TWR-18076

SPACE SHUTTLE

Solid Rocket Motors
Morton Thiokol Inc

Field Joint Protection System Rain Qualification Final Test Report

11 May 1989

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MORTON THIOKOL, INC.
Space Operations

TWR-18076

Field Joint Protection System Rain Qualification Final Test Report

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Reliability

Systems Safety

ABSTRACT

This report documents the procedures, performance, and results obtained from the Field Joint Protection System (FJPS) Rain Test. This test was performed to validate that the flight configuration FJPS prevents the accumulation of moisture in the Redesigned Solid Rocket Motor (RSRM) field joints when subjected to simulated prelaunch natural rain environments. Testing was completed on 10 March 1989 at the Morton Thiokol Static Test Bay T-18.

The FJPS test article was exposed to rain simulation for approximately 50 minutes. During the test, water entered through the open upper end of the systems tunnel and was funneled down between the tunnel and case. A sealant void at the moisture seal butt splice allowed this water to flow underneath the FJPS. The most likely cause of voids was improper bondline preparation, particularly on the moisture seal surface. In total, water penetrated underneath approximately 60 percent of the FJPS circumference. Because the test article was substantially different from flight configuration (no systems tunnel closeout), results of this test will not affect current flight motors.

Due to the omission of systems tunnel covers and systems tunnel floor plate closeout, the test assembly was not representative of flight hardware and resulted in a gross overtest. It is therefore recommended that the test be declared void. It is also recommended that the test be repeated with a complete closeout of the systems tunnel, sealed systems tunnel ends, and improved adhesive bondline preparation.

A redesign of the FJPS, to reduce installation time and improve performance, is being considered. Should a redesign occur, it is recommended that the new protection system be rain tested following CTP-0073.

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1
INTRODUCTION

This report documents the procedures, performance, and results obtained from the Field Joint Protection System (FJPS) Rain Test. The purpose of the test was to validate that the flight configuration FJPS prevents the accumulation of moisture in the Redesigned Solid Rocket Motor (RSRM) field joints when subjected to the prelaunch natural rain environments specified in MIL-STD-810D, "Environmental Test Methods and Engineering Guidelines."

The rain test was performed on 9 March 1989, and disassembly/inspection of the FJPS was completed on 10 March 1989. Testing was performed in the Morton Thiokol Static Test Bay T-18, in accordance with CTP-0073, "Qualification Test Plan For The Field Joint Moisture Seal Rain Test."

1.1 TEST ARTICLE DESCRIPTION

The test article consisted of a mated Solid Rocket Motor (SRM) short stack (7U76603), and an assembled FJPS (7U76498)(Figure 1). The short stack was in the vertical (flight) position for the rain test. The FJPS was designed and installed to protect the field joint from rain intrusion. Components of the FJPS include the joint heater, moisture seal, Kevlar moisture seal retainer straps, extruded cork, ablation compound, and vent valves (Figures 2, 3 and 4).

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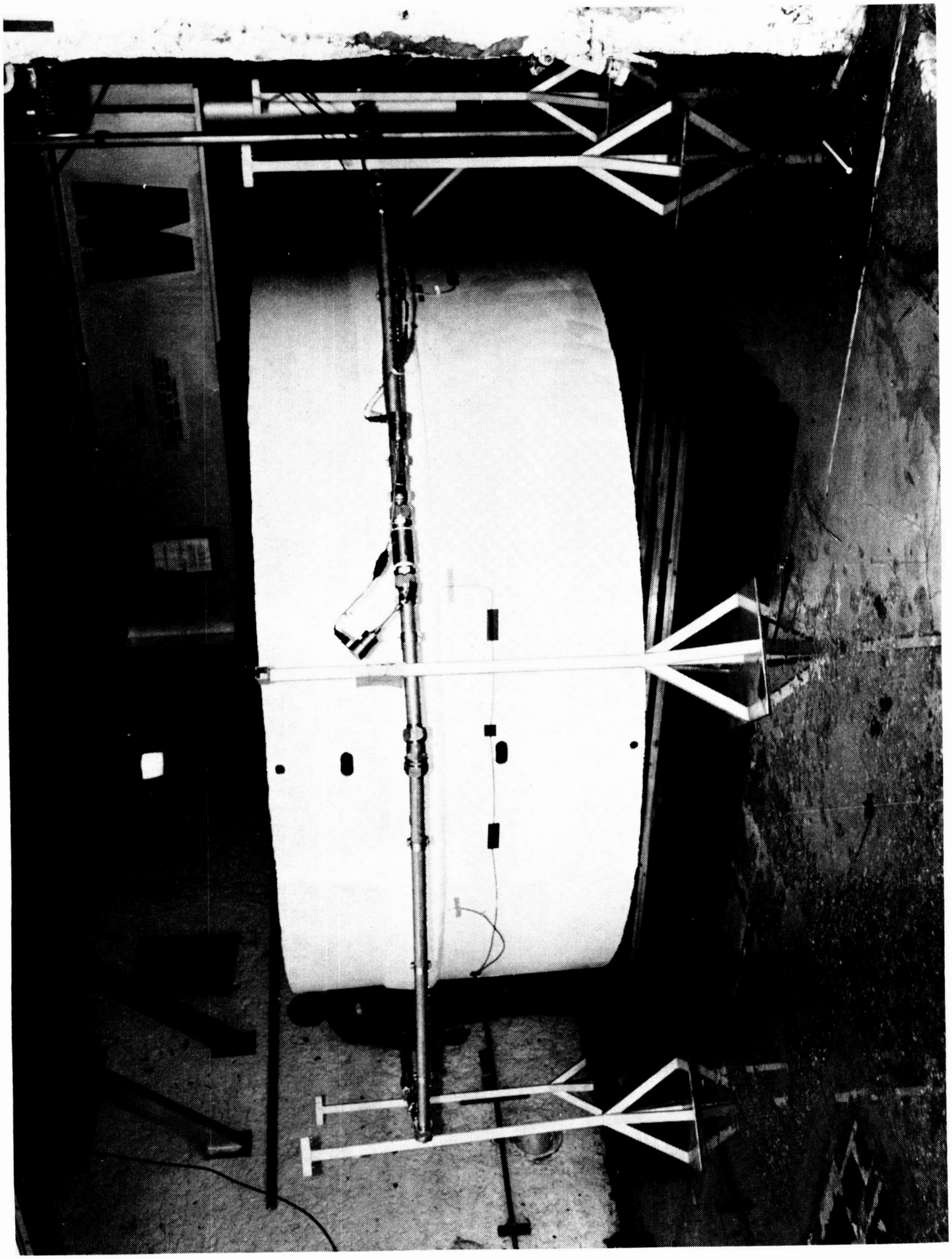


