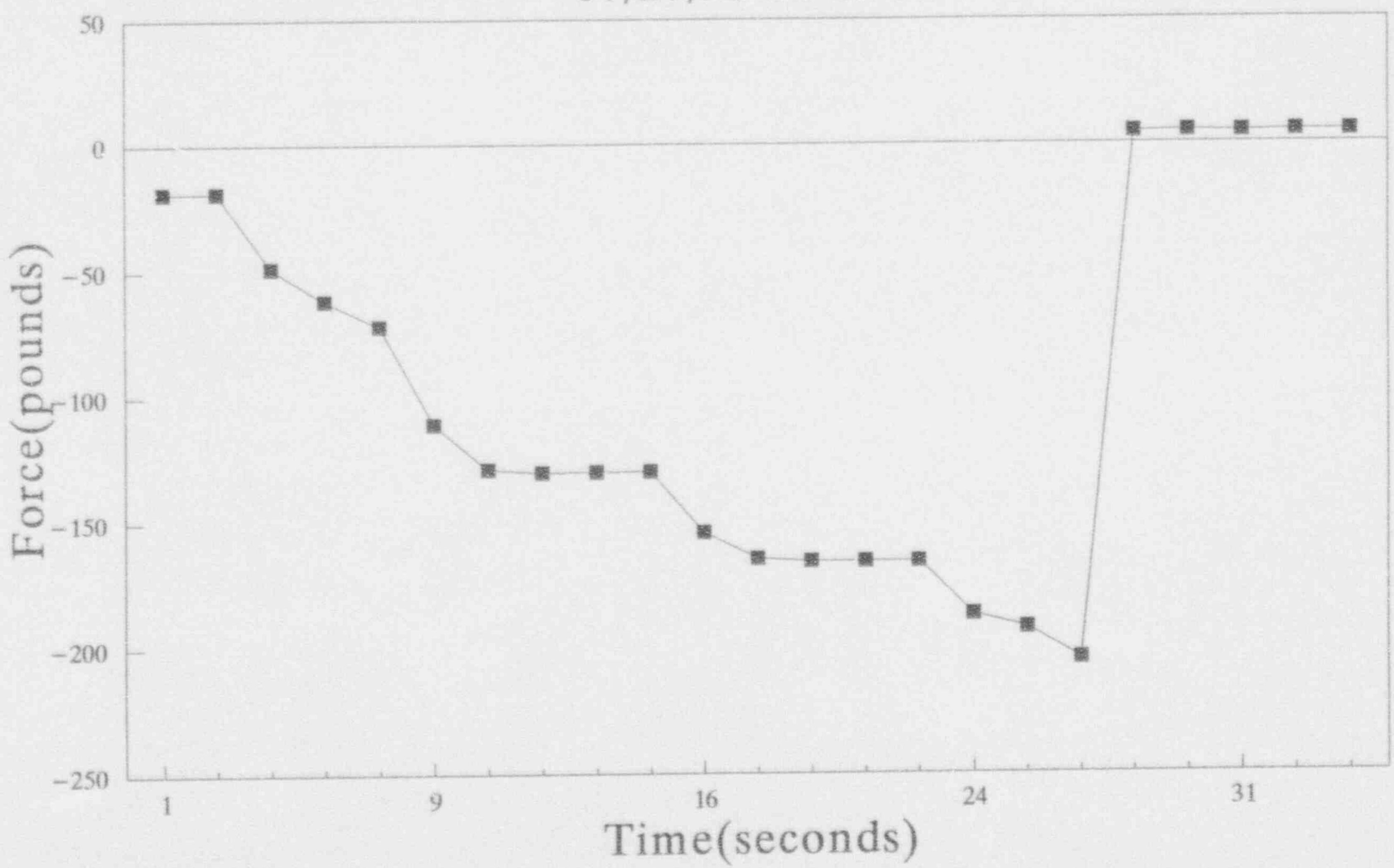
93/07/27 PS Tensile Trial #18

07/27/93 14:05:44



93/07/27 PS Tensile Trial #19

07/27/93 14:19:57



N-20

APPENDIX O

Source Assembly Tensile Test Data

C990 Source Assembly Tensile Test Data Sheet

Source Assembly Serial No. 0003

A. Initial Measurement

Micrometer Model No. S.M.E.

Serial No. N/A

Calibration Due Date Cobalt Measurement Lab

Initial Length see attached sheet

Test Engineer or Technician Blain Menna (ref Dave Whitby) Date 93/05/26

B. Additional Testing

Was any additional testing performed on source assembly (e.g., endurance testing)? Y [✓] N [ ]

If yes, indicate details of test (e.g., endurance test, date, first cycle no., last cycle no.)

20,000 cycles endurance test

C. Tensile Test

Force Transducer Model No. ______ N/A

Serial No. ______ This source assembly failed during RC Cable tensile Test.

Calibration Due Date ______

Test Force ______ N

Test Duration ______ s
(Attach a plot of the force measurement)

Test Engineer or Technician ______ Date ______

D. Final Length Measurement

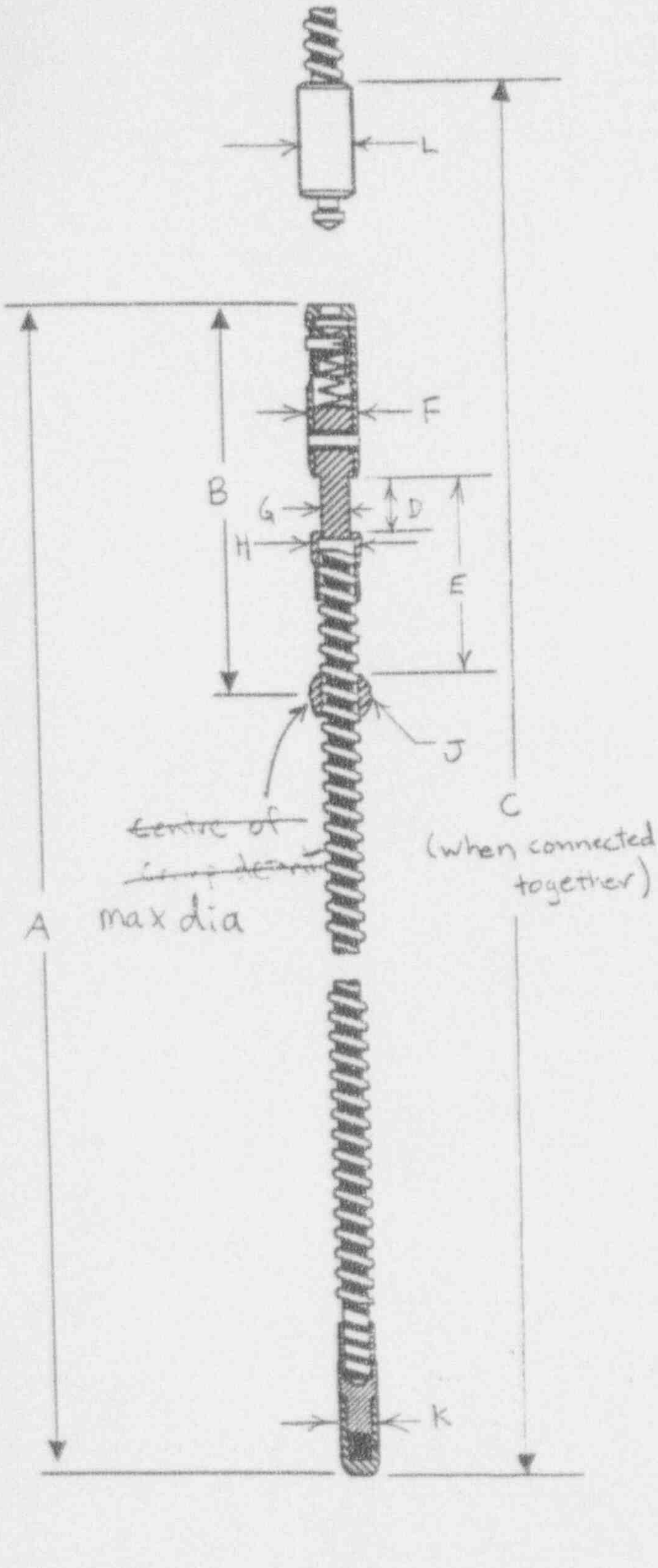
Micrometer Model No. SME

Serial No. N/A

Calibration Due Date Cobalt Measurement Lab

Final Length see attached sheet

Test Engineer or Technician Blain Menna (ref Dave Whitby) Date 93/07/28



Date: 93.05.26

C990 Serial No. 0003

A = ~~7.2??~~ 7.270"

B = 1.910"

C = 7.866"

D = 0.199"

E = 1.003"

DIA F = 0.247"

DIA G = 0.135"

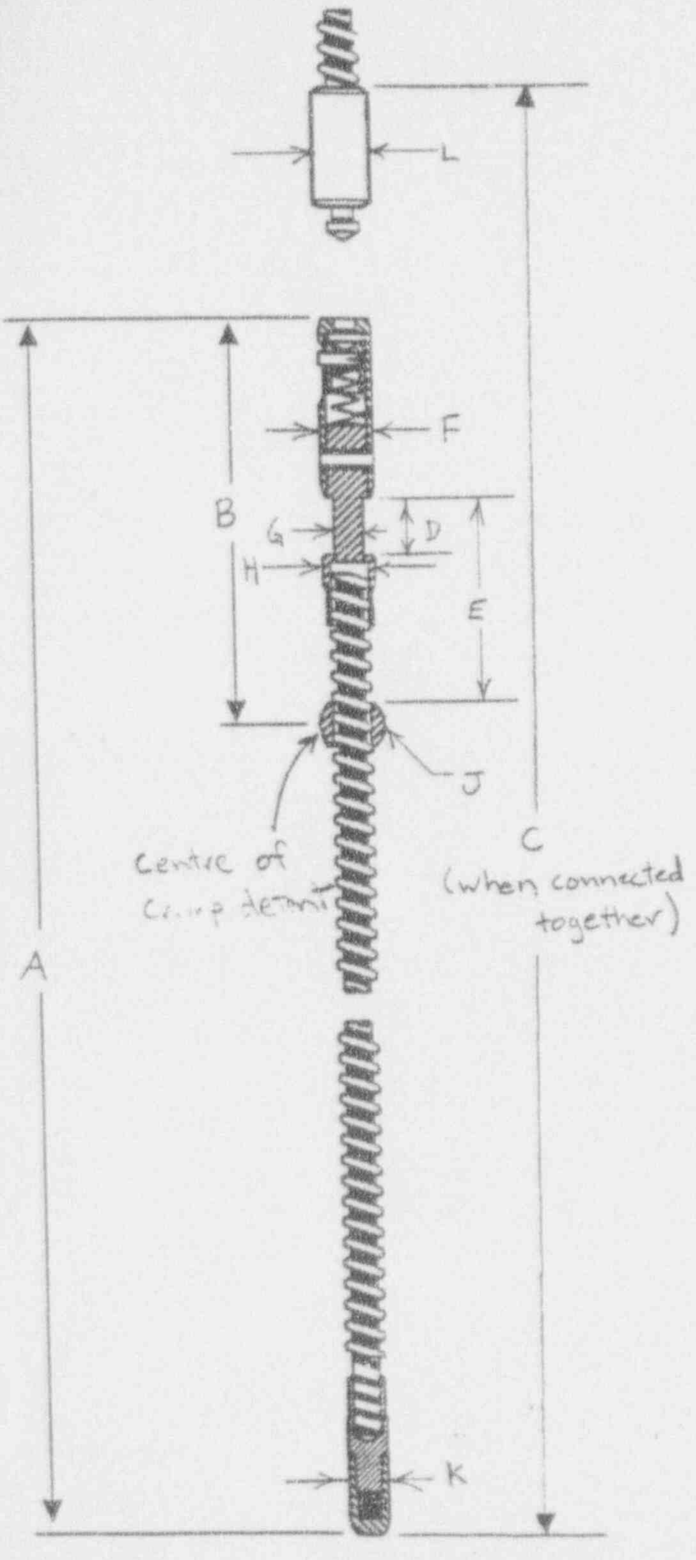
DIA H = 0.246"

DIA J = 0.308" MAX

DIA K = 0.189" MAX

DIA L = 0.246

Inspector's Signature [signature]



Date: 93.07.09

C990 Serial No. 0003

AFTER ENDURANCE TEST.

A = 7.271"

B = 1.912"

C = ______

D = 0.204"

E = 1.014

DIA F = 0.247"

DIA G = [illegible]

DIA H = 0.246"

DIA J = 0.300" (OVAL)

DIA K = 0.19"

DIA L = ______

NB. - ITEM SUSPENDED WITHOUT WEIGHT.

- DIMENSIONS ARE AN AVERAGE.

Inspector's Signature [signature]

C990 Source Assembly Tensile Test Data Sheet

Source Assembly Serial No. 0004

A. Initial Measurement

Micrometer Model No. SME

Serial No. N/A

Calibration Due Date Cobalt Measurement Lab

Initial Length see attached

Test Engineer or Technician Blair M[illegible] Date 93/07/28
(ref Mike Wymer)

B. Additional Testing

Was any additional testing performed on source assembly (e.g., endurance testing)? Y [✓] N [ ]

If yes, indicate details of test (e.g., endurance test, date, first cycle no., last cycle no.)

Tensile Test, 20 trials total

C. Tensile Test

Force Transducer Model No. LCCA-500

Serial No. 427544

Calibration Due Date 07/94

Test Force ≤ 1000 N (225 lb)

Test Duration 30 s minimum.
(Attach a plot of the force measurement)

Test Engineer or Technician Blair M[illegible] Date 93/07/28

D. Final Length Measurement

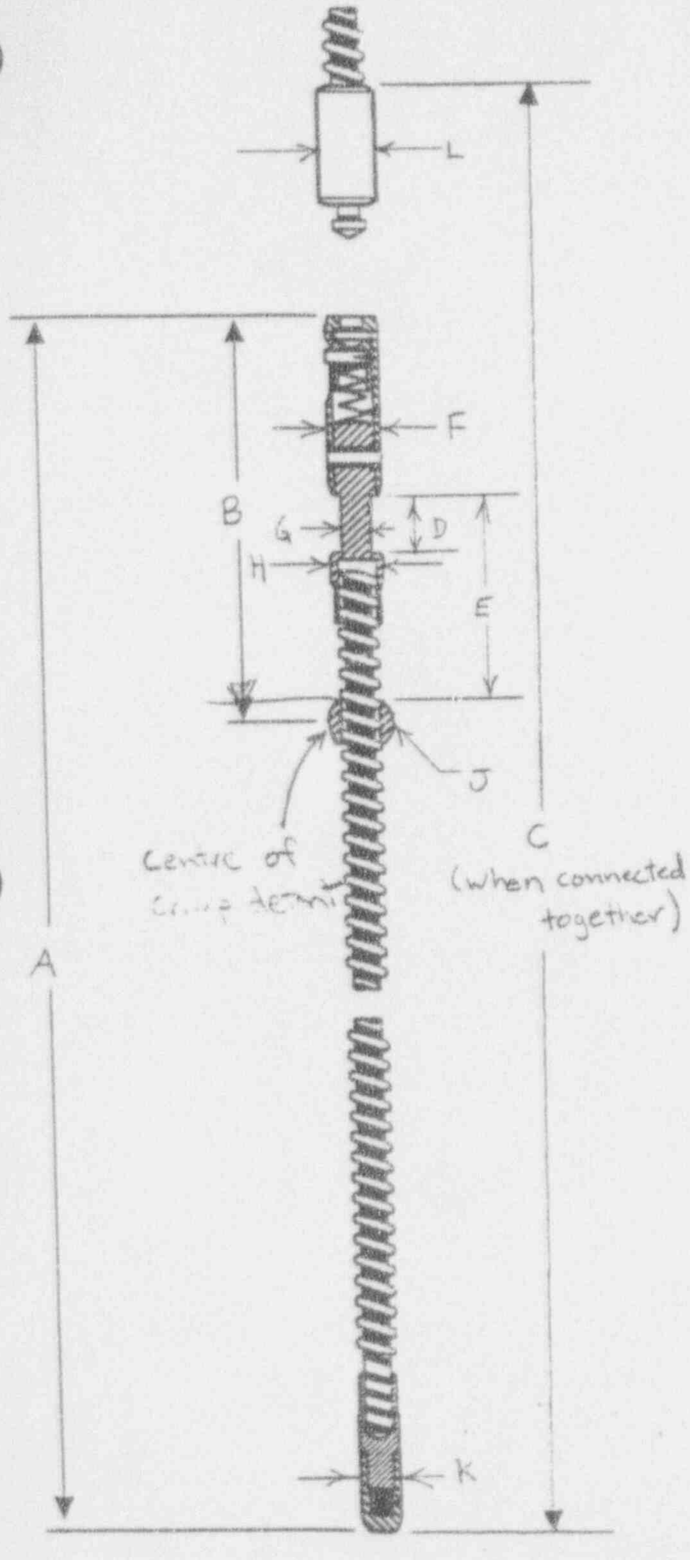
Micrometer Model No. as above

Serial No.

Calibration Due Date

Final Length see attached

Test Engineer or Technician Blair M[illegible] Date 93/07/28
(ref Mike Wymer).

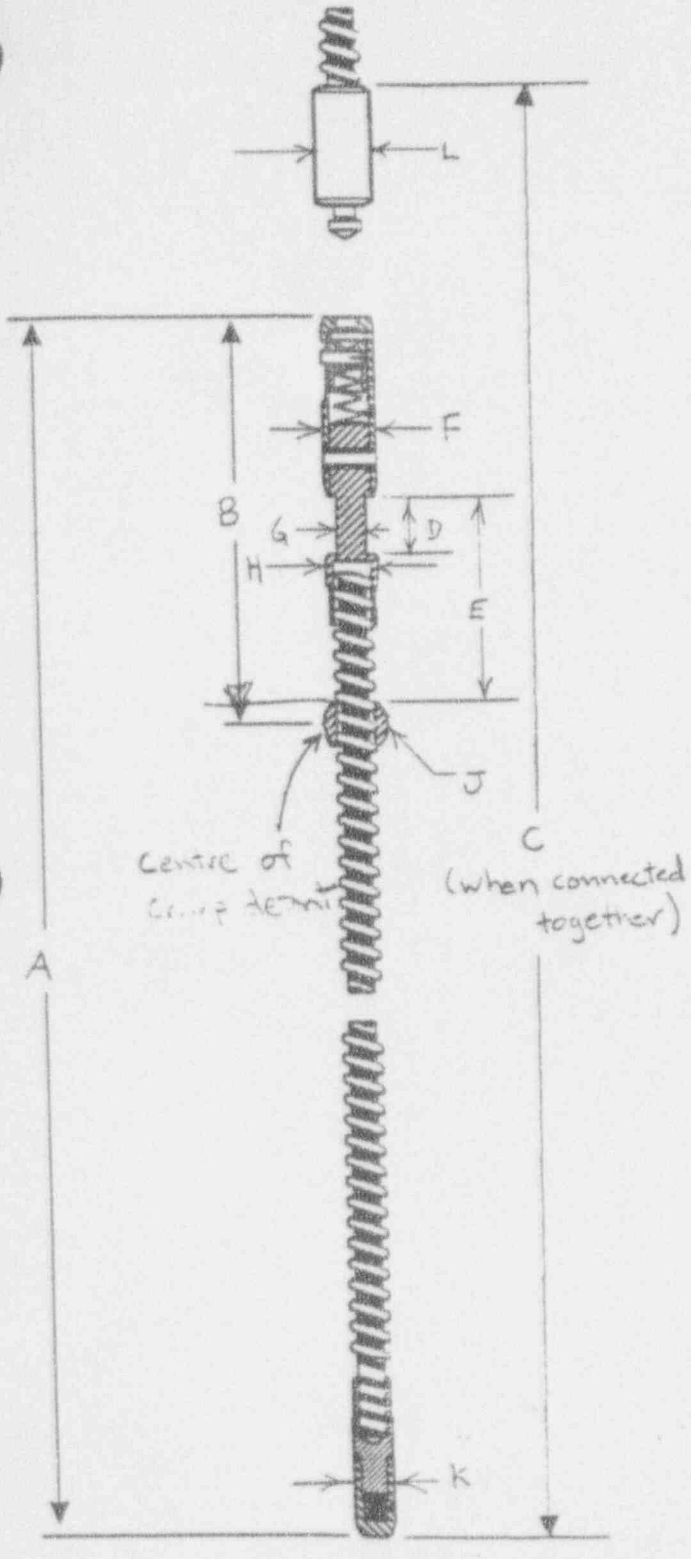


Date: 27 July 93.

C990 Serial No. 0004

A = 7.250"
B = 1.802" to end of lock ball
C =
D = 0.194"
E = 0.9985"
DIA F =
DIA G =
DIA H =
DIA J =
DIA K =
DIA L =

Inspector's Signature ____________________



Date: 28 July 93.

C990 Serial No. 0004

A = 7·259"

B = 1·819" to end off lock ball

C =

D = 0·196"

E = 1·014"

DIA F =

DIA G =

DIA H =

DIA J =

DIA K =

DIA L =

Inspector's Signature ____________________

C990 Source Assembly Tensile Test Data Sheet

Source Assembly Serial No. 0005

A. Initial Measurement

Micrometer Model No. S.M.E.

Serial No. N/A

Calibration Due Date Cobalt Measurement Lab

Initial Length see attached

Test Engineer or Technician Blair [illegible] (ref Dave Whitby) Date 93/07/28

B. Additional Testing

Was any additional testing performed on source assembly (e.g., endurance testing)? Y ☑ N ☐

If yes, indicate details of test (e.g., endurance test, date, first cycle no., last cycle no.)

