OMAHA PUBLIC POWER DISTRICT

Final Report on Analysis of

Prototype PORV Block Valve Steam Blowdown

Isolation Qualification Testing

for NUREG-0737, Item II.D.1 Issues.

April 1992

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1.0 PURPOSE

1.1 The purpose of this report is to provide the results and subsequent conclusions based upon the analysis of steam blowdown data acquired during open-to-close and close-to-open stroking of a prototype test valve at Wyle Laboratories from November 21, 1991 through December 17, 1991.

1.2 An additional purpose of this report is to show by conservative calculations, based on these test results, that the "as installed" configuration of the in-plant PORV block valves is adequate to perform their intended safety function as described by the requirements of NUREG-0737, Item II.D.1.

1.3 The results and conclusions discussed within this report are provided so sufficient justification is available to close all remaining issues associated with NUREG-0737, Item II.D.1, for the Fort Calhoun Nuclear Station.

2.0 BACKGROUND

2.1 Requirements for the operation of Power Operated Relief Valve (PORV) Block Valves were discussed in NUREG-0737 Item II.D.1, paragraph B. For convenience, this paragraph is stated below:

> "Block Valves--Qualification of PWR block valves is a new requirement. Since block valves must be qualified to ensure that a stuck-open relief valve can be isolated, thereby terminating a small loss-of-coolant accident due to a stuck-open relief valve. Isolation of a stuck-open power-operated relief valve (PORV) is not required to ensure safe plant shutdown. However, isolation capability under all fluid conditions that could be experienced under operating and accident conditions will result in a reduction in the number of challenges to the emergency core-cooling system. Repeated unnecessary challenges to these systems are undesirable."

2.2 In general, the nuclear industry satisfied the above requirements by tasking the Electric Power Research Institute (EPRI) with performing steam blowdown testing of various gate valves and motor actuators. This testing was performed at Duke Power's Marshall Station in 1980.

2.3 The NRC expressed concern to OPPD that the EPRI steam blowdown testing did not include the same type of gate valves and actuators that were installed at Fort Calhoun Station. Additionally, OPPD did not submit any other full size, full flow test data to demonstrate the operability of the block valves that would satisfy the NUREG-0737, Item II.D.1 requirements.

2.4 Based on these NRC concerns, OPPD committed to perform tests of an identical (in form, fit and function) PORV block valve. The NRC staff found this commitment acceptable for meeting the II.D.1 requirements to qualify the in-plant PORV block valves by testing.

2.5 Until a suitable prototype valve could be procured and tested, OPPD performed interim measures such as adjusting the torque switches on the actuators to provide the maximum available torque from the motors and installing new spring packs to allow the resulting maximum force to be applied to the valve stems. The NRC staff accepted these measures for providing reasonable assurance of valve operability for the interim time period until the existing block valves were fully qualified by testing.

2.6 In order to show whether the valve is qualified to perform its safety function, the valve must be able to fully close at its worst case design basis conditions with the actuator torque switch set at its expected setting or at the maximum setting allowed by actuator or motor limitations (Ref. 10.3).

2.7 To fulfill the above commitment, OPPD purchased a prototype test valve, configured a spare SMB-00 motor actuator with the same gear ratio and spring pack as the installed PORV block valve actuators, purchased a motor and contracted with a testing facility to perform the necessary steam blowdown tests.

3.0 BLOCK VALVE DESIGN BASIS

3.1 In order to determine the required test scenarios for operability requirements as stated in NUREG-0737, Item II.D.1, the design basis for operation of the plant's PORV block valves needed to be determined.

3.2 After extensive review of all operating and accident conditions, the following fluid conditions were determined to be the worst case design basis conditions for PORV block valve isolation operations as required by NUREG-0737, Item II.D.1. Inadvertent valve mispositioning and subsequent recovery operations were not considered since these were not required by the NUREG.

Max. Upstream Press. (psia)	Min. Downstream Press. (psia)	Max. Diff. Press. (psid)	Max. Flow (lbm/hr)	Temp. (° F)	Fluid
2421	15	2406	110,220	660	Sat. Steam

3.3 The steam blowdown isolation design basis conditions are based on closing a PORV block valve for a stuck-open PORV in accordance with Emergency Operating Procedure-00, "Standard Post Trip Actions," at 2350 psia and assuming a 3% instrument inaccuracy. The steam flow is limited by the orifice effect of the PORV. The PORV has a nameplate steam flow rating of 110,220 lbm/hr saturated steam flow (minimum required of 99,000 lbm/hr) at 2400 psia. The minimum downstream pressure of 15 psia provides for a maximum differential pressure across the block valve and is therefore conservative (Ref. 10.4).

3.5 Potential water and two-phase fluid flow conditions through the PORVs were postulated in Reference 10.5 for a complete loss of feedwater accident. However, analysis performed by OPPD (Ref. 10.6) showed that the complete loss of feedwater accident is not a credible accident at Fort Calhoun Station.

3.6 The NRC also had concerns about water flow conditions through the PORVs following a main feedwater line break accident. In Reference 10.2, the NRC accepted OPPD's analysis showing that the pressurizer does not completely fill with water. Thus, the PORVs are only required to discharge steam for a feedwater line break accident (Ref. 10.2).

3.7 In order to confirm the original sizing of the PORV block valve motor actuators, Crane Valve Division recalculated the valve stem thrust and torque requirements to operate the Model 797-U valve against 2500 psi differential pressure. The Crane calculation methodology was based upon empirical data and had been used by Crane for over twenty years to size operators for gate valves. Using this methodology, Crane determined that a thrust of 3653 lbs would be required to seat the valve, corresponding to a torque requirement of 57 ft-lbs. These values agreed with the original actuator sizing calculations (Ref. 10.6).

3.8 Subsequent to the EPRI-sponsored Marshall Steam Testing results, OPPD recalculated the required valve stem thrust using a more conservative differential pressure valve disc factor. This resulted in a new stem thrust requirement of 6812 lbs and 106 ft-lbs of required actuator torque (Ref. 10.6). These were the interim actuator thrust and torque values that the installed in-plant actuators were adjusted to (Section 2.5).