Figure 1. FJPS Rain Test — Test Article

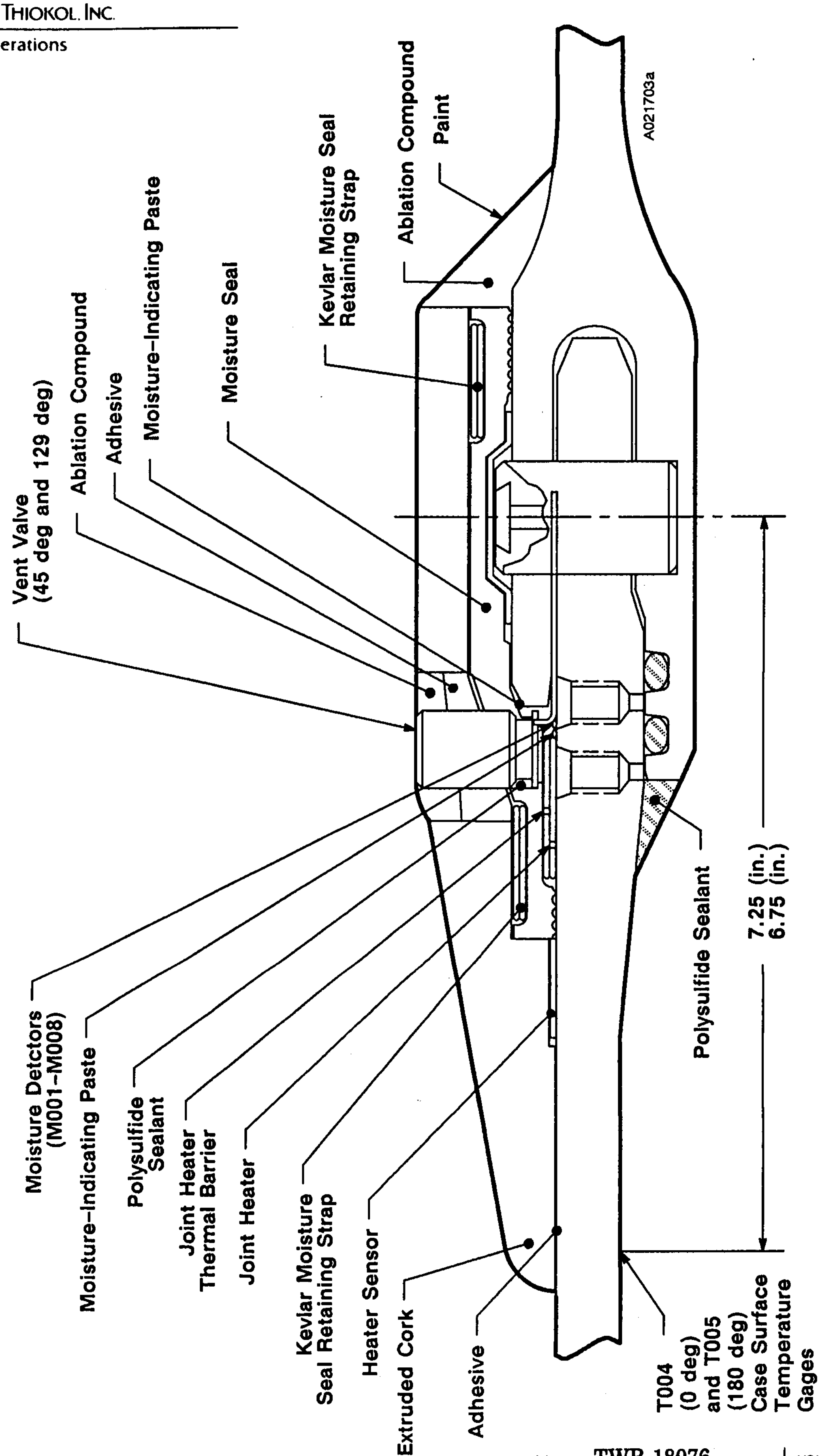


Figure 2. FJPS Rain Test—Test Article Cross Section

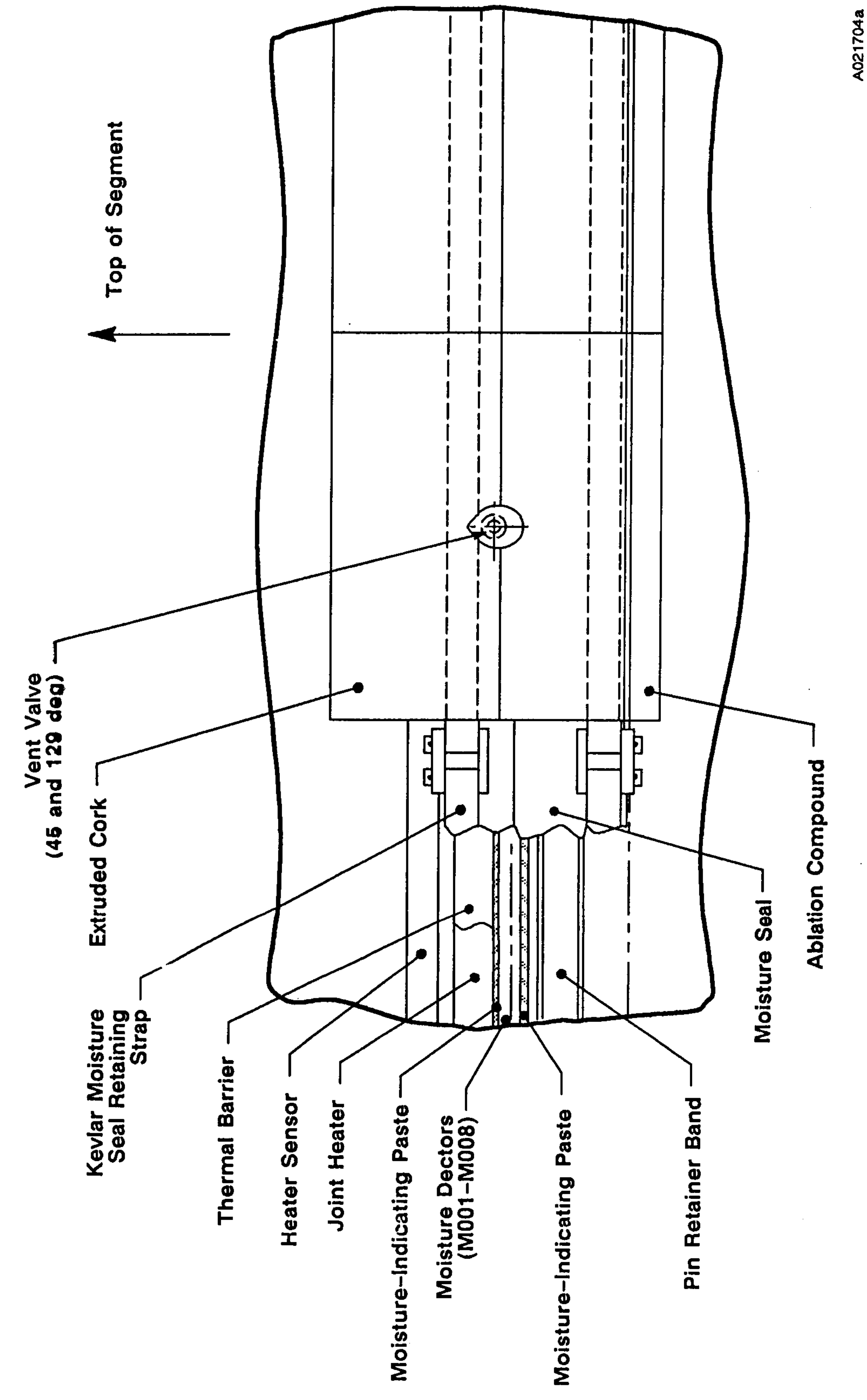
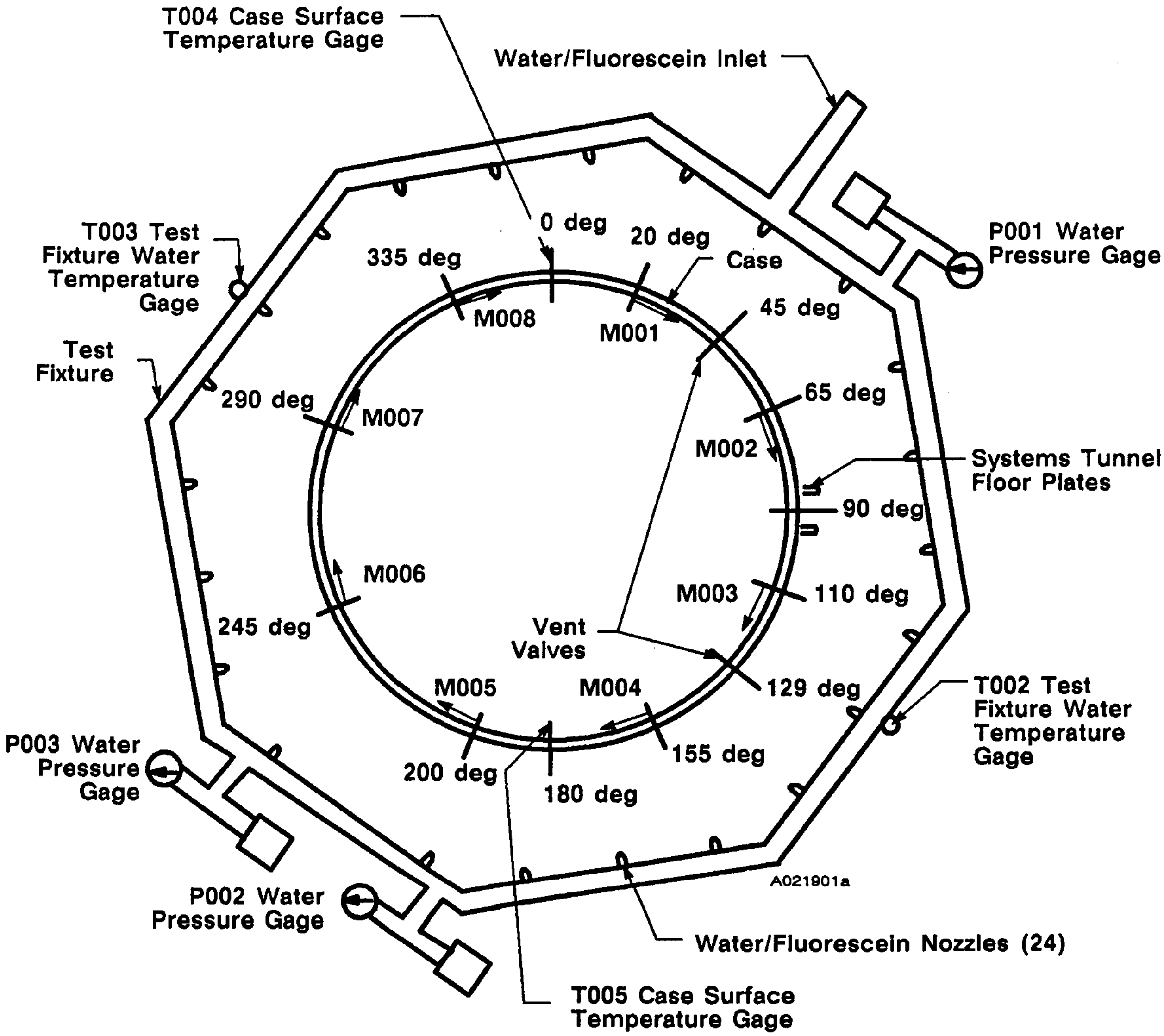


Figure 3. FJPS Rain Test—Top View of Test Article



Note: Moisture detection gages (M001 - M008) were installed every 45 deg, beginning at 20 deg. Each gage monitored moisture over the 45 deg it was installed. The gages were installed directly on the case D6AC steel between the joint heater and the clevis, per 7U76498

Figure 4. FJPS Rain Test - Top View of Test Configuration

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OBJECTIVE

The FJPS rain intrusion test objective was derived from the objectives in TWR-15723, Rev C, "Redesign D & V Plan," to satisfy the requirements of Contract End Item (CEI) Specification CPW1-3600 paragraphs as listed with the objective below:

A. Certify that the Field Joint Protection System moisture seal prevents the accumulation of moisture in the joint when subjected to specified natural (rain) environments (3.2.1.3h, 3.2.1.11b and 3.2.7.1.a5).

3

EXECUTIVE SUMMARY

3.1 SUMMARY

This section contains an executive summary of the key results from test data evaluation and post-test inspection. Additional information and details can be found in Section 6 (Results and Discussion).

During the test, water entered through the open upper end of the systems tunnel and was funneled down between the tunnel and case. A sealant void at the moisture seal butt splice allowed this water to flow underneath the FJPS. The most likely cause of voids was improper bondline preparation, particularly on the moisture seal surface.

Ultraviolet light and finger touch showed significant water leakage through both vent valves. Both vent valves were full of water. Small amounts of water were also found on the cork and sealant under one vent valve.

There was some penetration into the FJPS in areas that had no obvious adhesive voids or leak paths. This indicated that water penetrated through the paint, cork, and under the moisture seal. In total, water penetrated underneath approximately 60 percent of the FJPS circumference.

Because the test article was substantially different from flight configuration (no systems tunnel closeout), results of this test will not affect current flight motors.

3.2 CONCLUSIONS

The following listing is the conclusion as it relates specifically to the objective and CEI paragraphs. Additional information about the conclusion can be found in Section 6 (Results and Discussion).

Objective	CEI Paragraphs	Conclusions
A. Certify that the Field Joint Protection System moisture seal prevents the accumulation of moisture in the joint when subjected to specified natural (rain) environments.	3.2.1.2.h Case. The [case] joint shall prevent entry of rain as defined in 3.2.7. 3.2.1.11.b Case Field Joint Environmental Protection System. The field joint protection system shall function to prevent accumulation of rain into the field joints from the time of assembly of the Solid Rocket Booster (SRB) until launch, during and after being exposed to the ground environments of 3.2.7, as referenced in 3.2.1.3. 3.2.7.1.a.5 Natural Environment, Prelaunch, Rain. The RSRM design natural environment is as defined in NSTS 07700, "Space Shuttle Flight and Ground System Specification," Volume X, Appendix 10.10, "Natural Environment Design Requirements."	Objective was not met. It is concluded that two major errors were made during this test: the test article should have had the systems tunnel floor plates sealed, and the systems tunnel cover should have been installed. Also, better bondline preparation of FJPS components would have reduced the amount of voids within the FJPS.

3.3 RECOMMENDATIONS

Due to the omission of systems tunnel covers and systems tunnel floor plate closeout, the test assembly was not representative of flight hardware and resulted in a gross overtest. It is therefore recommended that the test be declared void. It is also recommended that the test be repeated. To improve the probability of moisture exclusion from the field joint, the retest should include a complete closeout of the systems tunnel, sealed systems tunnel ends, and improved adhesive bondline preparation.

A redesign of the FJPS, to reduce installation time and improve performance, is being considered. Should a redesign occur, it is recommended that the new protection system be rain tested following CTP-0073.

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INSTRUMENTATION

Moisture, temperature, and water pressure instrumentation was used to conduct the rain test and monitor the rain atmosphere conditions. Eight moisture detectors (M001 through M008) were installed directly on the case D6AC steel, between the joint heater and the clevis, per 7U76498 (Figures 3 and 4). The moisture detectors were set against the beginning of the clevis/tang interface. The detectors were installed every 45 deg, beginning with M001 at 20 deg. The detectors consist of two foil traces that run parallel, with a small gap (20 mil) between them. The gages indicate the presence of water whenever a droplet bridges the gap between the two foil traces. The moisture detectors were calibrated such that no moisture would indicate an "off" state (0 ±320 bits), and any detectable moisture would indicate an "on" state (1,600 ±320 bits).

Moisture-indicating paste was applied under the moisture seal, on each side of the moisture detectors, per 7U76498 (Figures 3 and 4). Also, fluorescein dye was added to the spray water to further aid in moisture detection. Fluorescein dye glows when exposed to ultraviolet light. The joint was inspected with an ultraviolet (black) light during disassembly of the FJPS.

Temperature gages (T001, ambient; T002 and T003, test fixture water; and T004 and T005, test article case surface) and water pressure (P001, P002, P003) were zeroed and calibrated in accordance with MIL-STD-45662.

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PHOTOGRAPHY

Still color photographs were taken of the FJPS pretest assembly (special emphasis on the moisture detectors and moisture-indicating paste installation), test set-up, typical instrumentation, and FJPS disassembly. Copies of the photographs taken (Negative Series 109405 and 109509) are available from the Morton Thiokol Photographic Services Department.

Color motion pictures of the overall test article and rain condition were taken with two documentary cameras.

6

RESULTS AND DISCUSSION

6.1 ASSEMBLY

The test article short stack segments were mated per 7U76603. The flight configuration FJPS was installed on the short stack, per 7U76498. Moisture seal installation deviated from standard test area procedures in that adhesive was applied around the edges of the moisture seal after the seal was installed. Previously, test personnel have applied adhesive under the moisture seal before installation. Systems tunnel covers were not installed, and both ends of the systems tunnel were open. Configuration of the test article and test fixture is shown in Figure 4.