Tensile test, 20 trials total

C. Tensile Test

Force Transducer Model No. LCCA-500

Serial No. 427544

Calibration Due Date 07/94

Test Force 1000 N (225 lb) minimum

Test Duration 5 s (minimum)
(Attach a plot of the force measurement)

Test Engineer or Technician Blair [illegible] Date 93/07/28

D. Final Length Measurement

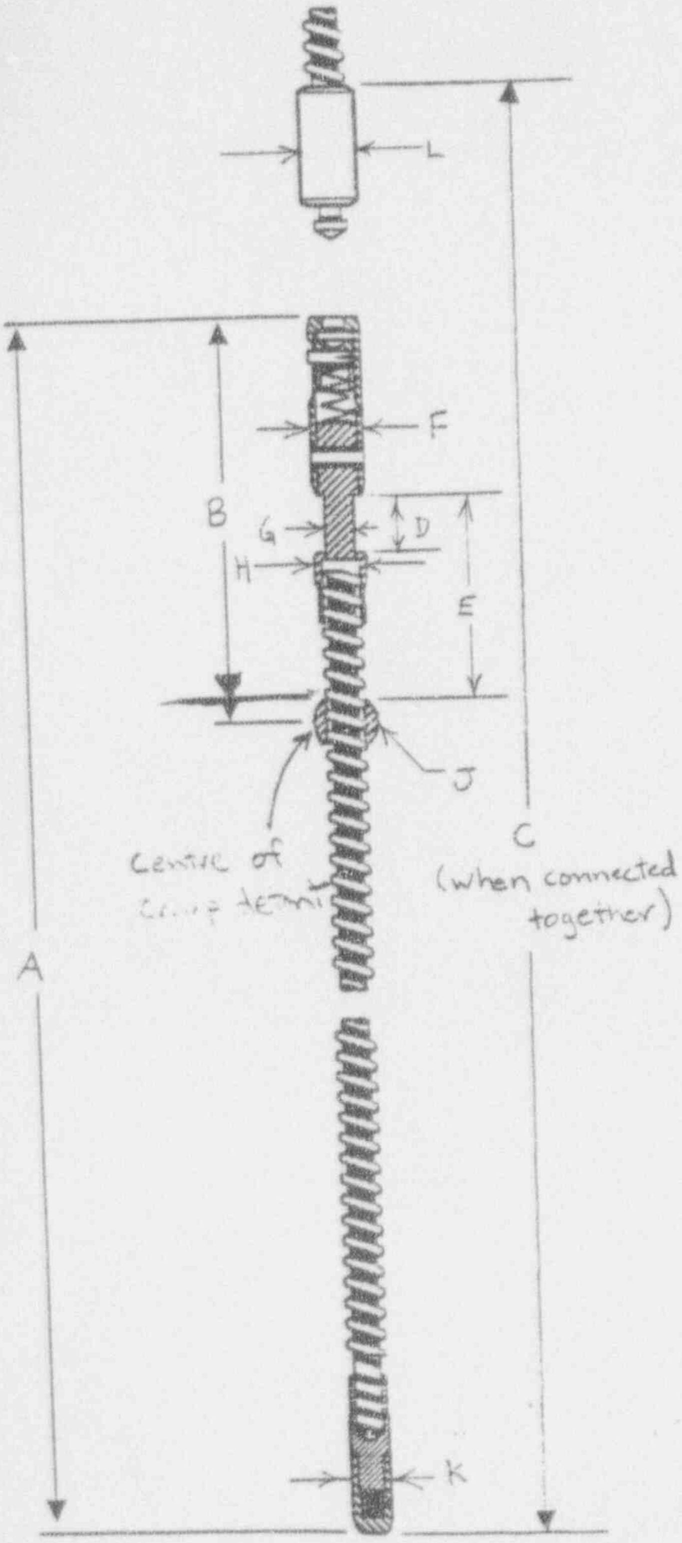
Micrometer Model No. as above

Serial No.

Calibration Due Date [illegible]

Final Length see attached sheet

Test Engineer or Technician Blair [illegible] (ref Mike Wymer). Date 93/07/28



Date: 93·07·23

C990 Serial No. 0005

(A) = 7.257"

(B) = 1.823" to end of lock-ball

C =

(D) = 0.200"

(E) = 1.022"

DIA F =

DIA G =

DIA H =

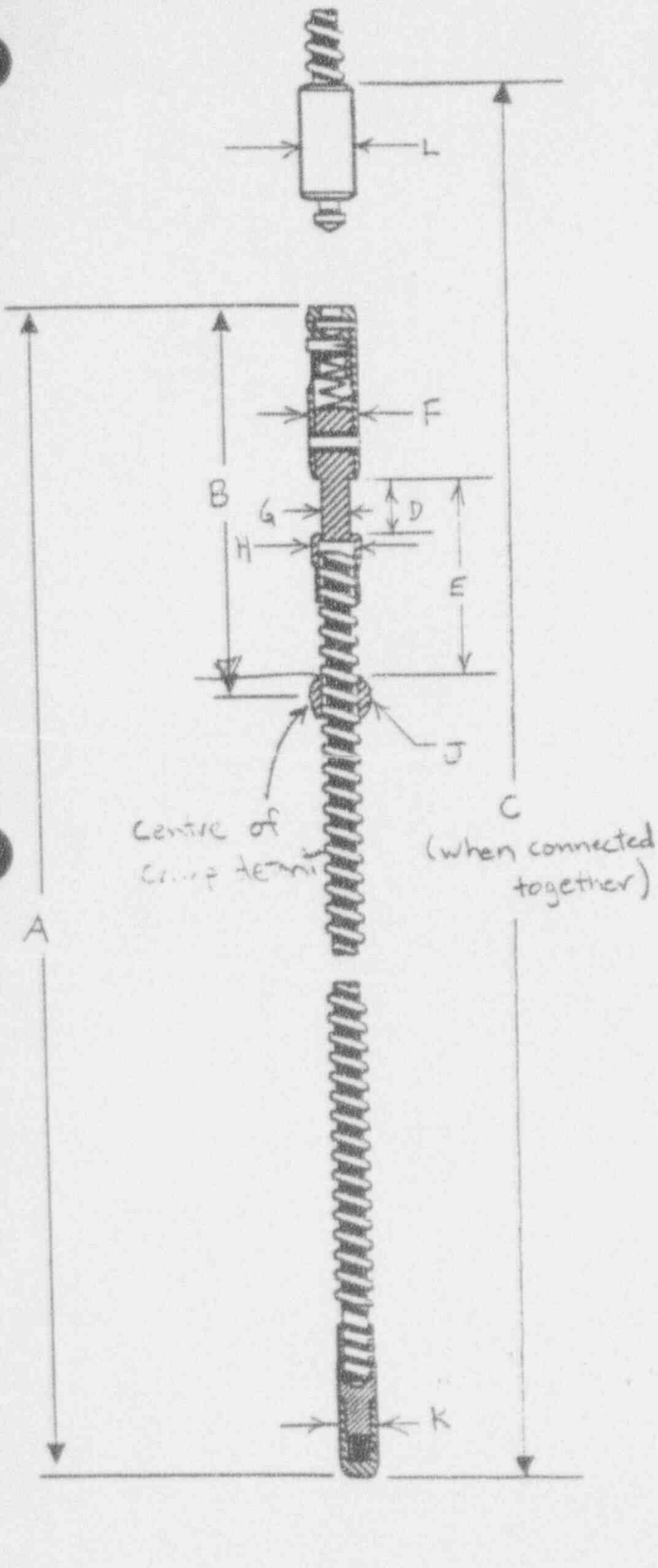
DIA J =

DIA K =

DIA L =

NOTE: PIGTAIL SUSPENDED WITHOUT AN ATTACHED WEIGHT

Inspector's Signature [signature]



Date: 27 July 93.

C990 Serial No. 0005

A = 7.275"

B = 1.8555" to end off lock ball

C = ______

D = 0.197"

E = 1.050"