4.0 VALVE AND ACTUATOR DESIGN DATA

4.1 VALVE DESIGN

4.1.1 In order to perform the testing, a prototype test valve was procured from CRANE-ALOYCO, INC., the in-plant PORV block valves' original manufacturer. This test valve was procured under Purchase Order S061012. The test valve was built to the same drawings and bill of materials as the in-plant PORV block valves, including manufacturing tolerances (Ref. 10.7).

4.1.2 Differences between the prototype test valve and the in-plant PORV block valves can be summarized as follows:

	IN-PLANT VALVES	TEST VALVE
Packing:	Asbestos Braid	Asbestos with Inconel Wire
Gland Flange:	A351 Grade CF8M (Casting)	A182 Grade F316 (Forging)
Bonnet Clamp:	A216 WCB (Casting)	A516 Grade 70 (Plate)

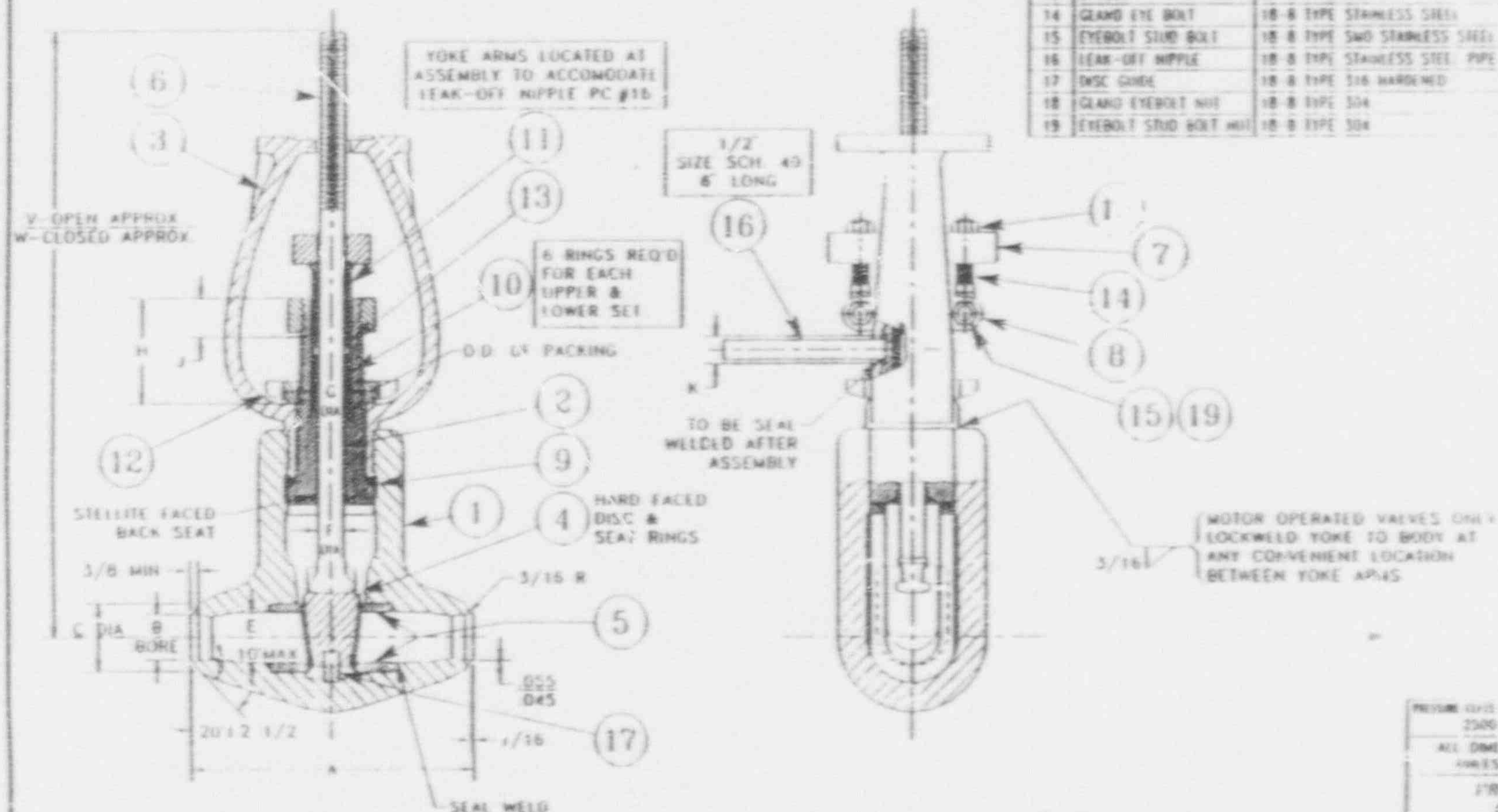
4.1.3 Of the above noted differences, the valve stem packing is the only item that could possibly affect the valve stem thrust by changing the friction loading on the valve stem. However, packing friction is significantly more dependent upon the packing gland nut torque (i.e., stem packing compression) than on the packing material. Additionally, the valve stem packing friction load was able to be measured separately from all other valve stem thrust measurements, so as not to mask or affect other critical stem thrust measurements.

4.1.4 The in-plant block valves were built to nuclear specifications while the prototype test valve was built to commercial grade specifications with additional requirements (RT, UT, PT, etc.) (Ref. 10.8).

4.1.5 Based on the above, it is OPPD's position that the prototype test valve and the in-plant PORV block valves are identical in form, fit and function. Figure 4-1 is a drawing of the prototype test valve.