6.2 TEST

The rain test was conducted per CTP-0073. The primary reference of the test plan for rain conditioning was MIL-STD-810D, Method 506.2, Procedure III, Watertightness. The entire circumference of the FJPS was exposed to rain simulation for approximately 50 minutes. Rain droplet size was between 2.0 to 4.5 mm in diameter, as determined by water pressure and nozzle design.

Three pressure gages (P001, P002, P003, locations shown in Figure 4) were used to monitor test fixture water pressure, and the results are included in the appendix. P001 was damaged at approximately 30 minutes into the test due to water in the gage connector. However, results of the other two gages show that constant water pressure (approximately 41 psi) was maintained throughout the test.

Five temperature gages were used, and the results are included in the appendix. Thermal conditioning brought the case surface temperature up to approximately 75° F before the test (T004 and T005, locations shown in Figures 2 and 4). Water temperature was approximately 47°F, except for approximately the first minute of testing (T002 and T003, locations shown in Figure 4). This temperature difference satisfied the test plan requirement that the test article be at least 18° F higher than the rain temperature at the beginning of the exposure period. This presented a worst-case scenario which could cause FJPS component separations.

Two moisture detection gages (MOO2, from 65 to 110 deg; and M003, from 110 to 155 deg) registered moisture at approximately five minutes into the test. M006, located from 245 to 290 deg, registered moisture at approximately 28 minutes into the test. All other gages showed no indication of moisture. Plots of the moisture detection gage results are included in the appendix. These plots show water indication, as an "on" or "off" function, versus time.

6.3 DISASSEMBLY

After the rain simulation, the FJPS exterior surface and surrounding case area was wiped dry with a towel. The FJPS was then allowed to air dry for approximately 16 hours, to prevent excess water from entering the FJPS during disassembly. Also prior to disassembly, a resistance check was performed on each moisture detector, and all gages were operational.

Disassembly began with removal of the splice plate. The Kevlar straps were then cut, and the moisture seal was peeled off. The thermal barrier was removed, then the heater. Lastly, the cork above the heater sensor and then the heater sensor were removed.

During disassembly, the FJPS was inspected for water penetration, voids, and any other anomalous conditions. An ultraviolet light was used to detect any fluorescein dye that may have penetrated the seal.

6.4 RESULTS

During disassembly, it became obvious that water had entered through the open upper end of the systems tunnel and was funneled down between the tunnel and case. A sealant void at the moisture seal butt splice allowed the water to flow into the FJPS (Figure 5). This void was located at approximately 90 deg, was 1 in. wide, and extended to the open space under the systems tunnel. The void was most likely due to improper bondline preparation and/or because the sealant may have been applied after its pot life had been exceeded. Sealant did not bond sufficiently to the moisture seal and the Kevlar retainer strap. A significant amount of water was found in this area. It was determined that this area was the major entrance for water into the FJPS. Once water entered this portion of the FJPS, it spread by capillary action around the case.

Ultraviolet light and finger touch showed leakage under the top edge of the moisture seal in several locations. The moisture detector gages did not detect all leakage because the water ran down the inside of the moisture seal instead of the case surface where the gages were mounted.

Ultraviolet light and finger touch showed significant water leakage through both vent valves. Both vent valves were full of water. Small amounts of water were also found on the cork and sealant under one vent valve.

An adhesive void was located over the Kevlar strap retainer clip at 100 deg. This void was approximately 3 in. long by 1.25 in. wide axially.

Adhesive voids were present where the bottom of the moisture seal was stretched over the pin retainer band trunnions. These voids did not contain water because they were open on the bottom. If these voids were present on a flight motor, however, they would allow water penetration and retention during submersion.

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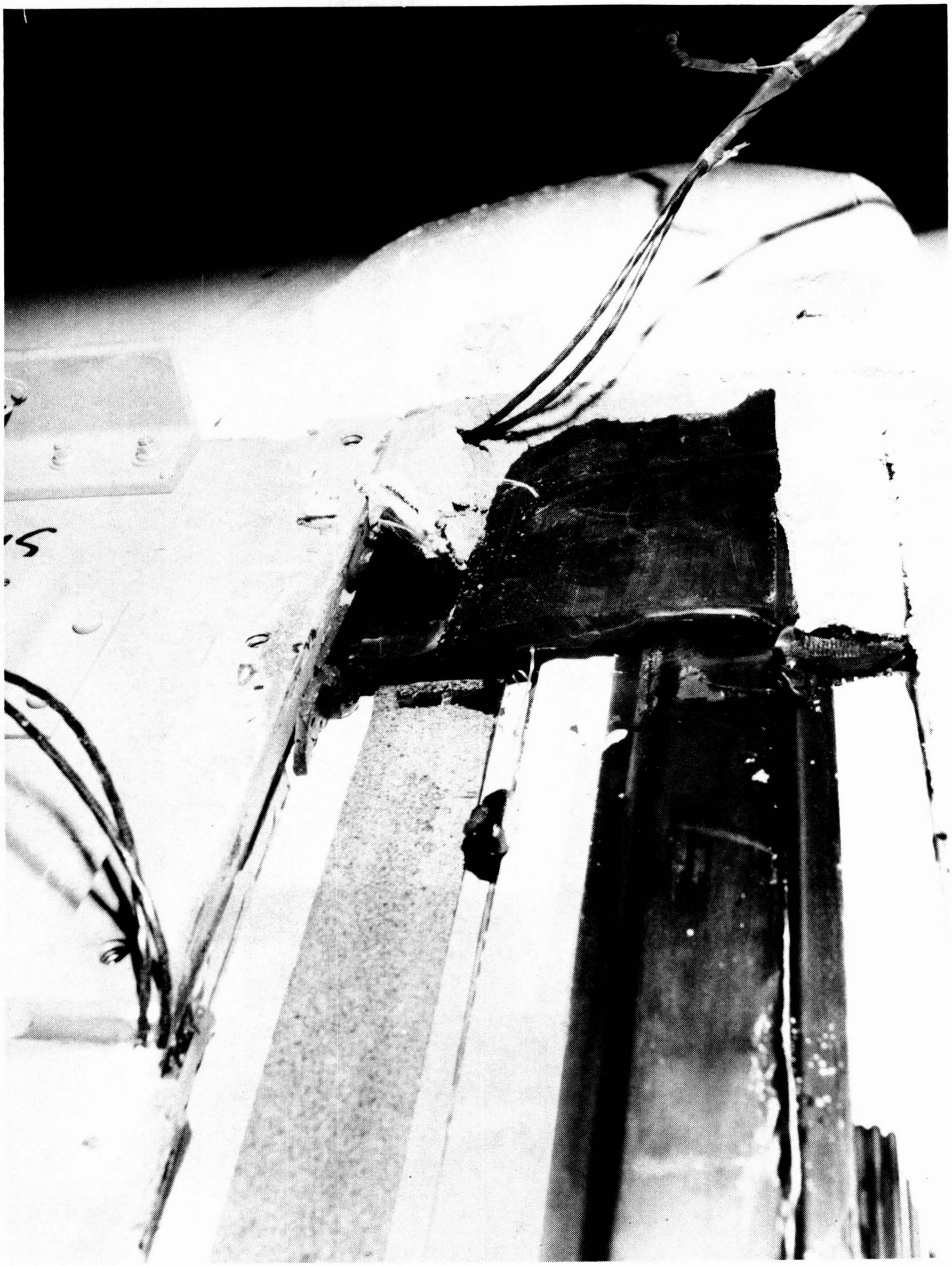

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Figure 5. FJPS Rain Test—Moisture Seal Butt Splice, Sealant Unbond

An adhesive void was located over the heater sensor at 235 deg (Figure 6). This void was approximately 10 in. long by 2 in. wide axially.

Drops of fluorescein were also detected under the moisture seal around the full circumference. Moisture was detected around the entire circumference of the grooved sealing surfaces on both the top and bottom of the moisture seal.

The inside surfaces of the cork were fluorescent and moist to the touch at numerous places around the joint. Moisture was also detected on most of the surface of the thermal barrier.

There was some penetration into the FJPS in areas that had no obvious adhesive voids or leak paths. This indicated that water penetrated through the paint, cork, and under the moisture seal.

Numerous small voids, some which contained water, were present within the FJPS. In total, water penetrated underneath approximately 60 percent of the FJPS circumference.

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N109405-20

Figure 6. FJPS Rain Test—Cork-to-Heater Sensor Unbond at 235 degrees

Drops of fluorescein were also detected under the moisture seal around the full circumference. Moisture was detected around the entire circumference of the grooved sealing surfaces on both the top and bottom of the moisture seal.

The inside surfaces of the cork were fluorescent and moist to the touch at numerous places around the joint. Moisture was also detected on most of the surface of the thermal barrier.

There was some penetration into the FJPS in areas that had no obvious adhesive voids or leak paths. This indicated that water penetrated through the paint, cork, and under the moisture seal.

Numerous small voids, some which contained water, were present within the FJPS. In total, water penetrated underneath approximately 60 percent of the FJPS circumference.

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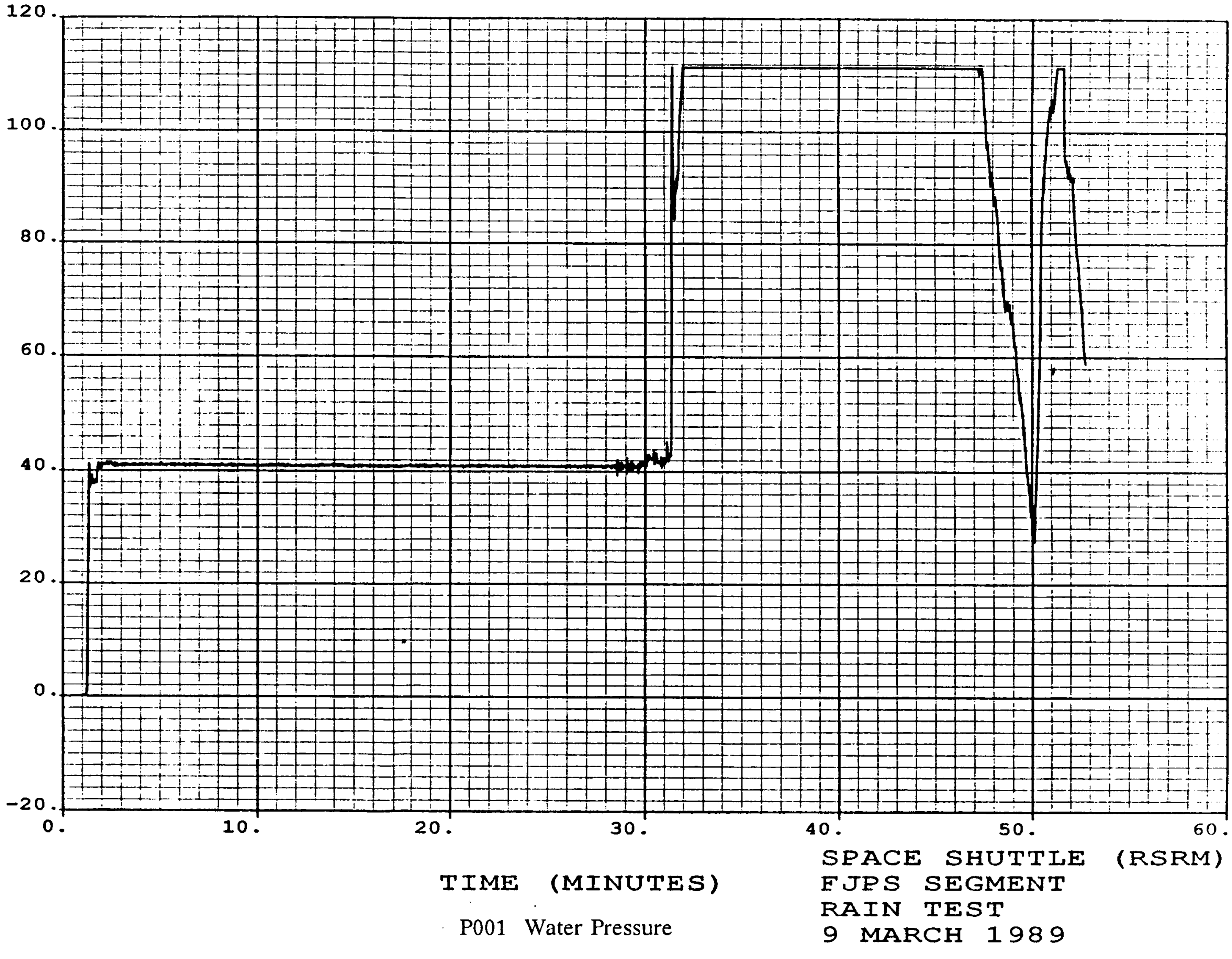
APPLICABLE DOCUMENTS