DIA F = ______

DIA G = ______

DIA H = ______

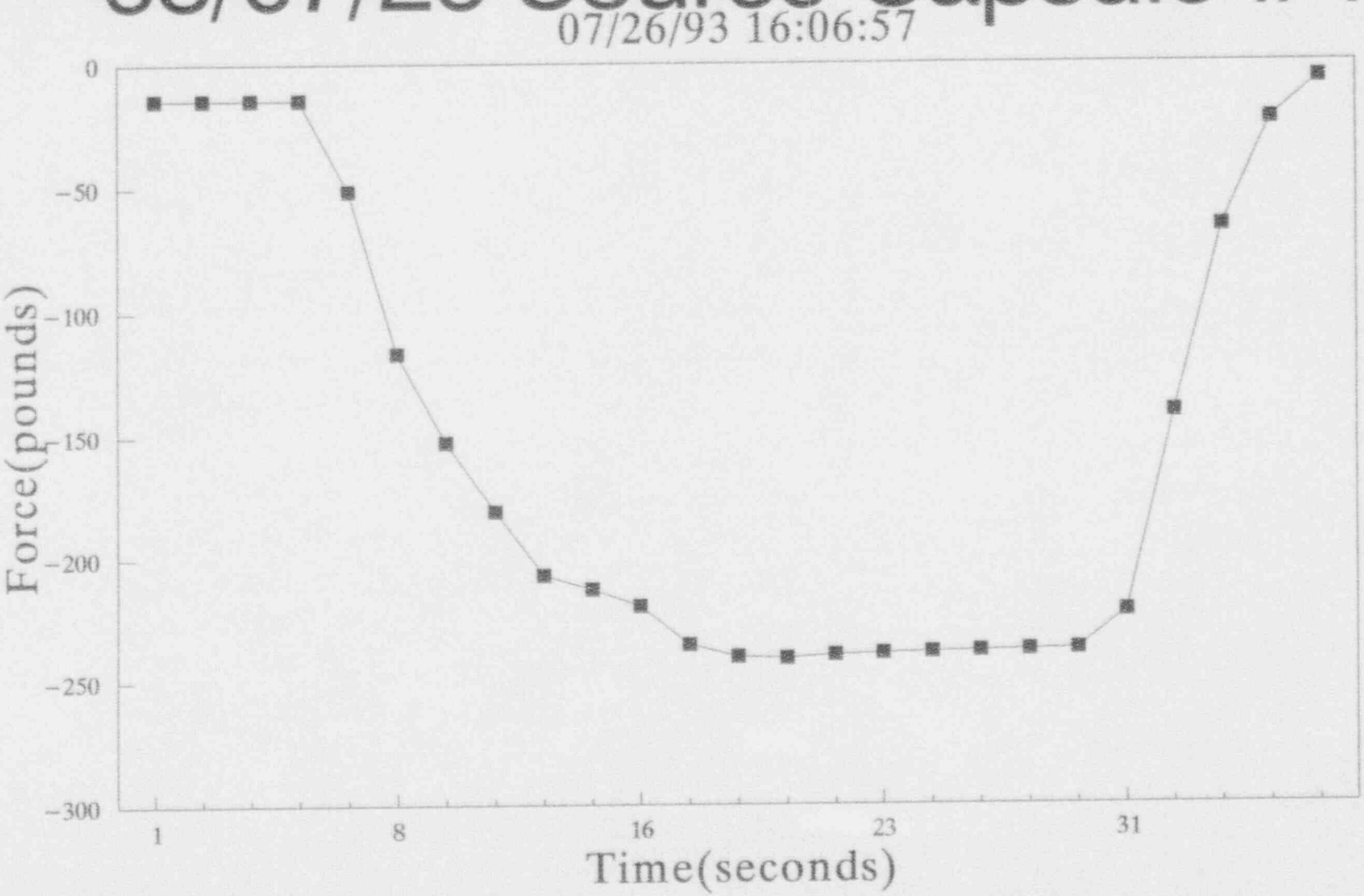
DIA J = ______

DIA K = ______

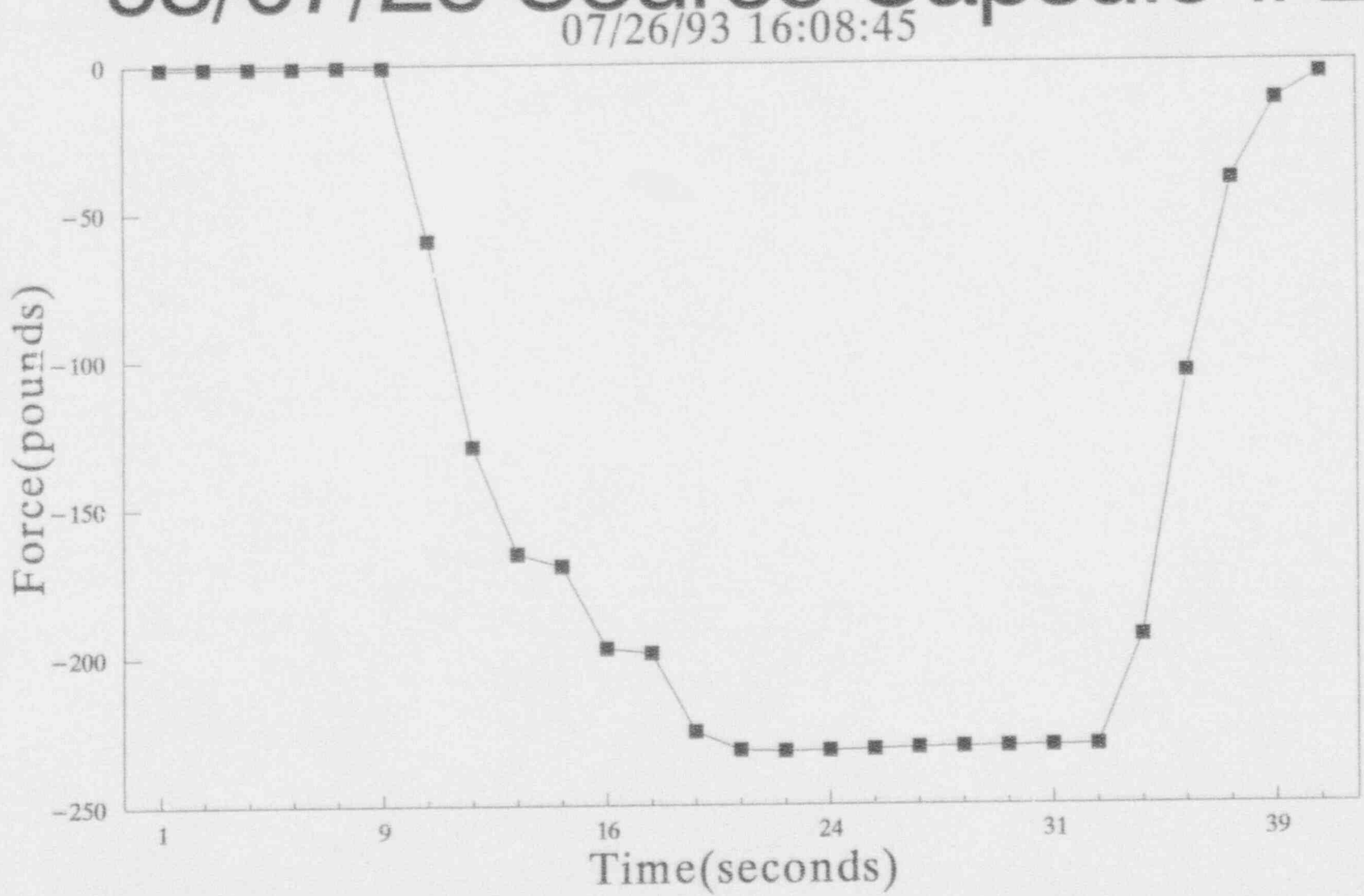
DIA L = ______

Inspector's Signature ______________________

93/07/26 Source Capsule #1

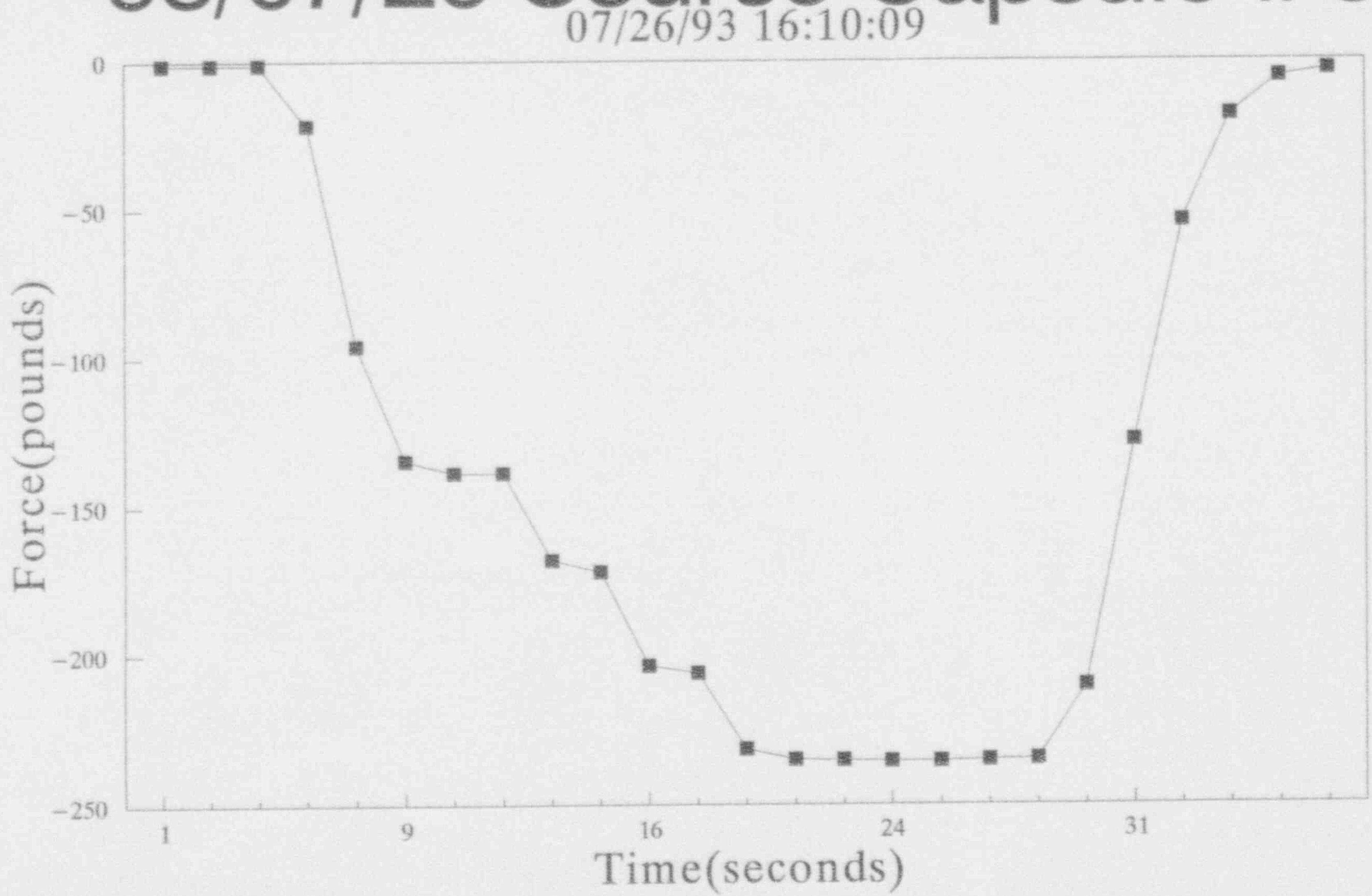


93/07/26 Source Capsule #2

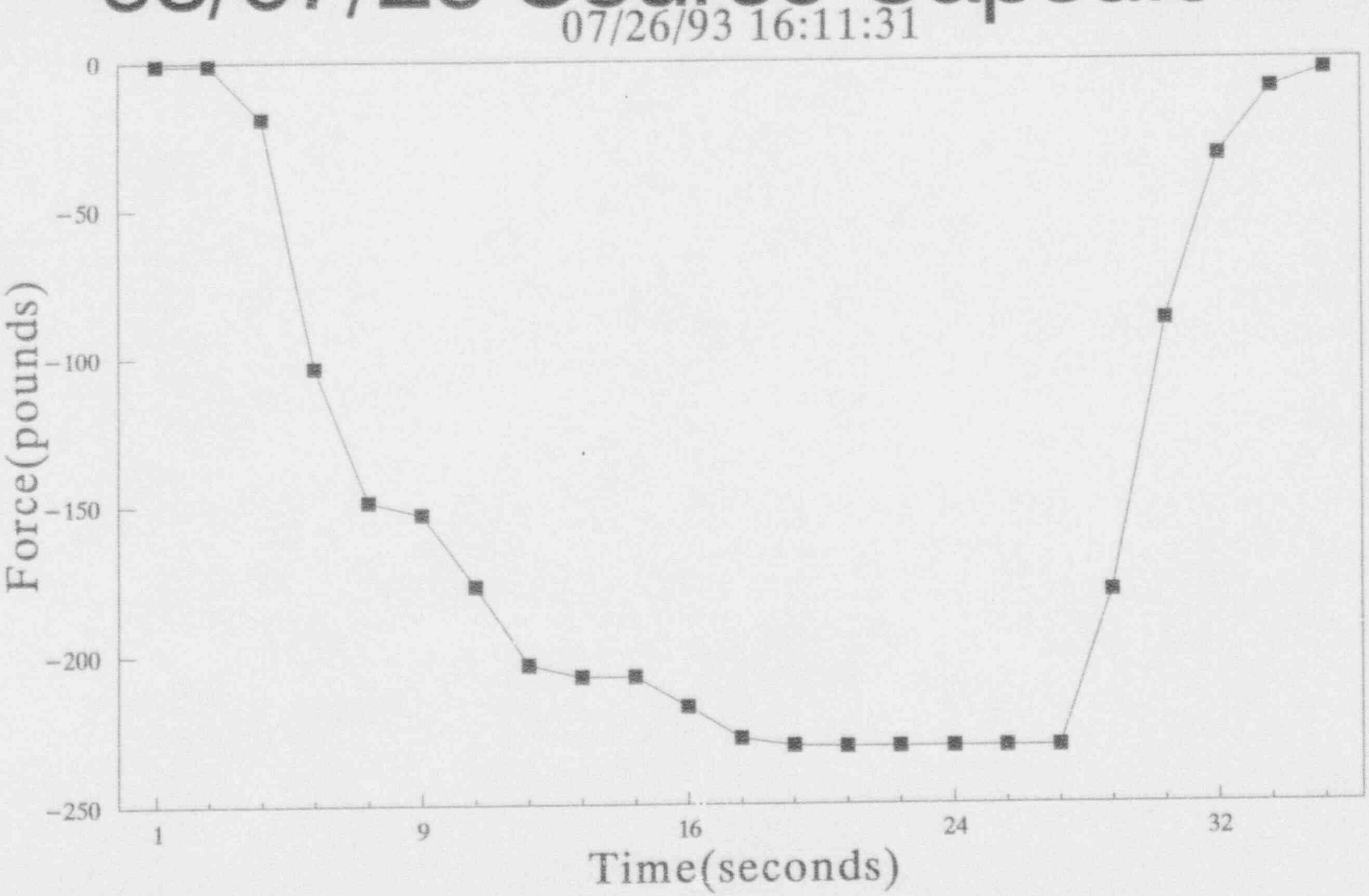


O-12

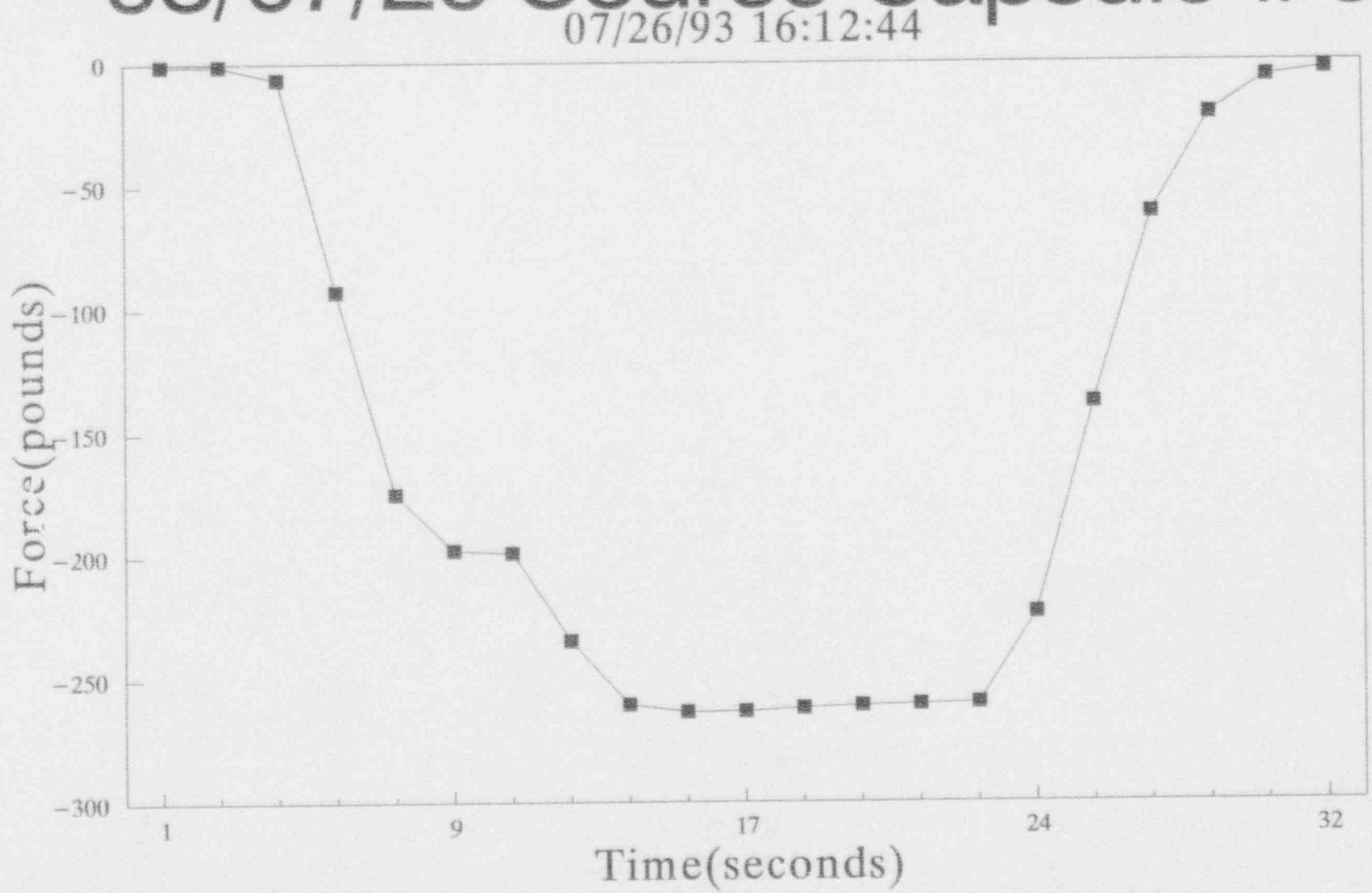
93/07/26 Source Capsule #3



93/07/26 Source Capsule #4



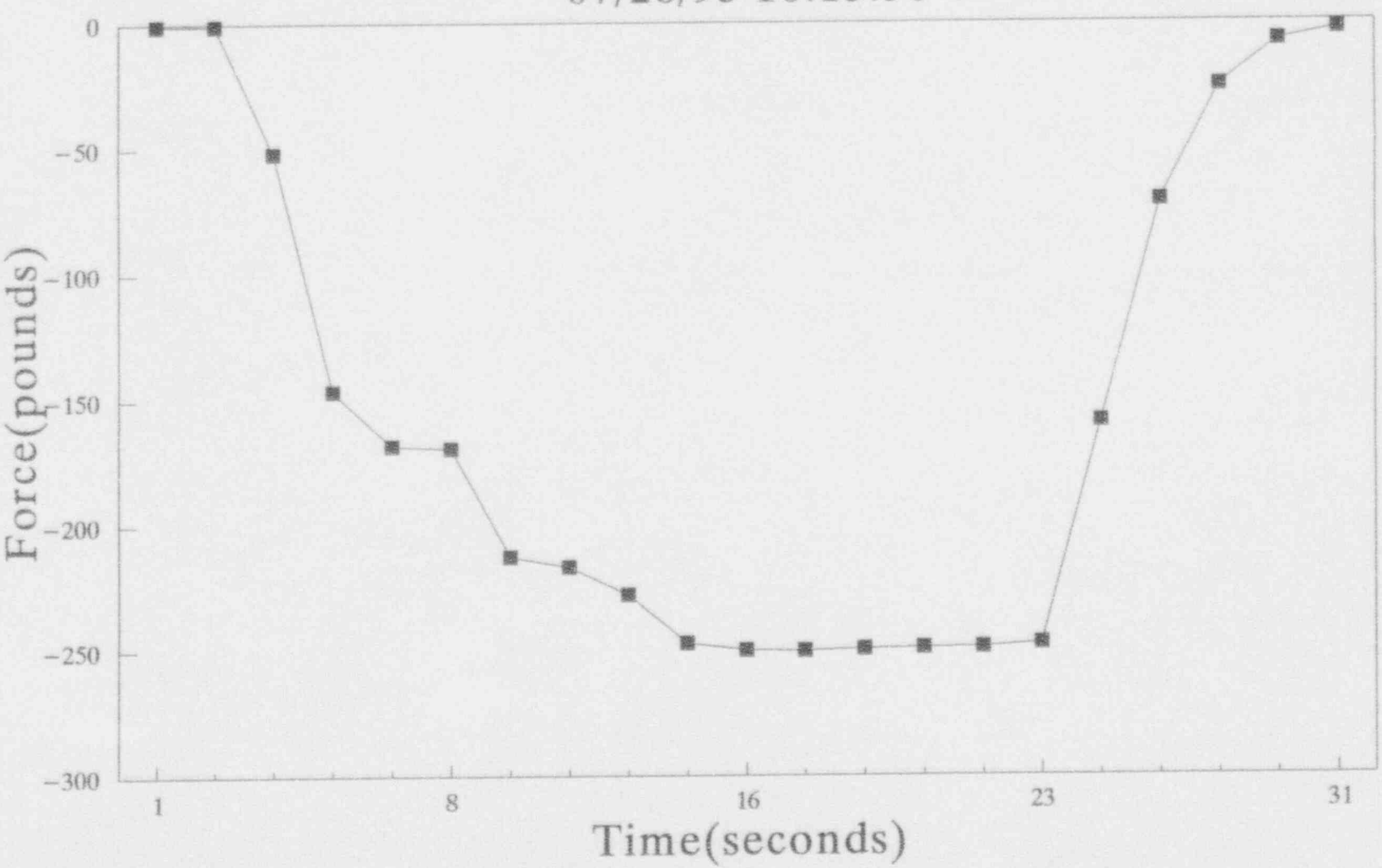