SIZE	A	B	C	E	F	G	H	J	K	V	W	WEIGHT	VALVE TAG #
2 1/2	13	2.168 2.168	2 31/32 +0 -1/32	2 5/16	1 1/8	1 3/4	5	1 7/8	1 1/4	30 1/4	27 1/4	230	HCV-150 HCV-151

ITEM NO	DESCRIPTION	MATERIAL DESCRIPTION	ASTM SPEC. NO
1	BODY	18-8 TYPE 316 ALLOY CAST STEEL	A351 GR CF-8M
2	BONNET	18-8 TYPE 316	A182 GR F316
3	YOKE	CARBON STEEL	A216 GR WCB
4	DISC	18-8 TYPE 316 ALLOY CAST STEEL	A351 GR CF-8M
5	BODY SEAT RING	18-8 TYPE 316	A182 GR F316
6	STEM	18-8 TYPE 316	A276 TYPE 316
7	GLAND FLANGE	18-8 TYPE 316 ALLOY STEEL	A182 GR F316
8	EYE BOLT RING	CARBON STEEL	A515 GR 70
9	SEAL RING	18-8 TYPE 316 ANNEALED SILVER PLATED	A182 GR F316
10	PACKING	BRAIDED ASBESTOS RINGS H/W 325	COMM
11	GLAND	18-8 TYPE 316 HARDENED	A182 GR F316
12	BONNET LOCKING RING	CARBON STEEL	A216 GR F316
13	SPACER	18-8 TYPE 316	A182 GR F316
14	GLAND EYE BOLT	18-8 TYPE STAINLESS STEEL	AISI TYPE 304
15	EYEBOLT STUD BOLT	18-8 TYPE 316 STAINLESS STEEL	A276 TYPE 316
16	LEAK-OFF NIPPLE	18-8 TYPE STAINLESS STEEL PIPE	A182 GR F316
17	DISC GUIDE	18-8 TYPE 316 HARDENED	A182 GR F316
18	GLAND EYEBOLT NUT	18-8 TYPE 304	AISI TYPE 304
19	EYEBOLT STUD BOLT NUT	18-8 TYPE 304	AISI TYPE 304



PRESSURE CLASS 2500 | VALVE SIZE 2 1/2"

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED

PRESSURE SEAL GATE VALVE ASSEMBLY

Figure 4-1

4.2 ACTUATOR DESIGN

4.2.1 The test valve's motor actuator was acquired from Fort Calhoun Station spare parts inventory. It was configured under Maintenance Work Order #11783 to make the overall actuator ratio and spring pack assembly the same as those of the installed motor-actuators on the in-plant PORV block valves. A new motor was also installed under the same Maintenance Work Order.

4.2.2 The test valve's actuator torque switch was set at a position of 3.0 in the closing direction and bypassed for 100% of valve stroke in the opening direction. This was done to ensure that valve characteristics could be monitored without the actuator shutting down during the valve stroke, and is consistent with the qualification requirements stated in Section 2.6.

4.2.2.1 Appendix A shows the relationship between the torque switch settings, spring pack displacement and actuator output torque. The accompanying plot is a combination of Limitorque Corporation's spring pack curve for an 0301-111 spring pack (torque switch setting vs. actuator output torque) and ITI-MOVATS torque switch setting calibration curves for an SMB-00 torque switch.

4.2.2.2 Reference 10.10 confirms the position that actuator output torque can reliably and accurately be determined by knowing the spring pack displacement vs. torque relationship. Thus, torque switch settings are <u>not a reliable</u> means of determining actuator torque unless the torque switch is balanced.

4.2.3 The new motor was purchased from Limitorque Corporation under Purchase Order C169350. A 7½ ft-lb motor (as installed on the in-plant PORV block valves) could not be procured. Therefore, a 10 ft-lb motor was installed on the test valve motor actuator. Appendix B and Appendix C show the generic motor performance curves for the in-plant installed 7-½ ft-lb motors and the test valve 10 ft-lb motor. These curves were produced by the motor manufacturers for prototype motors of the same frame types and sizes. It is important to note that <u>no accurate correlation between the curves can be made</u>. The motor curves are included in this report only for completeness.

4.2.4 To show that similarity between the test valve motor and the installed PORV block valve motors is immaterial, Appendices D, E and F are provided to show the test valve and actuator characteristics for open-to-close strokes at ambient conditions with no flow. These valve strokes are similar to what is done in the plant during actual MOV diagnostic testing. For the test runs in these appendices, the corrected thrusts at torque switch trip (TST) and the corresponding peak amps are as follows.

TEST RUN	CORRECTED THRUST AT TST	PEAK AMPS
1	7211 lbs	2.72
11	5915 lbs	2.72
27	7428 lbs	2.89

4.2.5 The last MOV diagnostic testing performed during the 1990 refueling outage produced the following results:

VALVE	ADJUSTED THRUST AT TST	PEAK AMPS
HCV-150	8700 lbs	1.406
HCV-151	9150 lbs	1.61

4.2.6 The motor current traces for the above testing are shown in Appendix G.

4.2.7 Correcting the above motor currents for the performance curve voltages and determining the respective motor torque results in:

TEST RUN	CORRECTED AMPS	MOTOR TORQUE (ft-lbs)
1	2.83	5 (extrap.)
11	2.83	5 (extrap.)
27	3.08	5.75 (extrap.)

VALVE	CORRECTED AMPS	MOTOR TORQUE (ft-lbs)
HCV-150	1.53	2.25
HCV-151	1.76	3.0

4.2.8 By comparing the above motor current and torque values, it can be determined that no correlation or similarity exists between the 7½ ft-lb motors and the 10 ft-lb motor. Examination of the actuator output thrusts (as shown in Sections 4.2.5 and 4.2.6) shows that the in-plant actuators with the 7½ ft-lb motors appear to be more efficient than the test valve actuator with the 10 ft-lb motor in converting the motor torque to valve stem thrust. With actuator output stem thrust being the key parameter in determining the valve and actuator output requirements, motor similarity between the test valve and the in-plant valves is therefore irrelevant. Differences between the 7½ ft-lb motor and the 10 ft-lb motor are justified in Section 8.5 of this report.

4.2.9 A different stem lubricant was used on the test valve than what was used on the in-plant PORV block valves. This was done because new lubricant will be used on the in-plant valves beginning with the 1992 refueling outage. Differences between the stem lubrication are discussed in Section 8.5 of this report.

4.3 VALVE AND ACTUATOR DESIGN SUMMARY

4.3.1 The following is a summary of the in-plant PORV block valves and actuators as compared to the prototype test valve and actuator.