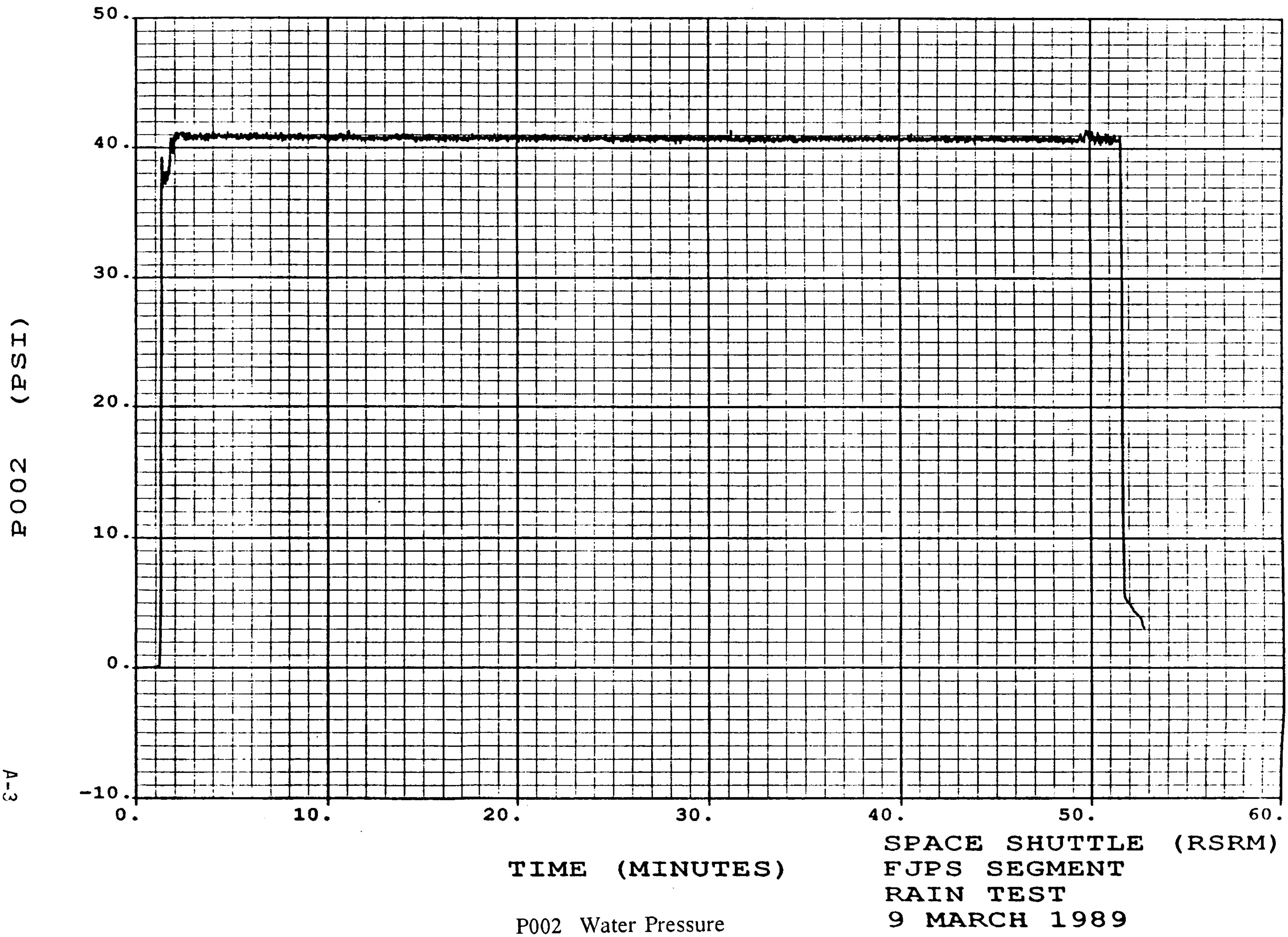
Morton Thiokol Document No.	
CPW1-3600	Prime Equipment Contract End Item (CEI) Detail Specifications
CTP-0073	Qualification Test Plan For The Field Joint Moisture Seal Rain Test
NSTS 07700	Space Shuttle Flight And Ground System Specification
TWR-15723	Redesign D&V Plan
TWR-19379	Field Joint Moisture Seal Rain Test Flash Report
Military Standards	
MIL-STD-45662	Calibration System Requirements
MIL-STD-810D	Environmental Test Methods And Engineering Guidelines
Drawing No.	
7U76498	Moisture Test, FJPS
7U76603	Short Stack Assembly, FJPS

