Tethered Satellite System Reflight (TSS-1R)

Post-Flight Engineering

Performance Report

June 1996

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TSS-1R (STS-75)

June 17, 1996

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1.0 Introduction

The first mission of the Tethered Satellite deployer was flown onboard Atlantis in 1992 during the Space Transportation System (STS) flight STS-46. Due to a mechanical interference with the level wind mechanism the satellite was only Deployed to 256 m rather than the planned 20,000 m. Other problems were also experienced during the STS-46 flight and several modifications were made to the Deployer and Satellite. STS-75 was a reflight of the Tethered Satellite System 1 (TSS-1) designated as Tethered Satellite System 1 Reflight (TSS-1R) onboard Columbia. As on STS-46, the TSS payload consisted of the Deployer, the Satellite, 3 cargo bay mounted experiments: Shuttle Electrodynamic Tether System (SETS), Shuttle Potential and Return Electron Experiment (SPREE), Deployer Core Equipment (DCORE), 4 Satellite mounted experiments: Research on Electrodynamics Tether Effects (RETE), Research on Orbital Plasma Electrodynamics (ROPE), Satellite Core Instruments (SCORE), Tether Magnetic Field Experiment (TEMAG) and an aft flight deck camera: Tether Optical Phenomena Experiment (TOP). Following successful pre-launch, launch and pre-deployment orbital operations, the Deployer deployed the Tethered Satellite to 19,695 m at which point the tether broke within the Satellite Deployment Boom (SDB). The planned length for On-Station 1 (OST1) was 20,700 m. The Satellite flew away from the Orbiter with the tether attached. The satellite was "safed" and placed in a limited power mode via the RF link. The Satellite was contacted periodically during overflights of ground stations. Cargo bay science activities continued for the period of time allocated to TSS-1R operations.

1.1 Scope

This document contains an engineering summary of the performance of the TSS-1R system during the STS-75 flight. Detailed data and results will be generated by the various science and dynamics teams in the form of reports and conference papers. A report on the results of the investigation into the tether break has been released through NASA Headquarters, and is titled, "TSS-1R Mission Failure Investigation Board, Final Report".

2.0 Element Summaries

This section consists of summaries of the engineering performance of the various elements that make up the TSS-1R payload complement. The elements for TSS-1R were the Deployer (MSFC/LMA), Satellite (Alenia), SETS (U. of Michigan), SPREE (Air Force), DCORE (Alenia), ROPE (MSFC/UAH), and TOP (Lockheed). A summary of the performance of each element is provided along with a description of anomalies and lessons learned as applicable.

2.1 Deployer

2.1.1 Deployer Summary

Deployer activation was initiated after payload bay door opening at approximately 00/03:27 MET (Note: All times in this section will be Mission Elapsed Time (MET) and are approximate times taken from the Console Log Books of the Deployer Operations Team unless otherwise noted). Deployer operations initiated with power up of the Data Acquisition and Control Assembly (DACA). DACA self check was successful, however; after activation the DACA indicated the tether length was 23.042 m and tether rate was -0.054 m/s. Length should be reset to 0 m by the DACA and the rate initializes at 19.462 m/s . See Section 2.1.2.1 for further details of the DACA initialization anomaly.

Following the DACA power-up, the reel launch lock was successfully released with a slight decrease (Å 1-2 N) in tensions as expected. Drive time was Å2 minutes.

Due to the inability to command to the DACA using the Command Editor (workstation problem), the Deployer Systems position had to manually build the relay and profile commands. Both of these exercises were completed successfully. Tether Length was set to zero to correct DACA initialization error.

Reel Motor checkout was initiated and results were nominal. After Reel Motor checkout was completed, Vernier Motor checkout was initiated and completed satisfactorily. Two observations were made during the Vernier Motor checkout: (1) Inboard/outboard tension differential was higher than during STS-46 (indicating a stronger vernier motor), (2) The brake appeared to slip at 50 to 55 N which is lower than previously observed but within design requirements. See Section 3.3.1 for further details.

Satellite Restraint Latch (SRL) checkout was then completed successfully. SRL group 2 was left open per the flight plan. This completed Deployer activation activities.

The Spacelab Smart Flexible Multiplexer/Demultiplexer (SFMDM) began experiencing problems (warm starts and core swaps). Due to these problems and the resulting troubleshooting, we were without data much of the time between MET 00/17:00 and 01/11:30. Fortunately, there were very few Deployer activities scheduled for this time frame.

Deployer Pre-Deployment operations began at ~ MET 00/21:25 with the application of power to the Satellite by closing the K8 and K9 relays in the Motor Power Conditioner (MPC).

At ~ MET 01/01:39 we noted that the Power Control Box (PCB) K2 relay was off. This relay provides power to the Deployer heaters. The relay was commanded back on at ~ MET 01/02:03. There was no impact since the Deployer heaters were not needed yet. We assume the K2 got turned off during some of the SFMDM problems.

The deploy of the Satellite was delayed for 24 hrs to gain confidence in the SFMDM and to allow the science community to regain some of the data they had lost due to the SFMDM problems.

A decision was made to change from Satellite telemetry mode to Deployer telemetry mode on the DACA before pulling the U1 umbilical. Normally the DACA would stay in Satellite telemetry mode for the entire mission. This change was made because of a concern that the SFMDM might warmstart when U1 was pulled and Satellite telemetry was no longer present. This was only a concern because of the problems which had been experienced with the SFMDM.

The DACA power cycle which was planned prior to SDB extension was deleted, again because of concerns that it might upset the SFMDM. The DACA had the correct constants and profile from the earlier uplinks. Reel Motor and Vernier Motor checkouts were completed nominally.

The Group 1 SRLs were opened with good feedback and the U1 umbilical was pulled also with the proper retracted feedback. The SDB was extended with a final encoder reading of 11.36 m which is nominal. This length measurement was then set to zero for flyaway.

Deploy operations began with Satellite flyaway at ~ MET 03/00:27. Flyaway was nominal with somewhat lower Upper Tether Control Mechanism (UTCM) and Reel Motor frictions than TSS-1. These can be explained based on the increased Vernier Motor output torque.

The Vernier Motor electronics temperature began to rise at a higher than expected rate. Had the rate continued Fault Detection Annunciation (FDA) and qualification limits would have been exceeded prior to reaching OST1. The FDA was increased from 50° C to 60° C. The temperature eventually stabilized at less than 50° C. See Section 2.1.2.2 and 2.1.3.2 for further details.

Deployment proceeded nominally until a tether length of 19695 m. At this point the tether broke within the SDB. Prior to the break, there were no indications on the Deployer that anything was wrong. All tensions, currents and profile information was nominal. An investigation into what caused the break was performed and is reported under the TSS-1R Mission Failure Investigation Board, initiated by Headquarters.

At ~ 03/21:21 the tether was slowly retracted onto the reel. The SDB was retracted and the SRLs were closed. Thermal data collection continued until the payload was prepared for deorbit. All thermal systems and temperatures were within predicted ranges.

Appendix A contains a set of plots of various Deployer parameters from the STS-75 mission. These plots are similar to the plots generated during system level testing of the Deployer before the mission (4S08 test).

2.1.1.1 Deployer Event Summary

The STS-75 launch occurred at GMT 053:20:18:00, which is 00/00:00:00 MET. Table 2-1 provides a summary of the Deployer related events. All flight times in this event summary will be given in MET and are approximate.

Table 2-1 Deployer Related Events From Launch Through Power Down

00/00/00	Launch
00/01:26	The orbiter payload bay doors are opened.
00/02:11	Spacelab SFMDM is turned on.
00/02:18	Uplinked the TMBUs to increase the upper limit on the DACA thermal FDA and to increase the filter on the Tether Stopped FDA.
00/02:36	Crew reports that 2 of 3 U1 status monitors indicate that U1 is retracted. The 2 monitors that indicate U1 is retracted are not valid until the DACA is turned on.
00/02:48	Changed to SFMDM Regular telemetry format
00/03:33	DACA was initialized. Initialization is nominal except for L and $L^{\bullet}$ (see Section 2.1.2.1).
00/03:43	Launch Lock was disengaged.
00/04:11	The DACA was placed in contingency command mode in order to uplink the relay table and profile. Relay table uplink was successful.
00/04:20	Tether length was commanded to zero from ground to correct DACA initialization problem.
00/04:36	Manual uplink of profile was started (Command Editor not working).
00/05:01	Manual uplink of profile was completed and uplink of constants was begun.
00/05:10	Uplink of constants was completed.
00/05:48	Reel Motor checkout was initiated. Checkout was nominal.
00/06:03	Vernier Motor checkout was initiated. Checkout was successful (see Section 3.3.1).
00/07:03	SRL functional checks initiated.
00/07:31	SRL functional checks were successfully completed. Group 2 left open as planned.
00/17:04	Experienced the first of what would be many problems with the SFMDM (warm starts and core swaps). Each time the Deployer was without data while Spacelab recovered the SFMDM. The records of the Deployer team are not complete relative to the time and number of SFMDM upsets and therefore no further instances will be documented in this summary.
00/21:25	Satellite activation was completed.

Table 2-1 Deployer Related Events From Launch Through Power Down (Cont'd)

01/01:39	Noted that PCB K2 relay (Deployer heaters) was off. Asked that it be turned back on.
01/02:02	PCB K2 relay back on.
01/15:35	Sent Nominal Mode command to the DACA to ensure that ground could still command to the DACA after all of the SFMDM and workstation problems. Command was accepted by the DACA.
01/16:29	Satellite team decided not to activate the Satellite heaters at this time as planned.
01/18:08	Uplinked command to set the MPC OCP to high. This was apparently set low during the SFMDM problems.
01/18:50	Management decision to delay deployment by 24 hrs.
02/10:05	PCB relay K7 was opened at the request of the Satellite team because RETE was getting hot. There was no noticeable change in Satellite heater current when K7 was opened.
02/11:27	Command is sent to change DACA from Satellite telemetry mode to Deployer telemetry mode. The purpose was to ensure that SFMDM would not be upset when U1 is pulled, which would cause Satellite telemetry to disappear. Command was rejected by DACA because DACA was not put into Contingency command mode first.
02/11:47	DACA is put in contingency command mode, command is sent to change to Deployer telemetry mode, DACA is returned to nominal command mode.
02/18:03	Satellite battery heaters activated
02/19:15	Nominal command mode command sent to DACA to verify the Deployer commanding console could command to the DACA (console had been rebooted).
	NOTE: A DACA power cycle was planned for about this time in the timeline. The DACA power cycle and subsequent profile and constant updates were not performed due to concern over possibly causing an SFMDM warmstart. The DACA had the correct profile and constants uplinked earlier.
02/21:20	Reel Motor checkout initiated. Checkout successfully completed.
02/21:36	Vernier Motor checkout initiated. Checkout successfully completed.
02/22:53	Group 2 SRLs commanded open. All 6 SRLs are now open.
02/23:17	Ground sent DACA Nominal command mode command to verify ability to command to the DACA (due to further workstation problems)
02/23:28	U1 commanded to retract. Retraction successful.
02/23:33	SDB extension initiated. Received both extend indicators. Encoder length reads 11.36 m.
02/23:52	Tether length commanded to zero by ground in preparation for flyaway (as planned)
02/23:54	Both torque test bits commanded on.
03/00/09	Video survey of boom is performed by the crew.
03/00:25	Both sets of inline thrusters commanded on.
03/00:26	Vernier Motor commanded on.
03/00:27	DACA control laws initiated to begin Satellite flyaway.
03/00:56	Crew reports oscillations in tether
03/01:02	LDot brake protection circuits set to high mode.
03/01:06	Vernier Motor electronics noted to be warmer than expected. Watching closely.
03/01:53	Inline 2 thruster off.

Table 2-1 Deployer Related Events From Launch Through Power Down (Cont'd)

03/03:55	Uplinked TMBU to change upper limit of Vernier Motor electronics FDA from 50° C to 60° C. Temp currently 46° C. Qual limit is 65° C.
03/04:53	Repositioned docking ring to original position.
03/05:11	Tether broke within boom at a deployed length of 19695 m
03/21:21	Control Laws are turned off. Tether retrieval procedure is initiated.
03/22:20	Brake on. Tether retrieval procedure is complete.
03/22:22	Boom retraction is initiated. Boom retraction was successful with both indicators indicating fully retracted.
03/22:40	SRLs commanded closed. All latches successfully closed.
03/22:50	PCB K8 and K9 relays are opened removing power from MPC.
08/03:08	PCB K2 relay closed after it was discovered that it had somehow been opened. Also PCB K5 (Hot Nest heaters) opened (it had been closed)
14/12:42	Deployer deactivation initiated
14/19:42	DACA/MCA/heaters powered back up to support mission extension due to landing waveoff
15/09/00	Deployer deactivation initiated

2.1.2 Deployer Anomalies/Observations

While the overall performance of the Deployer was nominal up until the tether break, there were minor anomalies or observations noted. With the exception of the tether break, none of these were serious and did not impact the operation of the Deployer. The following sections provide a description of these anomalies/observations.

2.1.2.1 DACA Configuration At Powerup

At DACA power-up, all indications were nominal except for the Tether Length and Rate. The Tether Length initialized at 23.042 m rather than zero m as is nominal. The Tether Rate nominally initializes at 19.462 m/s but initialized at -0.054 m/s. The Tether Length was commanded to zero and the DACA responded correctly. The Tether Length was monitored closely during Reel Motor checkout and Vernier Motor checkout with no change in length (no length change was expected). Review of the DACA schematics and discussions with the vendor determined that the tether measurement card which initializes the length and rate was also exercised when the length was set to zero, which indicated that the card was working. Review of high rate data also showed that the length had actually been set to zero during power-up of the DACA but for some reason the length changed to 23.042. This behavior has never been seen in testing. This indicated that there may have been some transient that occurred which may have caused the anomalous values. There was no trouble shooting identified that could definitively show that the DACA Tether Length and Rate circuit was working properly. The first positive indications would be when the Satellite was unlatched and when the boom was extended. These events would show whether or not the encoder and measurement circuit were working properly. A plan was developed to deploy on time using manual pulsewidth control if the circuit was not working properly. When the Satellite was unlatched and the boom extended, the encoder and measurement circuit worked as expected and the decision was made to deploy nominally under the control of the DACA Control Laws.

Late in the flight, the DACA was powered off in preparation for re-entry. Re-entry was then waived off for a day and the DACA was powered back on to monitor temperatures. The DACA initialized properly giving further evidence that the earlier anomaly was due to some transient.

2.1.2.2 Vernier Motor Temperature

During deployment, the temperature of the Vernier Motor electronics began increasing at a higher than expected rate. Predictions indicated that at the higher rate of increase, the temperature would possibly exceed the Fault

Detection Annunciation (FDA) limit of 50° set for the Vernier Motor electronics before it would be turned off nominally at OST1. The predictions indicated that a full deployment would be achieved before the electronics reached its qualification limit of 65° C. At MET 03/03:55 a new FDA limit of 60° C was uplinked to avoid distracting the crew with an alarm. At 60° C, there would be enough time to turn the Vernier Motor off before it reached the qualification limit. The temperature at the time of the uplink was 46° C. The Vernier Motor electronics temperature eventually stabilized at less than 50° C.

2.1.2.3 Tether Break

At 03/05:11 the tether broke a few meters above the top of the SSA. The deployed length was 19695 m. All parameters (tensions, pulsewidth, currents, tether rate) were nominal at the time of the break. There were no indications from the Deployer displays as to what happened to cause the break. Since the broken end of the tether was inside of the boom and the satellite and the rest of the tether was moving away from the orbiter, no orbiter maneuvers were required and tether cutters were not used. At 03/21:21 the remaining tether was spooled back onto the reel, the Deployer boom was stowed, the latches were closed and power was removed from the MPC leaving the Deployer in a quiescent monitoring mode for the rest of the mission. The tether break investigation has been performed by a separate team called the TSS-1R Mission Failure Investigation Board, and the final report is available.

2.1.3 Lessons Learned

2.1.3.1 Remote Site Operations

While remote site operations seems to be the wave of the future, the TSS-1R flight again demonstrated the importance of working face to face with the operators of the hardware. Because the Deployer team was located at JSC for the mission we participated in simulations with our JSC counterparts and had several opportunities to sit down with them and work through procedures in detail. The effect was a very well disciplined team (JSC and MSFC) that worked extremely well together during the mission on a very complicated piece of hardware. In moving to more emphasis on remote site operations, we must not forget the need to have the people who will be working together during the mission spend time together working out the details of the procedures. The MSFC Deployer team could have effectively supported the mission from MSFC given the time we spent at JSC working with the JSC Deployer team. If the plan had been for the Deployer team to be at MSFC during the mission, the team probably would not have been given the opportunities it was given to work closely with JSC and therefore would not have been as well prepared.

2.1.3.2 Fault Detection Annunciation (FDA)

Changes were made to some of the Deployer FDAs via uplink. This was because the need to change them was discovered too late to get into the flight cycle software. Several of the Deployer FDAs came under question prior to and during the flight. This was largely due to a difference in philosophy in defining FDA limits. The Space Shuttle community generally looks at FDAs as a warning that some action needs to be taken, therefore the FDA should be set allowing enough time for that action to be taken before damage occurs (e.g. a qualification limit is exceeded). The Deployer FDAs were set based on expected or predicted performance. Therefore, Deployer FDAs were set at some value above the predicted value with the rationale being that if the predicted value was exceeded something was wrong and the crew should know about it. The Vernier Motor electronics is an example of this. The FDA was set at 50° C, which was above the predicted temperature, but 15° C below the qualification limit. When it appeared the FDA would be reached, it was changed to 60° C, a more reasonable value since this is a point at which action needs to be taken and there is time to take that action before the qualification limit is reached. The lesson is to make sure FDA's for hardware that MSFC is responsible for are set consistent with the Space Shuttle community's philosophy. The ground crew will be monitoring closely (especially for thermal trends) and the flight crew should be trained to take action when an FDA occurs.

2.1.3.3 Action Requests (ARs)

Action Requests play an important role in missions that are relatively slow to unfold and which allow for a significant amount of time to allow for the proper coordination on an AR before it is needed to be implemented. For systems like the Deployer and Satellite, the AR system is much too slow and actually hinders the operators. In a deployment type mission decisions have to be made in minutes and sometimes seconds and the AR system does not support that. AR's are also not effective for documenting the history of what was done. On fast paced missions, you must rely on good training and good voice communication for making decisions. Another mechanism should be used to document what happened after the fact.

2.2 Satellite

2.2.1 Satellite Summary

2.2.1.1 Pre-Deployment

After the Orbiter payload bay doors were opened, a survey of the Satellite was taken by the Orbiter closed circuit television at approximately 0/01:40 MET (Note: All times in this section will be Mission Elapsed Time (MET) and are approximate times taken from the Console Log Books of the Satellite Systems, the Integrated Payload (IPL) Systems Lead and the IPL Satellite positions unless otherwise noted).

The Spacelab Smart Flexible Multiplexer/Demultiplexer (SFMDM) began experiencing problems (warm starts and core swaps) in the middle of day 0. Due to these problems and the resulting troubleshooting, we were without data and command capability via the U1 umbilical much of the time between MET 00/17:00 and 01/11:30.

Satellite activation was initiated by turning on Satellite external power, transmitter and receivers at MET 00/21:21. The main bus voltage at this time was 32.6 V and the receiver was drawing nominal current. The Attitude Measurement and Control System (AMCS), Earth Sensor (ES) and Sun Sensor (SS) were powered on at MET 00/21:24 and the gyros began warming up. Gyro warm-up was completed at MET 00/21:30. At MET 00/21:34 uplink was acquired (-87 dBm, 2081.082 MHz) and the transmitter (Tx) was powered up. Tx power was 31.3 dBm, Payload Interrogator (PI) Amplifier Gain Control (AGC) was at -63.47 dBm. This yielded a 26 dB difference which was judged acceptable by the Alenia Satellite personnel. The Satellite Linear Accelerometer (SLA) and Satellite Ammeter (SA) were powered up, AMCS constants updated and the Satellite experiments were then powered up.

After the Satellite and experiments were powered up, the Satellite systems and experiments underwent a series of checkouts. At MET 00/22:14, the Auxiliary Propulsion System (APS) status was checked out as nominal. Gaseous Nitrogen (GN2) temperature was 18.8 degree Centigrade (C) and other components registered 13-19° C. Tank pressure was at 262.9 bar and regulated pressure at 11.96 bar. GN2 mass was, according to ground computation, 60.8 ± 0.8 kilogram (Kg). The pre-flight ground measurement was 60.97 Kg. The ground computation was deemed by Satellite personnel to be within specified values. At MET 00/23:35 the gyro temperatures were 71.9 C for X and Z and 71.4° C for Y and Skew . The AMCS bus current was 1.75 Amp (A) and Satellite gave the go for Gyro calibration (GYROCAL) to begin. GYROCAL started at MET 00/23:38 and was completed at MET 01/00:04. Data acquisition on the ground was not good due to the GYROCAL software not running properly. It was determined to use default drift values (0) if a successful calibration could not be accomplished, however, the GYROCAL special computation was fixed and it was planned to uplink the (very small) drift values after the Satellite was put on internal power. APS checkout was completed by cycling the thrusters. GN2 consumed during APS checkout was 0.11 Kg.

At MET 01/02:16, a Radio Frequency (RF) command test was initiated by cycling payload (P/L) 1 and 2. The test was successful and a decision made to keep the RF link up until just prior to Satellite external power being turned off.

Earlier in the mission the Smart Flexible Multiplexer Demultiplexer (SFMDM) had experienced "warm starts". Keeping the RF link up would allow commanding to the Satellite in the event the SFMDM continued having problems. During this test, the Payload Power Distribution Assembly (PPDA) current had stepped from 1.04 A to 1.44 A. It was later explained that, during the APS checkout, the crew, when scheduling the AP checkout (APCO), issued an Item 20 on SPEC page 214 instead of on SPEC page 211. This caused the Power Verification Lamp Assembly (PVLA) to begin flashing. The crew corrected the problem without notifying the ground of the problem. This explains the current increase and why the APCO (Yaw checkout) took longer to complete than expected.

At MET 01/09:57, the TEMAG calibration "on" command was unsuccessfully sent from the Huntsville Operations Control Center (HOSC). This command was not accepted because it was sent as an attached command and the SDIO channel 0 (DACA) was off.

The Mission Management Team (MMT) decided to delay flyaway by 24 hours due to the problems being experienced with the SFMDM. Because of this delay, the activation of the Satellite battery heaters was also delayed in order to conserve battery energy. The Satellite remained fully powered, via U1, during this period. At MET 02/09:00 the RETE dc boom package (DCBP) temperature had reached 62° C during day passes and 41° C during night passes and was rising. The operational upper limit of the DCBP is 65° C and the Principal Investigator (PI) was concerned the thermistor might be failed on. Since there were no concerns about other temps downstream of the K7 relay, it was opened. Afterwards the DCBP temps began to fall back to a nominal range. At MET 02/20:09 RETE was again experiencing high temperatures and requested their unit be turned off. Due to another SFMDM warm start this was not possible. At MET 02/20:54 the SFMDM power cycle was completed and RETE was powered off. During this period the mission control center at Johnson was experiencing problems with their workstations and relied on the HOSC for verification of the receipt of RETE commands.

2.2.1.2 Flyaway and Deployment

At MET 02/23:02 the Satellite was changed over to internal power, the U1 was separated at MET 02/23:28 and the Deployer boom was extended.

During flyaway, the Satellite's performance was nominal. A ROPE/RETE compatibility test was successfully completed at MET 03/02:29 as was a PVLA test when the Satellite reached 99 meters (m). During flyaway and deployment the crew reported excellent visibility due to the flashing PVLAs and the retroreflective material on the Satellite fixed boom. Both of these capabilities were added/modified after the STS-46 mission. Stability of the Satellite was excellent and spin rates were within their deadband limits. The only spacecraft off nominal performance noted during deployment was a small imbalance of battery discharge (8%). The in-line thrusters were turned off at 1000 m rather than the planned 600 m. Gas consumption was still lower than planned due to a lower than expected flow rate.

When the tether had reached a length of 19.6952 km the tether broke. The Satellite separated from the Orbiter at an equivalent 80 ft/s orbit adjust maneuver and no separation maneuver was required. The Satellite was safed per Tether Break procedures in the Dynamics Book but additional precautions were taken to conserve gas and power in case a possibility existed to recapture the Satellite. The Main Isolation Valve and the Inboard/Outboard Payload Isolation Valve were closed, the PPDA powered off, and Auto reconfiguration and rate damping were disabled . Telemetry was lost at MET 03/05:38. The Satellite energy consumed at the time of the break was 934 Watt Hours (WH). Actual power level at the time of the break was 77 Watts (W).

2.2.1.3 Free Flight

The first time telemetry was reacquired, at MET 04/18:44, the Main Isolation, Inline 1 and Inline 2 valves were open skew gyro was off and all programs were descheduled. The APS valves were confirmed as being open instead of closed and tank pressure was 0 bar. In subsequent overflights of ground stations it was determined that all commands were being accepted except for the mode 3 commands, which meant that the Data Handling (DH) microprocessor was lost. This meant the Deployable Retrievable Booms (DRBs) could not be operated. Since they were not nominally operated until the Satellite reached On Station 1, at a tether length of 20,700 meters, the DRBs were never operated during the TSS-1R flight. Attempts were made to recover the mode 3 commanding capability (the DH microprocessor) by attempting to induce an On Board Data Handling system power drop, in effect a hard reset, by cycling power to the AMCS. This was attempted several times at MET 06/19:43 but was unsuccessful.

During free flight, the Satellite and tether remained stable and there were numerous opportunities for commanding and telemetry during over flights of ground stations. At MET 07/08:05, the Orbiter and Satellite orbits became close enough to communicate to the Satellite via the Orbiter Payload Interogator. The crew reported a visual sighting of the Satellite and Tether saying it looked completely straight with no bright spots except at the bottom. The closest approach was at MET 07/08:57 with a distance of approximately 47 nautical miles. The last contact with the Satellite was at MET 07/15:12. At this time the transmitter was weak and cycling. The estimated time of complete failure was MET 07/16:42.

2.2.1.4 Event Summary

The STS-75 launch occurred at GMT 053:20:18:00, which is 00/00:00:00 MET. Table 2-2 provides a summary of the Satellite related events. All flight times in this event summary will be given in MET and are approximate.

Table 2-2 Satellite Related Events From Launch Through Power Down

MET	ACTION	DETAIL
0/00:00	Liftoff	Launched on time. GMT: 053/20:18:00
0/01:09	MNC ON	
0/01:26	PLBD's open	
0/01:27	Go for orbit ops	
0/01:40	Sat. Insp. by CCTV cameras	No apparent Satellite H/W damage
0/03:34	DACA ACT	LENGTH CAME UP 23 M - SHOULD BE 0 DEPLOYER GUYS NEVER SAW THAT BEFORE
0/04:10	qui mon	all good
0/04:32	SWAPPED TO IOP P06	CMD EDITOR TEST GOOD, STILL NO PROB'S
0/05:00	DACA LOADED 16 SEG.	GOOD LOAD OF 16 SEGMENTS IN DACA
0/05:43	REEL MTR C/O	BRAKE MAY BE SLIPPING SOME, BUT C/O IS GOOD
0/05:45	HAVE NOT SEEN ANY HTR ACTIVITY SINCE SHIFT START	SM AND PM HTR BUS CURRENTS HAVE BEEN < THE VALUES OF 1 HTR PER 3.9.20
0/06:05	VERN MTR C/O	
0/15:20	RETE/ROPE/TEMAG OCR	PAP 002 is requesting to move TEMAG/ROPE/RETE c/o until after Gyro Calibration. They want to wait until we reload TFL 183 (Config 759). Execute pkg shows TEMAG c/o at 0/20:10 and ROPE/RETE c/o at 0/20:20.
0/15:40	Qui Monitoring	Nominal. PM HTR Current = .09 A. SM HTR Current = 1.51. Hot Nest Temp = 45.03 F. Hot Nest Vern Mtr = 15.72 C.
0/16:25	Qui Monitoring	Nominal. PM HTR Cur = 0.1A SM HTR Cur = 1.49 A. Hot Nest Temp = 45.03° F. Hot Nest Vern Mtr = 15.41 C.
0/17:05	PDI Decom fail	Problem with SFMDM. Talking about running CARRIER SSR-3: SFMDM WARM START RECOVERY. Called up to crew. Had data for a few seconds, then lost lock. Troubleshooting in work.

Table 2-2 Satellite Related Events From Launch Through Power Down (Cont'd)

MET	ACTION	DETAIL
0/17:25	Warmstart Recovery	Recovered SFMDM. SETS, SPREE, DCORE need to be recovered.
0/17:49	More troubleshooting	Talking about running SSR-4 in PL SYS.
0/18:05	Go for Power Cycle of SFMDM	CARRIER SSR-4 steps 6-12.
0/18:20	Power cycle good	Going to powerdown SPREE DPU.
0/18:50	SFMDM Warm start	Will restart SFMDM, then try SAT ACTIVATION
0/19:25	SFMDM Cold Start	
0/19:36	Crew unable to command SFMDM to regular format	
0/19:50	DDCS Crash Recovery	
0/20:30	AutoFail Over	Data recovered. Primary core and regular format loaded. Uploading GMEM to allow Carrier commands to pass through PF2. Pressing on to Satellite Activation.
0/20:23	IMU Align	
0/21:17	Satellite Activation started	Going to run RF link test steps 1-6 after SAT ACT performed. Need SDIO on for DACA.
0/21:21	Satellite on external power, TT&X RX on	Main bus voltage: 32.6 V; RX current ok
0/21:34	RF CMD (uplink) acquired	(-87 dBm, 2081.082 MHz)
0/21:36	Tx Powered up, proper current drawn	Tx pwr: 31.3 dBm; PI AGC: -63.47 dBm; 26 dB difference OK
0/21:51	SLA/SA activated	Nominal. SLA temp: 48.14° C
0/22.07	OBDH/AMCS dump	Uplinked AMCS Orbital Angular Change
0/22:10	ROPE/RETE activated	Nominal
0/22:13	TEMAG activated	Nominal
0/22:14	APS Status Checked & OK (all valves closed)	Temps (C): GN2 1.8.8; other comp.: 13-19 Pressures (bar):Tank 262.9; Reg. 11.96 Mass (kg): 60.8±0.8 (gnd. comp); last gnd. meas.: 60.97
0/22:22	Bat 1 and 4 temps low	Currently showing 13.8 and 14. 39. Batteries 2 and 3 nominal. Alenia estimates batteries 1 and 4 might warm up in 2 hours. Hold off uplinking Post Insertion TMBUs 1 and 2.
0/22:48	RETE Pwr cycle complete	CPH 3.8.5 Step B
0/22:50	Gyro Cal Update	Current plan to start Gyro Cal at 0/23:25. Planning on going to inertial hold then starting Gyro cal.

Table 2-2 Satellite Related Events From Launch Through Power Down (Cont'd)

0/23:35	TLM back: Go for gyro cal	Gyro temps (C): X,Z 71.9; Y,Sk 71.4; AMCS bus current 1.75A
0/23:35	Gyro Cal Started	Gyro Cal software did not start running. Looks like there's a problem with the Gyro Cal comp. Canceling Gyro Cal for now. Probably use pre-mission predictions for gyro drift.
0/23:45	TMBU uplinked	Crew reported many APS PRESS REG messages. Uplinked TMBU to inhibit message. Will watch from ground. MSID = P33K0003L.
1/00:44	Gyro Cal Update	Decided to eliminate anymore troubleshooting using real time data. Will use the pre-mission values stored in PROM. Drift rates stored in prom are zero. Trying to pull together a playback of data. DATA submitting MDRF for pulling the gyro cal data raw numbers. Plan is to update the software in the CDE and use the data on the tape. Maybe the data can be recovered and an estimate for gyro drift can be calculated. If recovered, we might be able to uplink the values.
1/01:48	APS checkout complete	Nominal c/o.
1/02:00	Battery 4 temp update	Battery 4 within limits now. Currently at 15.76° C
1/02:17	RF Command Check from ground	Sent RF test command. Sent PL 12-NO OP PWR ON/PWR OFF. Success.
	PPDA Current step 1.04 to 1.44 A	No experiment mode change identified; later explained that crew erroneously flashed PVLAs during APS C/O
1/03:13	Battery 1 temp update	Battery 1 within limits now. Currently at 15.21°C.
1/:03:20	TMBU uplinked	Uplinked two satellite post insertion TMBUs. (12342.5 and 12343.1). Waited until battery 1 and 4 temperatures were in limits.
1/04:20	Anomaly report - GyroCal	PLD T04 - Alenia & PLO concurred.
1/05:04	ACBP Temp	Value cycles between a good value and garbage data as expected preflight based on RETE modes.
1/06:15	PM Skin Temps	PM Skin Temp Sect 1 Temp 1 and 2 have gone out of limits high but still within overall range. Might be due to attitude. No concern right now.
1/06:20	APS mon	okay
1/06:20	Gyro Cal	Gyro Cal comp fixed and worked well with

		telemetry playback. Gyro drift values will be uplinked after INT PWR ON. Drift values very very very small.
1/06:30	PM Skin Temps	The above mentioned temps are now back within normal levels. The sensors must be very close to the skin and sensitive to the sun.
1/07:00	Possible DEPLOY delay	A MMT meeting will decide if MSFC wants to delay flyaway 24 hours for science reasons. If they decide to delay, Allenia wants to pwr down some instruments due to thermal reasons, satellite was not designed to stay docked for that long and needs the SM exposed to deep space to radiate heat. May turn off gyros and etc no essential items, also may not need to do bat htr act. No action until delay is called, and then Alenia will evaluate. Haven't called this to PAYLOADS, just sitting on it for now until further decisions are made.
1/07:35	SM Temp. rising	SM ENV 4 (CTU) & 5 (GYE-SBT): 33° C, up by 17° in 10 hr.
1/09:57	TEMAG Calibration ON CMD sent: No Joy	Cmd sent as attached (P33) while SDIO ch.0 (daca) was off
1/14:30	MMT Time	MMT to meet at 8:00am (MET 1/17:30) local to decide on deploy time. Prior to the MMT there's going to be a telecon with Lee Brisco and Dick Richards at 6:00 am
1/15:01	APS Monitor	Nominal
1/17:25	Batt Htr Act	Due to heating, want to delay HTR act until around 1/19:10 - 19:30 writing note. PLWN067.DOC
1/18:50	Delay Deploy 24 hr	The MMT has determined to wave off deployment of the satellite for 24 hours. Did not perform Satellite Battery Heater Activation. Going to leave satellite configured as is for now. Wait until thermal conditions change before powering off satellite subsystems.
1/18:50	RF Gyro/AMCS Constant Loading	Stored RF Constants (X, Y, Z, and Skew Constants) Stored AMCS Constants (Step Size Hold and Orbital Angular Change)
1/20:00	New Flyaway time	MET 03/00:27 (Orbit 49). One rev late: MET 03/01:58 (Orbit 50). Crew alerted not to turn on Sat. battery heaters. Sat. will remain fully powered unless equip. approaches upper temp. limits.

Table 2-2 Satellite Related Events From Launch Through Power Down (Cont'd)

1/20:05	Battery Heater Flt Note	Need a new time from Alenia when they want to perform Satellite Battery Heater Activation for tomorrowÕs deploy attempt.
1/20:05	Plan for 24 Waveoff	Worked with Alenia to develop a plan for next 24 hours for the satellite.
2/09:57	RETE DCBP Temp	Alenia reports that the RETE DCBP Temp is getting very close to the high operational limit during the day passes. The temps are 62 degC during the day pass and 41 degC during the night pass. The operational upper limit is 65 degC. PI's are worried that the thermostat may be failed on. They want to open the EMP PCB K7 relay. There is no concern about the other temps.
2/10:11	K7 Relay open	**NOTE**: Will need to command K7 relay closed before satellite powerdown during Pre-Deploy Prep.
2/10:12	APS Monitoring	All okay.
2/10:43	RETE DCBP Temp	The temps are decreasing. Alenia and POCC will continue to monitor the temps. Going to leave K7 open for now.
2/11:16	APS Monitoring	All okay.
2/11:25	RF Link Test completion	Finish RF Link Test now, so that if there are problems with the SFMDM, there is time to fix it.
2/11:33		Crew complete with step 10. Verified XMTR ENA - OFF.
2/12:27	APS Monitoring	All okay.
2/12:36	Need FN for DFO-4A	OCR: MSCI-001 replans science DFOs at beginning of OST1. Inserting DFO-4A before DFO-4C then deleting DFO-4B. Need a FN for DFO-4A procedure wrt DRB positioning.
2/13:30	FN - DFO-4A	PLWN084_.DOC → PLFN057_.DOC
2/13:34	APS Monitoring	All okay.
2/14:25	PCB K7 Close time	
2/14:36	RETE AR/FIWA	Anomaly Report and Failure Impact Workaround written for the RETE Heater problem
2/15:40	APS Monitoring	Nominal
2/16:00	RETE Pwr Consumption	The RETE Htr bus was budgeted at 30 Whr. In a worst case scenario (RETE Htr relay failed on at internal power up) the total consumption would be 60 Whr.

Table 2-2 Satellite Related Events From Launch Through Power Down (Cont'd)

2/16:40	PPDA Comp Problem	Alenia noticed the GO/NOGO flag on the PPDA Current Monitor special comp is cycling once every 5 to 10 seconds.
2/17:40	APS Monitor	Nominal
2/18:03	Satellite Heater Activation	Performed. Bat 1: 20.96, Bat 2: 23.43, Bat 3: 22.61, Bat 4: 22.61. Battery Heater Current: 7.18. Alenia reports this is lower than the predicts. They are checking.
2/18:05	Gyro/AMCS Constants Built	Verified RF Gyro/AMCS Constants. Built the set of command U1 (just in case).
2/18:23	Initialize Angles Built	Satellite Attitude Initial Angles (R=-6.3, P=29.4, Y=-12.65)
2/18:45	Built AMSAS Flag Damping	Set to 1 in database. Built U1 only.
2/19:45	Bat Htrs OFF	Temperatures: Bat 1: 40.14, Bat 2: 37.68, Bat 3: 37.68, Bat 4: 37.95
2/20:13	SFMDM Warm Start	Crew changing something with the DDCS probably caused warm start. RETE getting hot as well. Need to power off RETE.
2/20:54	RETE PWR OFF	Recovered from warm start. Command link established. Command sent to turn off RETE. Words from the SOC indicated that RETE didn't overtemp and should be okay. They saw temperatures in the high sixties (degC)
2/21:33	Reel Motor c/o complete	Successful
2/21:43	Vernier Motor c/o	Successful
2/21:44	RETE pwr back on	Unable to confirm end item response. MSFC confirmed for us. Workstations are dying fast. Data handler problem.
2/22:39	Satellite Ext Pwr OFF	
2/23:02	Satellite Int Pwr ON	
2/23:26	Crew go for U1 Sep and Boom extension	
2/23:28	U1 Separation	
2/23:33	Boom Motion	
2/23:40	Gyro Flyaway TMBU Onboard	
2/23:49	Boom Ext Cmplt	
2/23:53	Time tag commands on board	I/O ISO CL (04/06:34), ISO VALVES SECT PWR Off (04/06:34), P/L 06 LFA PWR OFF (04/06:35)
2/23:53	Yaw Pwr On	

Table 2-2 Satellite Related Events From Launch Through Power Down (Cont'd)

2/23:56	Dynamics block 4B cmpl	
3/00:25	Inline thrusters 1 & 2 on	
3/00:30	Inline 1 thrusters off	
3/00:44	PVLA test	
3/00:49	Side thrusters enabled	
3/01:02	AMCS memory dump	
3/01:08	PVLA test	99 m
3/01:25	ARD c/o	nominal performance. C/O complete at 3/01:47.
3/01:44	ARD deadband collapse to 0.3 deg/sec	Satellite is very stable
3/01:53	Inline 2 thrusters off	Temps: Tank=-4°C, IN2=-18°C; GN2 on board=44.38 Kg
3/01:58	SAT PASSIVE	satellite to passive mode.
3/02:09	PVLA On	
3/02:11	PVLA Off	Crew reported visible w/ binocular
3/02:29	ROPE PL01 PWR ON	
3/02:29	ROPE PL09 PWR ON	RETE/ROPE/PVLA compatibility test complete.
3/03:01	SAT SPIN	Crew commanded satellite to spin at -0.25. No yaw firing, rate is within deadband. Neg direction due to tether torque direction.
3/03:16	ES Chord Ref Angle	Uplinked ES Chord Ref Angle for 20.7 km.
3/03:20	AR2	Uplinking AR2 parameters into GR but not initializing yet.
3/03:40		Initialized AR2 parameters.
3/03:53		Clearing time-tag buffer
3/04:00		AR2 time-tag commands uplinked.
3/04:11	RETE DCBP Temps	RETE PI says boom package good up to 90¡C.
3/04:14	FN - AR2 pad	PLWN096_.DOC → PLFN068_.DOC
3/04:54	FN - APS PRESS REG FDA TMBU	PLWN097_.DOC is to uplink a TMBU to re-enable the APS PRESS REG FDA.
3/05:10	DRB TMBU	TMBU 12344 to disable DRB inhibit relay FDAs.
3/05:11	**TETHER BREAK** **19.6952 KM** **RATE 0.1**	**Tether broke inside of boom, several meters up the boom. Per TETHER BREAK in Dynamics book, satellite already safed. Will take more steps though. Satellite separating at 80 ft/sec. No sep maneuver required. Closed satellite MAIN ISO VLV and I/O PL ISO VLV.**

Table 2-2 Satellite Related Events From Launch Through Power Down (Cont'd)

3/05:24	PPDA off	Commanded PPDA off to conserve power to keep RF link with satellite as long as possible.
3/05:26	SS off	
3/05:26	ES off	
3/05:26	GYRO Z off	
3/05:28	Descheduled TULC	Descheduled TULC s/w routine to disable A/R.
3/05:43	PI LOCK DROPPED	SAFING CMPLT
	Sat Free Flight	Energy Consumed = 934 WH; I=2.58 A; Actual energy = 77 W
4/17:55	Payloads: Next contact @ 4/18:44	Data successfully acquired in the previous ground pass. Many TLM discrepancies: Main Valve, Inline 1 & 2 valves open, Satellite pressing on sending cmd Schedule VRPH2 program, DRB extension-retraction (3m 30")
4/18:44	Telemetry acquired. Main, inline 1 & 2 open, Skew Gyro off, All programs descheduled	
4/18:47	Schedule VRPH2	no joy- mode 3 cmd
4/18:48	H/W TLM ok, S/W TLM not ok	APS valves really opened; Tank pressure=0
4/18:49	DPY/RTR Powered, DPY/RTR Enabled DPY/RTR CMD - no joy ROPE (P/L09) OFF; ES1 &ES2 ON; PPDA ON	no joy- mode 3 cmd
4/18:51	TT BUFFER all zeroed; Memory dump=0	coherent with s/w telemetry unreliable
4/18:55	Ground pass complete	
4/20:22	AOS Start: ROPE CMD (B044), IN2, IN1, Main Close, GYRO PKG2 pwrd. on, 3 ROPE cmds, Schedule Start (3 times) No Joy, DPY/RTR on CMD (2 times)-No Joy	Tank & Regulated pressure about zero. Mode 3 cmds not operating. Not possible to extend DRB. OBDH uP activity shows cmd decoded (i.e. 3)
4/23:22	AOS (Hawaii)	Sat. COG is 2Km below Sat.
4/23:36	AOS (STL): DPY/RTR Pwr Off, ROPE cmds	PPDA current increase
5/01:13	AOS (STL):ROPE Cmds, SSE Pkgs. Pwrd. on, RETE CMDS, SSE Pkgs Pwrd. off	PPDA current increase, 5' min. of sun sensor data
5/01:23	AOS (MIL):	
5/02:37	AOS (Hawaii): P/L Lines are on	Further indication of S/W reset is TT cmds(P/I) not executed (4/22:35)
5/17:35	AOS: RETE CMDs, ROPE cmds, SSE Turned on, PVLA turned off, IN1 cycled successfully, SSE turned off,	RETE cmds recvd., no response

Table 2-2 Satellite Related Events From Launch Through Power Down (Cont'd)

5/20:47	AOS (Orbit 94): SSE on, RETE-ROPE cmds, SSE off	
5/22:11	AOS (Hawaii-orbit 95): MSCI: all sat. science to remain powered.	
5/22:23	AOS (STL)	
5/22:35	AOS (Bermuda): IN1 cycled, Sat AGC=.84	stronger link
5/23:37	AOS (KMTC-orbit 96)	
6/00:01	AOS (Goldstone)	
6/00:11	AOS (MLAC): IN1 cycled as cmd test	
6:01:15	Decision to pwr. dn. AMCS, all P/L lines but SLA	
6/01:42	AOS: Grp 1 (AMCS), 2 (P/L lines) 3 (SLA stby) cmds sent.	Verif ROPE (P/L 01) off
6/16:31	AOS (STL): Sat. still warm	batteries around 11-12 C
6/17:06	AOS (IOS)	
6/18:05	AOS (STL) POD go for pwr up science @ 6/18:52	Lock acquired AGC=-108
6/19:37	AOS (VTSS)	
6/19:43	LOCK (STL): ES1&ES2 ON, GYRO pkg 1 & 2 ON AMCS Powered on/off, AMCS Back off/of; Z gyro off; no DH uP TLM change; P/L 01, 05, 03, 06, 09 ON; SLA operate CMD; SSE ON; Sat. spinning at 0.47 RPM; SSE OFF	to induce an OBDH power drop (trying to get mode 3 cmds capability) - no joy
6/21:18	AOS (VTLL): ROPE CMDs	
6/21:34	AOS (Bermuda)	
6/22:50	AOS (VTSS)	
6/23:13	MSCI: PVLA not to be pwrd. any more	
7/00:17	AOS (Hawaii): ROPE cmds,	
7/01:24	AOS (DGSS)	
7/01:42	AOS (GTSS) - TLM	
7/02:08	AOS (HTSS)- TLM	
7/02:53	AOS (IOSS): IN1 cycled (3times) - no joy;	
7/03:04	AOS (DGSS) - TLM: Link to IOSS verified (data & clock)	
7/03:32	AOS (HTSS) - TLM	
7/04:03	AOS (AG01) Lock ok; problems w/ modulation	

Table 2-2 Satellite Related Events From Launch Through Power Down (Cont'd)

7/04:29	AOS (IOSS): IN1 & IN2 open cmds sent - no joy	no idle pattern
7/04:53	AOS (GTSS)- TLM	
7/05:36	AOS (AGO#2): IN1/IN2 cycled, ROPE cmds	
7/06:08	AOS (IOSS) - TLM + TLC	
7/06:34	AOS (GTSS): BAT3/4 VOLT<BAT 1/2 VOLT; BAT 1/2 curr=1.54 BAT 3/4 curr=2.68	unbalance 27% from avg.
7/07:14	AOS (AGO)	
7/08:19	AOS (GTSS): BAT1/2 curr=0.58A; BAT3/4=3.6A; Main V=29.53	
7/08:27	STS LOCK THE SATELLITE-BAD DATA	
7/08:52	ROPE CMD SA Autocheck ON/OFF	
7/08:58	SA Autocheck ON/OFF; RETE cmd sent	Battery unbalance 73% from avg.
7/09:05	AMCS Pwr OFF-No link available	
7/09:06	RETE MODE 1	
7/09:09	AMCS Pwr ON (twice sent)	also Z gyro comes on
7/09:11	Z gyro OFF	
7/09:13	RETE CMD ended Schedule start program-no joy (2 times)	
7/09:47	AOS (GTSS)	
7/11:27	AOS (GTSS):	Satellite still powered and transmitting telemetry Might last 1 more hr.
7/15:12	Satellite still powered-no telemetry	Only transmitter still active (estimated times)
7/16:42	Satellite unpowered	(estimated time)

2.2.2 Anomalies

This report will not attempt any conclusions as to the causes of Satellite anomalies which occurred during STS-75 since this requires a more thorough examination by Alenia.

At this time, it is unknown why the Satellite configuration changed between the time telemetry was lost after the tether break and was reacquired. It is also not clear why the mode 3 commands would not work. The failure fault tree for these anomalies obviously would have 2 branches, internally generated failures and externally generated failures. One theory proposes the OBDH ram pointer was at the wrong location, however, according to Alenia this failure is difficult to reproduce. If this Satellite design is used again, it would be advisable to include a "reset" capability in the OBDH. Another speculation is that ground or orbiting devices irradiated the satellite with greater than maximum electromagnetic radiation levels.

During early deployment the gas consumption was slightly higher than anticipated. However, according to Alenia, both the temperature and regulated pressure remained within nominal range. It is believed the small difference between the pre-flight predictions of gas consumption and actuals was due to slight differences in actual and predicted temperatures.

During deployment and free flight the battery voltage levels and current draw between the two sets of batteries became increasingly imbalanced beginning at 8% during deployment until it reached 73% at MET 07/08:58.

RETE DCBP temperature problems were probably caused by a thermistor which failed on. Since there was monitoring and control (via K7 relay) capability this never posed a threat to RETE science.

Unfortunately these anomalies may never be fully understood because there was only one Satellite and there is no longer any capability of reproducing them.

2.3 SETS

2.3.1 SETS Summary

SETS was powered up and began checkout activities at 00/11:10. The checkout was initially unsuccessful due to a filename inadvertently being omitted from the uplink. The second attempt was successful. SETS continued and completed power up and initialized FPEG. During FO-1D SETS telemetry dropouts were experienced and became significantly worse (Reference AR:HSCE-004 in Appendix B). Troubleshooting was begun by resending 3 commands that earlier may not have been accepted, but this did not correct the problem. Next 2 SDIO resets were tried with no success. Ground Malfunction procedure SETS-003 was then started. After Block 3, SETS was showing "ON" but SDIO receive status shown "N". Another SDIO reset was tried with no success. A DEP reset was performed per malfunction procedure and was successful.

SETS also began having a noisy data problem. AR:HSCE-002 (Reference Appendix B) was answered in response to this problem.

During the operation of SETS FO6D, it was learned that the noise which was experienced with the SRPA and Langmiur Probe at the beginning of the mission was directly related to the FES being turned on. SETS continued to perform FO's.

At MET 02/07:08 SETS reported the DEP disabled the FPEG 2 high voltage. After troubleshooting, it was determined that FPEG 2 was operating nominally and the high voltage disable was due to a transient condition.

After the tether break it was decided to perform as much of the Post Retrieval Science as would be possible. SETS continued with these activities. There was a concern about the SETS Electron Gun temperature during parallel SETS FO6C and FES operations but the temperature stayed well below the upper limit.

In summary, except for some data problems early in the mission, SETS performed well.

2.4 SPREE

2.4.1 SPREE Summary

Early in the mission a problem began occurring with warmstarts, as mentioned earlier. The first occurrence was while SPREE was being powered up and configured. At MET 00/18:36 SPREE was repowered after SETS and DCORE SDIO channels were turned off. SPREE received good data with no warm starts. When SETS channel was reactivated another warm start occurred. A core swap on the smartflex was performed and experiments were brought back up, but the SFMDM data system was still exhibiting marginal performance. SETS, SPREE and DCORE were powered off and safed at MET 00/21:02 for further troubleshooting, in parallel with Satellite activation, which was completed at MET 00/21:25.

The SFMDM performance was still low during this time. Several caucuses and meetings were held during the day to decide what direction to take. SFMDM problems continued to occur. The experiments were powered back on with a five minute delay between each activation. This began at MET 01/04:37 and continued until MET 01/05:17. SFMDM core swap occurred at approximately MET 01/05:51. During experiment recovery, SPREE noticed their DOL status was incorrect. This was explained as a result of the core swap, since all DOL lines are drawn low after a core swap. SPREE performed an immediate power down, to get into a safe configuration. While this was in work, experiments again lost all data. After much discussion, an SFMDM complete power cycle was performed. Procedure was not completed successfully because commanding was to the wrong core. Finally, an SFMDM power cycle was complete.

At MET 01/09:24 another SFMDM warmstart occurred but was contributed to the SPREE SDIO channel being active for a long time before SPREE DPU was turned on. Explanation for DPU reset was that the DEP was not receiving handshaking from SFMDM and, therefore, stopped trying to talk to the SFMDM. At MET 01/09:36 SFMDM power cycle was completed. SFMDM core swap was performed and another SFMDM power cycle was completed. Then one at a time with a five minute interval between each, the SDIO channels were activated, followed by DDCS activation. This was successfully completed at MET 01/11:22. SETS required a DEP reset but was then successful. At this time, the ground team finally isolated the problem to a bad cable from the DDCS to the SFMDM and it was replaced. The resulting recovery actions, including powerup of all experiments, was completed at MET 01/11:43. Nominal operation of all experiments was established and continued nominally for several shifts.

The first minor problem that occurred in the SPREE hardware was a media error message from recorder 1 (FDR 1) about 30 minutes after activation. The error caused the recorder to stop recording. Malfunction procedures were implemented and FDR-1 was advanced past what appeared to be a bad section of tape. Recording was begun and no further problems occurred with FDR-1 for the rest of the mission. This problem had occasionally shown up in ground testing.

A second minor problem occurred early regarding the Electrostatic Analyzers (ESAs). Excessive noise was noted on the output channels immediately after turning on ESA-B high voltage. As this could have been an indication of insufficient outgassing - resulting in arcing - of the Microchannel Plates (MCPs), the ESA-B high voltage was disabled. Over the next several hours the ESA was turned on momentarily to observe the noise level, which was tailing off as time progressed. Eventually it reached an acceptable level and was left on for the rest of the mission with no further problems.

AT MET 02/06:58 SPREE reported questionable values for orbital potential. After research, they realized that the excessive noise was attributed to a hardware modification incorporated for this mission which increased the sensitivity of the instrument. A software parameter change (noise threshhold limit) was made to mask some of the low-level backround noise which was causing the erratic readings.

SPREE high voltage was safed per the procedure for flyaway and operated nominally up to the tether break.

After the tether break, SPREE continued operating as a part of the planned Post Retrieval Safing procedures with the hardware and software performing nominally throughout the remainder of the mission.

2.5 DCORE

2.5.1 DCORE Summary

The DCORE experiment performed nominally during the mission. The experiment powered up nominally with no problems.

At MET 00/12:40 DCORE began the DMS power on checkout of opening and closing the DMS and was concluded at MET 00/12:49. The DCORE experiment was activated at MET 00/13:15 successfully with acceptable measurements on all of the units. The experiment was put in standby mode at MET 00/13:29 while the EGAs were warming up which began at MET 00/13:45.

To reduce emon erroneous sounding, they were disabled at MET 00/14:42 and were to be enabled after DCORE checkout.

When the SFMDM began to experience warm starts due to the DDCU, DCORE (which was to be expected) had to reset their buffers before the experiment could function properly. This activity had to be done after each warm start.

Only two of the three planned SLA calibrations were performed by MET 01/05:26. The third calibration was deemed not required by CORE.

Around MET 01/23:00 the PSE requested Near Real Time (NRTs) plots for DVG pressure due to possible RCS firings and other orbiter maneuvering. The plots showed peeks during those times.

At MET 02/20:10 the SFMDM warm started again possibly due to crew DDCU manipulation. DCORE had to go through resetting their experiment.

The U1 was separated at approximately MET 02/23:28. When the inline thrusters were turning on the DVG pressure was read at -3.8 Ltorr.

The EGAs performed well in the generation of more current than was expected.

After the tether break, DCORE supported SETS with DVG pressure measurements for the rest of the mission.

2.5.2 Anomalies

There were no known anomalies with the DCORE hardware or software during the mission. Alenia has also published a report, "CE RP AI0070" on DCORE performance for TSS-1R.

2.5.3 Lessons Learned

2.5.3.1 DCORE PDECU Reset

Early on in the TSS-1R mission preparation, DCORE suggested to modify the PDECU to reduce reset time in the event the SFMDM warm started. The TSS-1R team and spacelab felt that the SFMDM would not warm start again due to testing and TSS-1 mission success. The SFMDM did unexpectedly warm start during the mission and a cumbersome procedure was performed. Experiments should be designed with the capability of resetting their CPUs in a timely manner. In retrospect, the TSS-1R program should have accepted their ECR that would have required to make hardware and software changes.

2.5.3.2 Emblem Changes

It is necessary to always communicate changes to individuals responsible so possible impacts can be assessed. Changing an emblem is a esoteric item, but this out-of-the-board change, cost MSFC and KSC a great deal of man power that could have otherwise been avoided.

2.5.3.3 Procurement/Receiving

Use credit cards for as many purchases as possible since one can be utilized in purchasing flight hardware. MSFC receiving processing timeliness showed to be a problem in obtaining vendor hardware. The only method to verify delivery status is by personally going to the building and inquiring the status.

2.5.3.4 Shipping

When shipping international shipments, the partners can ship directly to Huntsville customs without clearing it in the city the equipment arrives. Never send custom related equipment directly to a contractor, instead send it to MSFC so the contractor will not have to pay bond/duty. When the PEDs ship their hardware, make sure they put a name and mission so shipping and POCC individuals can identify ownership.

2.6 ROPE

2.6.1 ROPE Summary

2.6.1.1 Hardware

The ROPE experiment was first powered on at MET 00/22:10. Check out of the DIFP and FS subsystems was successfully completed per the command timeline. Due to the delay in the satellite deployment and considering the low pressure in the Orbiter cargo bay, the SPES subsystem was activated MET 02/00:08. ROPE performance during the PDC was nominal. ROPE was successfully power cycled during the satellite external/internal power change and during the ROPE/RETE calibration FO. ROPE performance during the deployed phase was nominal. ROPE was nominal for the 10+ minutes following the tether break and was properly shut down as the satellite was safed. When the satellite was subsequently powered on for the free-flight period, ROPE performance was again nominal.

The only minor problem that occurred on ROPE was that SPES 1/2 did not come on after the initial commanding after tether break during the ground pass commanding while the satellite was in the free flight mode. They were successfully brought on-line during the next command opportunity. The link between the satellite and the ground is suspected as the reason as to why SPES 1/2 did not activate at first. ROPE performance was nominal during the entire free-flight period . In summary, the ROPE hardware performed as designed during the TSS-1R mission.

2.6.1.2 Operations

The ROPE sync comp was successfully tested during the PDC phase by both the OC team and the ROPE support team. The commanding from both the ECO and the ROPE SUPPORT positions went fine. The only hitch was that the wrong command chain was sent for the first IV24 execution. Commanding for the free-flight period was very good. Coordination between ROPE SUPPORT, ECO, and JSC PAYLOADS to accomplish the desired ROPE commands during free-flight was excellent. The effort to obtain night pass data from the satellite was also outstanding. NASA did a heroic job in essentially implementing a new mission on very short notice.

2.6.2 Anomalies

No anomalies were experienced by ROPE during the mission.

2.6.3 Lessons Learned

2.6.3.1 Hardware changes since TSS-1

Several changes were made to ROPE for TSS-1R in order to enhance the science return.

1. BMSP current/ voltage control: Both hardware and software changes were implemented to provide for better control of the BMSP bias at the lowest voltages. This worked very well. No BMSP voltage oscillations of the type seen on TSS-1 were experienced.

2. Heat sink for diodes: During the second DC24 operation at a tether length of about 16 km, it was evident that the Zener diodes in the ROPE FS had become active due to both the high current and charging levels at the satellite. It is clear that the addition of heat sinking capability to these diodes along with isolating the BMSP from the boom bracket was a necessity. Whether these changes from TSS-1 would have been sufficient to protect the diodes from overheating during the OST-1 FOs where repeated current and charging levels of the same or higher values would have occurred is still an open question.

3. SPES vent tube plug: The sun pulse experienced during TSS-1 in the SPES sensors was not eliminated by the addition of a plug to the vent tubes. This was obviously not the solution as compared to placing a cap over the vent tube. However, data corruption involved only a few sweeps scattered throughout the deployed phase.

2.6.3.2 Operations

ROPE was 30 minutes late in being powered on during the execution of the ROPE/RETE calibration FO. ROPE collected only 2.5 hours of data during the deployed phase with all of its subsystems active before the tether broke. In light of this, losing 30 minutes of data (specifically DEP101 FOs) was significant and was avoidable. The crew was turning the satellite lights off and on and was hindering the nominal execution of the timeline. The OC team was much too passive in getting ROPE powered on, despite repeated requests from both ROPE and RETE. Tolerance by the OC team of interference by the crew into nominal operations when no malfunction condition is evident should not be allowed.

2.6.3.3 NASA Philosophy

The time spent chasing paperwork for a Class C experiment (ROPE) on a reflight was excessive, expensive, and required time and resources that should have gone to testing and calibration. The loss of verification paperwork from TSS-1, which had nothing to do with success of the ROPE experiment, contributed to this misspent time. The experiment certification signed by the PI or his/her representative should mean more than it currently does as a bookkeeping exercise. In a future of declining budgets, experiments such as ROPE should be focused on testing and flight operations, with the PI being held responsible for the success.

When focused on hardware testing, experiment teams should expect from NASA an attitude of full support and coverage. Unattended operations of a thermal vacuum facility while ROPE flight hardware was under test almost ruined the experiment and resulted in approximately 10 weeks of intense time consuming troubleshooting and testing to isolate and repair the damage. In an era of declining funds, NASA must be diligent in pursuing practices that will provide for the successful operation of experiments in flight. Reducing coverage on necessary tests does not promote success.

2.7 TOP

2.7.1 TOP Summary

The TOP experiment flew on the STS-75 (TSS-1R) mission, and was operated almost through the entire mission. TOP checkout performance was initiated very early immediately following payload activation at MET 0/07:00. The first checkout period was allocated to last until MET 0/09:00. It seems that there was some difficulty in locating all the experiment hardware components in the orbiter cabin and the checkout could not be performed within the allocated time. However during the next TOP operation period the checkout was completed and the camera operation was verified. At this point the down link video had a jitter problem but the on orbit video by all account was very good.

During the first day the jitter was fixed and TOP operations became nominal. The tether deployment was delayed because of the problems with the SFMDM. This delay permitted the performance of several unscheduled TOP operations. The tether deploy was postponed 24 hours. From the TOP experiment standpoint everything was nominal.

During the tether deploy and prior to the break there was only one operation of the TOP experiment. This was scheduled to occur at MET 02/03:35 but because of the one day delay this occurred at MET 03/03:35. The objective of this experiment performance was the observation of the tether and the satellite when the voltages were reasonably high and the satellite was still closer to the orbiter. According to the flight plan the tether length at this time was about 10 to 12 km length. This operation was performed using the zoom lens optics and the video was recorded on the orbiter.

After the tether break several electron beam induced experiment TOP observations were performed. The analysis of the data is in progress.

During the USMP phase of the mission the TOP experiment was operated to make some airglow and sprite observations. Since the TOP instrument was on board, working well and was able to take data which was of higher quality than some of the lately planned NASA upper atmospheric free flyer satellite it was thought that TOP should operate as much as possible. It was recognized that TOP could do a longitude survey of gravity waves to help finding the wave source regions on the earth. The other science goal was the study of Sprites, which is an extension of our ground based observations of the previous flights with equipment quite similar to TOP. We thought that by observing through 5 - 10 storms we could get definitive observations for establishing the frequency of sprite occurrence in the southern hemisphere as observed from above.

Several performances of TOP FO's were scheduled to satisfy these objectives during the USMP phase of the mission.

2.7.2 Observed Anomalies

The TOP experiment operated very reliably during the TSS-1R mission.

There were two anomalies detected. At the beginning of the mission the down link video was observed to be showing an instability. This manifested itself as a slightly unstable picture. The problem was tracked down to a frame synchronizer on the ground which was included in the TV circuits at White Sands. Once this was removed the down link picture looked excellent and was immediately adopted for the NASA select television for public broadcasts.

Another anomaly was noticed when the video seemingly lost synchronization for a very brief interval. This occurred for a few seconds. A power down and power up sequence eliminated the problem. The camera was on for more than 30 - 40 hours after this occurrence and the problem never re-occurred during the entire mission. It is not clear whether the problem was internal to the TOP instrument or it was caused by some external set up configuration.

2.7.3 Lessons Learned

The TOP team has obtained an excellent data set and wants to thank everyone for the data which was obtained for us. We are especially grateful; to the crew who in some instances made critical adjustment to TOP which allowed us to the highest quality data. During the TSS-1R phase of the mission the TOP operations went very smoothly.

During the USMP phase there was a certain disconnect between the Marshall POCC and the JSC team. The Marshall team strongly encouraged us to stay around and support the USMP phase of the mission because it was thought that the crew was not too busy during these latter phases of the mission and it would be highly beneficial if some additional TOP science could be accomplished during this phase. The JSC team was less supportive and it was clear to us that some detailed decisions were made by persons who were not familiar with the experiment. This was particularly awkward when they performed what amounted to censorship about what could be uplinked to the crew in the form of crew notes.

We were strongly encouraged to support the mission during the USMP phase by Marshall and the Marshall POCC assisted us in timelining some TOP operations. From these operations during the USMP phase we have learned some key lessons:

Lesson 1. Perhaps there should have been a refresher training session scheduled just before the mission. In spite of the considerable effort expended in training the crew it appears that there were still some deficiencies in some crew member's overall perspective about TOP science goals. Having the science goals more clearly in focus, I believe, would have helped them in performing the work. I also think that we should have focused more on the overall science training rather than the operational details which the crew was able to acquire very easily.

Lesson 2. In future we should continue to encourage positive reporting which was frequently done during the performance of the TSS-1R TOP experiments. In an experiment which depends on repeated performances and in which experiment the success of each performance changes the best approach to accomplishing the overall goals it is necessary to follow some positive reporting procedure. Positive reporting also raises the morale of the POCC personnel and the experiment team.

3.0 Discipline Summaries

3.1 Avionics

3.1.1 Avionics Summary

The data provided in this report is based on information obtained during the mission by the personnel supporting the Avionics Integrated Payload HOSC position. Support began approximately 12 hours prior to launch and continued until approximately 12 hours after the tether break. The primary objective of the Avionics Team was to monitor performance and support resolution of anomalies for the TSS-1R Electrical Power Distribution System (EPDS) and the Command and Data Management System (CMDS). The console position was manned in two 12 hour shifts. Avionics team members not on console during the mission were on call. EL Laboratory provided support for making Non Real Time Plots.

This report provides a summary of overall performance, discussion of anomalies and lessons learned. All times are reported as MET.

3.1.1.1 Avionics System Overview

The EPDS consists of orbiter supplied ac, dc, and auxiliary power provided to the EMP, Deployer subsystems, MPESS Experiments, and the Satellite prior to flyaway. The orbiter Standard Switch Panel uses cabin payload power to control relays within the EMP and Deployer subsystems. The two main components of the EMP EPDS are the Power Control Box (PCB) and the HDDR fuse box. The PCB distributes ac and dc power to the EMP and Deployer subsystems through relays within the PCB. Auxiliary power is routed through the HDDR fuse box to the SFMDM and the MCA. The Power Relay Box (PRB) distributes payload power to the SFMDM. Auxiliary power for the SFMDM is routed from the HDRR fuse box through the PRB on a separate bus. The Deployment Pointing Panel (DPP) uses cabin payload power and auxiliary power to control pyro-initiator circuits. The MPESS experiment electrical power is supplied by the payload primary power via the Science Power Control Box (SPCB). Power to the attached Satellite is routed through the U1 Umbilical and power after separation of the U1 Umbilical is provided by Batteries.

The CMDS provided command and control capability to, and data and telemetry from, the EMP, Deployer, Experiments, and the Satellite.

Commanding from the ground was from the JSC Multi-Program Support Room (MPSR) for the systems and from the MSFC Science Operations Center for the experiments. On board Orbiter commands were sent from the Payload General Support Computer (PGSC), to the SFMDM, the MPESS mounted experiments (DCORE, SETS, and SPREE). or from the Mission Control

Display System (MCDS), to the Deployer and Satellite. The EMP SFMDM processes commands from the Orbiter PFMDM and interfaces with serial and discrete commands to the Deployer, through the Deployer to the Satellite, and to MPESS science instruments.