Valve Tag Number:	HCV-150/151	Test Valve
Valve Manufacturer:	CRANE	CRANE
Valve Model Number:	797-U	797-U
Valve Nominal Size:	2½ in.	2½ in.
Valve ANSI Class:	2500#	2500#
Valve Type:	Flex-Wedge Gate	Flex Wedge Gate
Valve Stem Pitch:	¼	¼
Valve Stem Lead:	½	½
Valve Dwg. Number:	H-30321	CA00691
Valve Spec. Number:	16.01, Rev. 1	N/A
Actuator Manufacturer:	Limitorque	Limitorque
Actuator Model Number:	SMB-00-7½	SMB-00-10
Overall Ratio:	46.8	46.8
Spring Pack P/N:	0301-111	0301-111
Stem Lubricant (pre 1992 RFO):	Never-Seez NG-165	Mobilux EP-1
Stem Lubricant (post 1992 RFO):	Mobilux EP-1	

5.0 VALVE BLOWDOWN TESTING

5.1 Selection of Test Vendor

5.1.1 WYLE Laboratories in Norco, California was selected as the test facility to perform the blowdown testing under Purchase Order S067877.

5.2 Test Loop Configuration

5.2.1 The flow test loop was configured so pressure losses during steam blowdown conditions could be matched as closely as possible to the expected in-plant steam blowdown conditions. This was accomplished by evaluating the in-plant PORV piping arrangement from the pressurizer, up to and including the PORVs, and configuring the flow test facility accordingly.

5.2.2 After evaluating the in-plant piping arrangement, the following piping configuration requirements were specified to and used by the test facility (Ref. 10.5):

5.2.2.1 Piping upstream of the test valve to the steam and water accumulators shall have an effective resistance coefficient of 4.6.

5.2.2.2 For flow stabilization and instrumentation considerations, the pipe shall be 2½ inch, Schedule 160, for at least 10 pipe diameters upstream of the test valve.

5.2.2.3 For flow stabilization and instrumentation considerations, piping downstream of the test valve shall be 2½ inch, Schedule 160, 2 feet long.

5.2.2.4 Installation of a PORV or equivalent valve/orifice combination with a flow area of .00653 sq. feet (1.094 inches diameter) downstream of the test valve.

5.2.2.5 Piping downstream of the PORV or valve/orifice combination shall be 4 inch size for a minimum length of 5 pipe diameters. Beyond this point, any larger pipe size may be used.

5.2.2.6 The resulting steam and water test loop configurations are shown in Figure 5-1.

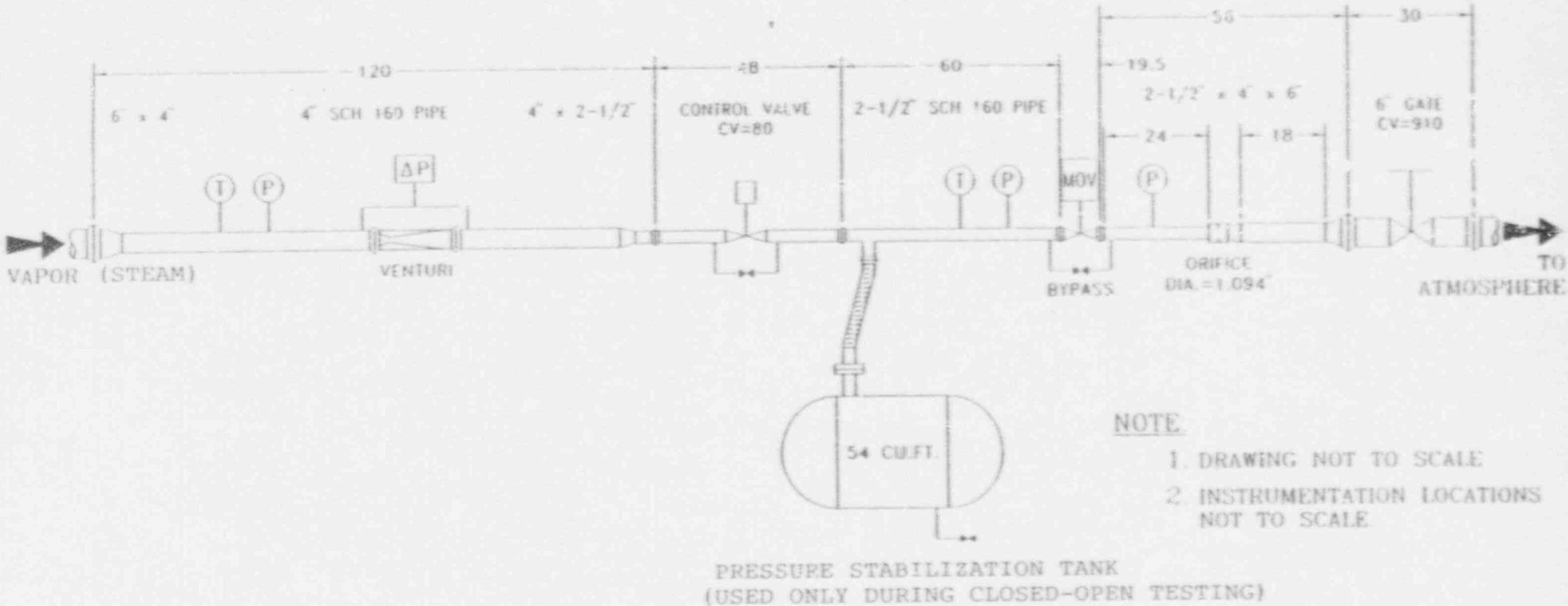

120
48
60
56
30
19.5
24
18
6" x 4"
4" SCH 160 PIPE
4" x 2-1/2"
CONTROL VALVE
CV=80
2-1/2" SCH 160 PIPE
2-1/2" x 4" x 6"
6" GATE
CV=910
T
P
ΔP
MOV
VAPOR (STEAM)
VENTURI
BYPASS
ORIFICE
DIA.=1.094"
TO
ATMOSPHERE
54 CU.FT.
NOTE
1. DRAWING NOT TO SCALE
2. INSTRUMENTATION LOCATIONS
NOT TO SCALE
PRESSURE STABILIZATION TANK
(USED ONLY DURING CLOSED-OPEN TESTING)

Figure 5-1

5.3 Valve and Test Loop Instrumentation

5.3.1 The following is a list of instrumentation utilized in the test loop for measuring valve performance characteristics.