APPENDIX A

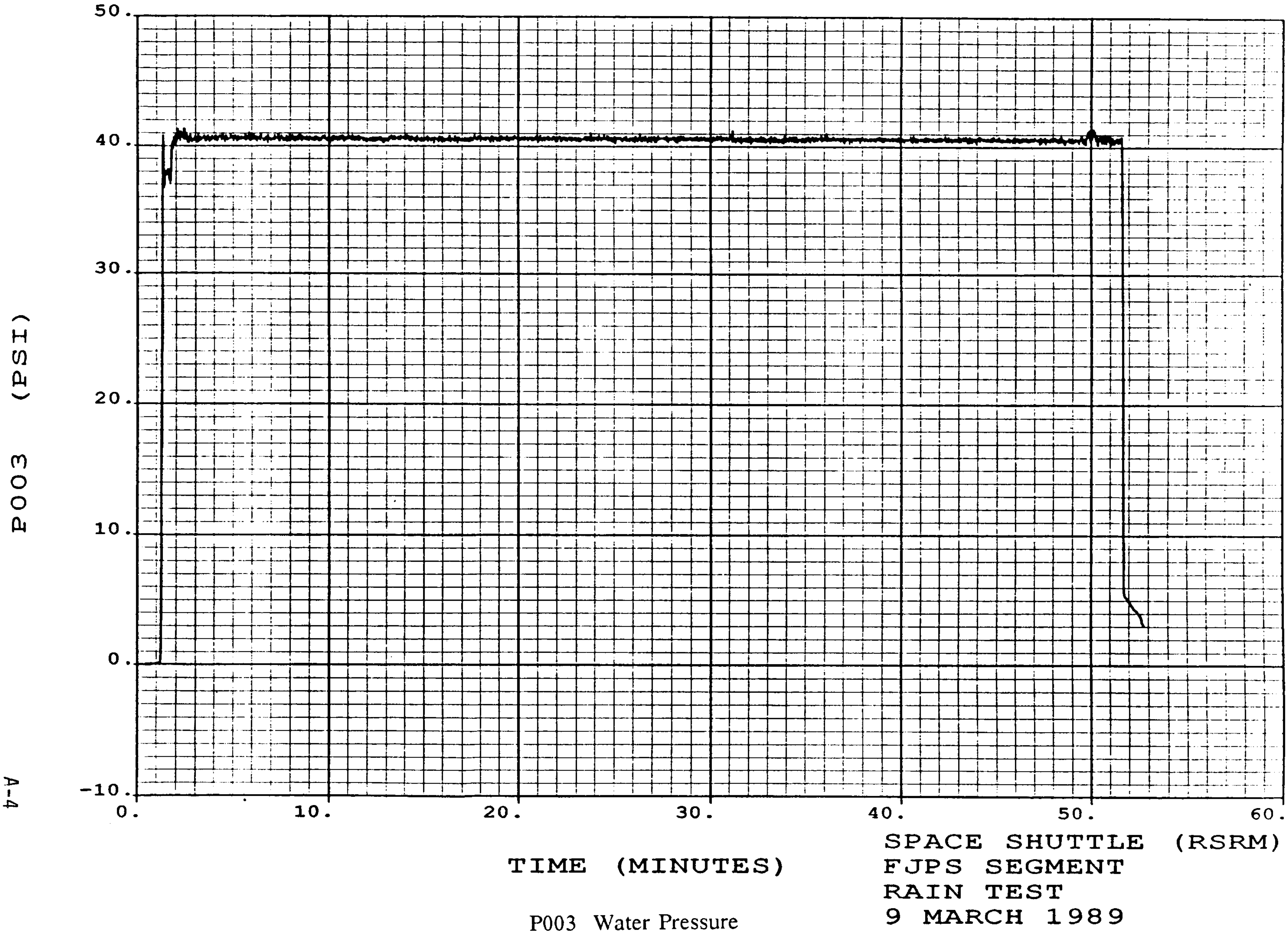
FIELD JOINT PROTECTION SYSTEM RAIN TEST - RESULT PLOTS



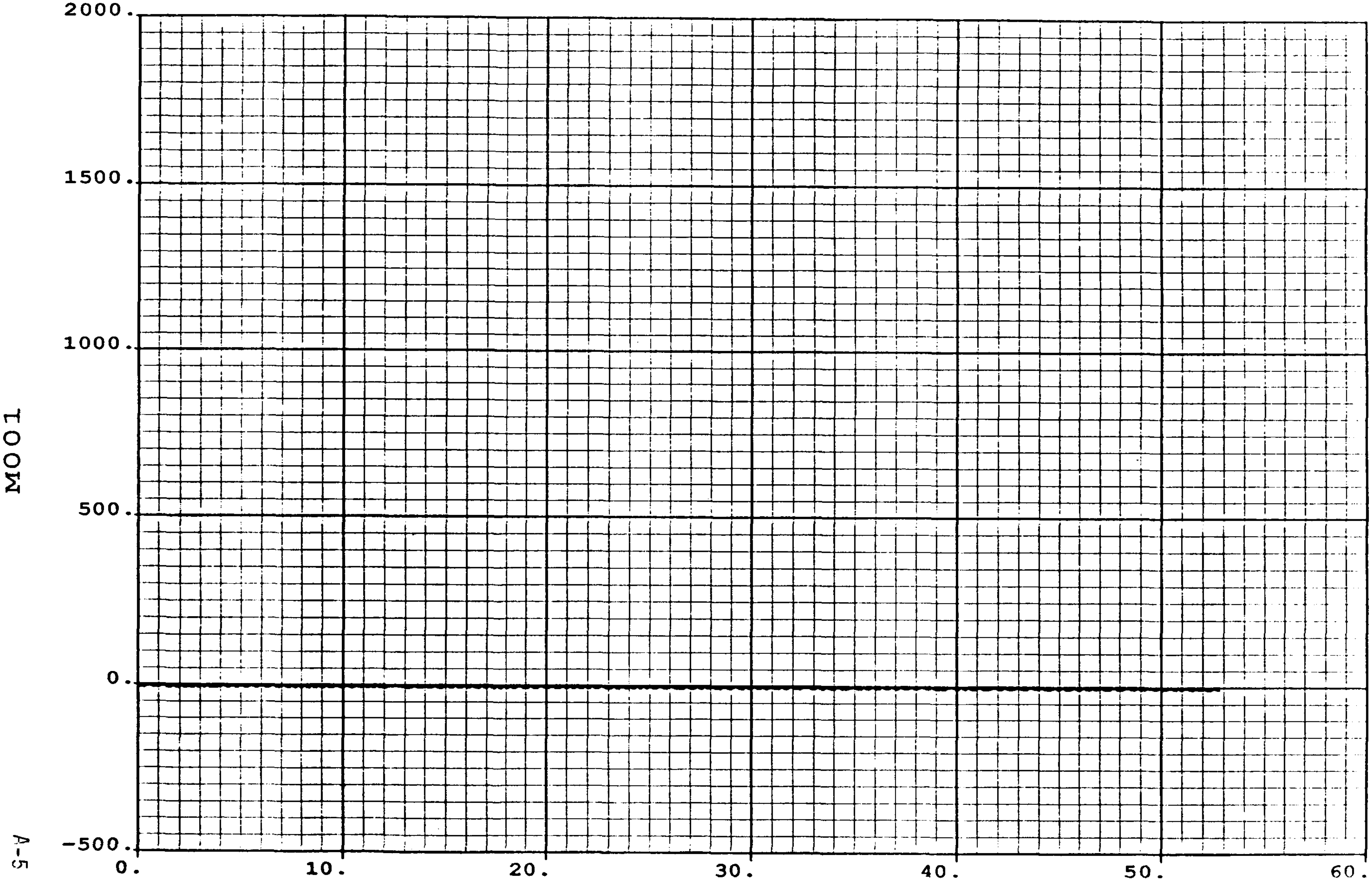
P001 Water Pressure



P002 Water Pressure



P003 Water Pressure

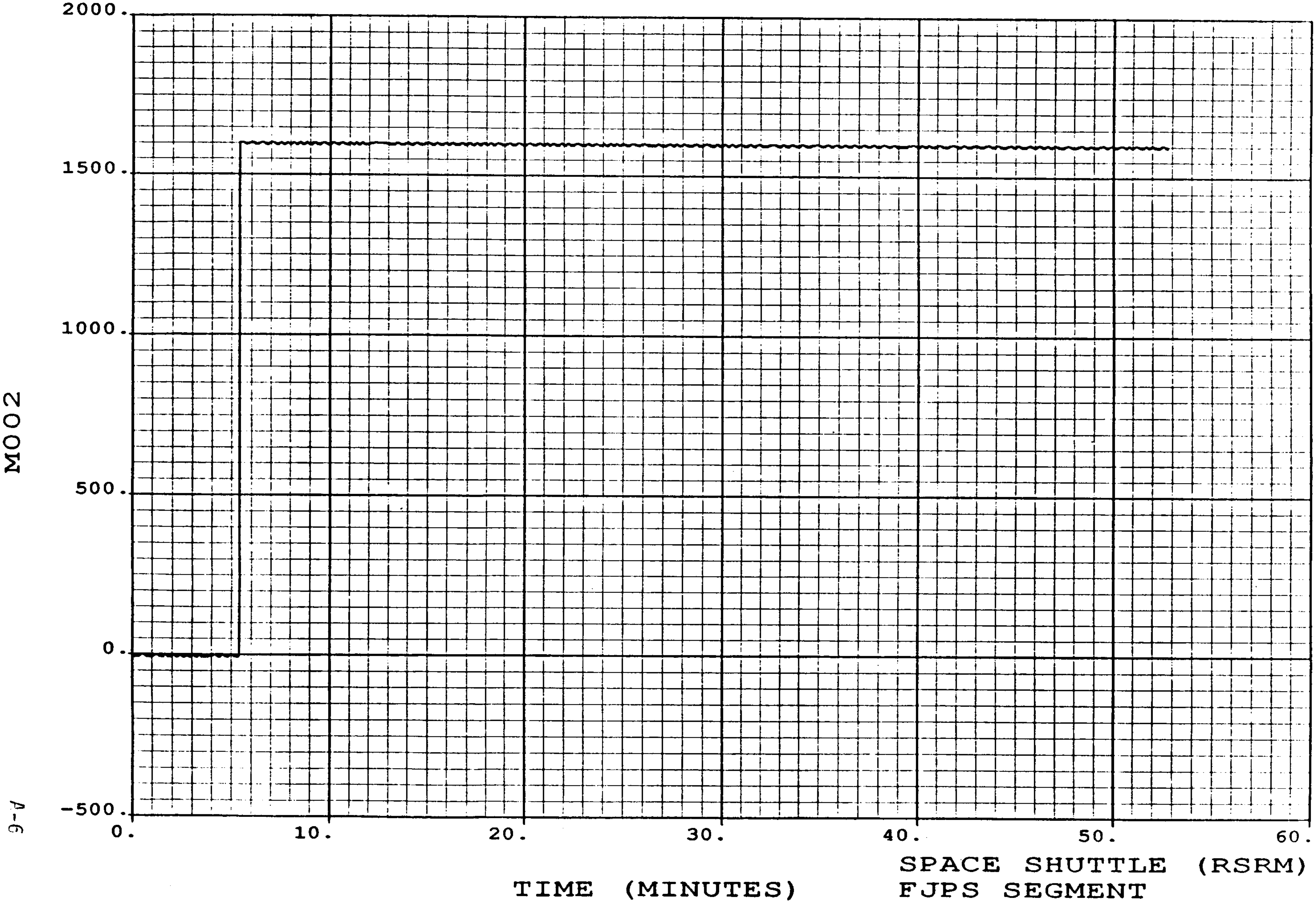


Note: Vertical units are in Bits. Water indication is either "Off" (0±320 Bits) or "On" (1600±320 Bits).

TIME (MINUTES)