93/07/26 Source Capsule #5



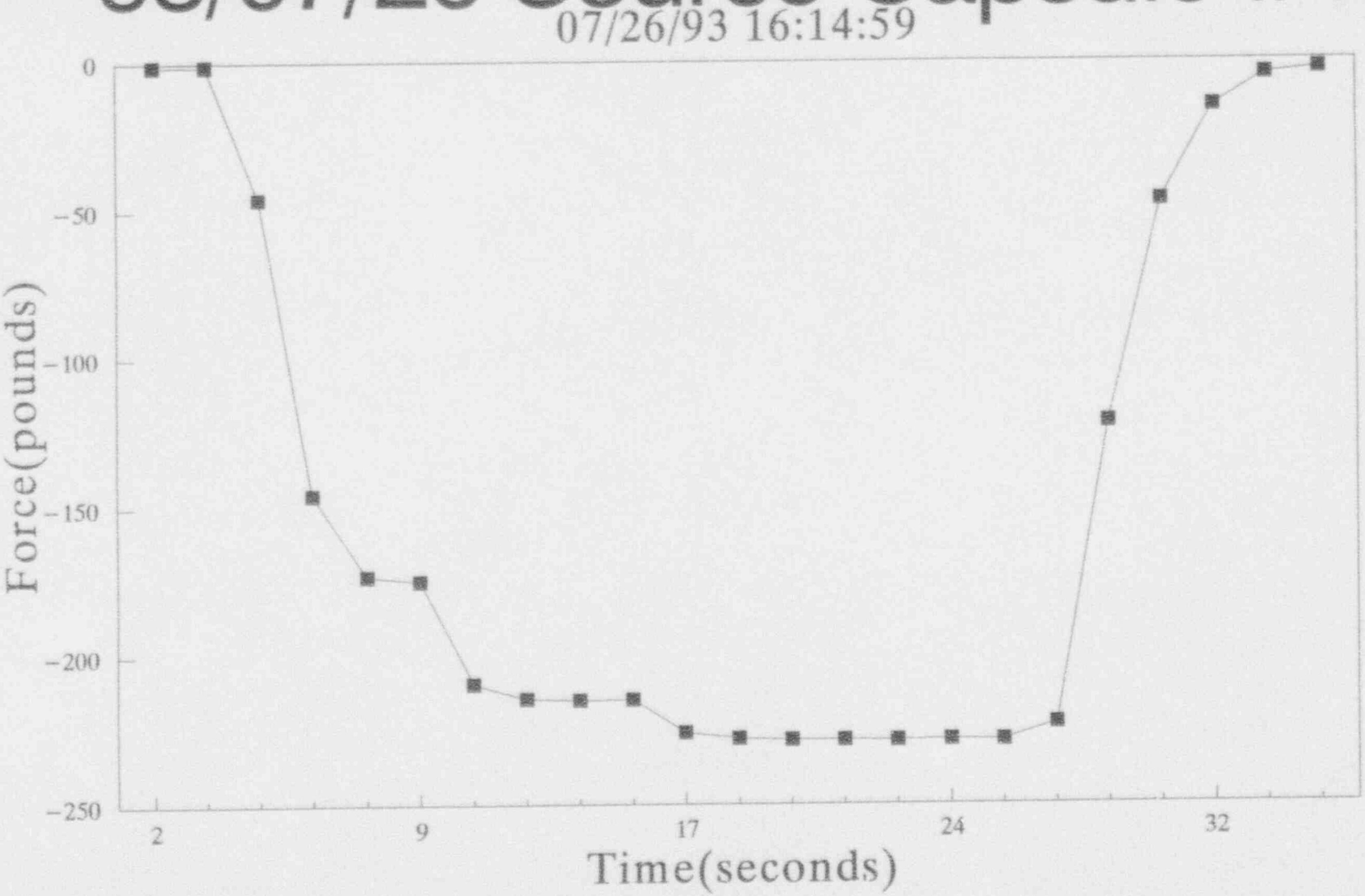
0-15

93/07/26 Source Capsule #6

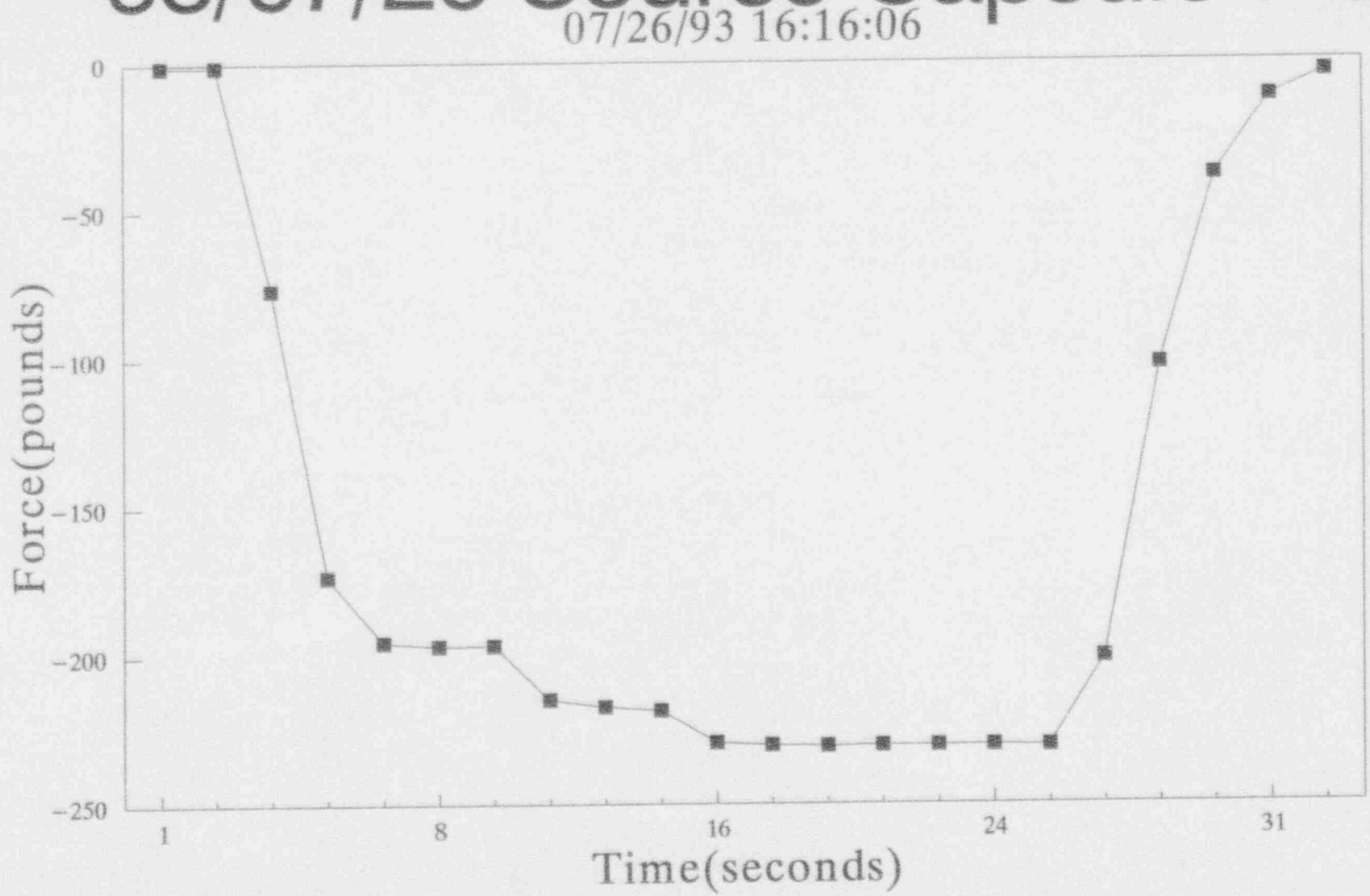
07/26/93 16:13:56



93/07/26 Source Capsule #7

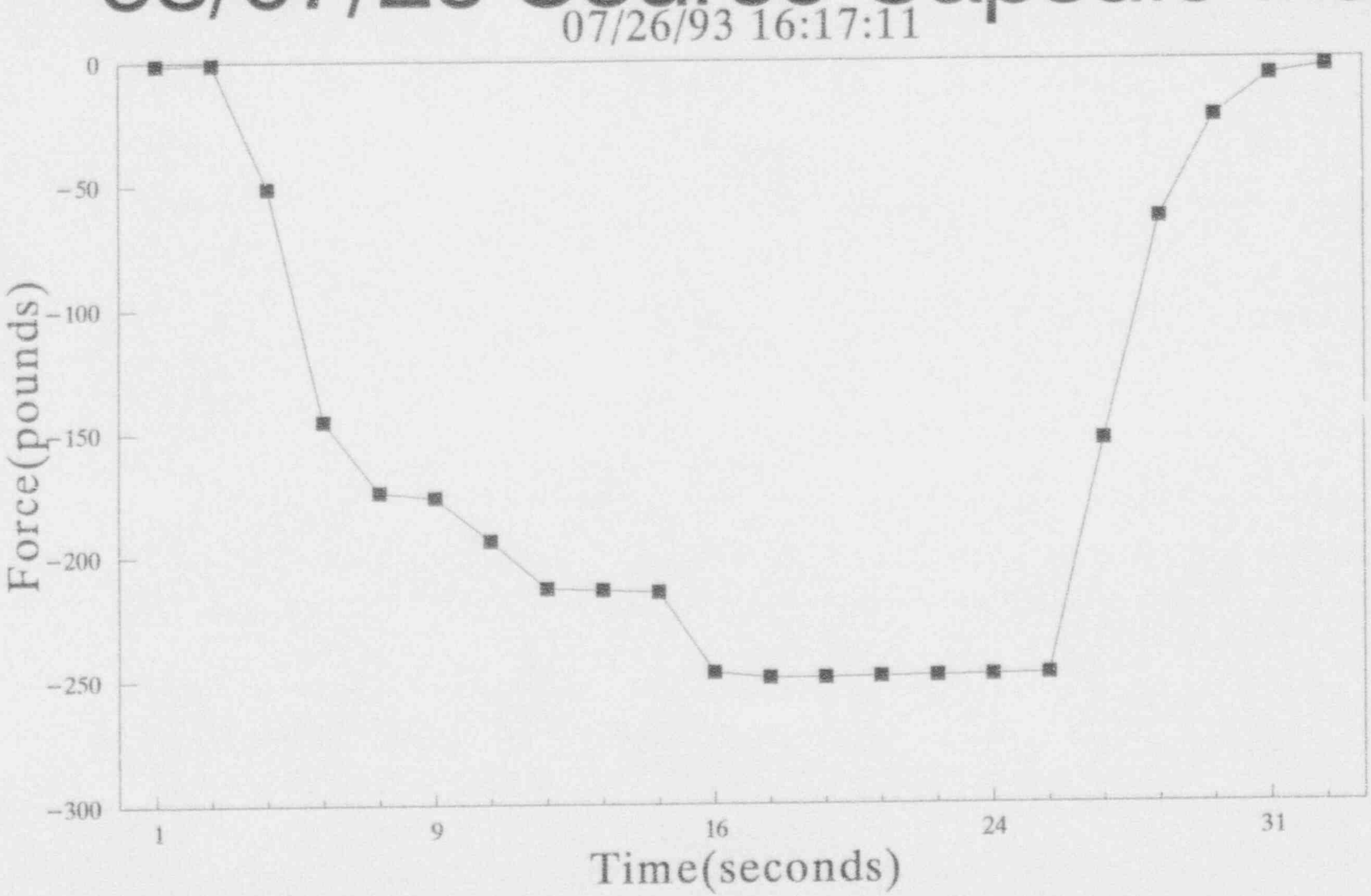


93/07/26 Source Capsule #8

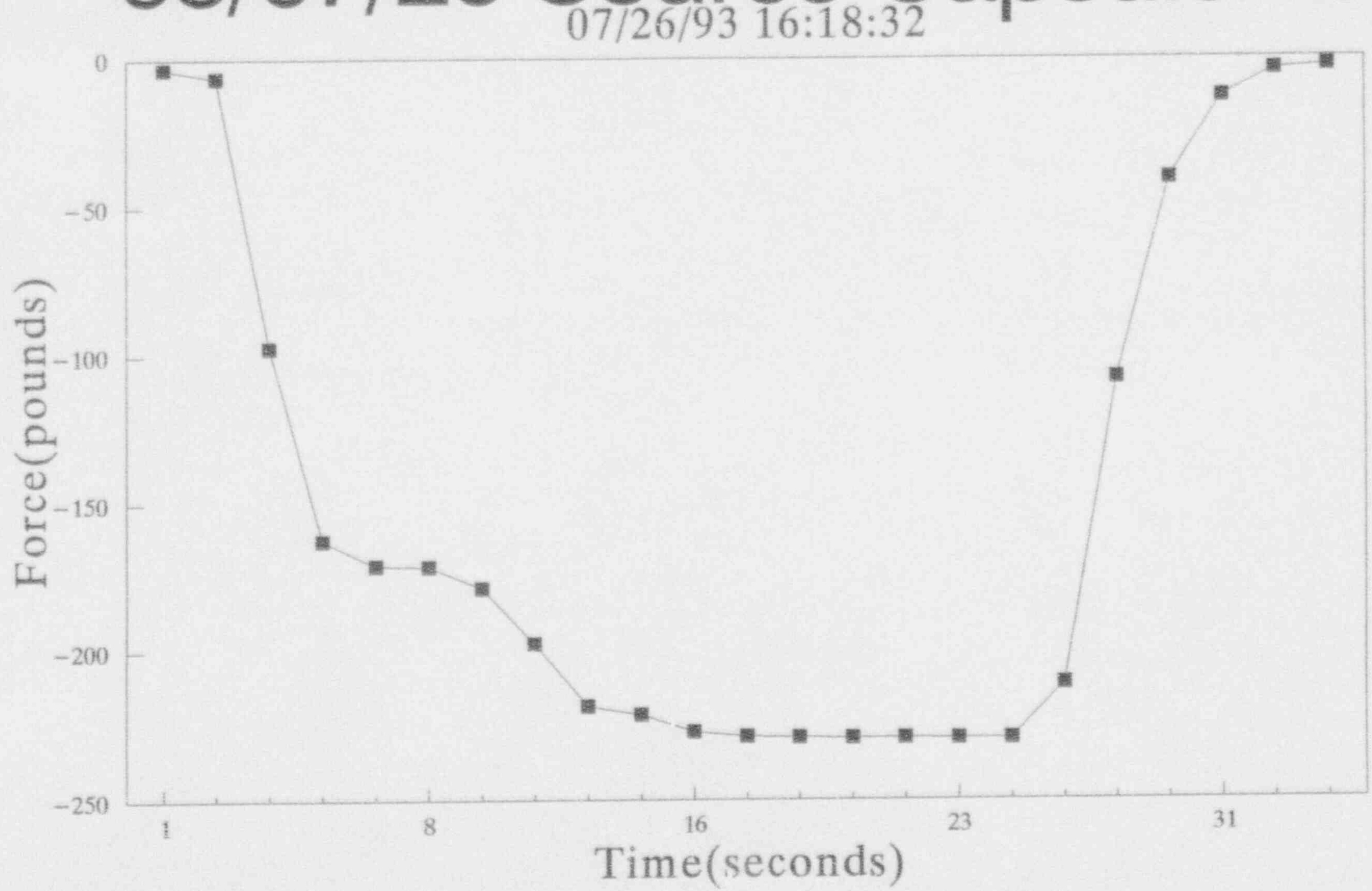


0-18

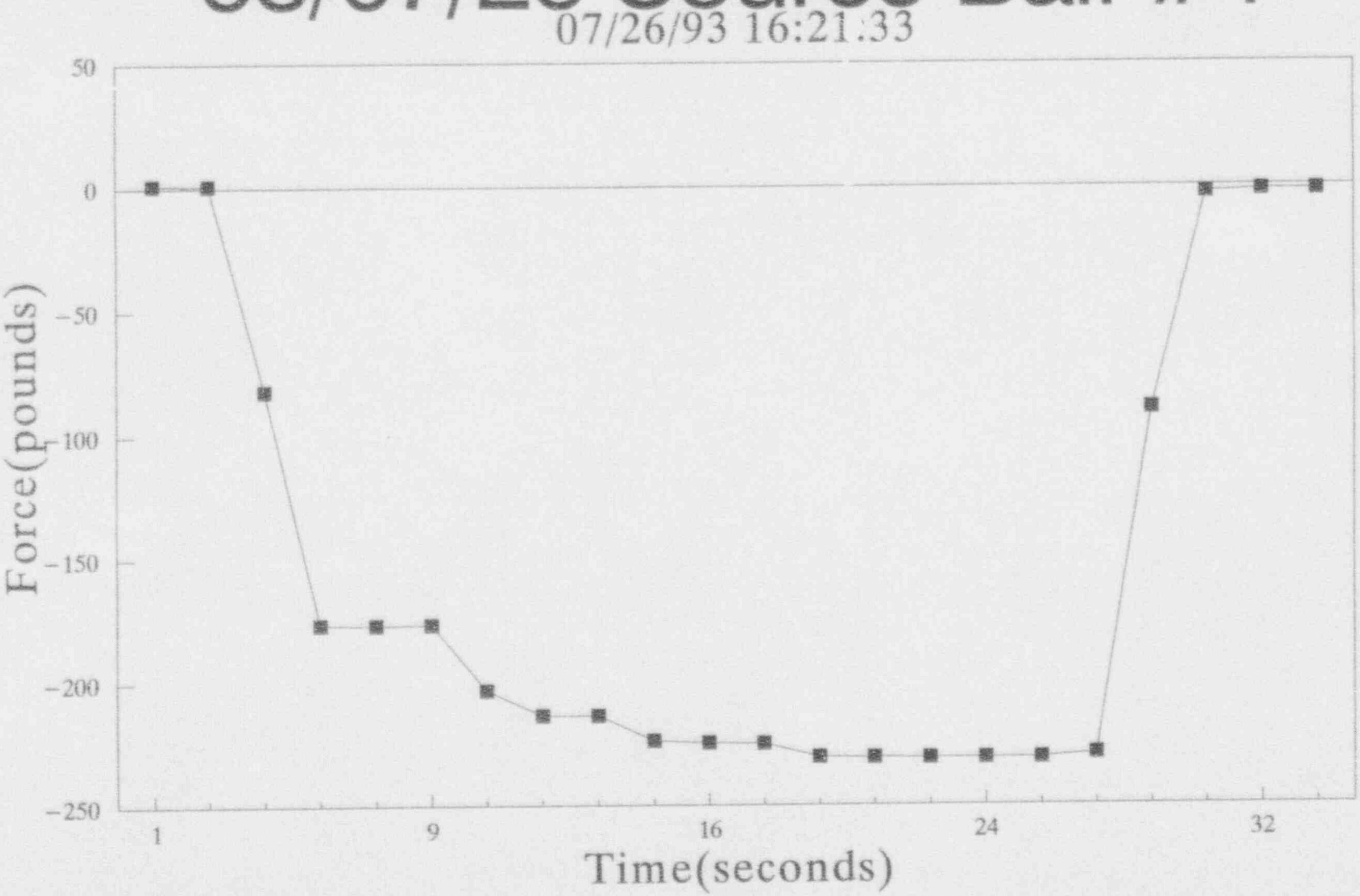
93/07/26 Source Capsule #9



93/07/26 Source Capsule 10

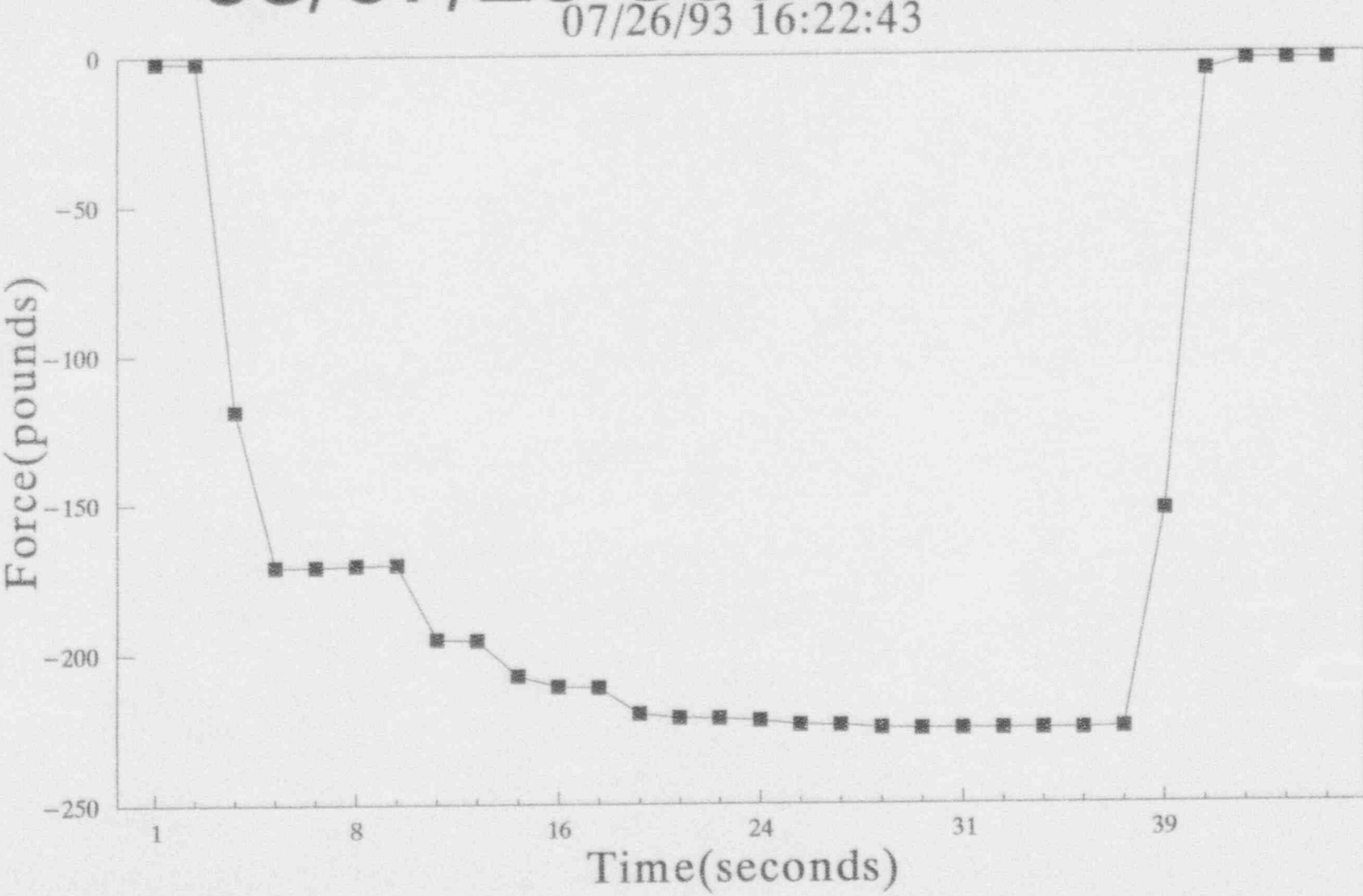


93/07/26 Source Ball #1

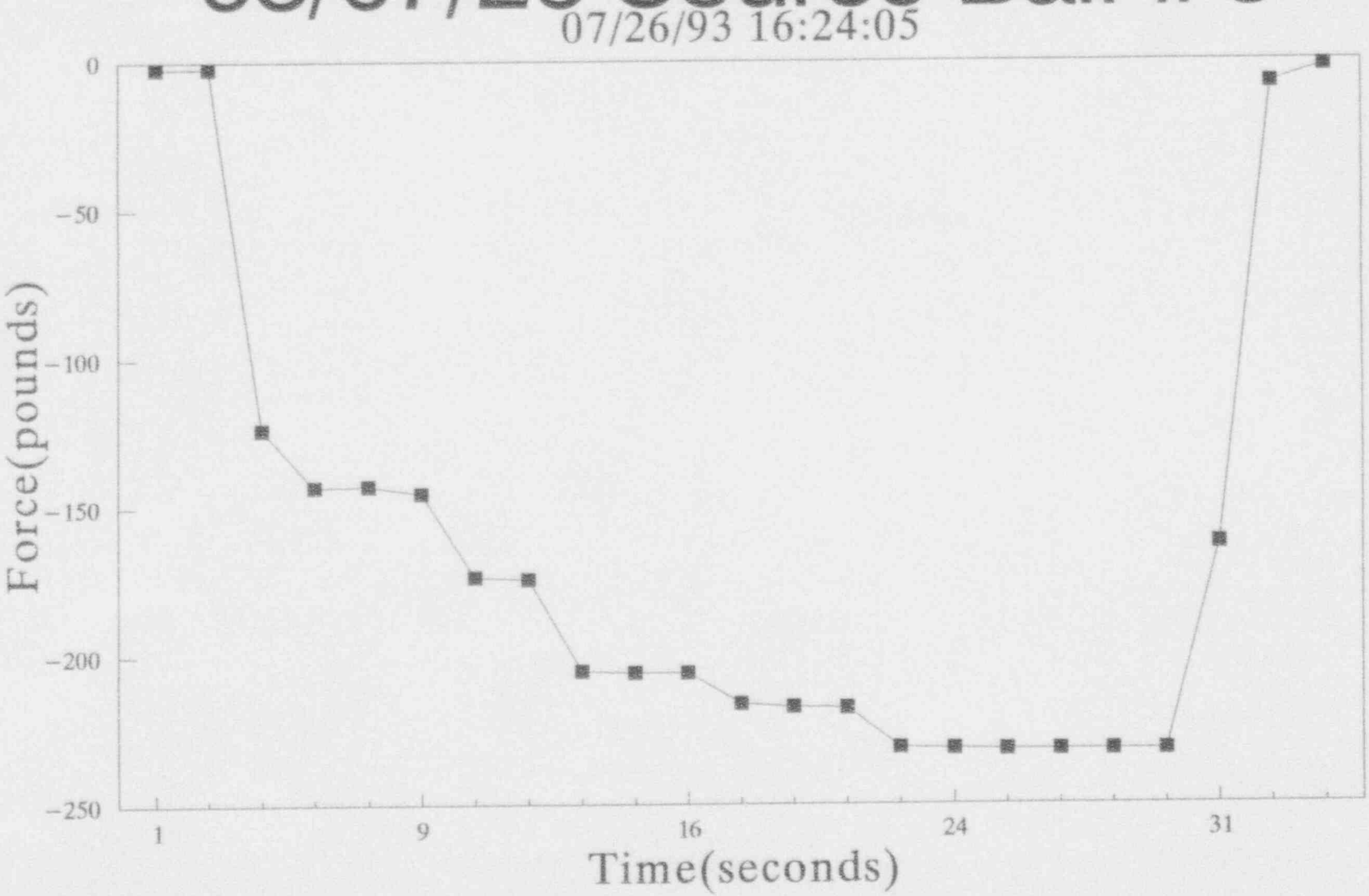