MEASUREMENT	RANGE	ACCURACY
Steam Vessel Pressure	0 - 3000 psig	±0.3%
Steam Vessel Inventory DP	0 - 20 psid	±0.3%
Flow Venturi Inlet Pressure	0 - 3000 psig	±0.3%
Flow Venturi Diff. Pressure.	0 - 30 psid	±0.3%
Test Valve Inlet Pressure	0 - 3000 psig	±0.3%
Test Valve Inlet Temperature	0 - 700 °F	±0.5 °F
Test Valve Outlet Pressure	0 - 3000 psig	±0.3%
Actuator Motor Voltage	0 - 600 VAC	±0.21%
Actuator Motor Current	0 - 20 Amps	±2.01%
Valve Stem Position	0 - 15"	±0.15%
Valve Stem Thrust	0 - 15,000 lbs	±1.5%
Spring Pack Displacement	0 - 1"	±0.52%
Actuator Open Limit Switch	Open/Close	
Actuator Close Torque Switch	Open/Close	

5.3.2 The accuracies stated above were determined using the "square root-sum of the squares" methodology and are conservative.

5.3.3 All data was acquired at a sampling frequency of 1000 Hz.

5.3.4 Fluid conditions instrumentation (temperature, pressure, flow, etc.) was installed as shown on Figure 5-1.

5.4 Blowdown Test Scenarios

5.4.1 In order to accurately measure valve performance and determine/evaluate for data trends, the following test conditions were established for valve blowdown isolation stroke testing.

TEST MEDIA	VALVE TEMP (°F)	VALVE PRESS. (psig)	MAX. STEAM FLOW (lbm/hr)
Air	Ambient	0	None
Steam	596	1485	Orifice Controlled
Steam	636	1985	Orifice Controlled
Steam	653	2235	Orifice Controlled
Steam	668	2485	130,000
Air	Ambient	0	None

5.4.2 The maximum flow conditions shown above were chosen so as to bound the design basis fluid conditions discussed in Section 3.2.

6.0 STEAM BLOWDOWN TESTING RESULTS

6.1 Steam blowdown testing was conducted in accordance with the system configuration and steam conditions, with the exception of steam flow, as discussed in previous sections of this report. Table 6-1 is a summary of the actual stroke testing of the prototype test valve with an overall actuator ratio of 46.8.

6.2 As can be seen by the results listed in Table 6-1, the minimum design steam blowdown flow rate of the PORVs (99,000 lbm/hr) was exceeded. Therefore, the steam blowdown flow conditions established during the testing were considered conservative and acceptable. Additionally, the actual maximum line pressure and differential pressure exceeded the worst case design basis values discussed in Section 3.2 of this report.

6.3 In order to determine the test valve's stem thrust measurements at disc wedging conditions during the valve open-to-close stroke, the following conservative method of analysis was utilized for each of the valve open-to-close strokes.

6.3.1 The plotted wedging stem thrust (from Appendix H through L) was converted to an "apparent" strain.

6.3.2 This "apparent" strain was then corrected for the observed "zero" shift. This resulted in "true" strain.

6.3.3 The resulting "true" strain was then converted to a "true" load using the strain gauge calibration curve shown in Appendix M.

6.3.4 The wedging load was then determined by subtracting the "true" load from the "zero" load (at "zero" strain as determined by the strain gauge calibration curve).

6.3.5 A load correction was then added to the "true" wedging load. This load correction was determined by test runs at elevated temperatures and pressures but no differential pressure and flow. This correction was based upon the expected "running" load (stem rejection load + stem packing friction load) and compared to the "measured" running load. This load correction was deemed necessary since the tensile load resulting from the elevated stem temperatures appeared to mask the expected compressive running loads. These load corrections are shown in Table 6-2.

6.3.6 The resulting "actual" wedging loads are shown in Table 6-3. Additionally, the measured stem position, spring pack displacement and actuator torque are shown at valve disc wedging and at torque switch trip.

6.3.7 This method of analysis was used since a problem was noteu during two segments of the original calibration of the stem thrust strain gauge. This calibration problem resulted in unrealistic strain-to-thrust conversions which gave very high compressive loads (when plotted).

6.3.7.1 This calibration problem was most likely due to a cocking of the valve stem during the initial compressive loading (during calibration), causing stem bending (tensile load) at the strain gauge. After a 3300 pound compressive load was applied to the valve stem, the stem became "realigned" and a predictable compressive load curve resulted thereafter. Appendix M shows the resulting corrected calibration curve from which the valve disc wedging loads and running load corrections were determined.

6.3.7.2 This method of analysis assumes that the strain gauge curve is applicable in tensile loading as well as compressive loading.

6.4 The cyclic loading observed during the valve strokes (shown in Appendices H through L) were due to a valve stem-to-actuator stem nut misalignment and was noted during all the test runs.

6.5 The actuator's torque switch was unbalanced; that is, the torque switch, while at a setting of 3.0 in the closing direction, tripped at spring pack displacements which corresponded to torque switch settings of about 1.5. This shows that "torque switch settings" alone cannot determine an actuator's operability.

6.6 The valve was considered fully closed when the valve disc experienced "disc wedging".

6.6.1 "Disc wedging" is the point where the valve disc is fully inserted (closed) into the valve seat but has not been "jammed" or wedged into the seat. This wedging was identified as the instant just prior to the essentially vertical section of the valve stem thrust plot (as shown in Appendices H through L).

6.7 For all valve close-to-open strokes at ambient conditions, valve stem packing friction load was measured by the valve stem thrust strain gauge. The packing friction load varied from 350 pounds to 700 pounds. Packing loads used in determining the running load correction values and the subsequent valve factor analysis were conservatively assumed to be constant at 350 pounds (except for Test Run 36 which had a 700 pound packing load). Utilizing a low value of stem packing friction load is conservative in that it maximizes the valve disc friction component of the measured stem thrust.

6.8 An interesting phenomenon observed during the blowdown testing was a reduction in measured valve stem running loads (going from full open to full closed) during steam flow conditions. This phenomenon was also observed during some of the Idaho National Engineering Laboratory (INEL) valve testing and has been explained and understood in the MOV industry as follows:

6.8.1 As the valve is going closed and reducing the flow area through the valve bore, the reduction in flow area causes a reduction in pressure below the valve disc (venturi effect).

6.8.2 All through the valve stroke, valve upstream pressure exists in the valve bonnet cavity. This bonnet cavity pressure is attempting to push the valve stem out of the valve body. This is generally referred to as "piston effect" or "stem rejection load." However, this bonnet cavity pressure is also pushing on the top of the valve disc.