Telemetry data from TSS-1R except the Satellite was provided to the SFMDM. The SFMDM buffers and routes the data for both on-board display by the PGSC, and for input to the Payload Data Interleaver (PDI) payload port. The Satellite data in the attach mode was via the Deployer Data Acquisition Assembly (DACA) to another PDI payload port. Telemetry for deployed Satellite was via an RF link to the Orbiter Payload Interleaver and PSP to the PDI payload port. The PDI interleaves the Satellite and SFMDM data together with Orbiter data for Orbiter downlink to the ground.

3.1.1.2 Summary of Overall Performance

3.1.1.2.1 EMP Flight Summary

EMP activation was nominal. Activation was initiated approximately MET 00:02:00 and was completed at about MET 00:02:45. The SFMDM core activation was nominal and occurred at MET 00:02:11. The EMP power system performance was nominal throughout the mission.

The SFMDM exhibited several warm starts during the mission. The first warm start occurred at approximately 001:05:54. The SFMDM anomaly is covered in the Software summary, section 3.2.1. However, the PGSC (DDCS) data cable was replaced by the crew and the DDCS performance became nominal for several hours. The cable was replaced with serial number 1002, which is the same cable used for the PAD IVT.

3.1.1.2.2 Deployer Flight Summary

The Deployer performance was nominal during activation and during the mission except for the DACA.

At approximately 000:03:33:12 the tether length indicated 23.04 meters instead of the nominal value of zero and the tether rate indicated a negative 0.05 meter/sec instead of the expected value of 19.46 meters/sec. At 000:04:21 the tether length was successfully commanded to zero. The anomaly was suspected to be in the DACA Encoder Card. Action Report AR HSCE-003 (reference Appendix B) was generated for the anomaly. It was determined nominal tether length and rate measurements were required for nominal tether deployment using the DACA profile. It was concluded the health of the DACA Encoder Card would be verified when the boom was extended 100%.

The DACA Encoder Card circuit and concluded a command to reset the tether length and rate would accomplish most of the same functions as a DACA power cycle. It was concluded if the DACA provided the correct length and rate when the boom was extended 100%, the DACA length counter would operate nominally during flyaway.

A telecon at MET 01:20:30 with the SCI, the DACA supplier, the Lockheed Martin Chief Engineer and Deployer Software Engineer resulted in a high degree of confidence that the DACA length and rate data would operate nominally during flyaway. They concluded the command to reset the length to zero exercised most of the functions on the DACA Encoder Card. The preliminary conclusion was that voltage spikes were the most likely cause of the anomaly.

A voltage plot was performed and no voltage spikes were found, however, the sample rate for the measurement was only one sample per second.

A contingency plan for fly-away was approved by the TSS-1R Mission Manager, the Chief Engineer, and the Flight Director. The nominal DACA profile was to be implemented for flyaway if the length read 11.3 +/- 0.2 meters when the boom was extended 100%. Otherwise, deployment would be accomplished by the crew using Manual Pulsewidth Commands.

During reel motor checkout at MET 02:21:27:10 the tether length decreased by one count. When the SRL's were opened at 002:22:52 the tether length increased by one count. When the boom was extended 100% the tether length read a nominal 11.354 meters. The length and rate was again commanded to zero. The DACA was considered to be operating nominally and the decision was made to use the DACA nominal profile for Satellite flyaway. The DACA performance during flyaway was nominal.

3.1.1.2.3 Experiment Activation and Operation

The MPESS Experiments were all activated and the electrical power and command/telemetry was nominal except for the SFMDM warm starts. Beginning at flyaway near real time data plots were made in 45 minute increments for tether length versus MET time, EGA1/2 actual and echo current plots versus MET time, and TCVM current versus MET time. The plots were discontinued when the tether broke.

3.1.1.2.4 Sattellite Activation

Satellite activation was nominal. Hot nest heaters were turned off and battery heaters were turned on.

3.1.1.2.5 TSS Systems Checkout

The TSS Systems Checkout was nominal. At MET 02:21:34 the reel motor checkout was successfully completed, and at MET 02:21:41 the vernier motor checkout was successfully completed. The SRL's test and the RF Link test was successfully completed.

3.1.1.2.6 Predeploy Operations

All predeploy operations were nominal. External power was removed from the satellite at MET 02:22:35. Satellite battery activation was completed at MET 02:23:04. The SRL's were opened and the U1 umbilical was released at MET 02:22:52. Boom extension began at MET 02:23:28 and was extended 100% at MET 02:23:44. The satellite RF link was successfully established. The DACA tether length was commanded to zero at MET 02:23:52. Go for flyaway was given at MET 03:00:17 and flyaway was initiated at MET 03:00:27 when the vernier motor was commanded on.

3.1.1.2.7 Flyaway

The flyaway portion of the mission was nominal until the tether break which occurred at MET 03:05:11. The excess tether was rewound on the reel at MET 03:22:06. The boom was retracted at MET 03:22:36 and the SRL's were closed at MET 03:22:43.

3.1.2 Lessons Learned from TSS-1R

The decision to evaluate all the TSS-1 and TSS-1R changes to the verification was a good decision. The verification program overlapped with testing and operations. A better system needs to be established which will minimize the logistics time. A paperless system for this effort would reduce the engineering effort by about 25%.

The time allowed for operations training needs to be increased. To much time was spend during simulations on learning how to retrieve and manipulate data, respond to action items, and write shift reports.

3.2 Software

3.2.1 Software Summary

The DACA (Data Acquisition and Control Assembly) software performed nominally during the TSS-1R mission. The deploy mission profile operated as tested. However, on initial power-up, a tether length reading of 23.4

meters was observed. After further investigation, it was determined that the length reading was zero (as it should have been) in the first DACA telemetry frame and was 23.4 meters in subsequent frames. This problem is discussed in Section 3.1.1.2.2. The length parameter was later commanded to a value of zero. During boom extension, it was shown that the tether length counter was incrementing properly.

During the mission, several SFMDM (Smart Flexible Multiplexer/Demultiplexer) warm-starts and core-swaps occurred (reference Appendix C). These problems occurred prior to flyaway. They had not been observed during extensive ground testing. One apparant cause was traced during the mission prior to flyaway to a bad cable from the PGSC to the SFMDM and it was replaced. However, additional warm starts/core swaps occurred after the changeout and seemed to coincide with operations on the PGSC and in particular with non-DDCS software applications commanded by the crew.

The Spacelab Integration Contractor has conducted various tests with a flight Payload General Support Computer (PGSC) connected to an engineering model SFMDM at the software development lab in Huntsville to determine the cause of the failures that occurred during the mission. The SFMDM has not experienced any warm starts or core swaps while under test. A plan has been formulated to perform one day of testing at KSC post flight using the flight SFMDM, the flight DACA, and the flight experiments that connect to the SFMDM. This testing did take place and the problem is suspected to be a hardware problem in the SFMDM itself. The SFMDM has been returned to Huntsville for failure analysis.

The PGSC software performed nominally during the flight.

3.2.2 Lessons Learned

1. The display screens for the HOSC and JSC should be identical, where possible, to allow efficient communication between the sites during mission simulations and the mission.

2. One project document should control all flight and ground databases used during the mission and during ground check-out.

3.3 Mechanisms

3.3.1 Mechanisms Summary

Up until tether failure the performance of the TSS Deployer Mechanisms was nominal. No workarounds were required before or during deployment.

The launch lock released with a nominal (slightly fast) drive time. Bus voltage was higher than nominal at this time. This makes the drive time improvement as expected.

Reel motor checkout was nominal. Vernier motor checkout resulted in two observations:

1. Inboard/outboard tension differential due to the vernier motor was higher than during TSS-1. This motor is operated by an electronic driver that was modified since TSS-1 to cause a ramping of motor voltage during power-up. The current limit on the new box was at the high end of the specification limits; that of the old was at the lower end of these limits. The increase in drive authority of this drive system was about 15% at zero rate. The increase in motor torque was somewhat less than this figure, but the system performance losses magnify the relative effect of motor torque changes.

2. There was definite evidence of inboard slippage during vernier motor checkout. The tension returned to the plateau it had achieved during reel motor checkout (after brake application). The brake was clearly slipping at 50 to 55 N. This is much lower than the value achieved in TSS-1 or observed during 4S08 but was within design requirement limits for this device. This would not have been a problem at On-Station 1 since the Control Laws would maintain the on-station length with or without the brake applied. Also, if for some reason the Control Laws were disabled, the brake would not slip at that deployed length due to the small reel pack radius which results in a much smaller torque on the reel than during the vernier motor checkout when the pack radius is larger.

Latch operation was nominal for both groups. U-1 separation occurred properly with three full retract indications. Boom extension occurred with nominal drive time and currents. Only motor A was exercised. Two full extension indications were observed. Docking ring rotation was accomplished in both directions.

Flyaway was nominal. Both reel and UTCM losses were low to nominal. The UTCM losses appeared very low, but this is a computational illusion. The algorithm for the computation of UTCM friction requires knowledge of the motor characteristics. The values used for the JSC computation were based on the old (TSS-1) vernier motor, as this was characterized at system level on the s/n 001 controller but not yet characterized at system level for the s/n 003 (TSS-1R) controller. After correction for this effect the friction of the UTCM seems more comparable to that of TSS-1.

Reel Motor current was high compared to TSS-1 values. This is also due to the increased vernier motor output torque. The reel motor torque is commanded to be higher to track profile with the stronger vernier motor.

A rapid and worrisome increase in the temperature of the vernier controller was noted. Although this concerned us greatly during the initial deployment, the rate of increase eventually became small. The temperature essentially stabilized at less than the FDA limit (50° C) and in fact the FDA limit was increased to prevent an unnecessary alarm.

After the orbiter rotated to TEA a larger than expected change in outboard tension was observed. This change is due to losses incurred by the tether dragging across the UTCM bugle and the skiprope damper eyelet. Expected values for outboard tension were used to follow this effect through the remainder of the mission. In general, these losses were always about twice what was expected. It has always been assumed the damper eyelet losses were much smaller than those on the UTCM bugle. If this is the case, then the bugle coefficient of friction was twice what was measured during the UTCM TVAC JQAT test. The operating forces on the skiprope damper motors needs to be measured (roughly, at least) post mission. A TVAC test may also be warranted for one or more of these motors. Mission Specialist Jeff Hoffman also noted that, during the period of maximum rate, the damper spider was riding 10-20 cm high, deflected towards the satellite. Although not surprising, we had not observed this in ground test due to the effects of gravity on the damper spider.

The tether snapped at an indicated length of roughly 19695 m. There was no observable spike in tensions before or after the event. The rate prior to the event was about 1 m/s. Encoder motion ceased in a period of less than 250 ms. The point where the tether had separated was roughly halfway up the boom, with the end visible from the crew compartment.

After the failure the vernier motor was still powered and apparently continued to run. The temperature of the controller started to decline. This is consistent with the motor being run in the no load condition, where the dissipation of the switching resistors would be greatly reduced. It is apparent that the unit was running at greatly reduced loads. After some time, power was removed from the unit.

The following day the reel motor was used to retract the tether from within the boom onto the reel. This was accomplished by stepping up the reel motor pulse width in steps of 5, waiting ten minutes for evidence of motion, and then again increasing the pulse width. Some evidence of motion became apparent at a PW of 30. Clear evidence of motion occurred at 35 PW, where the system remained until retraction was assured. During retraction a steady velocity of 0.008 to 0.009 m/s and a steady state inboard tension of 0.3 N were observed until the end of the tether apparently passed through the LTCM. The reel was left turning at a PW of 35 until a period adequate to assure full retraction had elapsed.

The boom was retracted. Current during the retraction was judged to be high, but not excessive. Boom retraction time was also increased somewhat above nominal. Both boom retract indicators showed full retract. Both latch groups were closed. Proper closure signals were indicated.

3.4 Dynamics

3.4.1 Dynamics Summary

In general, the dynamic behaviors of the combined tethered system up until the tether break can best be described as nominal. While some interesting phenomena were observed, preliminary analysis indicates that the system was well behaved and in most areas matched preflight predictions quite closely. Presently, detailed data reduction and analyses is just beginning, so in some areas the discussion will be brief and perhaps even speculative. The intent, however, is to present as broad a perspective as possible of the dynamic performance of the TSS-1R system.

From a true dynamics standpoint, the behavior of all the subsystems involved in TSS-1R (deployer, satellite, tether, orbiter, etc.) have a profound impact on one another. However, for purposes of this report they will be separately discussed. The dynamics of the deployer will be discussed first, followed by the satellite performance and then the predominate dynamics of the tether, including skiprope.

3.4.1.1 Deployer Dynamics

The deployment in general went very much as expected. The outboard tension shown in Figure 1 (reference Appendix D) gives a good overview of the deploy timeline. The outboard tensiometer is saturated pre-flyaway. At flyaway, the tension drops to the level produced by the action of the inline thrusters. Inline 1 (IL1) is turned off at about 1 deployed meter. At 5100 seconds, or 1100 meters, IL2 is turned off (this was later than planned due to low net tension). Some of the DACA segment transitions are evident on this plot as well, causing abrupt tension changes due to changing deployment rates. At about 9000 seconds, or approximately 6 km, the orbiter attitude changes from pointing the deployer boom along the tether (line-of sight) to a torque equilibrium attitude (TEA). This attitude causes the tether to wrap slightly over the exit bugle, increasing friction outboard of the tensiometer and thus raising its reading.

The deployer performance during flyaway was generally as expected. The effects of the flyaway changes that were made for TSS-1R produced a relatively smooth, controlled flyaway, as illustrated by the tether rate shown in Figure 2 (reference Appendix D). The vernier motor ramp up and the length error ramp out (accomplished by the "d" parameter) allowed tether motion about 25 seconds after the deploy command was issued, as expected.

Overall, the deployment progressed nominally. The deployer tracked the DACA commanded length and length rate within expected bounds. The encoder length and length command are shown in Figure 3, and the rate and rate command are shown in Figure 4 (reference Appendix D). The actual rate sensed by the encoder did seem to be more noisy than expected, and more so than experienced during ground hardware testing. This was most obvious in the vicinity of about 15 km (near maximum deployment rate). Since the nominal pulsewidth is closest to saturation in this region, and the sensed rate is used to compute the pulsewidth command while the motor is operating in generator mode, the erratic rate signal did cause frequent pulsewidth saturation during this time. This can be seen in the pulsewidth plot of Figure 5 (reference Appendix D). Since the pulsewidth saturated only briefly, it had little effect on the deployment rate or control of libration. The cause of this rate signature is not presently known. Since it can also be seen in the tensiometer data, and more importantly the satellite accelerometer data, it is possibly due to longitudinal waves "traveling" along the tether. These would not have occurred during ground testing.

The orbiter Ku-band rendezvous radar achieved lock on the satellite at about 25 meters, providing additional sources for length and rate and the primary source for libration measurements. (The satellite AMCS also provided a libration source until active spin was initiated.) The open loop in-plane libration control (via control of tether reeling rate and length) performed as expected. Figure 6 (reference Appendix D) shows the in-plane libration (as measured by the radar) along with the commanded angle from the DACA profiling software. This shows the excellent tracking of the commanded libration, for the most part to within 1 degree. The exception is during the initial flyaway period, when this motion is controlled primarily by orbiter maneuvering. Figure 7 (reference Appendix D) shows the out-of-plane libration angle, which ideally should be zero, and is not controlled. The solid line is from the radar, and the dashed line is from the satellite AMCS. An initial out-of-plane motion is evidenced from the satellite libration source, with deviations in excess of 10 degrees occurring shortly after flyaway. This reaffirms the crew report that they had to roll the orbiter to manage the out-of-plane libration. This same behavior was experienced during STS-46, with the explanation being a lateral leak of the in-line thruster nozzle assembly. Since this assembly was redesigned to be "leak proof", another cause must be underlying this behavior on STS-75. The larger excursions of the satellite source libration data on Figure 7 (reference Appendix D) are due to attitude excursions during auto rate damping checkout, not out-of-plane libration.

3.4.1.2 Satellite Dynamics

Overall the dynamic behavior of the satellite appeared to have been nominal. As mentioned before, there was some initial out-of-plane libration that is as yet unexplained. However it was easily controlled by orbiter maneuvering. The most significant behaviors concerning the satellite involve the auto rate damping checkout, satellite spin, and pendulous motion.

Figure 8 (reference Appendix D) shows the satellite pitch and roll rates. The ARD checkout was performed per the Dynamics Book procedure, with the satellite ARD operating as expected. This event produced the large pitch and roll rates around 4000 seconds after flyaway. Although the scale is too large to show the pendulous frequencies clearly, pendulous motion was observed throughout the deployment. The pendulous frequencies closely matched the expected frequencies, and the motion was well behaved. The obvious sinusoidal signature occurring in pitch and roll rates, beginning around 6000 seconds, is due to the satellite spin combined with orbital rotation rate. The yaw rate illustrated in Figure 9 (reference Appendix D) clearly shows the buildup of spin rate, beginning when the satellite was set to passive mode around 5500 seconds. The tether twist torque slowly spun up the satellite, and after the active spin control was enabled, the AMCS fired yaw thrusters to periodically slow the spin. The tether torque can be deduced from the slope of the yaw rate curve, reaching a maximum of about 0.0009 N-m at around 11 km. The torque began to subside, as evidenced by the "flattening" sawtooth slopes at around 16000 seconds. The twist torque had practically disappeared by the time the tether broke.

3.4.1.3 Tether Dynamics

The tether behavior represented the area of greatest uncertainty prior to the mission. Since there are few, if any, direct measurements for most tether behaviors, they remain the most elusive and difficult to quantify at present. Overall, the tether appears to have behaved dynamically as expected, offering few surprises.

The frequency or period of the bobbing (plum-bob) mode can be deduced by close observation of tension and satellite acceleration data. This period should provide a means of determining a composite tether stiffness (AE) value. At flyaway, the period of bobbing was about 2 seconds, resulting in an AE value in the nominal range. At longer tether lengths, however, the correlation of bobbing period with day/night cycling results in AE values that go counter to the expected variation of AE with temperature. This will require more analysis.

A more widely known phenomenon that was observed during the deployment has been referred to as "the bow". During periodic reports, the crew noted that they could observe a large bow in the tether as it stretched from the boom tip to the satellite. Although they could not estimate its amplitude, the repeatedly emphasized its "huge" appearance. Presently, it is believed that this bow was actually nominal in amplitude. Although preflight simulations of tether motions (such as skiprope) were never thought to precisely predict correlated spatial and temporal responses during the mission, they were believed to reflect expected envelopes of typical tether motions. These simulations did predict tether bowing during deployment (on the order of 25 to 50 meters maximum mid node deflection). This bow is due to the combined actions of Coriolis, electrodynamic, and aerodynamic forces, all of which deflect the tether rearward during deployment. The question, then, is one of measuring the size of the bow observed during TSS-1R, and finding whether it lies within the predicted envelope.

The methods available for measuring the amplitude of the bow are many and varied. The skiprope observers, to be discussed later, are one. A second but related method involves more precise reconstruction of the satellite attitude, which has yet to be done. A third involves comparing the straight line range between the orbiter and satellite to the actual (stretched) deployed tether distance. The difference between these two measurements can be related to the amplitude of an assumed bow shape (e.g. half sine wave). This has been done, but the straight line range measurement must come from the radar range, and this measurement has very large uncertainties (relative to the sensitivity of the calculation), as does the actual stretched tether measurement. Finally, visual comparisons between simulated data and flight video can yield an indirect measurement, at least to some order of accuracy.

This latter approach has been initiated, with the aid of a 3-D animation program. Figure 10 (reference Appendix D) illustrates a “zoomed-in” snapshot of what an observer stationed on the aft flight deck would see if they were looking at the satellite at 16 km deployed length. Although it appears quite large, the actual amplitude of the bow (mid point deflection of the tether) for this case is about 50 meters, oriented about 15 degrees out-of-plane. This comes from the preflight simulation of the "nominal" case, which includes all known tether disturbances. The field of view of the zoom lens is 2 degrees, with the satellite in the center of the image. If one “zooms out”, the apparent size of the bow decreases. With no zoom at all (naked eye), the bow is barely detectable. This illustrates that optical effects can present the appearance of a very large bow, with fairly small actual tether deflections. Upon initial review of the sequences of this animation, members of the STS-75 flight crew commented that the animation appeared very much like what they observed in flight. The next step in this process will be to use flight video (taken under known optical configurations) to correlate with the animation tool.

3.4.1.4 Skiprope Observers

Although their real "action" was yet to come, the performance of the skiprope observers during the deployment can generally be considered nominal (in so far as that they executed and produced "reasonable" outputs). The question remains as to whether the observers' outputs can be correlated to what actually occurred during the flight. Although the outputs created by the observers during the mission was archived, the present plan involves re-executing the observers with post mission data. This will provide "cleaner" data to the observers, and allow for some optimization or fine tuning of the observer execution. This effort is only beginning to get underway. Nevertheless, an example of the output of the Time Domain Skiprope Observer (TDSO) is shown in Figure 11 (reference Appendix D). This figure depicts 1000 seconds of motion of the mid-point of the tether, looking along the tether axis, from 14000 to 15000 seconds (in the vicinity of 15 km). This represents the region of maximum deployment rate, where the observers were never really designed to operate. Despite this fact, based on the amplitudes and the general motion of the trace, the outputs appear to be "reasonable" based on pre-flight predictions.

3.5 Thermal

3.5.1 Thermal Summary

This section briefly documents the overall performance of the TSS deployer Thermal Control System (TCS) and provides a graphical record of measured deployer temperatures throughout the mission (reference Appendix E). Although the TSS portion of the mission was shortened due to the tether break, temperatures were monitored throughout the mission.

As an overall assessment, the deployer TCS maintained most of the hardware within worst case design temperature limits and all hardware well within its qualification limits. Prior to the reflight mission, design limits were established by MSFC while timeline predictions were performed by Rockwell. Qualification limits, the limits to which the individual hardware components were actually tested, remained unchanged from the original TSS-1 mission and were established by Martin Marietta.

The first page of Appendix E shows the overall TSS-1R hardware layout, while the second and third pages provide locations and descriptions of all deployer flight thermistors. Figures 1 through 15 of Appendix E plot deployer thermistor temperatures for the entire approximate 375 hour on-orbit mission.

Figure 16 plots the approximate average deployer temperature under the MLI "tent", while Figure 17 shows the freon inlet temperatures. Applicable design and qualification temperature limits are also listed on each plot.

After reviewing the flight data, the following items of interest are noted:

a. In comparing the preflight predictions with flight data, the average deployer temperature under the MLI "tent" was predicted to be about 5 ° C at satellite fly-away, vs. about 4 ° C per flight data. Also, at the time of the tether break, this same average temperature was predicted to be about 2 ° C vs. about 5 ° C per flight data. Since the actual orbiter attitude timeline, after the TSS portion of the mission, did not match the expected timeline, pre/post-TSS flight comparisons are not applicable for the post-TSS mission phase.

b. As shown in Figure 13 of Appendix E, the vernier motor and its electronics exceeded their 28.5 ° C design limits, with the motor reaching about 47 ° C and the electronics about 35 ° C. After reviewing the preflight timeline predictions it was found that their rate of temperature rise during deployment was higher in the flight data. However, neither the motor nor the electronics approached their qualification limits of 80 ° C and 65° C, respectively. This difference implies that a problem exists with the tip canister thermal models, which will be reassessed if the model is used for future flights.

c. The latch motor temperatures (Figure 6 of Appendix E) slightly exceeded their predicted +7.1° C design limits, but remained well below their +73° C qualification limits. Although this exceedence is not significant, it could imply a slight problem with the latch thermal models, such as the effective emittance assumptions for the MLI blankets covering much of the latch motors. This will also be revisited if the models are used in a reflight.

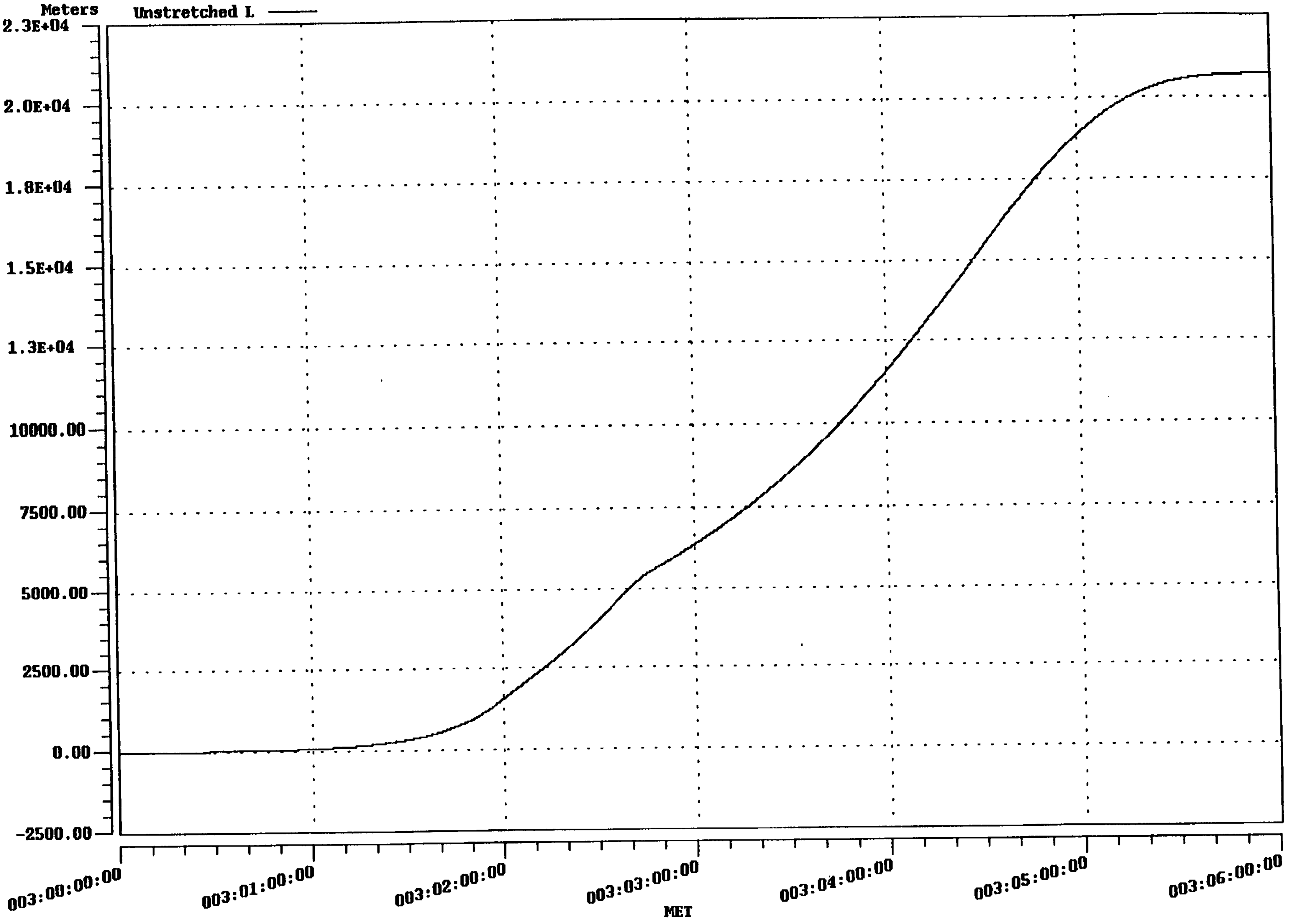
d. The only deployer TCS heaters activated during the mission were those of the satellite restraint latch motors and possibly, the vernier motor electronics. The latch motor heater on/off set points are -17.2/-12.2° C, while those of the vernier motor electronics heaters are -3.9/1.1° C. Since the satellite was lost, the large "hot nest" heaters, located in the upper satellite support structure, were not activated.

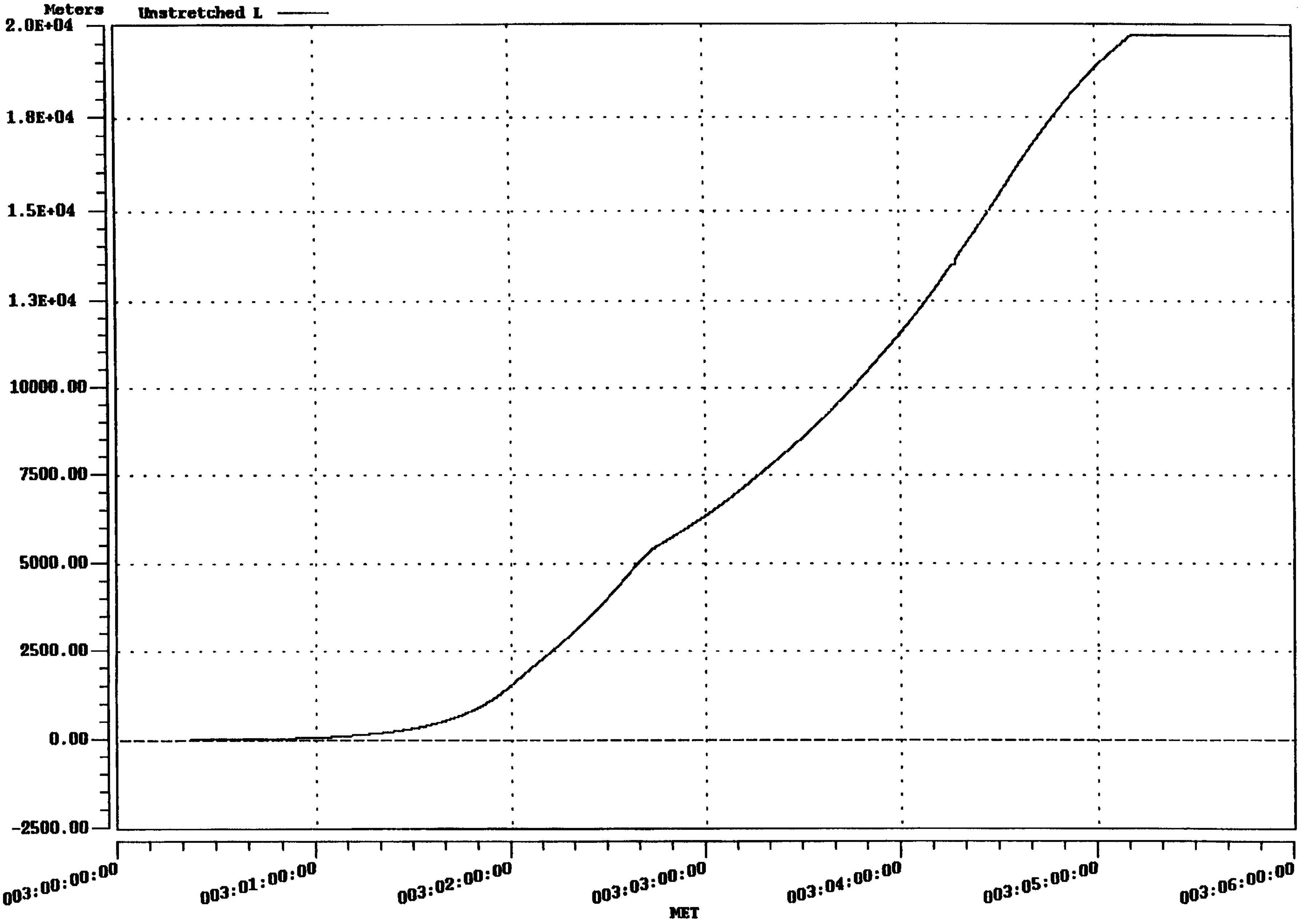
e. Freon temperature loop inlet temperatures remained around 10° C during the TSS portion of the mission and never exceeded about 23° C for the remainder of the mission. Although the pre-mission upper design limit was 16.7° C, the 23° C experienced during the post-TSS portion of the mission was not a problem for any coldplate mounted deployer electronics boxes, which remained at least 20° C below their upper qualification temperature limits.

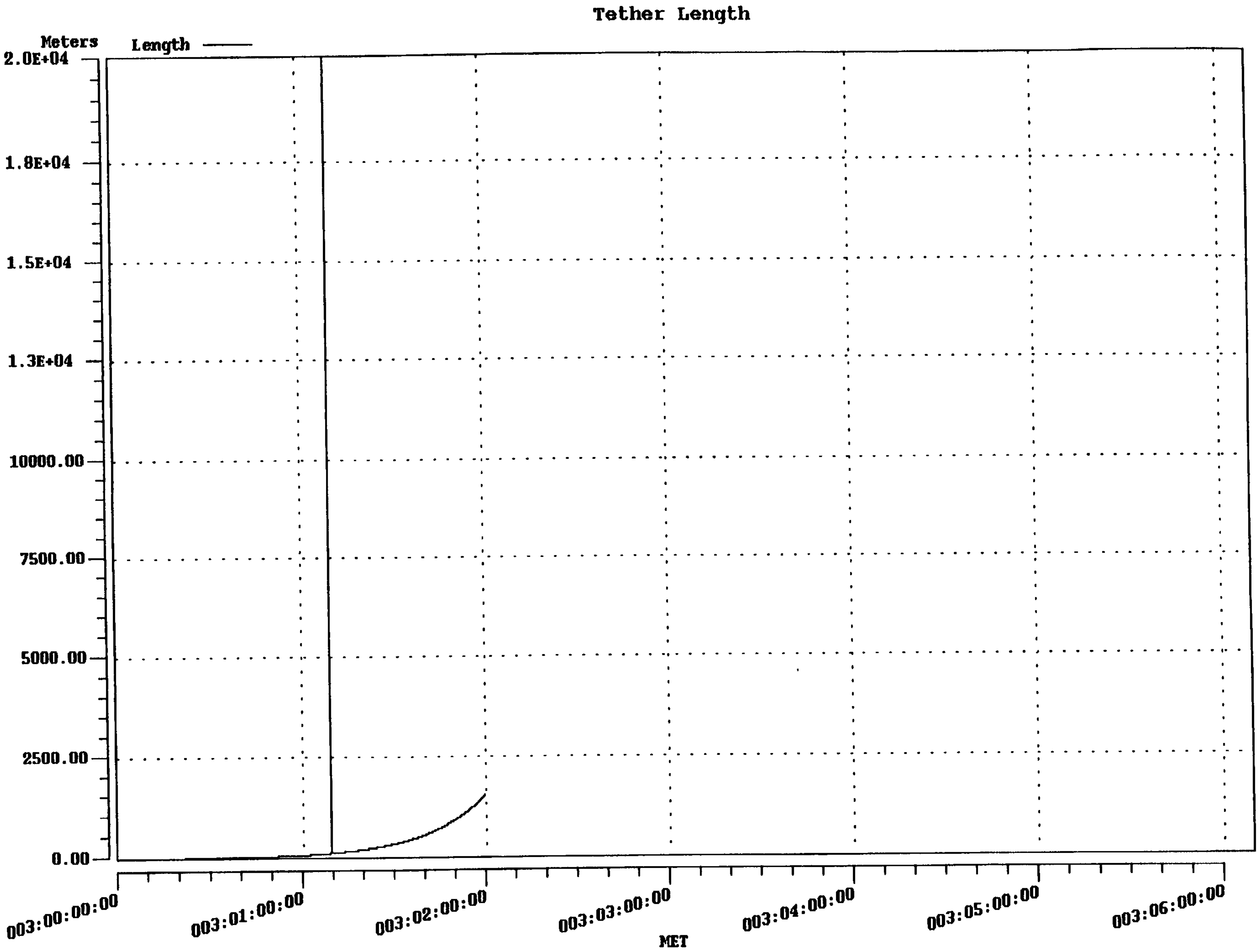
In summary, the deployer TCS performed well at maintaining all hardware within established qualification limits, although some preflight design temperatures were exceeded. The deployer IPL thermal model, for the most part, represents the on-orbit thermal response of the deployer components with reasonably good accuracy. If the hardware reflies, however, the tip canister and satellite restraint latch thermal models will need reassessing, in order to improve their accuracy.

Appendix A Deployer Data Plots

Commanded Tether Length




Spooled Tether Length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1.3E+04
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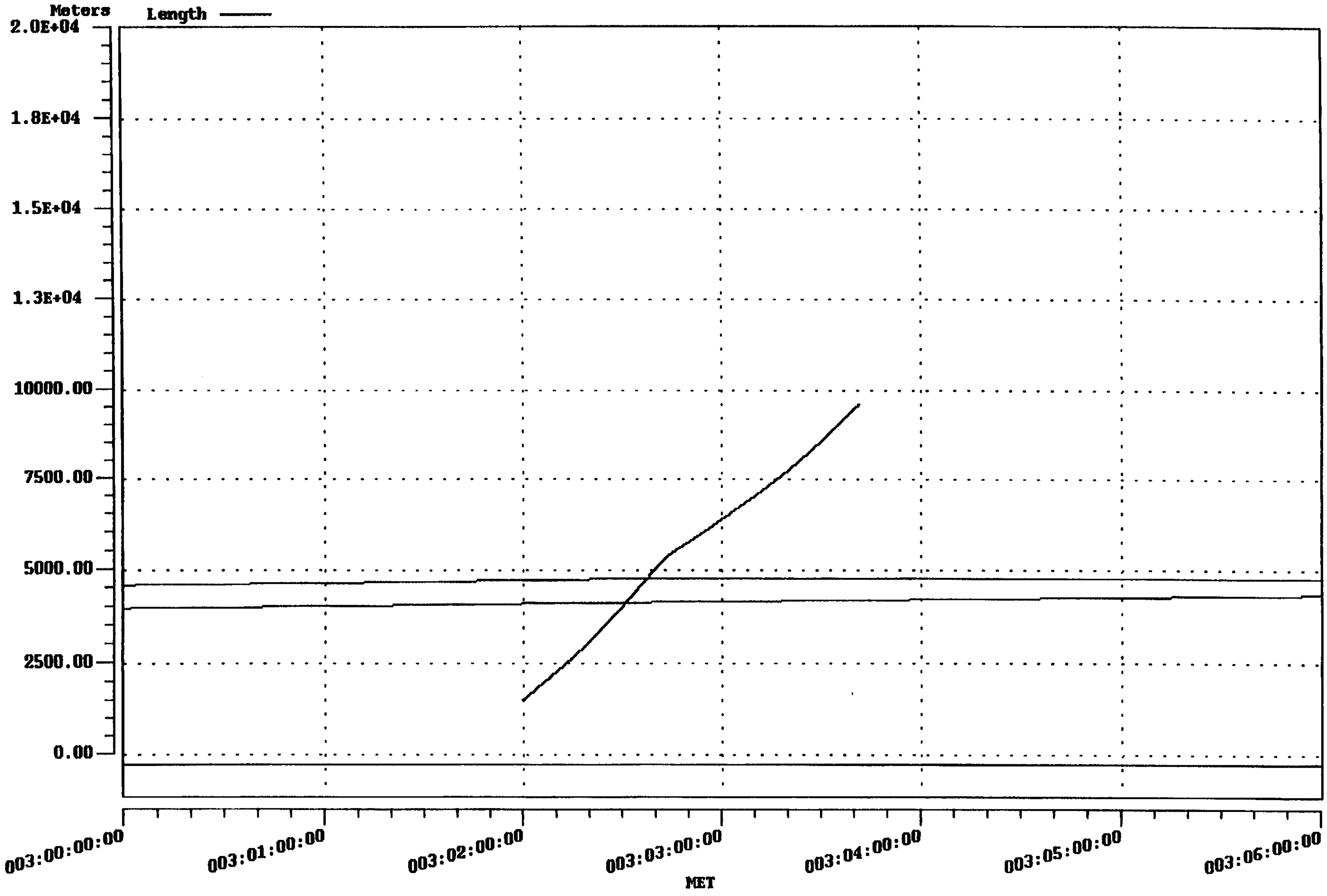
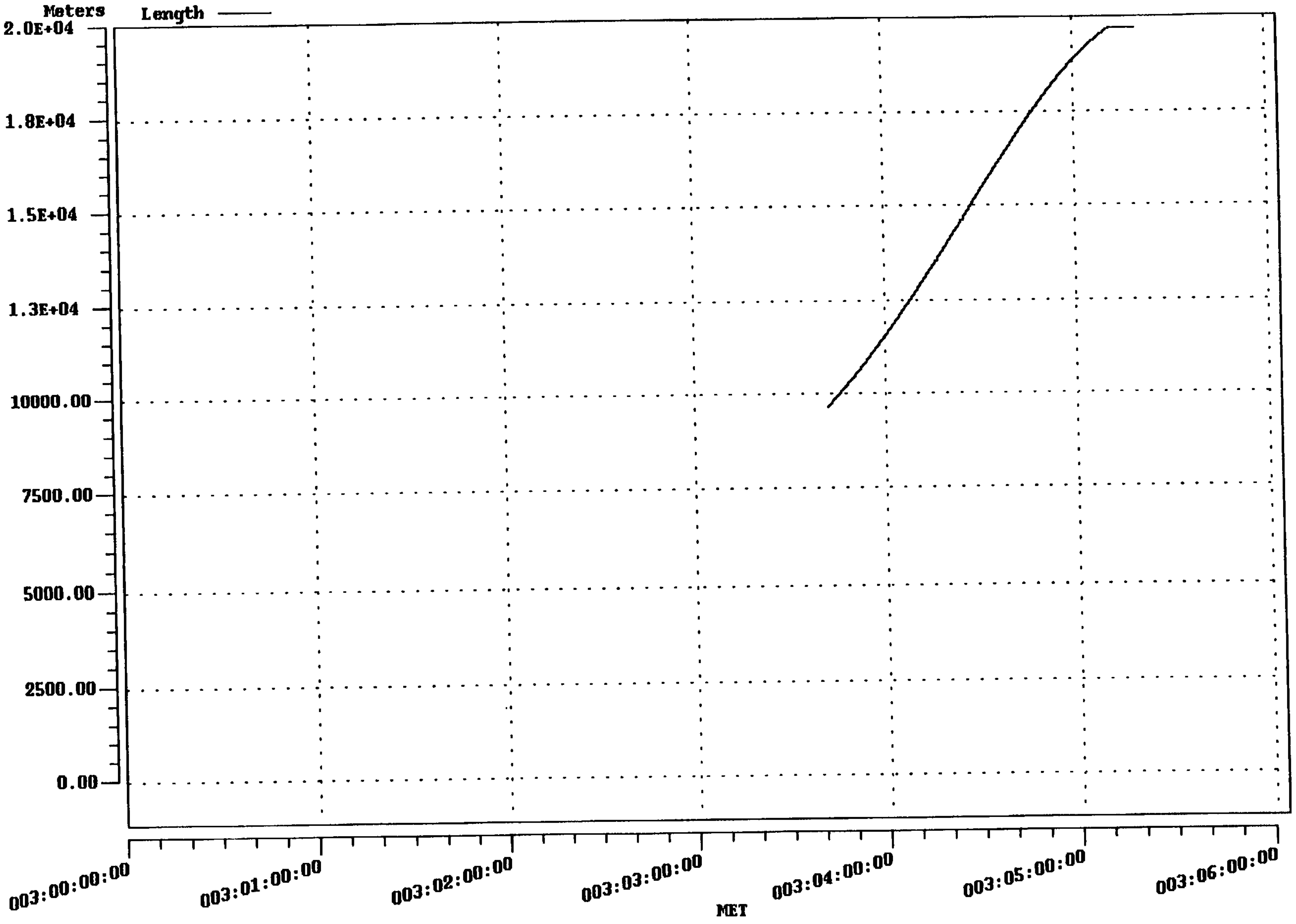
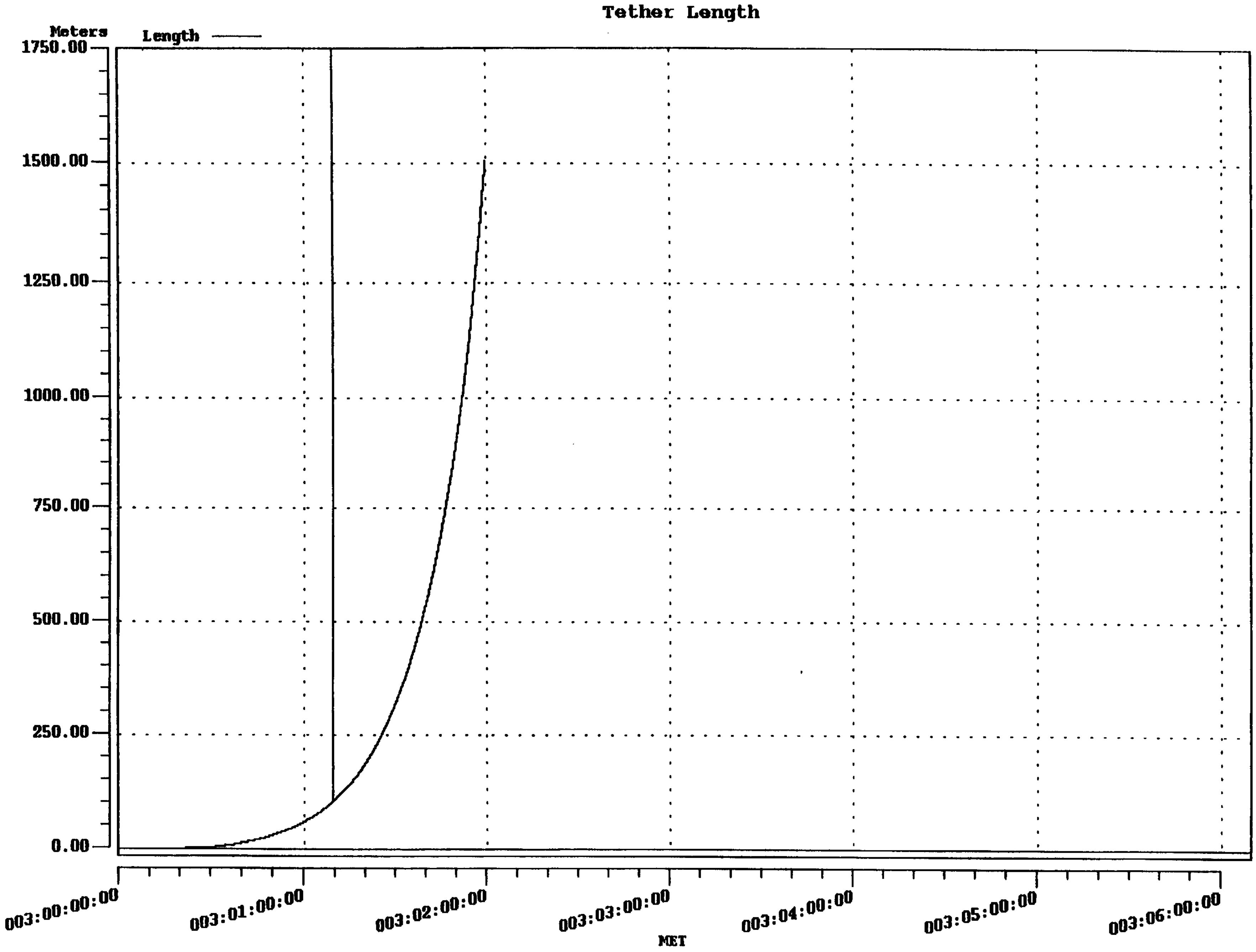


Tether Length

Tether Length

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Meters
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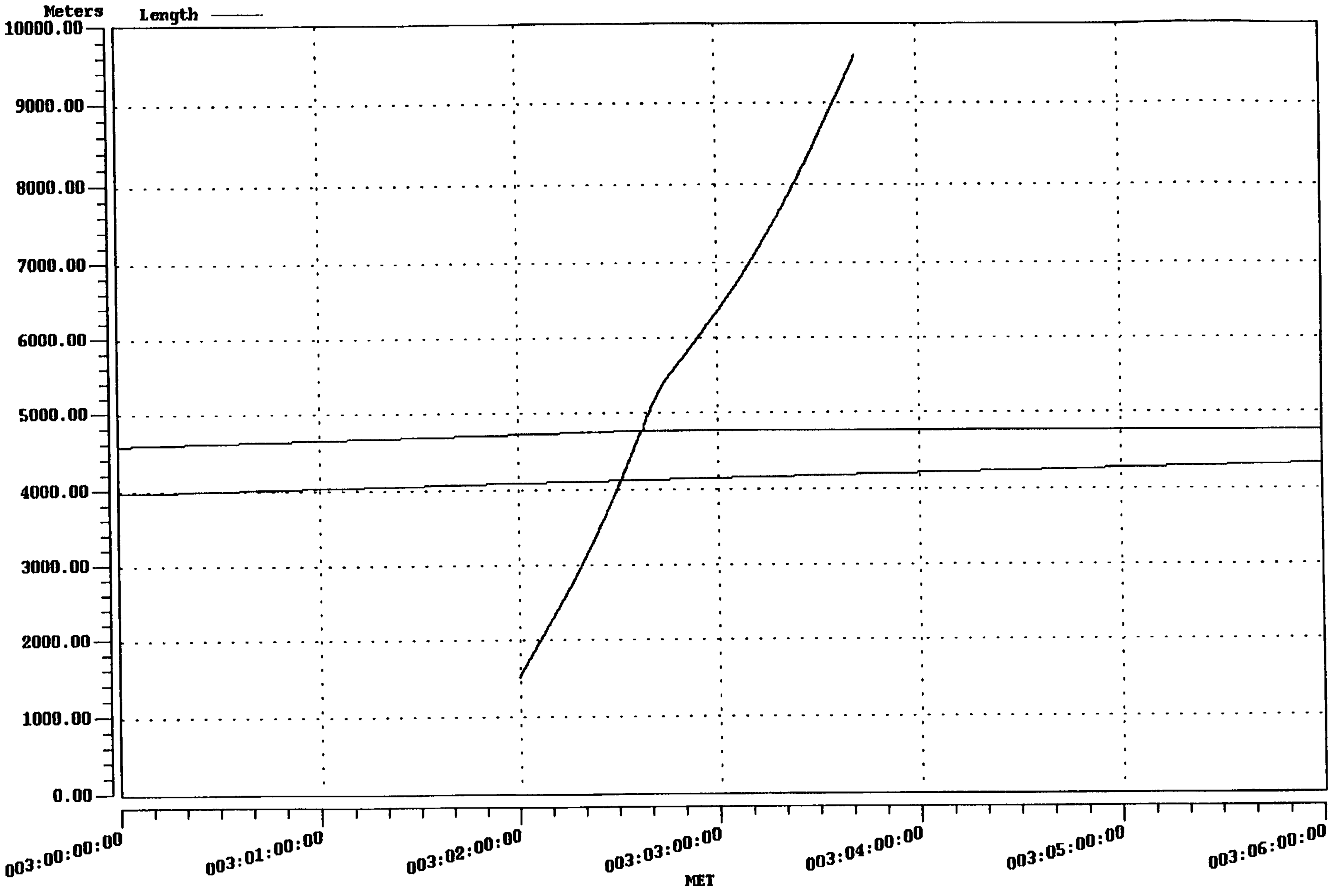
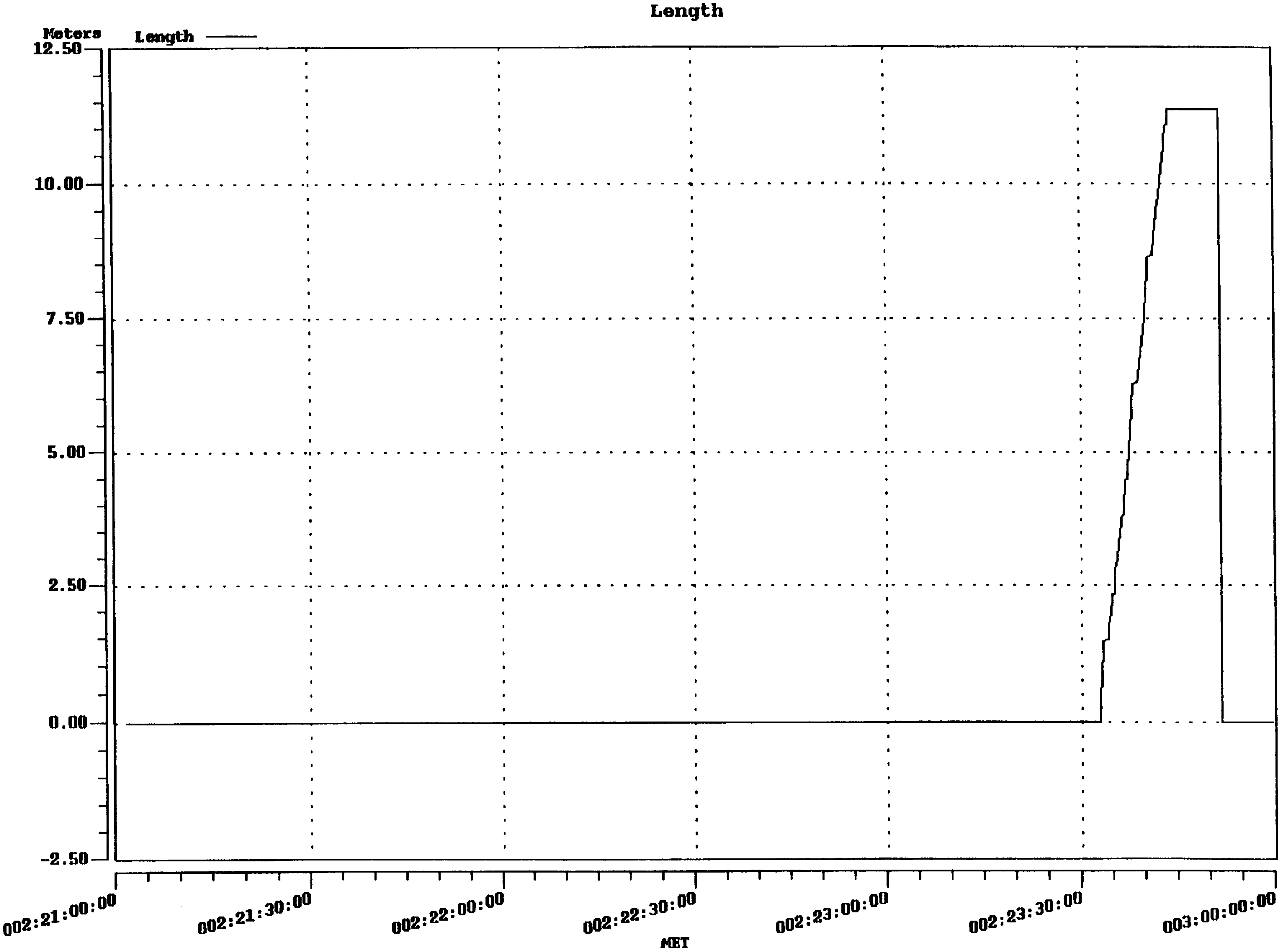
MET

Tether Length

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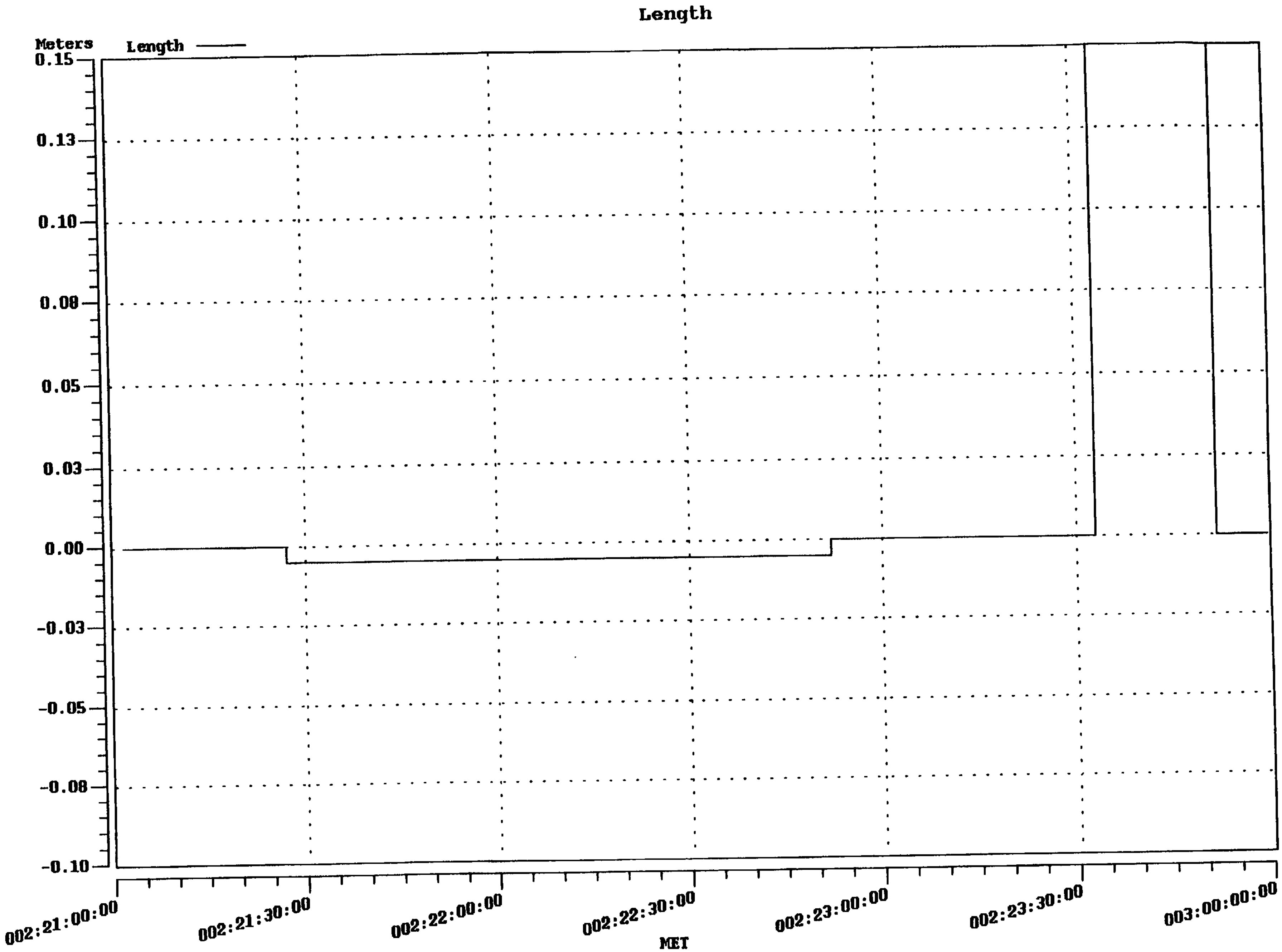
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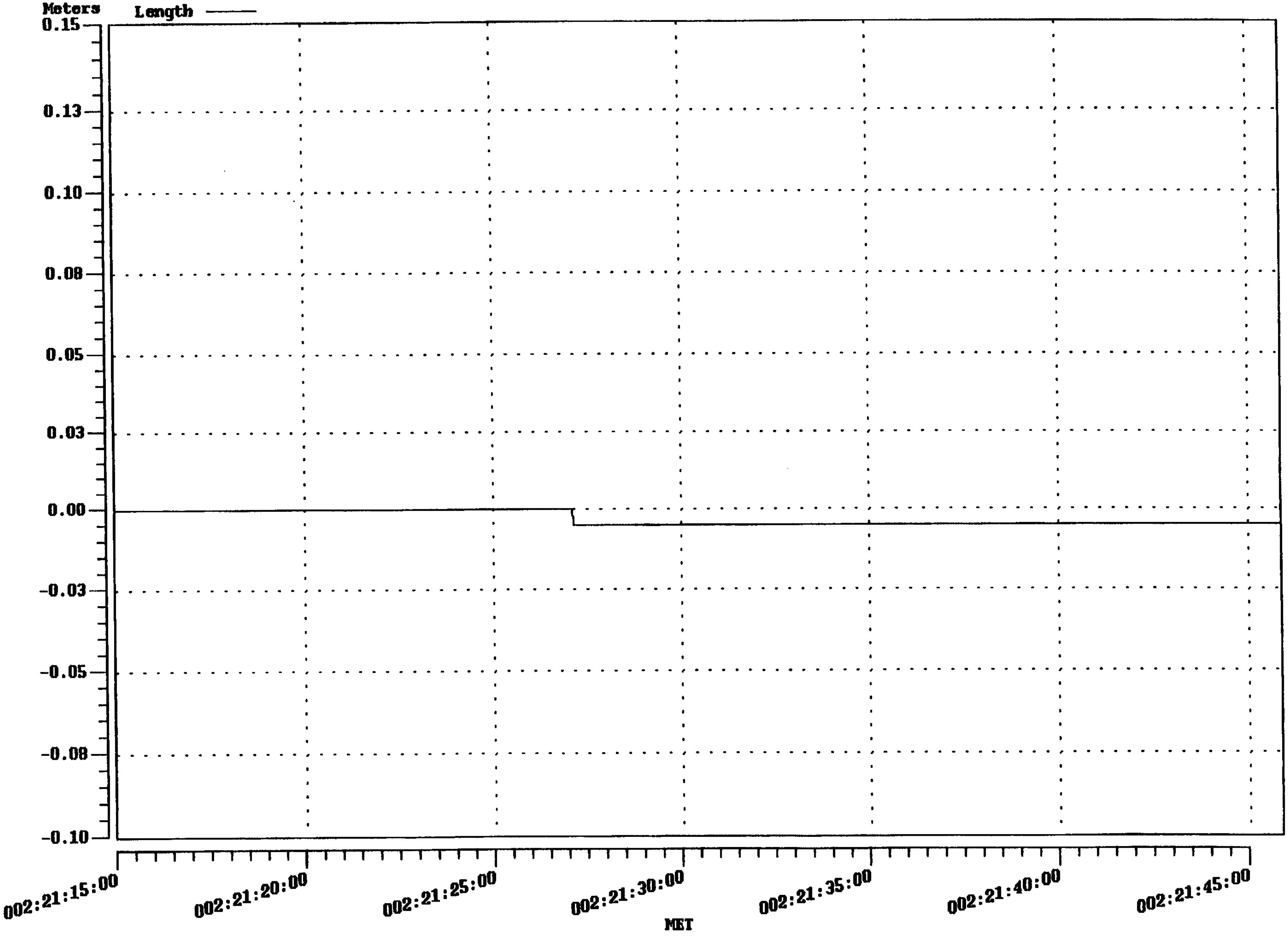
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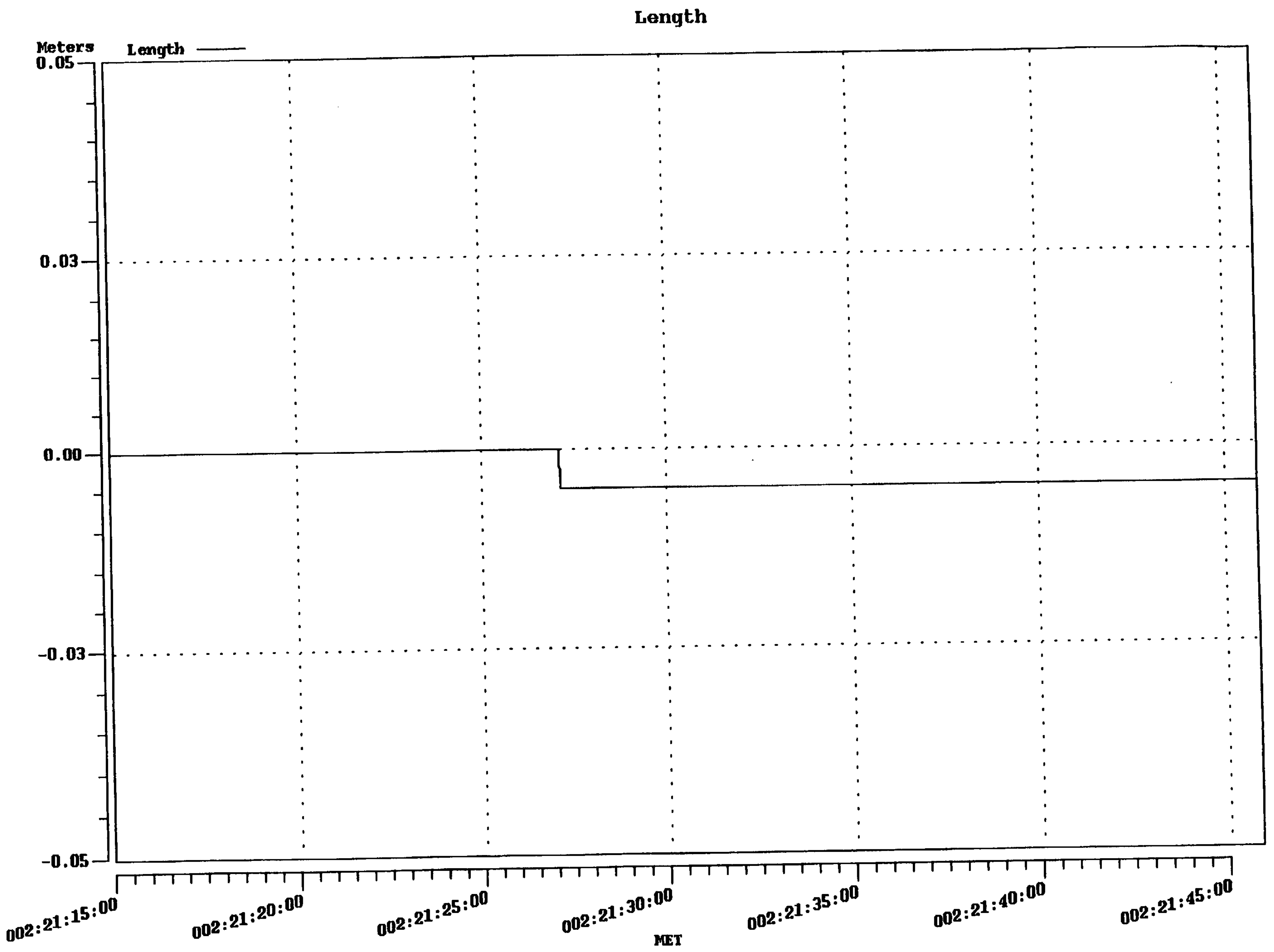
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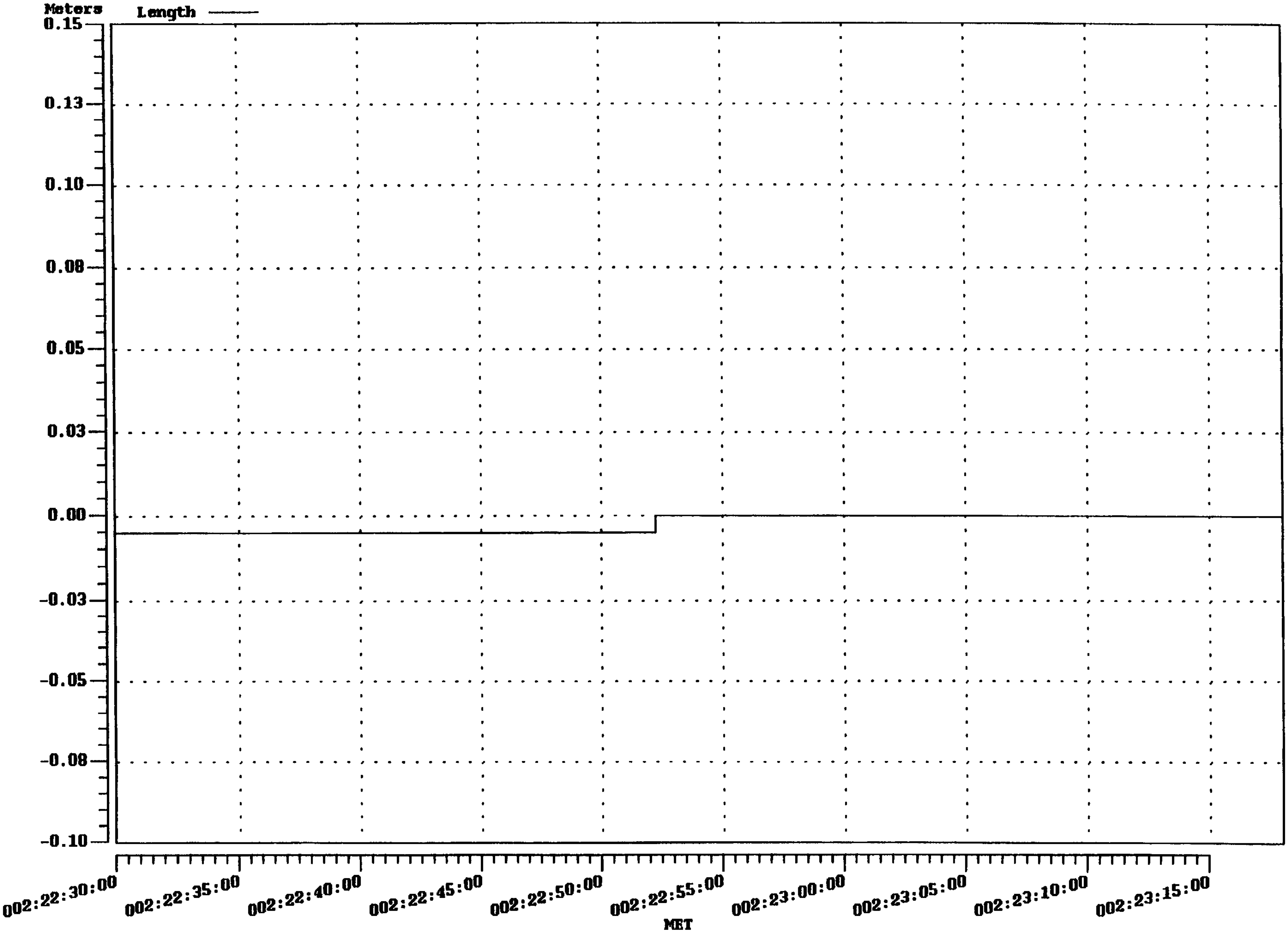