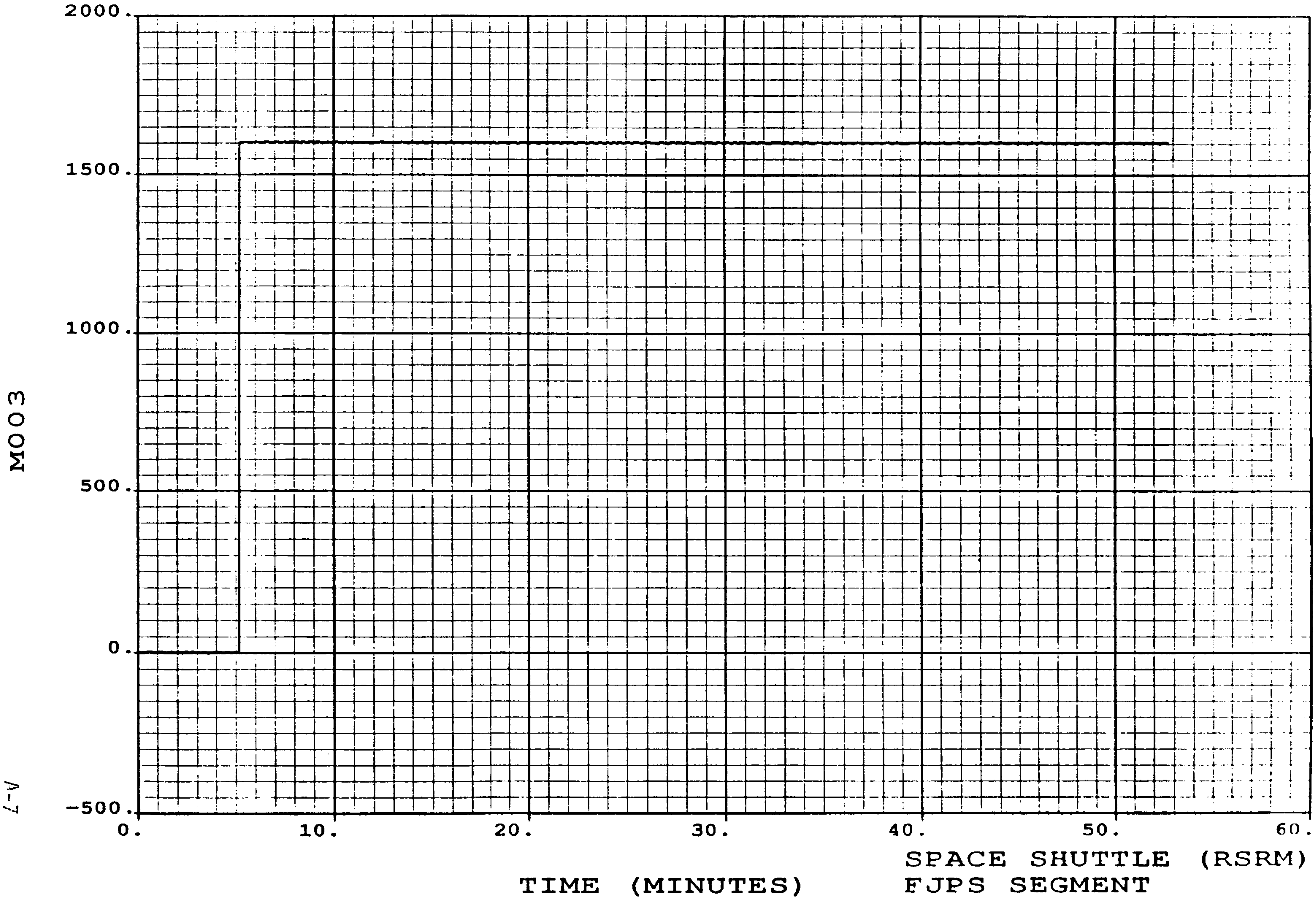
M001 Moisture Dector Gage

SPACE SHUTTLE (RSRM)
FJPS SEGMENT
RAIN TEST
9 MARCH 1989

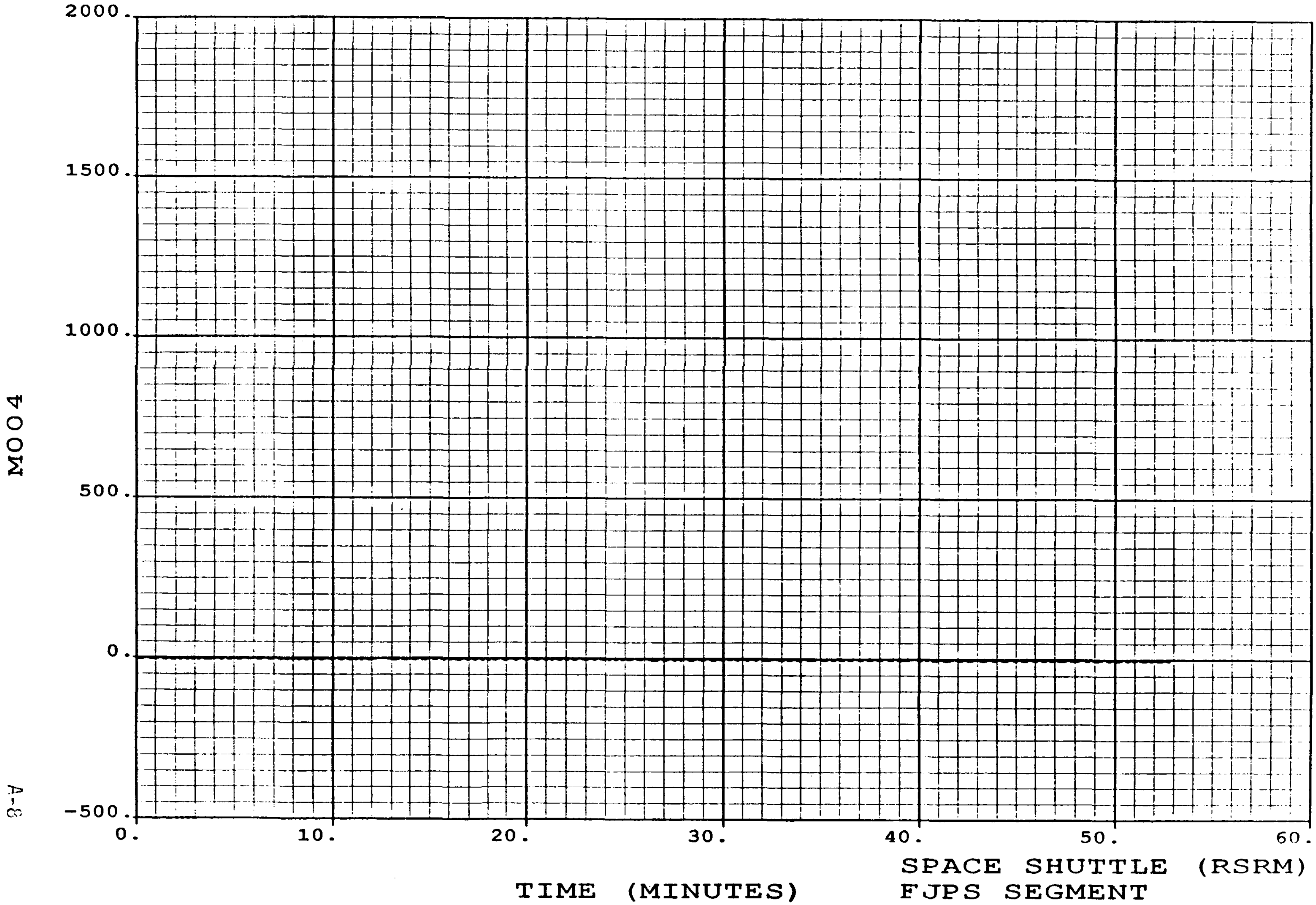


SPACE SHUTTLE (RSRM)
FJPS SEGMENT
RAIN TEST
9 MARCH 1989

M002 Moisture Dector Gage



M003 Moisture Dector Gage



M004 Moisture Dector Gage

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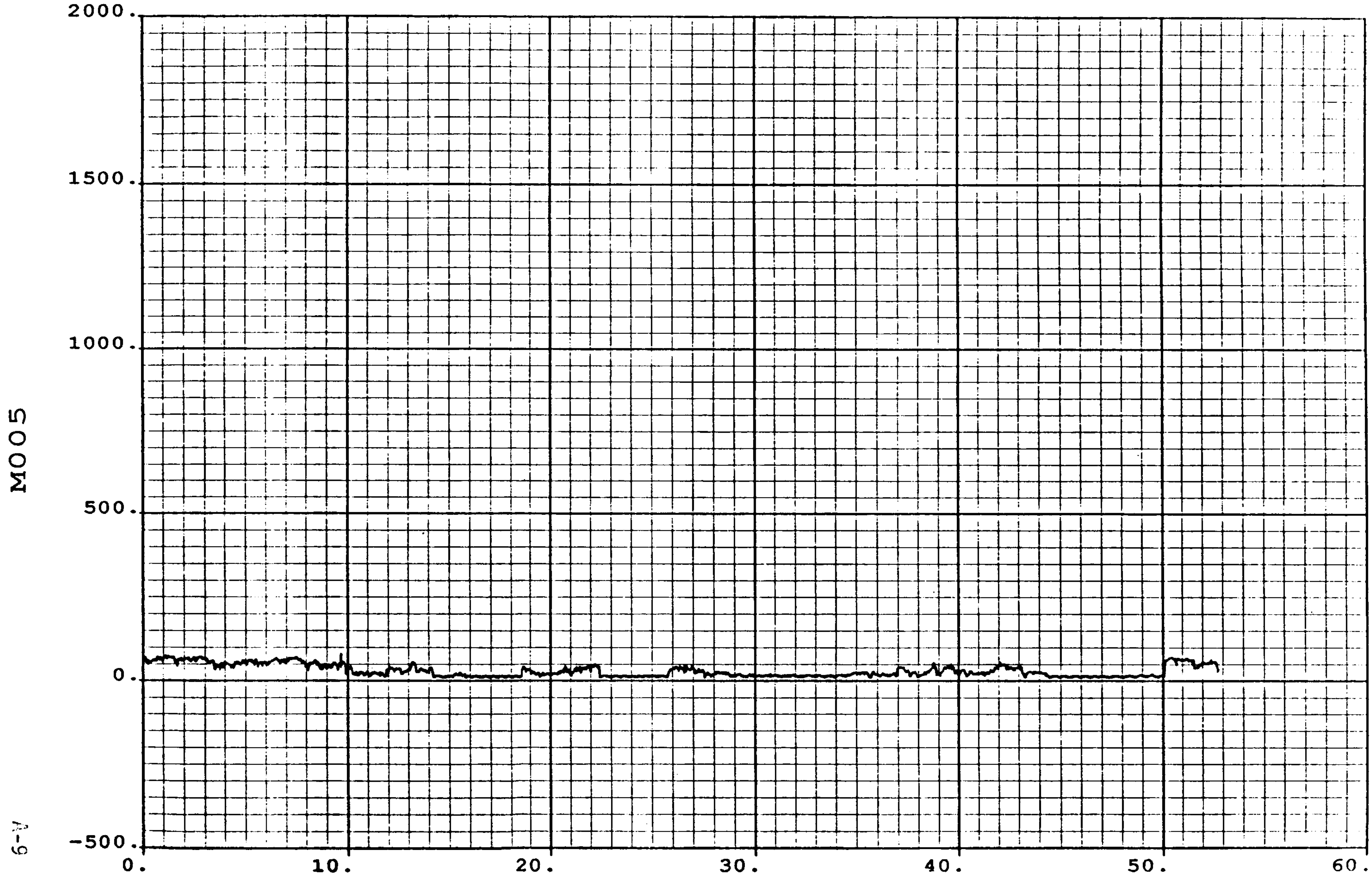
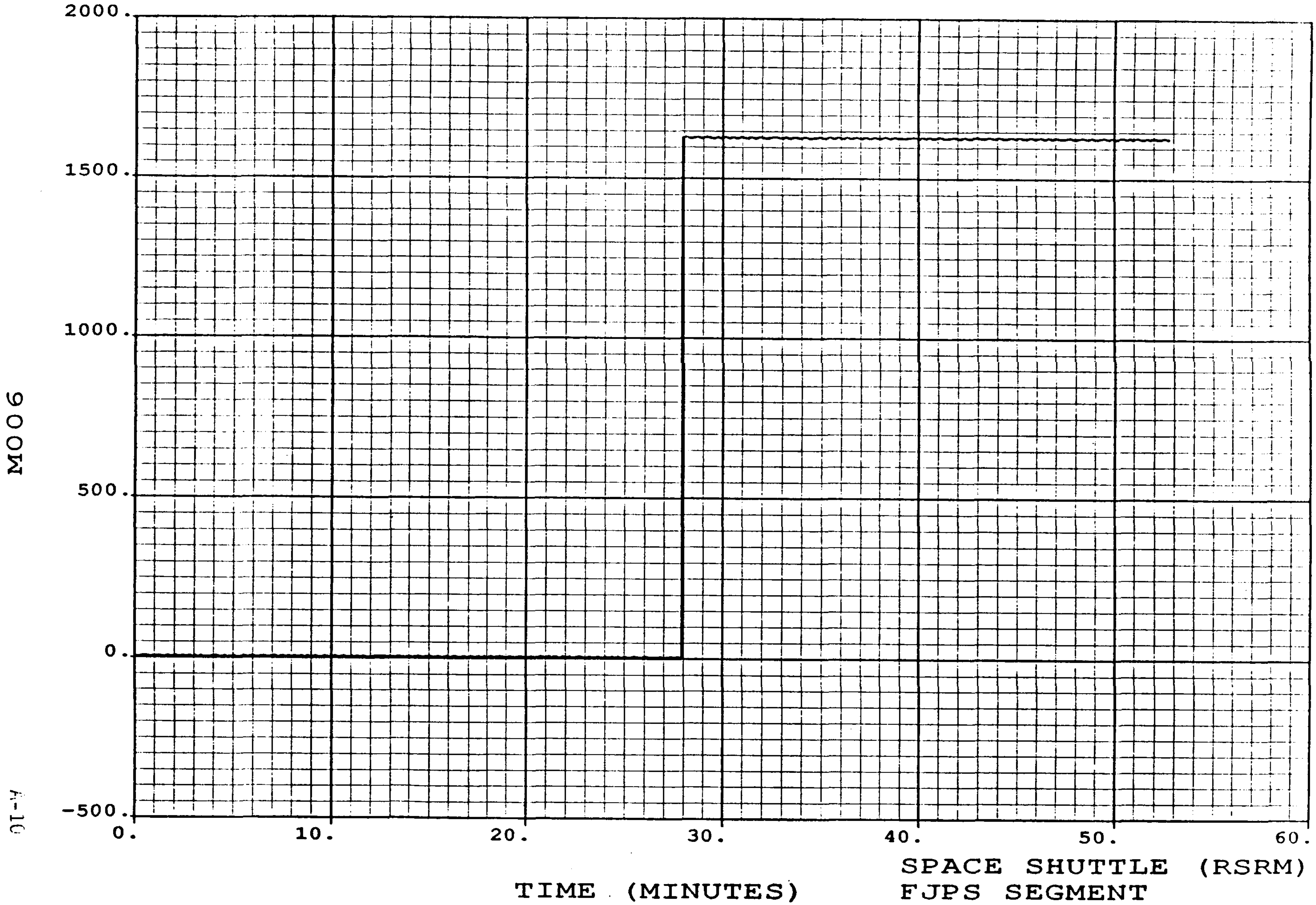
FJPS SEGMENT
RAIN TEST
9 MARCH 1989