6.8.3 When the pressure below the valve disc drops to a certain value, the force caused by the differential pressure from the top of the valve disc to the bottom of the valve disc overcomes the "stem rejection load" and aids in closing the valve disc.

PROTOTYPE BLOCK VALVE TEST RUN SUMMARY

Test Run No.	Valve Stroke	Fluid	Max. Temp. (degrees F)	Max. Pressure (psig)	Max. Diff. Press. (psid)	Max. Flow (lbm/hr) (NOTE 1)	Stem Stroke (inches)	Stroke Time (sec)	Torque Switch Setting
1	Open to Close	Air	Ambient	Ambient	0	0	2.81	8.99	<3
2	Close to Open	Air	Ambient	Ambient	0	0	2.76	8.73	Bypassed
3	Open to Close	Steam	588	1500	0	0	2.76	8.96	<3
4	Open to Close	Steam	606	1508	1493	55,833	2.76	8.96	<3
5	Open to Close	Steam	615	2000	0	0	2.75	9.06	<3
6	Open to Close	Steam	642	1944	1938	74,815	2.75	8.94	<3
7	Open to Close	Steam	571	2264	0	0	2.79	9.04	<3
8	Open to Close	Steam	654	2227	2227	86,667	2.76	8.99	<3
9	Open to Close	Steam	640	2518	0	0	2.75	9.06	<3
10	Open to Close	Steam	563	2518	2518	105,851	2.76	9.01	<3
11	Open to Close	Air	Ambient	Ambient	0	0	2.75	8.93	<3
12	Close to Open	Air	Ambient	Ambient	0	0	2.75	8.75	Bypassed
13	Close to Open	Steam	600	1537	1537	0	2.77	8.80	Bypassed
14	Close to Open	Steam	600	1682	1682	55,873	2.77	9.04	Bypassed
15	Close to Open	Steam	642	2160	2160	not avail.	2.81	9.16	Bypassed
16	Close to Open	Steam	613	1938	0	0	2.81	9.08	Bypassed
17	Close to Open	Steam	657	2250	0	0	2.77	9.12	Bypassed
					(NOTE 2)				
27	Open to Close	Air	Ambient	Ambient	0	0	2.83	9.24	>3
28	Close to Open	Air	Ambient	Ambient	0	0	2.85	9.00	Bypassed
29	Open to Close	Steam	560	2209	0	0	2.90	8.97	>3
30	Close to Open	Steam	569	2250	0	0	2.83	8.91	Bypassed
31	Close to Open	Steam	658	2345	2345	73,600	2.84	9.20	Bypassed
					(NOTE 3)				
32	Open to Close	Air	285	Ambient	0	0	2.80	8.96	>3
33	Close to Open	Air	232	Ambient	0	0	2.79	8.71	Bypassed
34	Close to Open	Steam	642	2394	2394	105,730	2.83	9.39	Bypassed
35	Close to Open	Steam	660	2394	2690	96,190	2.79	9.11	Bypassed
36	Open to Close	Steam	656	2339	2339	94,286	2.77	8.97	>3
37	Open to Close	Water	Ambient	Ambient	0	0	2.80	8.97	>3
38	Close to Open	Water	Ambient	Ambient	0	0	2.76	8.86	Bypassed
39	Open to Close	Water	Ambient	500	0	0	2.81	9.03	>3
40	Close to Open	Water	Ambient	500	0	0	2.75	8.93	Bypassed
41	Open to Close	Water	Ambient	500	500	237,477 (NOTE 4)	2.81	9.04	>3
42	Close to Open	Water	Ambient	536	536	218.311 (NOTE 4)	2.77	8.93	Bypassed
43	Open to Close	Water	544	1209	0	0	2.81	9.05	>3
44	Close to Open	Water	550	1200	264	not avail.	2.82	8.85	Bypassed
45	Open to Close	Water	542	1245	1227	224,719	2.86	9.15	>3

TABLE 6-1

PROTOTYPE BLOCK VALVE TEST RUN SUMMARY

Test Run No.	Valve Stroke	Fluid	Max. Temp. (degrees F)	Max. Pressure (psig)	Max. Diff. Press. (psid)	Max. Flow (lbm/hr) (NOTE 1)	Stem Stroke (inches)	Stroke Time (sec)	Torque Switch Setting
46	Close to Open	Water	544	1227	1227	203,947	not avail.	not avail.	Bypassed
47	Open to Close	Water	525	1500	0	0	2.83	9.03	>3
48	Close to Open	Water	546	1513	0	0	not avail.	not avail.	Bypassed
49	Open to Close	Water	582	1500	1500	228,192 (NOTE 4)	2.80	9.01	>3
50	Close to Open	Water	554	1527	1527	222,312 (NOTE 4)	2.77	9.13	Bypassed
51	Open to Close	Water	Ambient	Ambient	0	0	2.78	8.94	>3
52	Close to Open	Water	Ambient	Ambient	0	0	not avail.	not avail.	Bypassed
53	Open to Close	Water	542	1598	1598	261,538	2.87	9.19	>3
54	Close to Open	Water	542	1600	1600	not avail.	not avail.	not avail.	Bypassed

NOTES: 1) All flows are steady state values. Some flow peaks were observed but were not considered for analysis.

2) Test Runs 27 through 31 were conducted after spring pack and torque switch adjustments.

3) Test Runs 32 through 54 were conducted after the valve was dissassembled for inspection and reassembled.

4) Flows are corrected for the proper fluid density.