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-0.10
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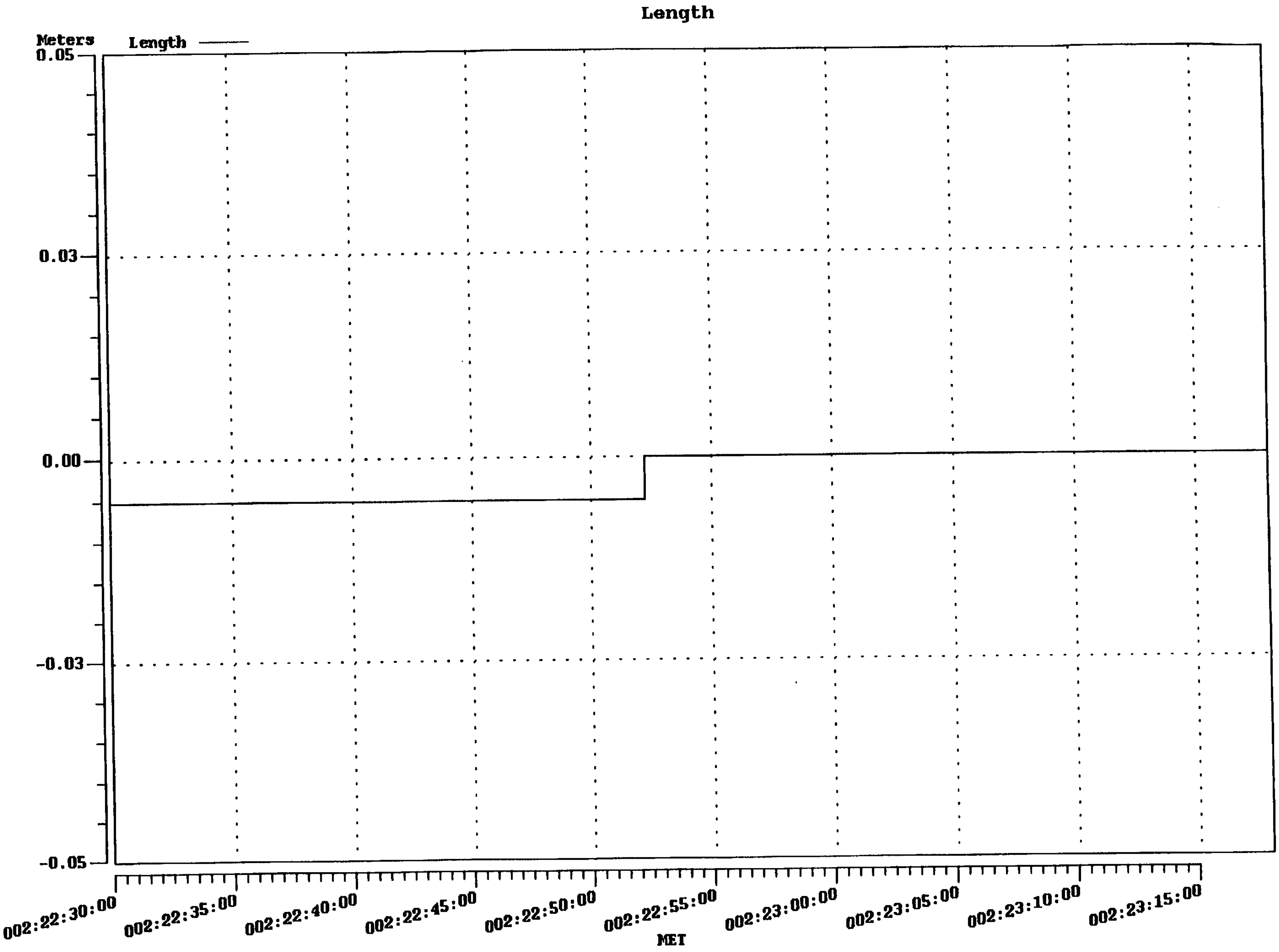
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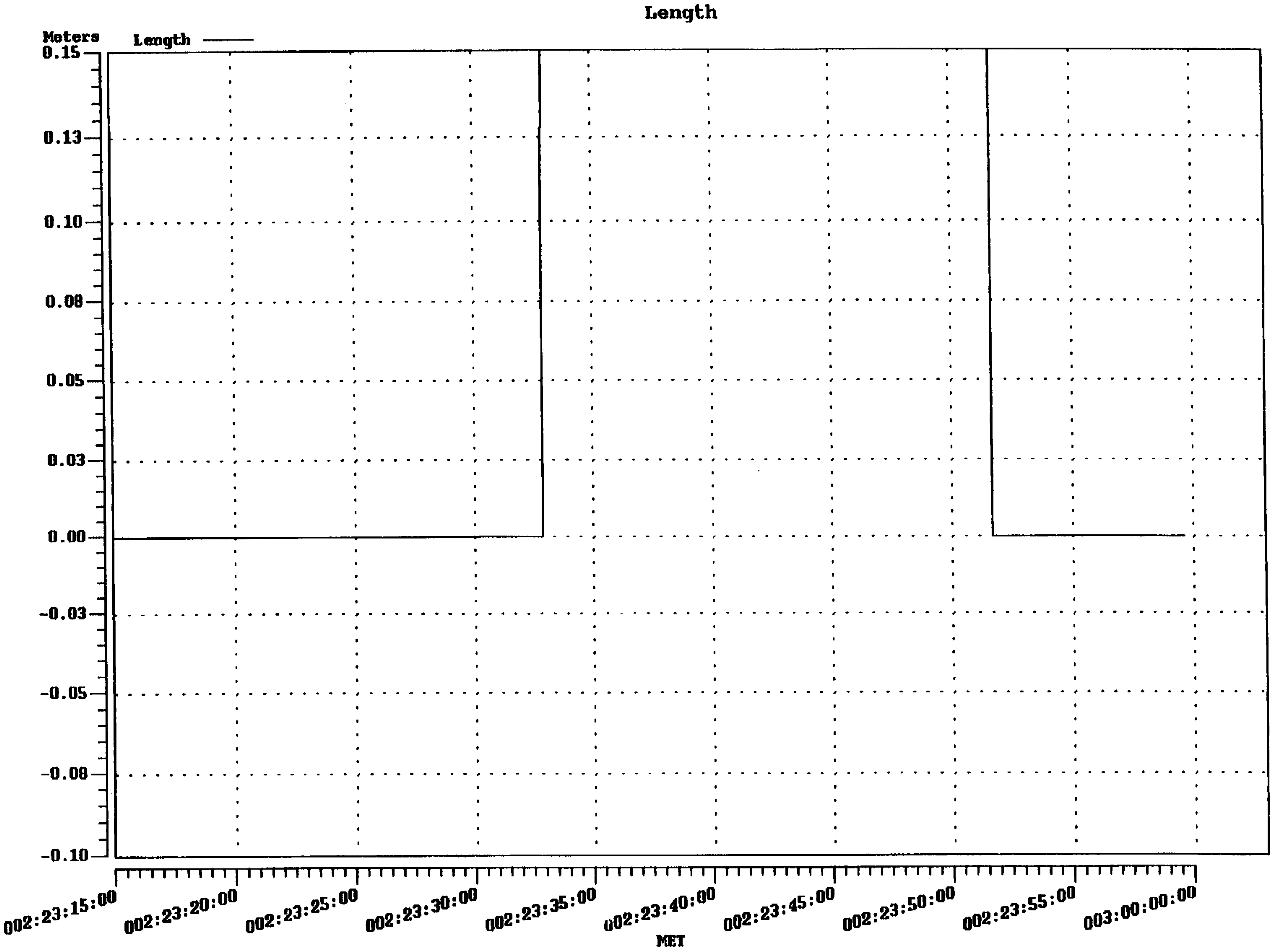
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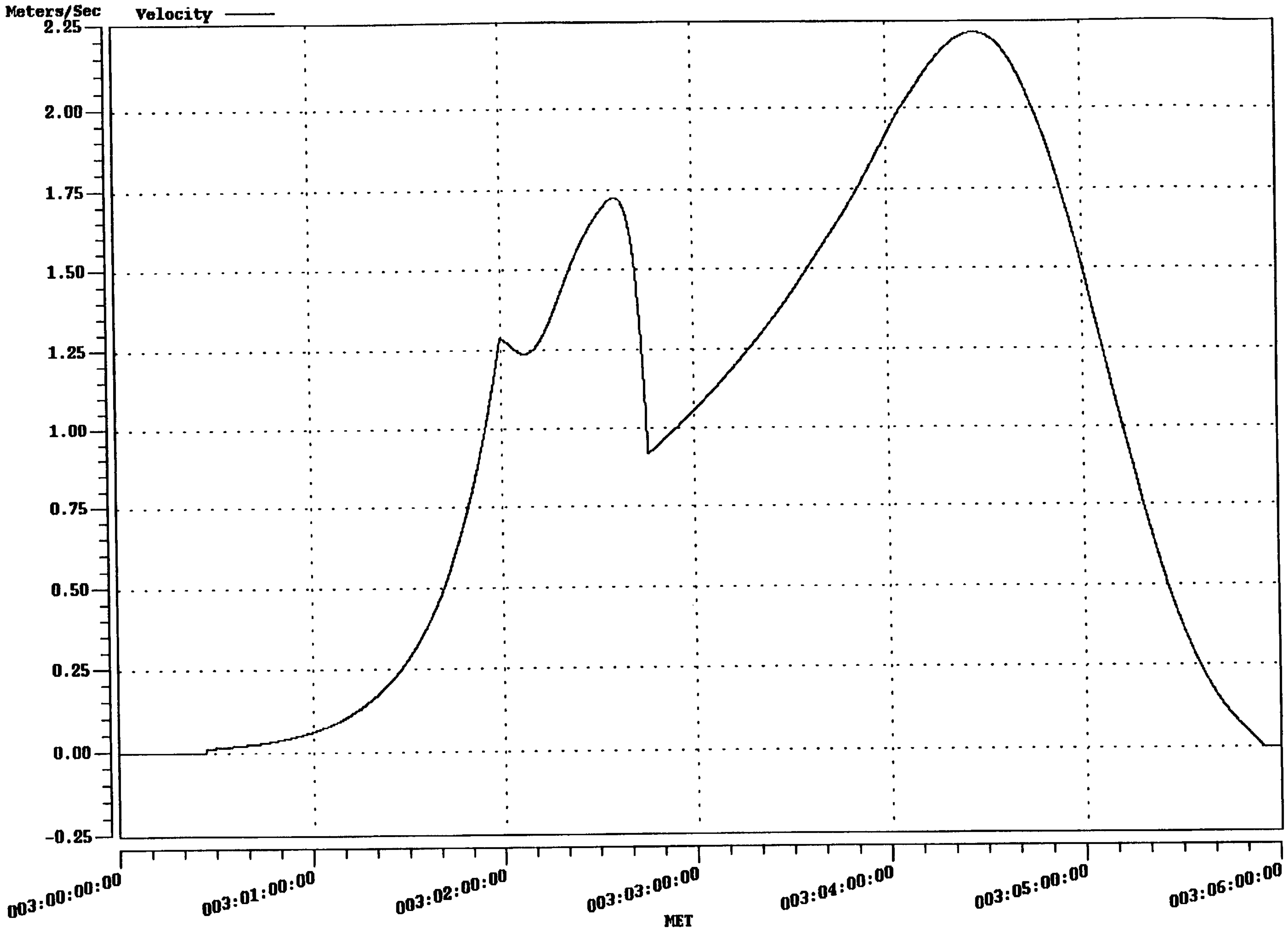
MET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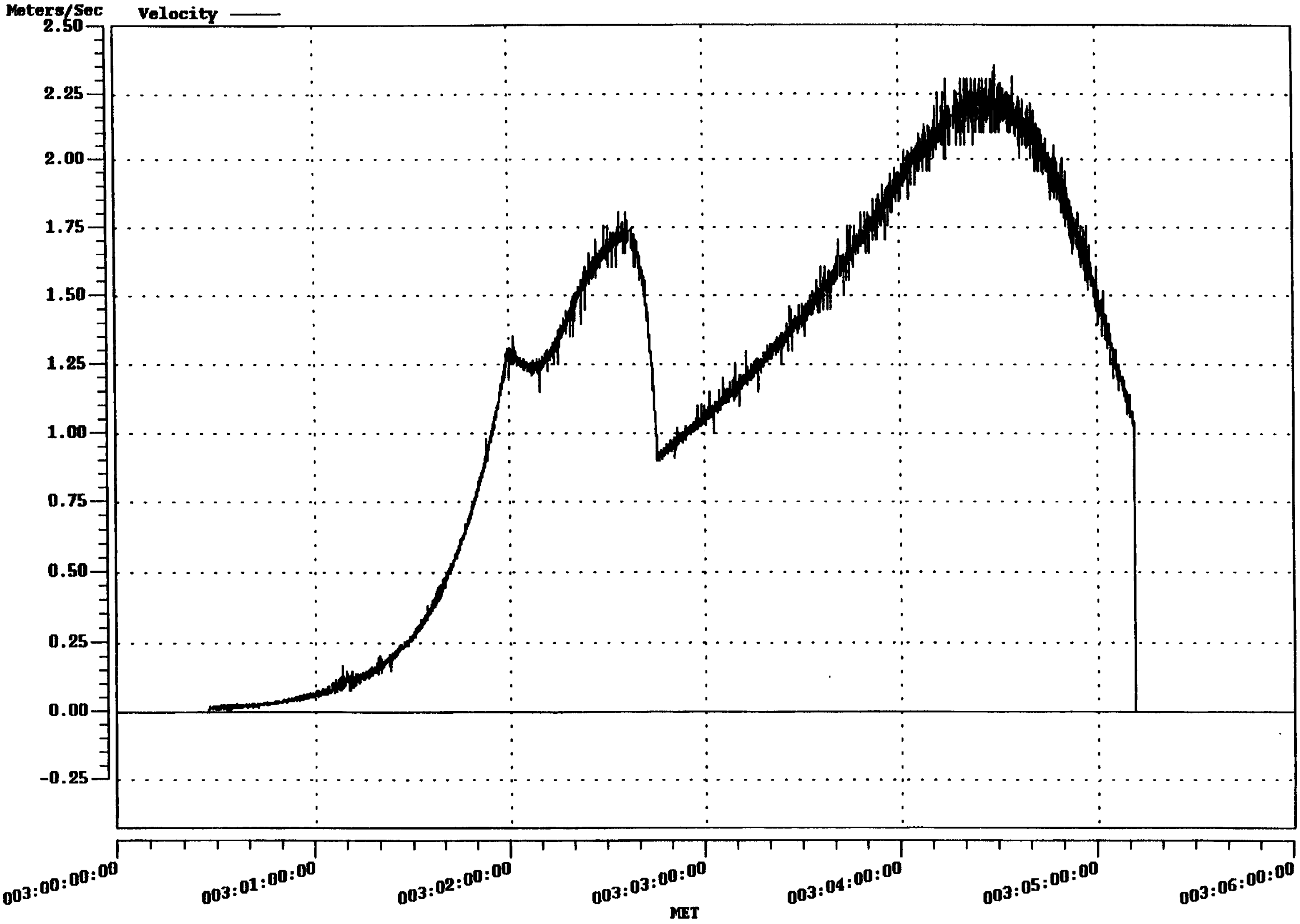
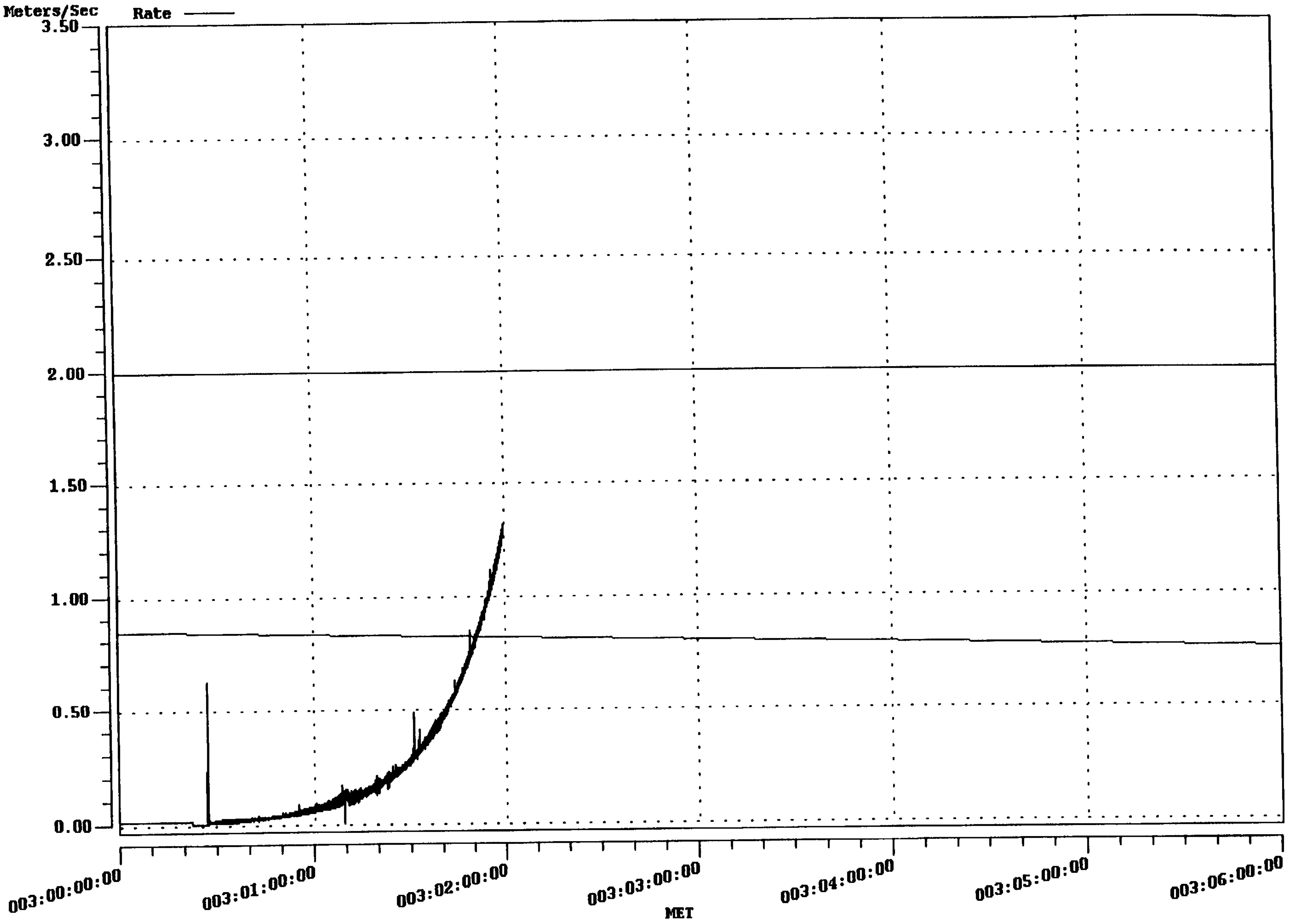


Spool Tether Velocity

Tether Rate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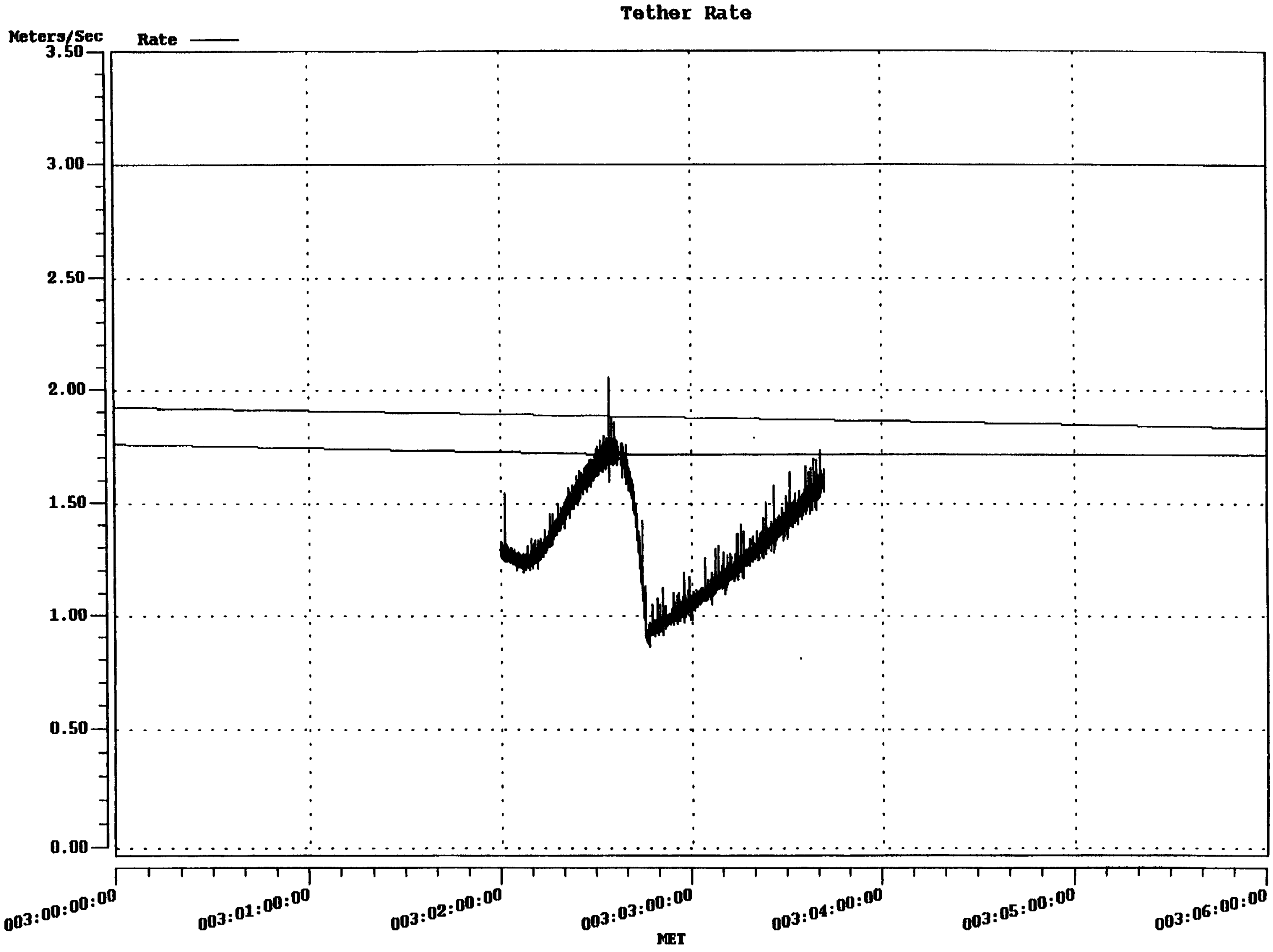
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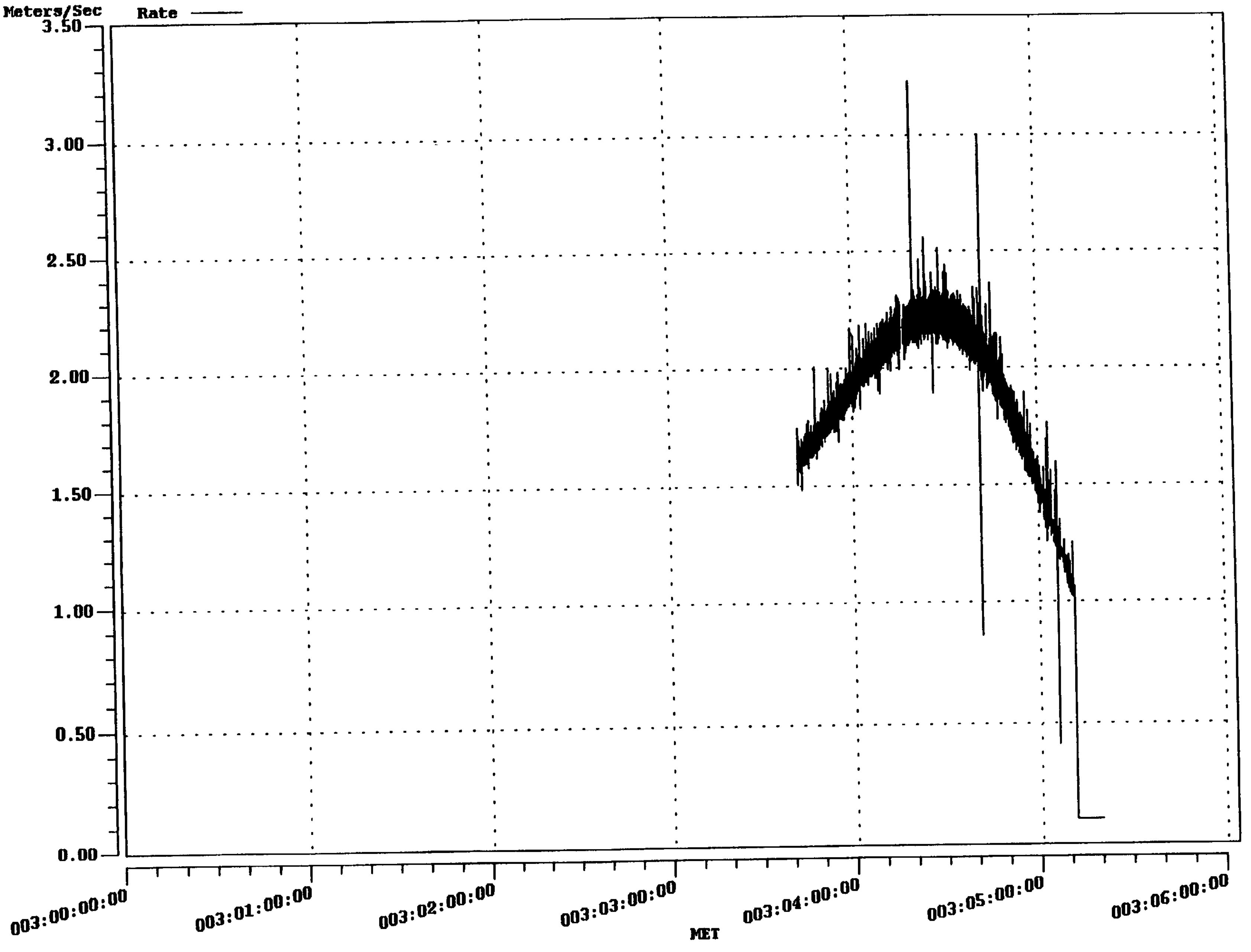

Tether Rate

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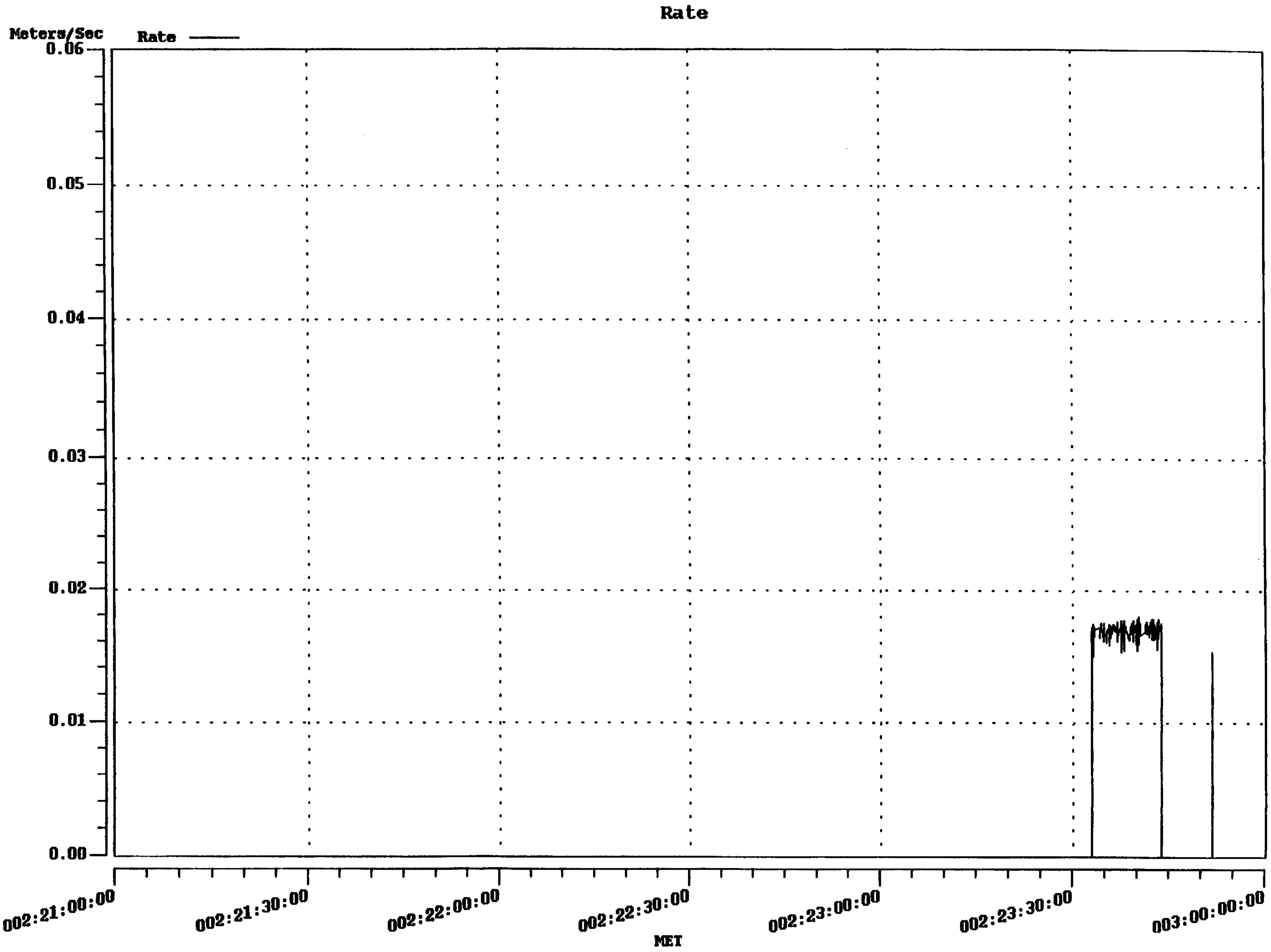
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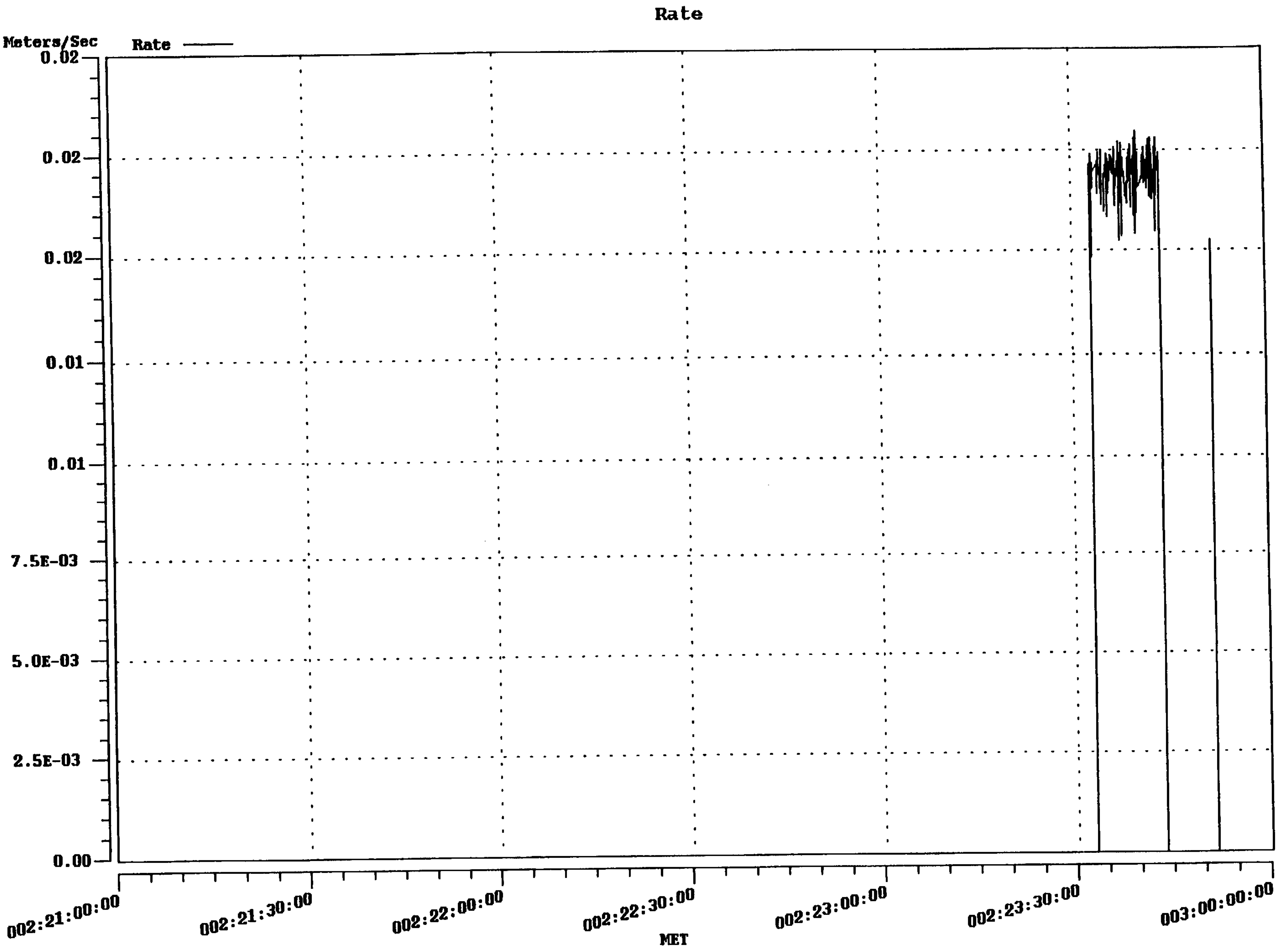
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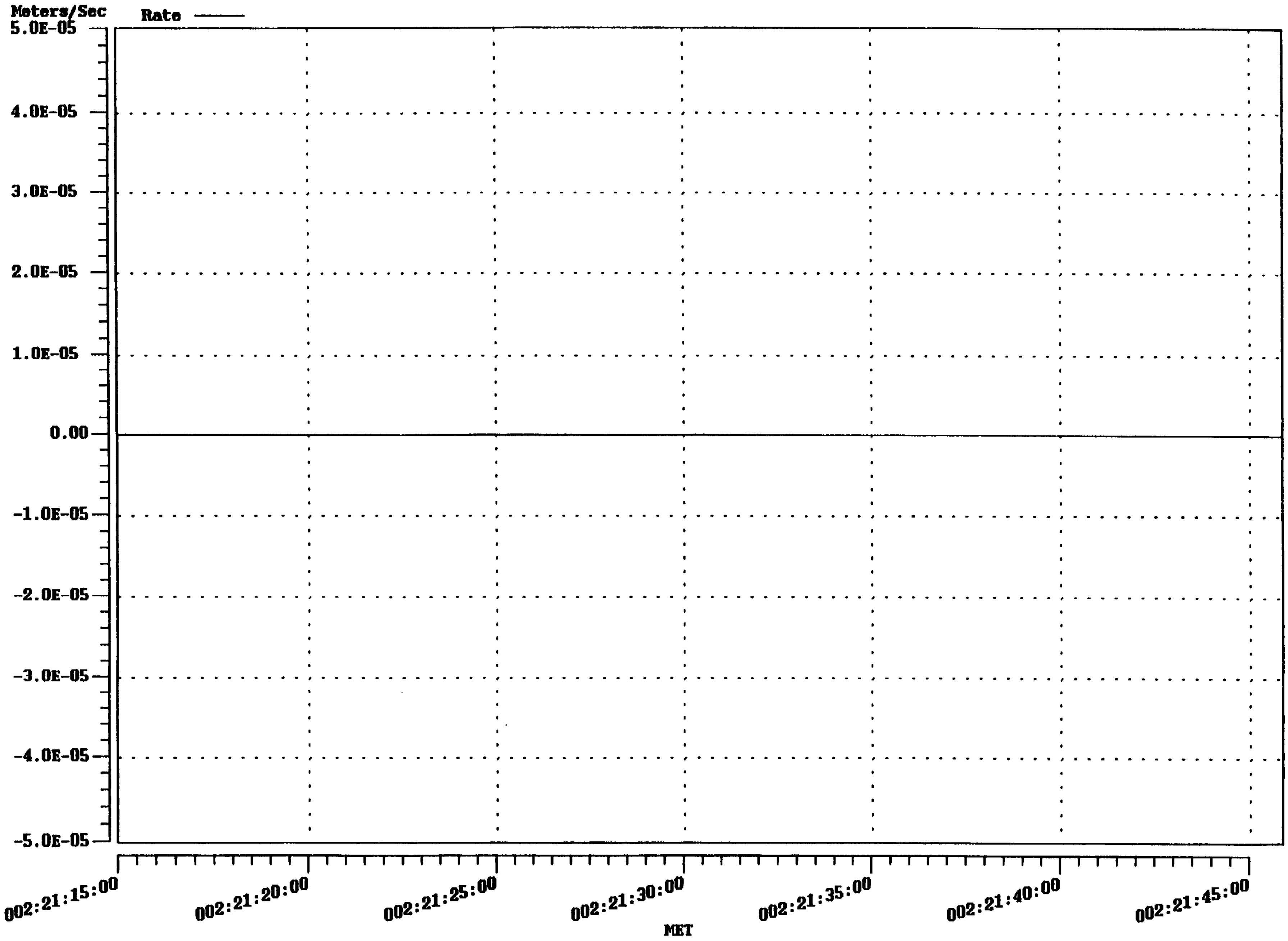
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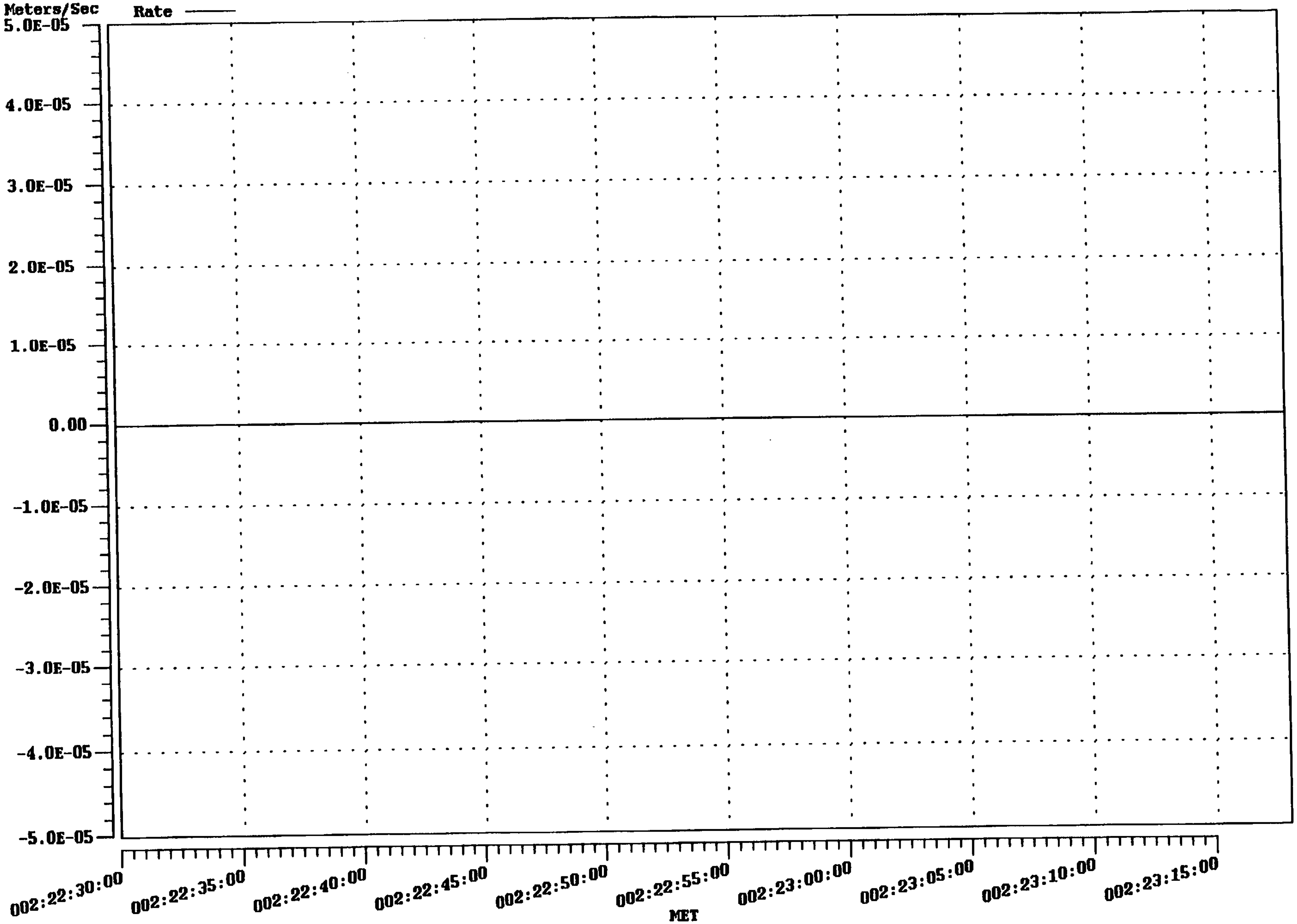
Rate



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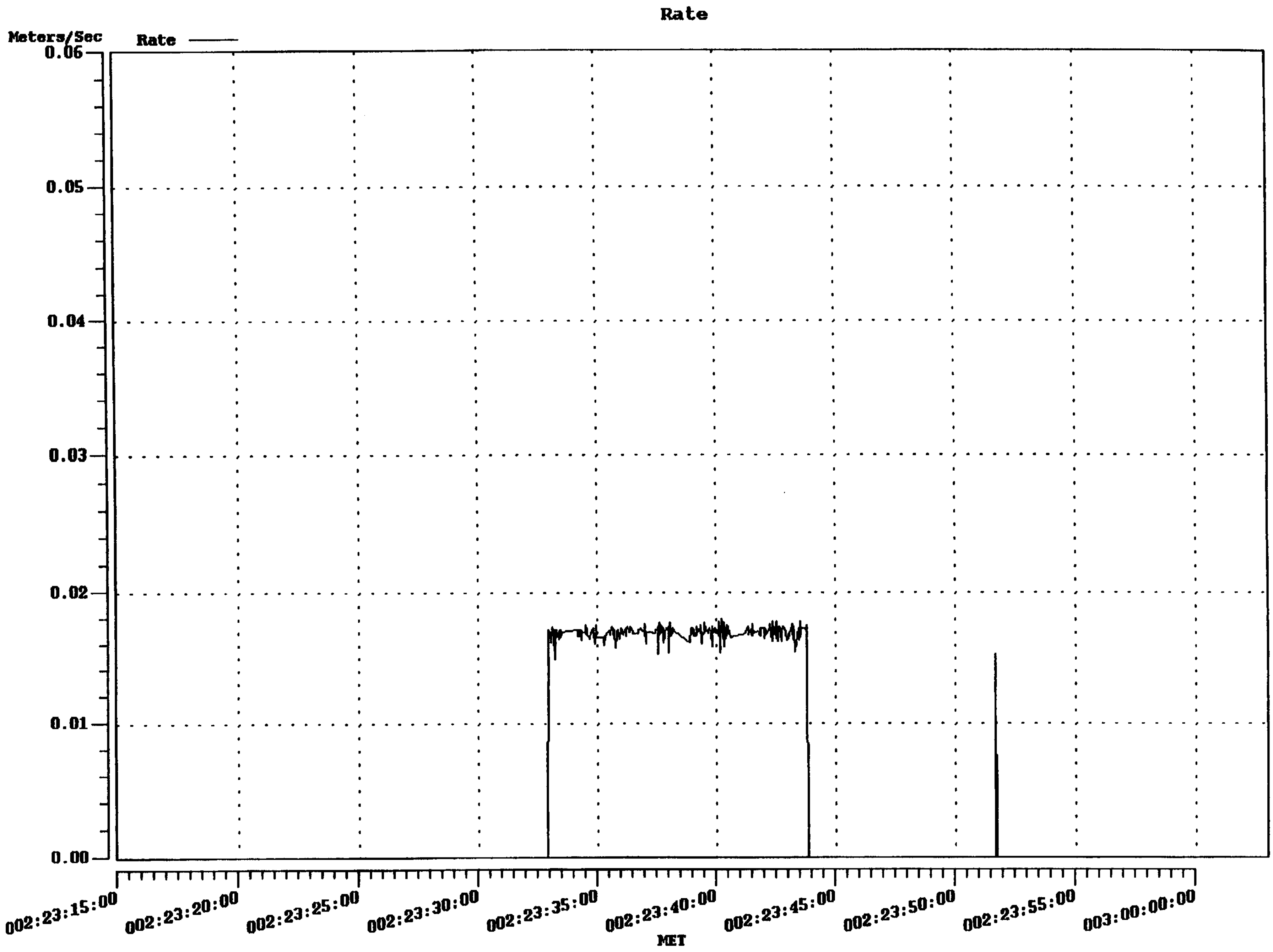
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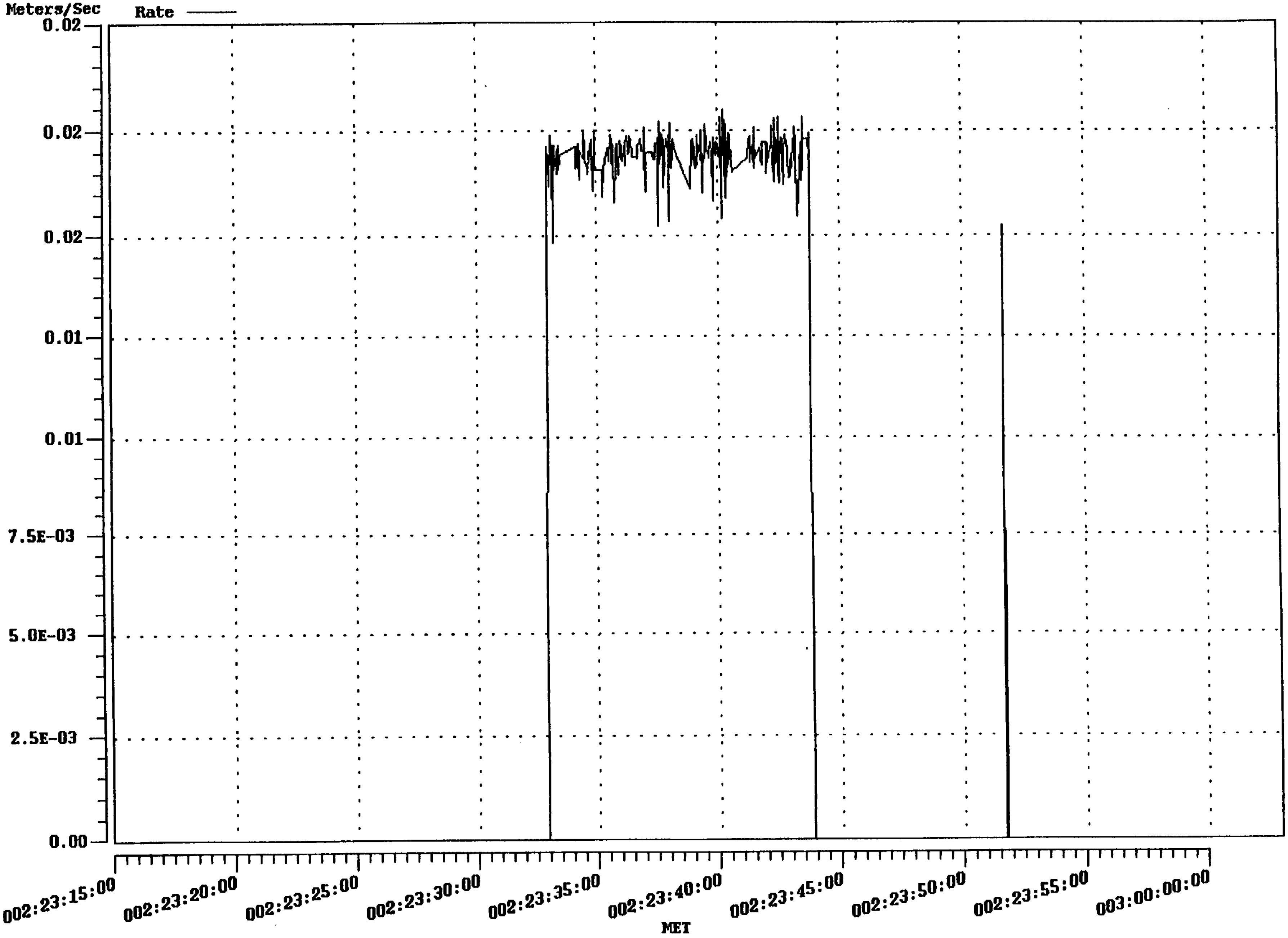
MET



Rate

Meters/Sec
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MET

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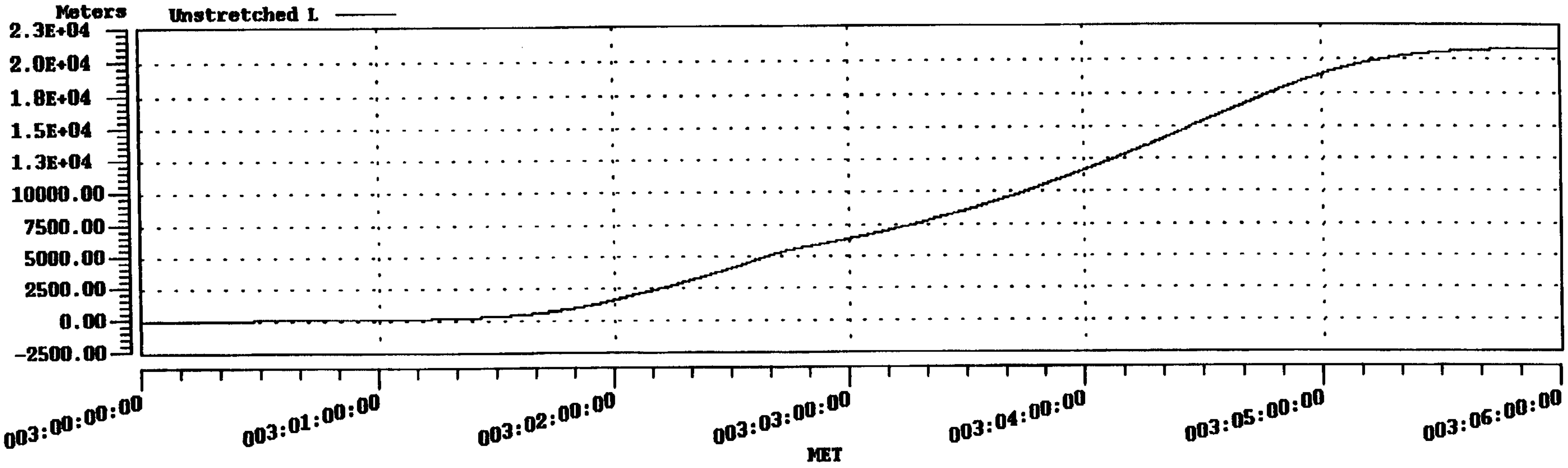

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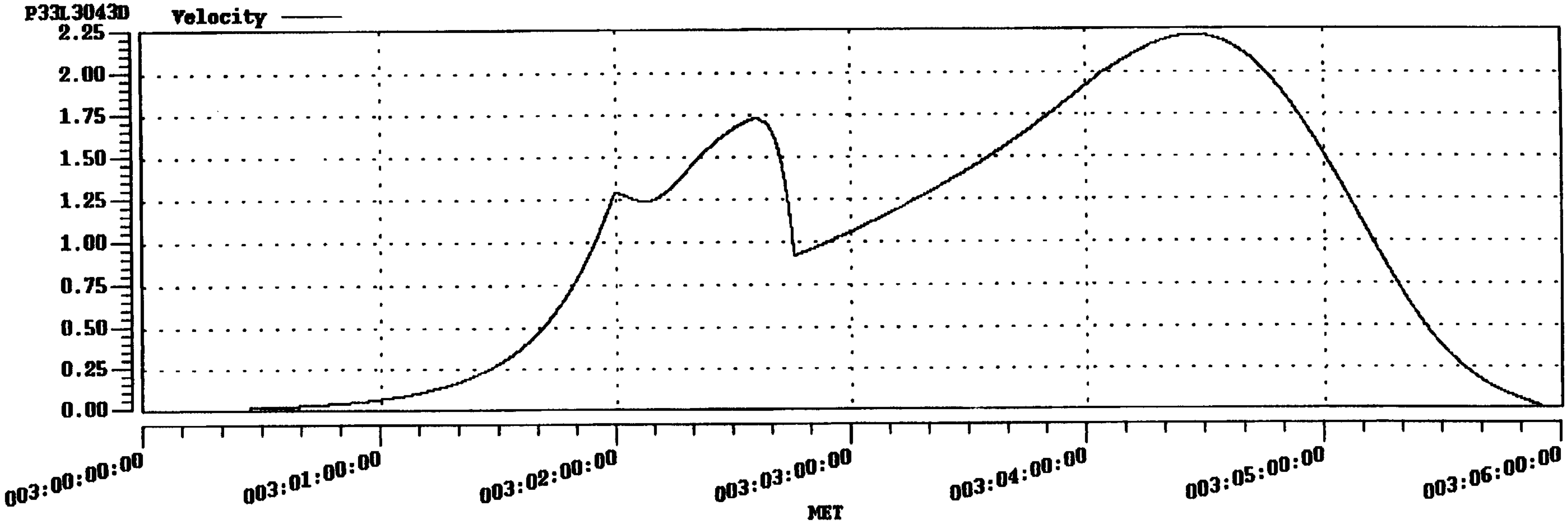
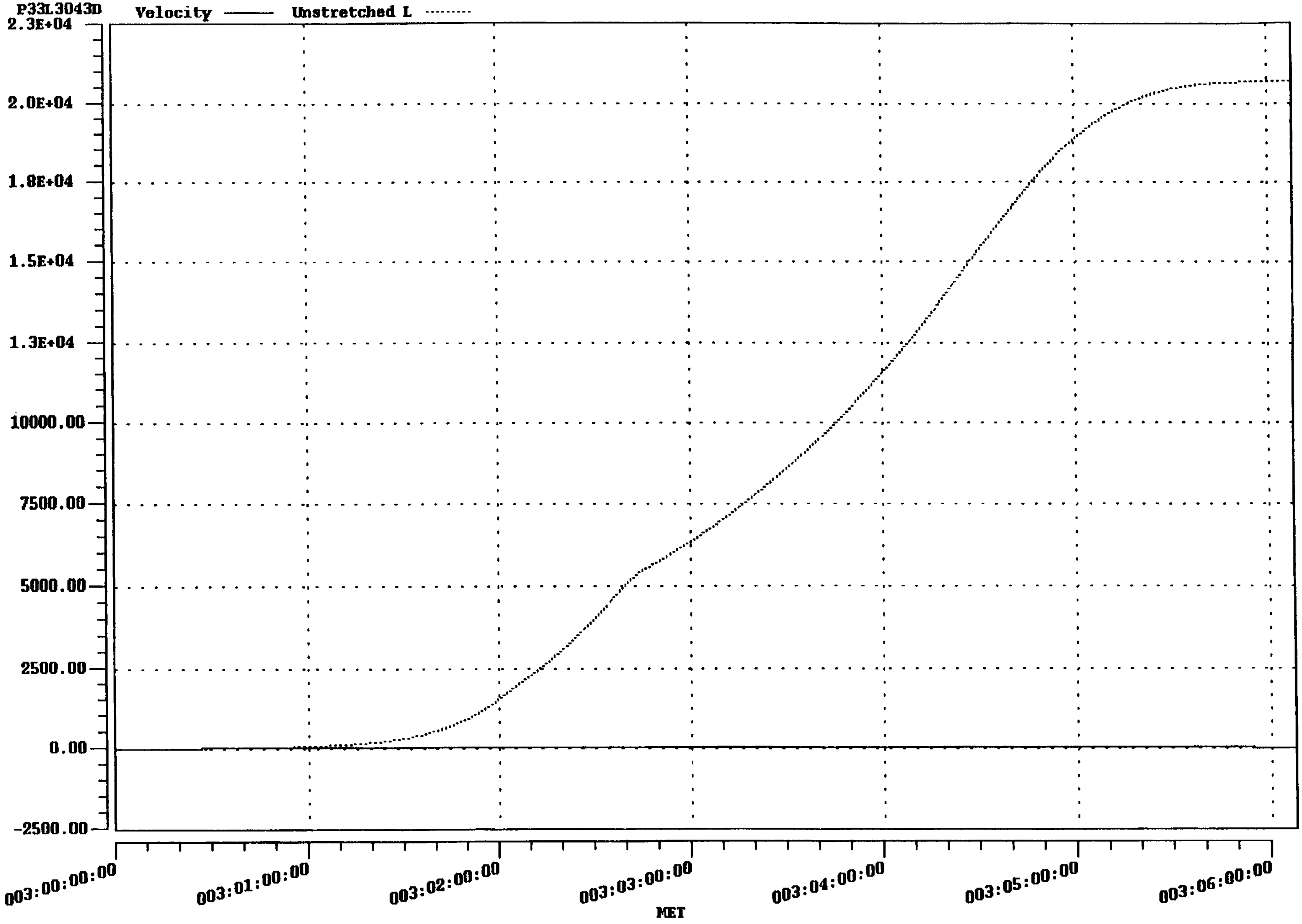
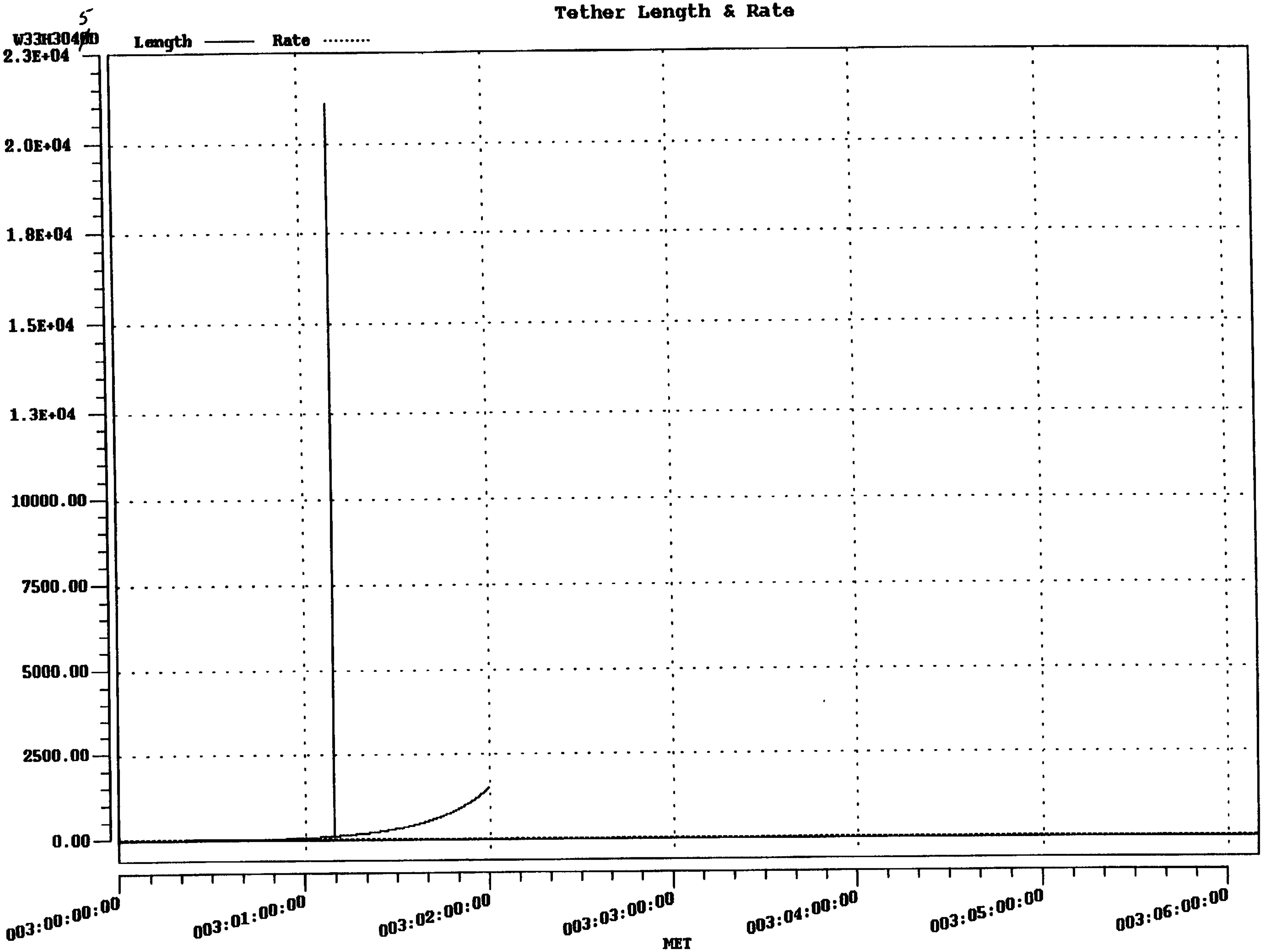
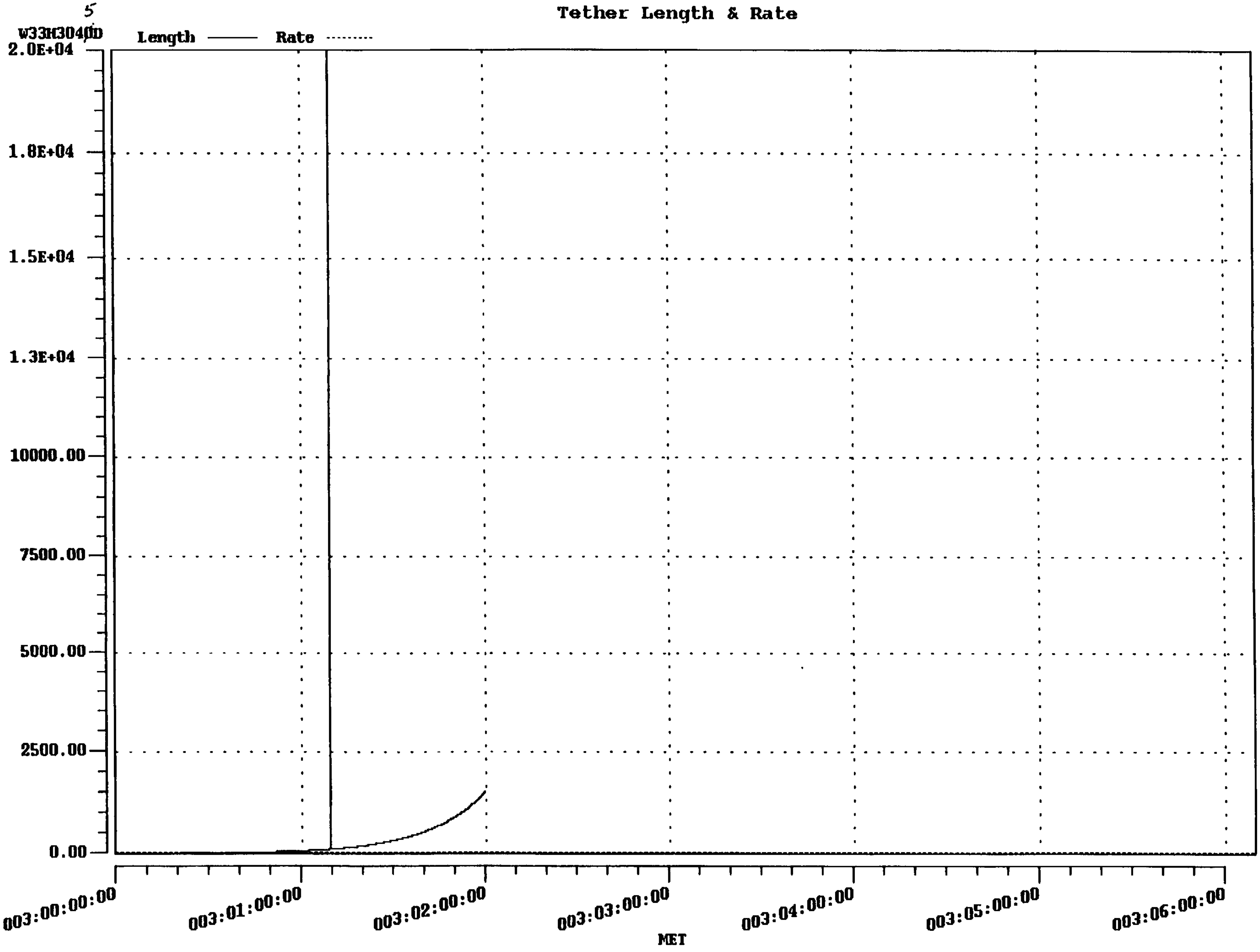


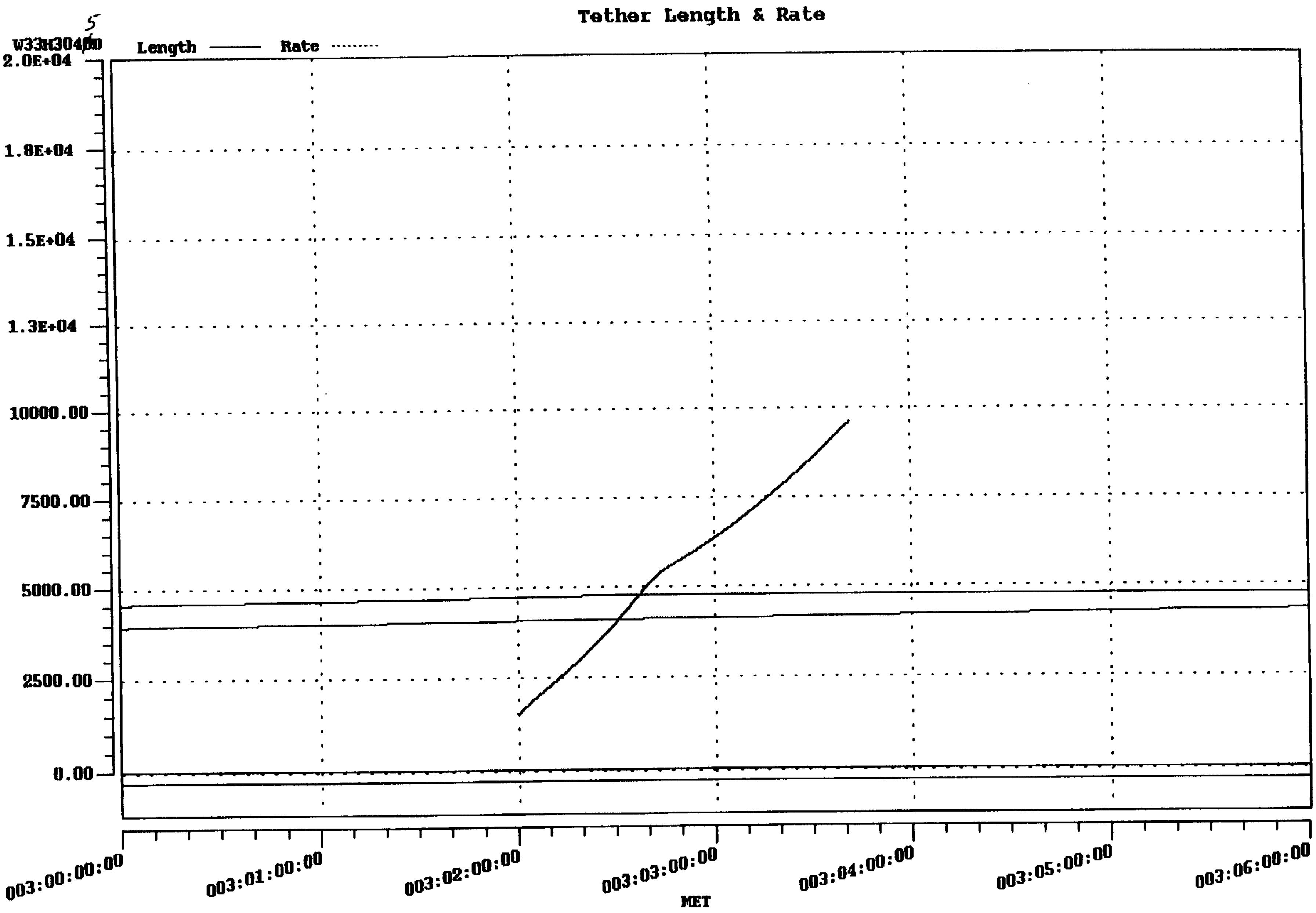
Commanded Tether Length & Vel.