0-21

93/07/26 Source Ball #2



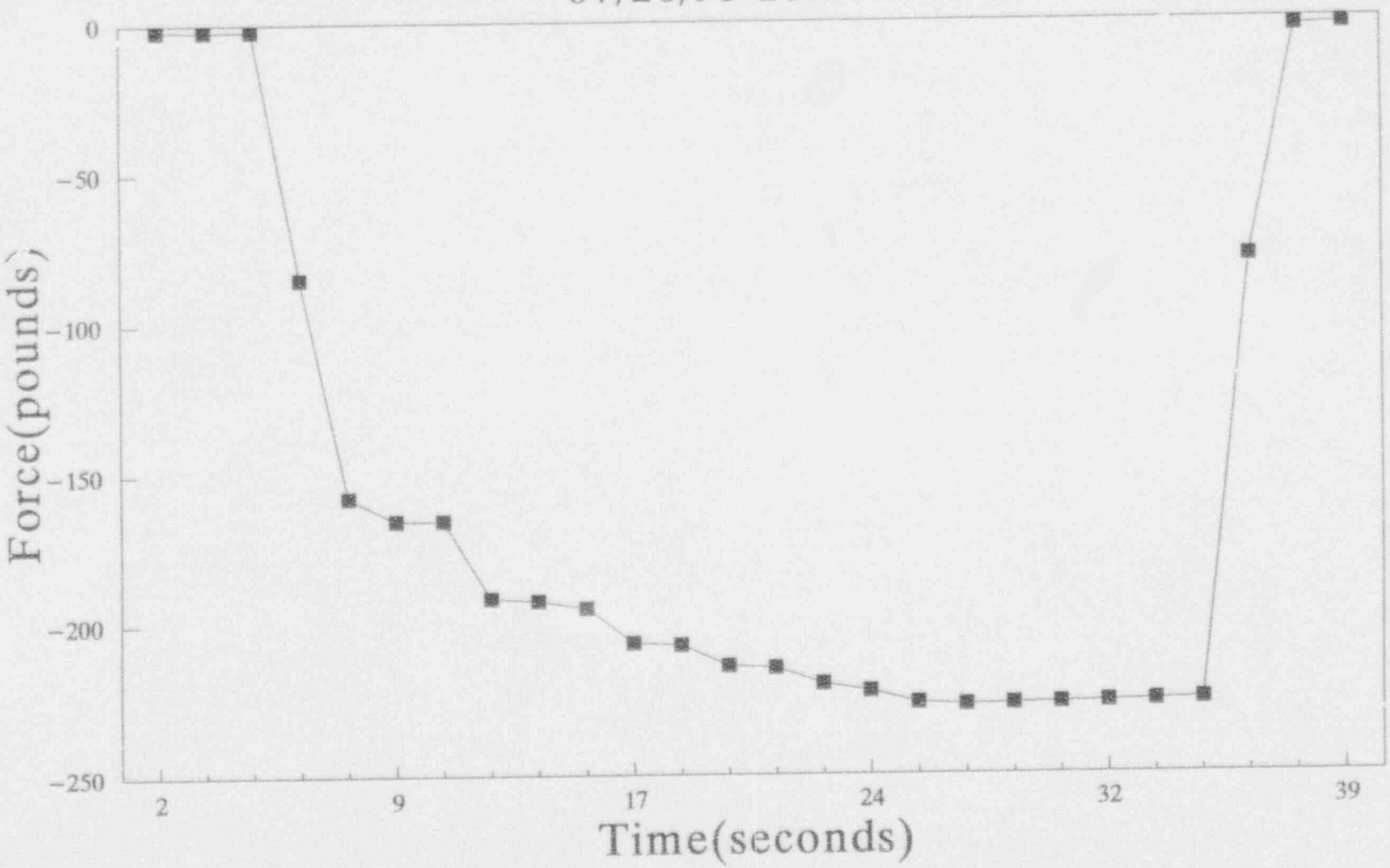
93/07/26 Source Ball #3



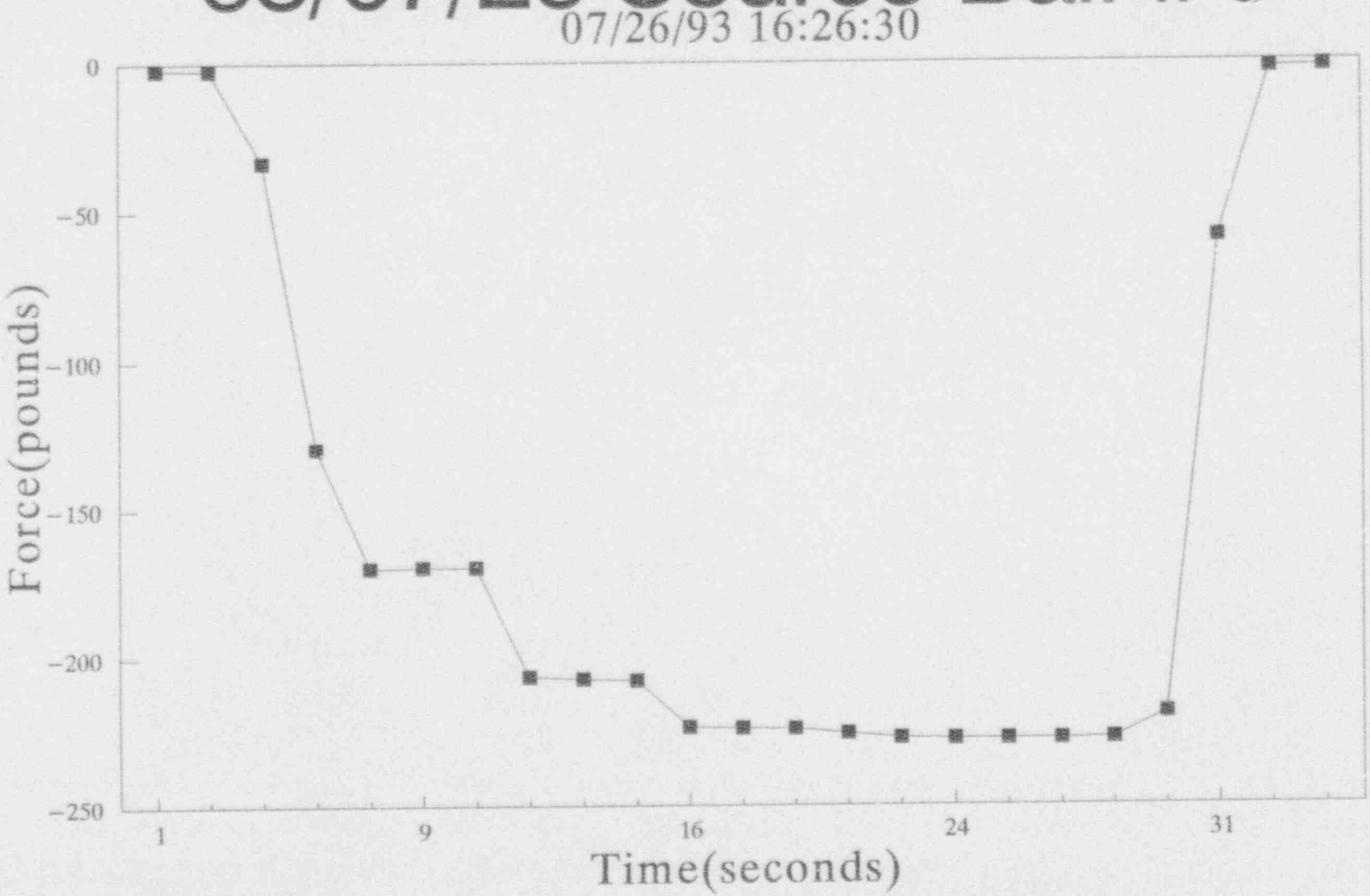
0-23

93/07/26 Source Ball #4

07/26/93 16:25:15

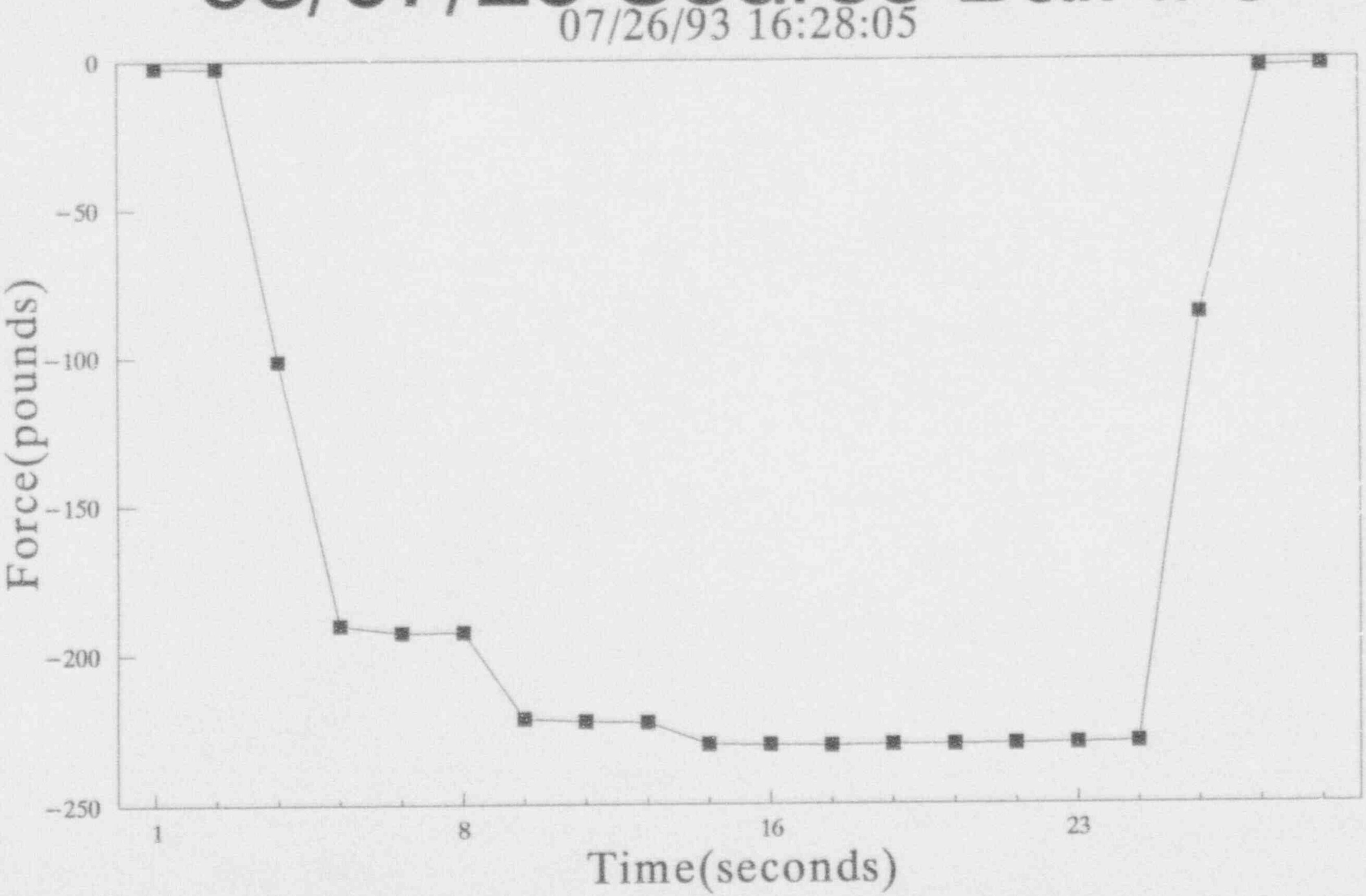


93/07/26 Source Ball #5

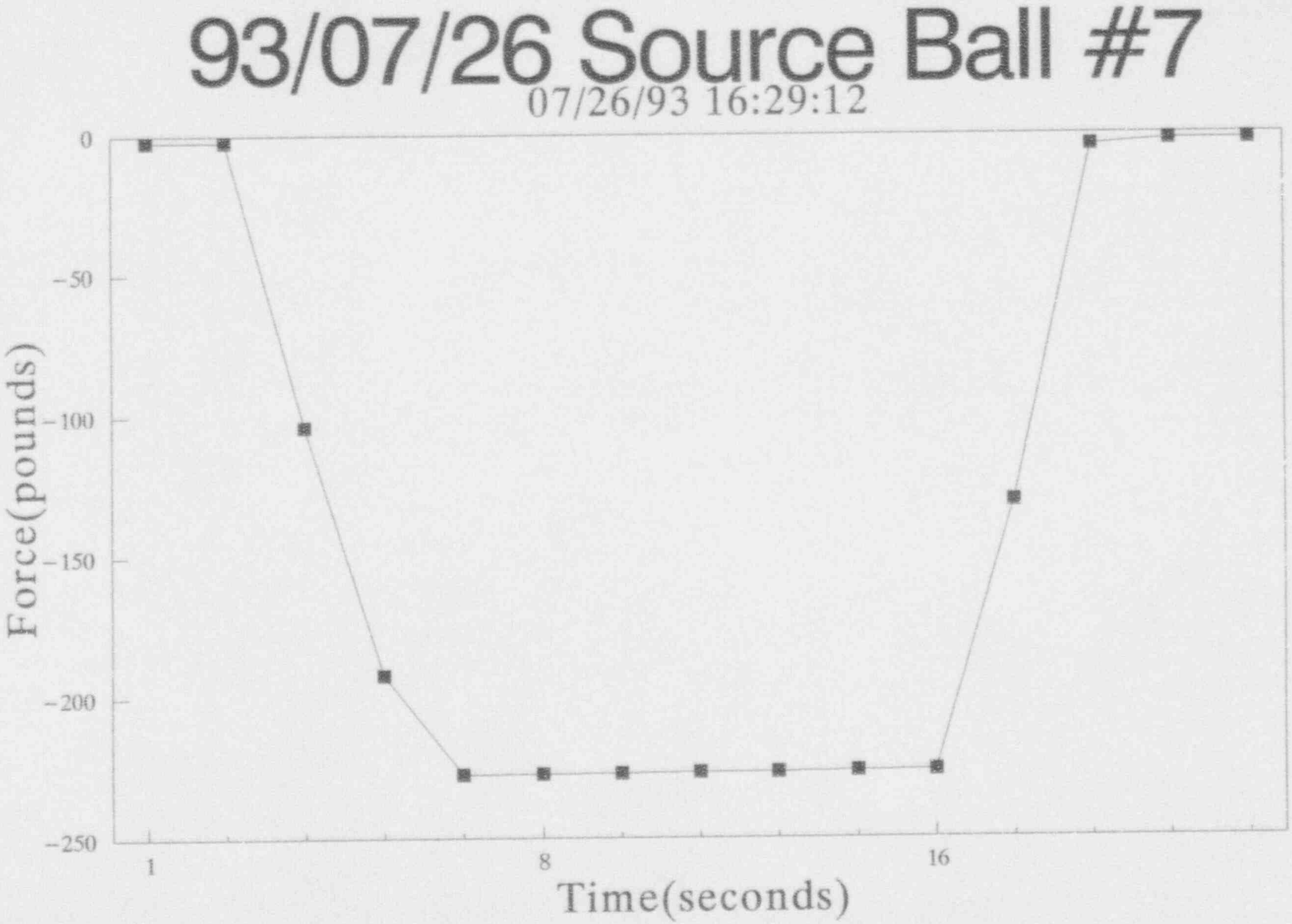


0-25

93/07/26 Source Ball #6



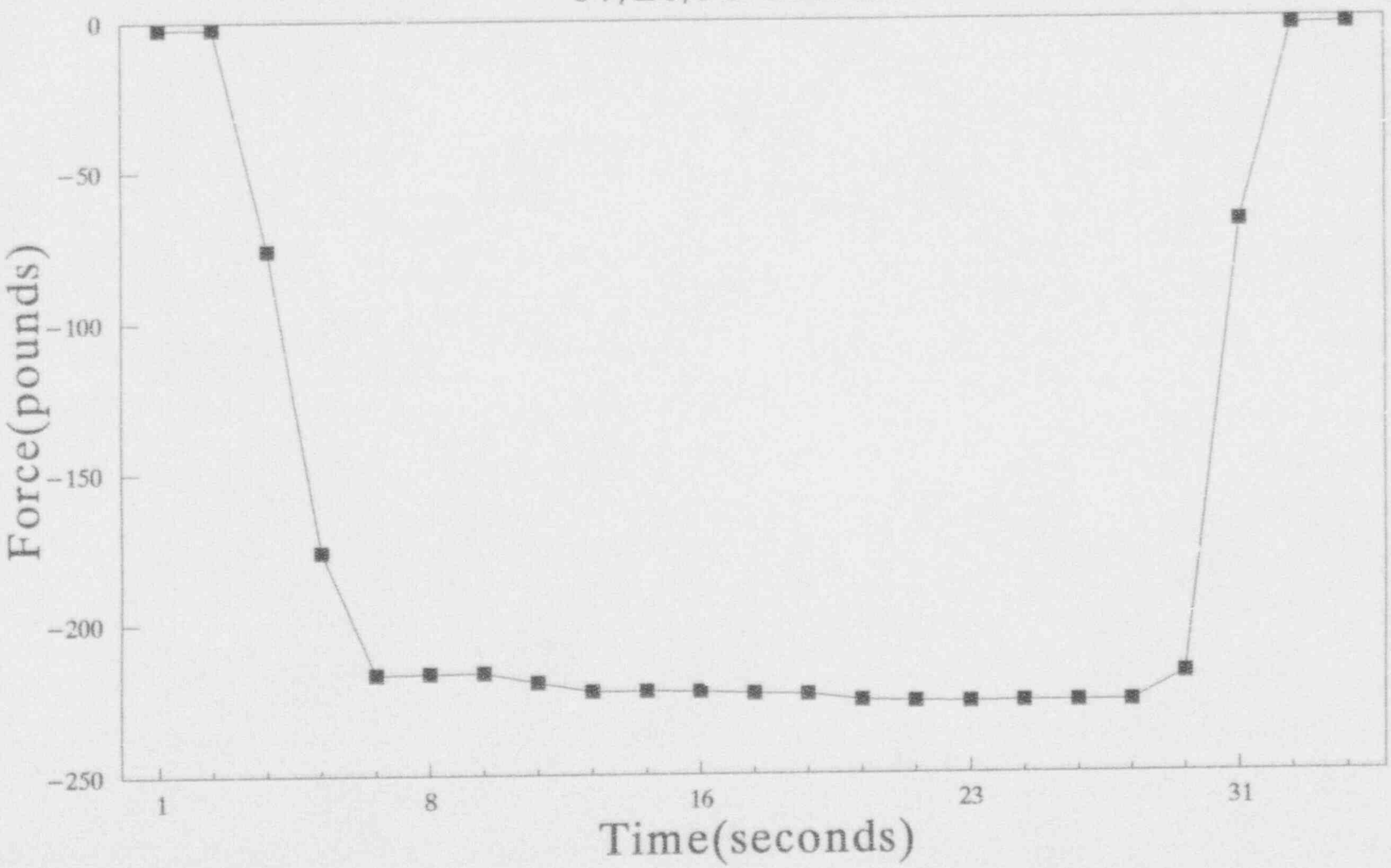
0-26


93/07/26 Source Ball #7
07/26/93 16:29:12
Force(pounds)
0
-50
-100
-150
-200
-250
Time(seconds)
1
8
16