TABLE 6-1

LOAD CORRECTION DETERMINATION WORKSHEET

TEST RUN NUMBER	ZERO STRAIN (A)	ZERO LOAD (B)	PLOTTED RUNNING LOAD	APPARENT STRAIN (C)	TRUE STRAIN (C+A)	TRUE LOAD (D)	TRUE RUNNING LOAD (B-D)	MAX. VALVE PRESSURE	STEM REJECTION LOAD (1) (E)	STEM PACKING LOAD (F)	EXPECTED RUNNING LOAD (E+F)	RUNNING LOAD CORRECTION (E+F)-(B-D)	REMARKS
3	141	355.62	-489	-22.23	118.77	62.75	-293	1500	-1491	-350	-1841	-1548	FOR T.R. 4
5	163	645.49	-667	-30.30	132.70	246.20	-399	2000	-1988	-350	-2338	-1939	FOR T.R. 6
7	159	592.78	1067	-48.50	110.50	-46.25	-639	2264	-2250	-350	-2600	-1961	FOR T.R. 8
9	150	474.20	-1820	-85.91	64.09	-657.74	-1132	2518	-2503	-350	-2853	-1721	FOR T.R. 10
29	180	869.48	-1957	-88.95	91.05	-302.59	-1172	2339	-2325	-350	-2675	-1503	FOR T. R. 36 (NOTE 2)

NOTE: 1) STEM REJECTION LOAD IS MAXIMUM LINE PRESSURE X STEM CROSS-SECTIONAL AREA.
STEM CROSS SECTIONAL AREA IS .994 SQ. INCHES.

2) USE OF THIS MAXIMUM LINE PRESSURE YIELDS A CONSERVATIVE LOAD CORRECTION.
THIS PRESSURE IS THE MAXIMUM OF TEST RUN 36 AND IS GREATER THAN THE 2209 PSIG OBSERVED IN TEST RUN 29.
PACKING LOAD FOR TEST RUN 36 IS 700 POUNDS.

TABLE 6-2

WEDGING LOAD DETERMINATION WORKSHEET

TEST RUN NUMBER	ZERO STRAIN (A)	ZERO LOAD (B)	PLOTTED WEDGING LOAD	APPARENT WEDGING STRAIN (C)	CORRECTED WEDGING STRAIN (C + A)	CORRECTED LOAD (D)	WEDGING LOAD (B-D)	LOAD CORRECTION (NOTE 1) (E)	REAL WEDGING LOAD (B-D) + E	STEM POSITION	SPRING PACK DISP. (INCHES)	ACTUATOR OUTPUT TORQUE (NOTE 2)	PLOTTED THRUST AT TST	REAL THRUST AT TST	SPRING PACK DISP. (INCHES)
4	152.8	511.09	-3490	-158.64	-5.84	-1579	-2090	-1548	-3638	0.05	0.061	60.5	-9491	-7232	0.129
6	172	764.07	-4598	-209.00	-37.00	-1990	-2754	-1939	-4693	0.06	0.080	67.0	-9023	-7343	0.135
8	164	658.66	-5808	-264.00	-100.00	-2820	-3478	-1961	-5439	0.04	0.099	73.6	-8737	-7194	0.132
10	150	605.96	-6795	-308.86	-1[illegible]8.86	-3464	-4070	-1721	-5791	0.05	0.112	77.9	-8974	-7096	0.112
36	90	-316.36	-6618	-300.82	-210.82	-4280	-3964	-1503	-5467	0.03	0.096	72.5	[illegible]1023	-8105	0.155

NOTE: 1) FROM TABLE 6-2

2) FROM APPENDIX A

TABLE 6-3

7.0 DATA ANALYSIS

7.1 Apparent Valve Factor Determination

7.1.1 In order to utilize the test results to confirm the in-plant PORV block valve operability completely, "apparent" valve factors were calculated for the test valve at the disc wedging stem position for the various steam blowdown test runs.

7.1.2 These apparent valve factors (AVFs) were determined using the equation below from Reference 10.9, which is derived from the classic form of the industry valve stem thrust equation for gate valves going in the closed direction. The word "apparent" is used because it is assumed the valve stem thrust <u>not</u> due to valve stem packing friction loads or stem rejection loads is due solely to friction between the valve disc and disc guides/seats.

$$AVF = \frac{F_S - SPL - (P \cdot A_S)}{DP \cdot A_D}$$

where: AVF = Apparent Valve Factor

F_S = Measured Valve Stem Thrust (lbs)

SPL = Measured Stem Packing Friction Load (lbs)

DP = Measured Valve Differential Pressure (psid)

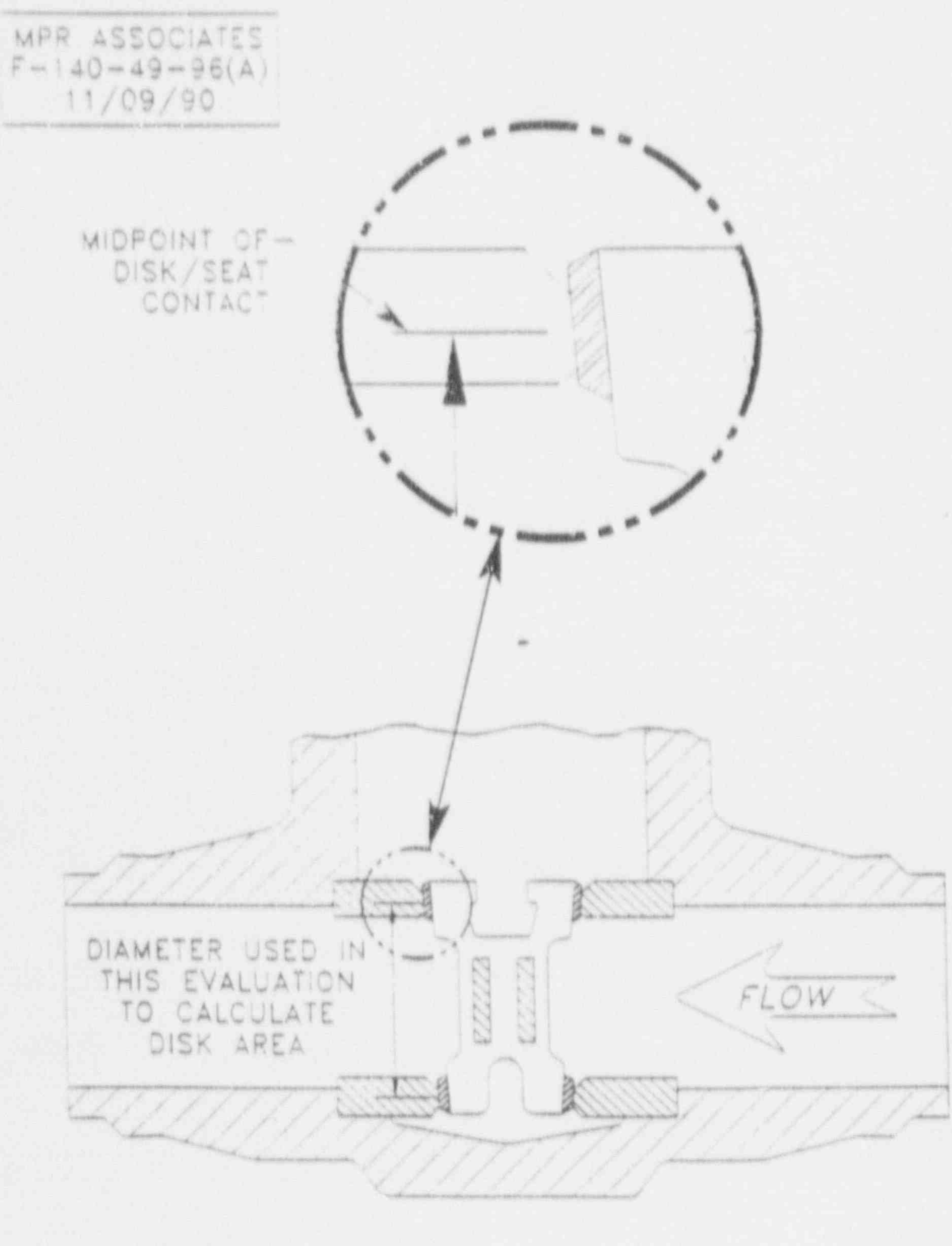
A_S = Cross-sectional Area of the valve Stem (in^2)