Tether Length & Rate




Tether Length & Rate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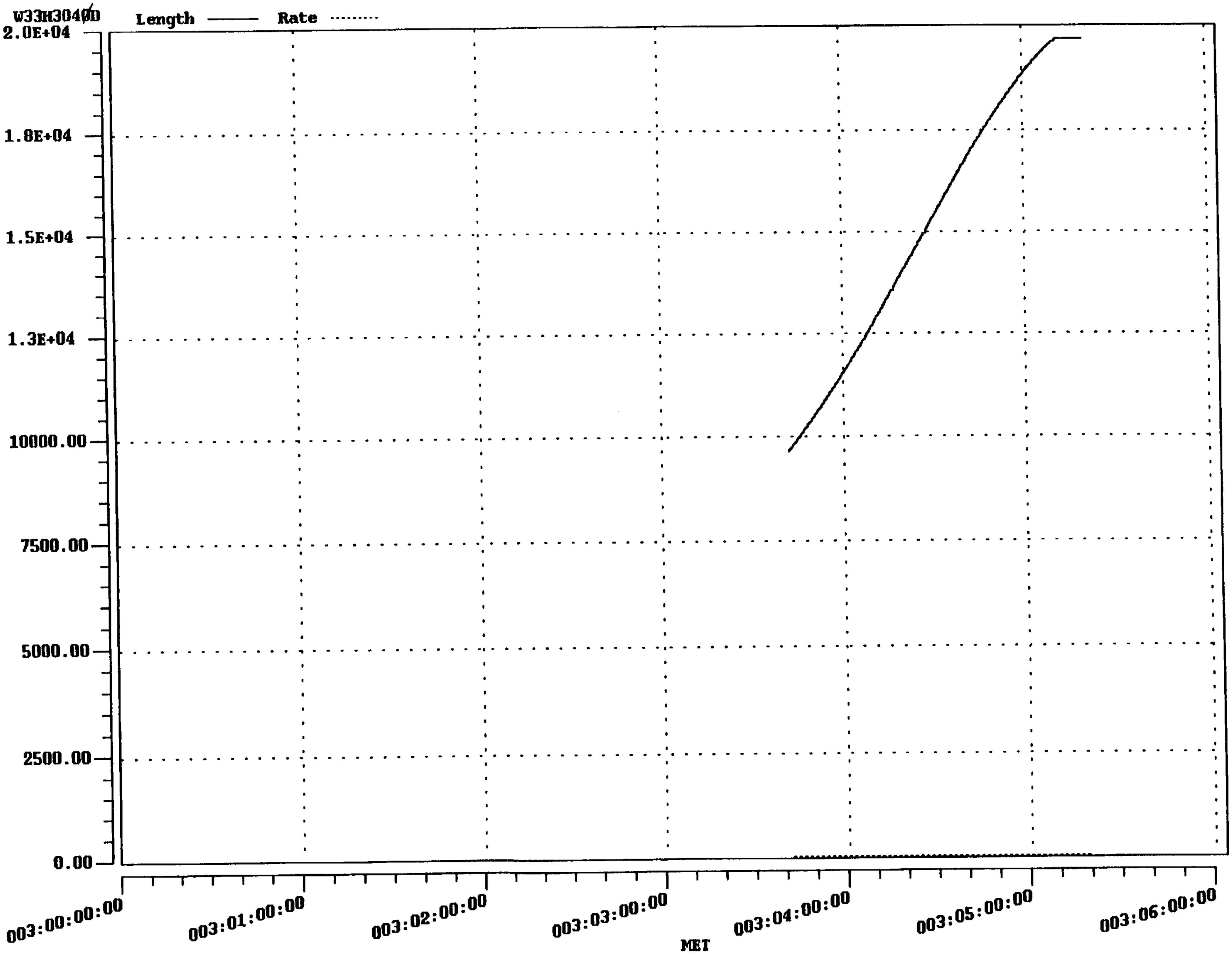
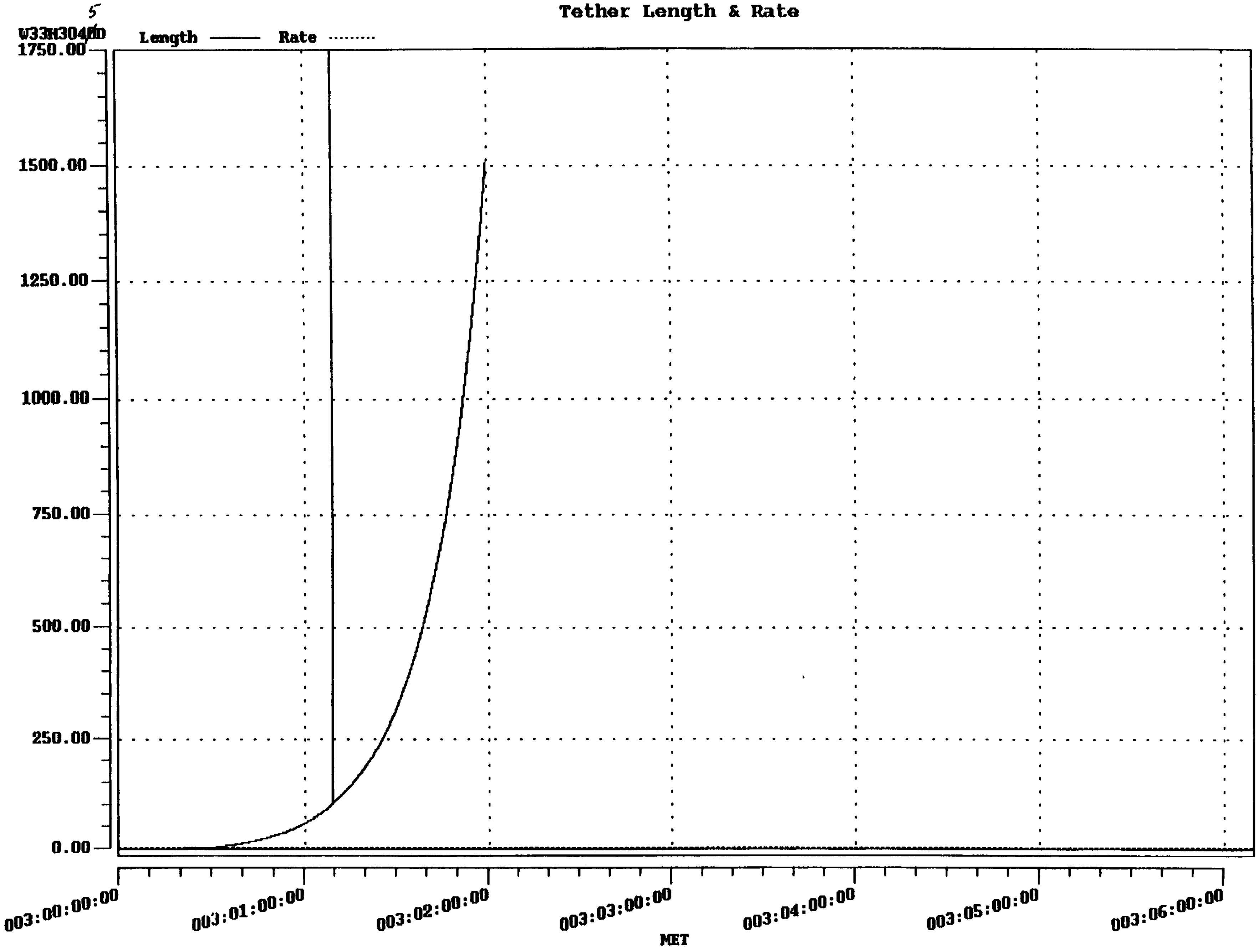
MET

Tether Length & Rate

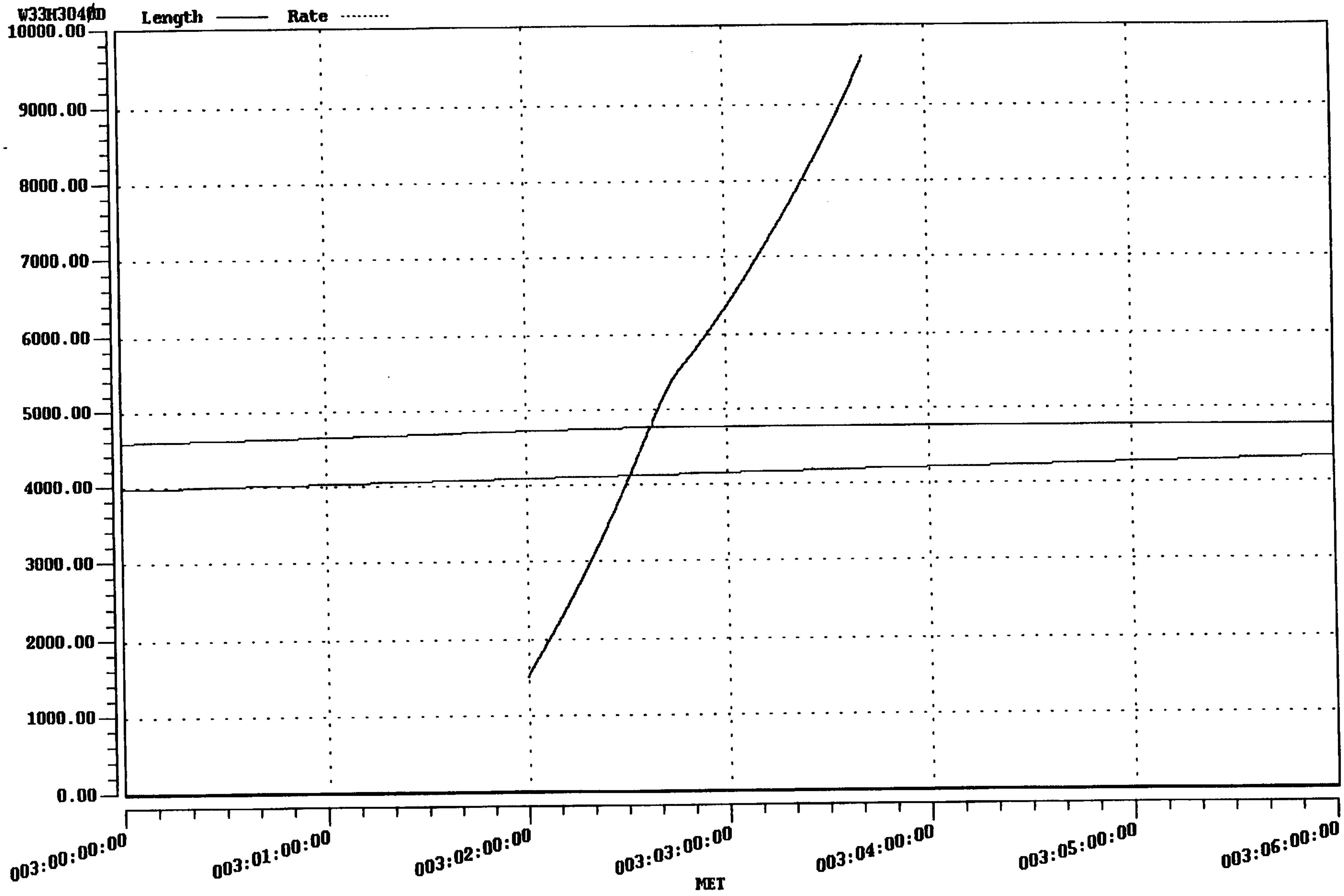
5

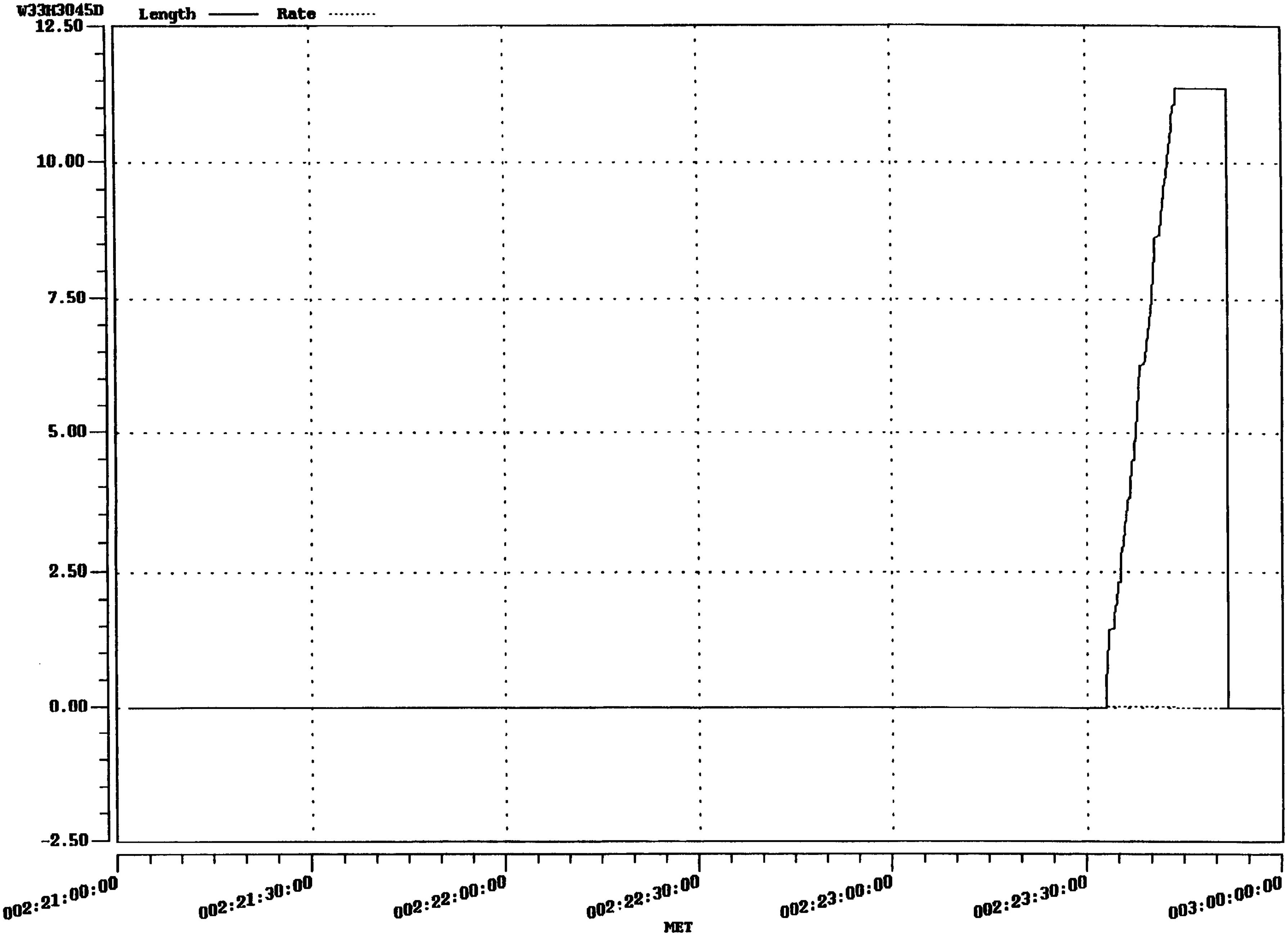



Tether Length & Rate
5
W33H304ЮD
Length ———
Rate ········
1750.00
1500.00
1250.00
1000.00
750.00
500.00
250.00
0.00
003:00:00:00
003:01:00:00
003:02:00:00
003:03:00:00
003:04:00:00
003:05:00:00
003:06:00:00
MET

5

Tether Length & Rate

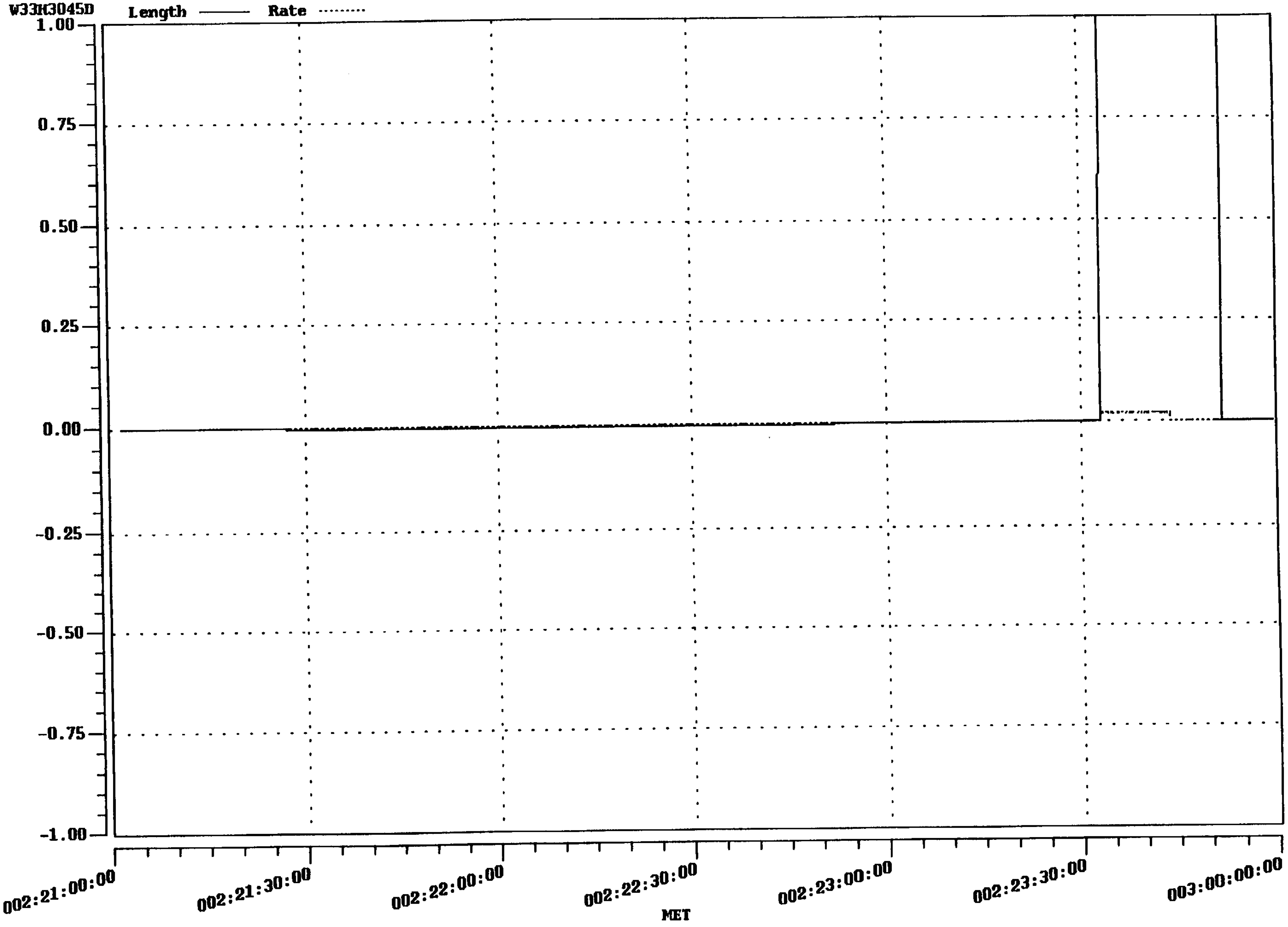


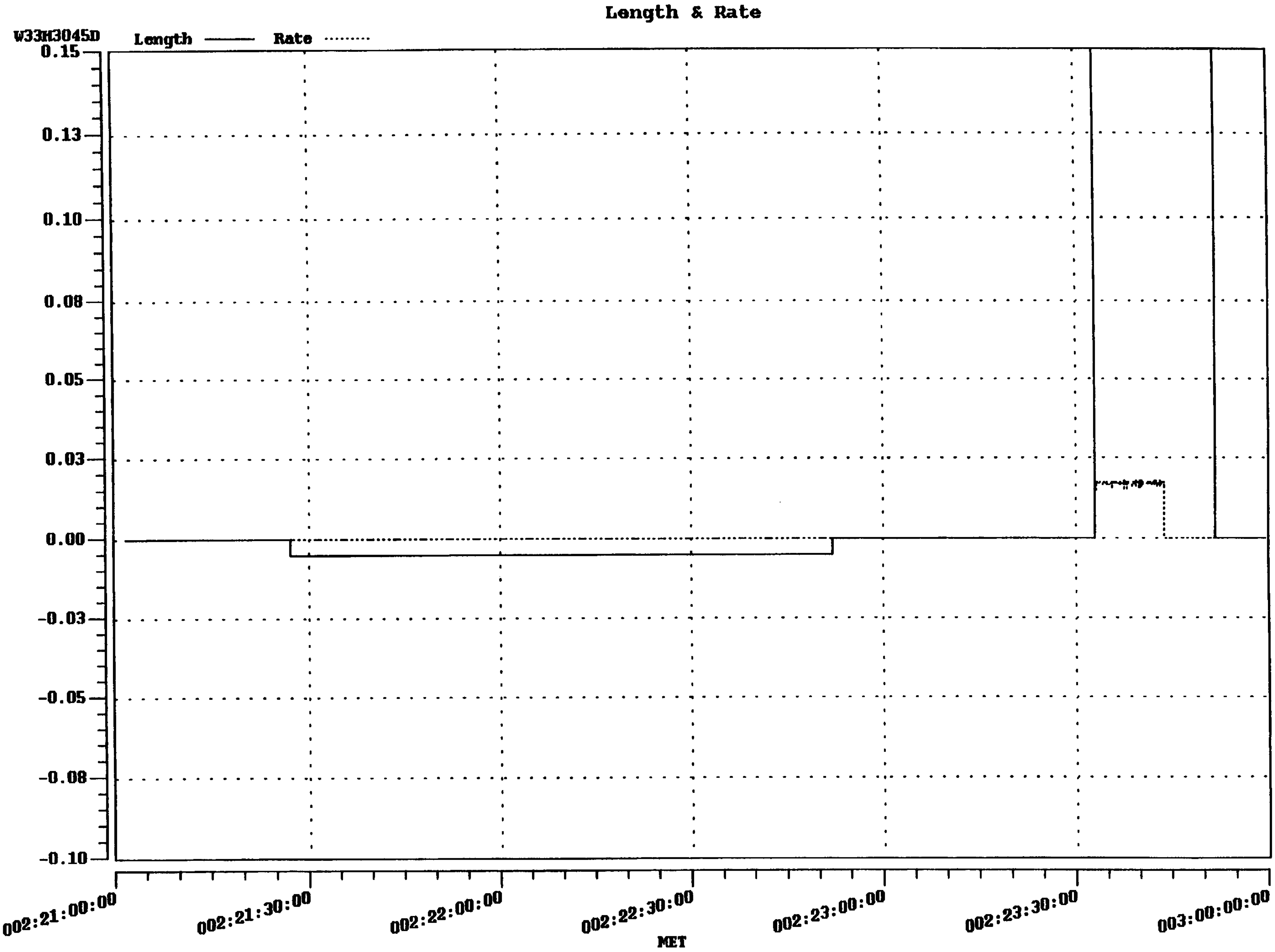


Length & Rate

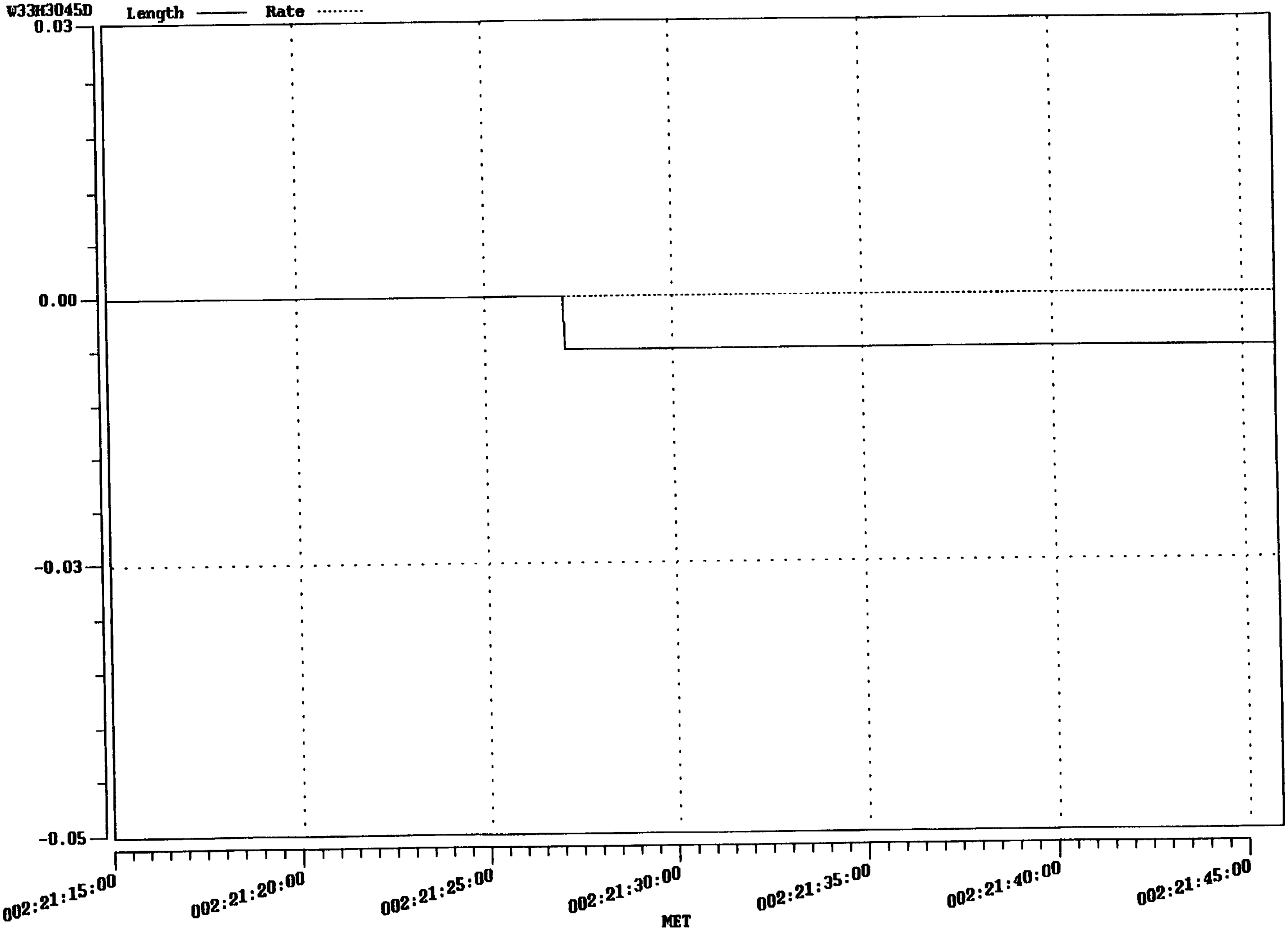
W33H3045D
Length
Rate
12.50
10.00
7.50
5.00
2.50
0.00
-2.50
002:21:00:00
002:21:30:00
002:22:00:00
002:22:30:00
002:23:00:00
002:23:30:00
003:00:00:00
MET

Length & Rate


W33H3045D
Length
Rate
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
002:21:00:00
002:21:30:00
002:22:00:00
002:22:30:00
002:23:00:00
002:23:30:00
003:00:00:00
MET


Length & Rate
W33H3045D
Length
Rate
0.15
0.13
0.10
0.08
0.05
0.03
0.00
-0.03
-0.05
-0.08
-0.10
002:21:00:00
002:21:30:00
002:22:00:00
002:22:30:00
002:23:00:00
002:23:30:00
003:00:00:00
MET

Length & Rate


W33H3045D
Length
Rate
0.03
0.00
-0.03
-0.05
002:21:15:00
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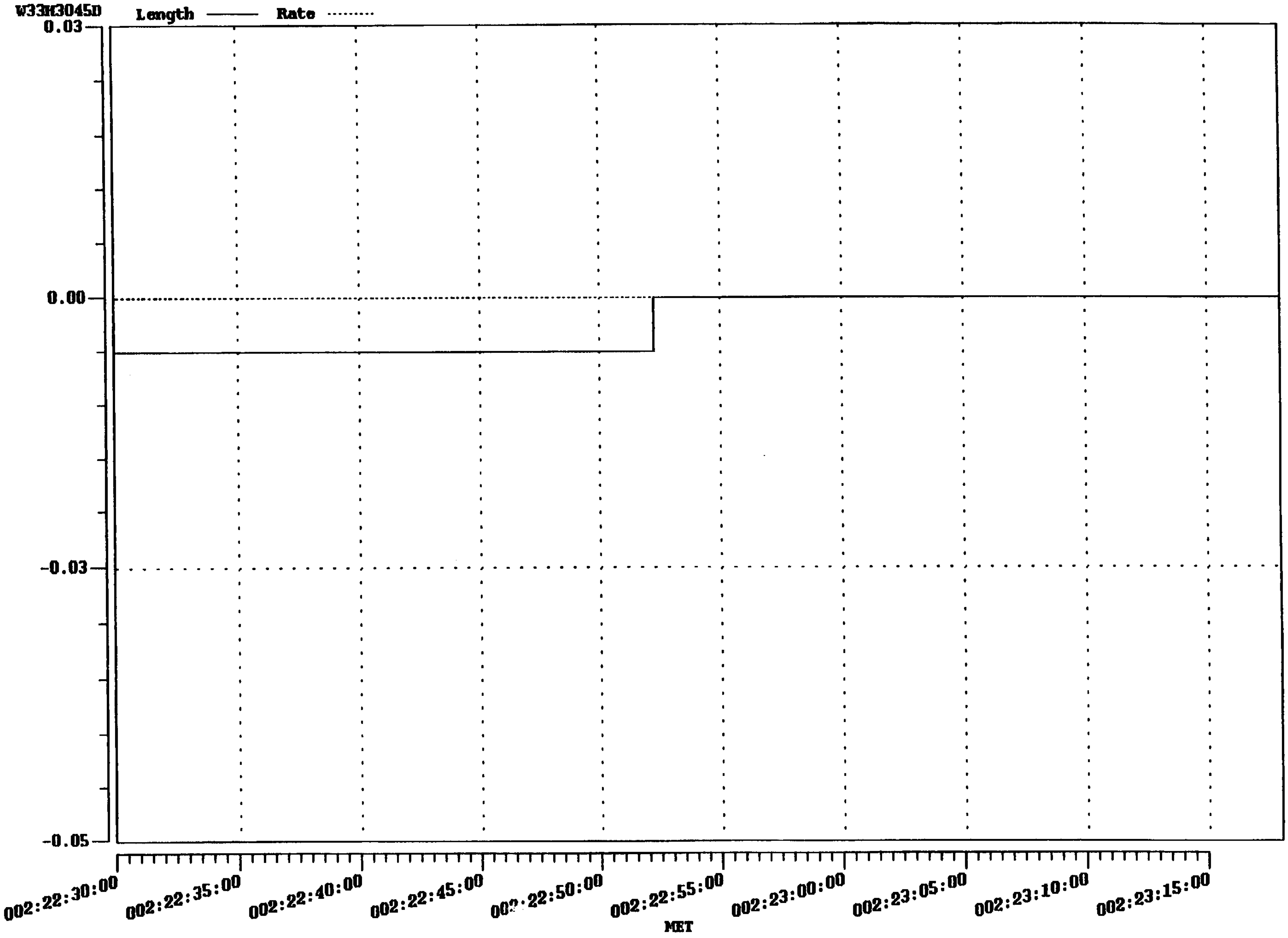
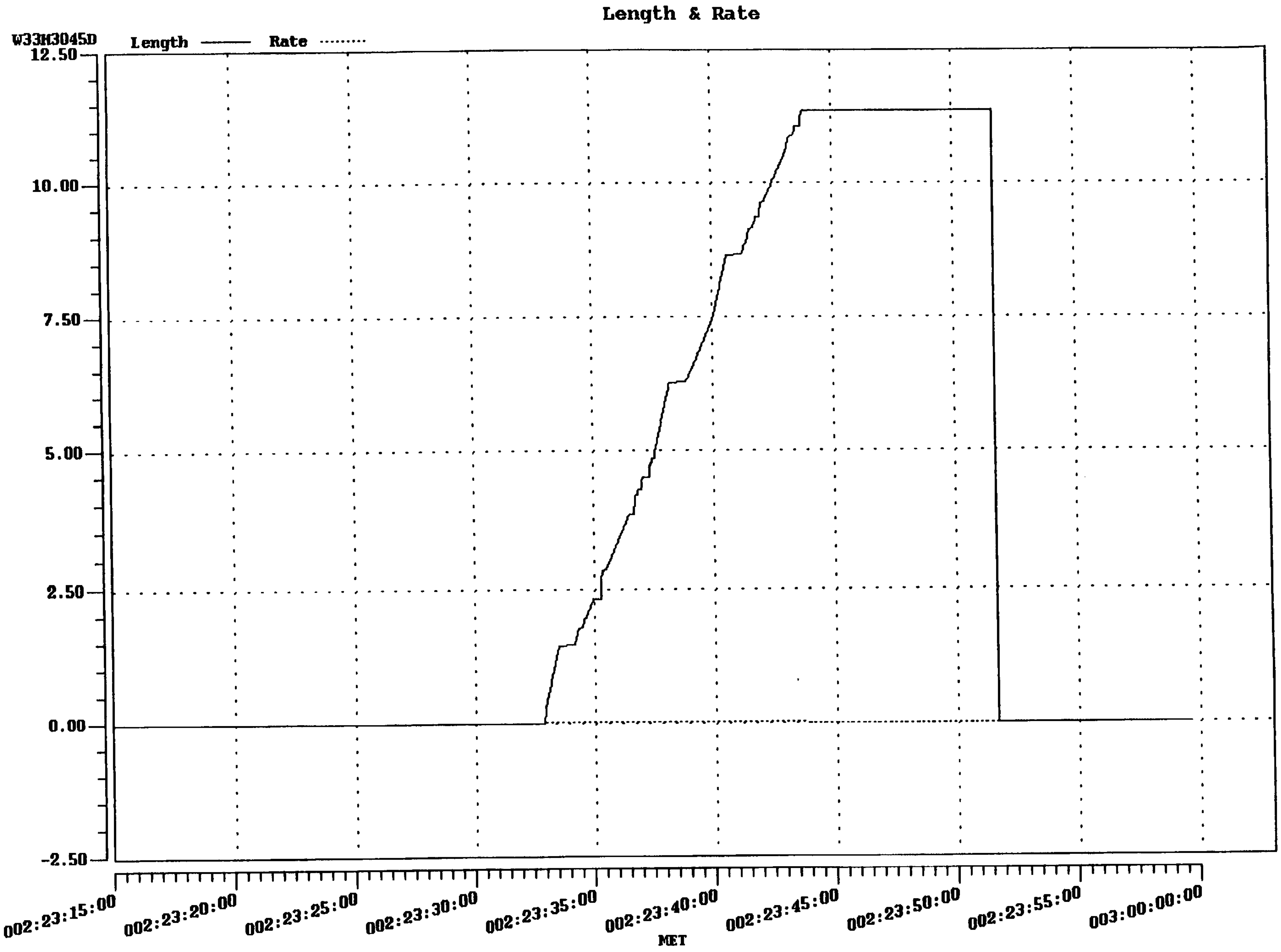
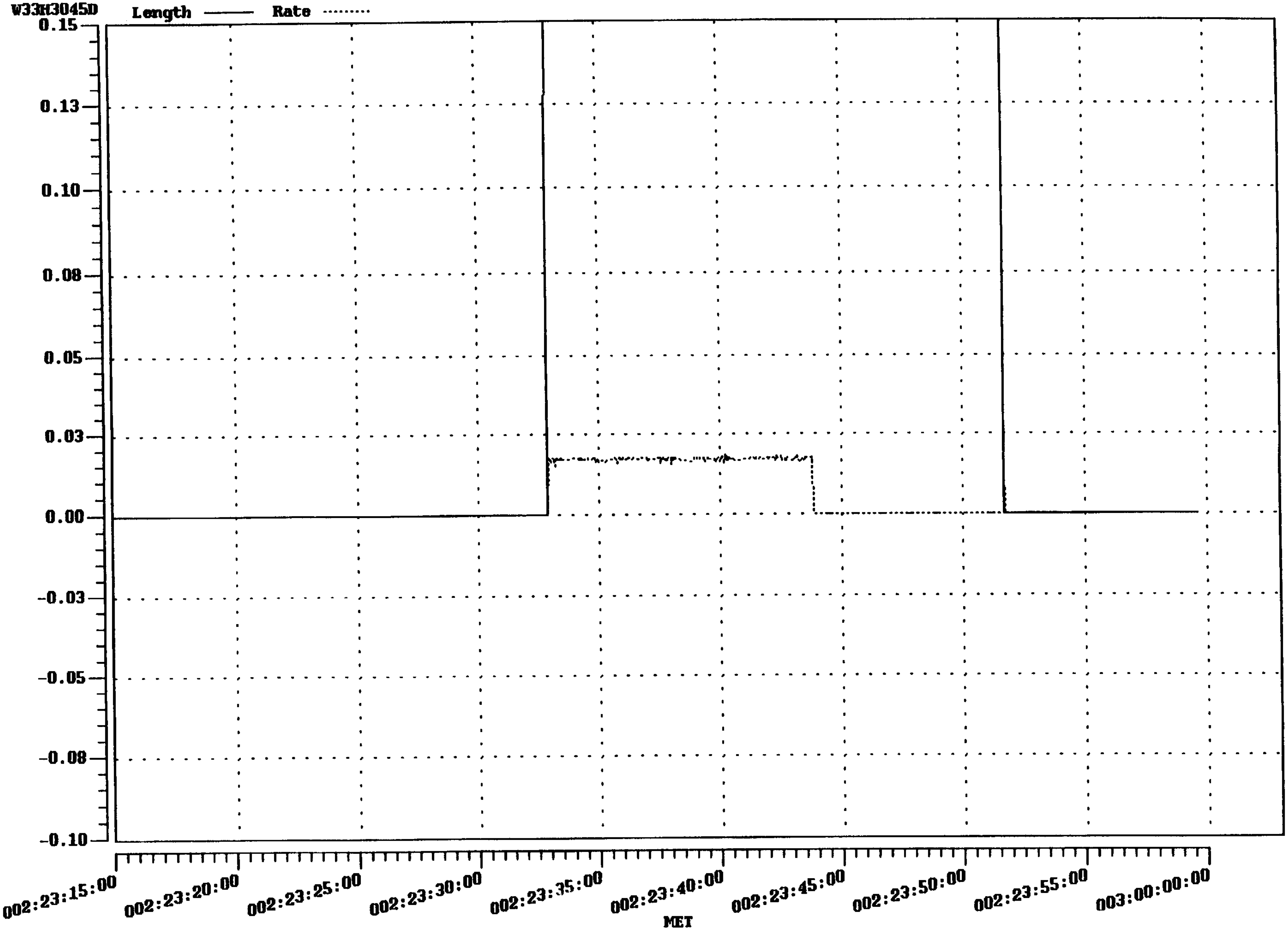
002:21:25:00
002:21:30:00
002:21:35:00
002:21:40:00
002:21:45:00
MET

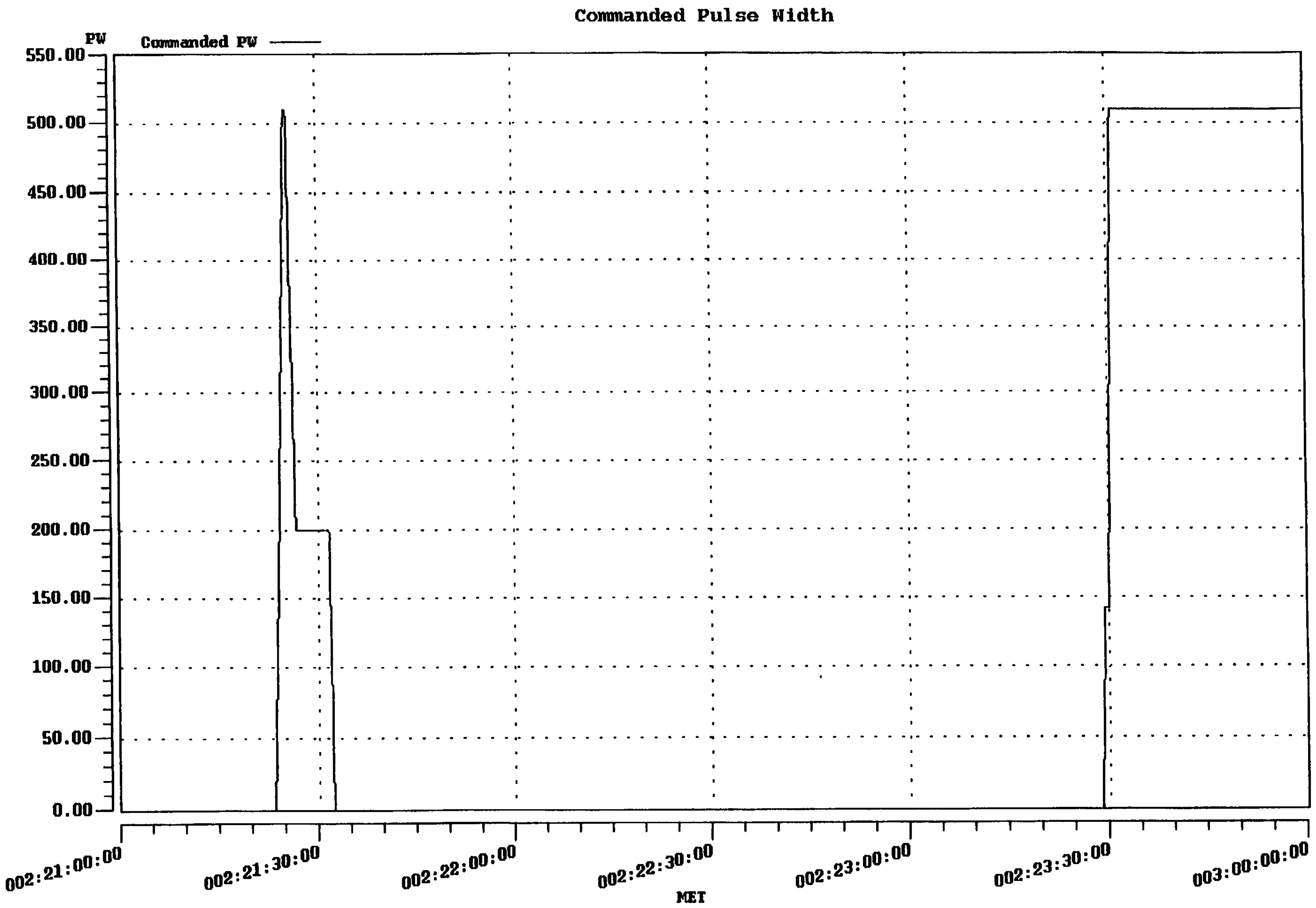
Length & Rate


W33H3045D
Length
Rate
0.03
0.00
-0.03
-0.05
002:22:30:00
002:22:35:00
002:22:40:00
002:22:45:00
002:22:50:00
002:22:55:00
002:23:00:00
002:23:05:00
002:23:10:00
002:23:15:00
MET


Length & Rate
W33H3045D
Length
Rate
12.50
10.00
7.50
5.00
2.50
0.00
-2.50
002:23:15:00
002:23:20:00
002:23:25:00
002:23:30:00
002:23:35:00
002:23:40:00
002:23:45:00
002:23:50:00
002:23:55:00
003:00:00:00
MET


Length & Rate

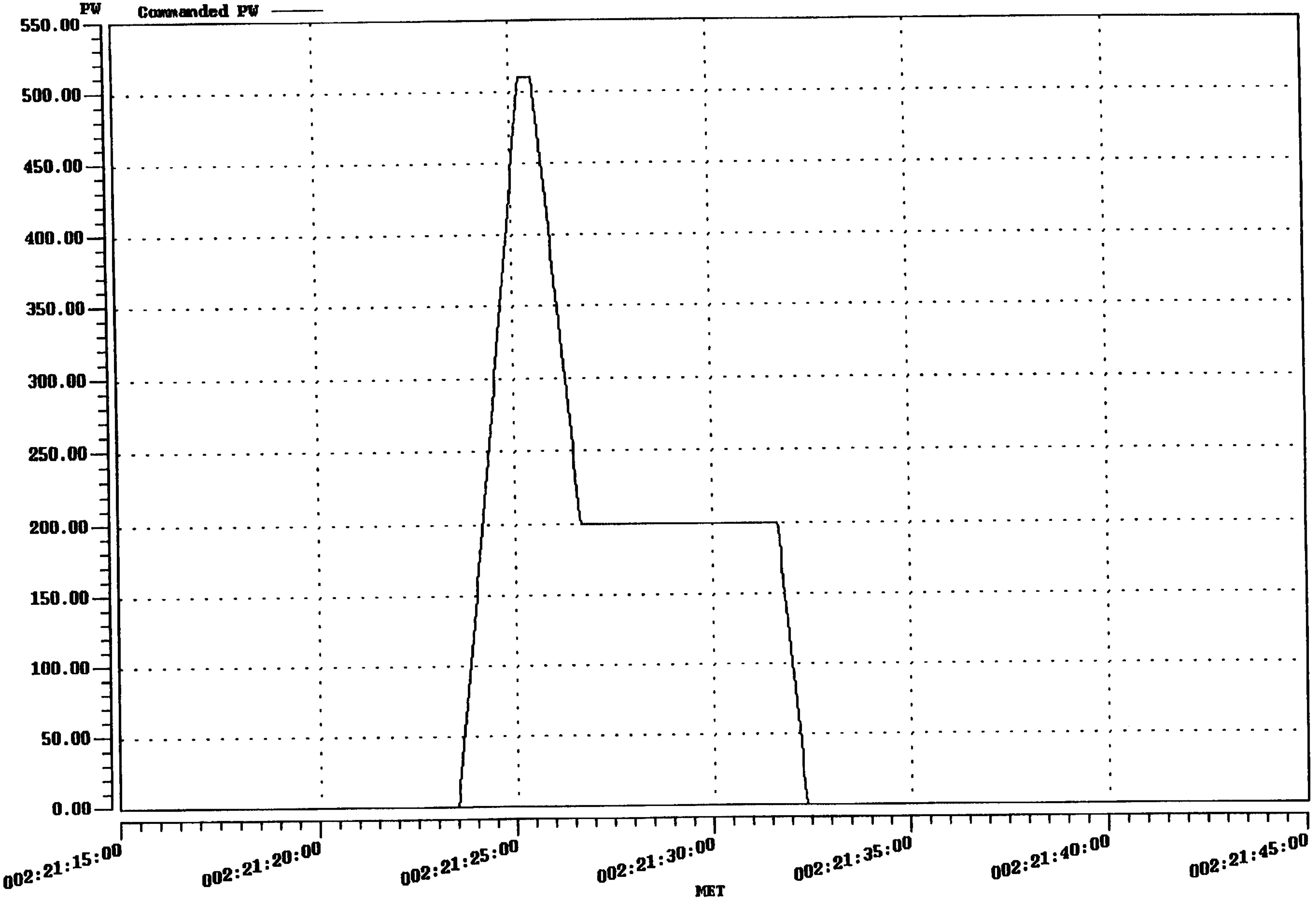
W33H3045D
Length
Rate
0.15
0.13
0.10
0.08
0.05
0.03
0.00
-0.03
-0.05
-0.08
-0.10
002:23:15:00
002:23:20:00
002:23:25:00
002:23:30:00
002:23:35:00
002:23:40:00
002:23:45:00
002:23:50:00
002:23:55:00
003:00:00:00
MET

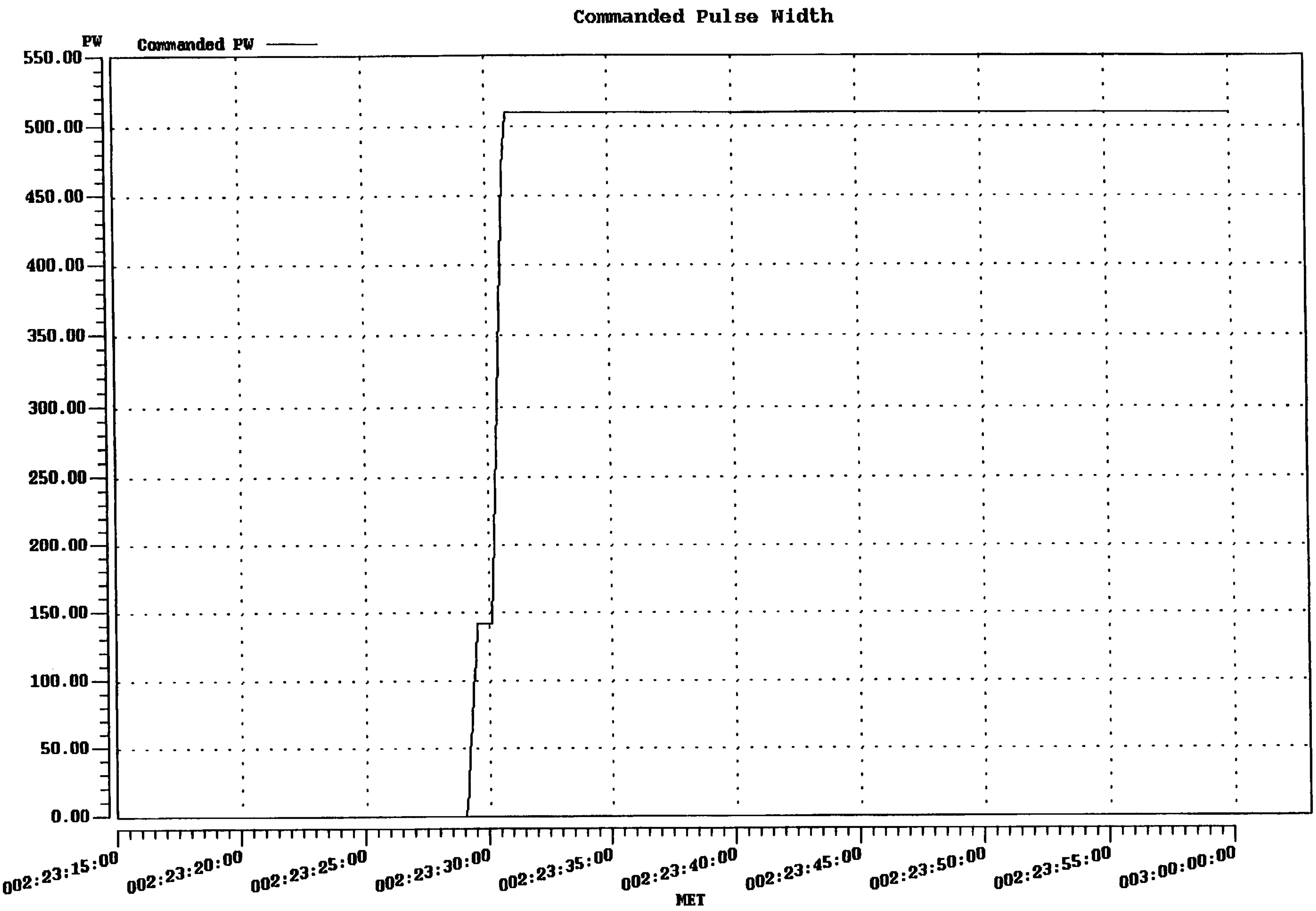


Commanded Pulse Width

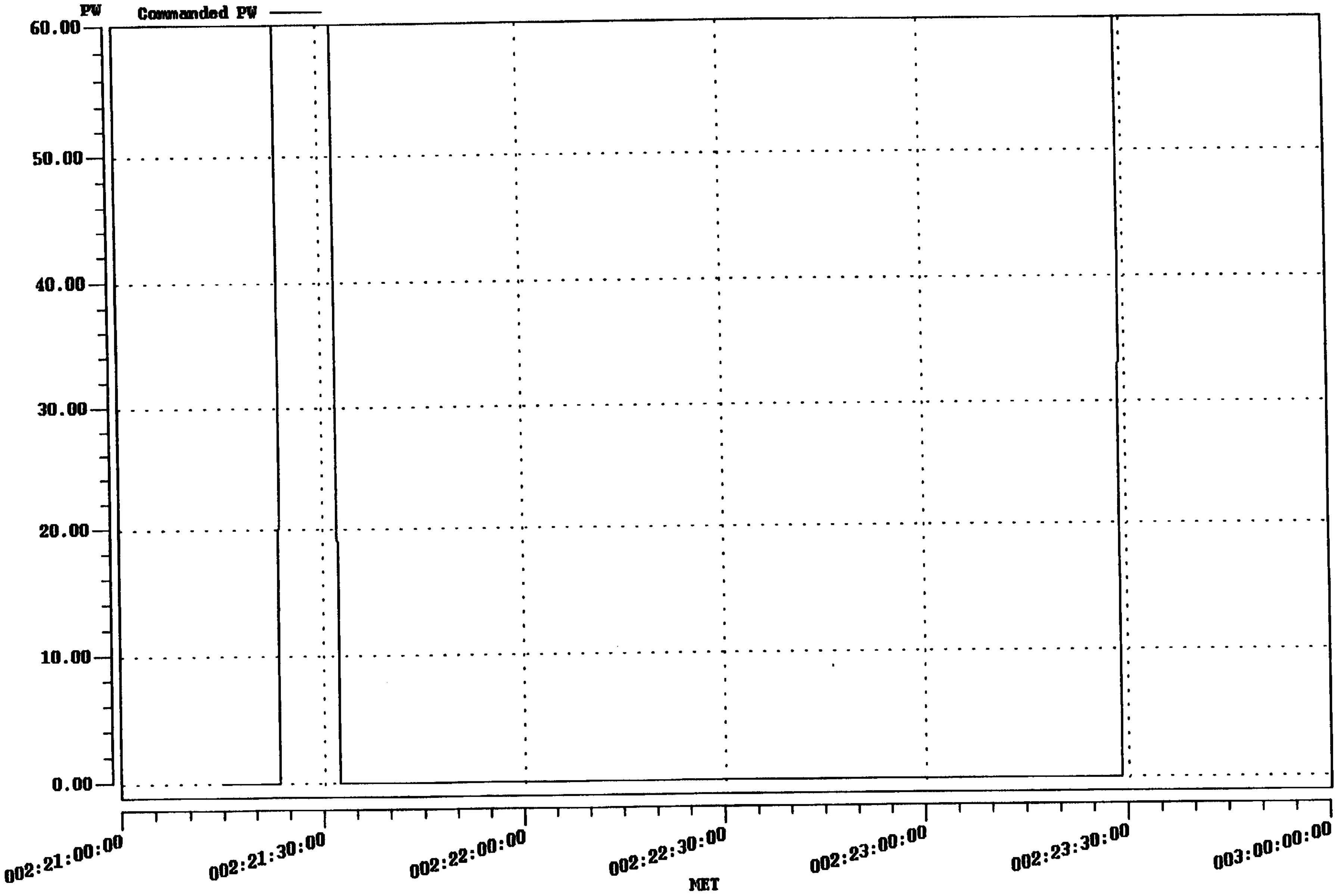
JSC Plot

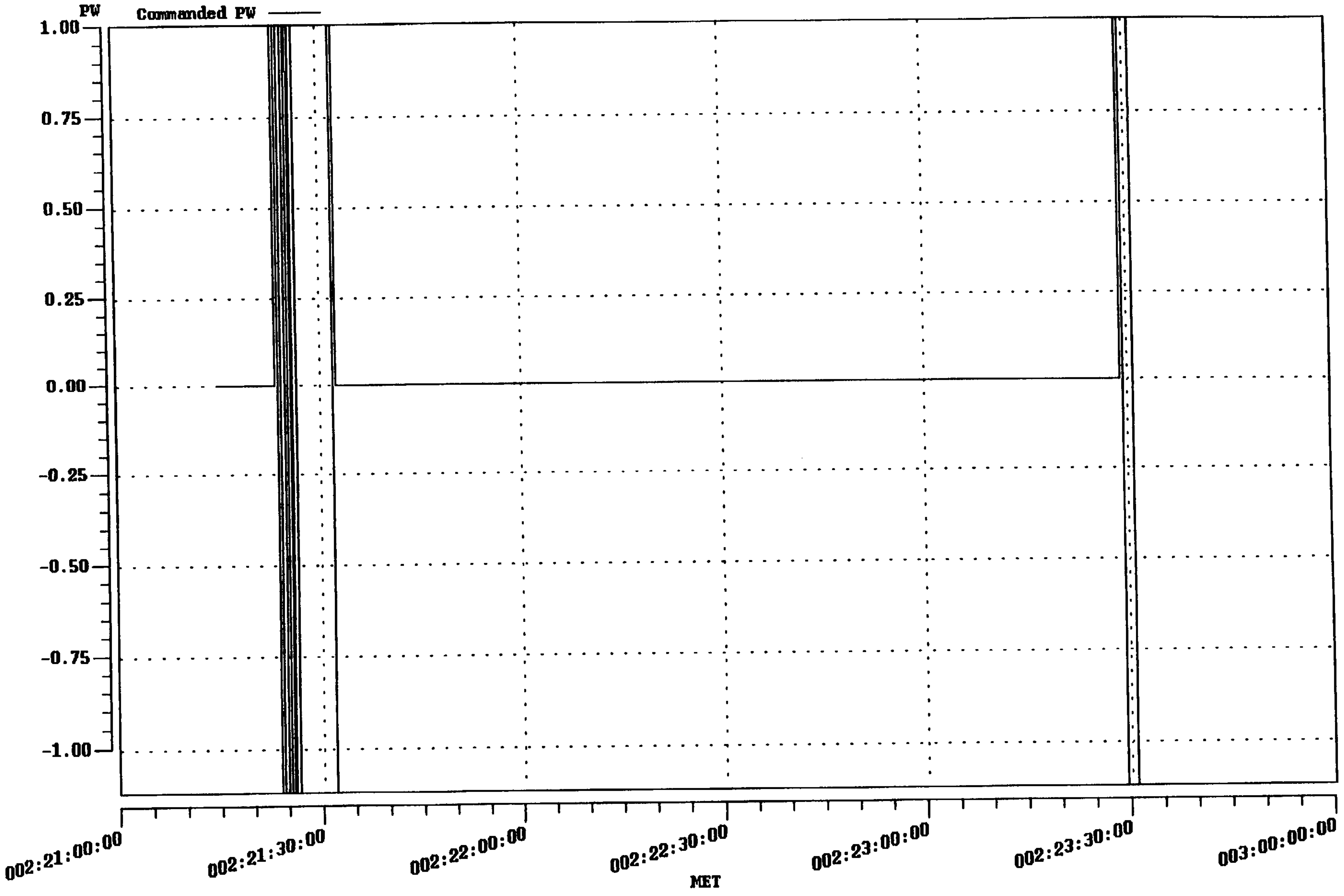
Commanded Pulse Width



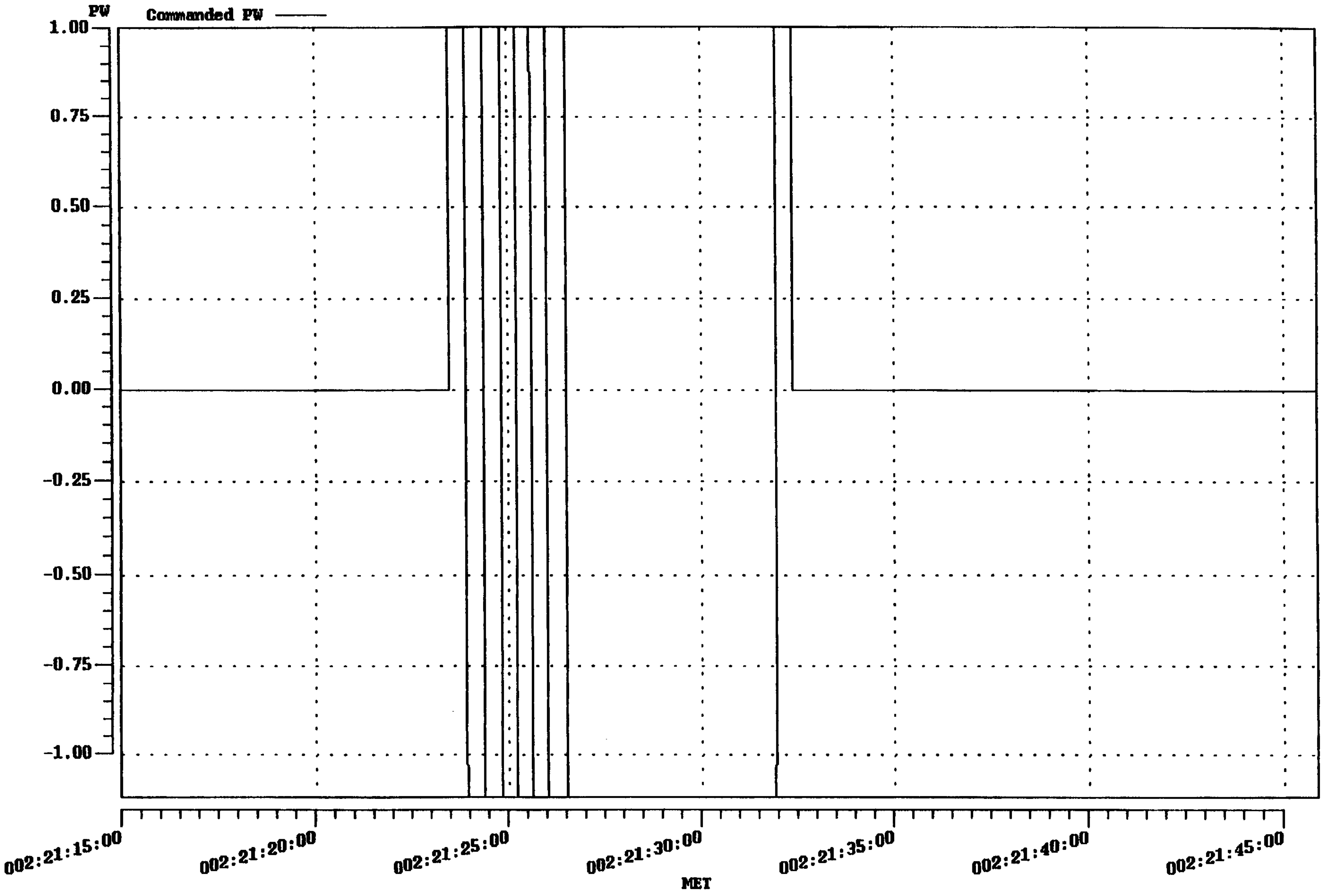

Commanded Pulse Width
PW
Commanded PW
550.00
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
002:23:15:00
002:23:20:00
002:23:25:00
002:23:30:00
002:23:35:00
002:23:40:00
002:23:45:00
002:23:50:00
002:23:55:00
003:00:00:00
MET