0-27

93/07/26 Source Ball #8

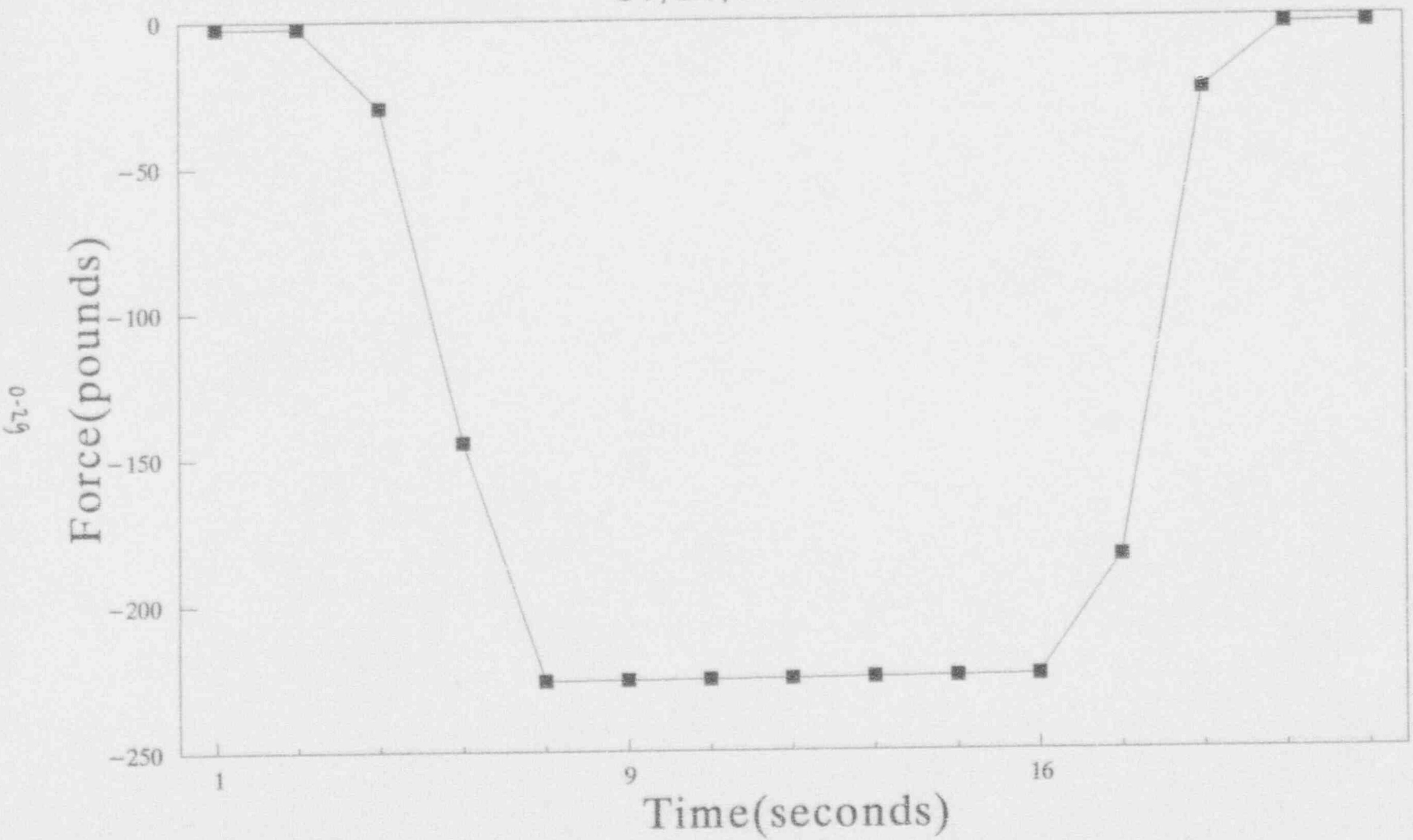
07/26/93 16:30:07



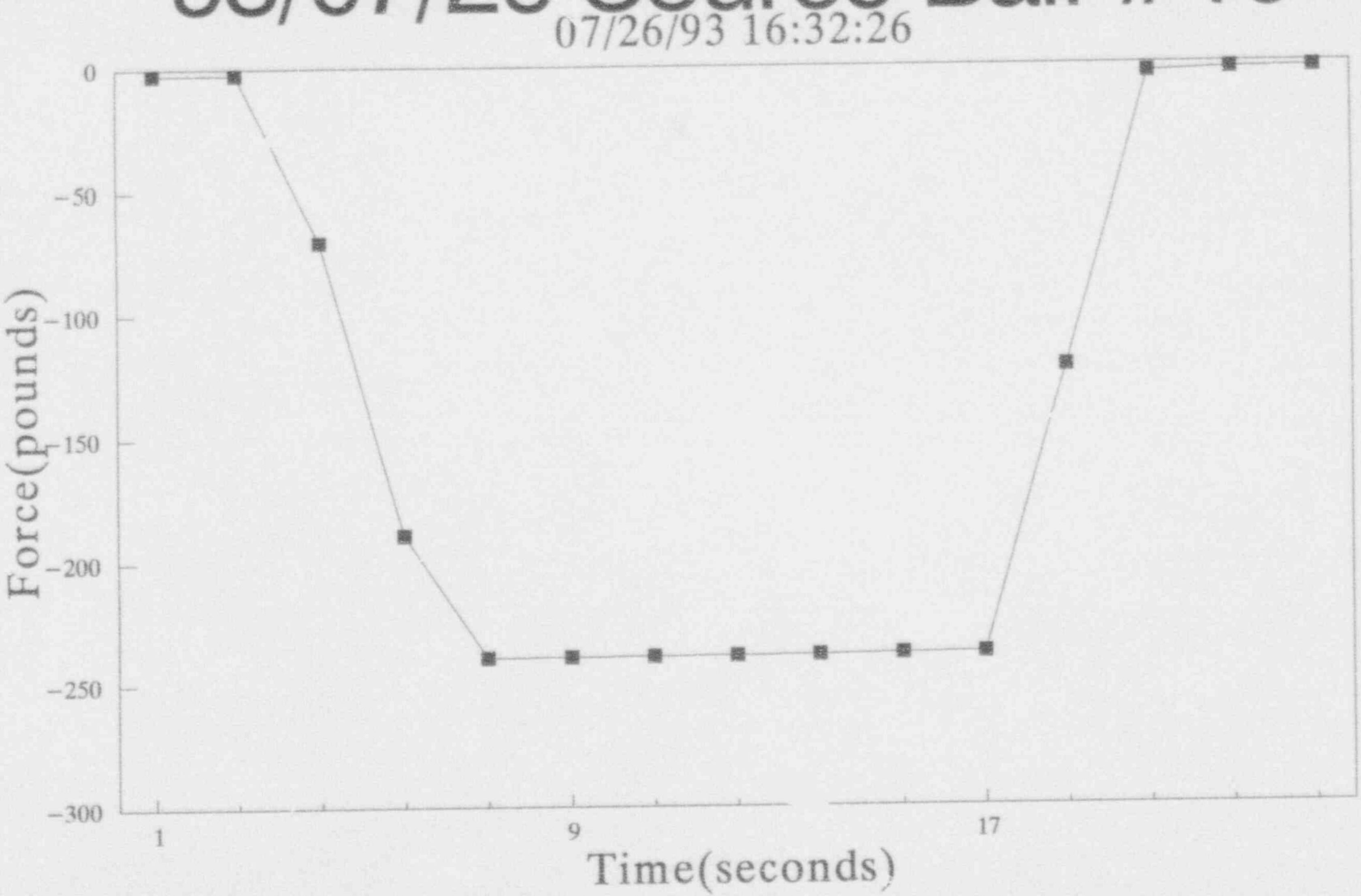
D-28

93/07/26 Source Ball #9

07/26/93 16:31:16



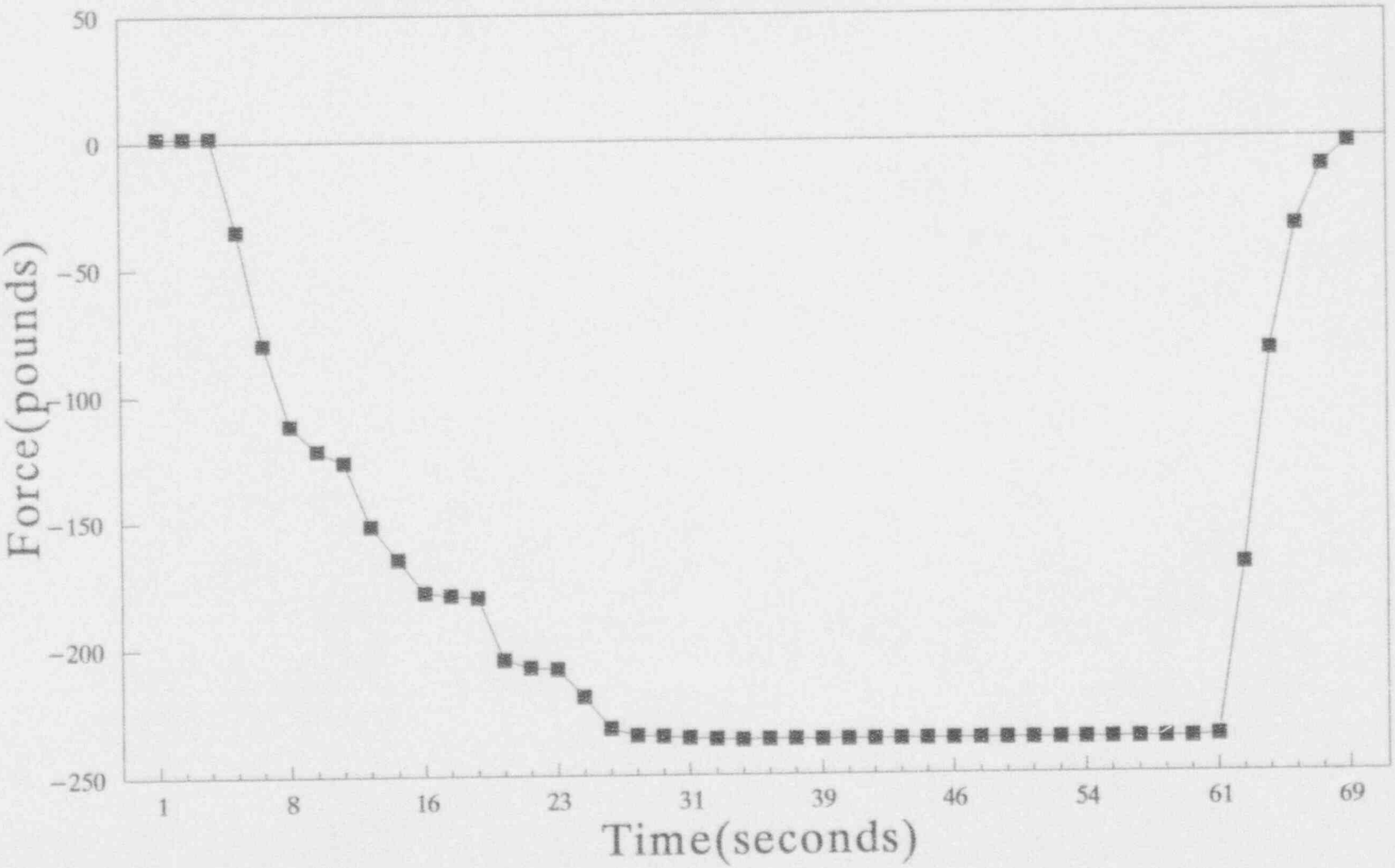
93/07/26 Source Ball #10



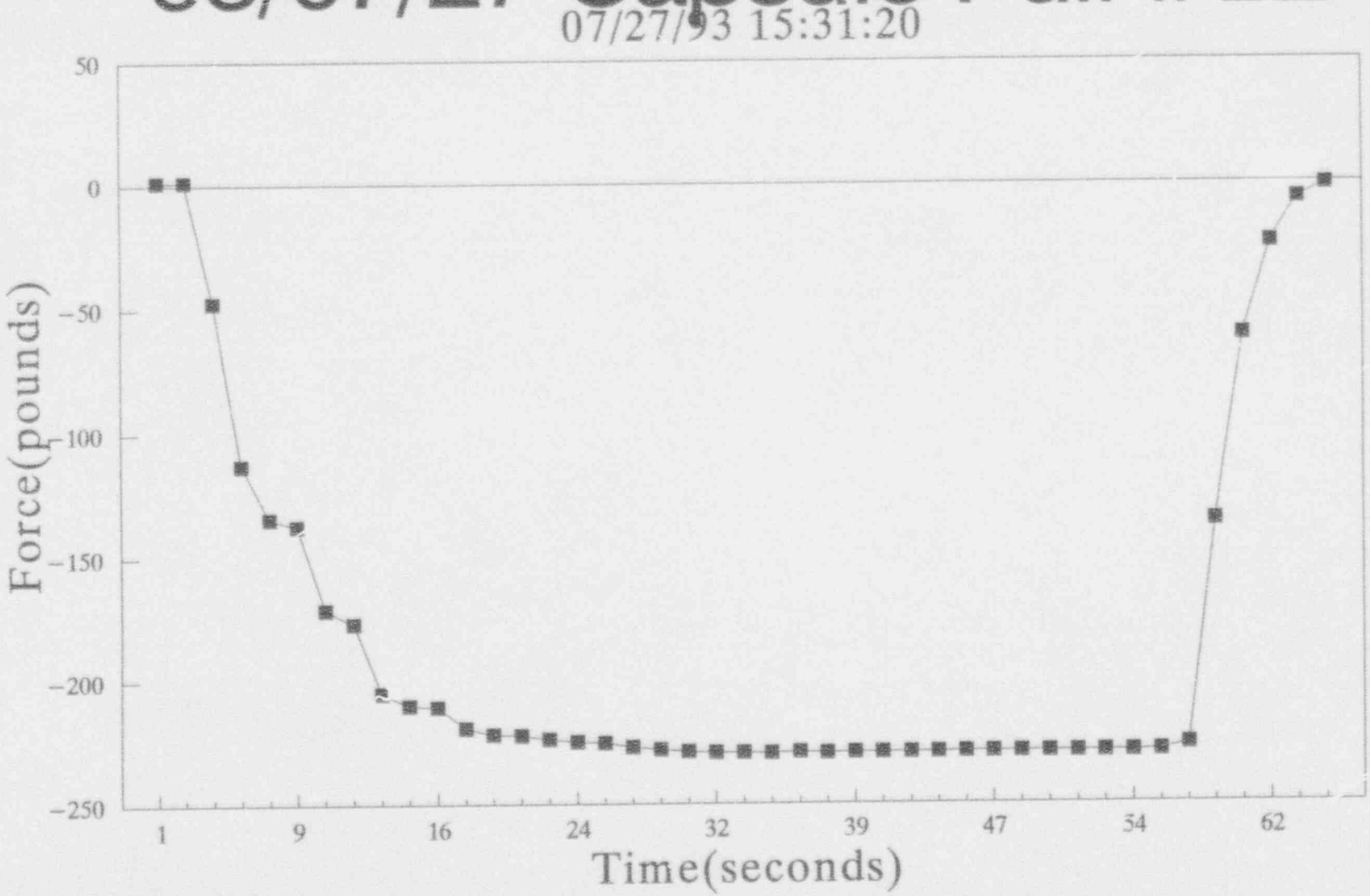
0-30

93/07/27 Capsule Pull #21

07/27/93 15:29:37



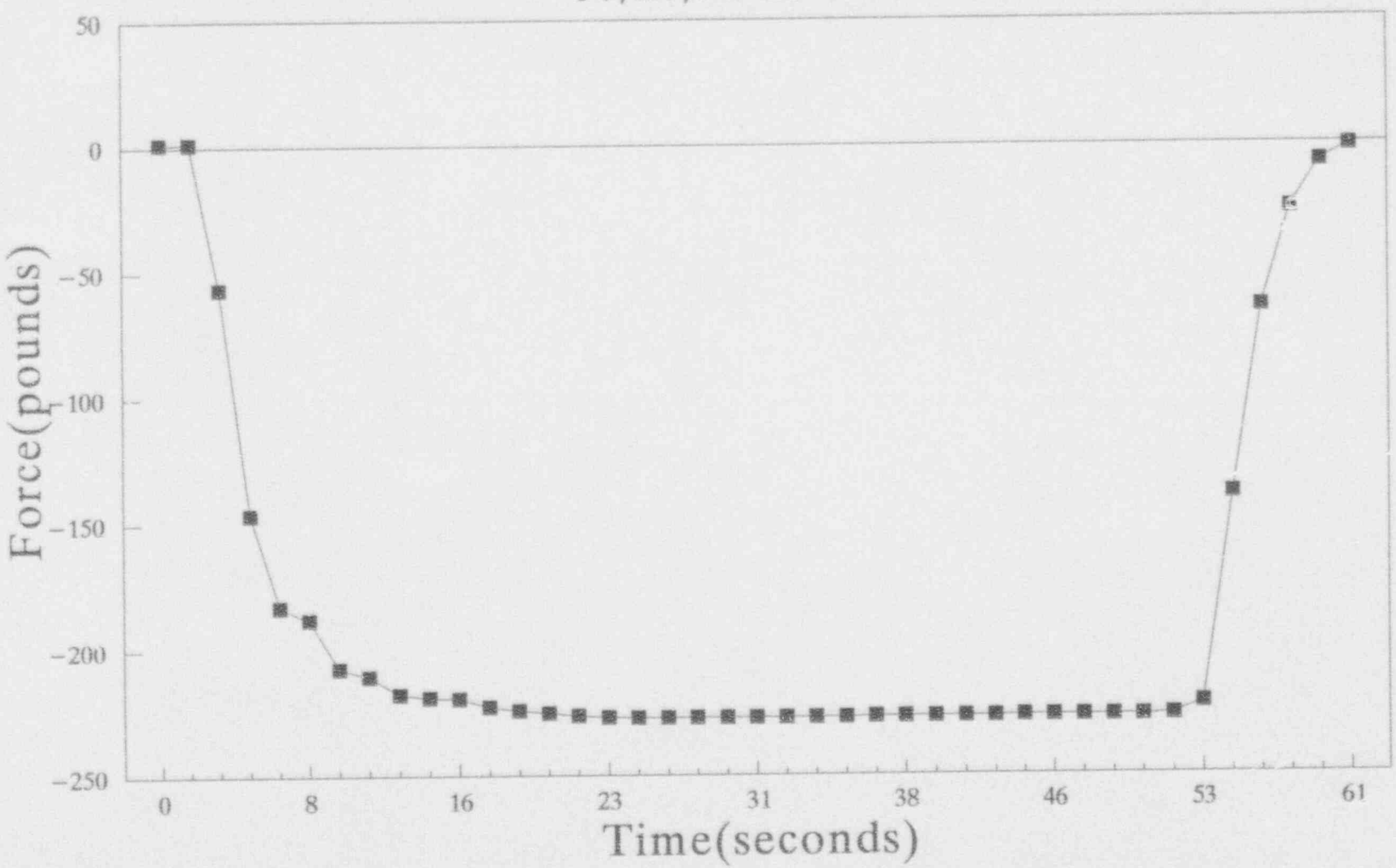
93/07/27 Capsule Pull #22



0-32

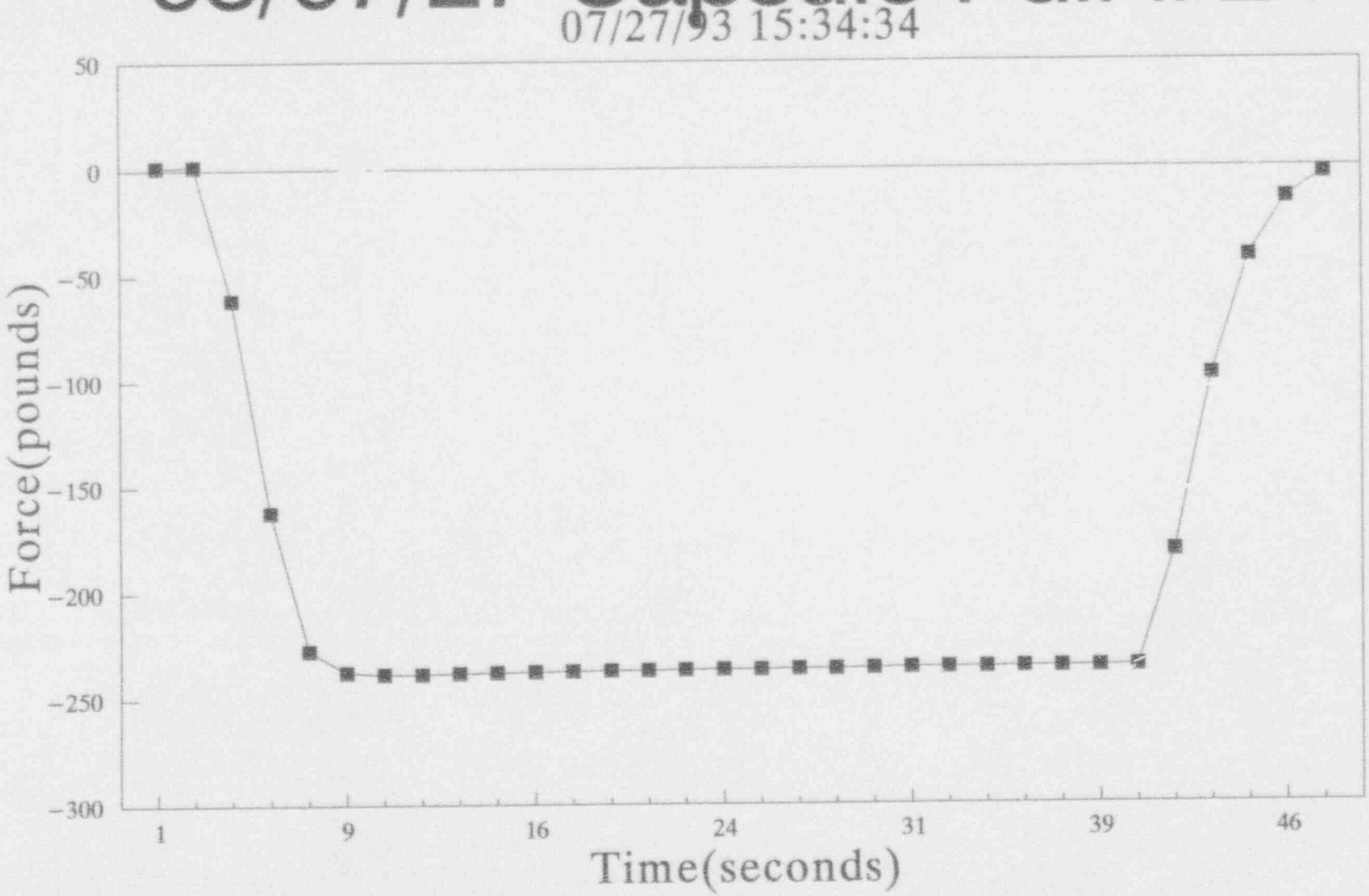
93/07/27 Capsule Pull #23

07/27/93 15:33:00



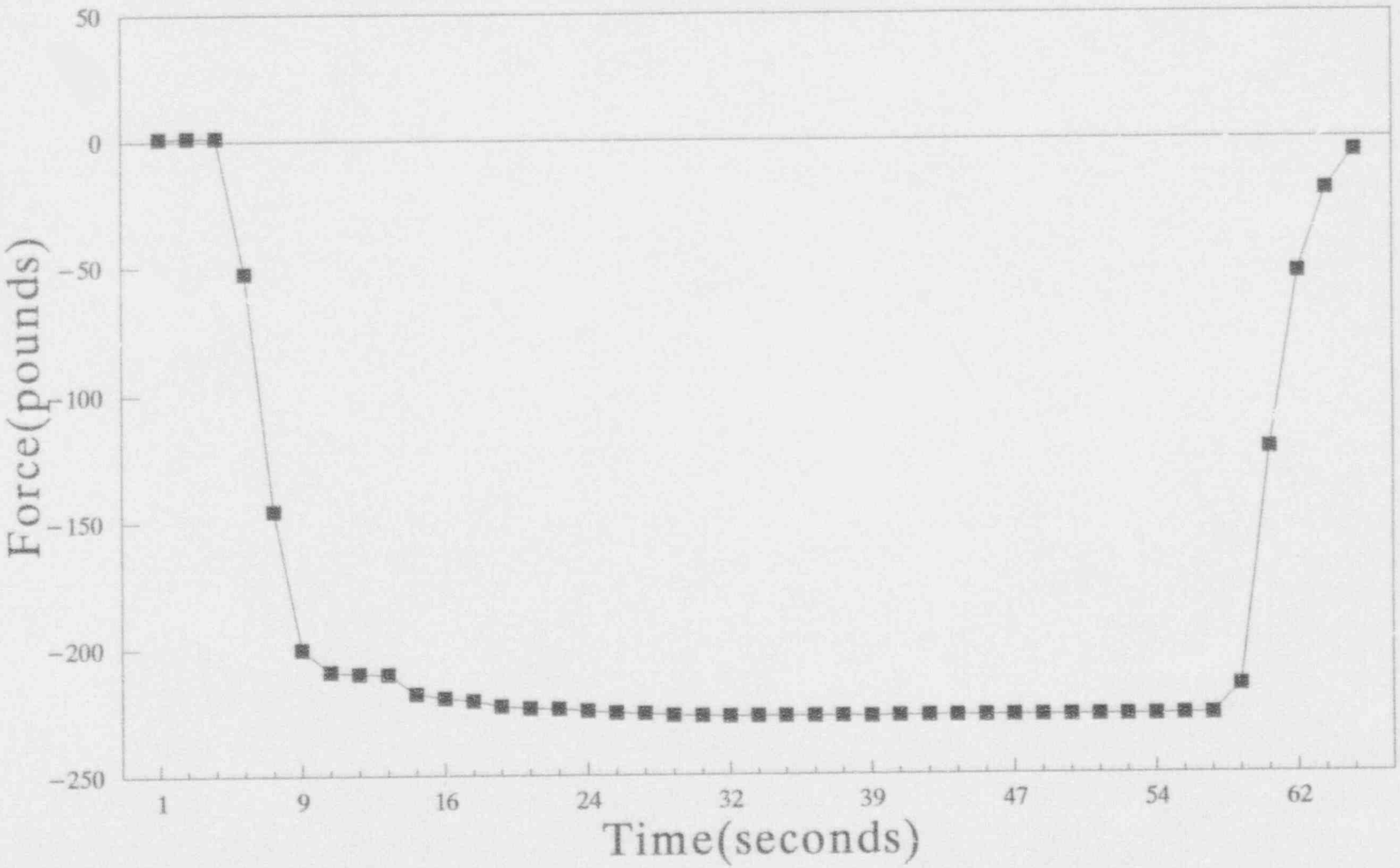
0-33

93/07/27 Capsule Pull #24



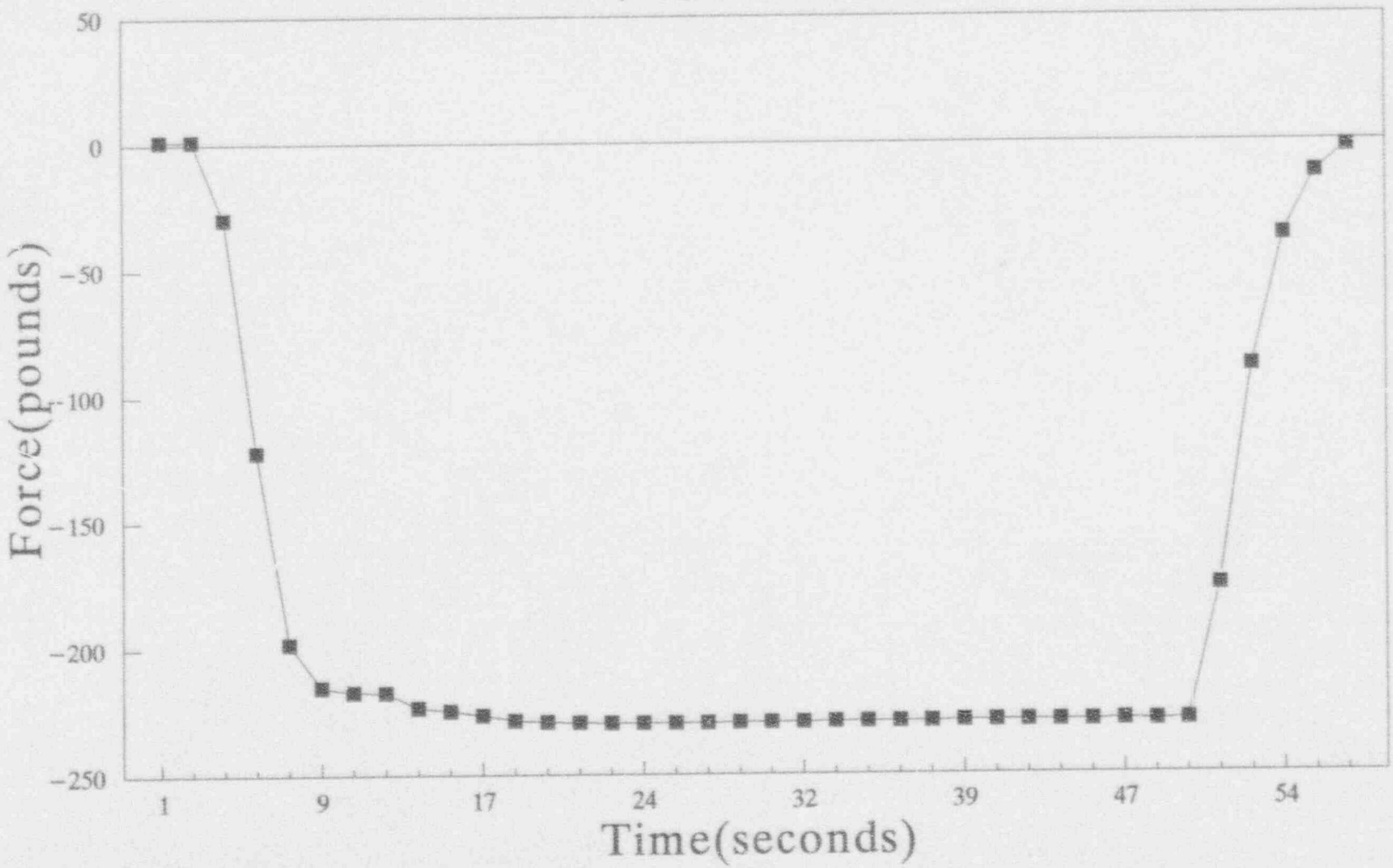