M005 Moisture Dector Gage



M006 Moisture Dector Gage

SPACE SHUTTLE (RSRM)
FJPS SEGMENT
RAIN TEST
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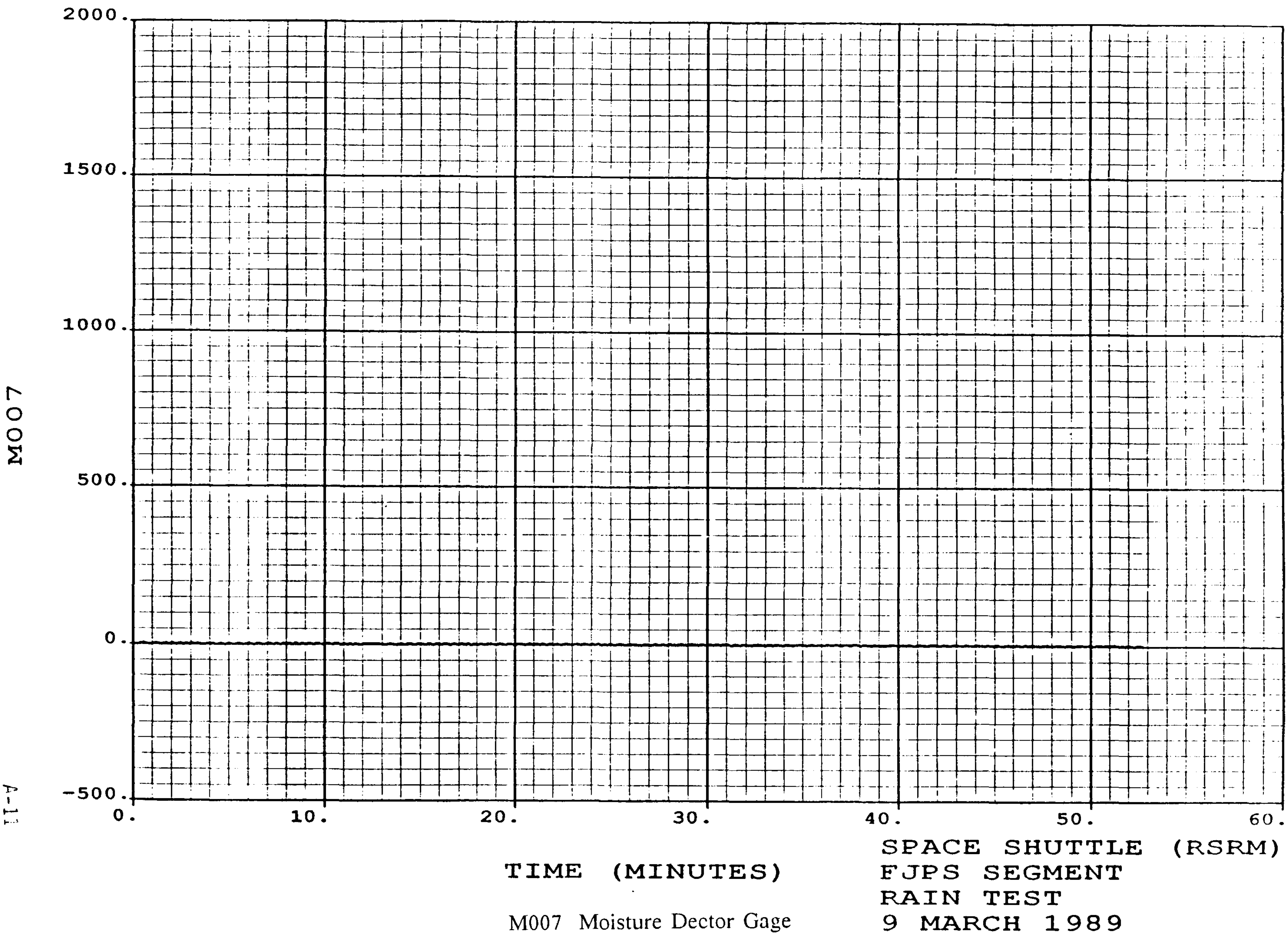
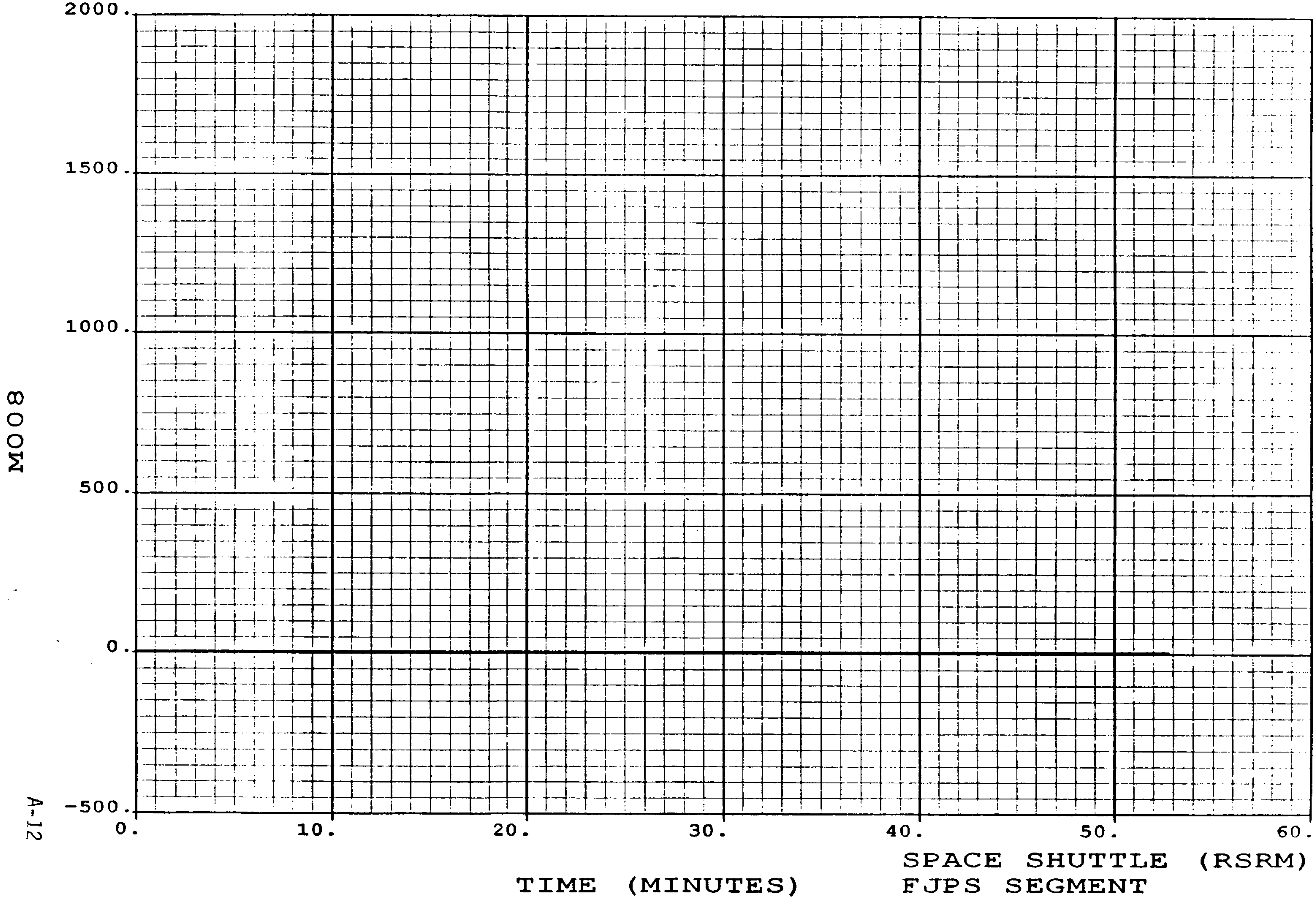


M007 Moisture Dector Gage



M008 Moisture Dector Gage

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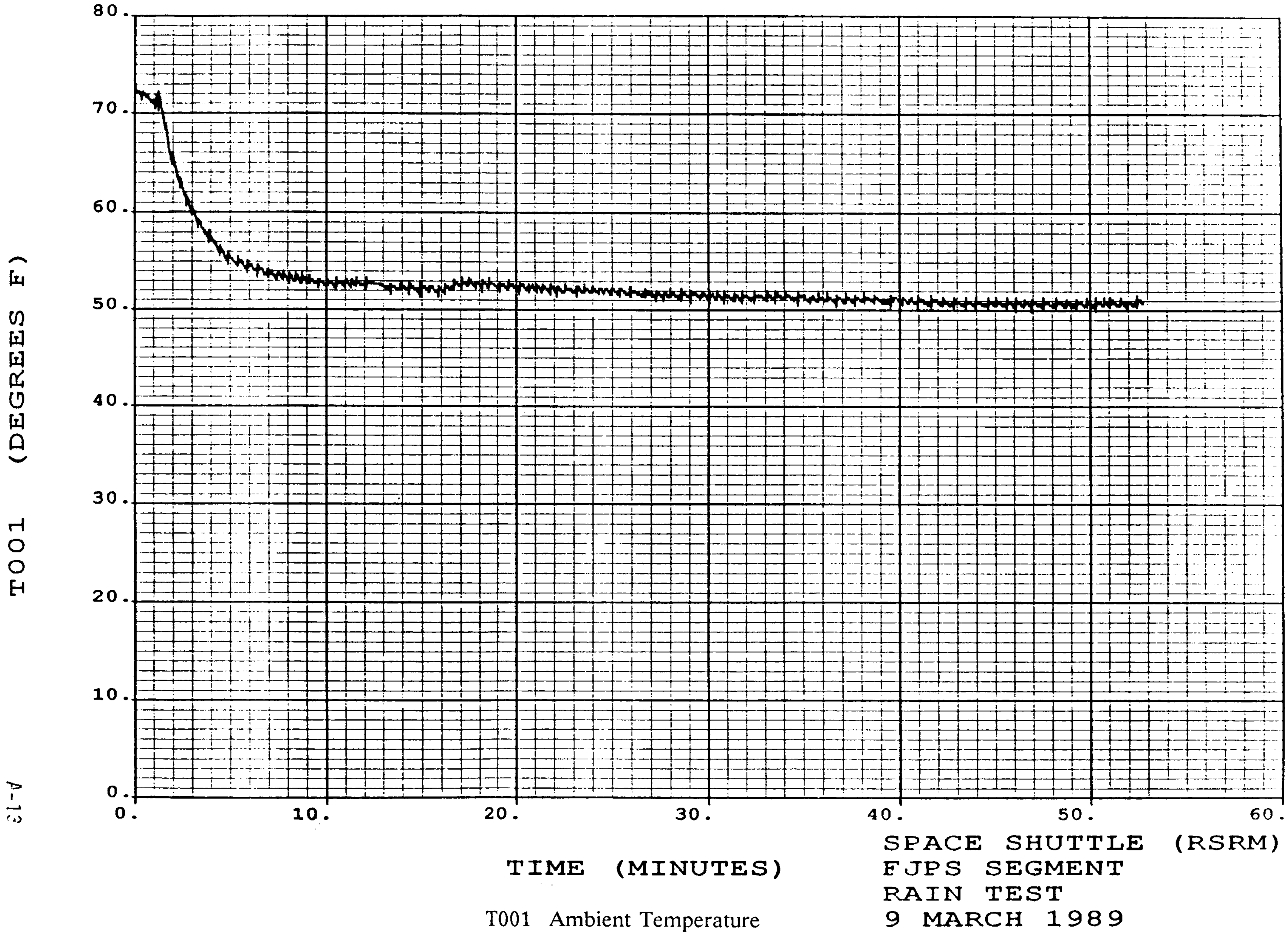
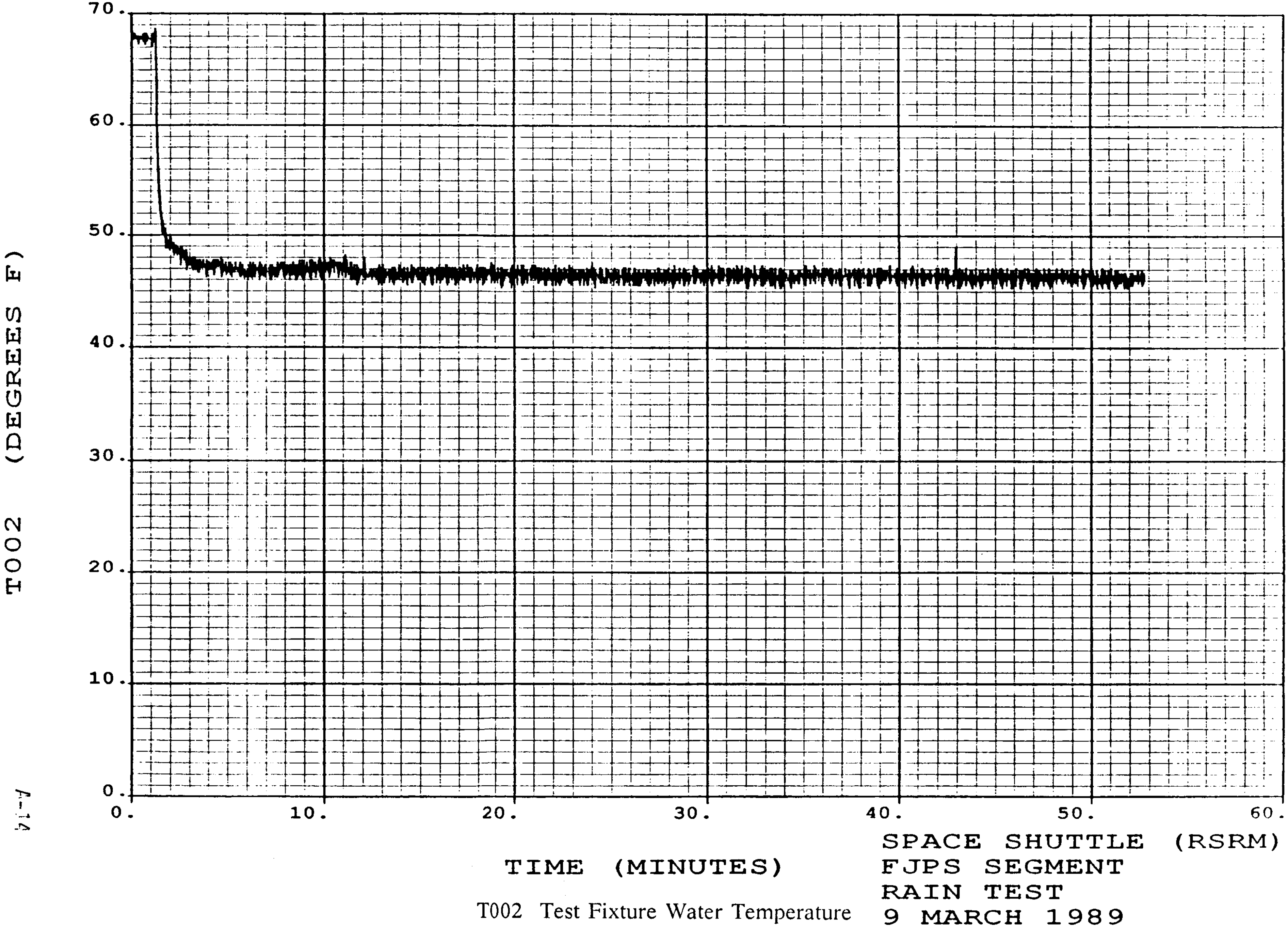
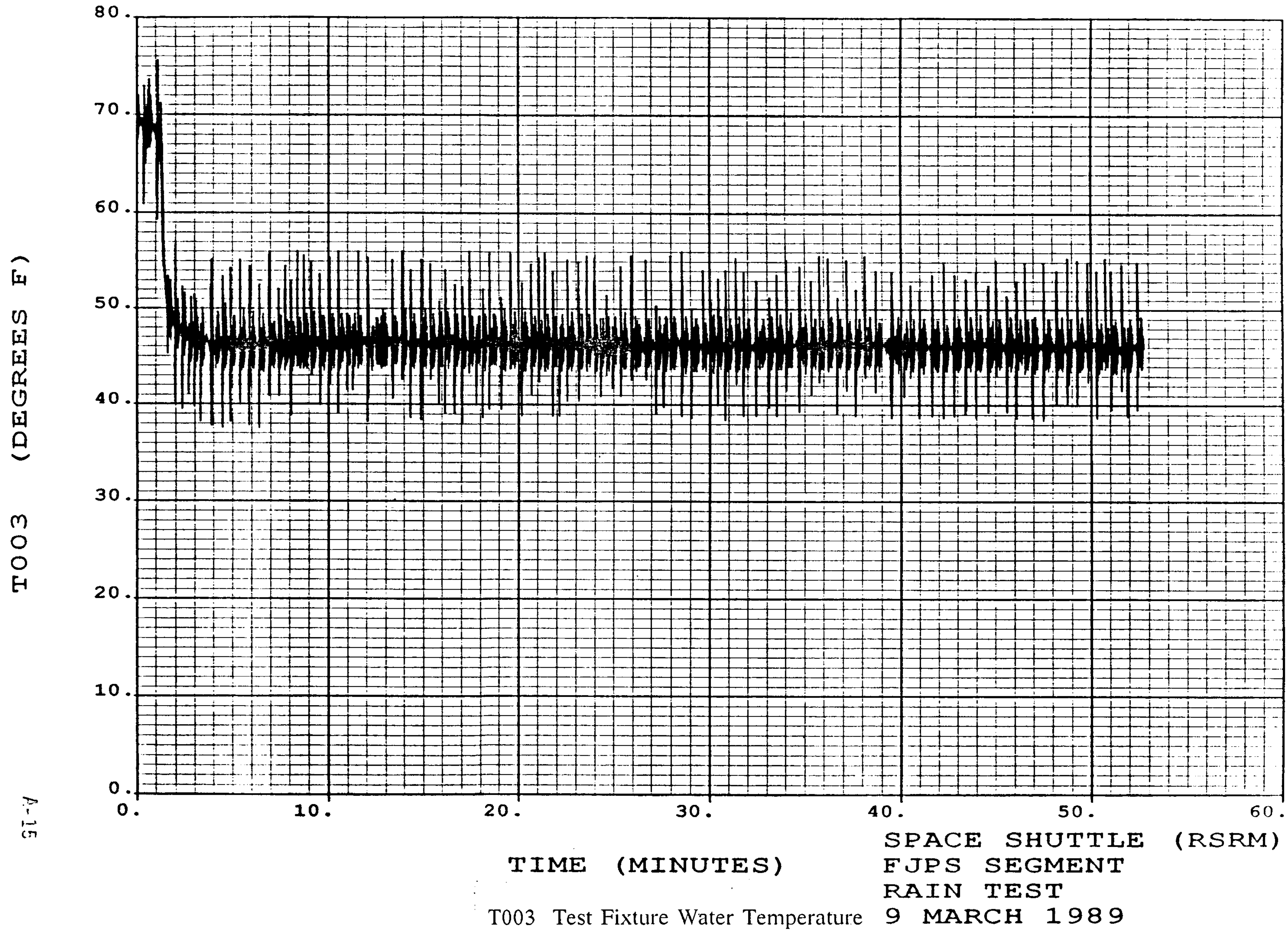