Commanded Pulse Width

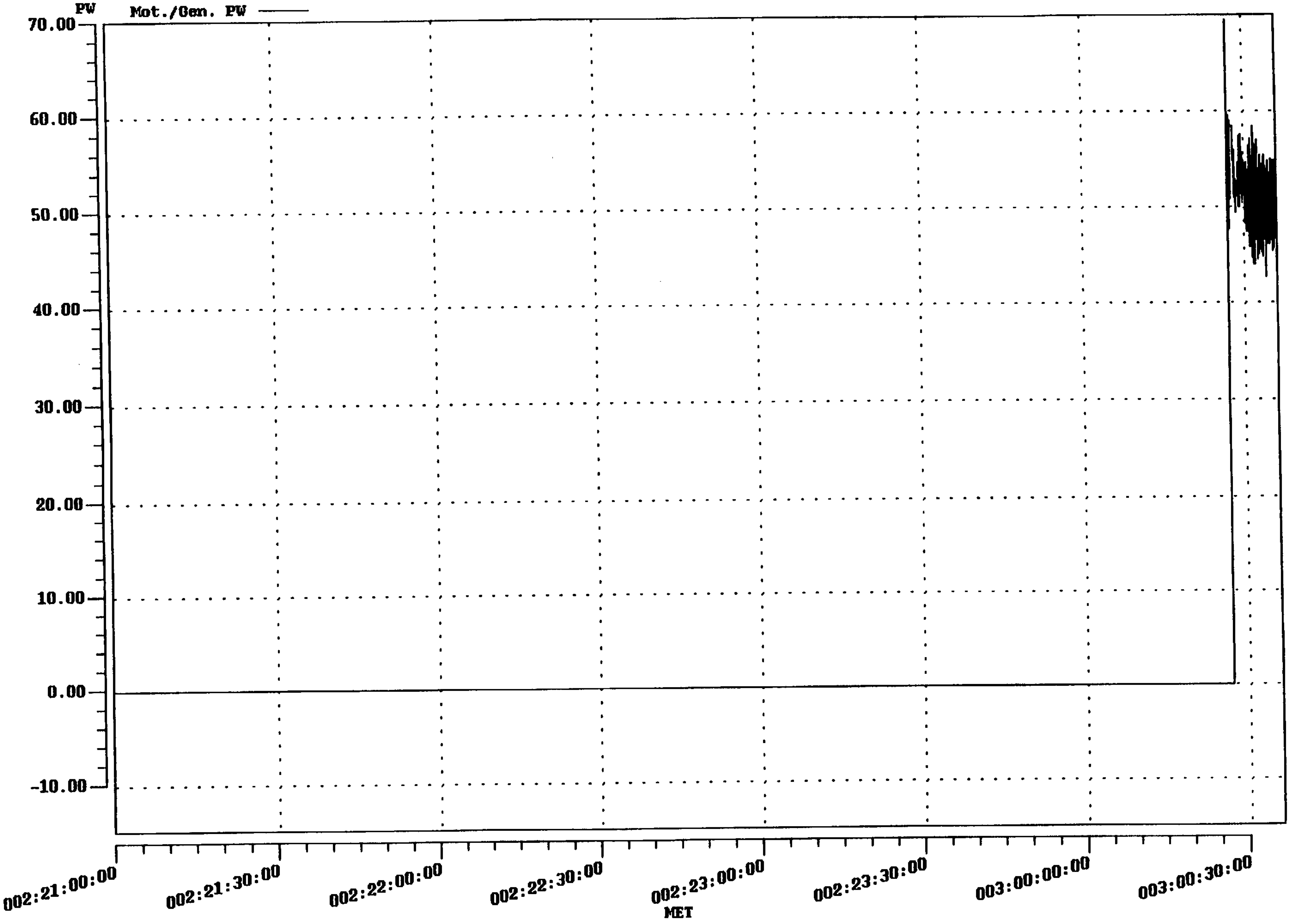


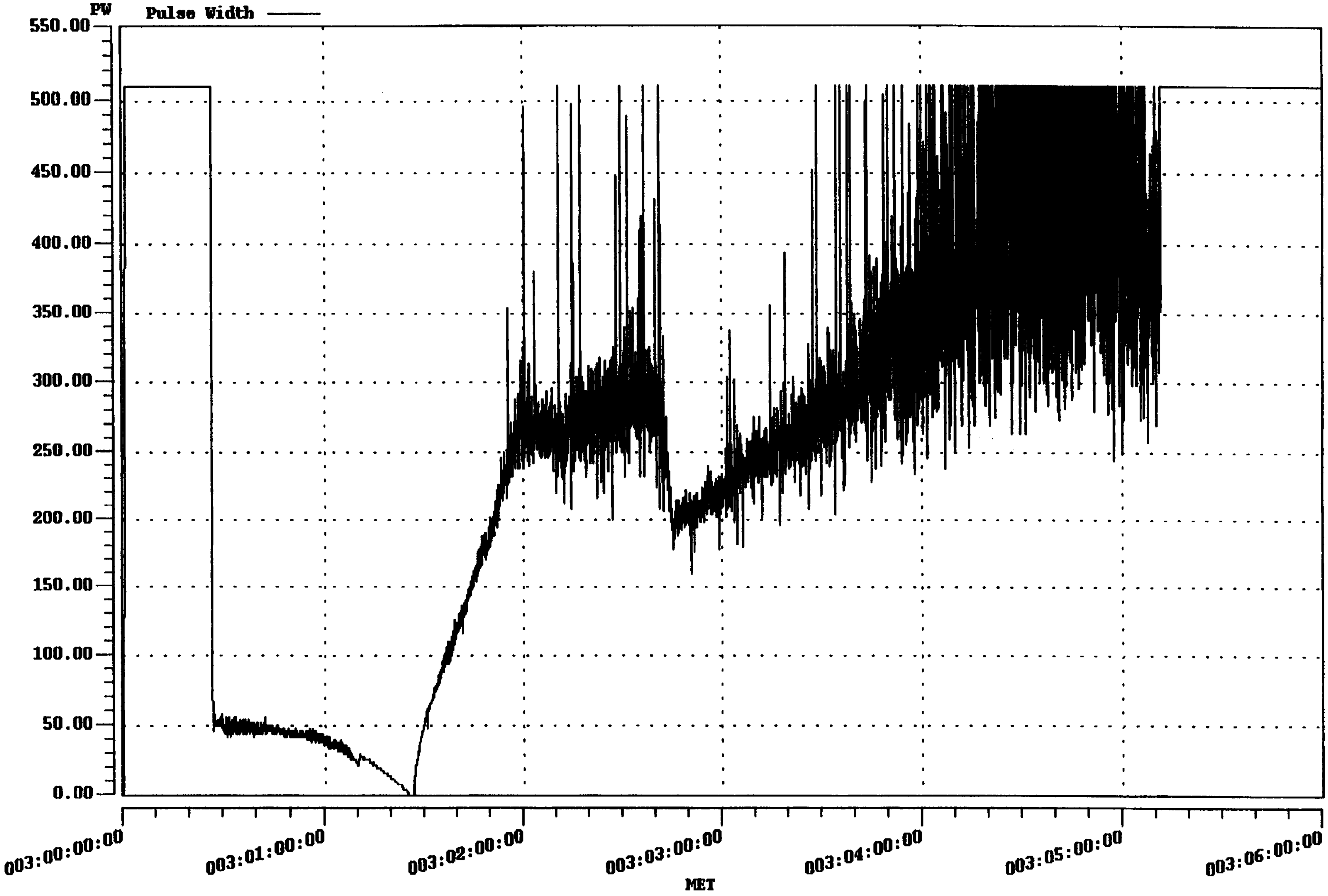

Commanded Pulse Width

Commanded Pulse Width

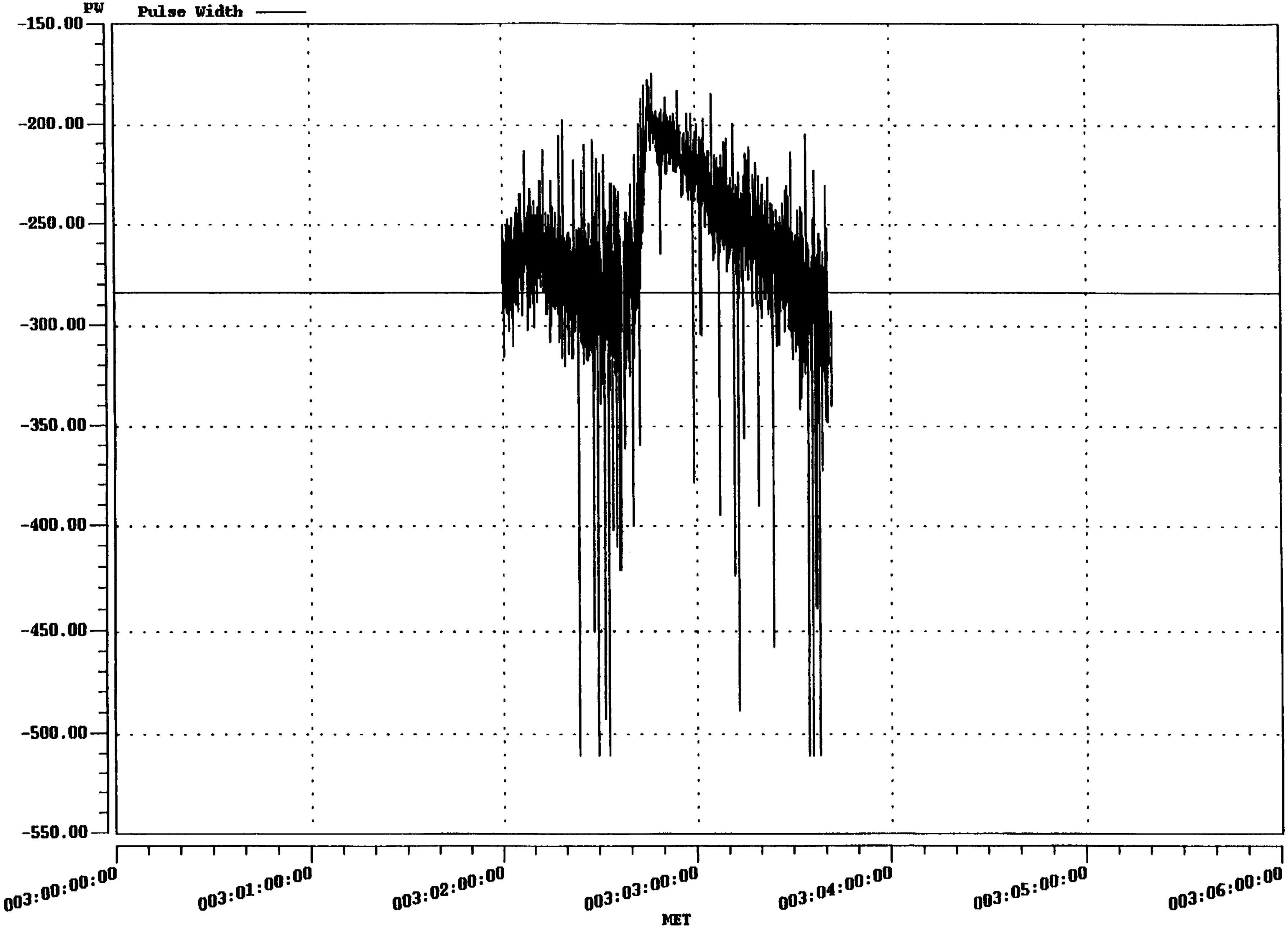


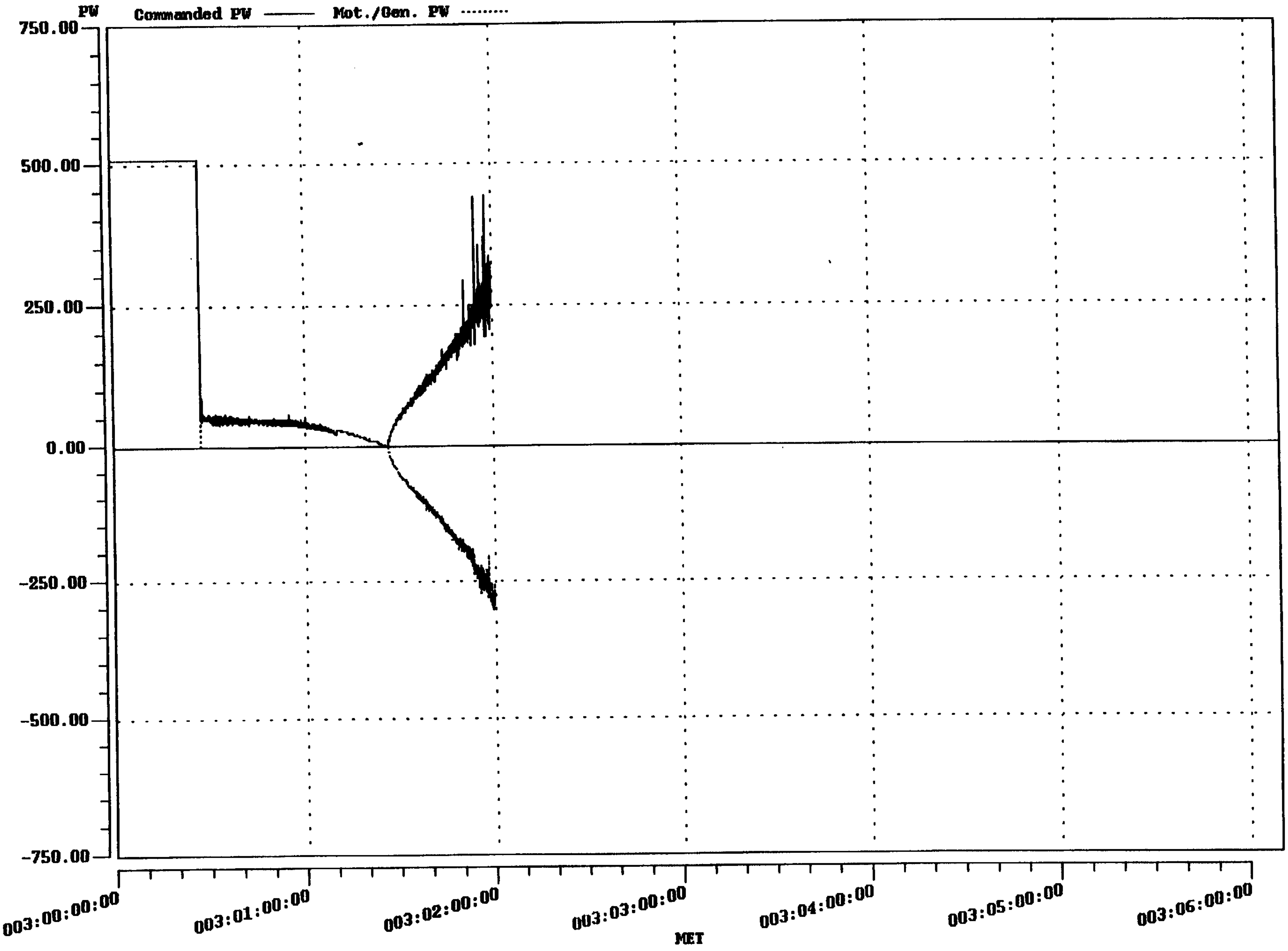
Motor/Generator Pulse Width



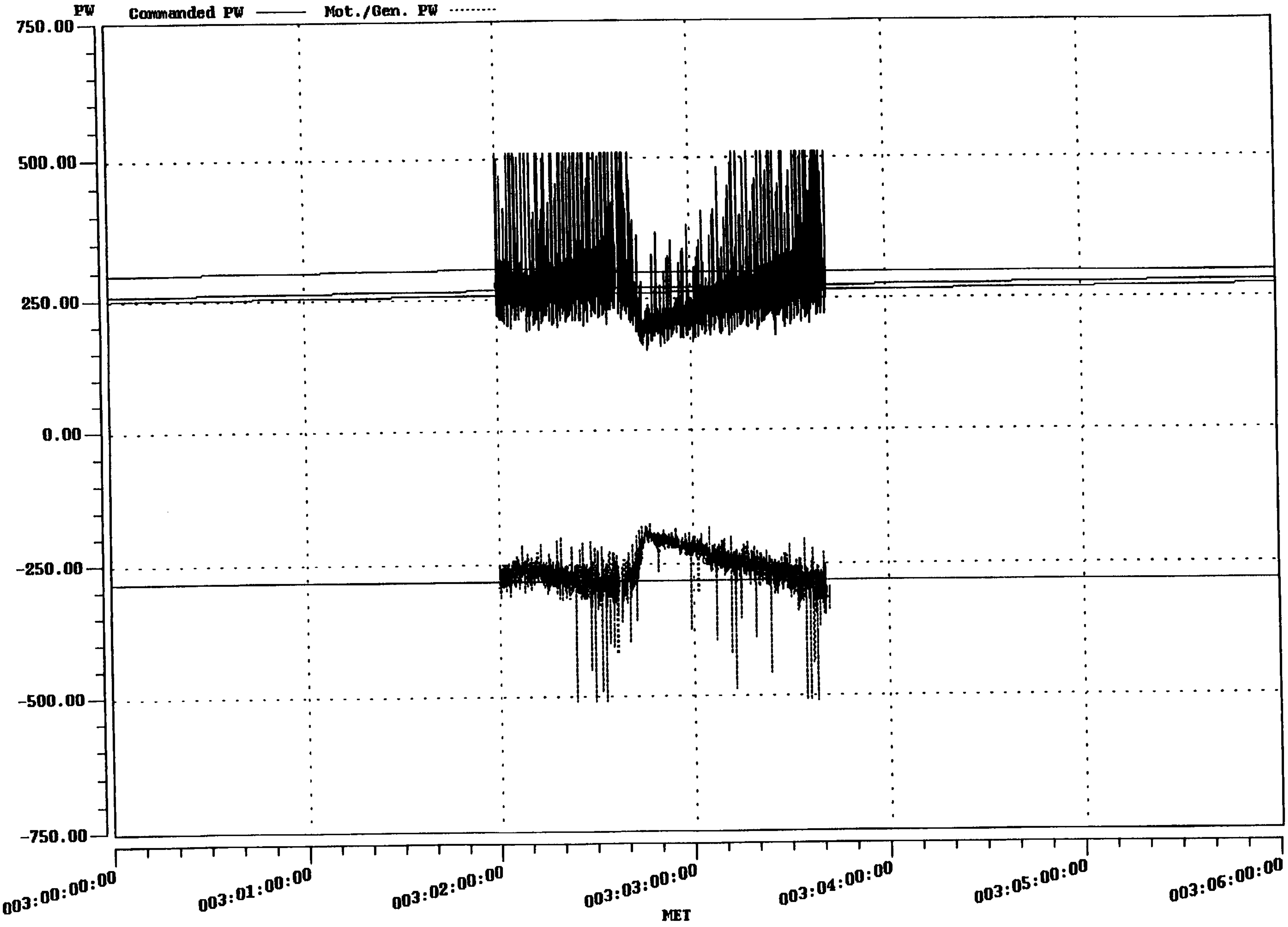

Commanded Pulse Width

Motor/Generator Pulse Width



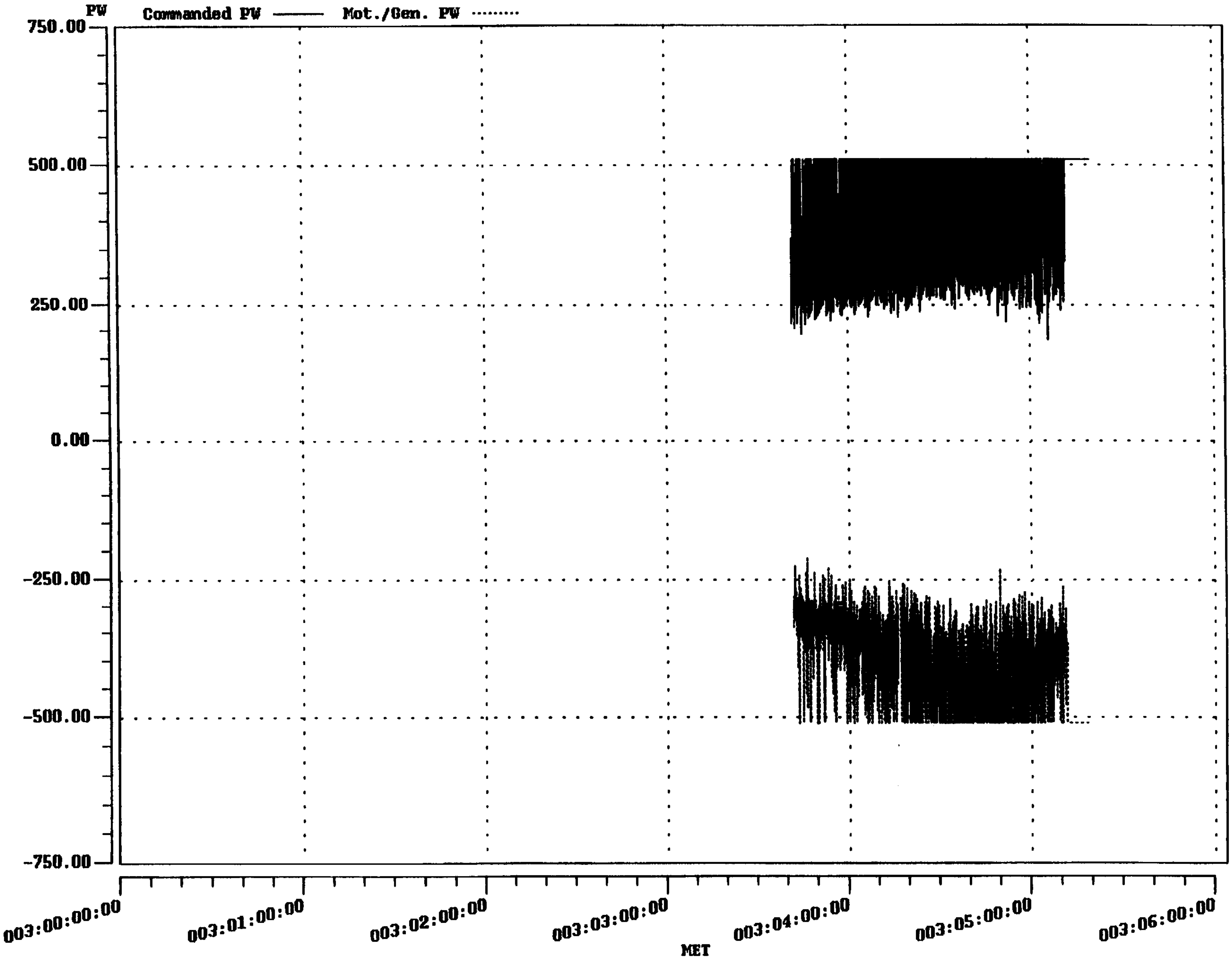


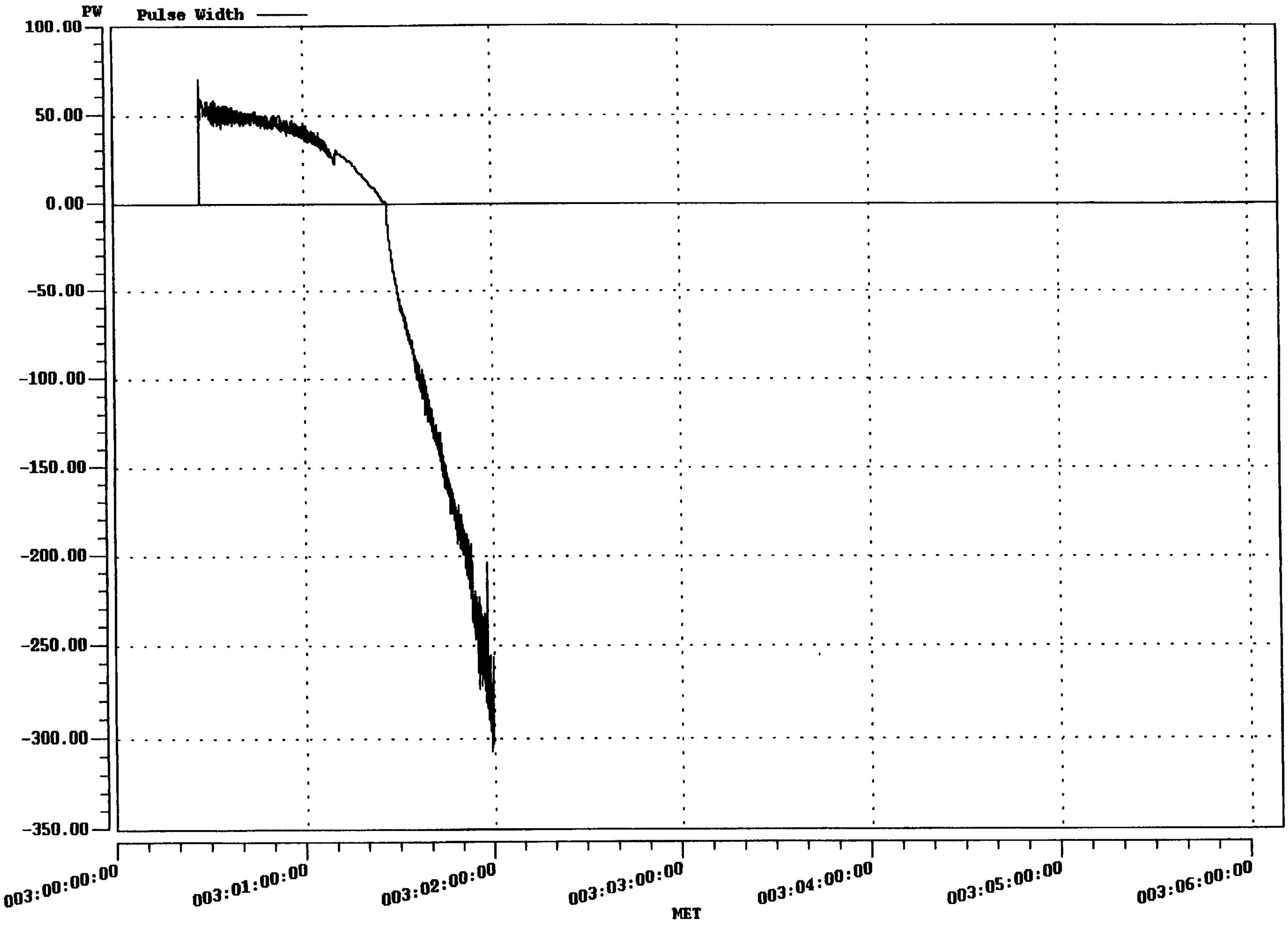
Commanded & Mot./Gen. Pulse Width



Commanded & Mot./Gen. Pulse Width

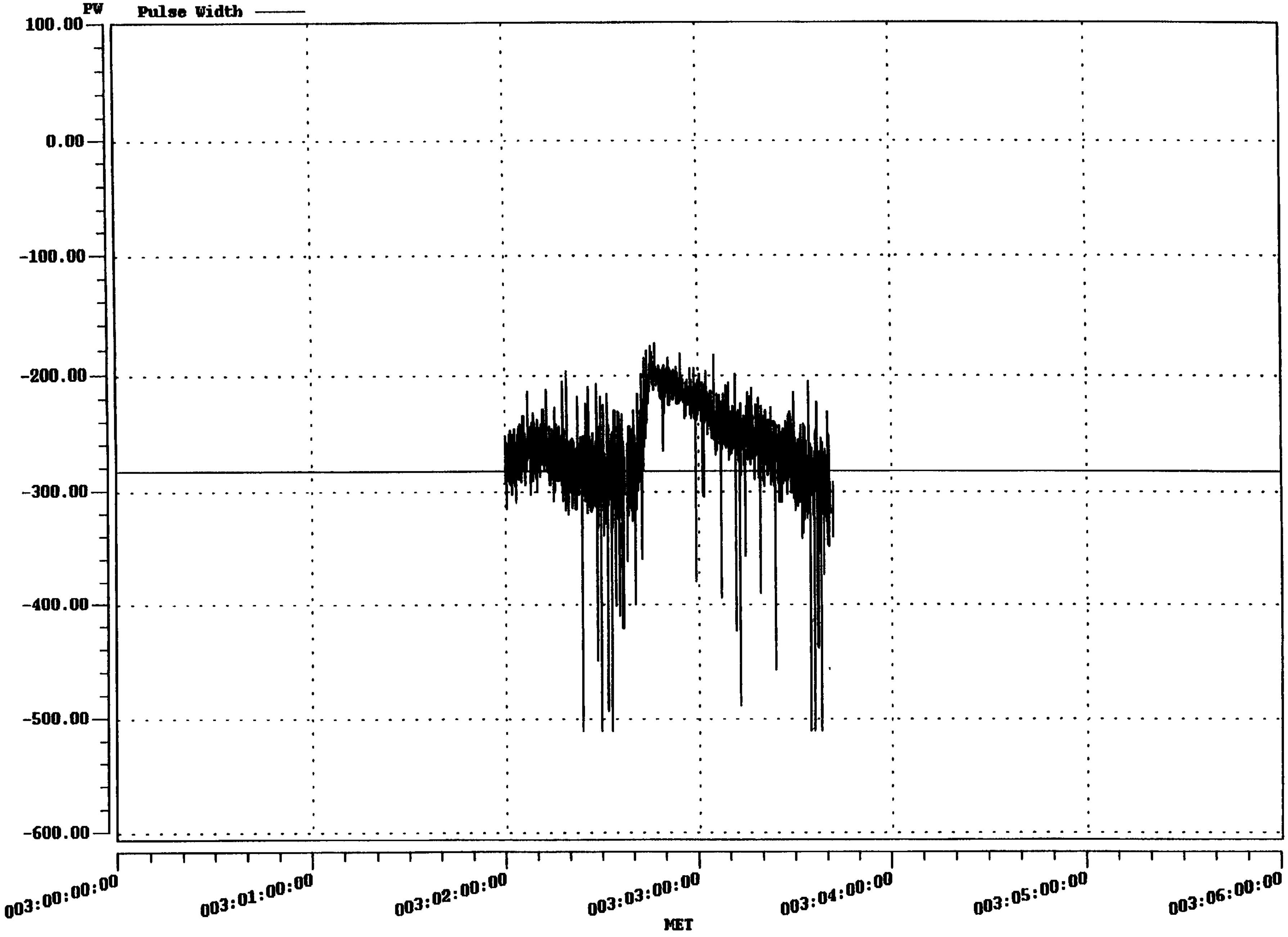
Commanded & Mot./Gen. Pulse Width

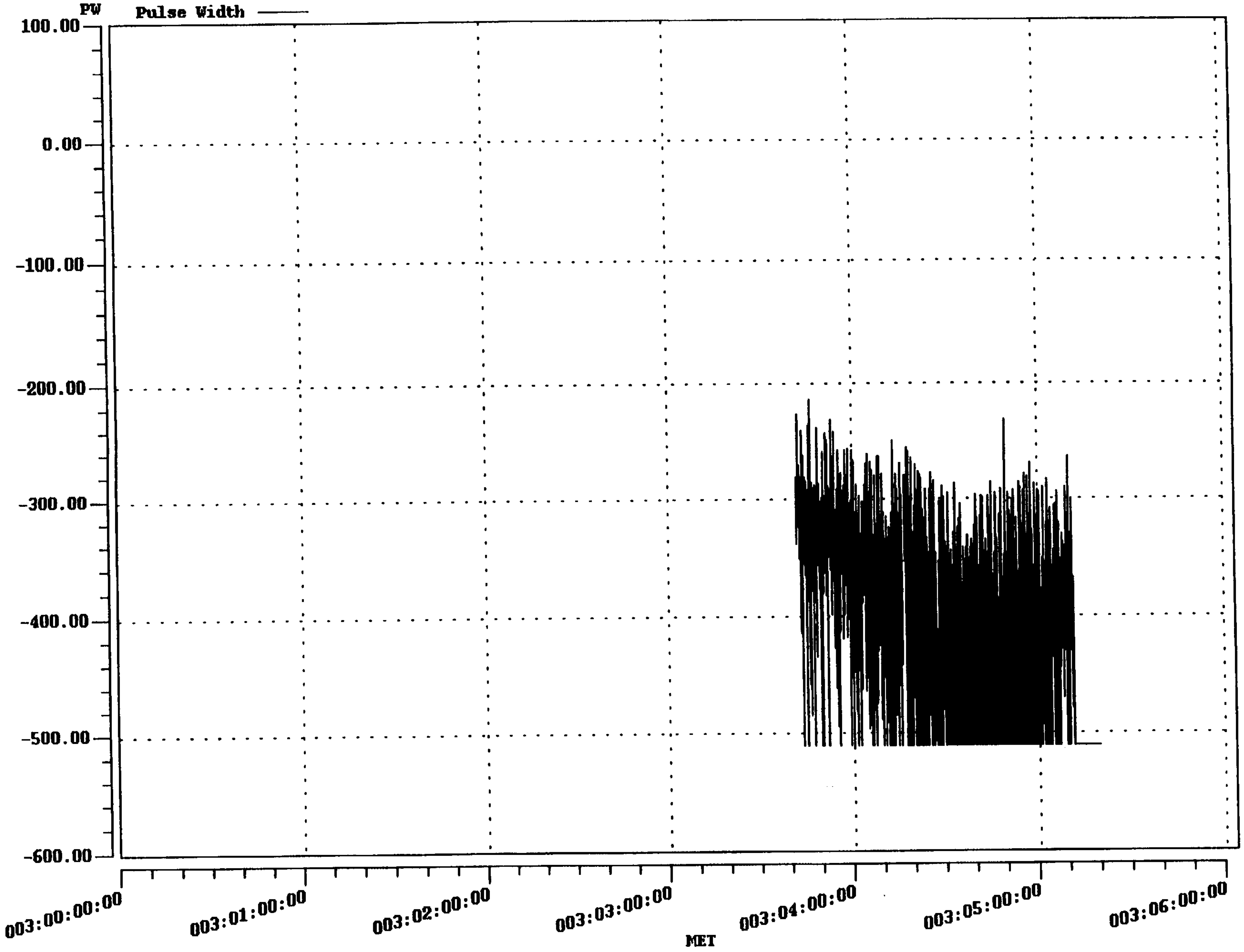




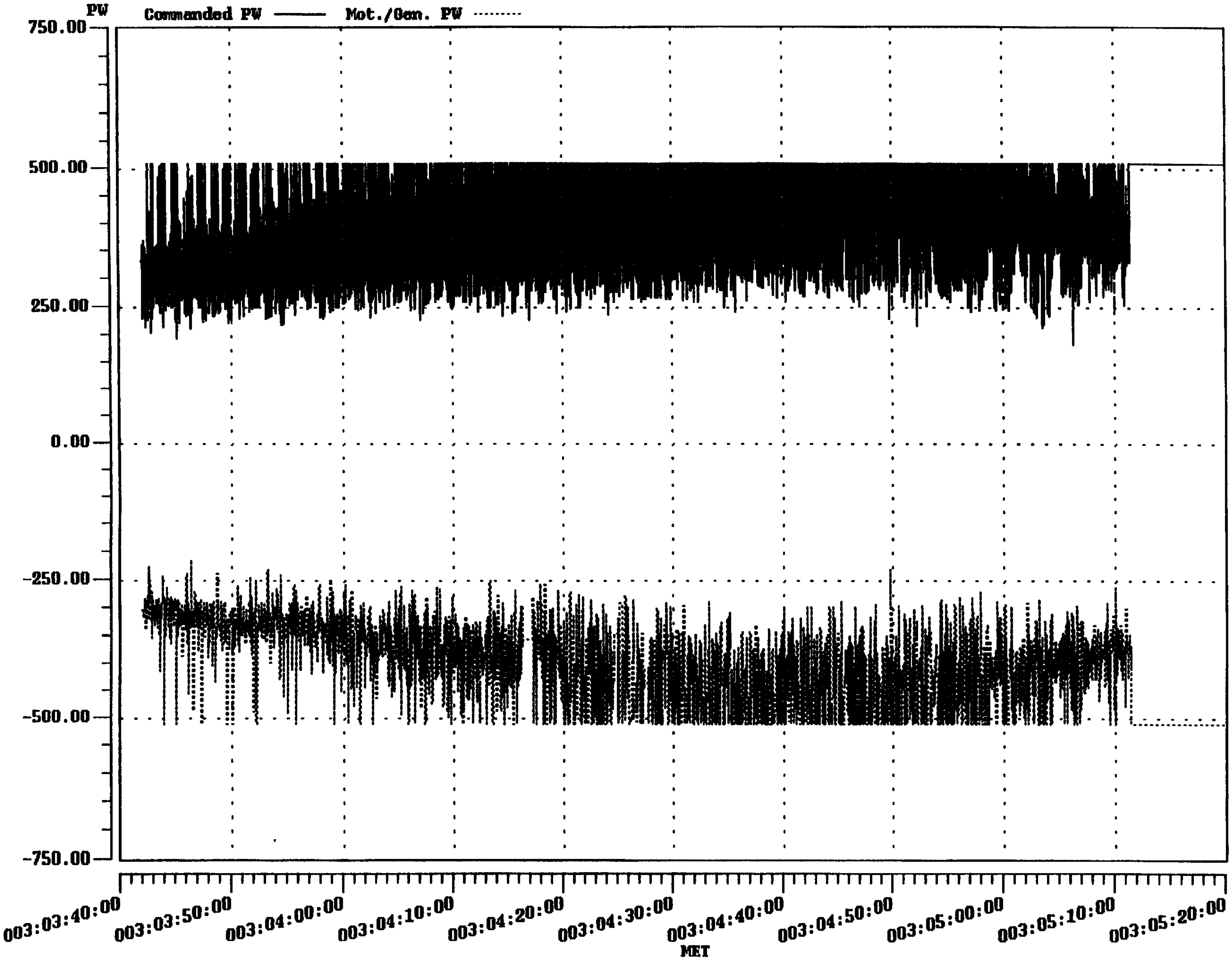
Motor/Generator Pulse Width

Motor/Generator Pulse Width



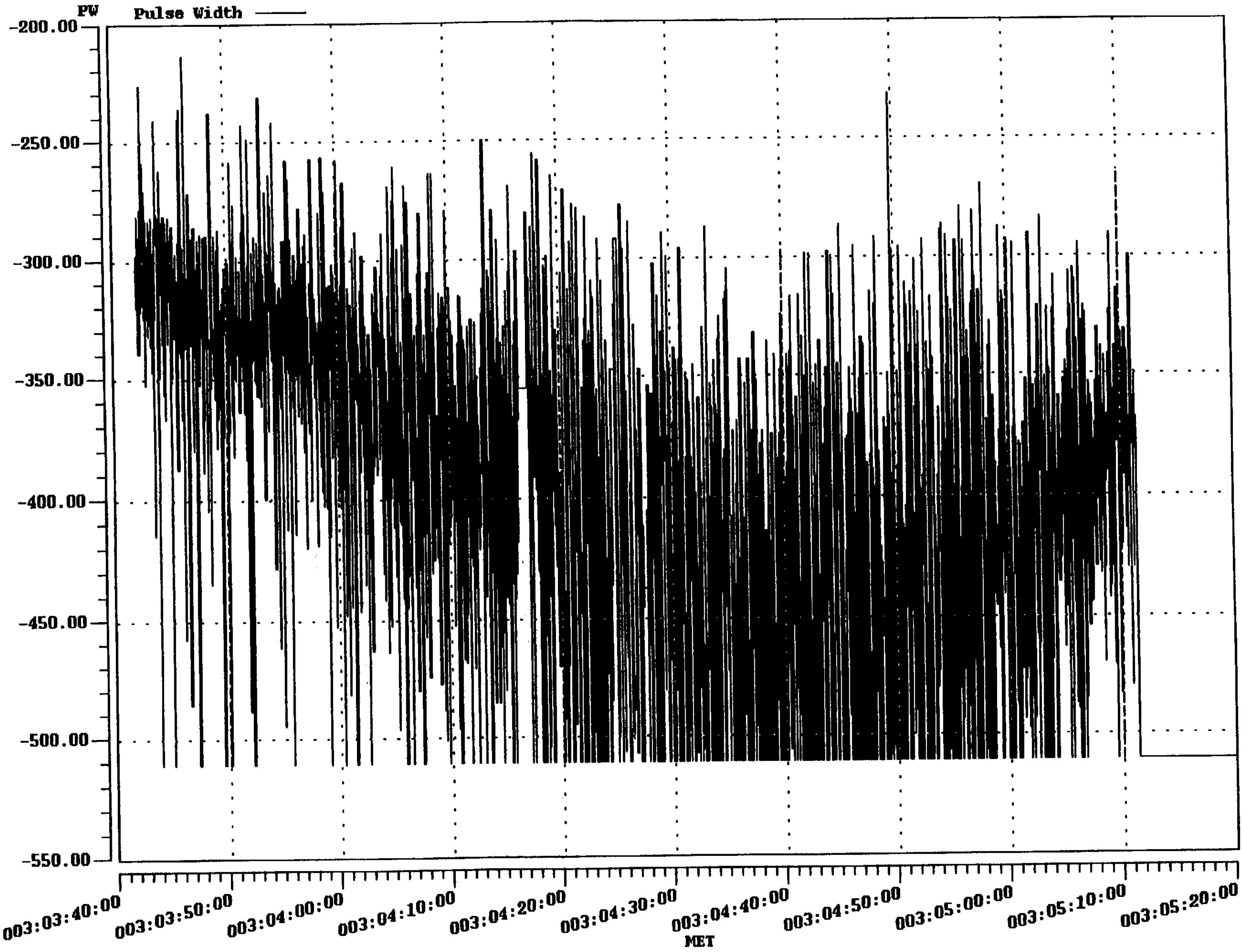


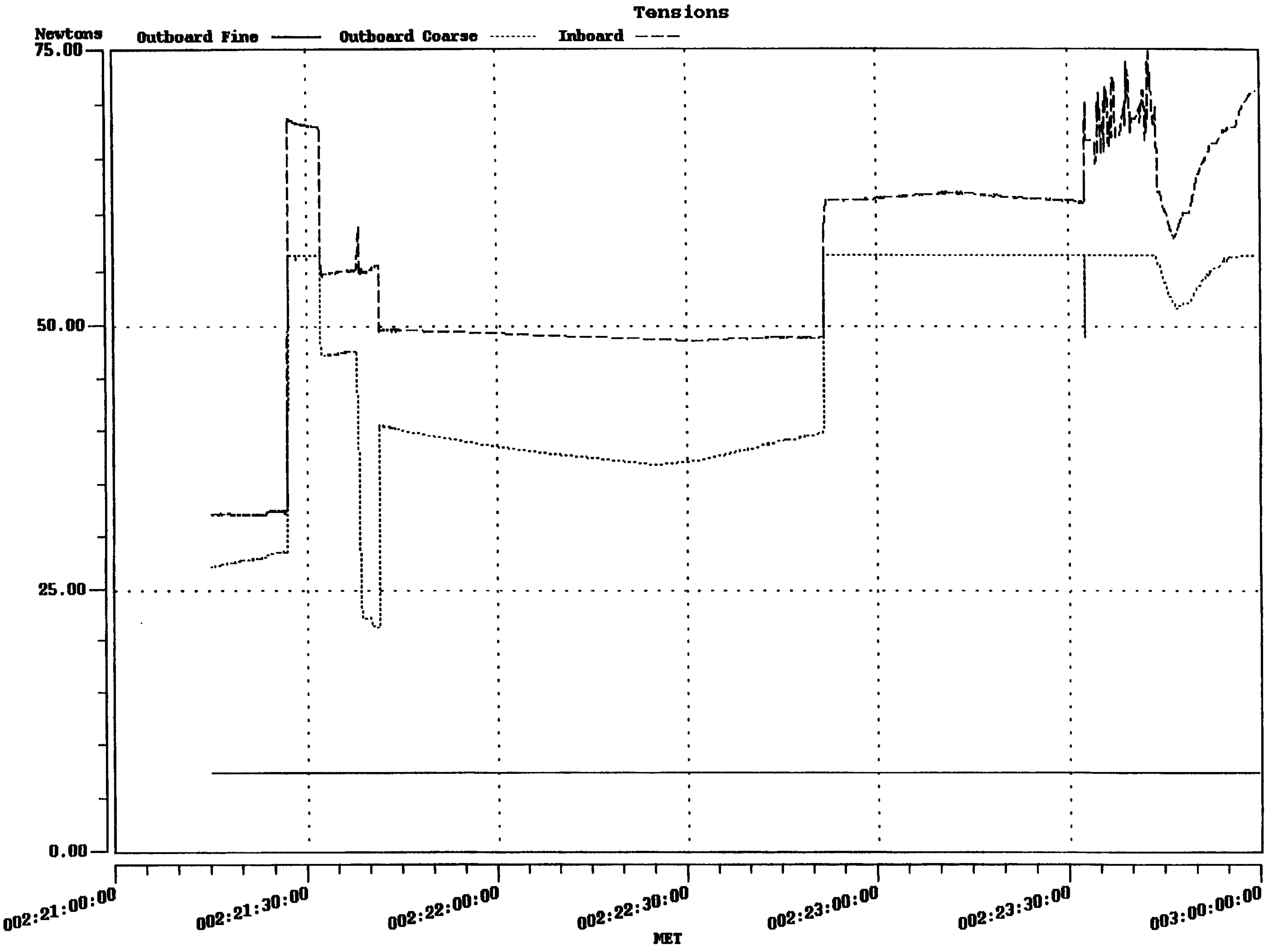
Motor/Generator Pulse Width

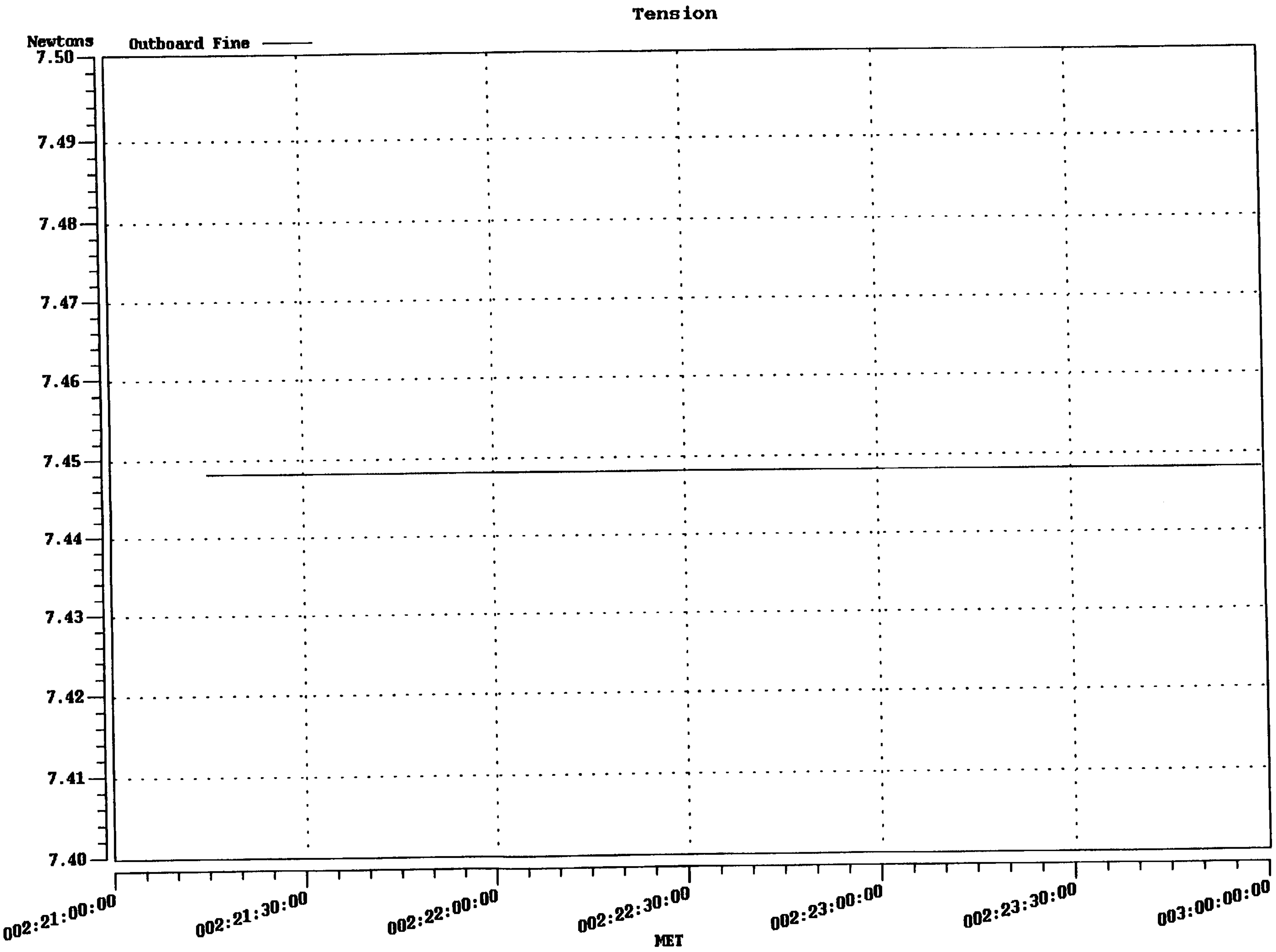


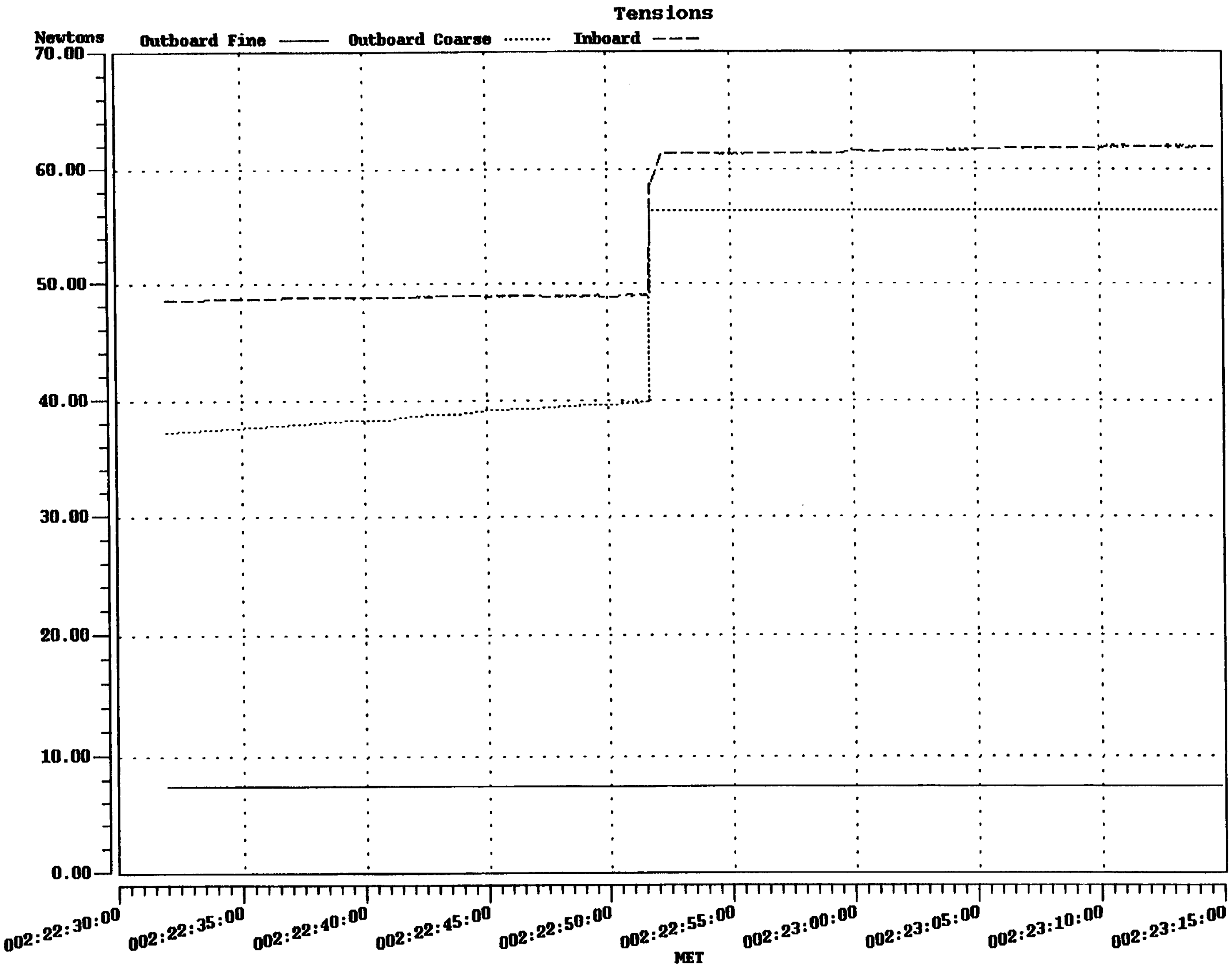
Commanded & Mot./Gen. Pulse Width

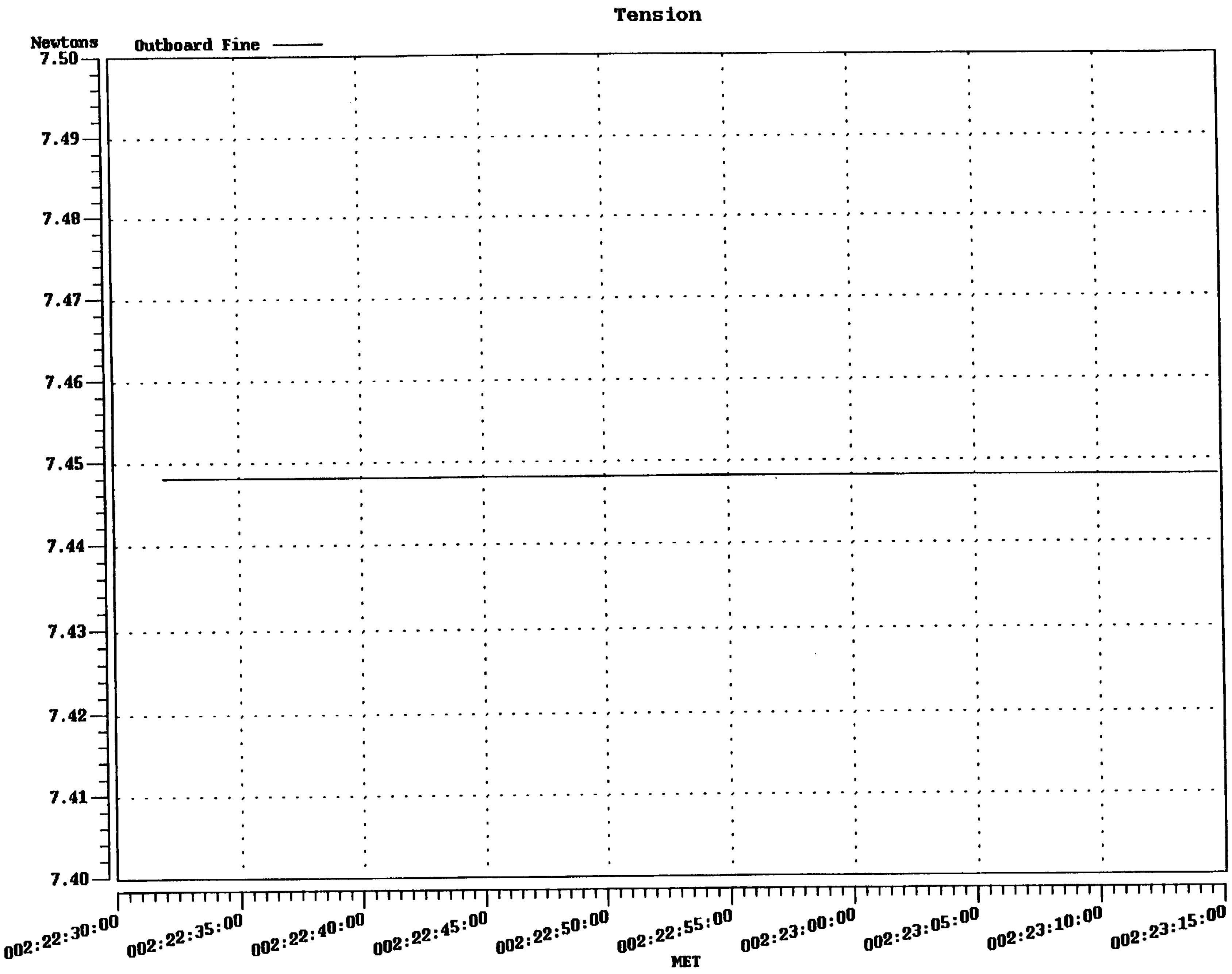
Motor/Generator Pulse Width

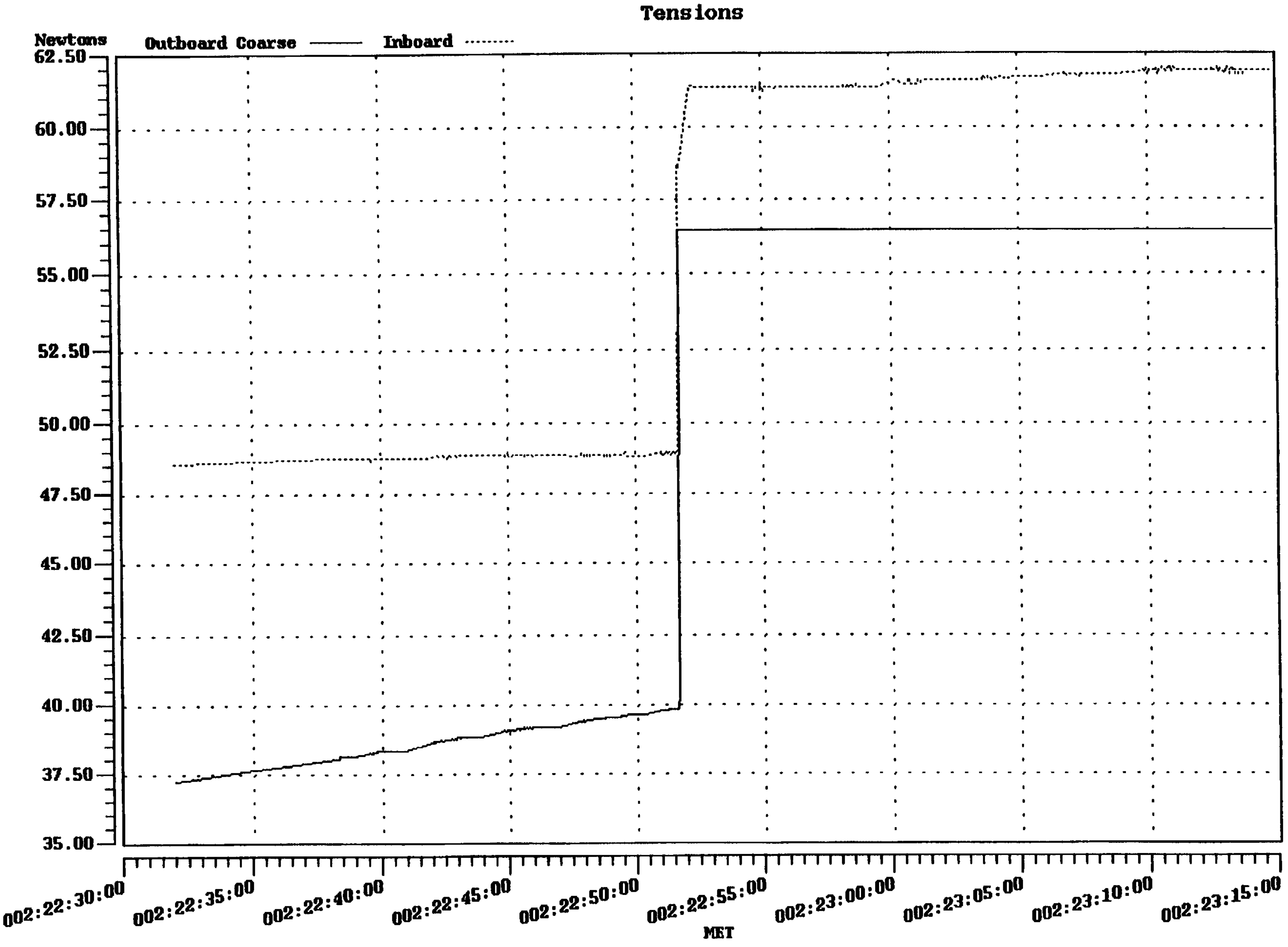



Tensions
Newtons
Outboard Fine
Outboard Coarse
Inboard
75.00
50.00
25.00
0.00
002:21:00:00
002:21:30:00
002:22:00:00
002:22:30:00
002:23:00:00
002:23:30:00
003:00:00:00
MET

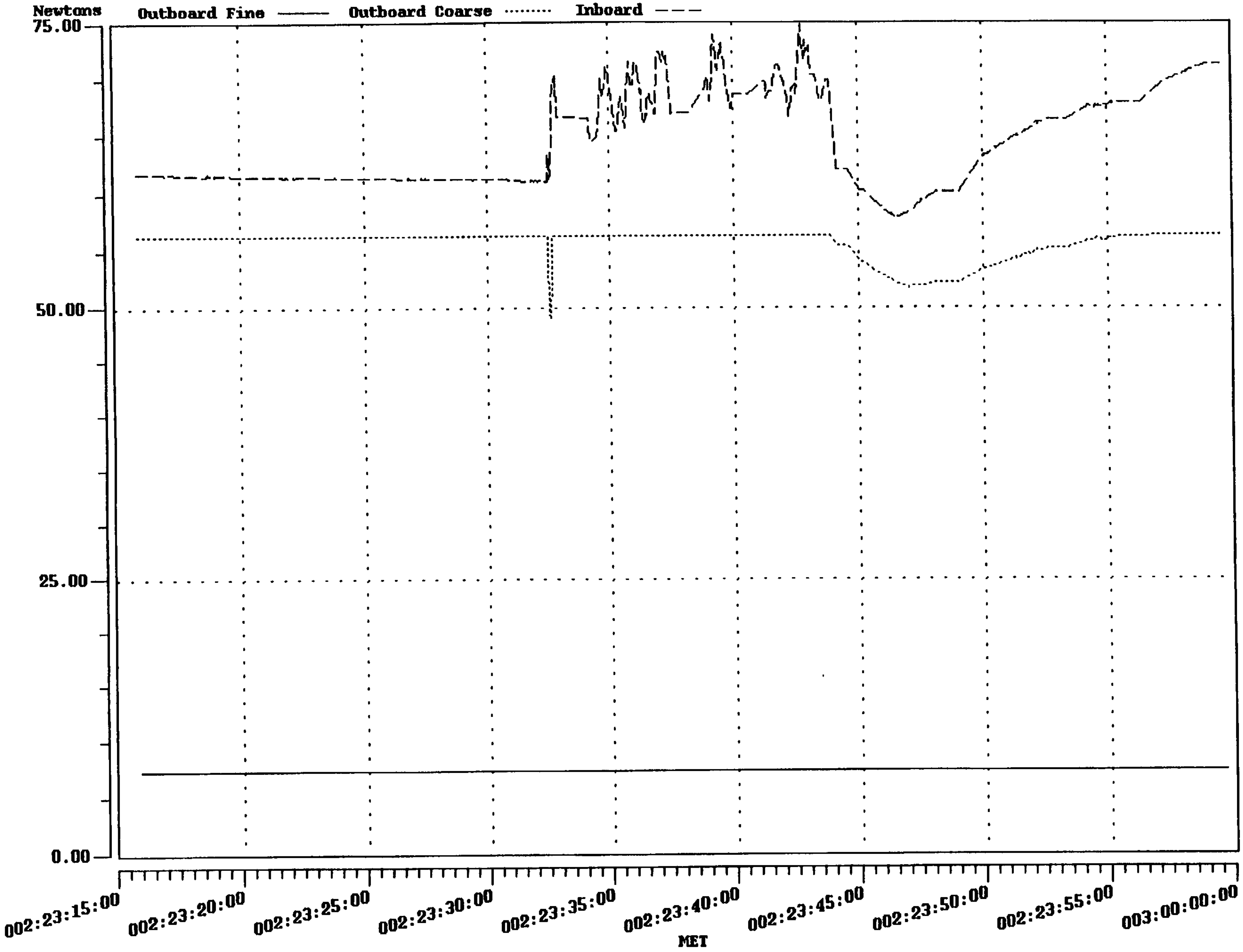

Tension
Newtons
Outboard Fine
7.50
7.49
7.48
7.47
7.46
7.45
7.44
7.43
7.42
7.41
7.40
002:21:00:00
002:21:30:00
002:22:00:00
002:22:30:00
002:23:00:00
002:23:30:00
003:00:00:00
MET

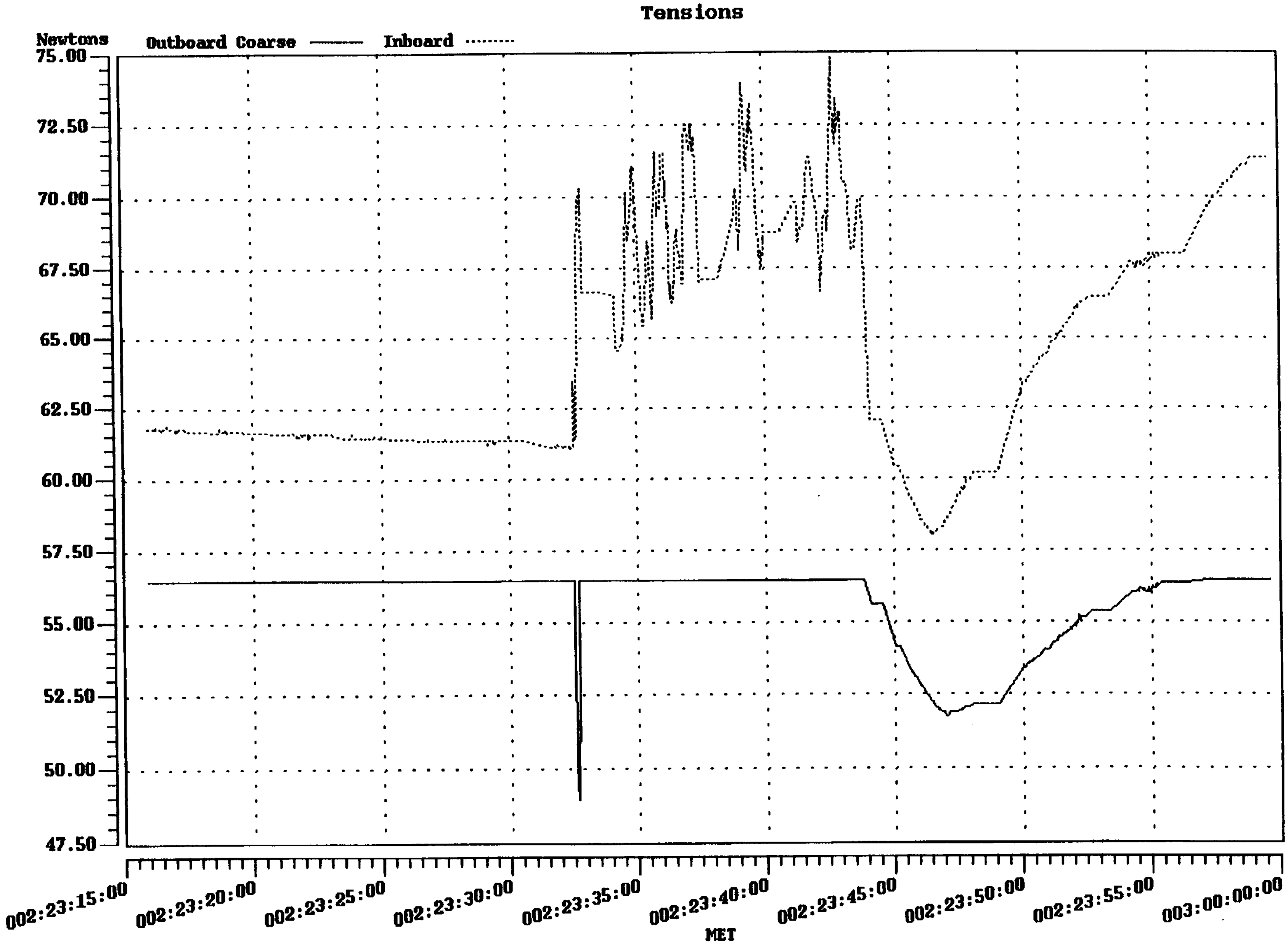

Tensions
Newtons
Outboard Fine
Outboard Coarse
Inboard
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
002:22:30:00
002:22:35:00
002:22:40:00
002:22:45:00
002:22:50:00
002:22:55:00
002:23:00:00
002:23:05:00
002:23:10:00
002:23:15:00
MET

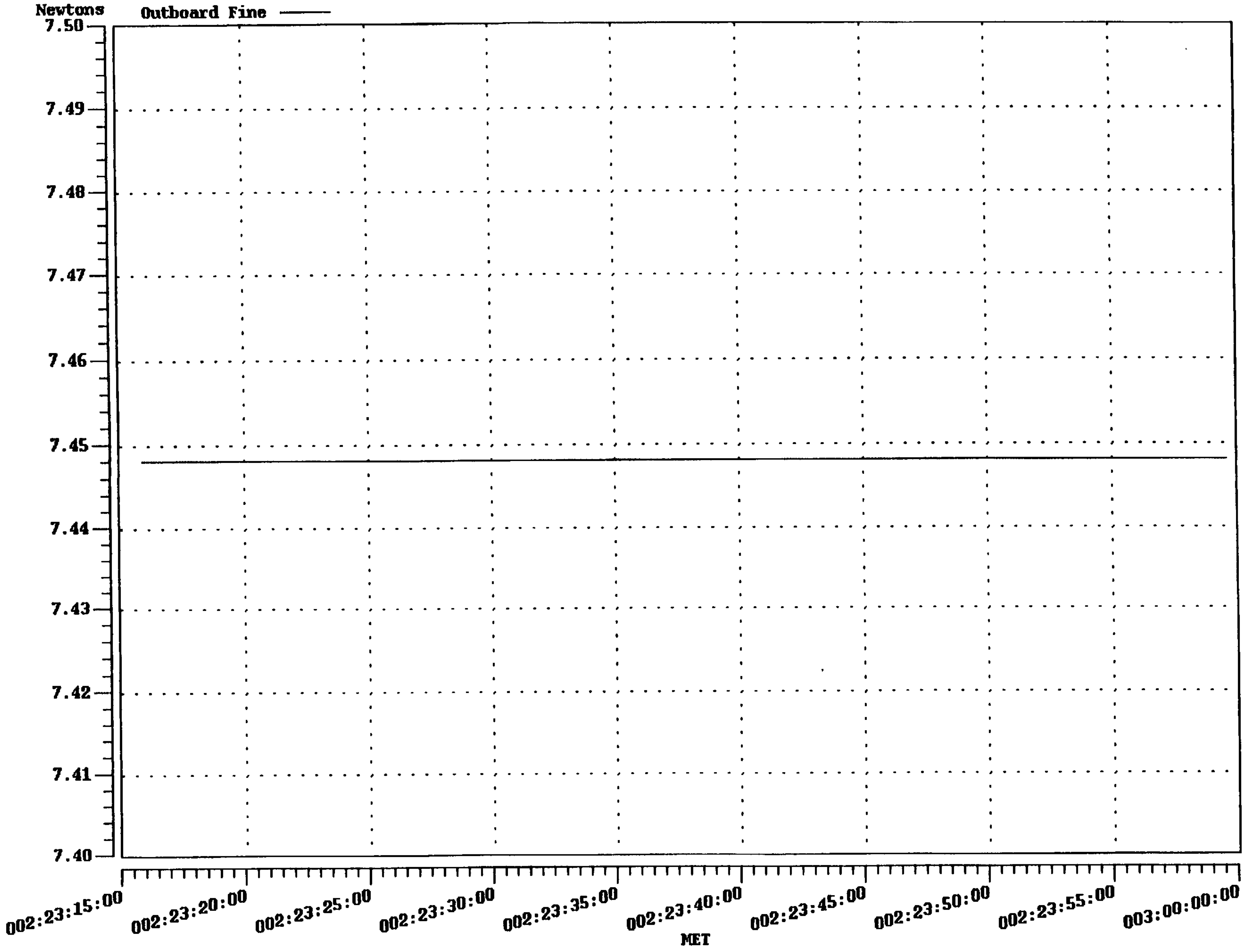

Tension
Newtons
Outboard Fine
7.50
7.49
7.48
7.47
7.46
7.45
7.44
7.43
7.42
7.41
7.40
002:22:30:00
002:22:35:00
002:22:40:00
002:22:45:00
002:22:50:00
002:22:55:00
002:23:00:00
002:23:05:00
002:23:10:00
002:23:15:00
MET