93/07/27 Capsule Pull #25

07/27/93 15:35:46



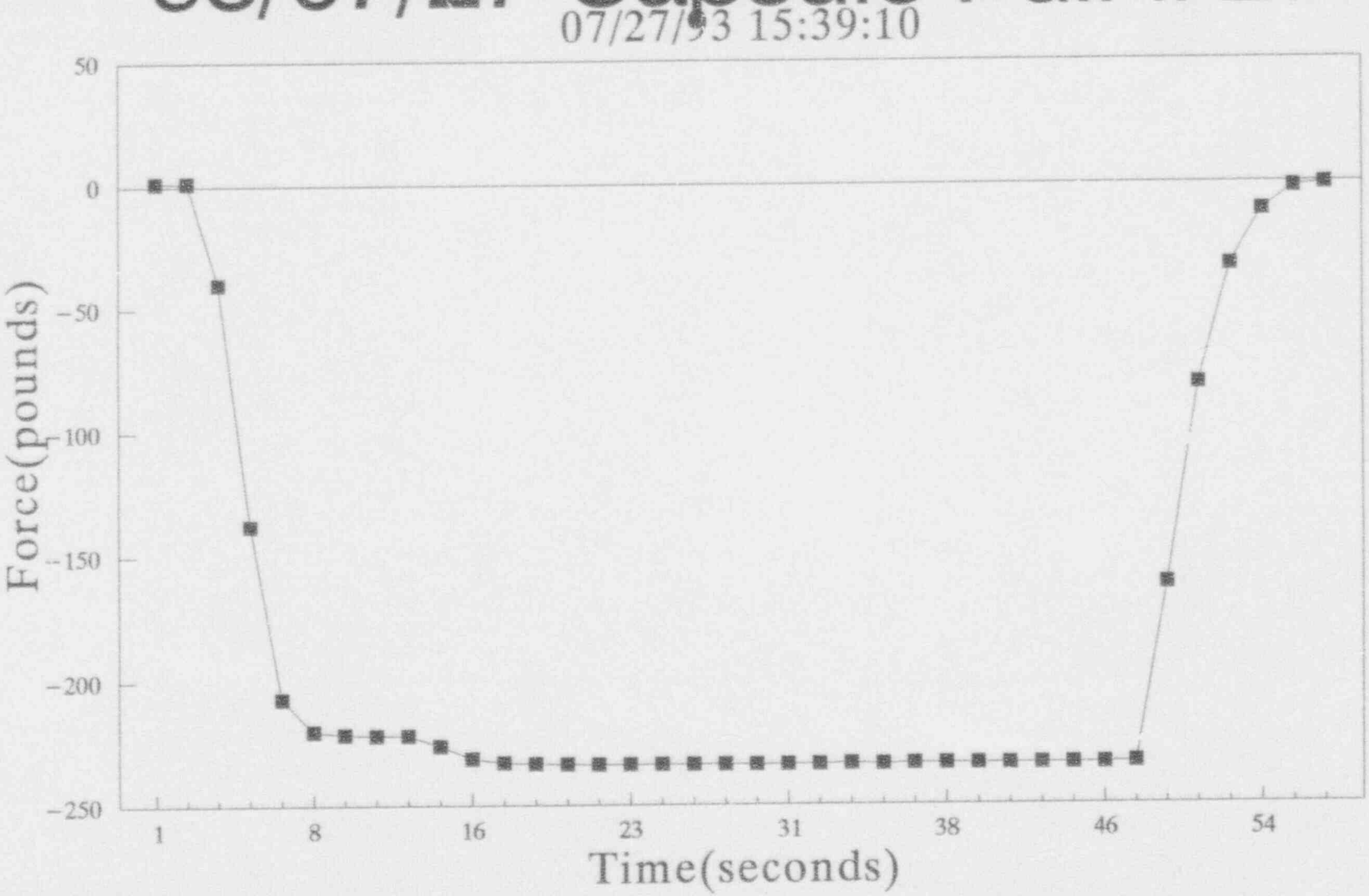
93/07/27 Capsule Pull #26

07/27/93 15:37:39



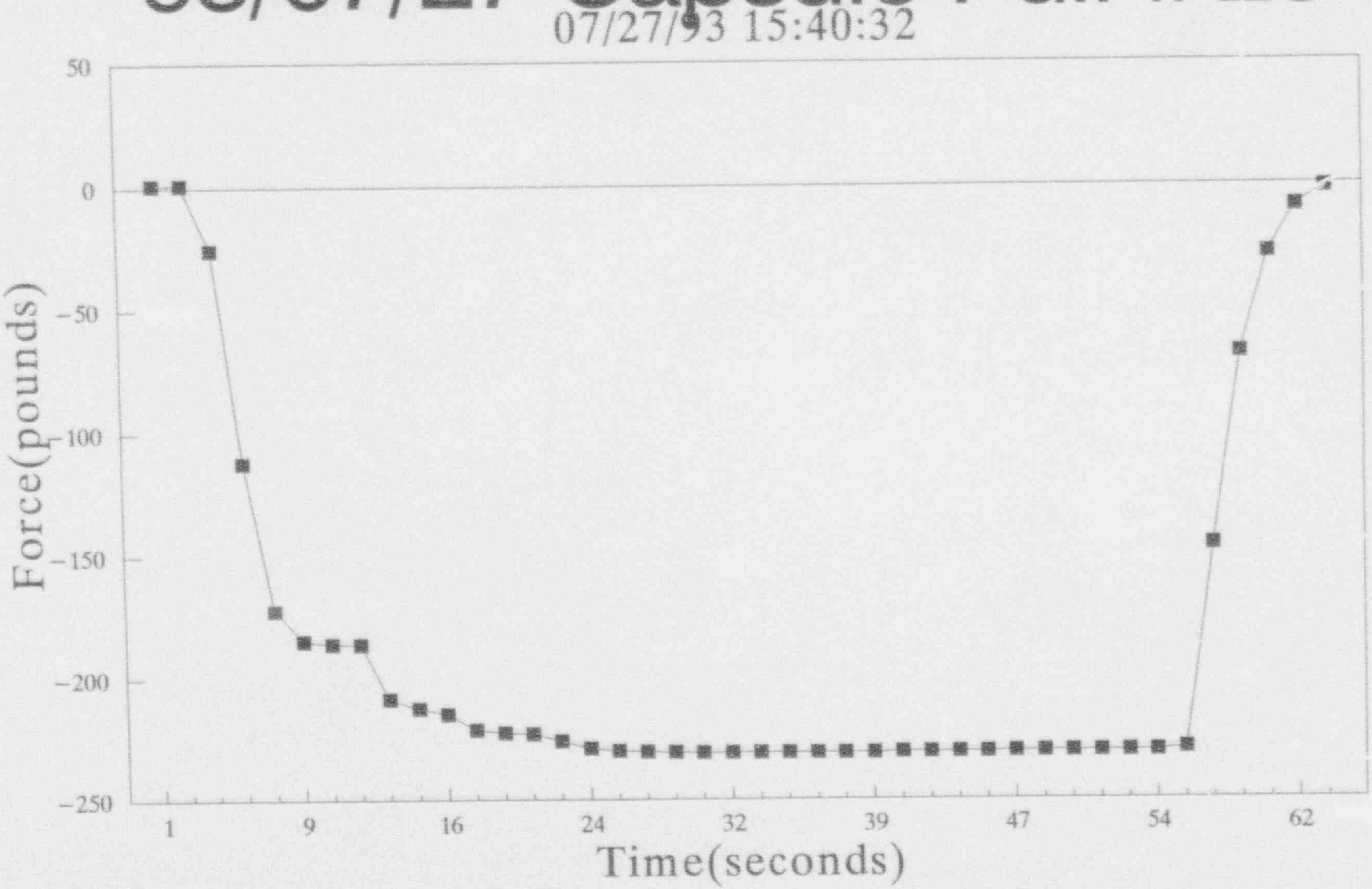
0-36

93/07/27 Capsule Pull #27



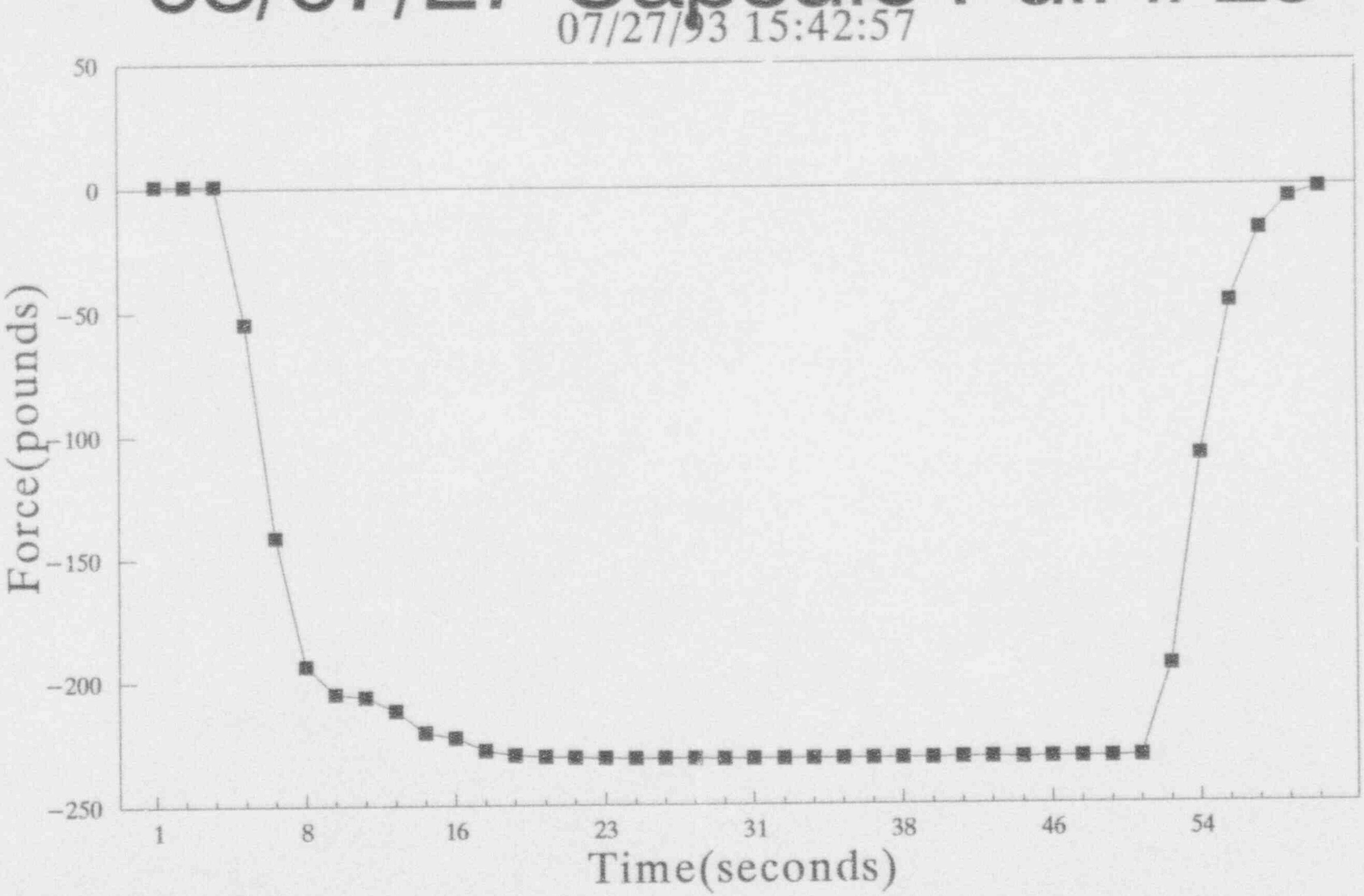
O-37

93/07/27 Capsule Pull #28



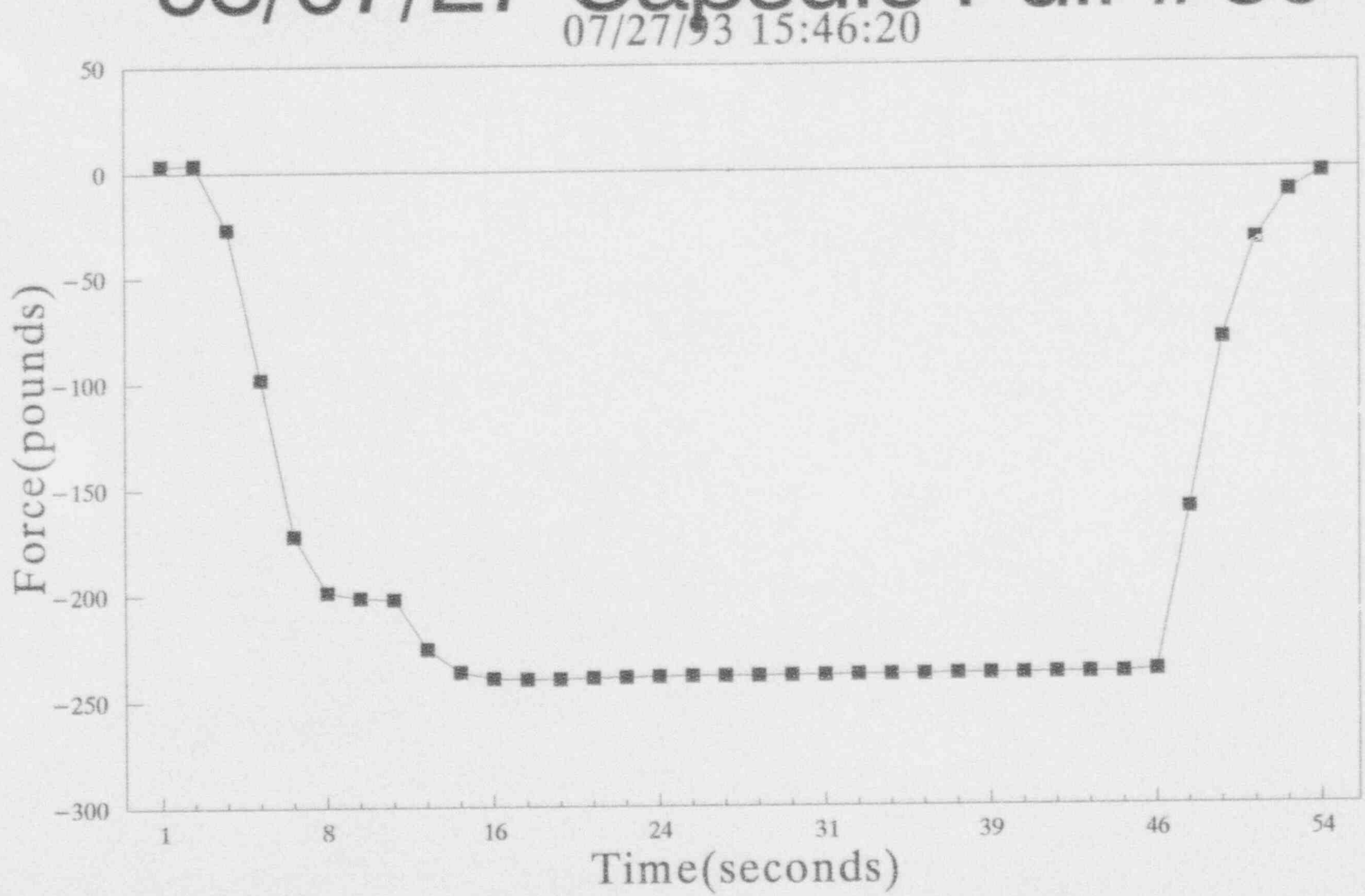
D-38

93/07/27 Capsule Pull #29

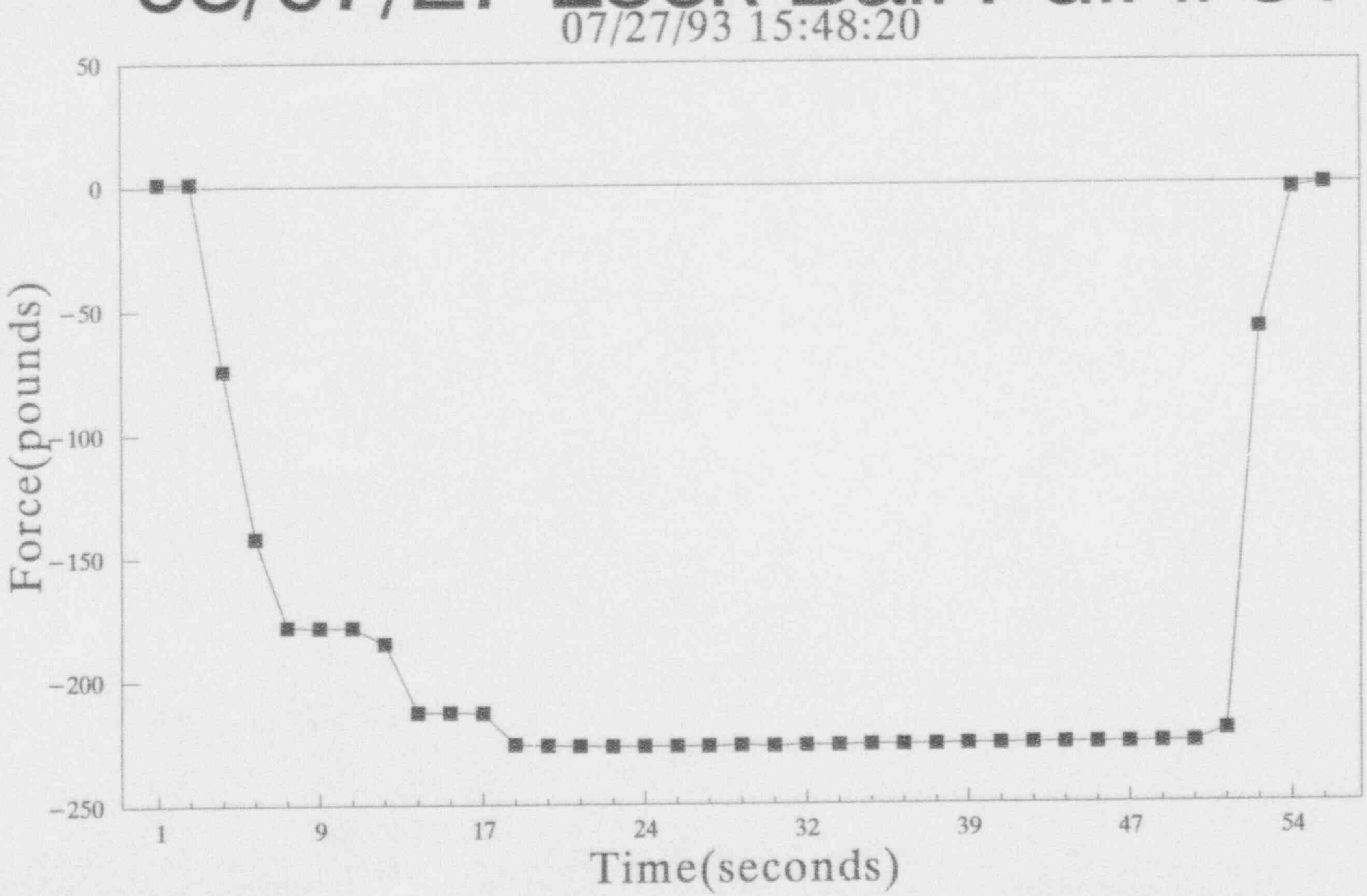


0-39

93/07/27 Capsule Pull #30

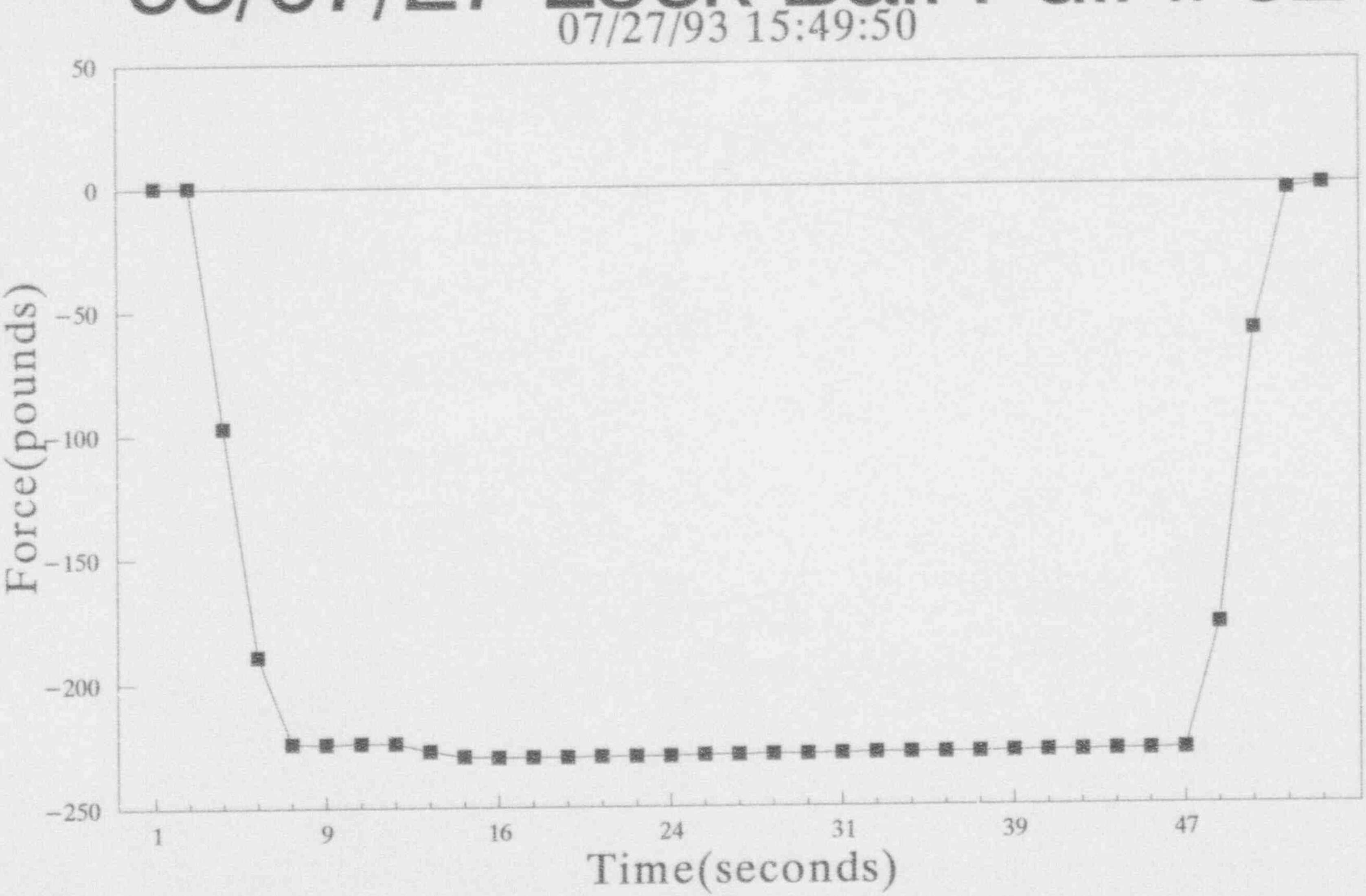


93/07/27 Lock Ball Pull #31

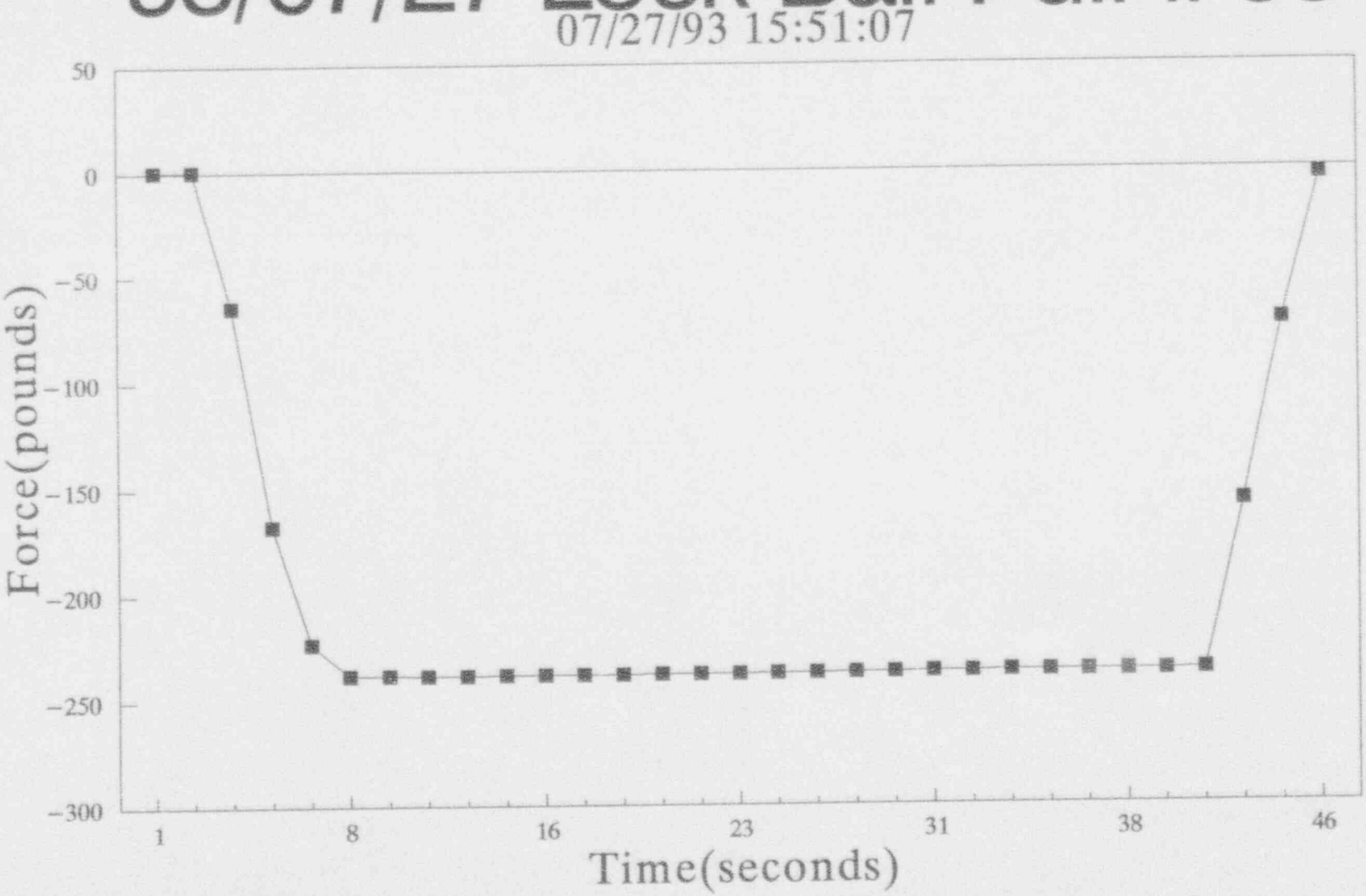


0-41

93/07/27 Lock Ball Pull #32

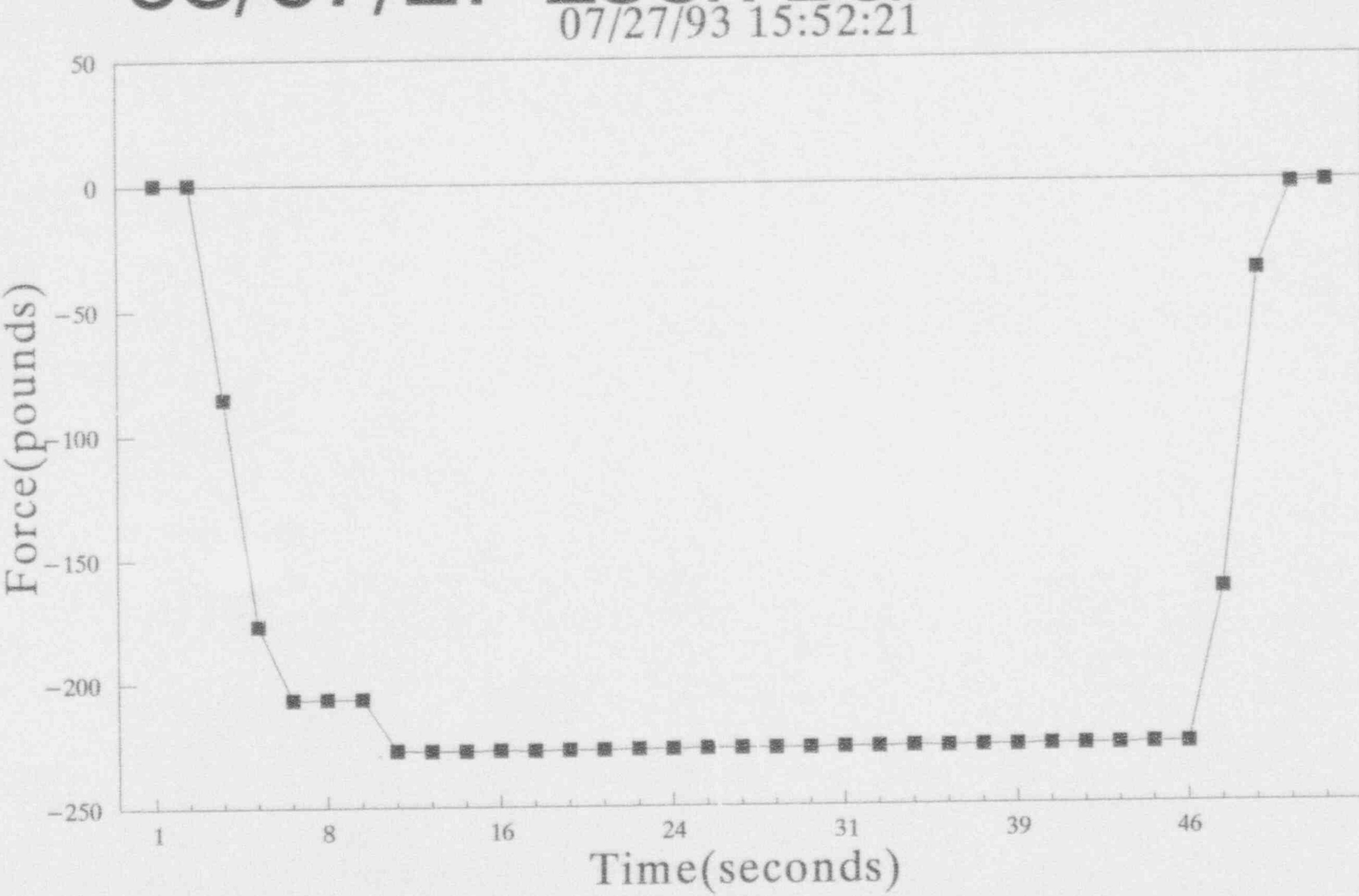