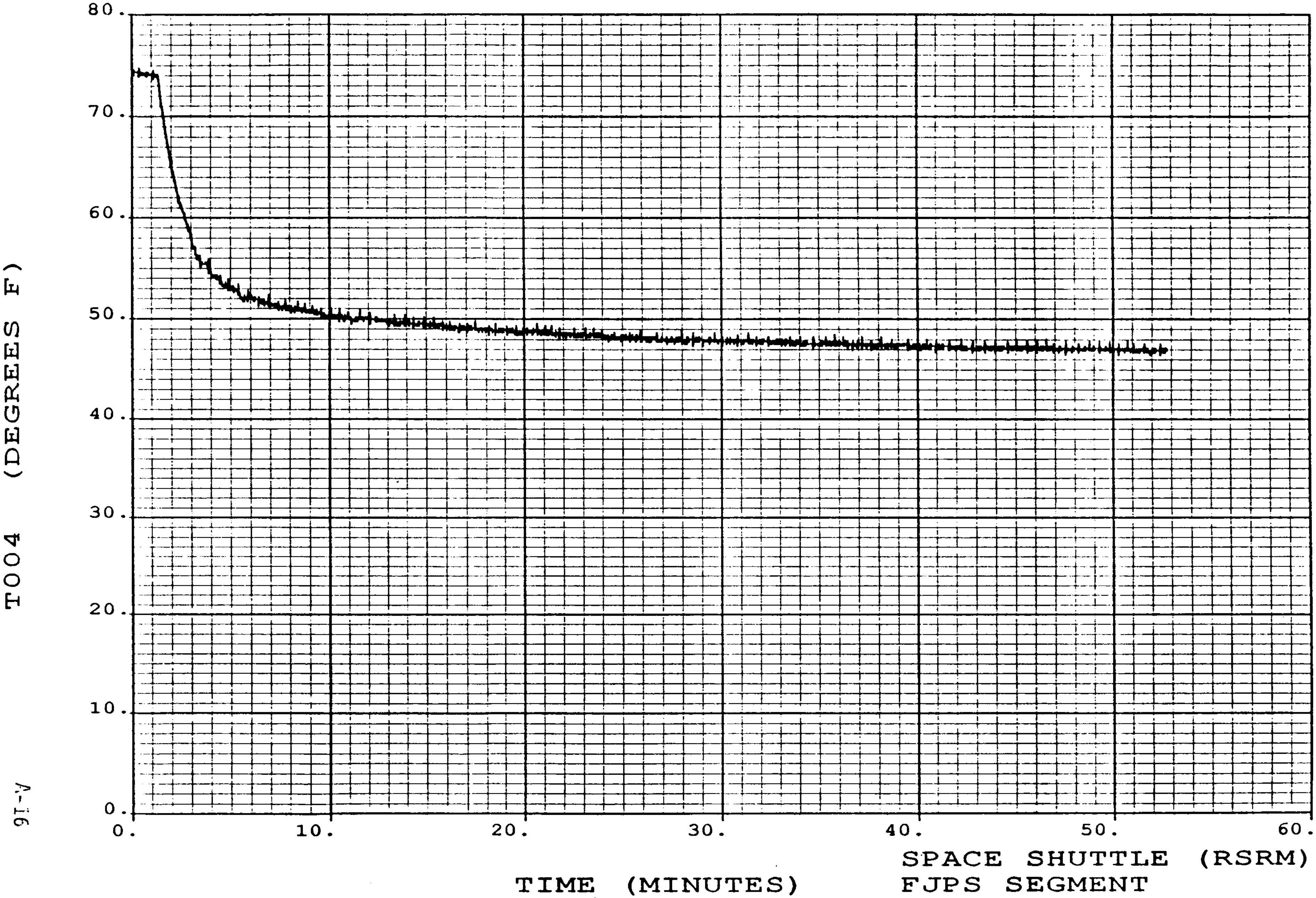
T001 Ambient Temperature



T002 Test Fixture Water Temperature



T003 Test Fixture Water Temperature



SPACE SHUTTLE (RSRM)
FJPS SEGMENT
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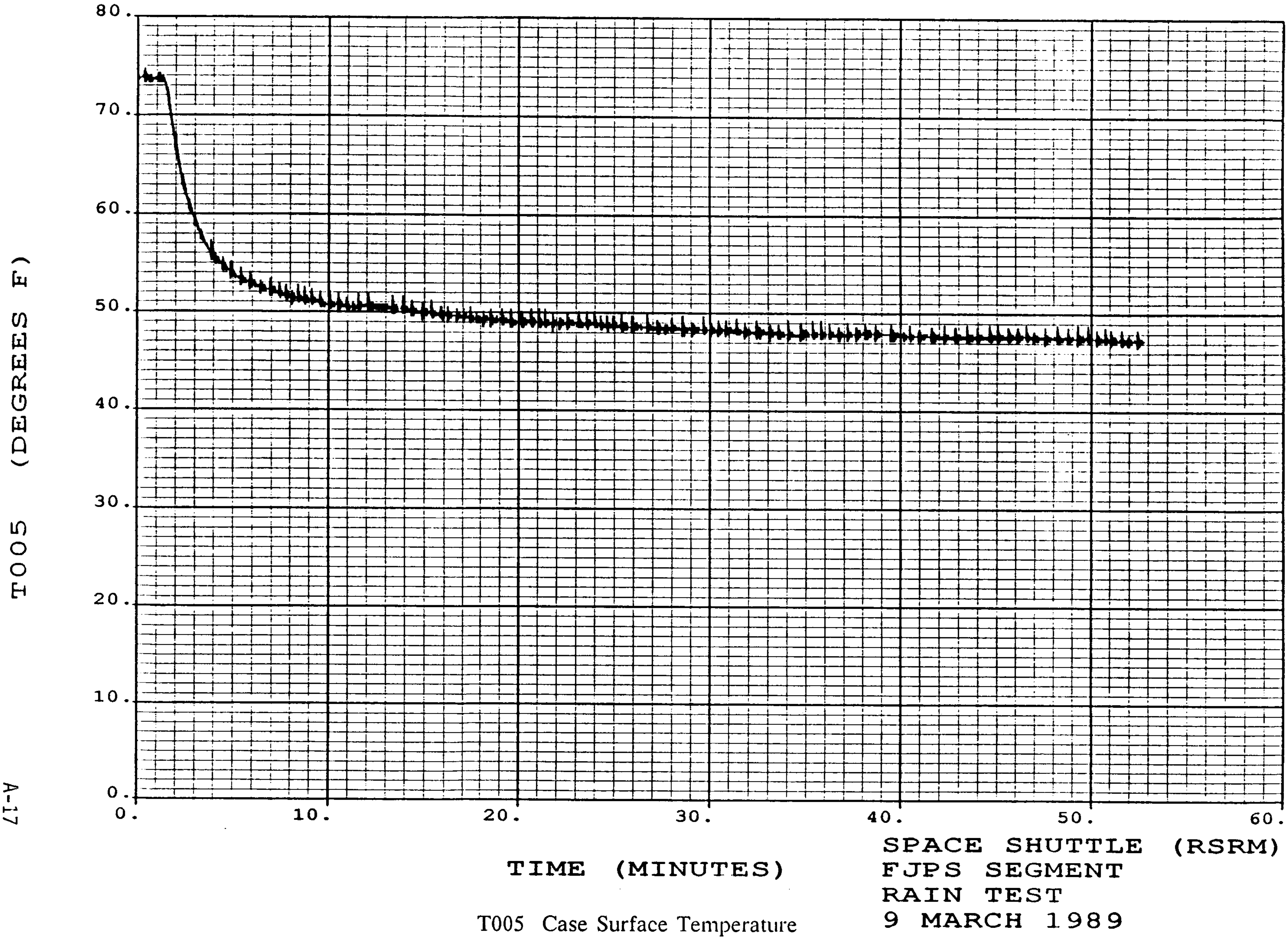
T004 Case Surface Temperature



T005 Case Surface Temperature

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