Tensions
Newtons
Outboard Coarse
Inboard
62.50
60.00
57.50
55.00
52.50
50.00
47.50
45.00
42.50
40.00
37.50
35.00
002:22:30:00
002:22:35:00
002:22:40:00
002:22:45:00
002:22:50:00
002:22:55:00
002:23:00:00
002:23:05:00
002:23:10:00
002:23:15:00
MET

Tensions


Newtons
Outboard Fine
Outboard Coarse
Inboard
75.00
50.00
25.00
0.00
002:23:15:00
002:23:20:00
002:23:25:00
002:23:30:00
002:23:35:00
002:23:40:00
002:23:45:00
002:23:50:00
002:23:55:00
003:00:00:00
MET


Tensions
Newtons
Outboard Coarse ——
Inboard ········
75.00
72.50
70.00
67.50
65.00
62.50
60.00
57.50
55.00
52.50
50.00
47.50
002:23:15:00
002:23:20:00
002:23:25:00
002:23:30:00
002:23:35:00
002:23:40:00
002:23:45:00
002:23:50:00
002:23:55:00
003:00:00:00
MET



Tension

Newtons
Outboard Fine
7.50
7.49
7.48
7.47
7.46
7.45
7.44
7.43
7.42
7.41
7.40
002:23:15:00
002:23:20:00
002:23:25:00
002:23:30:00
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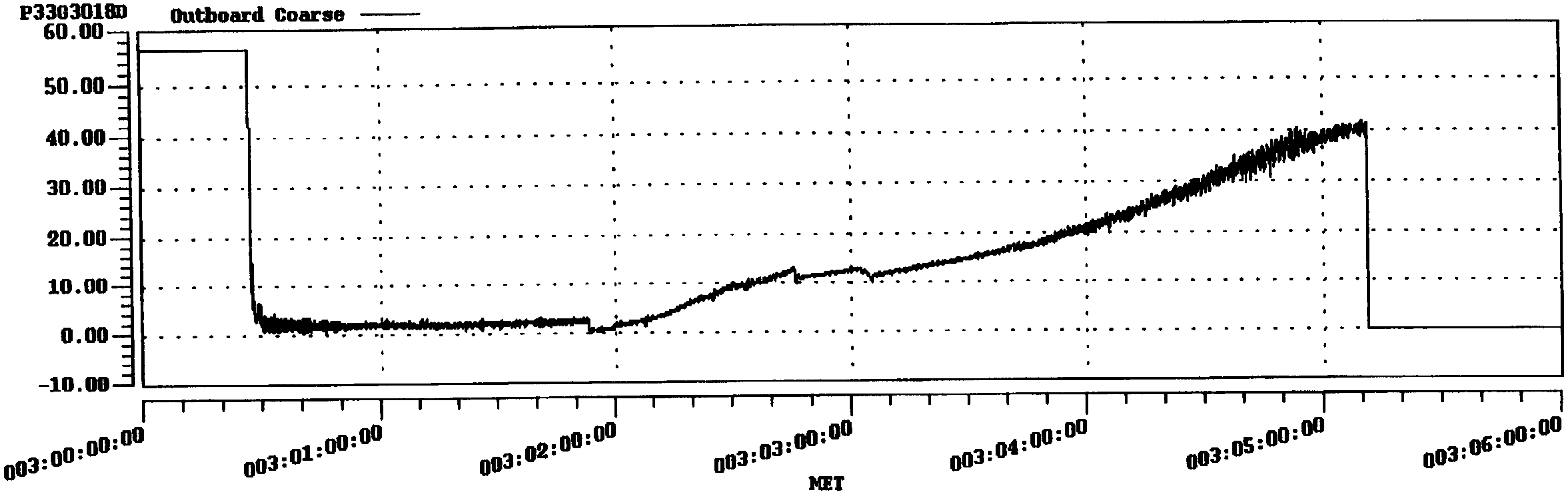
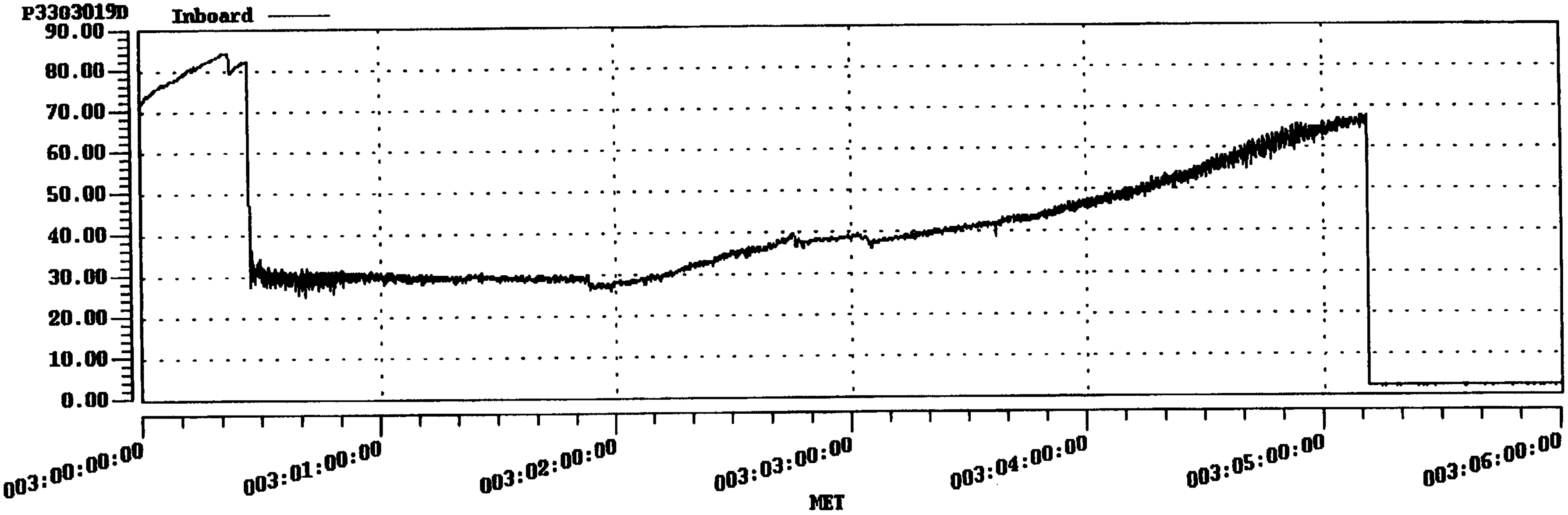
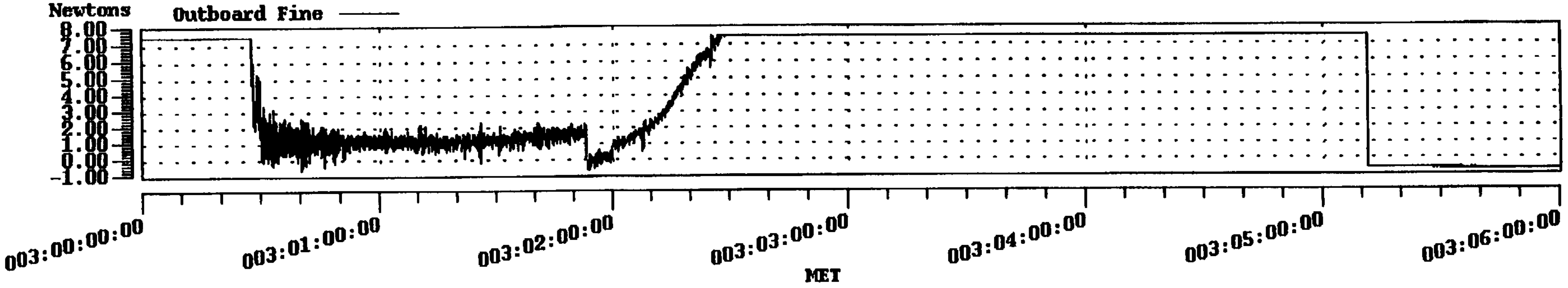
003:00:00:00
MET

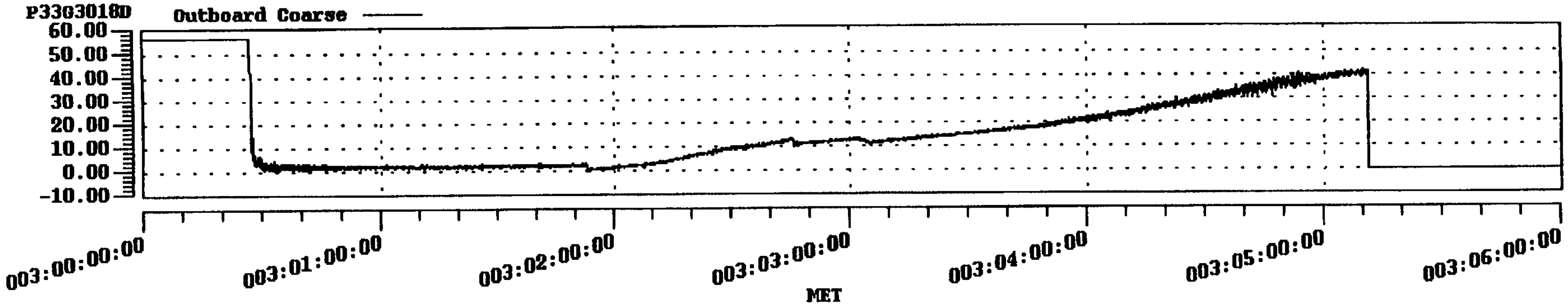

Outboard Coarse Tether Tension


Inboard Tether Tension

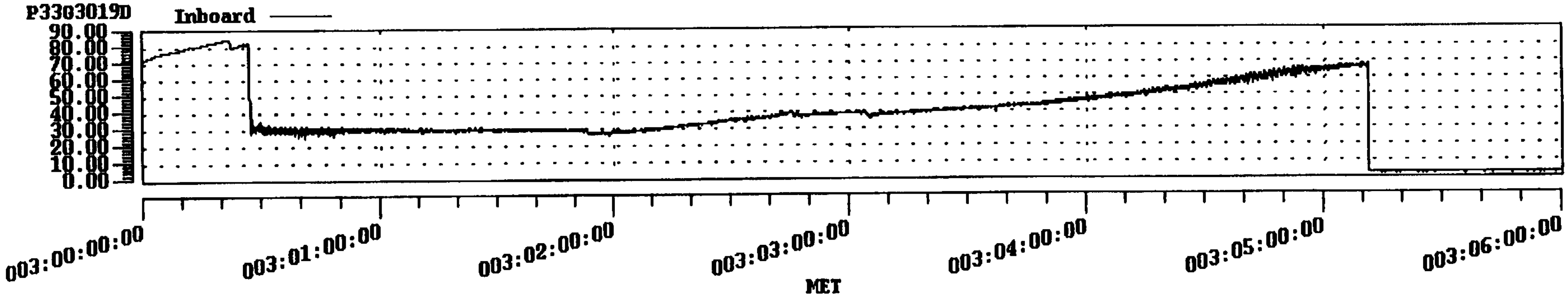
Outboard Fine Tether Tension



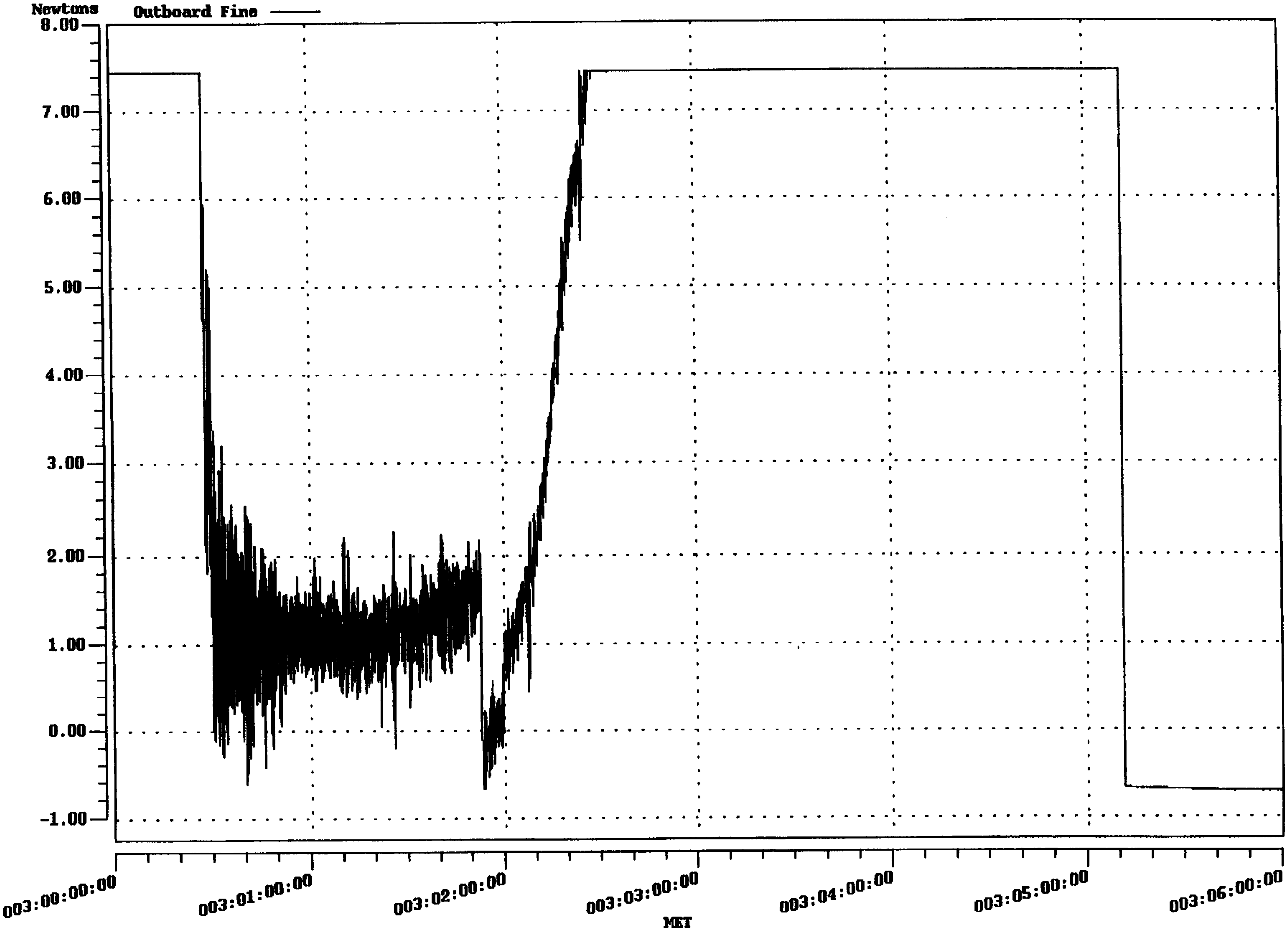
Outboard Coarse Tether Tension



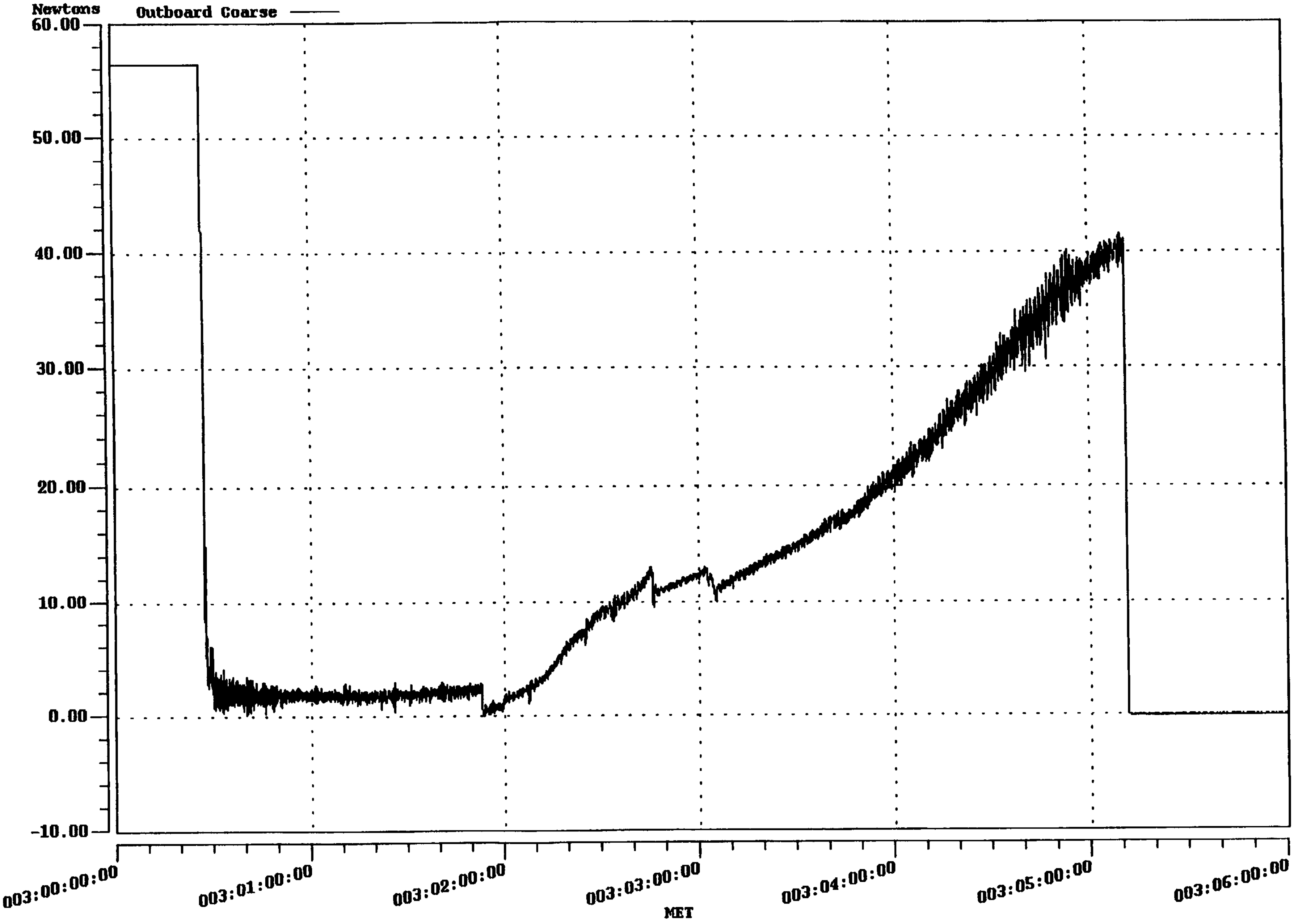
Inboard Tether Tension

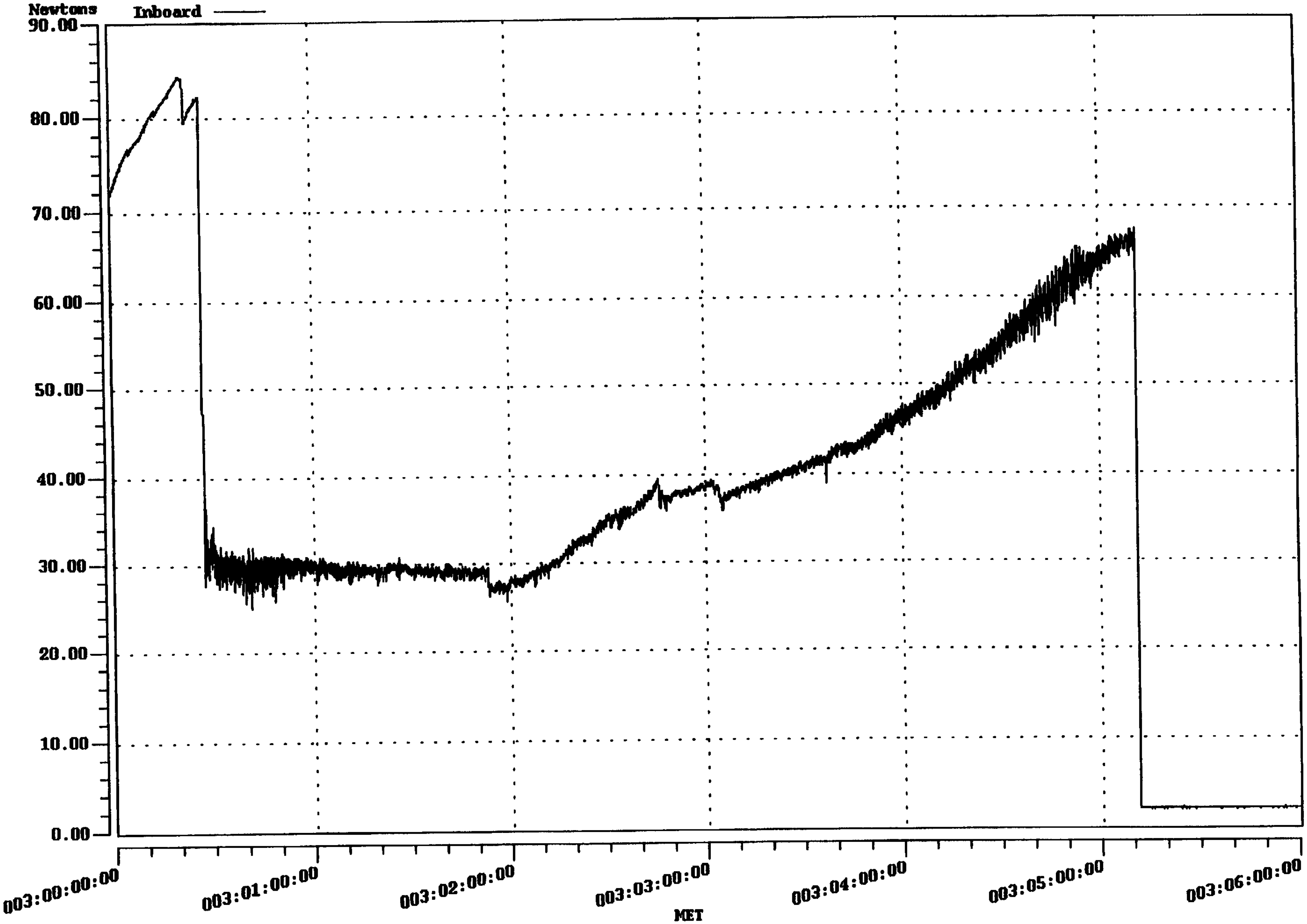


Outboard Fine Tether Tension



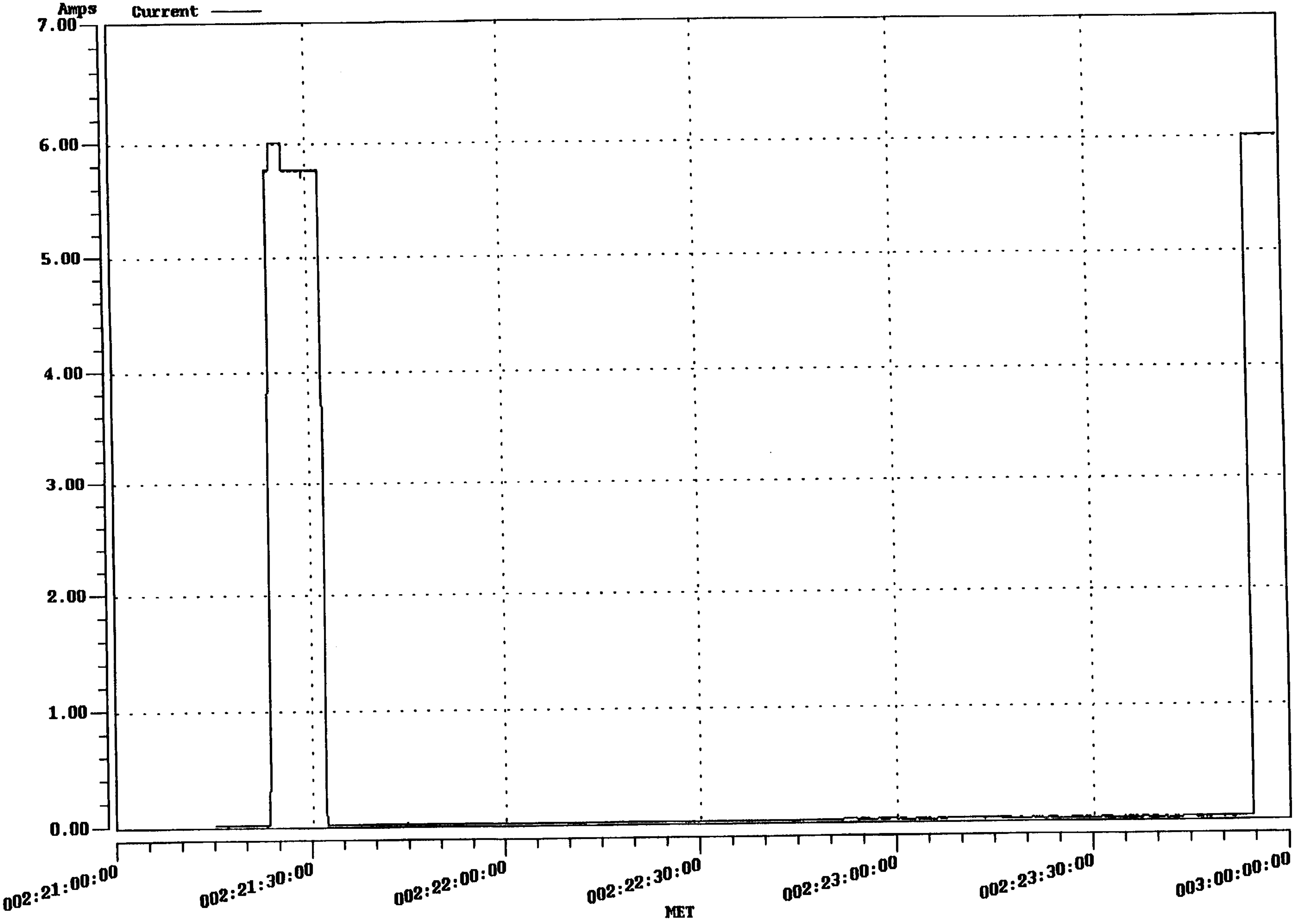
Outboard Coarse Tether Tension



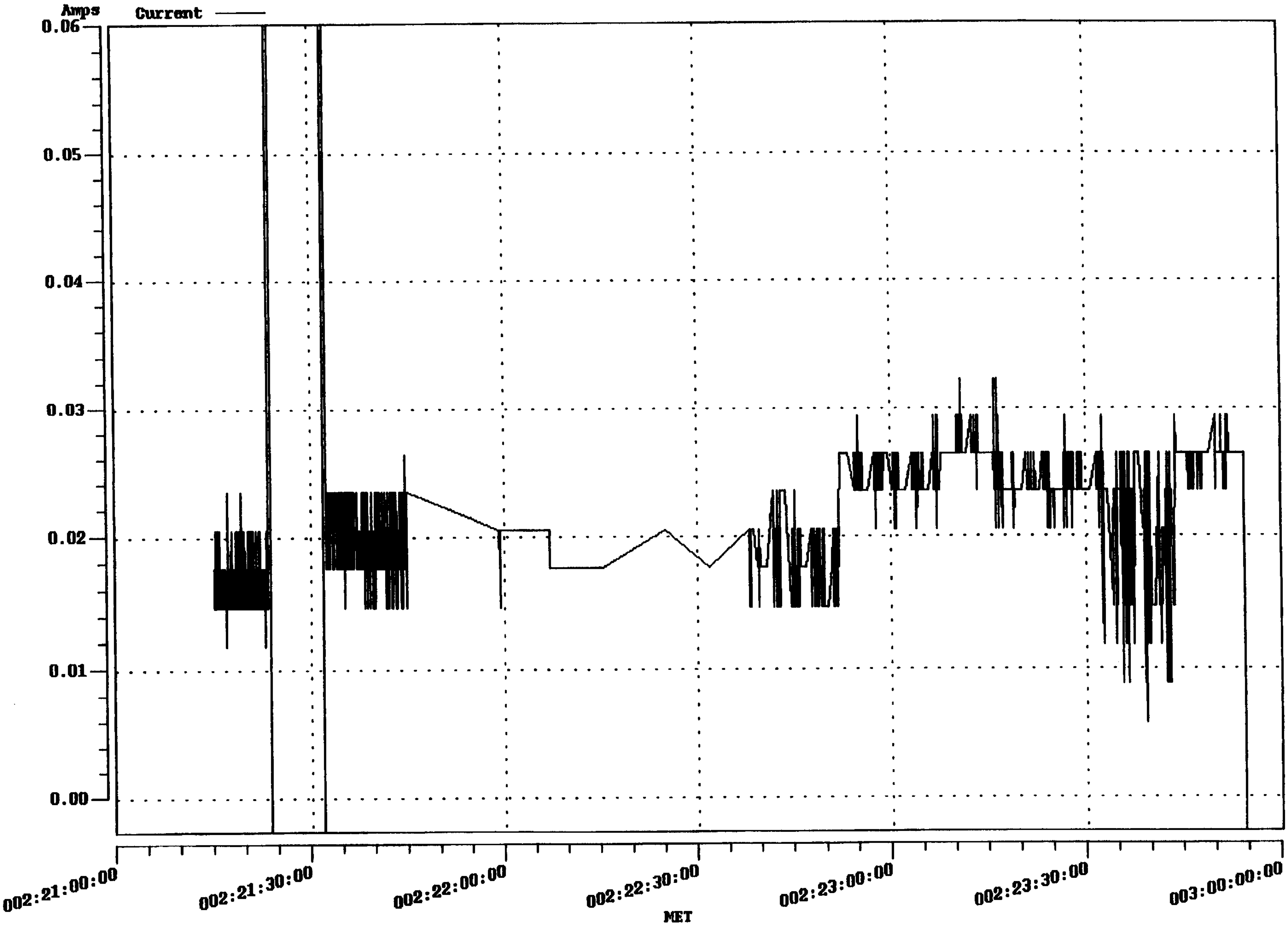


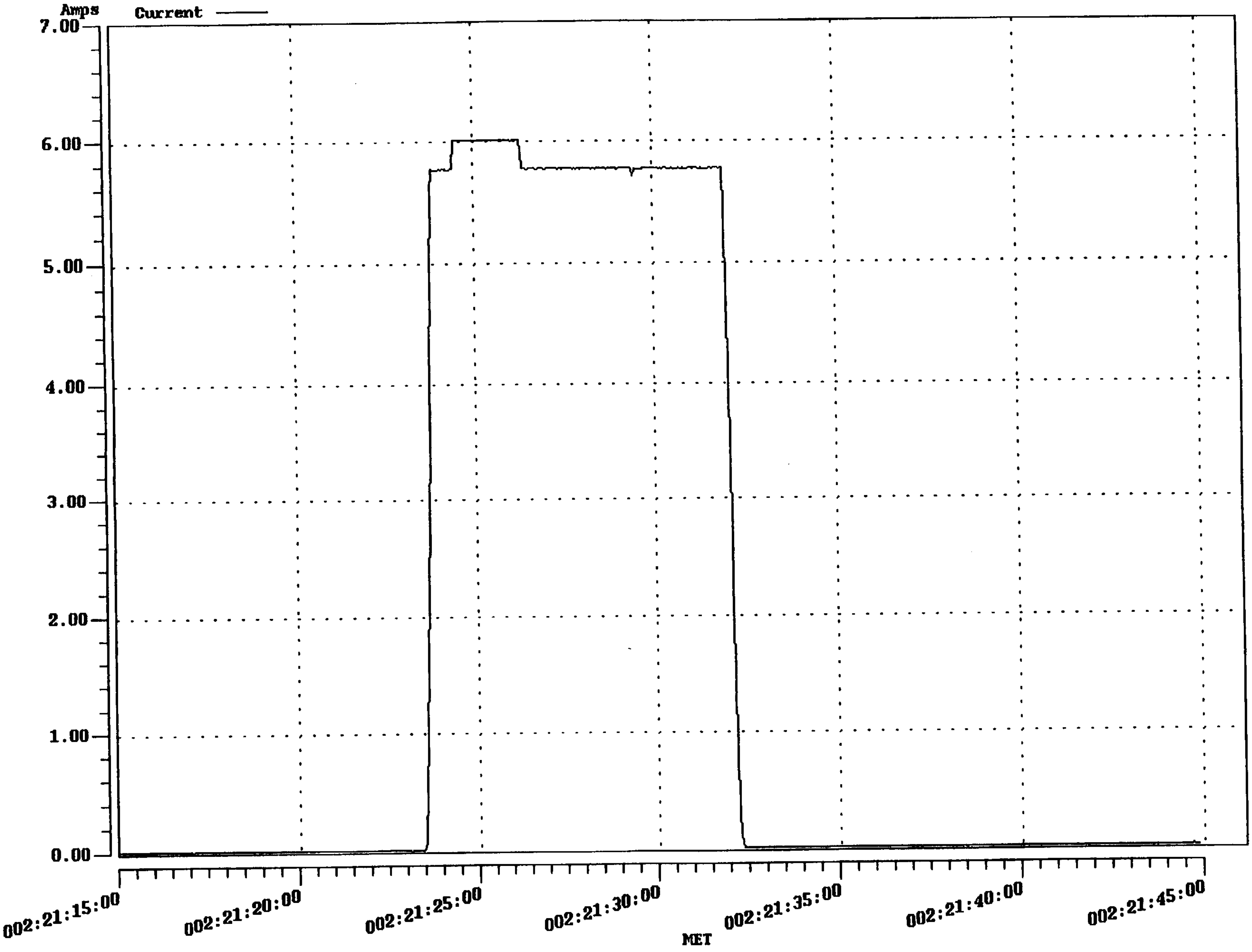
Inboard Tether Tension

Reel Motor Current



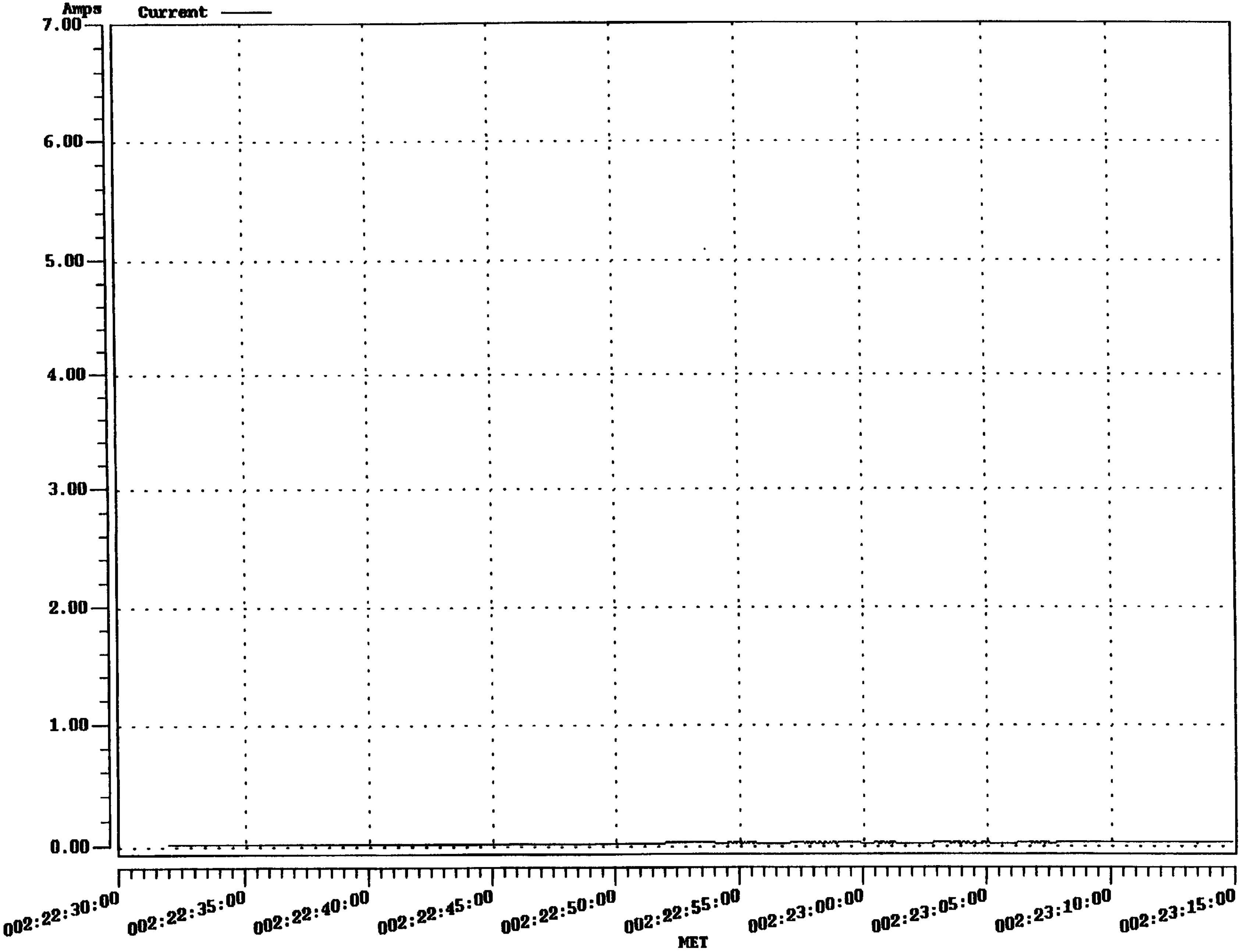
Reel Motor Current



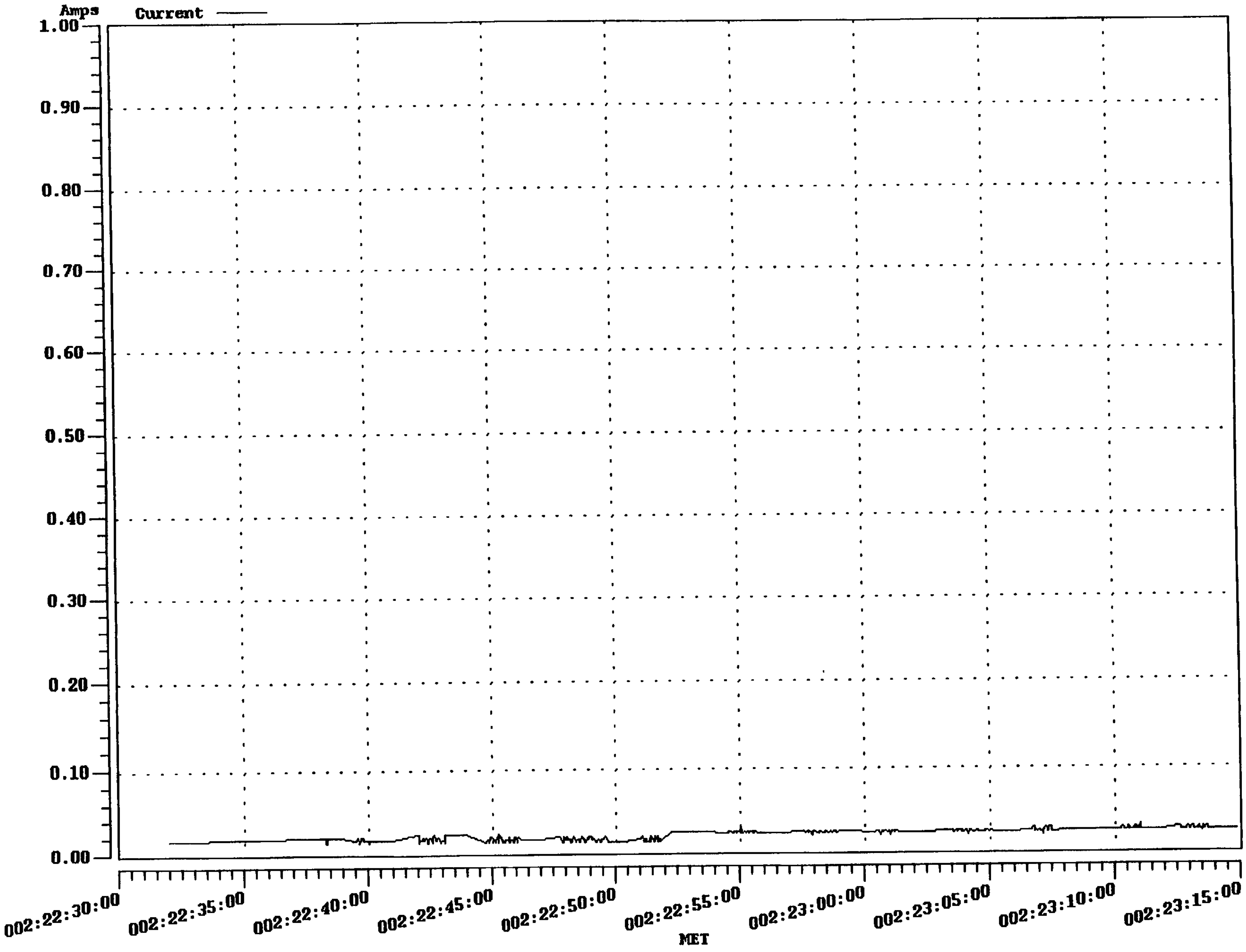


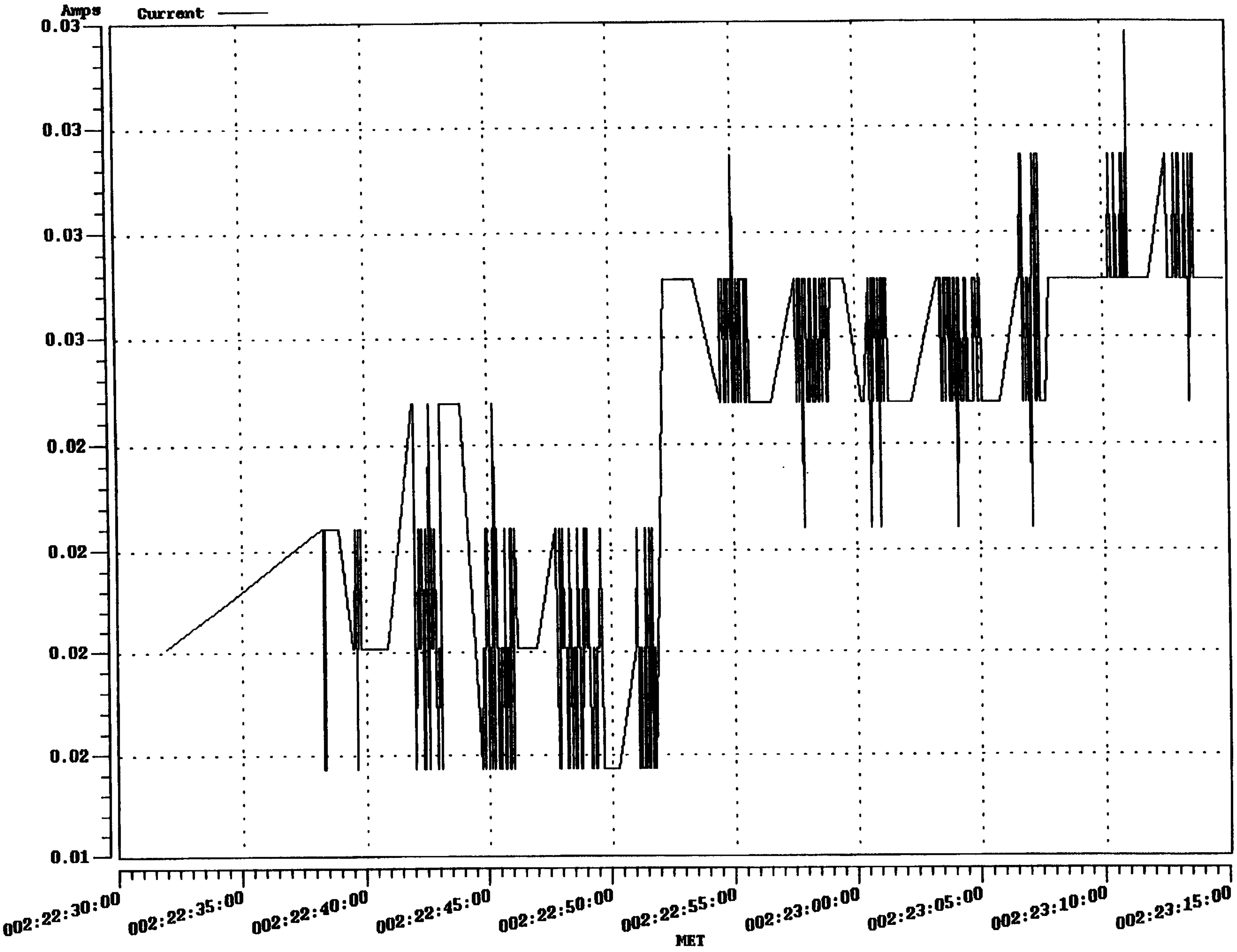
Reel Motor Current

Reel Motor Current

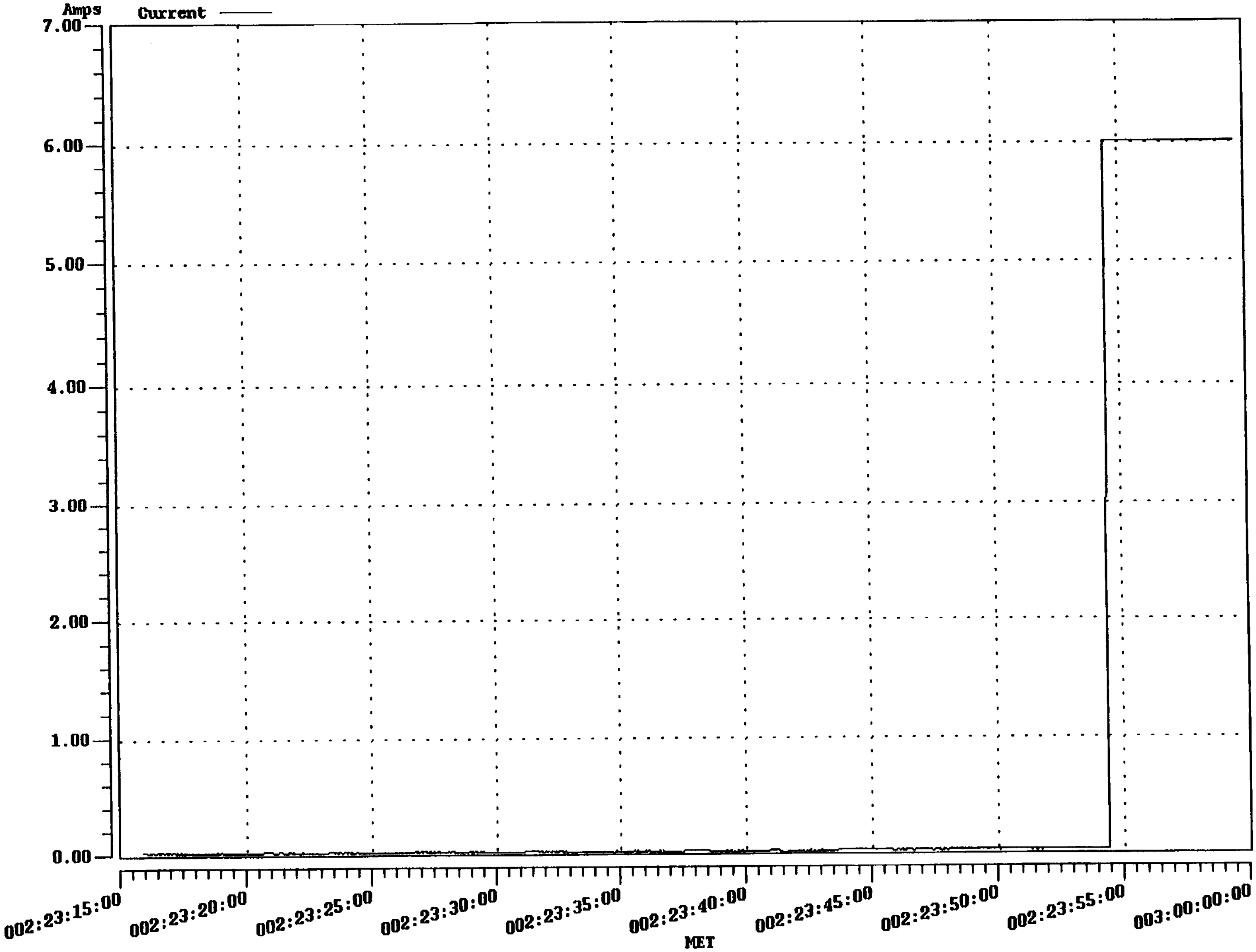


Reel Motor Current

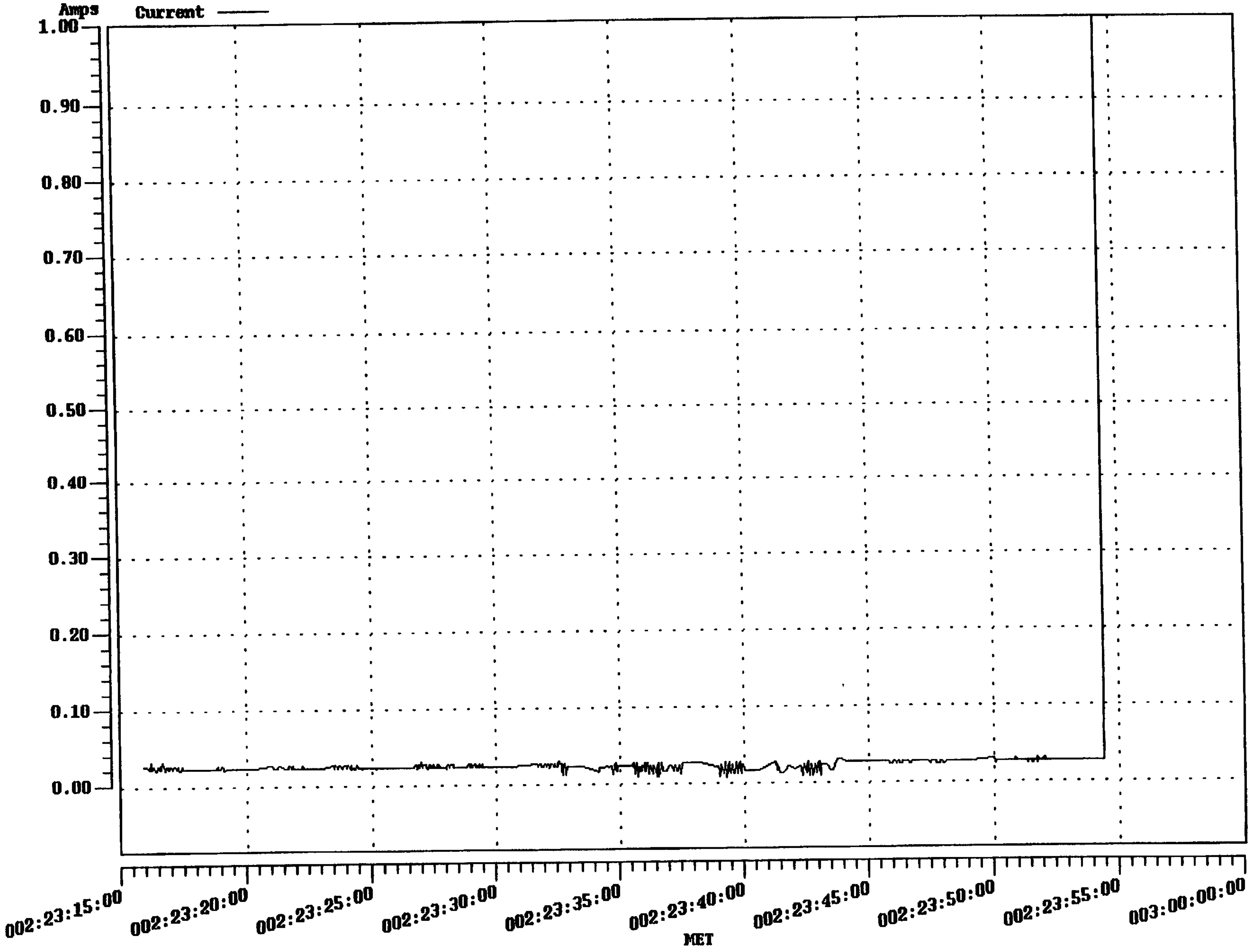




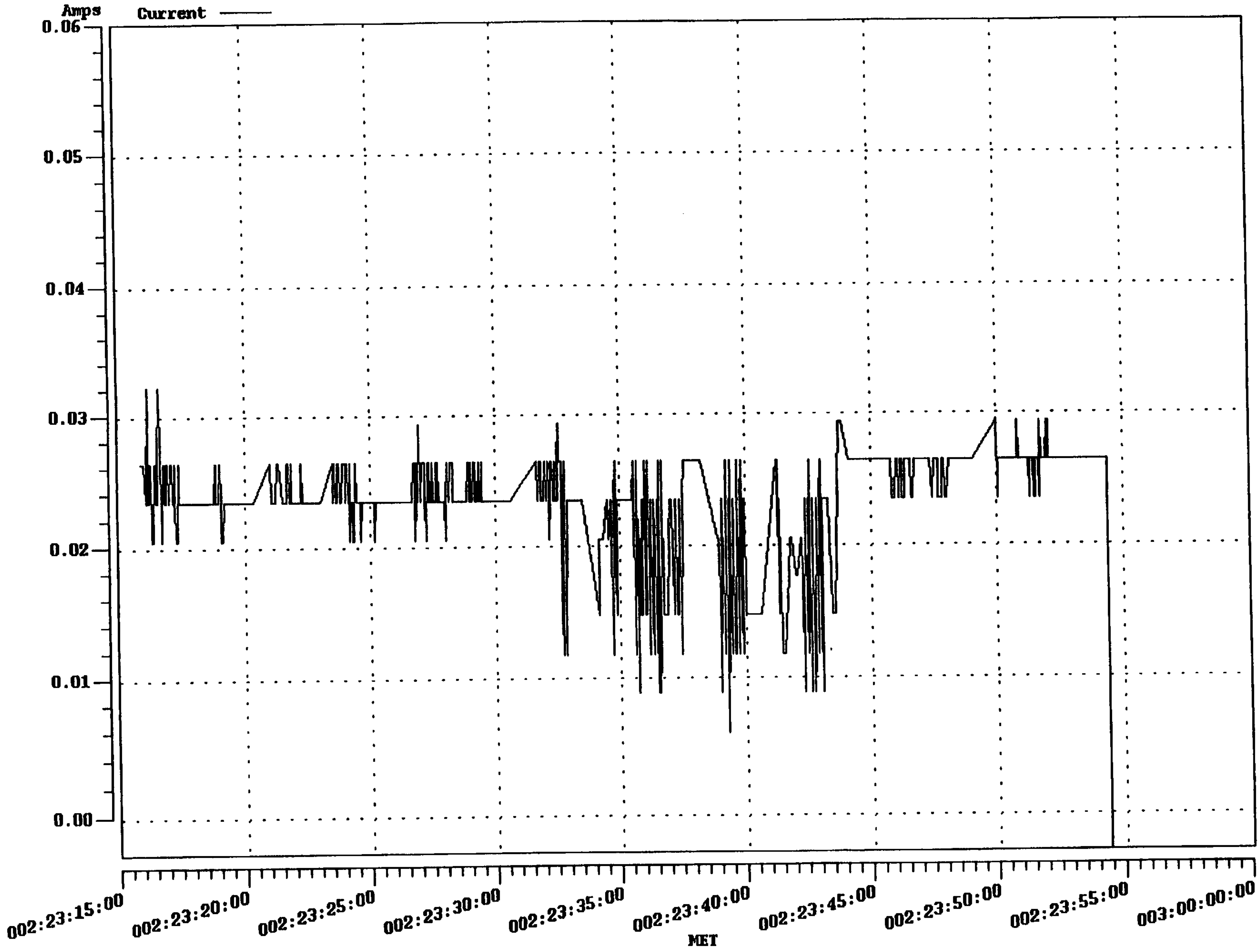
Reel Motor Current

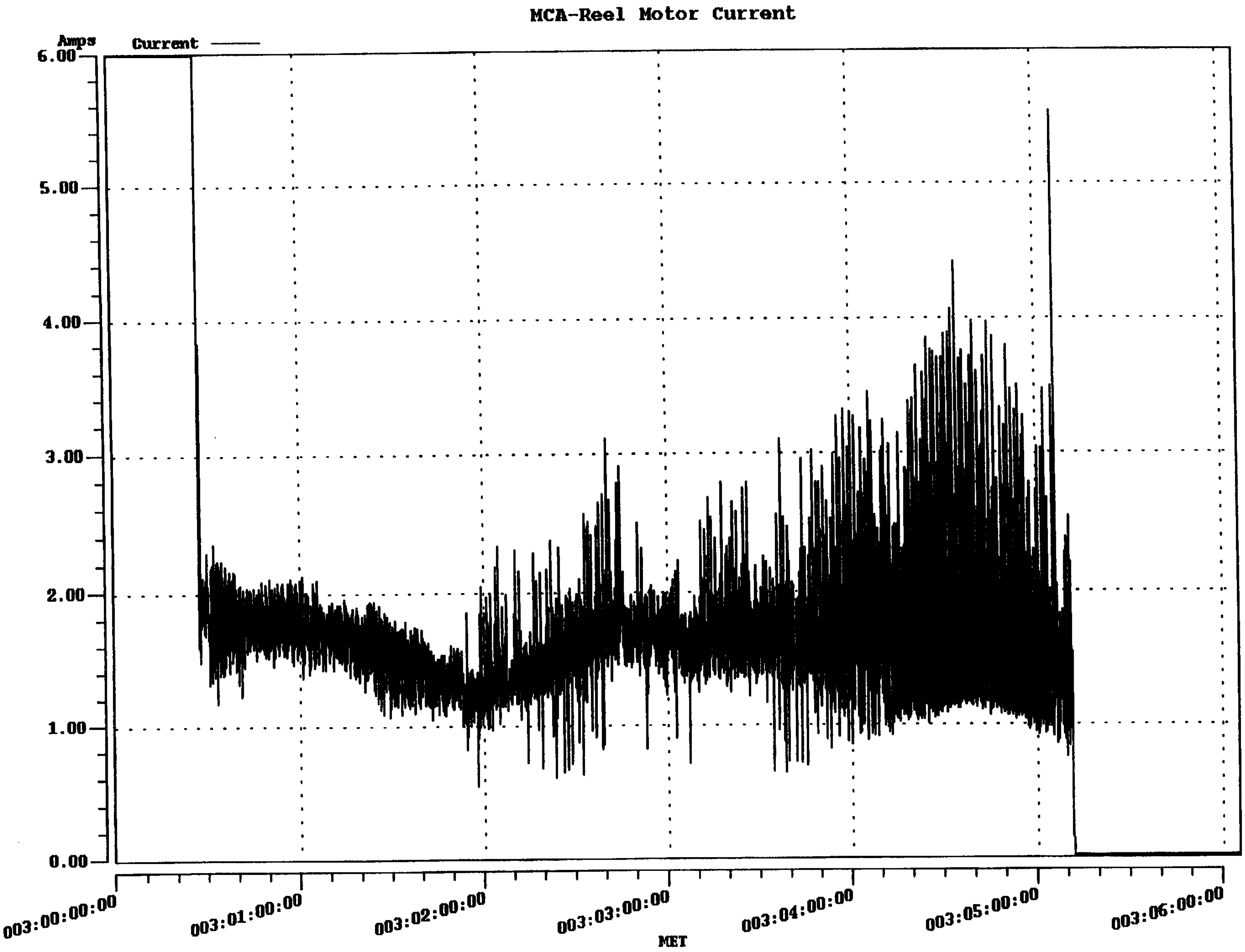

Reel Motor Current

Reel Motor Current



Reel Motor Current




MCA-Reel Motor Current
Amps
Current
6.00
5.00
4.00
3.00
2.00
1.00
0.00
003:00:00:00
003:01:00:00
003:02:00:00
003:03:00:00
003:04:00:00
003:05:00:00
003:06:00:00
MET