93/07/27 Lock Ball Pull #33



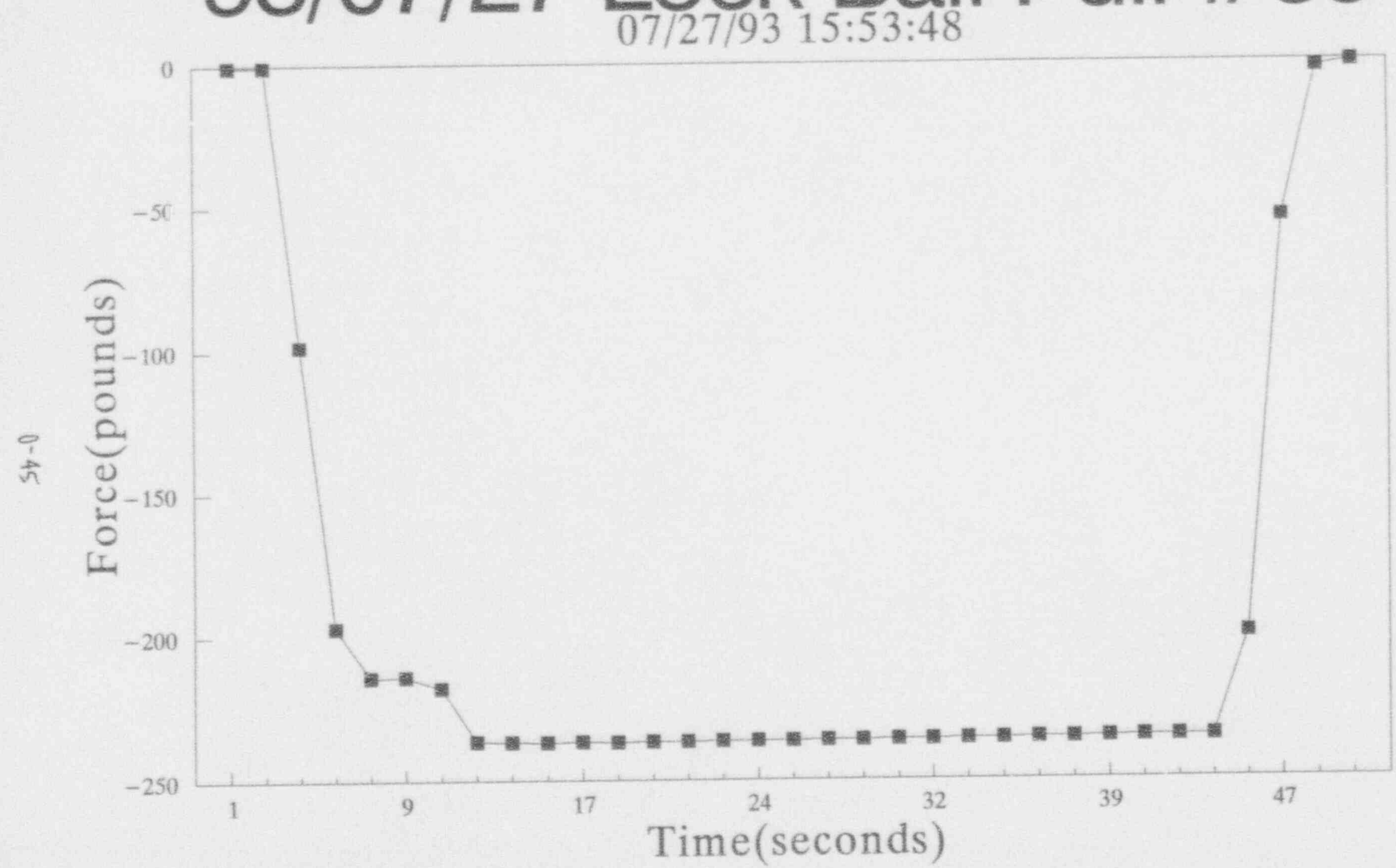
0-43

93/07/27 Lock Ball Pull #34



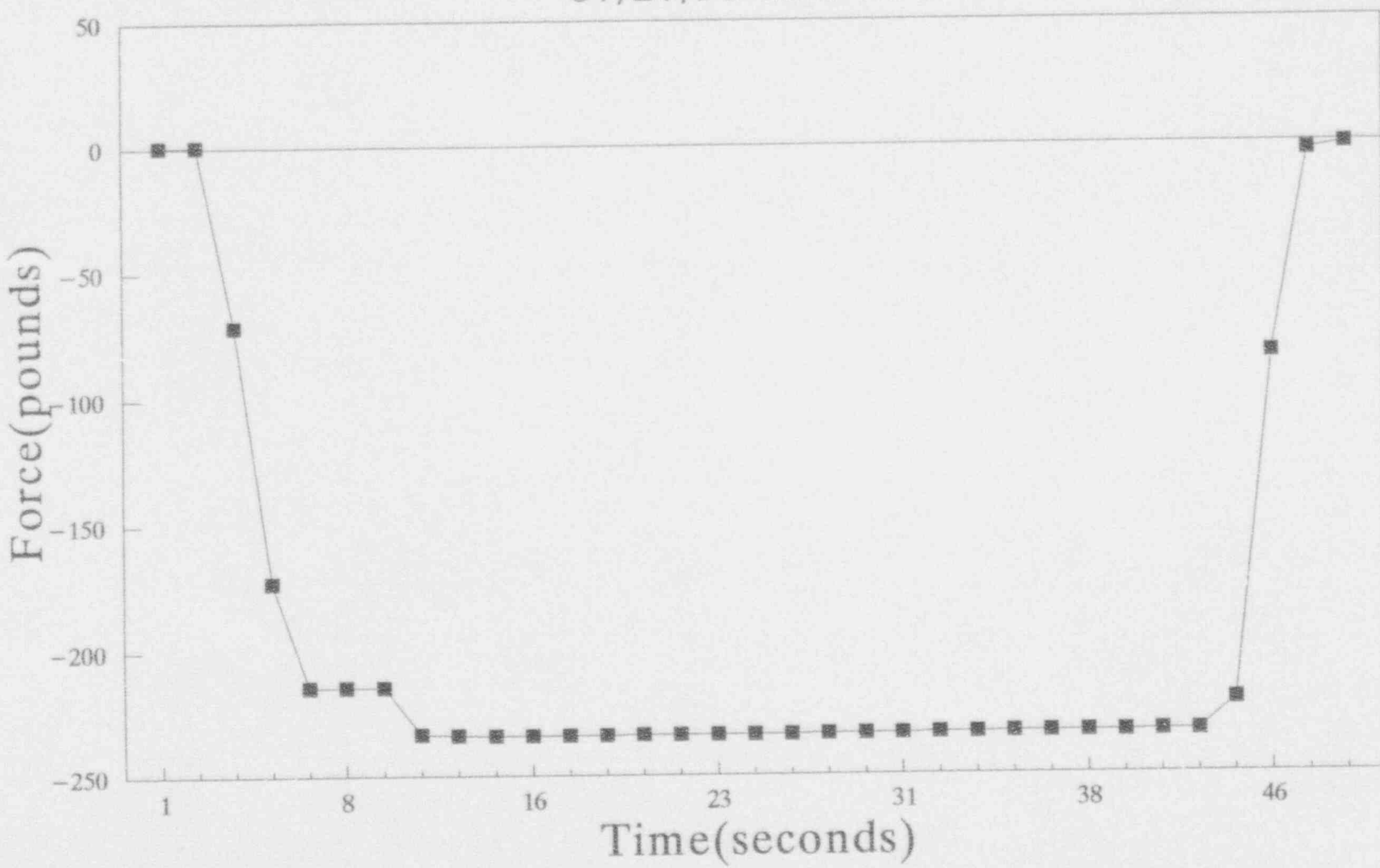
D-44

93/07/27 Lock Ball Pull #35



93/07/27 Lock Ball Pull #36

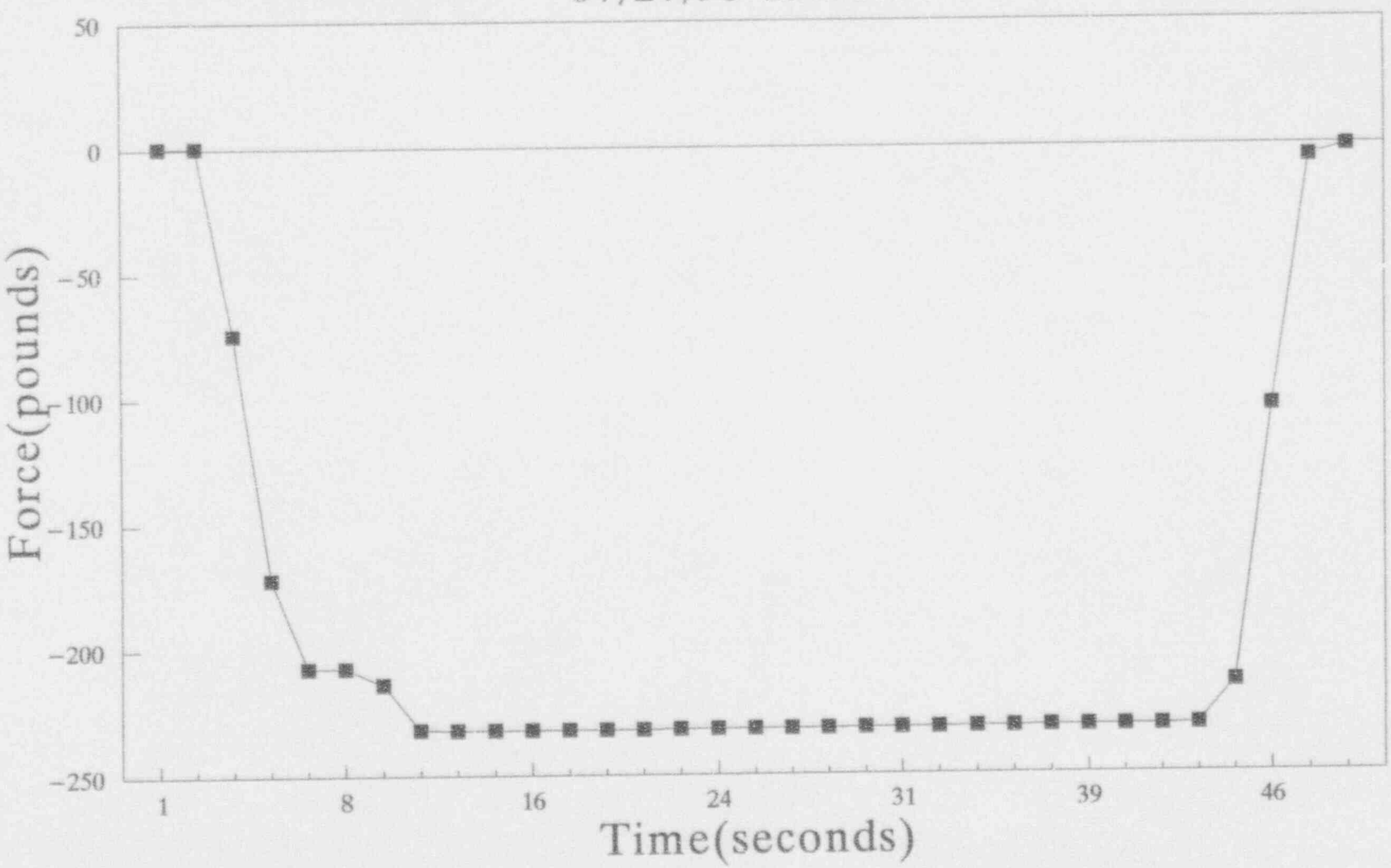
07/27/93 15:54:56



0-46

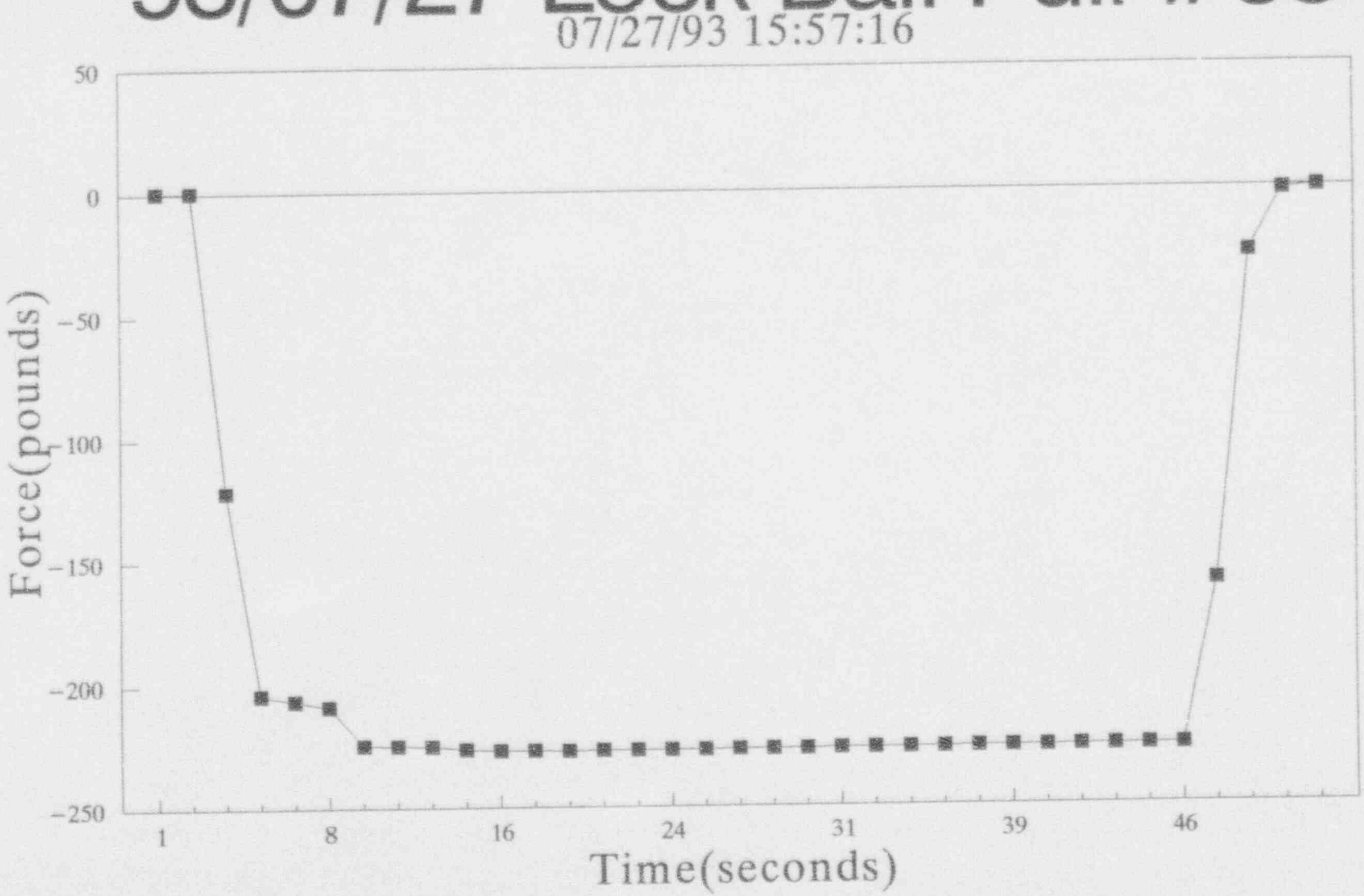
93/07/27 Lock Ball Pull #37

07/27/93 15:56:07



0-47

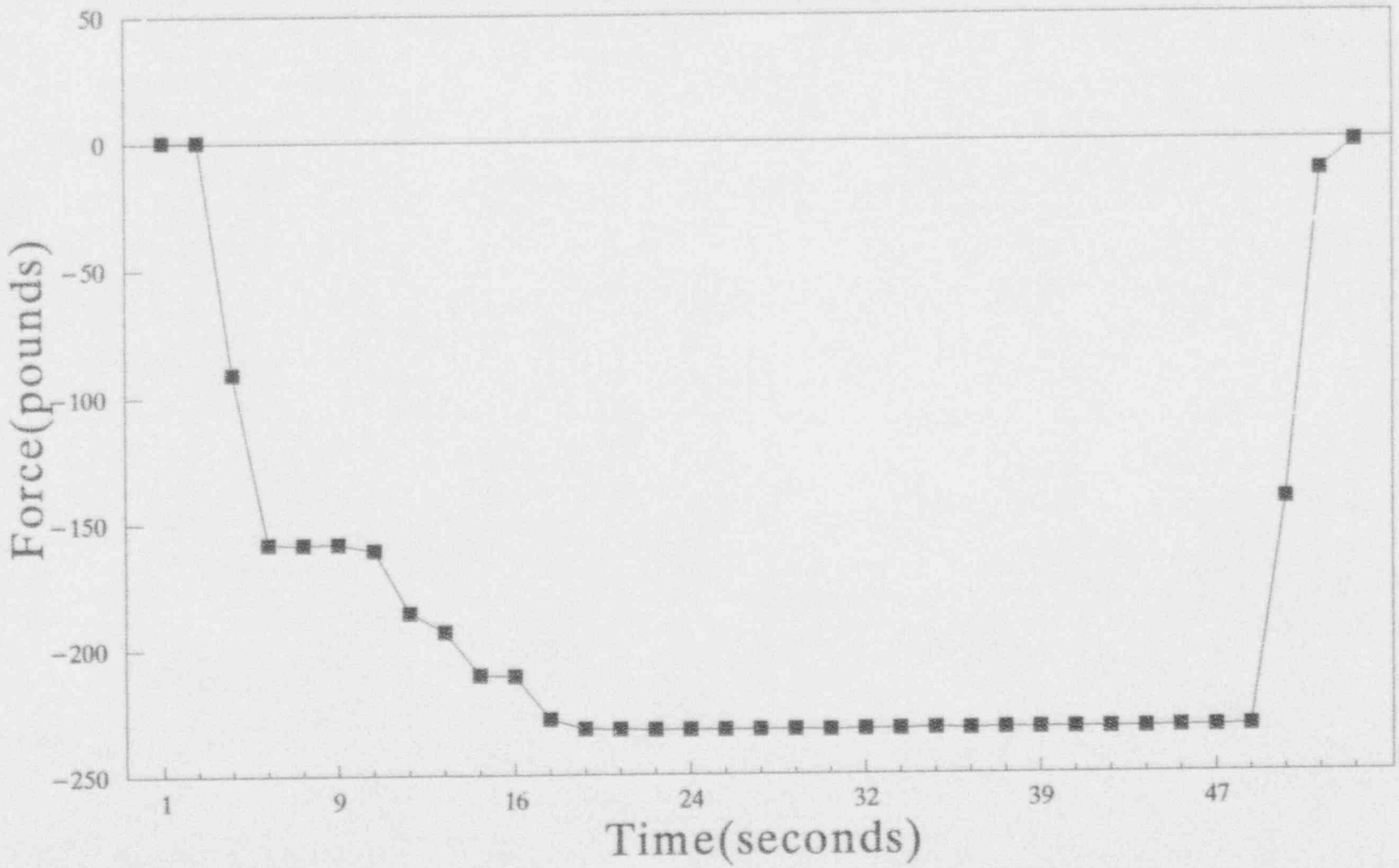
93/07/27 Lock Ball Pull #38



0-48

93/07/27 Lock Ball Pull #39

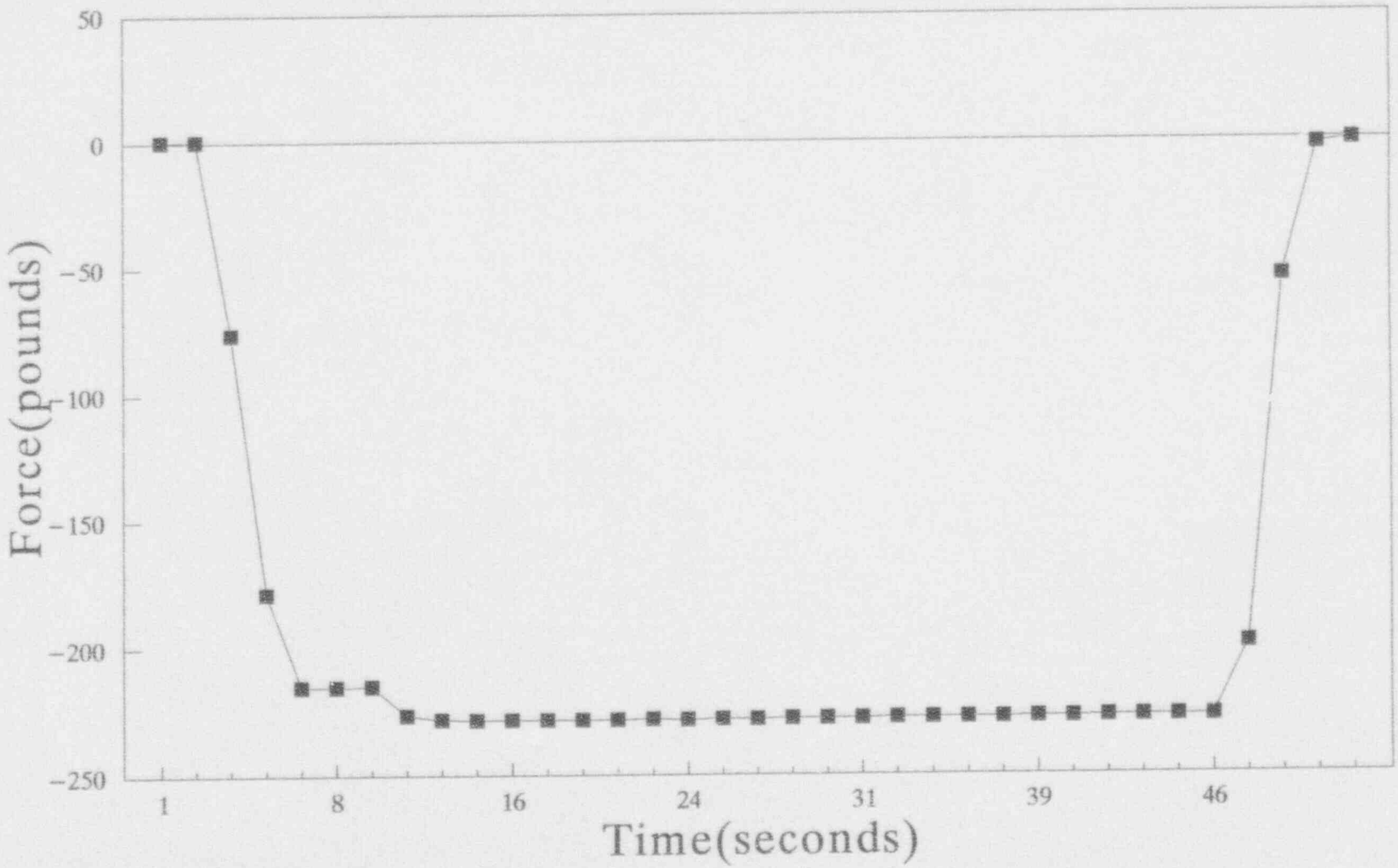
07/27/93 15:58:29



0-49

93/07/27 Lock Ball Pull #40

07/27/93 15:59:44



0-50