Appendix B Action Requests Generated By TSS-1R Chief Engineer

```
R: HSCE-001  Res APP@    0/07:59          ST75          MET:  111/01:47
age 1      +----------------------------------------+  GMT:  164:22:05
           | Subject: Tether Length Anomaly         |   YR: 96
-Request:--+  Author: L.Marshall                    +------(scroll 30 lines)-+
 Identify contingency plans for deployment assuming encoder card in DACA is |
 degraded or lost.                                                           |
                                                           <End of Request> |
  Ref AR:    -        -         -         -         -                       |
-HSOM Comment:---------------------------------------------(scroll 5 lines)-+
                                                           <End of Comment> |
----------------------------------------------------------------------------+
 App: HSOM A     HSCE       - POD       - SMGR    Act: TSSL TSMD TSSA        |
     0/08:01                                      Req by: 0   /10:0          |
----------------------------------------------------------------------------+
```

```
R: HSCE-001              Page 2                    ST75
-Response:--------------------------------------------------------(scroll 80 lines)-+
When both latch groups are opened prior to boom extension, it is possible           |
that a change in tether length will be seen. Or during boom extension, a            |
tether length change will be evident. At that point, if a length change is          |
not detected, this would indicate a problem with the DACA tether I/F card.          |
The I/F card has two chips that process encoder data for length and rate.           |
If length data was good and rate data was bad, a possible work around               |
could be done by changing DACA control parameters but if length data is             |
lost, deployment using manual pulsewidth and radar for length measurement           |
would be the only option.                                                           |
----- Section by TSSA                                                               |
------section by IPL DYNAMICS                                                        |
If the encoder can not be used by the DACA Ken Welzyn has been asked by Ron         |
Geiger to put together a plan to perform an open loop pulse manual deploymen        |
t. Satellite spin would be inhibited so that gyro's can be used for librati         |
on measure. Early deploy would use visual plus laser gun. After radar lock          |
on this would be used to guide deployment. Table in Dynamics book would be          |
used as basis for plulse width with adjustments to stay on profile. Some th         |
ought on deploying to shorter length to avoid running out of tether. Also m         |
ust worry ldot low trip. Astronaut can turn off for no impact if watching.          |
These guidelines will be discussed futher tomorrow.                                 |
----- Section by TSMD                                                               |
Concur with team. In addition we are looking at the data during time of pow         |
er up to see if there are any clues there. We will continue to work with            |
JSC located Deployer team.                                                          |
----- Section by TSSL                                                               |
                                                              <End of Response>     |
------------------------------------------------------------------------------------+
                                                                                    |
Act: TSSL A      TSMD S       TSSA S        -           -     Ref AR:    -          |
     0/09:22     0/08:41      0/08:24                          HSOM Notes:          |
App: HSCE A      HSOM A                                                             |
     0/09:40     0/09:43                                                            |
------------------------------------------------------------------------------------+
```

```
R: HSCE-002  Res APP@     0/08:09            ST75            MET:  111/01:48
age 1      +-------------------------------------------------+ GMT:  164:22:06
           | Subject: SETS Charging Observations             |  YR: 96
-Request:--+  Author: L.Marshall                             +------(scroll 30 lines)-+
 Define behavior of periodic SETS charging and possible impact on science.          |
 Describe plan for validation with other instrumentation readings (e.g.,            |
 SPREE and RETE).                                               <End of Request>    |
                                                                                    |
  Ref AR:    -          -          -          -          -------(scroll 5 lines)-+
--HSOM Comment:-------------------------------------------------<End of Comment>    |
-----------------------------------------------------------------------------------+
-----------------------------------------------------------------------------------+
 App: HSOM A      HSCE         - POD        - SMGR     Act: TSSS                    |
     0/08:10                                          Req by: 0   /9 :30            |
-----------------------------------------------------------------------------------+
+----------------------------------------------------------------------------------
```

```
R: HSCE-002              Page 2                  ST75
-Response:-----------------------------------------------------(scroll 80 lines)-+
 SETS ACTING EIE:                                                                 |
 After the chief engineer requested the noisy data problem exiting on the SET    |
 experiment, the PED informed us that it was approximately a 1.3 hz that they    |
 were not expecting on their 2 sensors.  The source of this additional           |
 frequency is not known.  There is no EMC data existing on such a low frequen    |
 Per the timeline SETS was activated prior to the other experiments, but in      |
 actuality the USMP experiments were active when SETS got their first measure    |
 ment.  We met with the USMP PEDs & mission manager and verified their           |
 activation times and the possiblity to turn them off for SETS troubleshootin    |
 The USMP mission manager agreed after polling his PEDs that they could          |
 turn off USMP for 5 minutes or less with no science impact.  IDGE requested     |
 it be done after 0/09:15.  We met with the SETS team again to inform them of    |
 USMP's activation sequence.  If approved, they would need 3 minutes to dete-    |
 rmine if USMP caused this problem.  They suggested to wait after SPREE and      |
 RETE was activated to verify the problem.  SPREE is to be activated about       |
 00/16:00 and RETE 00/19:21.                                                      |
 The frequecy of this is off and on.  SETS has not done a long term plot of      |
| the frequency.  The science impact is TBD.  They feel that they could filter    |
| this out, but they are working to see if there could be a workaround.           |
| Dawn Trout is continue to work this problem.  She will be coming back in the    |
| morning to see what additional support she can provide.                         |
| ----- Section by TSSS                                                           |
|                                                            <End of Response>   |
+--------------------------------------------------------------------------------+
| Act: TSSS A          -          -          -          -    Ref AR:     -       |
|     0/08:32                                                HSOM Notes:         |
| App: HSCE A     HSOM A                                                          |
|     0/08:33    0/08:54                                                          |
+--------------------------------------------------------------------------------+
```

```
R: HSCE-003  Res APP@    0/12:21             ST75          MET:  111/01:48
age 1       +-----------------------------------------+  GMT:  164:22:06
            | Subject: Contingency Deploy Plan        |   YR: 96
-Request:--+  Author: M.Galuska                       +------(scroll 30 lines)-+
 A contingency deploy plan is required by TSSPO on 6:00pm CST, Friday          |
 2/23/96. The plan is required if the DACA encoder card has failed. In the     |
 plan, the following should be evaluated:                                      |
 If manual pulse width is used, evaluate the loss of radar before and after    |
 MSTL.                                                                         |
 If we lose radar prior to 200 meters should we stop spin?                     |
 If we use manual pulse width, do we want to send auto rate damping to         |
 .5 degrees/sec?                                                               |
 If passive spin, what is the minimum rate during deploy?                      |
 Do we stop spin if we lose radar or it is degraded?                           |
 If we are in manual pulse width, should we start RET1 and RET2 early?         |
 What else could this card failure in the DACA affect (over torque, brake      |
 circuits,...)?                                                                |
 What can be done before boom extension to gain confidence in the card?        |
                                                            <End of Request>   |
|                                                                              |
|  Ref AR:     -          -          -          -          -                   |
+-HSOM Comment:-------------------------------------------(scroll 5 lines)-+
                                                            <End of Comment> |
|                                                                              |
+------------------------------------------------------------------------------+
+------------------------------------------------------------------------------+
| App: HSOM A     HSCE        - POD        - SMGR     Act: TSSL TSSP TSSA      |
|    0/12:26                                          Req by: 1   /3 :0        |
+------------------------------------------------------------------------------+
```

```
R: HSCE-003                Page 2                      ST75
-Response:-------------------------------------------------------(scroll 80 lines)-+
 Contigency plan has been finalized and approved. If a card failure exists,        |
 this would not impact brake circuit operations.The encoder provides the MCA       |
 2 seperate and redundant encoder pulsetrains of data to the MCA which is          |
 independant of the 2 data pulsetrains to the DACA and the DACA I/F card.          |
 Any confidence gained in the I/F card from power cycling the DACA will be         |
 minimal. Only tether movement seen when all SRL's are opened or when the          |
 boom is extended will provide concrete evidence that the DACA I/F card is         |
 working properly.                                                                 |
 ----- Section by TSSA                                                             |
 RECOMMEND IMPLEMENTATION OF''TSS DEPLOY PLAN REV B''DATED02/23/96,IF THE          |
 ENCODER HAS, INDEED, FAILED.RECOMMEND WE STAY WITH THE ORIGINAL TIMELINE          |
 UNLESS CONDITIONS MAKE THIS IMPOSSIBLE.WE MUST TAKE CARE THE SATELLITE IS         |
 NOT EXPOSED TO EXCESSIVE RADIATION FROM THE KU-BAND RADAR.                        |
 ----- Section by TSSP                                                             |
 CONCUR WITH TEAM RECOMMENDATION.  ADDITIONALLY WE ARE CONTINUING TO WORK          |
 WITH SATELLITE TO UNDERSTAND IMPACT OF Ku BAND RADIATION ABOVE 10 V/m             |
 DIRECTED TOWARD THE SATELLITE SENSORS WHEN THEY ARE OPERATING.  SATELLITE         |
 WAS TESTED TO 107.5Vm, HOWEVER, RETE, ROPE, TEMAG, LFA WOULD NEED TO ESTABLI      |
 SH WHAT THEY COULD WITHSTAND IF WE ARE REQUIRED TO GO INTO HIGH POWER RADAR       |
 MODE.  INITIAL TALKS WITH RETE INDICATE THERE IS SOME MARGIN WITH RESPECT TO      |
  THE Ku BAND LIMITATIONS FOUND IN THE ICD-2-19001 PAR. 4.2.3.6.                   |
 AT THE TIME OF RESPONCE OUR TEAM HAD REVIEWED OPTION C AND WILL CONTINUE TO       |
 STAY IN CLOSE CONTACT WITH JSC DEPLOYER TEAM.                                     |
 ----- Section by TSSL                                                             |
                                                              <End of Response>   |
-----------------------------------------------------------------------------------+
 Act: TSSL A      TSSP S     TSSA S           -           -    Ref AR:     -       |
      1/06:31     1/05:43    1/04:57                            HSOM Notes:        |
 App: HSCE A      HSOM A                                                           |
      1/06:44     1/06:46                                                          |
+----------------------------------------------------------------------------------+
```

```
AR: HSCE-004  Res APP@    0/15:47             ST75              MET:  111/01:49
Page 1       +-------------------------------------------+  GMT:  164:22:07
             | Subject: SETS Loss of Telemetry           |   YR: 96
+-Request:--+  Author: T. Lavoie                         +------(scroll 30 lines)-+
| 1)  Specify the cause of the loss of telemetry anomaly.                         |
| 2)  Identify corrective action that was undertaken to recover telemetry.        |
| 3)  Evaluate impacts to the mission for failure to recover telemetry.           |
| Note:  Please include MET times in response where possible.                     |
|                                                              <End of Request> |
|                                                                                |
|  Ref AR:    -         -         -         -         -                           |
+-HSOM Comment:------------------------------------------------(scroll 5 lines)-+
|                                                              <End of Comment> |
+--------------------------------------------------------------------------------+
| App: HSOM A     HSCE        - POD        - SMGR     Act: TSSS                  |
|     0/16:46                                         Req by: 0   /20:0          |
+--------------------------------------------------------------------------------+
```

```
R: HSCE-004               Page 2                   ST75
-Response:-------------------------------------------------------(scroll 80 lines)-+
 Sets plan was a) to resend 3 commands that were possibly rejected                 |
               b) recycle SDIO                                                     |
               c) put malfunction procedure SETS 003 into work per Flight          |
 Note SETS-001.                                                                    |
 At 00/14:09 the 3 commands were resent but no change was seen in the minor        |
 frame corruption.  At 00/14:16 SETS cycled the SDIO channel with no joy.          |
 At 00/14:22 again cycled SDIO channel again with no result.  At 00/14:36          |
 SETS lost all telementry.  They again tried another SDIO recycle at 00/14:45      |
 again nothing.  AT 00/14:53 Ground malfunction SETS-003 was performed.  At        |
 14:55 SETS received data - DEP reset worked and SDIO reset worked and             |
 regular operations were continued.                                                |
 This problem could be related to the problem which occured later at 00:16:50      |
 when a warmstart occured while SPREE was powering on and going through their      |
 checkout.  This is an as yet unresolved problem that is currently being           |
 worked.                                                                           |
 The loss of telemetry would have a major effect on science, however the           |
 smartflex problem overshadows the loss of telemetry, since the science can-       |
 not be powered on or commanded until this problem is resolved.                    |
 ----- Section by TSSS                                                             |
                                                              <End of Response>   |
-----------------------------------------------------------------------------------+
 Act: TSSS A          -            -            -            -    Ref AR:    -     |
     0/20:55                                                       HSOM Notes:     |
 App: HSCE A     HSOM A                                                            |
     0/20:58    1/06:47                                                            |
-----------------------------------------------------------------------------------+
-----------------------------------------------------------------------------------
```

```
R: HSCE-005  Res APP@     1/09:40              ST75            MET:  111/01:50
age 1       +--------------------------------------------------+ GMT:  164:22:08
            | Subject: Deploying without DDCS                  |  YR: 96
-Request:--+  Author: Todd MacLeod                             +------(scroll 30 lines)-+
 Evaluate the pro's and con's of the following concept and advise.                       |
 Disconnect the DDCS from the SFMDM.                                                     |
 Deploy to OST1 with all science timelines being issued from the ground.                 |
 Once on OST1, reconnect DDCS and run science timelines from the DDCS.                   |
 Disconnect DDCS from SFMDM prior to RET1.                                               |
| During RET1, ground will issue all science commands.                                   |
| Reconnect DDCS to SFMDM once on OST2 & perform science timelines with DDCS.            |
| Disconnect DDCS prior to RET2, then perform RET2 and docking without DDCS.             |
|                                                                  <End of Request>      |
|                                                                                        |
|  Ref AR:      -          -          -          -          -                            |
+-HSOM Comment:----------------------------------------------------(scroll 5 lines)-+
|                                                                  <End of Comment>     |
|                                                                                        |
+---------------------------------------------------------------------------------------+
| App: HSOM A      HSCE          - POD        - SMGR    Act: TSSL TSSP TSSA TSSS TSCO     |
|      1/09:53                                           Req by: 1   /11:0                 |
+---------------------------------------------------------------------------------------+
```

```
AR: HSCE-005               Page 2                    ST75
+-Response:-------------------------------------------------(scroll 80 lines)-+
| DCORE EIE:                                                                  |
| THE DCORE EXPERIMENT CAN OPERATE THE MISSION WITH THE DDCU.  THE COMMANDS   |
| NORMALLY SENT VIA THE DDCU WOULD BE SENT FROM THE GROUND THROUGH THE ECO.   |
| DCORE DOES NOT HAVE THE CAPABILITES TO SEND TIME TAGGED COMMANDS.           |
| ----- Section by TSCO                                                       |
| SETS/SPREE EIE:                                                             |
| Both SETS and SPREE can issue  the timeline commands from the ground. A pla |
| n was discussed earlier on 2/23/96 that showed SPREE would command themselve|
| s and SETS would be commanded from ECO.  SETS and SPREE have the capability |
| to send time tagged commands.                                               |
| ----- Section by TSSS                                                       |
| SYSTEM  SUPPORT                                                             |
| INITIAL CONDITION:                                                          |
| ESTABLISH THE DDCS IS FAULTY.  IF FAULTY, WHY USE DDCS OST1 AND OST2?  IF   |
| NOT FAULTY, WHY NOT USE DDCS THROUGHOUT THE TIMELINE.  IT IS MY OPINION     |
| THAT UNTIL A KNOWN WORKING CONFIGURATION EXISTS, WE WILL BE GUESSING ON     |
| WHAT IS BEST TO DO.                                                         |
| PRO:                                                                        |
| THE DDCS WILL REMOVE A LOAD FROM THE SFMDM.  IF THE SITUATION IS ONE OF LOAD|
| ING AND TIMING, CAUSING WARM STARTS, THEN THIS WILL HELP.                   |
| CON:                                                                        |
| THIS WILL SLOW SCIENCE OPERATIONS DOWN,        REDUCING THE TOTAL SCIENCE   |
| THAT CAN BE ACCOMPLISHED BY A MINIMUN OF 25 PERCENT.                        |
| ----- Section by TSSP                                                       |
| If the DDCS is determined to be the cause of SFMDM warm starts/core swaps,  |
| it should not be connected during deploy/ret-1 or reconnected at OST-1 or   |
| OST-2. If the DDCS is not determined to be suspect, there could still be an |
| advantage to not connecting the DDCS at any time because the load on the SFM|
| DM would be reduced.                                                        |
| ----- Section by TSSA                                                       |
| Concur with team.  If we can prove the DDCS is inducing the problem it is no|
| t needed for the mission.  To configure it in during OST1 & 2 could cause gr|
| eater delays than issuing grd commands.  If we can prove that the combinatio|
| n of experimentsand DDCS is causing the problem then it becomes a matter of |
| priorty and again DDCS would be low priorty and should not be used.         |
| ----- Section by TSSL                                                       |
|                                                          <End of Response> |
+-----------------------------------------------------------------------------+
| Act: TSSL A      TSSP S     TSSA S     TSSS S     TSCO S    Ref AR:     -   |
|         1/11:47  1/11:15    1/11:27    1/10:36    1/10:29    HSOM Notes:    |
| App: HSCE A      HSOM A                                                     |
|         1/11:48  1/11:59                                                    |
+-----------------------------------------------------------------------------+
```

```
R: HSCE-006  Req CAN@    1/17:37            ST75          MET:  111/01:58
age 1       +--------------------------------------+  GMT:  164:22:16
            | Subject: TFL CHG TO VIEW SFMDM(Q) DATA |    YR: 96
+-Request:--+  Author: R. GREEN                    +------(scroll 30 lines)-+
| REQUEST FROM JSC SPRING LOADED(REAL TIME CHANGE) OF TFL TO A MODE WHICH SUPP |
| ORTS SFMDM QUIESCENT DATA IN THE EVENT A CORE SWAP OR WARM START OCCURS.THIS |
| DATA WILL BE REQUIRED IN DETERMINING CAUSE OF ANOMALY.                       |
|                                                             <End of Request> |
|                                                                              |
|  Ref AR:       -         -         -         -         -                     |
+-HSOM Comment:--------------------------------------------(scroll 5 lines)-+
| HSOE shall submit a CHIT to JSC requesting this TFL change.                  |
|                                                             <End of Comment> |
+------------------------------------------------------------------------------+
| App: HSOM       HSCE        - POD        - SMGR   Act:                       |
|                                                   Req by: 0   /0 :0          |
|                                                                              |
+------------------------------------------------------------------------------+
```

```
R: HSCE-006          Page 2                  ST75
-Response:----------------------------------------------(scroll 80 lines)-+
                                                        <End of Response> |
--------------------------------------------------------------------------+
Act:                 -          -          -          -  Ref AR:    -     |
                                                          HSOM Notes:     |
App: HSCE       HSOM                 SMGR                                 |
                                                                          |
--------------------------------------------------------------------------+
```

```
AR: HSCE-007  Res APP@     2/08:10            ST75           MET:  111/01:51
Page 1      +------------------------------------------+  GMT:  164:22:09
            | Subject: Warm Start EMI Investigation    |   YR: 96
+-Request:--+  Author: Todd MacLeod                     +------(scroll 30 lines)-+
| Investigate whether SFMDM warm start that occurred near a strong E-field       |
| measurement was caused by EMI (conducted or radiated).                         |
|                                                            <End of Request> |
|                                                                                |
|  Ref AR:  -          -          -          -          -                       |
+-HSOM Comment:---------------------------------------------(scroll 5 lines)-+
| JOHN, PLEASE ATTATCH DAWN'S REPORT TO THIS AR RESPONCE                         |
|                                                            <End of Comment> |
|                                                                                +
+-------------------------------------------------------------------------------+
| App: HSOM A      HSCE          - POD        - SMGR     Act: TSSL              |
|     2/08:12                                            Req by: 2    /14:0      |
+-------------------------------------------------------------------------------+
```

```
R: HSCE-007             Page 2                  ST75
-Response:-----------------------------------------------------(scroll 80 lines)-+
 See Dawn Trouts' write up which has been attached to this AR.                    |
 ----- Section by TSSL                                                            |
 Hard copy report states that SFMDM warm start was not caused by EMI.             |
 ----- Section by HSCE                                                            |
                                                            <End of Response>     |
----------------------------------------------------------------------------------+
 Act: TSSL A          -          -          -          -    Ref AR:     -         |
     2/10:15                                                 HSOM Notes:          |
 App: HSCE A     HSOM A                                                           |
     2/10:18    2/10:19                                                           |
----------------------------------------------------------------------------------+
```

```
AR: HSCE-008  Res APP@    4/10:00          ST75          MET:  111/01:51
Page 1       +---------------------------------------+  GMT:  164:22:09
             | Subject: RETE Current Signature       |   YR: 96
+-Request:--+  Author: Tony Lavoie                   +------(scroll 30 lines)-+
| Investigate the problem with RETE current signature described by Satellite |
| Lead.                                                                      |
|                                                          <End of Request> |
|                                                                            |
|  Ref AR:   -         -         -         -         -                       |
+-HSOM Comment:-------------------------------------------(scroll 5 lines)-+
|                                                          <End of Comment> |
|                                                                            |
+----------------------------------------------------------------------------+
| App: HSOM A     HSCE       - POD       - SMGR   Act: HSOM                  |
|    4/10:02                                      Req by: 4   /3 :0          |
+----------------------------------------------------------------------------+
```

```
R: HSCE-008               Page 2                        ST75
-Response:---------------------------------------------------------(scroll 80 lines)-+
 THE DATA WAS BAD NO PROBLEM EXISTS                                                   |
 ----- Section by HSOM                                                                |
                                                                <End of Response>     |
-------------------------------------------------------------------------------------+
 Act: HSOM A           -          -           -           -    Ref AR:      -        |
     4/10:06                                                    HSOM Notes:          |
 App: HSCE A     HSOM A                                                               |
     4/10:07    4/10:08                                                               |
-------------------------------------------------------------------------------------+
```

```
AR: HSCE-009  Res APP@    4/15:17           ST75         MET:  111/01:52
Page 1      +-------------------------------------------+  GMT:  164:22:10
            | Subject: Experiment Shutdown Plan         |   YR: 96
+-Request:--+  Author: Mike Galuska                      +------(scroll 30 lines)-+
| With the increasing thermal loop temperatures, the experiments may be         |
| required to shut down prior to the planned times. Prepare a plan in the       |
| event that the experiments reach their yellow line limits.                    |
|                                                             <End of Request> |
|  Ref AR:       -         -         -         -         -                      |
+-HSOM Comment:-----------------------------------------------(scroll 5 lines)-+
|                                                             <End of Comment> |
+-------------------------------------------------------------------------------+
| App: HSOM A     HSCE       - POD       - SMGR     Act: TSSL TSTH TSSS TSCO    |
|     4/15:19                                       Req by: 4   /16:0          |
+-------------------------------------------------------------------------------+
```

```
R: HSCE-009             Page 2                  ST75
--Response:------------------------------------------------------(scroll 80 lines)-+
 jHIS RESPONSE IS FOR THE DCORE SHUTDOWN IN THE EVENT OF TEMPERATURE RUNAWAY        |
 DCORE'S SHUTDOWN PROCEDURE WILL BE ACCORDING TO F013, SCIENCE OPS CHECKLIST,       |
 PAGE 10-13, BEGINNING WITH STEP 2 AND CONTINUING TO THE END OF SHUTDOWN PROC       |
 EDURE. THIS IS ALL THAT IS REQUIRED.                                               |
| ----- Section by TSCO                                                             |
| SPREE will follow standard shutdown procedure per POH page 11.12-1.               |
|  SETS nominally will follow standard shutdown procedure per POH SSR-G5, page      |
|  B.6-11.  Should  conditions warrant a rapid powerdown, then only steps 3,        |
| 5, 7, 9, 13, 15, 19 and 21 need be performed.                                     |
| ----- Section by TSSS                                                             |
| The TSS coolant inlet temperature may exceed the flight rule A6-23.3 limit        |
| of 62F due to extended duration FES inhibits.  Based on a test period of 7.5      |
|  hours at MET 4/08:00 to 4/15:00 the expected temperature of Deployer boxes       |
| has been estimated during AADSF operation and FES inhibit for 8hrs.               |
| The coolant inlet temperature is expected to increase by 5F during AADSF          |
| ops. and with FES inhibit the coolant inlet temp. cannot be controlled.           |
| The pre-flight perdictions showed approximately 8 hours with an uncontrolled      |
| coolant inlet at starting at about MET 7/02:00.                                   |
| The deployer and SFMDM temp. estimates show no boxes will go above the FDA        |
| =imits with and estimated TSS coolant inlet temp. of 69F.    This is the          |
| estimated coolant temperature peak at MET 7/10:00.                                |
| SEE flight note TSS-1R#TSTH01 for supporting data.                                |
| ----- Section by TSTH                                                             |
| Avionics/SW recommended that the SFMDM and PCB not be powered down during th      |
| e USMP prime ops.  Powering down would make TSS fluids measurements unavaila      |
| ble and would also make commanding the TSS pumps unavailable.  The SFMDM dra      |
| ws about 5 amps (150 W).                                                          |
| ----- Section by TSSL                                                             |
|                                                            <End of Response>      |
+-----------------------------------------------------------------------------------+
| Act: TSSL A      TSTH S      TSSS S      TSCO S        -   Ref AR:      -         |
|     4/23:41     4/22:43     4/21:23     4/16:23            HSOM Notes:            |
| App: HSCE A      HSOM A                                                           |
|     5/16:20     5/16:23                                                           |
+-----------------------------------------------------------------------------------+
```

```
AR: HSCE-010  Res APP@    4/17:34           ST75            MET:  111/01:52
Page 1       +----------------------------------------+ GMT:  164:22:10
             | Subject: Satellite Configuration       |  YR: 96
+-Request:--+  Author: Mike Galuska                  +------(scroll 30 lines)-+
| It appears that the satellite is in a different configuration than when    |
| the break occurred and that the software routines are inactive.  Is this   |
| due to autoreconfiguration? If so, what would be the predicted configuration |
| if autoreconfiguration is executed?                                         |
|                                                          <End of Request> |
|                                                                             |
|  Ref AR:      -          -          -          -          -                |
+-HSOM Comment:--------------------------------------------(scroll 5 lines)-+
|                                                          <End of Comment> |
+----------------------------------------------------------------------------+
| App: HSOM A      HSCE        - POD       - SMGR    Act: TSSL TSSA           |
|      4/17:35                                       Req by: 4   /19:0        |
+----------------------------------------------------------------------------+
```

```
R: HSCE-010            Page 2                      ST75
-Response:----------------------------------------------------(scroll 80 lines)-+
 After speaking with satellite representatives, the only thing powered on the |
  satellite is the AMCS, OBDH, and TT&C at the present time.  The fact that t |
 he satellite routines are inactive is not due to autoreconfiguration.  Autor |
 econfiguration will not be executed.                                         |
 ------ Section by TSSA                                                       |
 ------ Section by TSSL                                                       |
                                                          <End of Response>  |
------------------------------------------------------------------------------+
| Act: TSSL A     TSSA S          -           -           -    Ref AR:     -  |
|      4/23:42    4/18:47                                        HSOM Notes:  |
| App: HSCE A      HSOM A                                                     |
|      5/16:22    5/16:24                                                     |
+-----------------------------------------------------------------------------+
```

Appendix C Record of SFMDM Warm Starts/Core Swaps

RECREATION OF A PORTION OF THE CDMS LOG FOR TSS-1R

		DATA ANALYSIS
#	GMT	DESCRIPTION
1	54/13:20:08	WARMSTART; TASK CREATION ERROR - CT_DLY>0
2	54/13:38:18	WARMSTART; I/O TRANSFER ERRORS
3	54/14:06:02	WARMSTART; TASK CREATION ERROR - CT_DLY>0
4	54/15:10:31	CORESWAP; NO OTHER CORE FAILED, L TO R
5	55/01:58:38	CORESWAP; OTHER CORE FAILED
6	55/04:15:09	CORESWAP; SPREE CHANNEL LOSS PRIOR TO SWAP
7	55/06:01:10	CORESWAP/PWR CYCLE TO PRIMARY CORE (LEFT)
8	56/16:27:23	WARMSTART; TASK CREATION ERROR, FILESAVE OPS
9	57/11:38:47	WARMSTART; TASK CREATION ERROR, FILESAVE OPS

** TOTAL PAGE.002 **

Appendix D Dynamics Data

Outboard Tension Vs Time

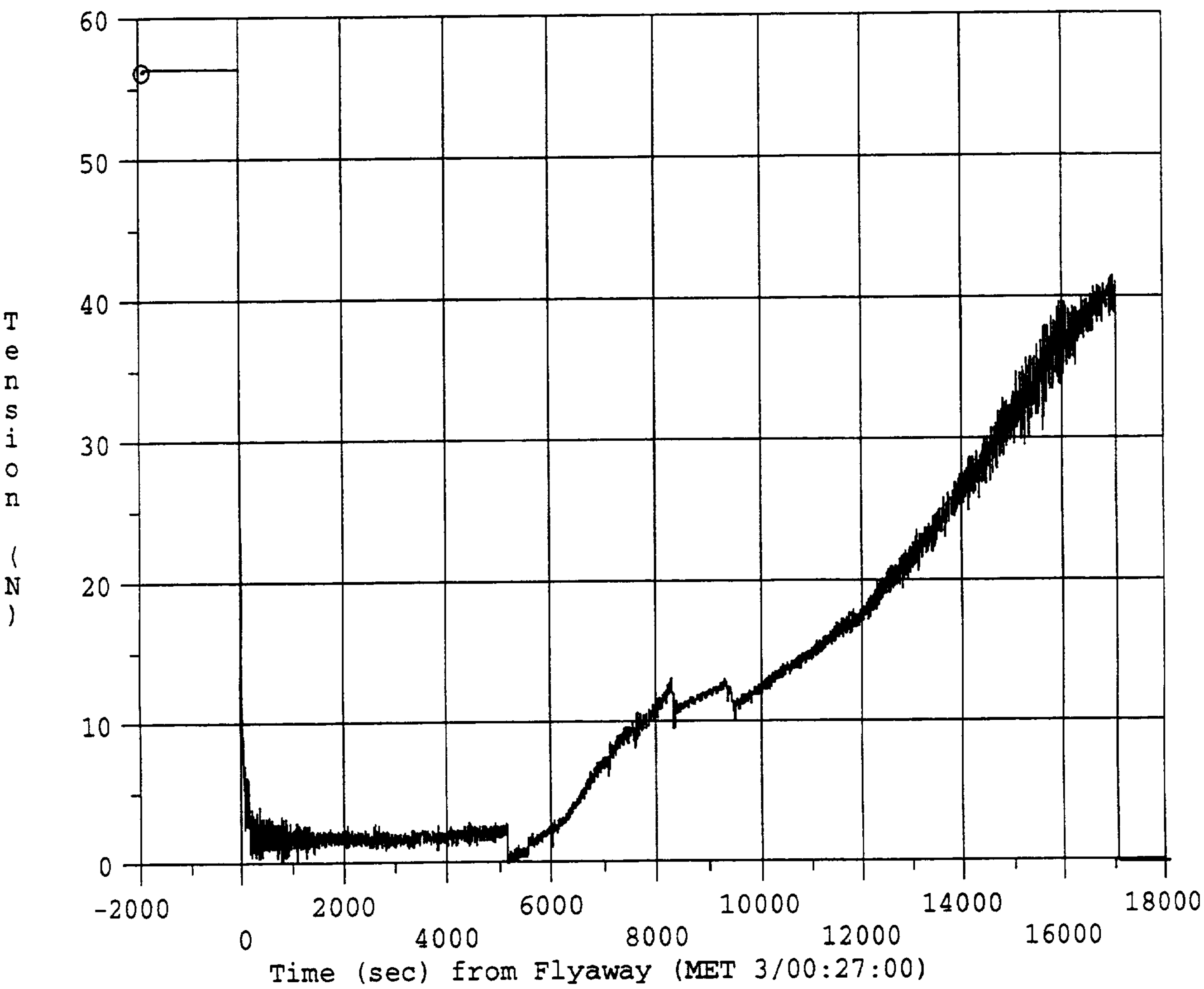


Fig. 1

Tether Rate and Command Vs Time

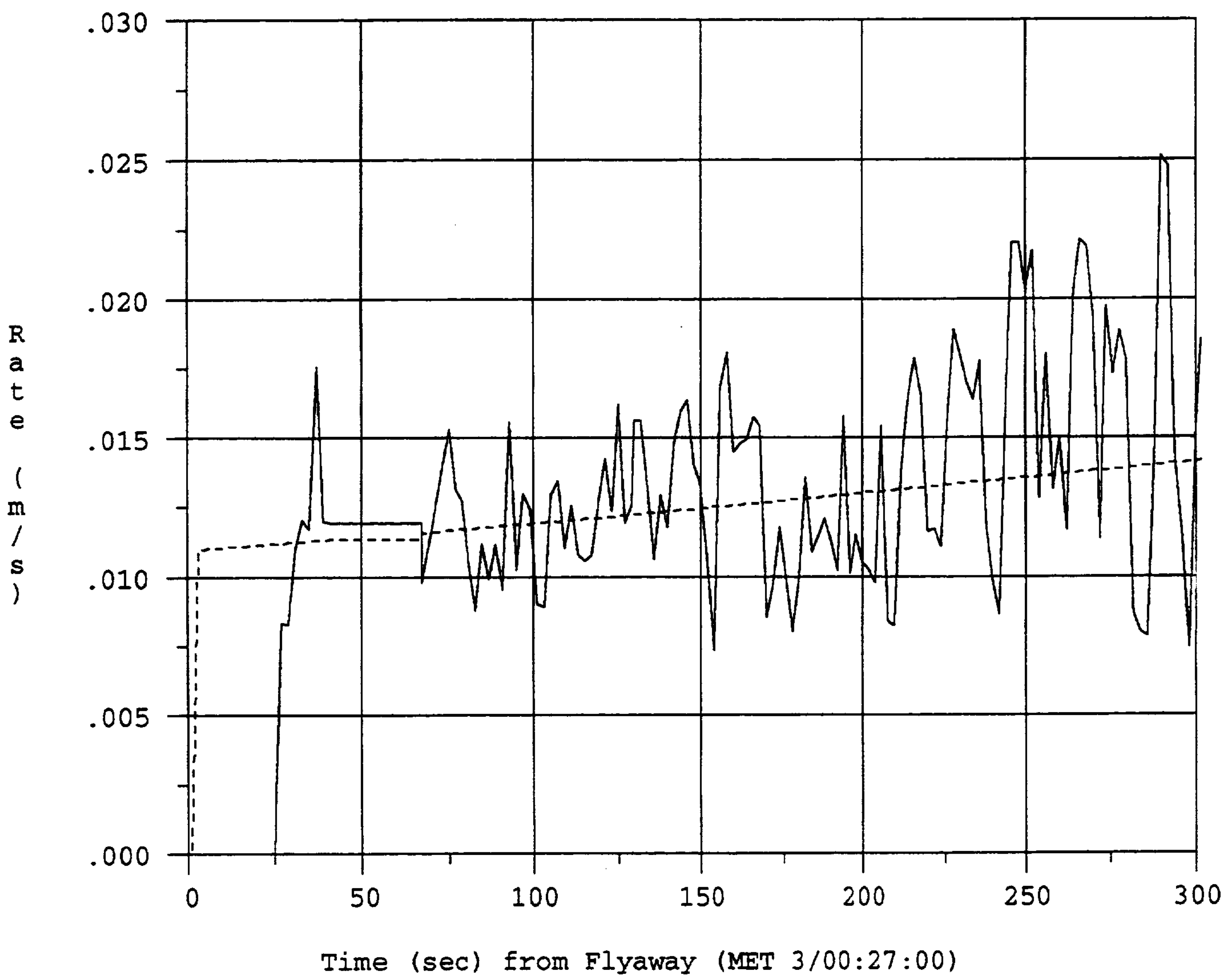


Fig. 2

Tether Length and Command Vs Time

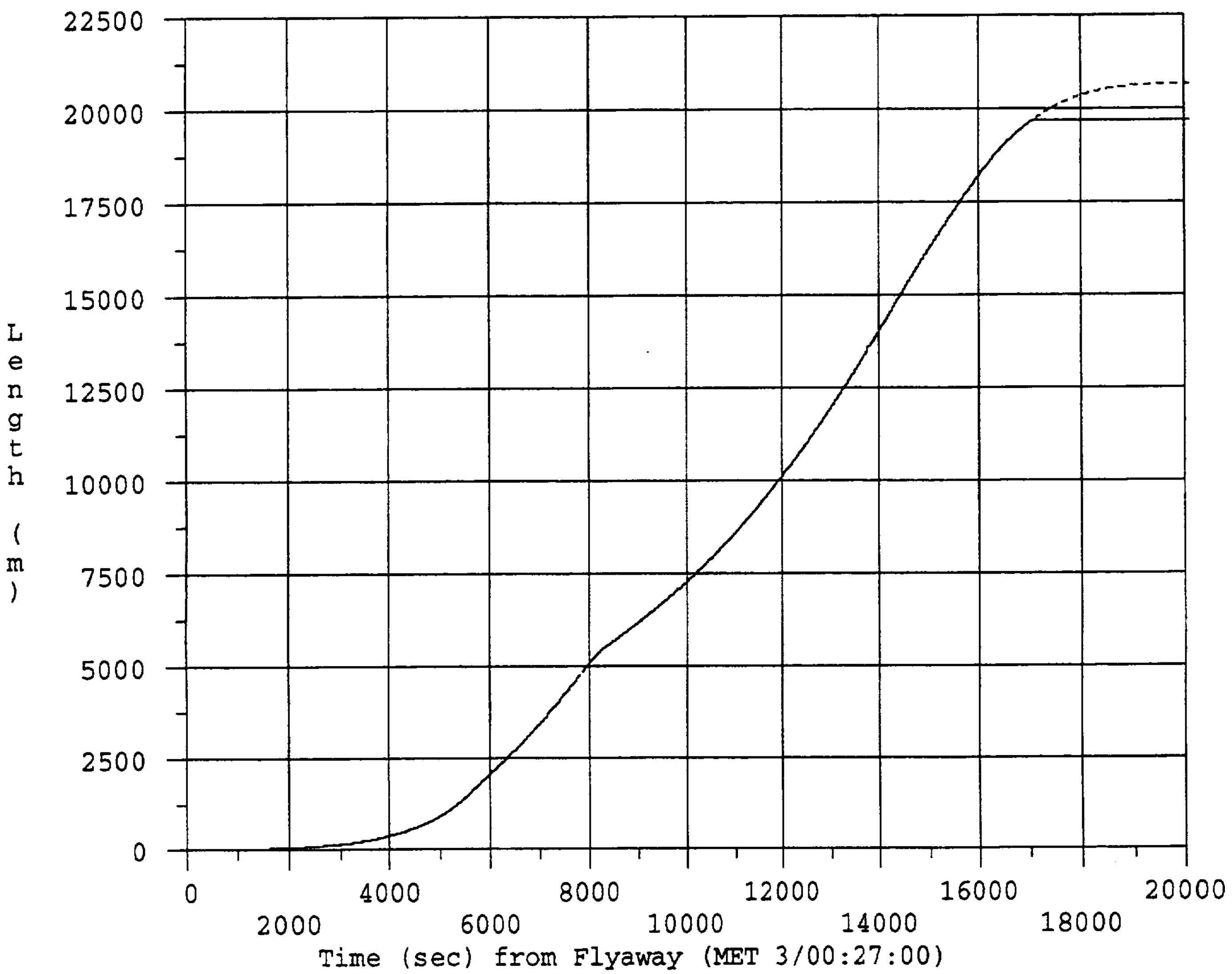


Fig. 3

Tether Rate and Command Vs Time

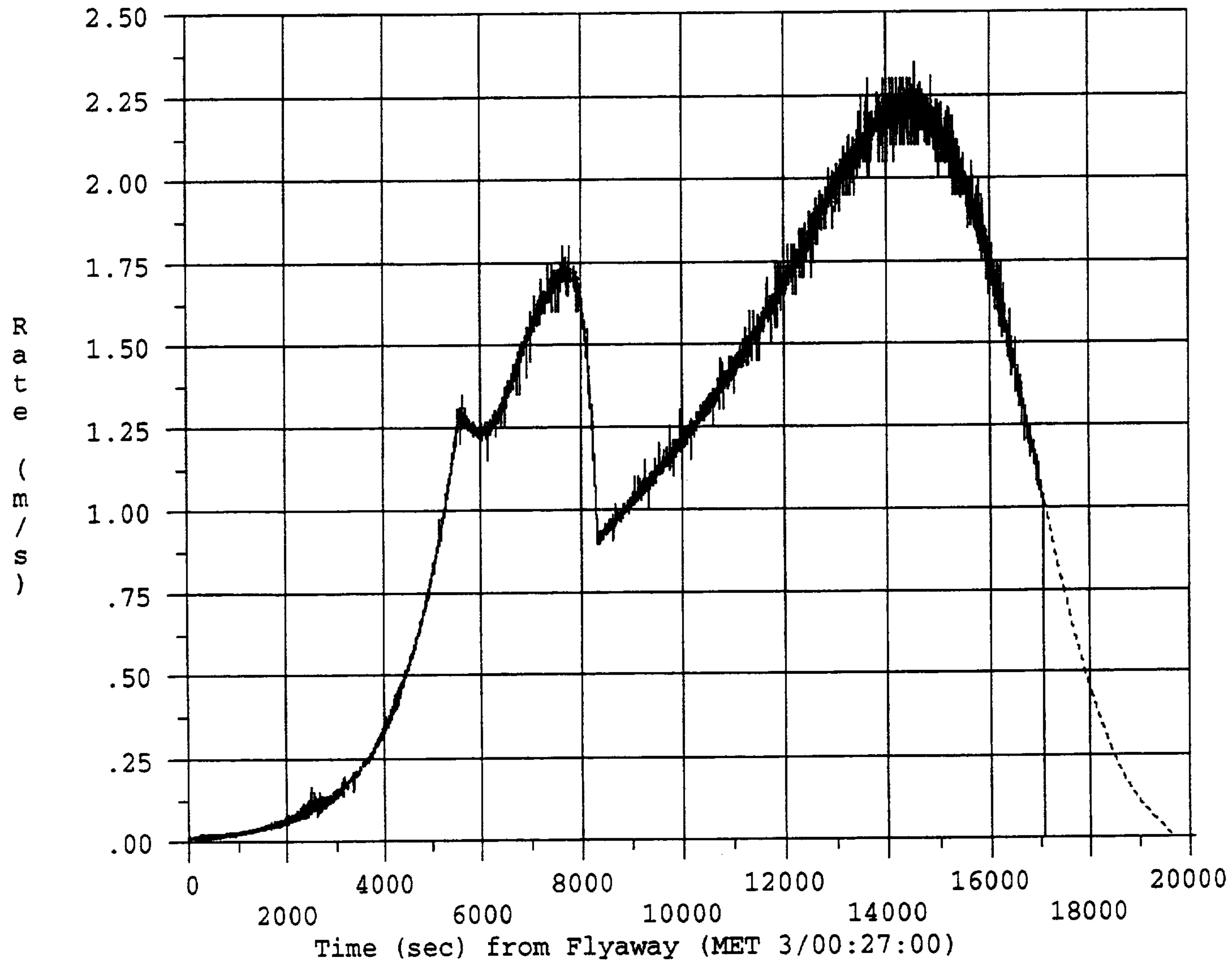


Fig. 4

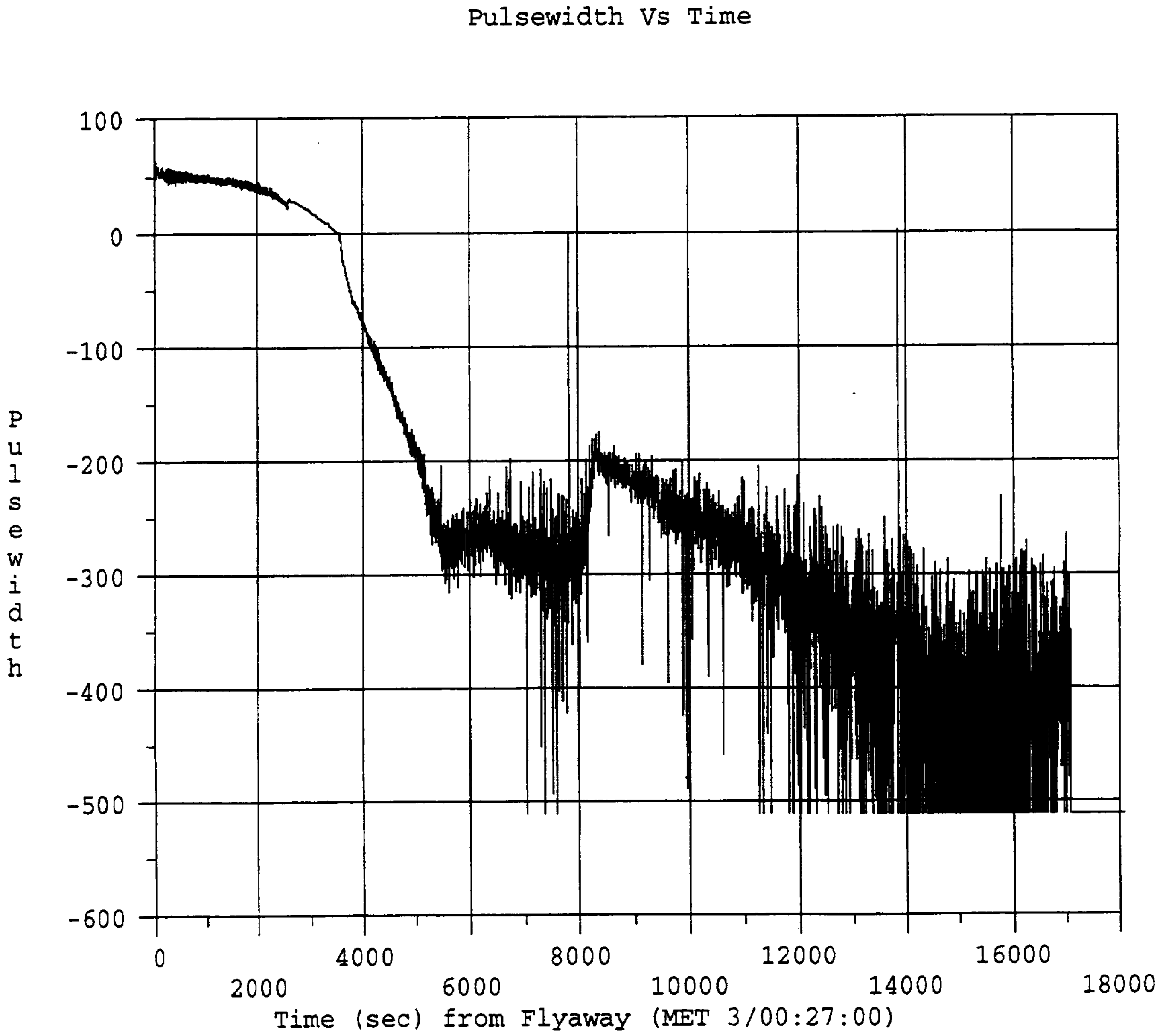

Pulsewidth Vs Time
100
0
-100
-200
-300
-400
-500
-600
Pulsewidth
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Time (sec) from Flyaway (MET 3/00:27:00)

Fig. 5

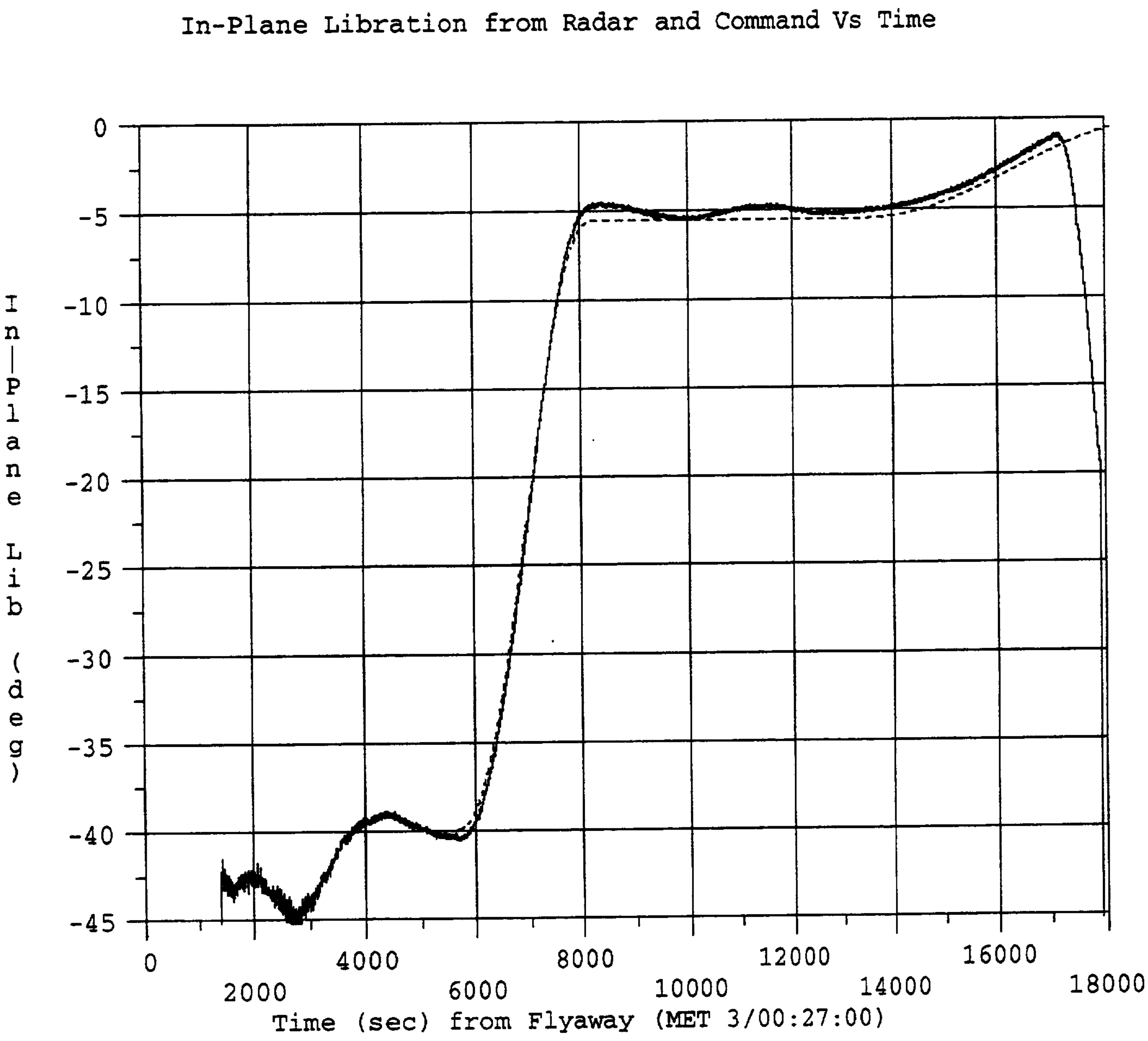

In-Plane Libration from Radar and Command Vs Time
In—Plane Lib (deg)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Time (sec) from Flyaway (MET 3/00:27:00)

Fig. 6

Out-of-Plane Libration from Radar and Satellite AMCS vs Time

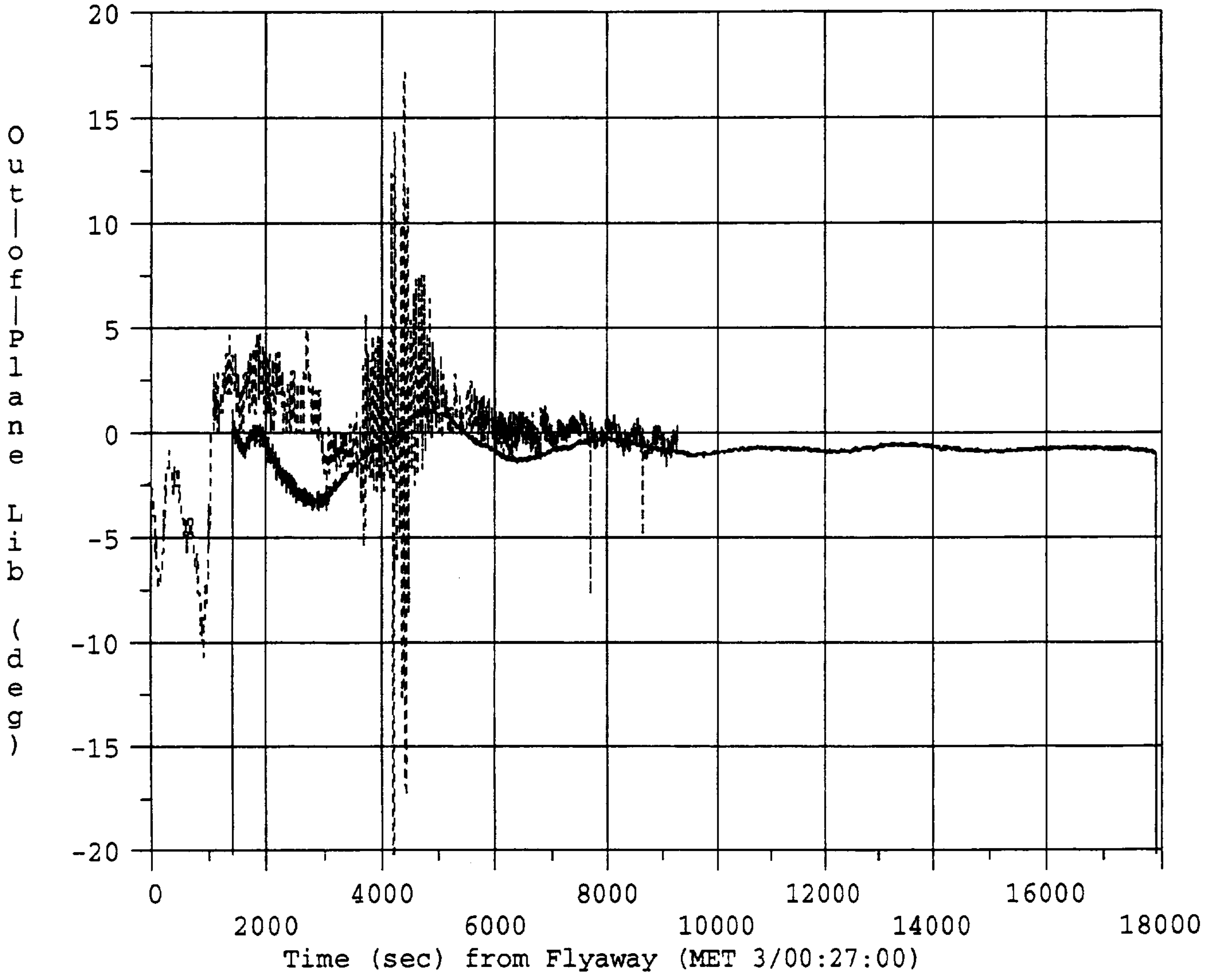
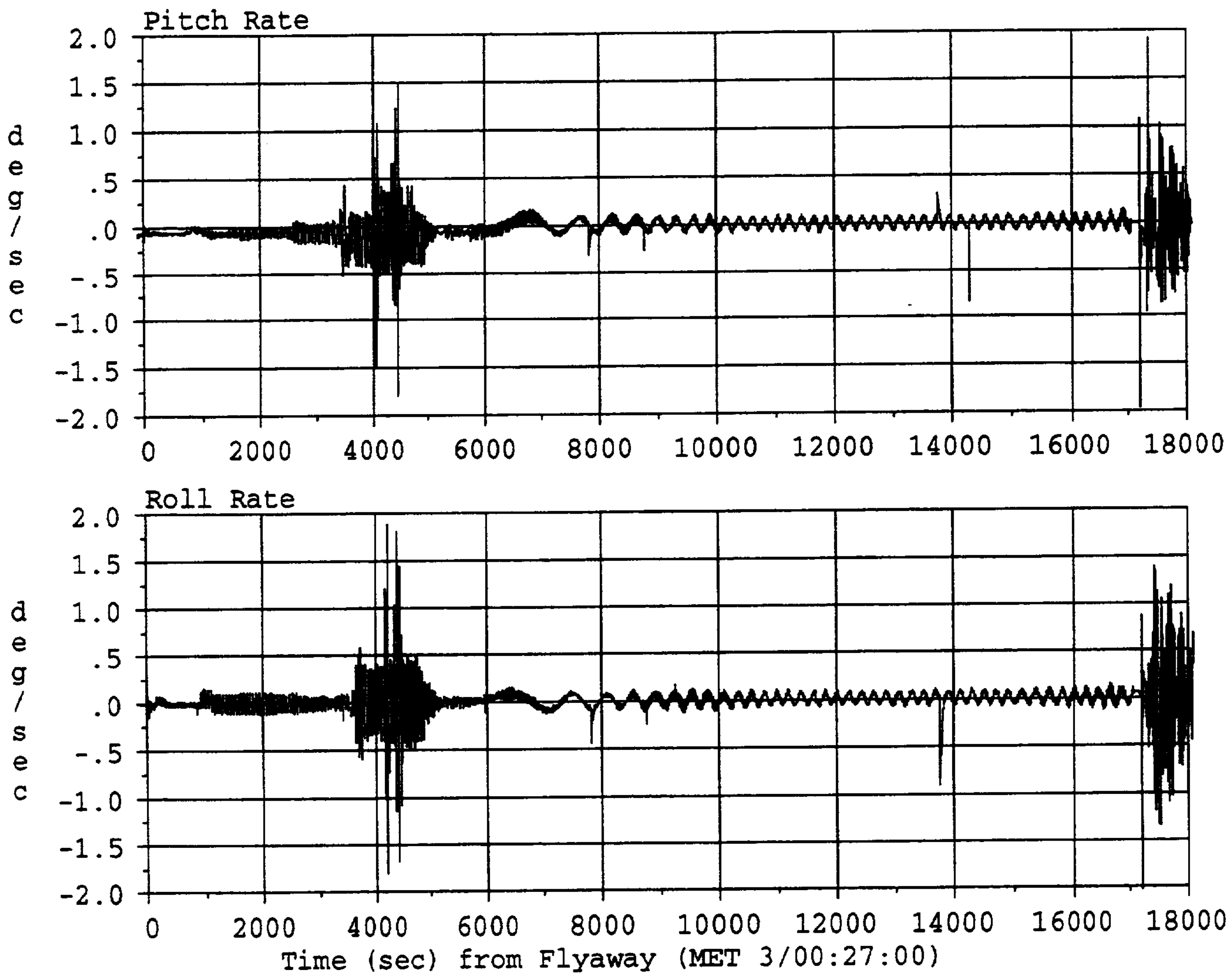


Fig. 7



Satellite Pitch and Roll Rates Vs Time

Pitch Rate

Roll Rate

Fig. 8

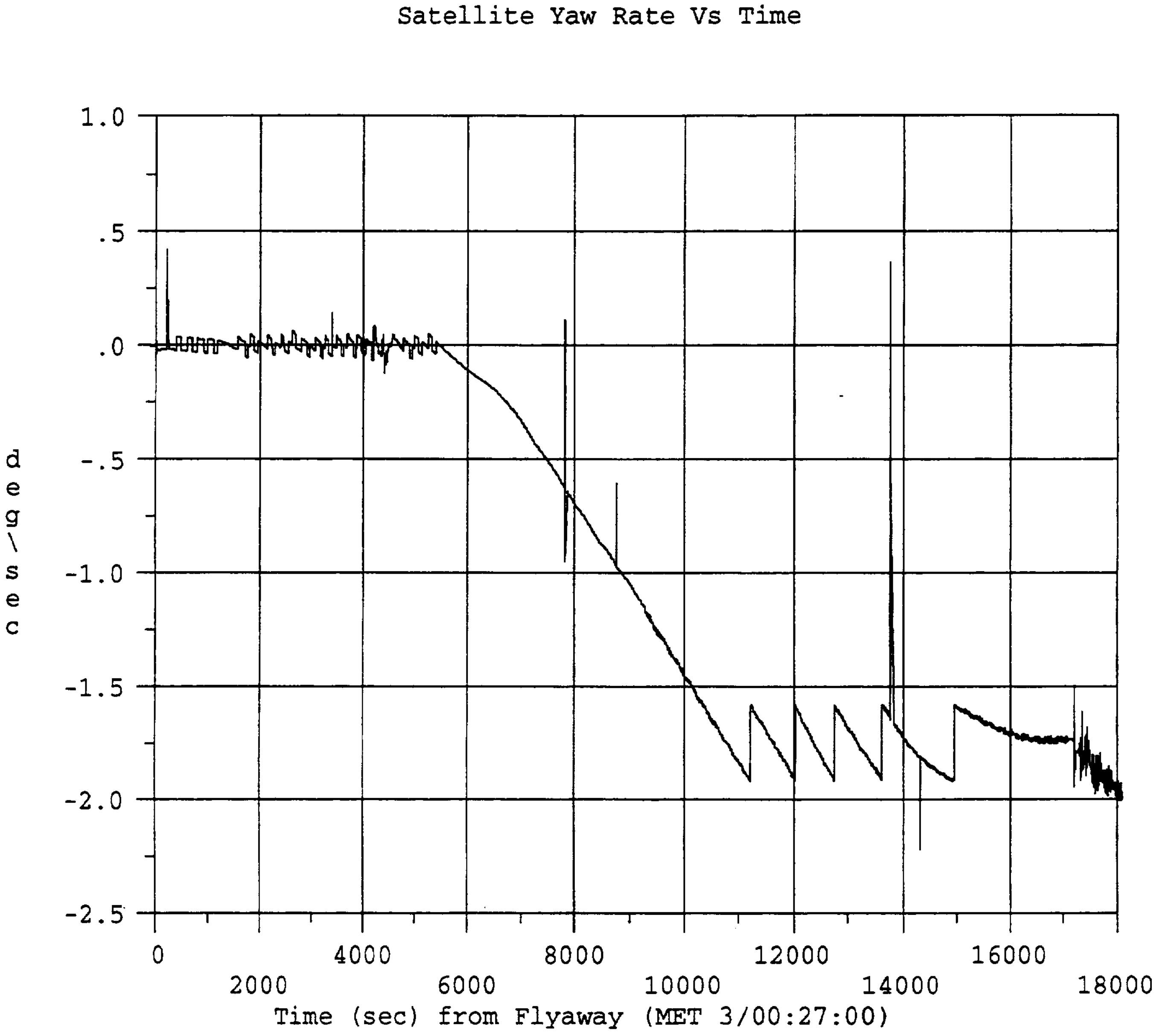

Satellite Yaw Rate Vs Time
1.0
.5
.0
-.5
-1.0
-1.5
-2.0
-2.5
d e g \ s e c
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Time (sec) from Flyaway (MET 3/00:27:00)

Fig. 9

Simulated View Tracking Satellite from Aft Flight Deck
Deployed Length = 16km, ~50 meter Bow Amplitude, Bow Plane is 16 deg toward Stbd
Field of View = 2 degrees

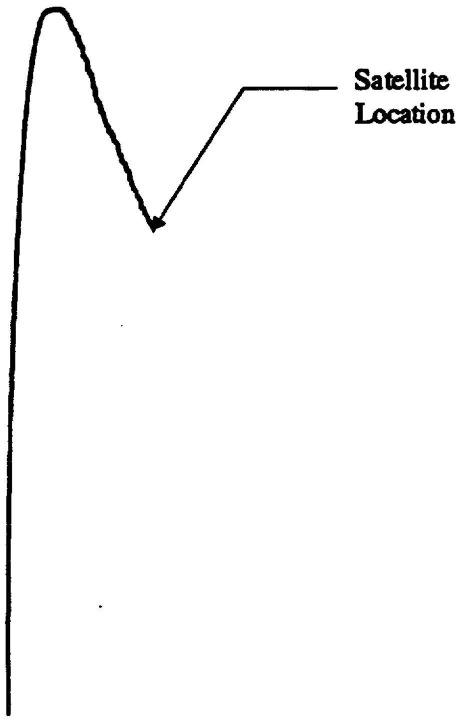


Figure 10

TDSO Mid Node Position, 14000 to 15000 sec

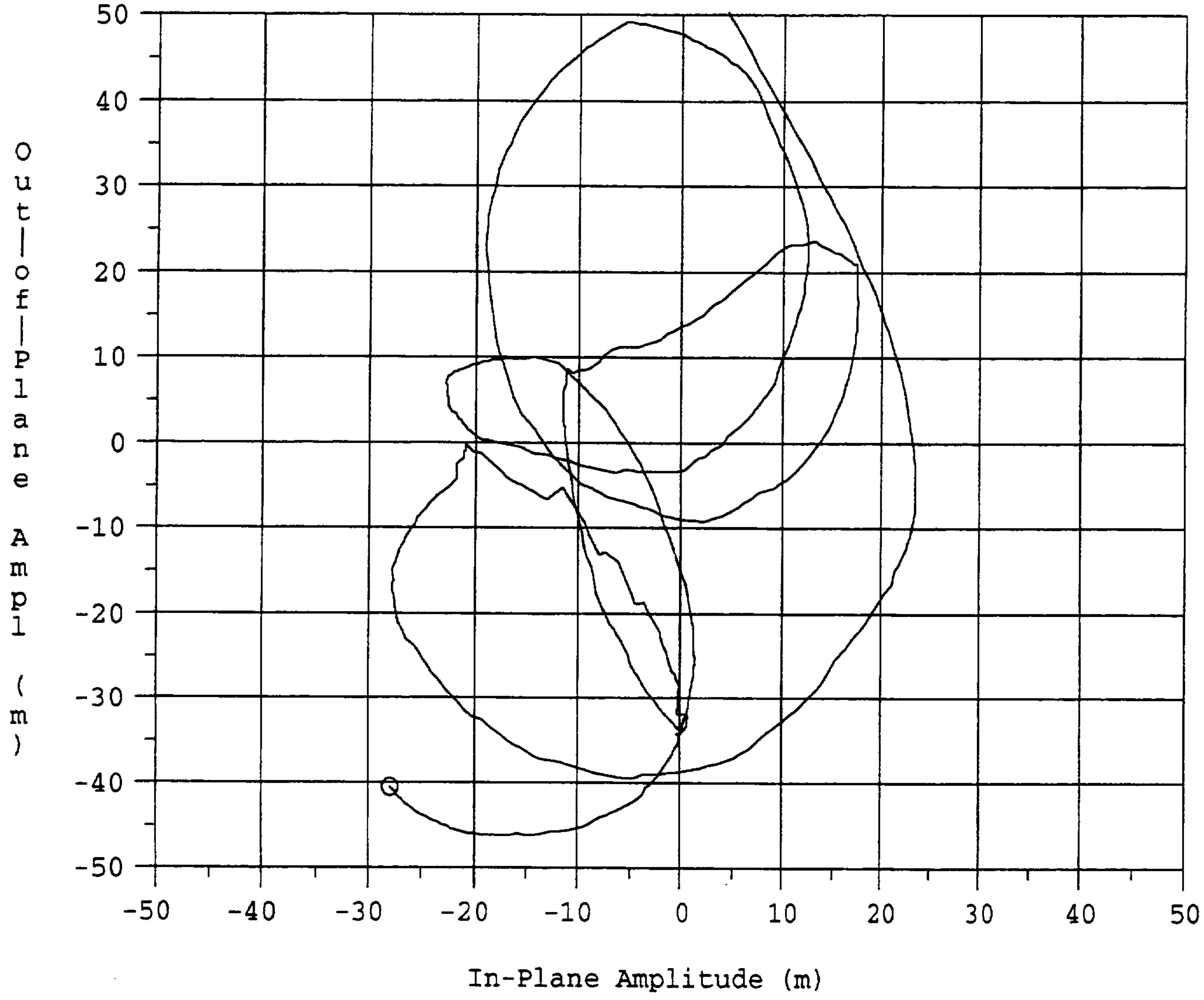
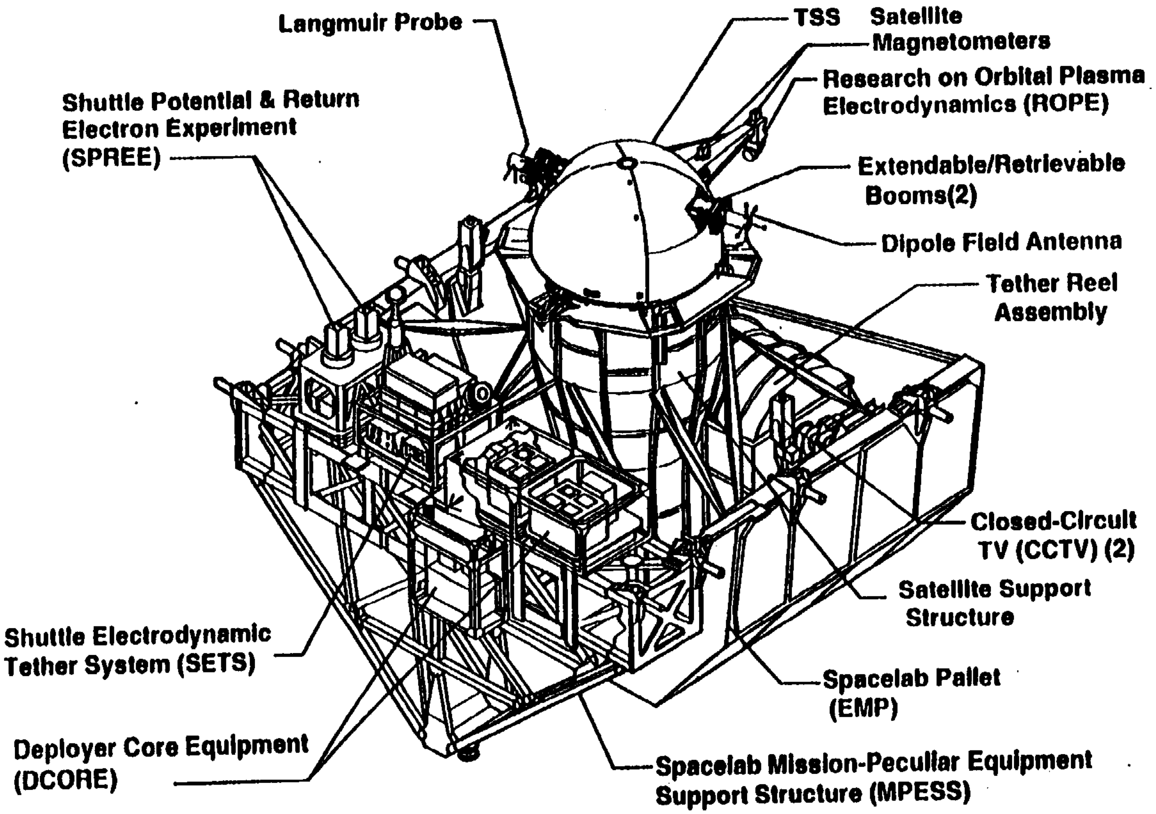


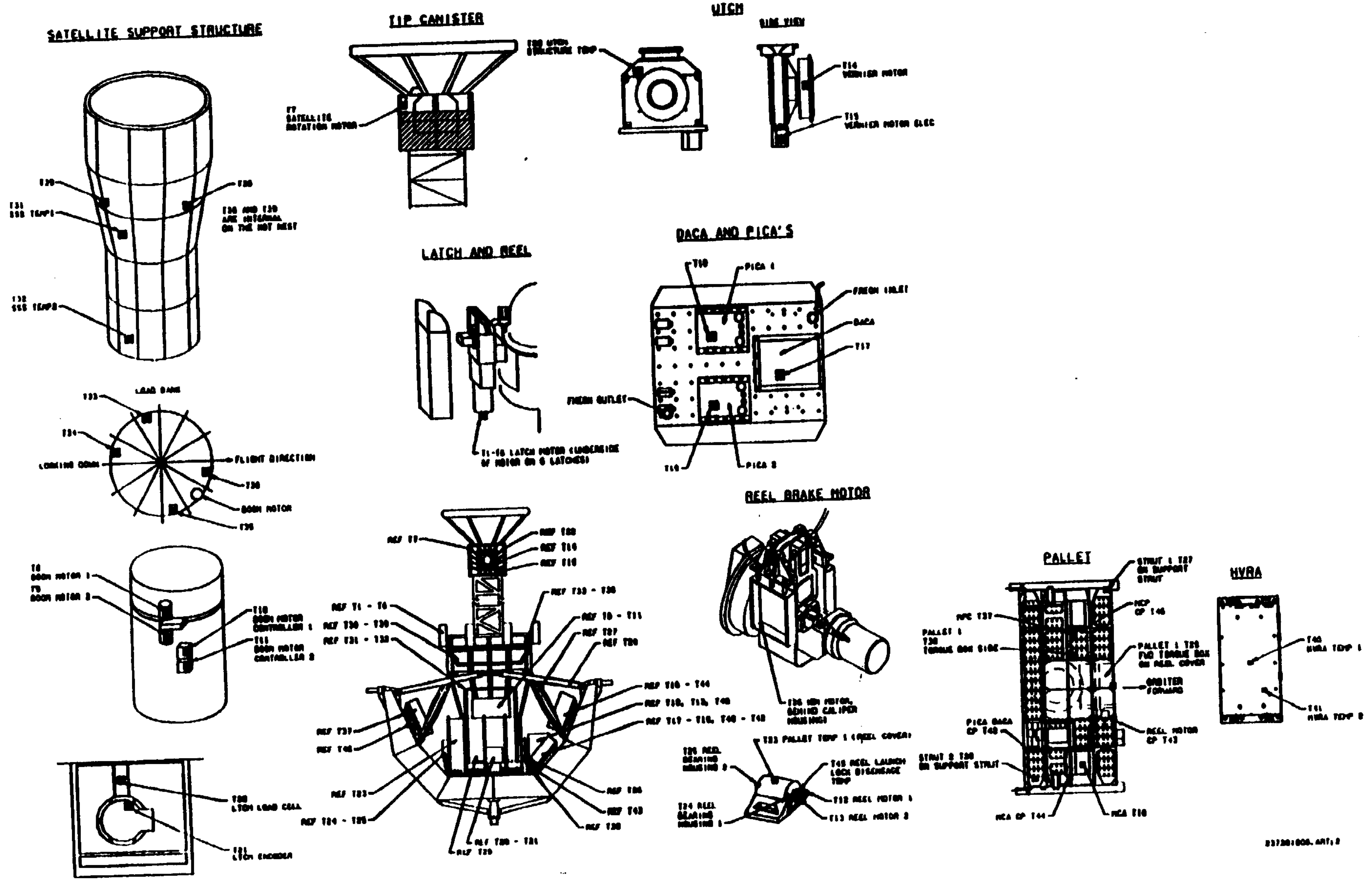
Fig. 11

Appendix E Thermal Data

Tethered Satellite System

The TSS for the STS-75 Mission Is Mounted on Two Major Equipment Carriers: (1) the Enhanced Multiplexer-Demultiplexer Pallet (EMP), and (2) a Spacelab Mission-Peculiar Equipment Support Structure (MPESS). The Equipment Is Divided So That the Basic Satellite and All Tether Control Hardware Is Mounted on the EMP, and All TSS Mission Dedicated Scientific Instruments Are Integrated on the MPESS. These Science Instruments Operate in Conjunction With Complementary Instruments in the Satellite.





Deployer flight thermistor locations

TSS deployer flight thermistors

Description	TSS ref.	MSID type P33xxx	*	Flight meas ID	Deployer TC	FDA limits °C	Sensor range °C	Qual Temp
Latch motor 1	T1	T3239A	2	T01T001A	TC101	–23/50	–55/70	–33/33
Latch motor 2	T2	T3240A	2	T01T002A	TC102	–23/50	–55/70	–33/33
Latch motor 3	T3	T3241A	2	T01T003A	TC103	–23/50	–55/70	–33/33
Latch motor 4	T4	T3242A	2	T01T004A	TC104	–23/50	–55/70	–33/33
Latch motor 5	T5	T3243A	2	T01T005A	TC105	–23/50	–55/70	–33/33
Latch motor 6	T6	T3244A	2	T01T006A	TC106	–23/50	–55/70	–33/33
Sat rot motor	T7	T3245A	2	T01T007A	None	–23/50	–55/70	–33/73
Boom motor 1	T8	T3246A	2	T01T008A	TC1008	–15/40	–55/70	–20/45
Boom motor 2	T9	T3247A	2	T01T009A	TC1009	–15/40	–55/70	–20/45
Boom MTR CTL no. 1	T10	T3278A	2	T01T042A	TC1010	–15/40	–55/70	–20/45
Boom MTR CTL no. 2	T11	T3279A	2	T01T043A	TC1011	–15/40	–55/70	–20/45
Reel motor no. 1	T12	T3248A	4	T01T010A	TC1012	–5/30	–25/60	–10/80
Reel motor no. 2	T13	T3249A	4	T01T011A	TC1013	–5/30	–25/60	–10/80
Vernier motor	T14	T3250A	2	T01T012A	None	–10/55	–55/70	–45/80
Vernier motor elec	T15	T3251A	2	T01T013A	None	–10/50	–55/70	–25/55
MCA	T16	T3252A	2	T01T014A	TC1016	–5/30	–55/70	–10/50
DACA	T17	T3253A	2	T01T015A	TC1017	–5/30	–55/70	–10/50
PICA no. 1	T18	T3254A	2	T01T016A	TC1018	–10/30	–55/70	–21/62
PICA no. 2	T19	T3255A	2	T01T017A	TC1019	–10/30	–55/70	–21/62
LTCM load cell	T20	T3256A	3	T01T018A	TC226(5)	–25/40	–45/60	–50/50
LTCM encoder	T21	T3257A	3	T01T019A	TC1012(5)	–25/55	–45/60	–40/80
UTCM structure	T22	T3258A	1	T01T020A	None	none	–45/60	–25/50
Reel cover	T23	T3259A	2	T01T021A	TC1023	–25/40	–55/70	–37/40
Reel BRNG CVR no. 1	T24	T3260A	2	T01T022A	TC1024	–25/40	–55/70	–29/40
Reel BRNG CVR no. 2	T25	T3261A	2	T01T023A	TC1025	–25/40	–55/70	–39/40
Brake motor	T26	T3262A	2	T01T024A	TC1026	–25/40	–55/70	–40/70
Strut no. 1	T27	T3263A	1	T01T025A	TC1027	none	–45/60	–42/37
Strut no. 2	T28	T3264A	1	T01T026A	TC1028	none	–45/60	–43/36
Fmt torque box (PLT1)	T29	T3265A	1	T01T027A	TC1023	none	–45/60	–52/54
Side torque box (PLT2)	T30	T3266A	1	T01T028A	TC1030	none	–45/60	–52/54
SSA up struc (SSA1)	T31	T3267A	1	T01T029A	TC1031	none	–45/60	–51/38
SSA low struc (SSA2)	T32	T3268A	1	T01T030A	TC1032	none	–45/60	–44/41
Load bank no. 1	T33	T3271A	5	T01T033A	TC1033	–60/60	–60/80	–71/42
Load bank no. 2	T34	T3272A	5	T01T034A	TC1034	–60/60	–60/80	–71/42
Load bank no. 3	T35	T3273A	5	T01T035A	TC1035	–60/60	–60/80	–71/42
Load bank no. 4	T36	T3274A	5	T01T036A	TC1036	–60/60	–60/80	–71/42
MPC	T37	T3322A		T01T048A	TC366	–5/30	–55/70	–10/50
Hot nest(2)	T38	T2018A			TC131	N/A	–283/320° F	–57/63
Discrete hot nest(3)	T39	X1509Y			None	——	——	
HVRA no. 1	T40	T3281A		T01T045A	TC1040	–35/40	–55/70	–55/50
HVRA no. 2	T41	T3280A		T01T044A	TC1041	–35/40	–55/70	–55/50
Coldplate–DACA/PICA	T42	T3275A		T01T039A	TC1042	–5/30	–55/70	–10/~~33~~ 40
Coldplate–reel motor	T43	T3277A		T01T041A	TC1043	–5/30	–55/70	–10/~~33~~ 40
Coldplate–MCA	T44	T3276A		T01T040A	TC1044	–5/30	–55/70	–10/33
Reel launch lock MTR	T45	T3270A		T01T032A	TC200	–23/50	–55/70	–40/70
Coldplate–MPC	T46	T3321A		T01T047A	TC1045	–5/30	–55/70	–10/33

*1. Spacelab Data Index. TSS, ICD–B–18411A–A04, rev A.
2. MDAC thermistor.
3. MDAC thermostat, indicates overtemp (open) at >65° C.
4. Deployer TBT TC's for reference (Bounds FLT).
5. External case thermocouples only.

Fig. 1 MCA, MPC & Coldplate Temps. vs. MET

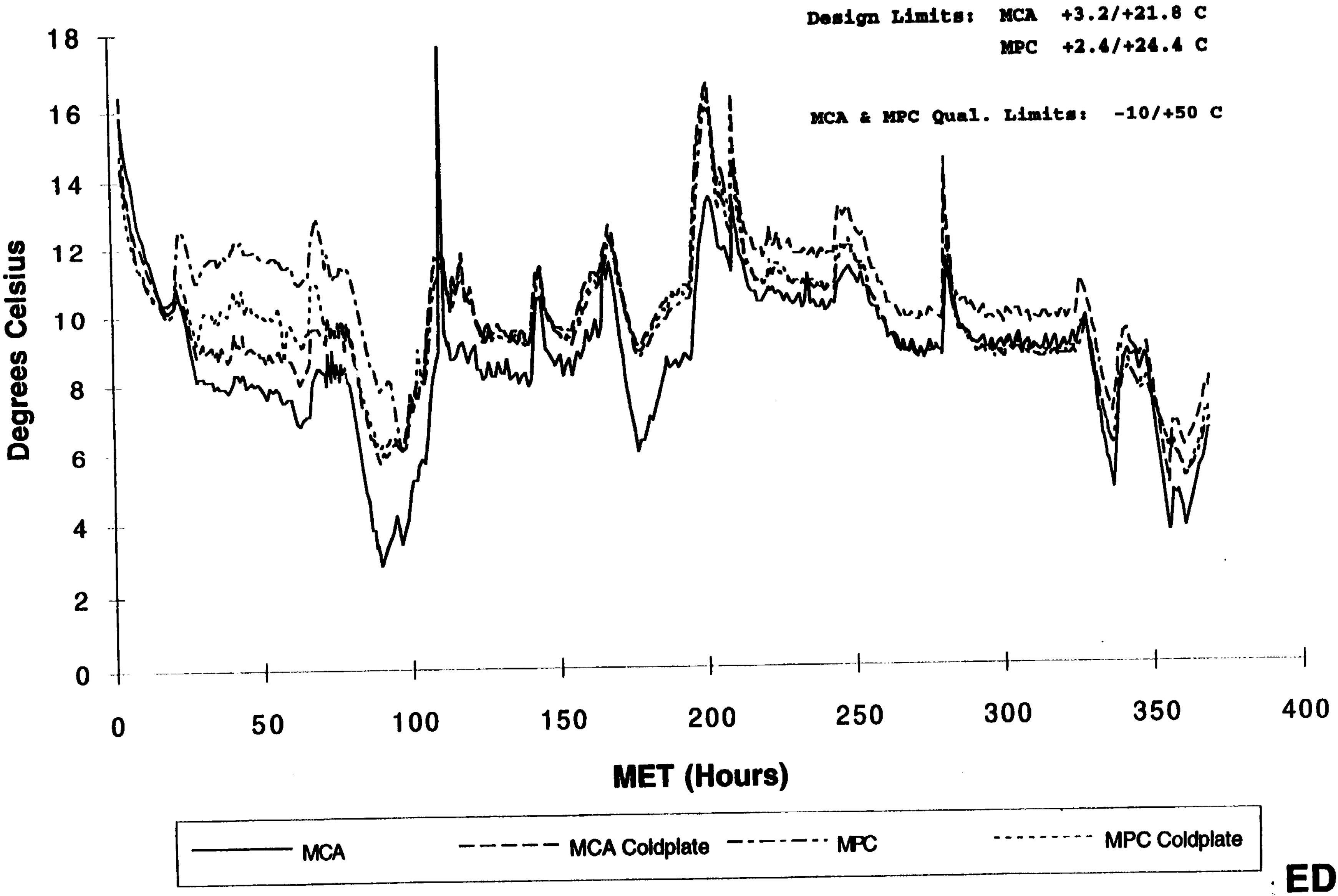


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Fig. 2 DACA, PICA 1 & 2, & Coldplate Temp. vs. MET

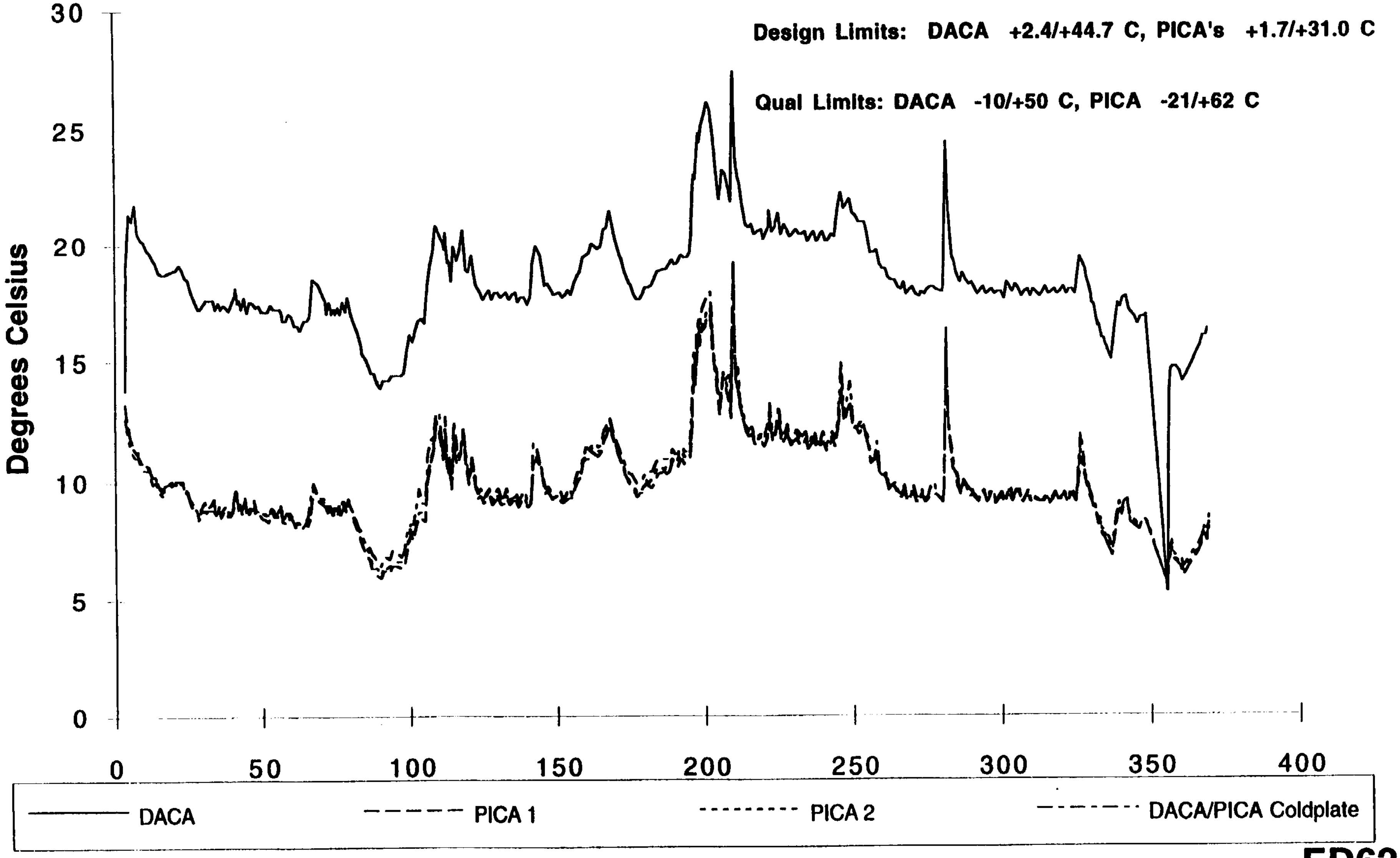
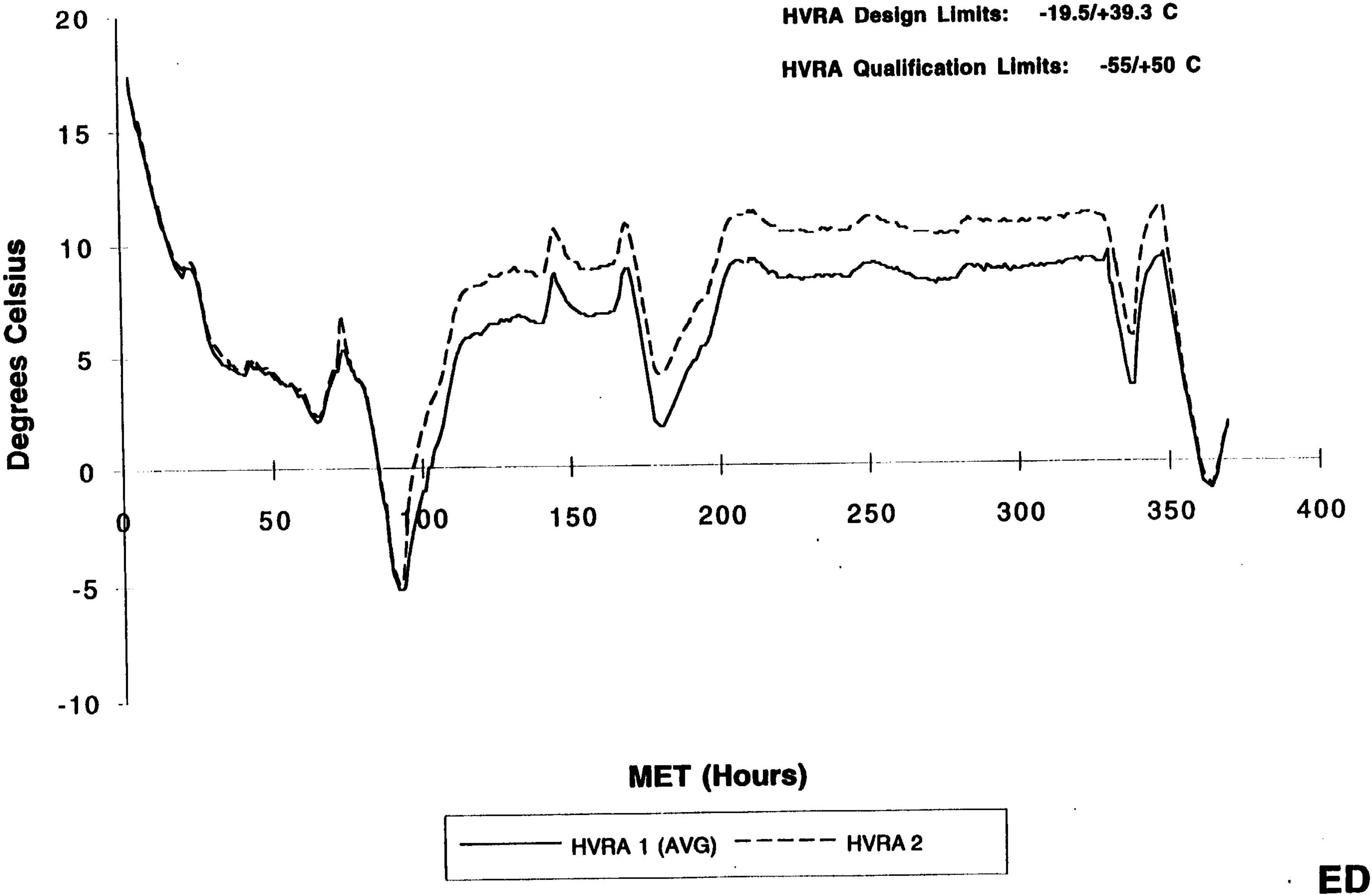
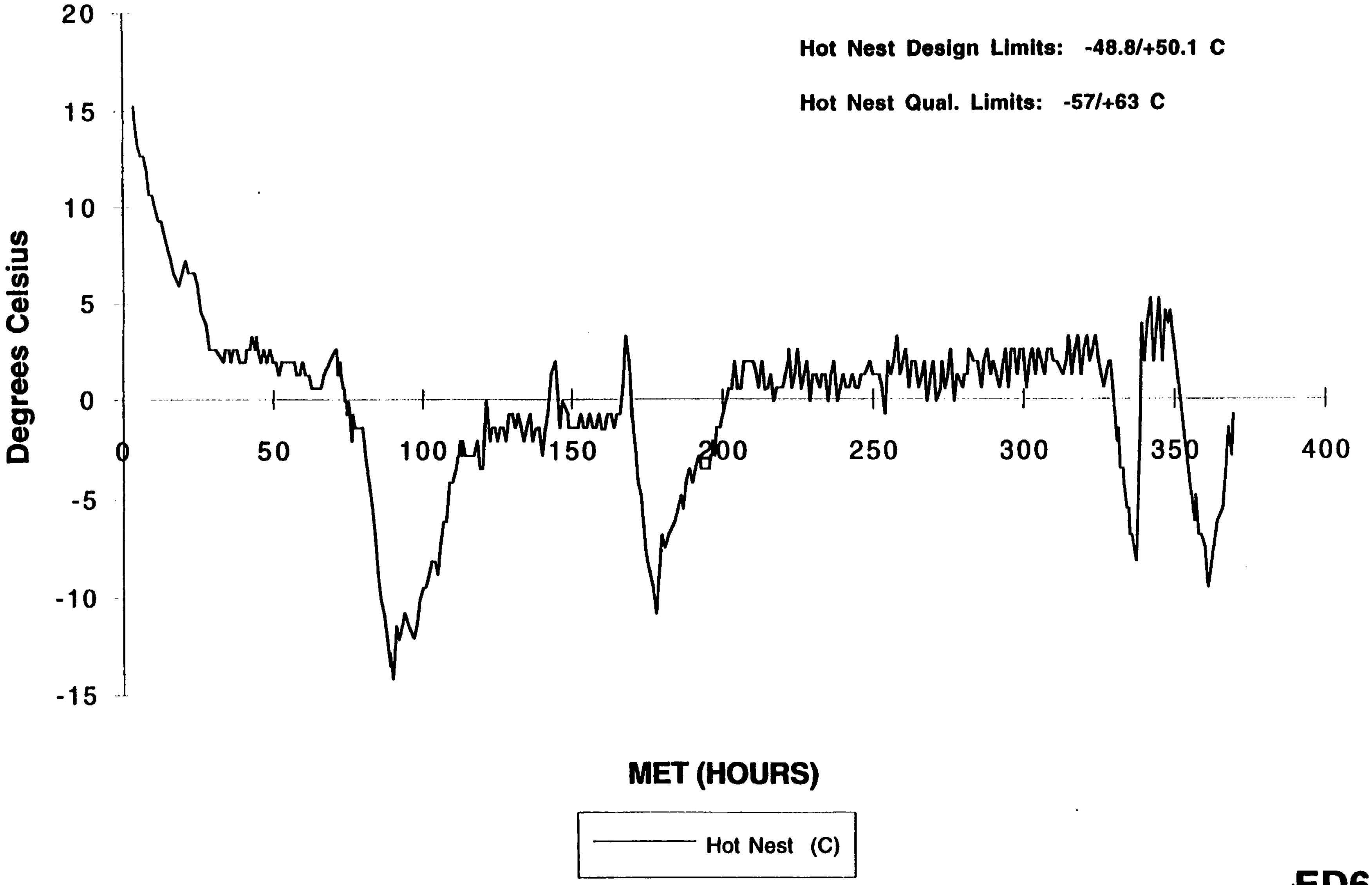


Fig. 3 HVRA 1 & 2 Temperatures vs MET


HVRA Design Limits: -19.5/+39.3 C

HVRA Qualification Limits: -55/+50 C

Fig. 4 Hot Nest Temperature vs. MET

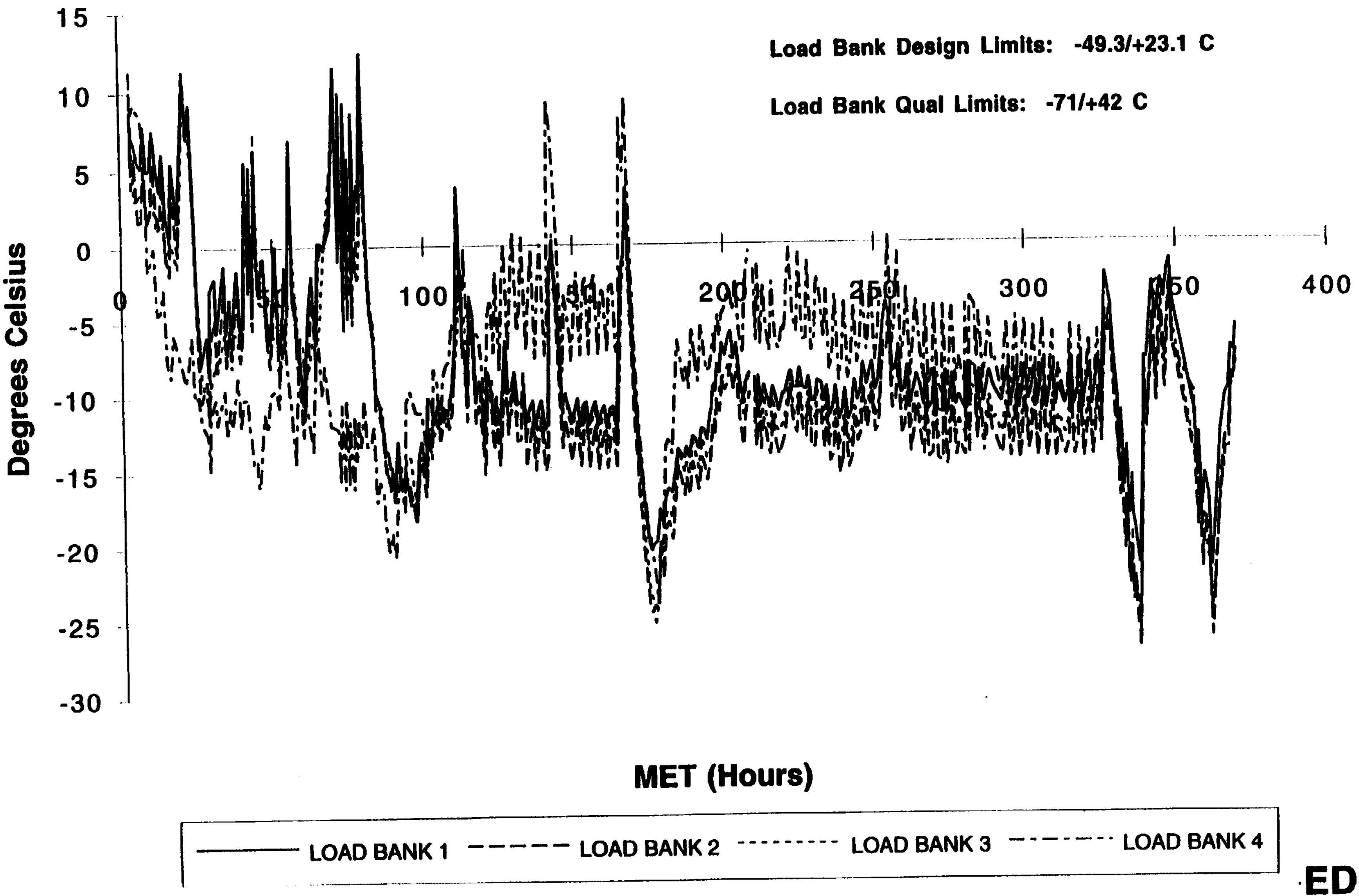


Hot Nest Design Limits: -48.8/+50.1 C

Hot Nest Qual. Limits: -57/+63 C

ED62

Fig. 5 Load Bank Resistor Temps. vs. MET



Load Bank Design Limits: -49.3/+23.1 C

Load Bank Qual Limits: -71/+42 C

Fig. 6 Latch Motor Temps. vs MET

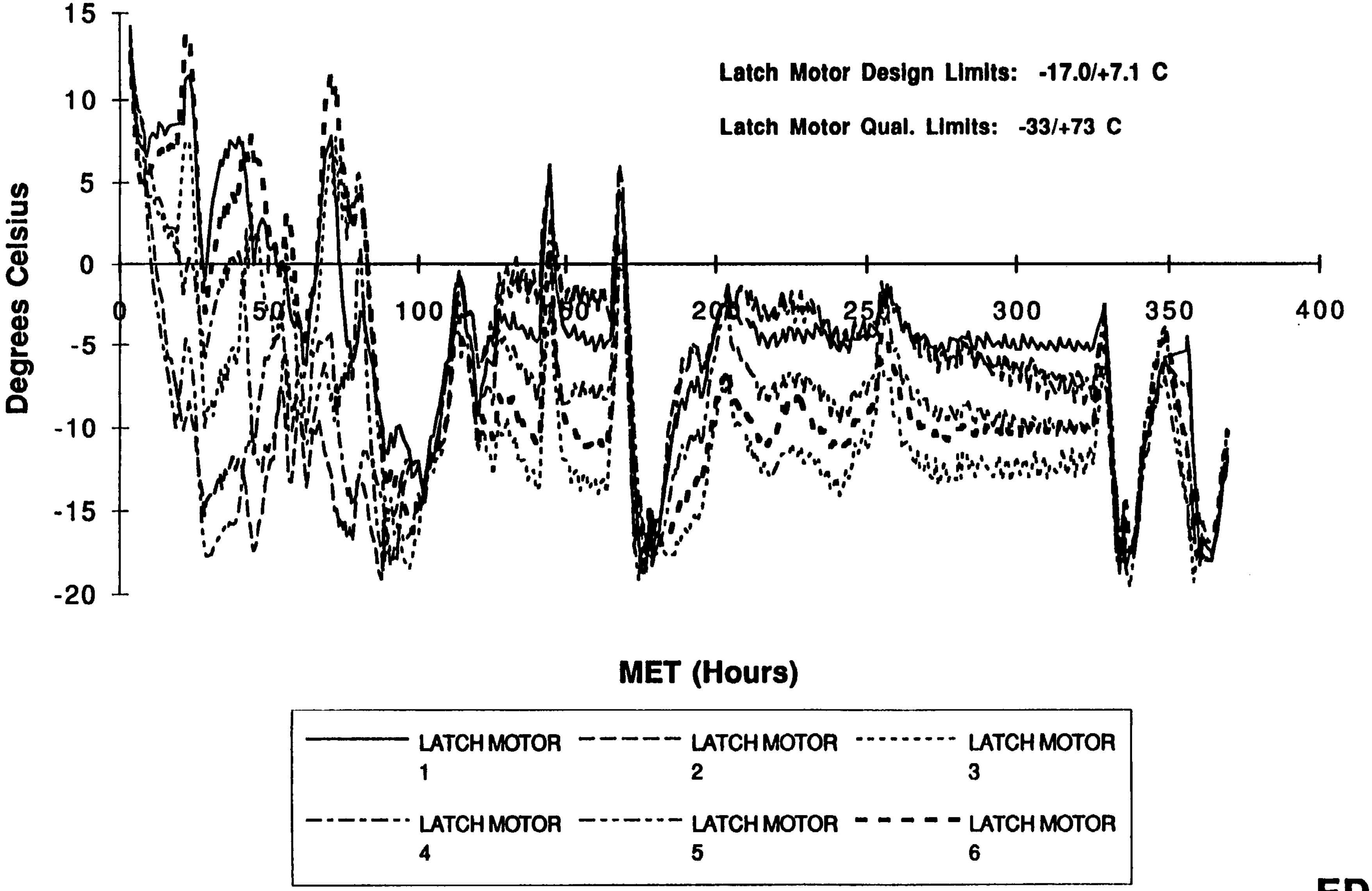


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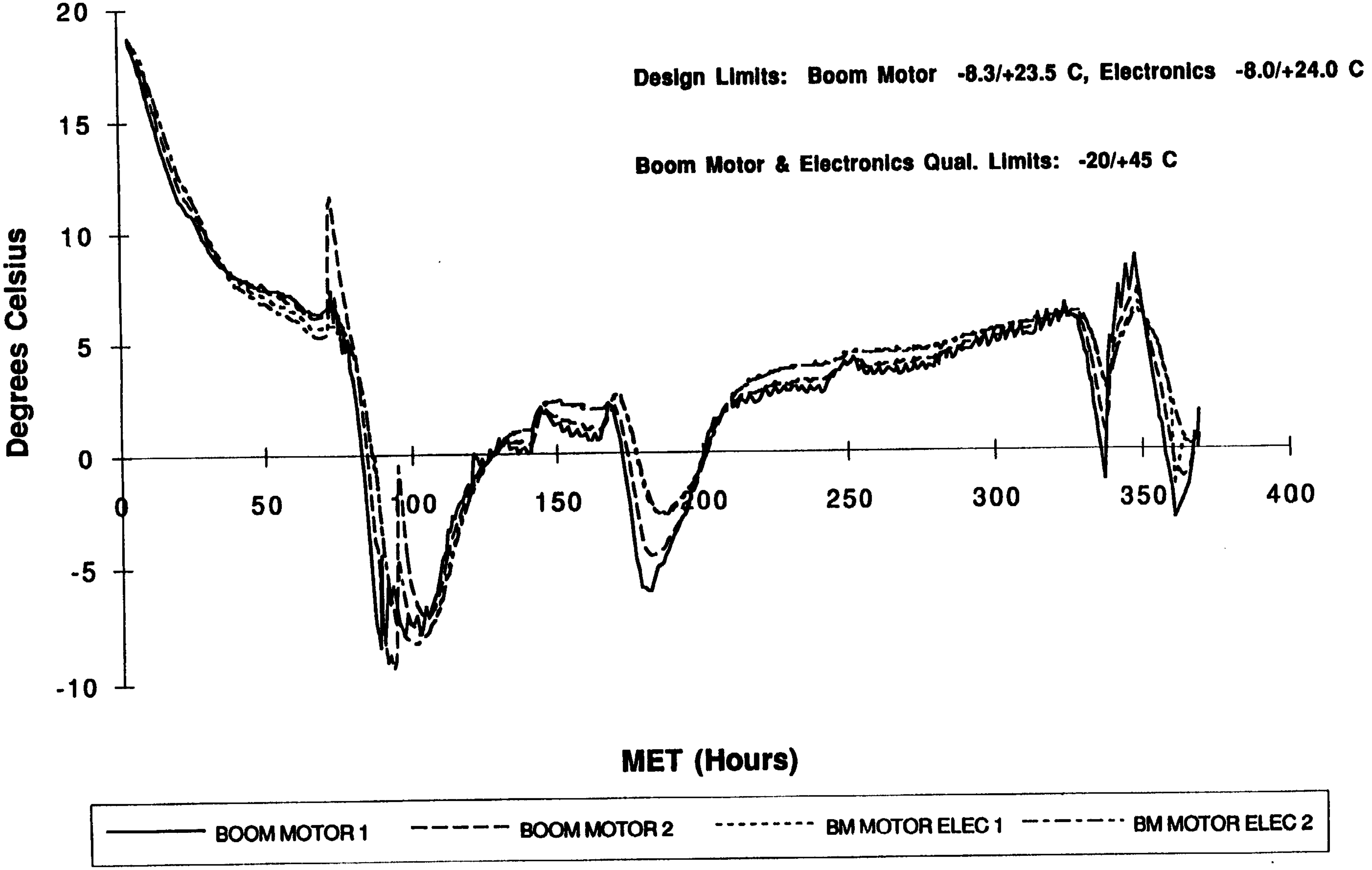
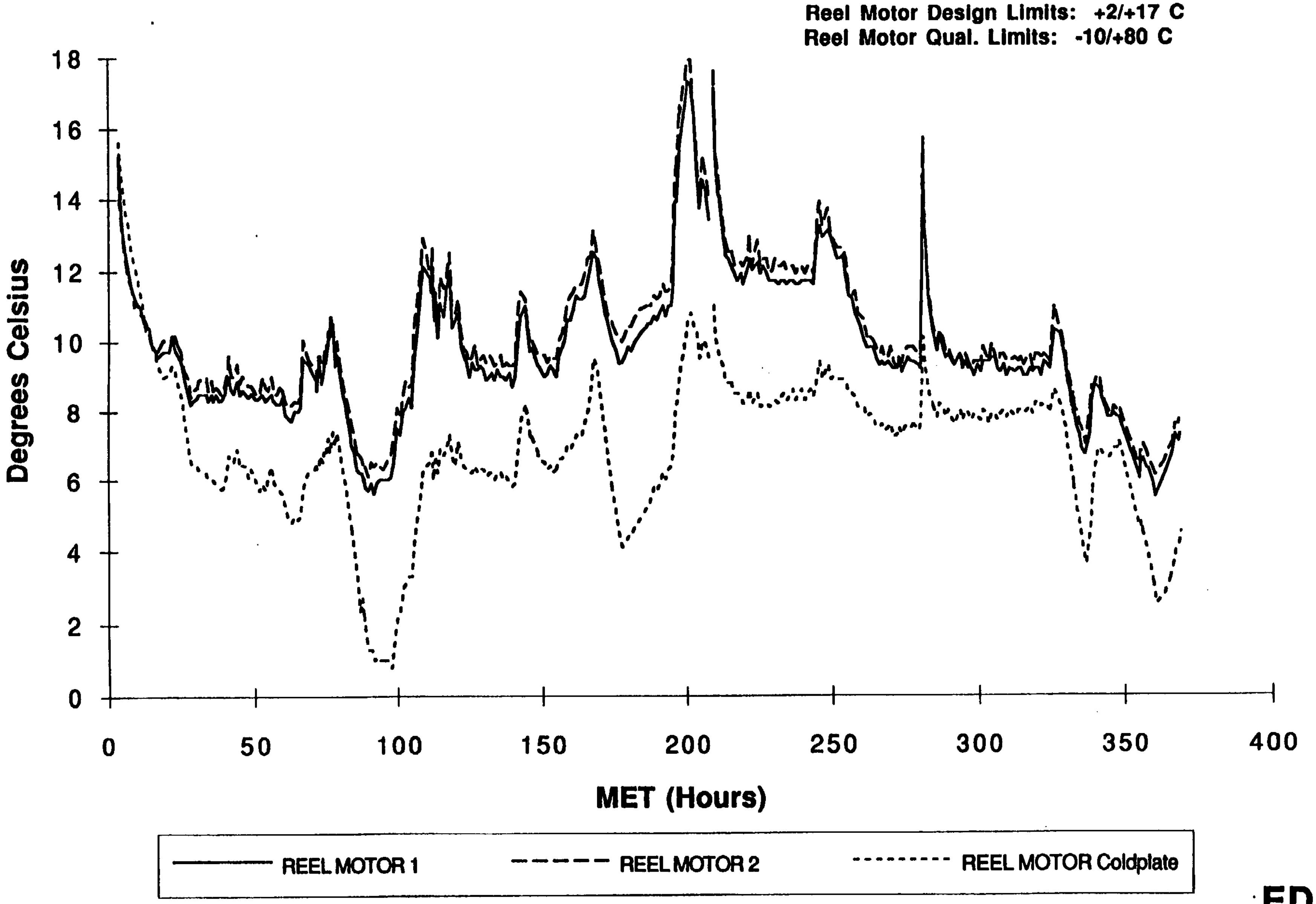
Fig. 7 Boom Motors & Electronics vs. MET



Design Limits: Boom Motor -8.3/+23.5 C, Electronics -8.0/+24.0 C

Boom Motor & Electronics Qual. Limits: -20/+45 C

Fig. 8 Reel Motor #1 & #2 and Coldplate vs. MET



Reel Motor Design Limits: +2/+17 C
Reel Motor Qual. Limits: -10/+80 C

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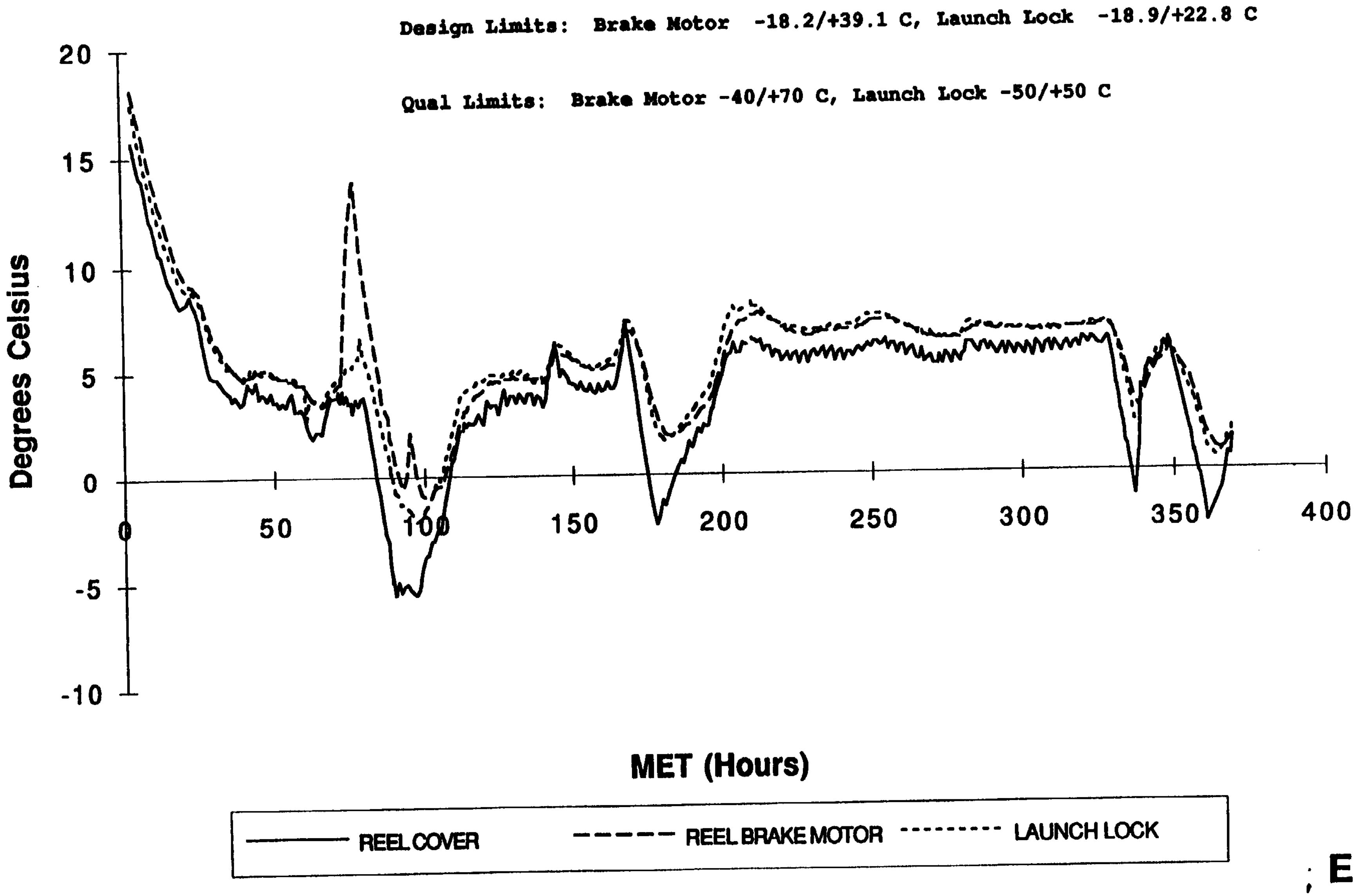
Fig. 9 Reel Cover, Brake Motor, & Launch Lock Temps vs MET



Design Limits: Brake Motor -18.2/+39.1 C, Launch Lock -18.9/+22.8 C

Qual Limits: Brake Motor -40/+70 C, Launch Lock -50/+50 C

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Fig. 10 Reel Bearing #1 & #2 Temps. vs. MET

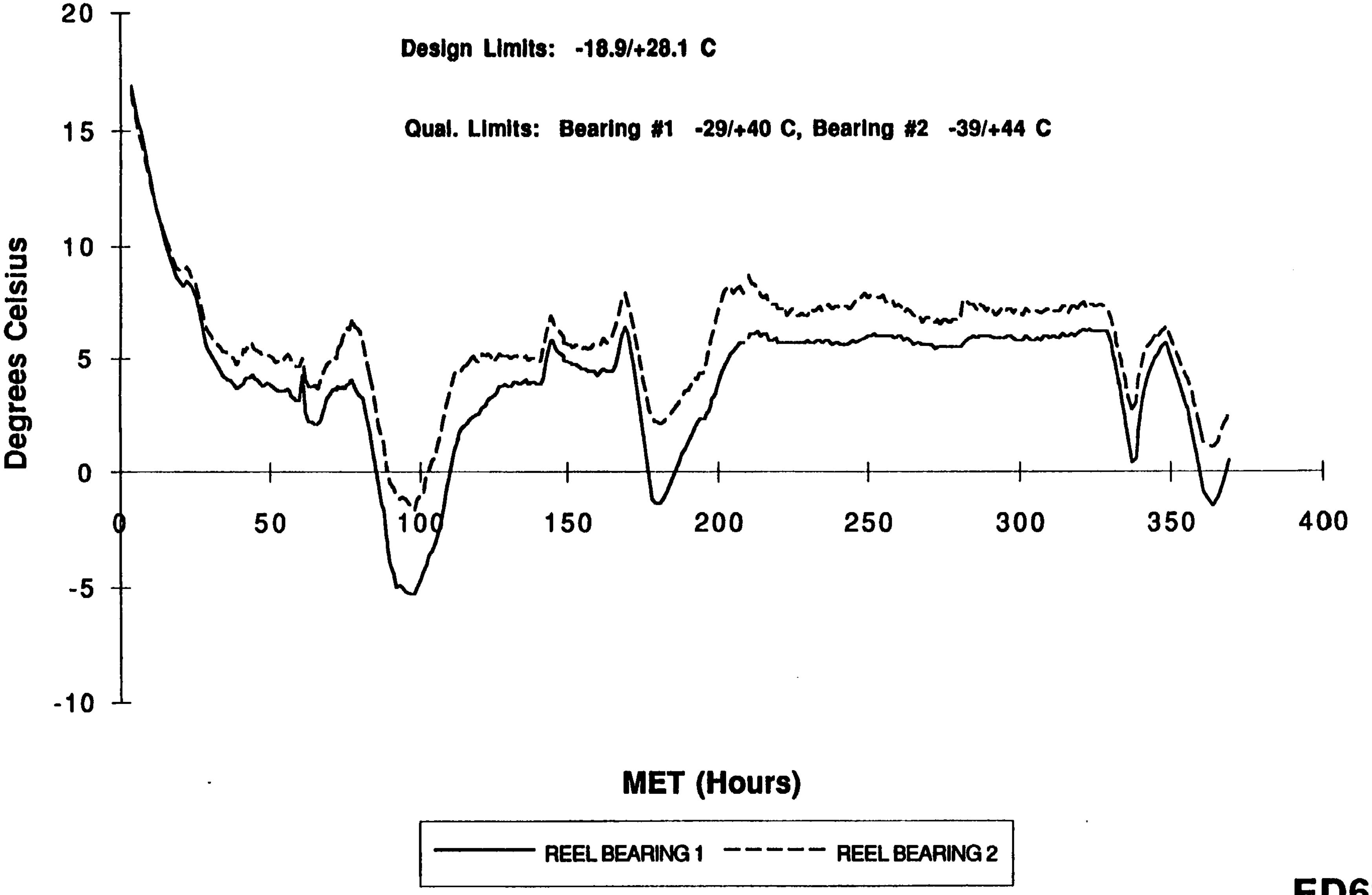

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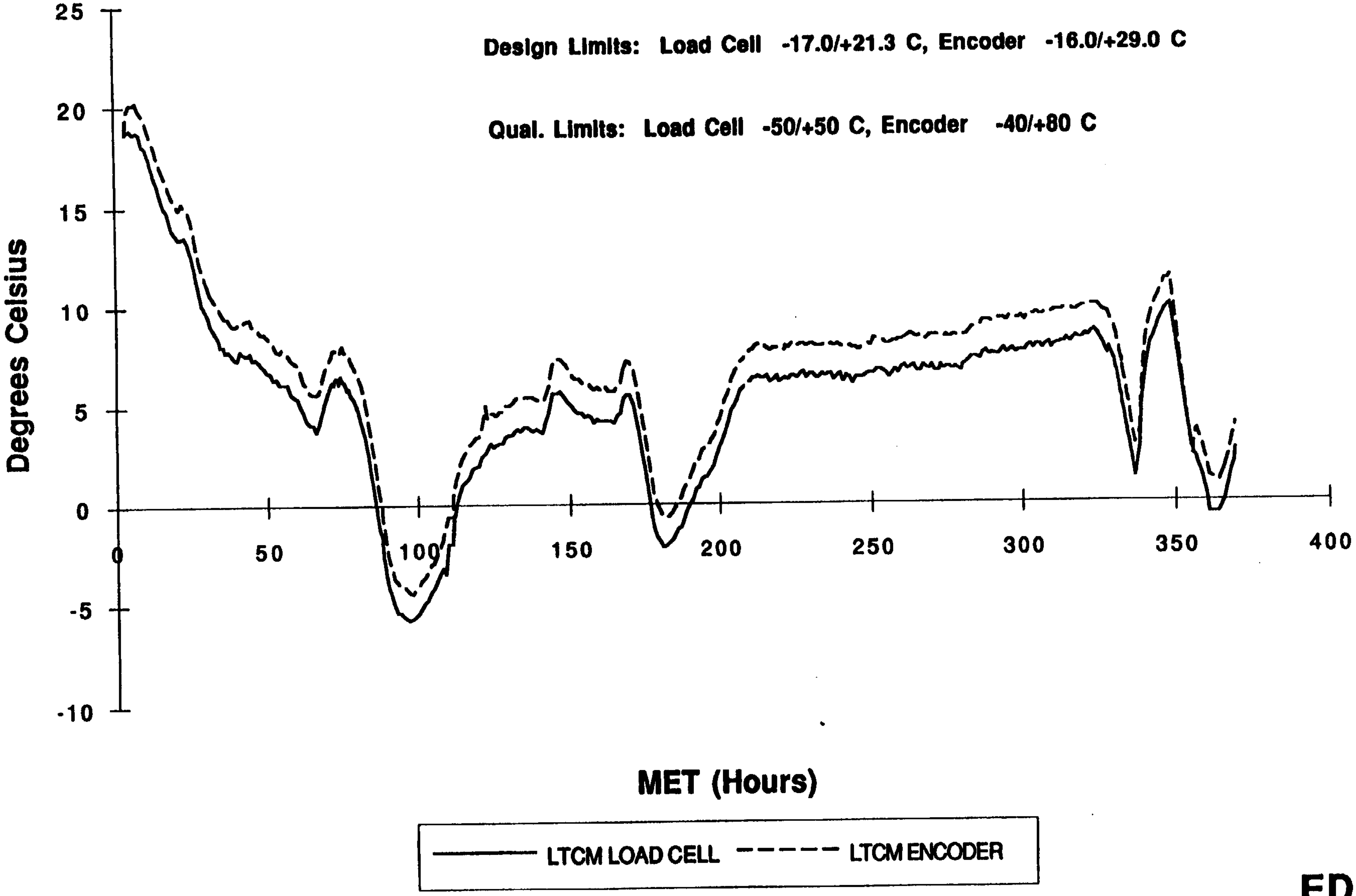
Fig. 11 LTCM Load Cell & Encoder Temps. vs. MET



Design Limits: Load Cell -17.0/+21.3 C, Encoder -16.0/+29.0 C

Qual. Limits: Load Cell -50/+50 C, Encoder -40/+80 C

ED62

Fig. 12 UTCM Structure & Docking Ring Motor Temps. MET

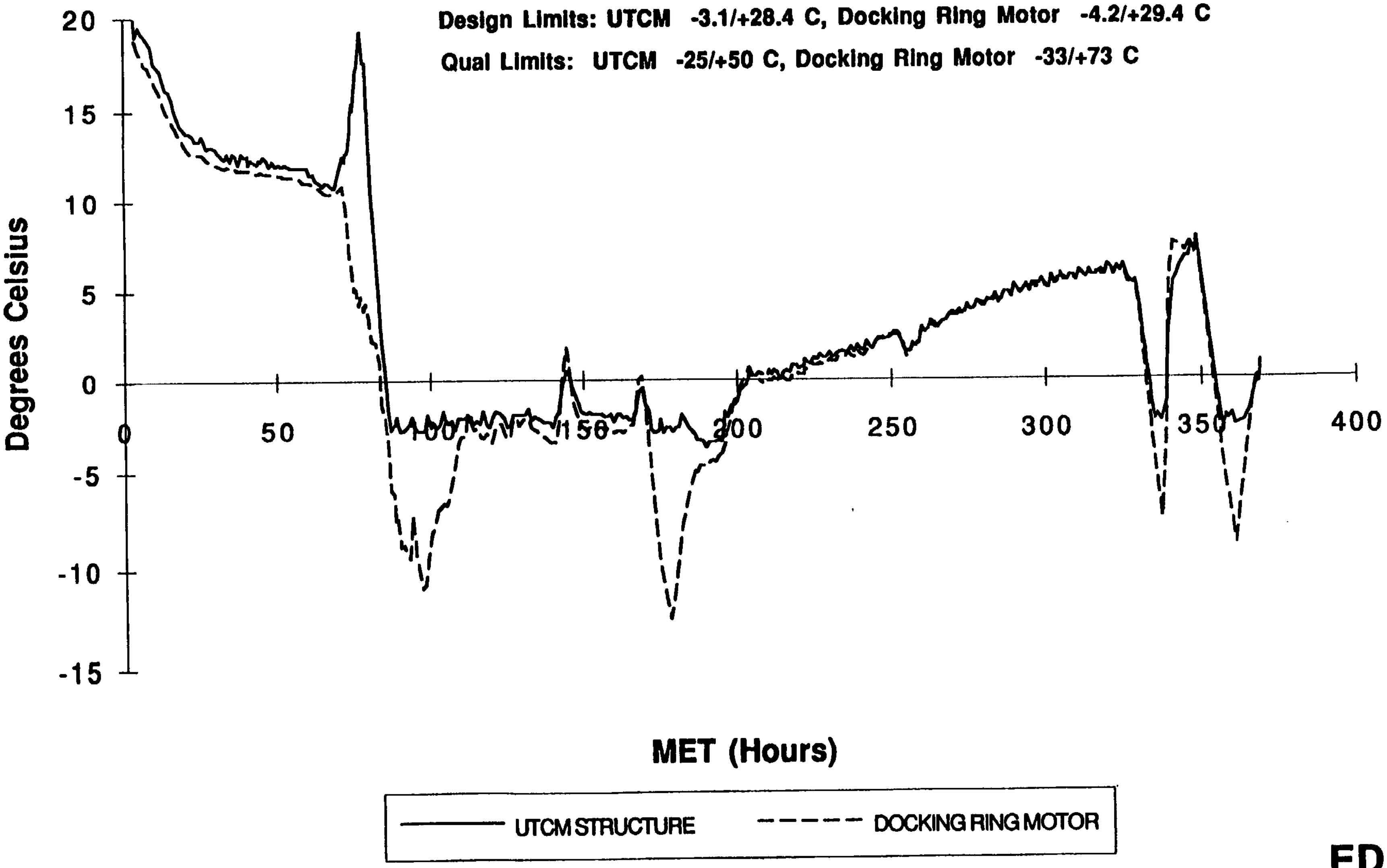


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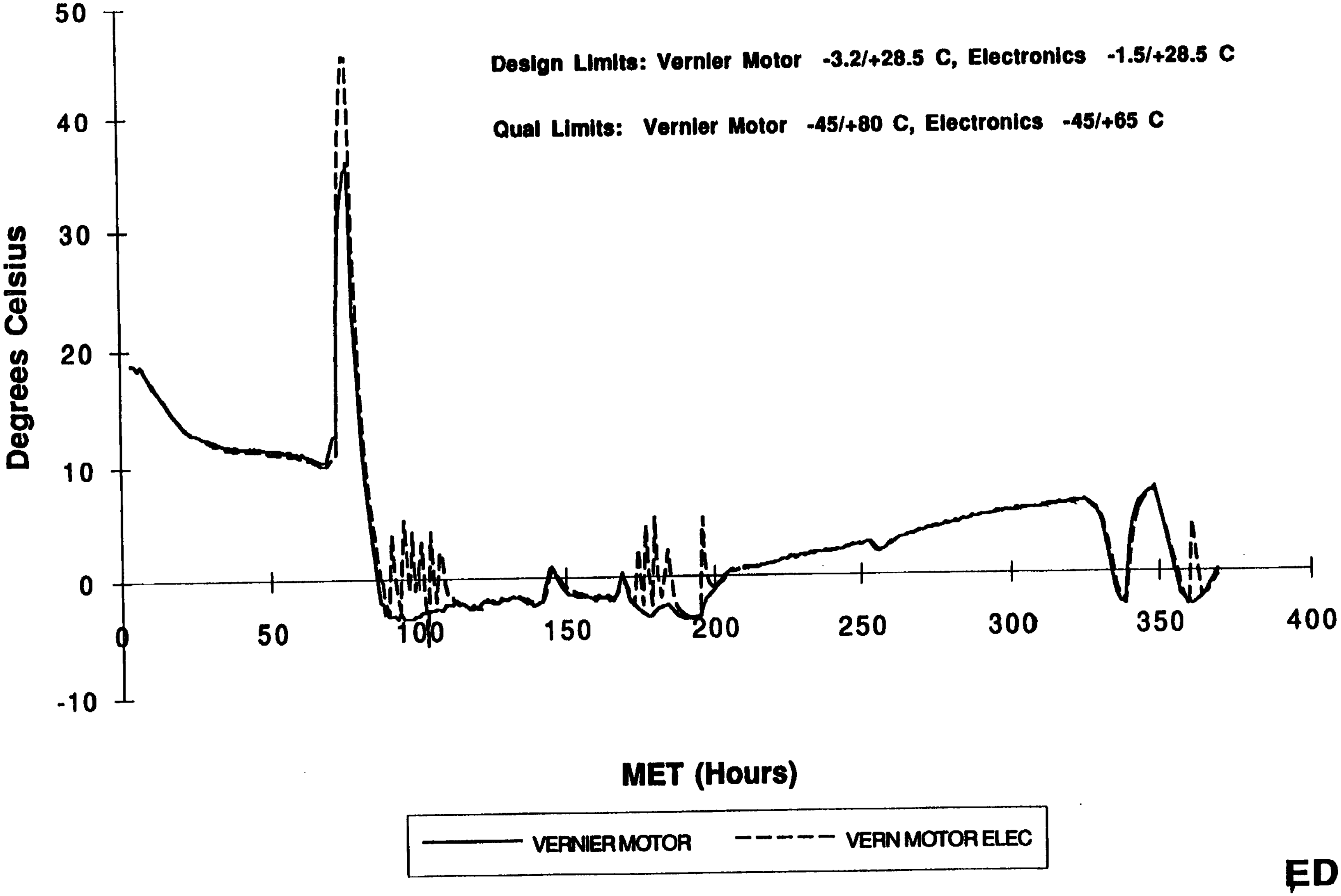
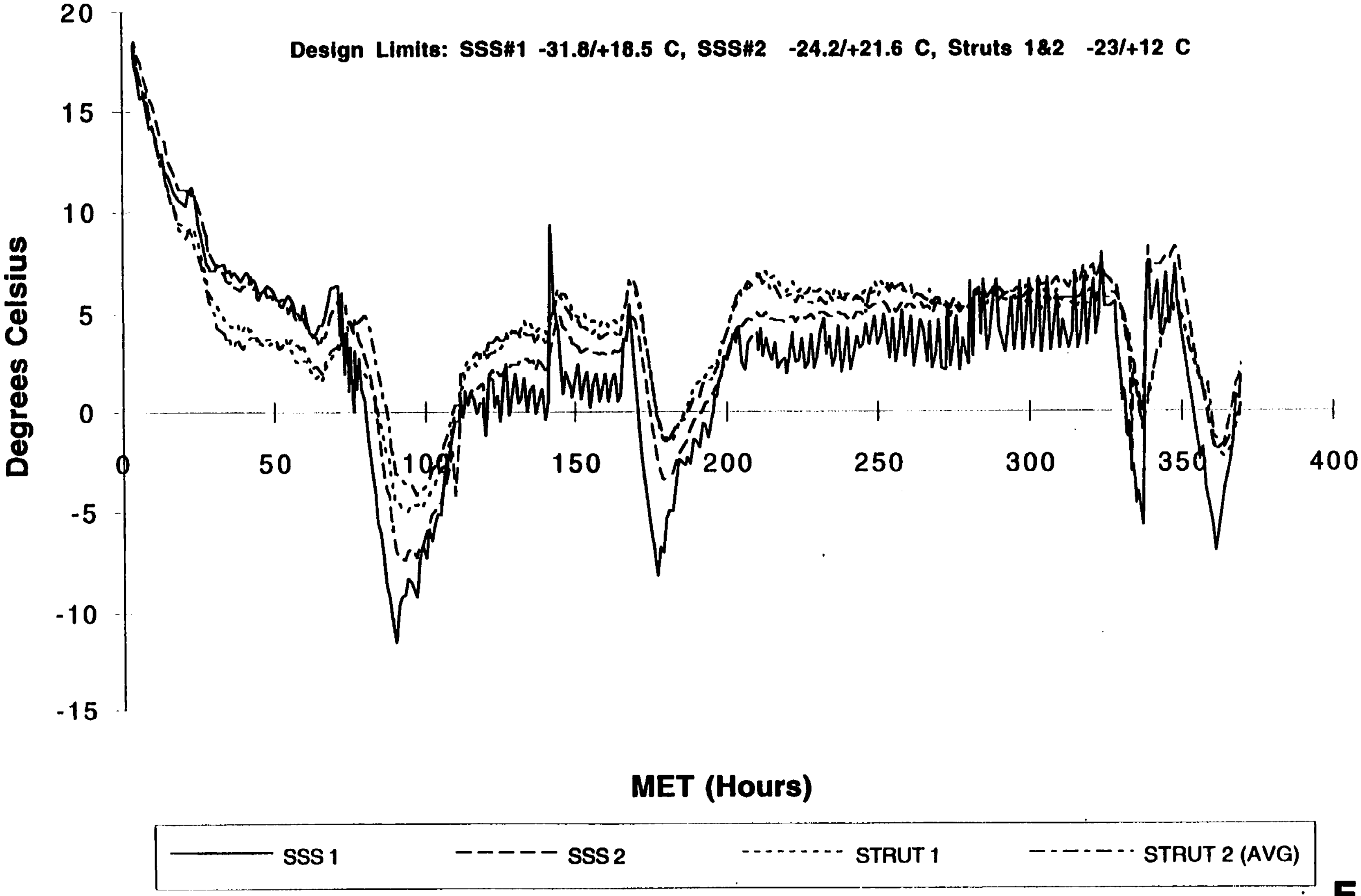
Fig. 13 Vernier Motor & Electronics Temps. vs. MET



Design Limits: Vernier Motor -3.2/+28.5 C, Electronics -1.5/+28.5 C

Qual Limits: Vernier Motor -45/+80 C, Electronics -45/+65 C

Fig. 14 SSS #1 & #2, Strut #1 & #2 Temps. vs. MET



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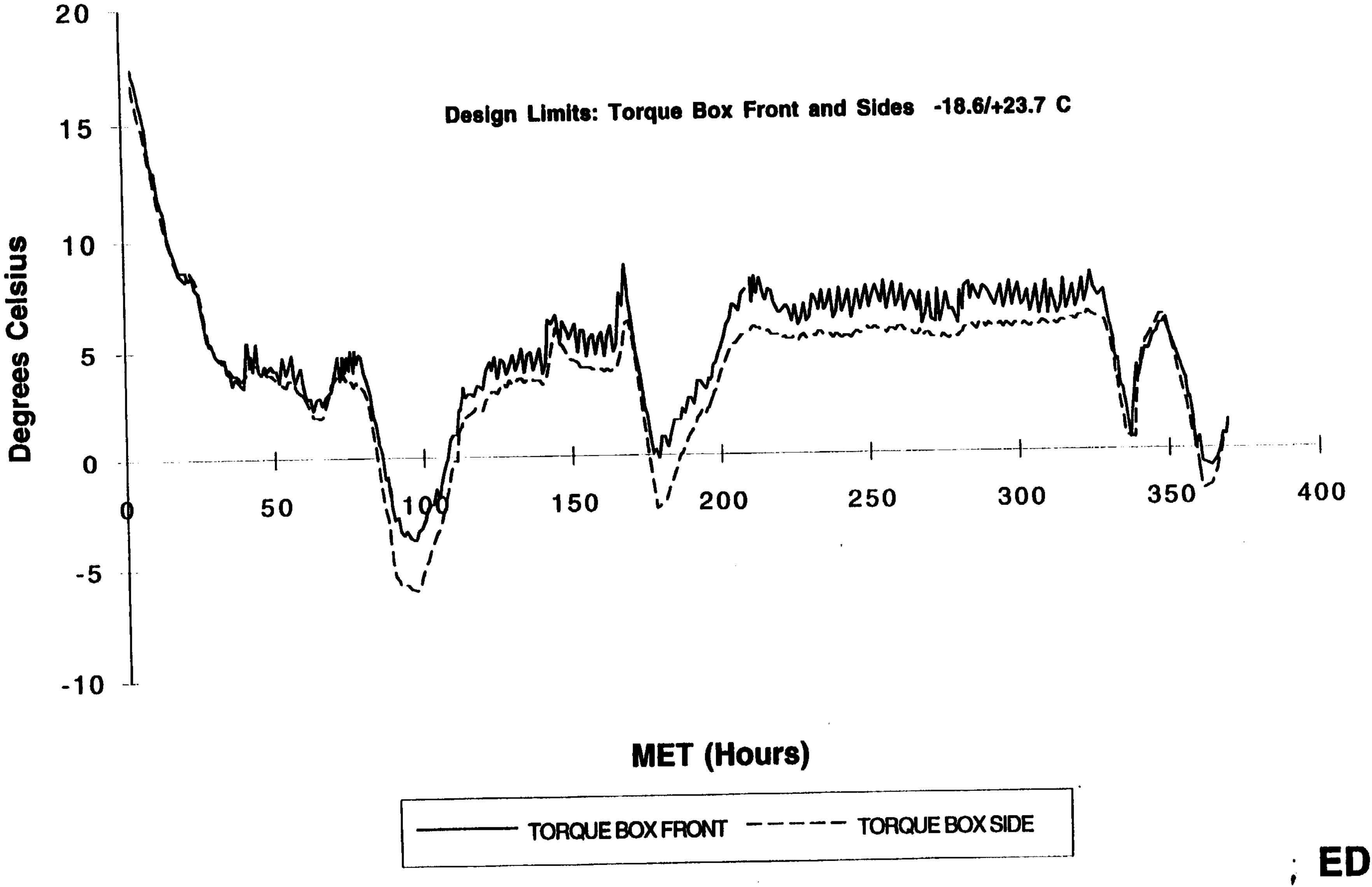

Fig. 15 Torque Box Front & Side Temps. vs. MET

Design Limits: Torque Box Front and Sides -18.6/+23.7 C

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Fig 16. Deployer Average Temp. vs. MET

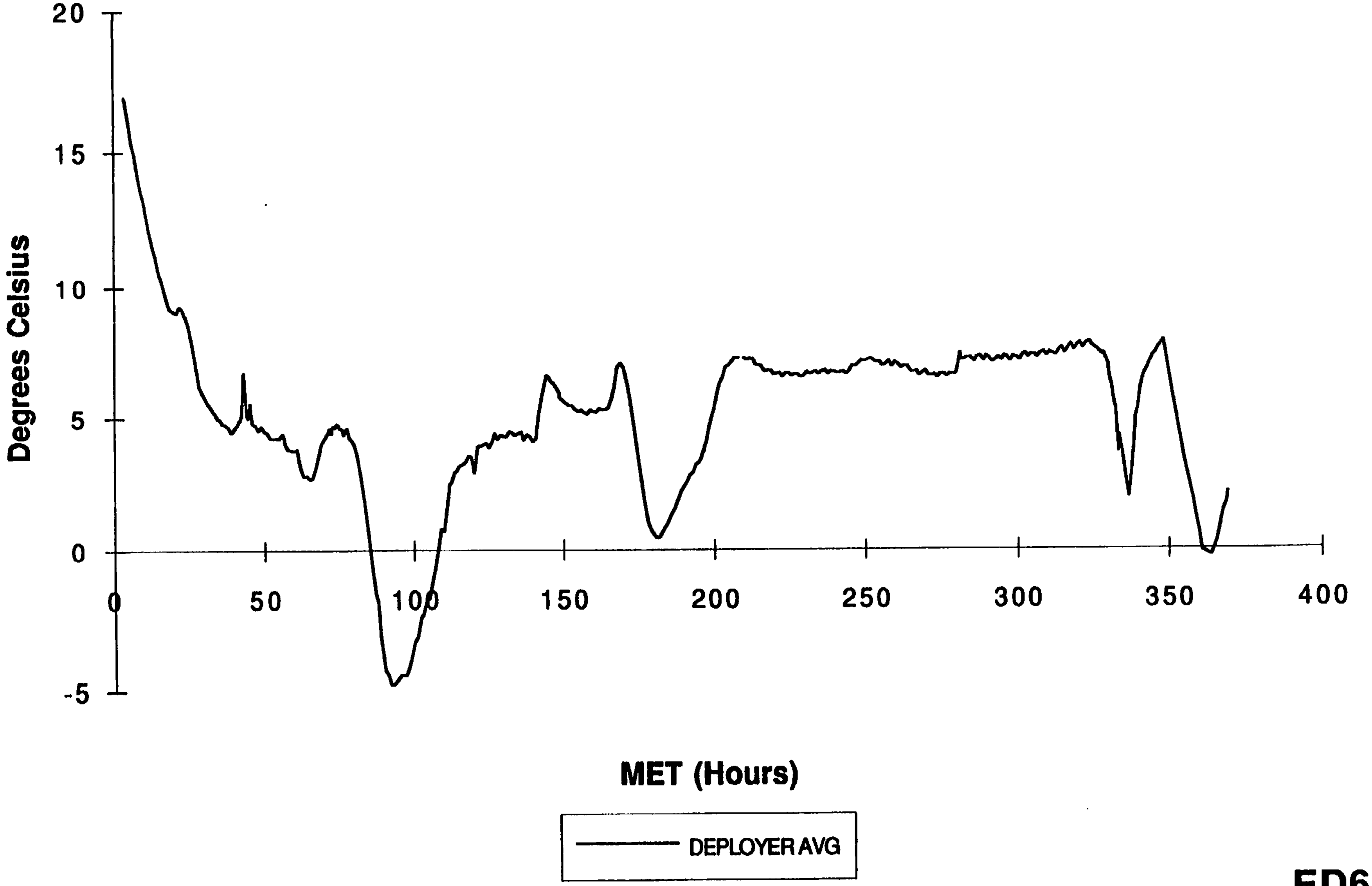

Fig. 17 Freon Inlet #1 & #2 Temps. vs. MET