P = Measured Test Valve Inlet Pressure (psig)

A_D = Valve Disc Area (in^2)

7.1.3 Corrected F_S at "wedging" was taken from Table 6-3, while DP and P were taken directly from the plots in Appendices D through H. A_S and A_D are based upon valve geometry. The valve disc area (A_D) is based on the mean contact diameter between the downstream valve disc and seat. This diameter was obtained from dimensional inspections at the WYLE test facilities during test valve inspections. For convenience and clarification, this measurement location is shown in Figure 7-1.

7.1.4 Table 7-1 shows the results of the determination of AVFs for valve disc wedging for the various open-to-close test runs.



DISK AREAS USED IN THIS EVALUATION

Figure 7-1

PORV BLOCK VALVE DATA ANALYSIS RESULTS SUMMARY
(Valve Open to Valve Closed)

Valve:	2.5 inch Flex-Wedge Gate
Manuf:	CRANE
Actuator:	Limitorque SMB-00-10

Downstream Mean Seat Diameter:	2.573 inches	(area =	5.1996	sq. inches)
Stem Diameter:	1.125 inches	(area =	0.9940	sq. inches)

DISC WEDGING

Test Run 4	Stem Thrust (lbs):	3638 lbs
	Upstream Press. (psi)	1508 psig
	Diff. Pressure (psid):	1493 psid
	Stem Packing Load (lbs)	350 lbs
	App. Valve Factor:	0.230
Test Run 6	Stem Thrust (lbs):	4693 lbs
	Upstream Press. (psi)	1944 psig
	Diff. Pressure (psid):	1938 psid
	Stem Packing Load (lbs)	350 lbs
	App. Valve Factor:	0.239
Test Run 8	Stem Thrust (lbs):	5439 lbs
	Upstream Press. (psi)	2227 psig
	Diff. Pressure (psid):	2227 psid
	Stem Packing Load (lbs)	350 lbs
	App. Valve Factor:	0.2[illegible]8
Test Run 10	Stem Thrust (lbs):	5791 lbs
	Upstream Press. (psi)	2518 psig
	Diff. Pressure (psid):	2518 psid
	Stem Packing Load (lbs)	350 lbs
	App. Valve Factor:	0.224
Test Run 36	Stem Thrust (lbs):	5467 lbs
	Upstream Press. (psi)	2339 psig
	Diff. Pressure (psid):	2339 psid
	Stem Packing Load (lbs)	700 lbs
	App. Valve Factor:	0.201

TABLE 7-1

8.0 APPLICATION OF TEST VALVE RESULTS TO IN-PLANT VALVES

8.1 Safety Function Operation

8.1.1 Because of the qualification requirements of the test valve and the in-plant PORV block valves, the point of "disc wedging", as determined from the open-to-close valve stroke data during steam blowdown test runs, was considered to be where the valve completely performed its design basis function.

8.1.2 Because of identical valve designs, this disc wedging valve position is considered to be applicable to the in-plant PORV block valves.

8.1.3 Therefore, the valve's motor operator must be able to provide enough valve stem thrust to close the valve to the disc wedging position for the valve to satisfactorily perform its safety function of isolating steam blowdown flow.

8.2 Determination of Worst Case Valve Factor

8.2.1 In order to perform an in-plant PORV block valve operability evaluation, a "worst case" valve stem thrust and "apparent" valve factor must be determined.

8.2.2 The strain gauges used to measure the test valve stem thrust in the closing direction have a total inaccuracy of ± 1.5%. Applying this inaccuracy to the measured disc wedging valve stem thrust (and subtracting stem packing friction loads) from the 2500 psig steam blowdown test run results in:

$$\text{Total Stem Thrust} \times (1.015) - \text{Packing Loads} \times (.985) = \text{Worst Case Stem Thrust}$$

$$5791 \times (1.015) - 350 \times (0.985) = 5533 \text{ lbs}$$

8.2.3 This value of 5533 lbs is the worse case stem thrust <u>required above the valve stem packing friction load</u> (available thrust) for proper safety function (isolating steam blowdown flow at 2518 psig/2518 psid) operation of the test valve.

8.2.5 Pressure and differential pressure measurements have an inaccuracy of ± 0.3% of 3000 psig (± 9 psig). In order to maximize the apparent valve factor calculation, the valve inlet pressure and differential pressure must be minimized. Thus, at the maximum steam blowdown conditions for disc wedging for the 2500 psig steam blowdown test run, the valve inlet pressure and valve differential pressure could have been as low as:

Valve Inlet Pressure: 2518 psig - 9 psig = 2509 psig

Valve Differential Pressure: (2518 psig - 9 psig) - (0 psig + 9 psig) = 2518 psig

8.2.4 Utilizing the formula for determining apparent valve factors (Section 7.1.2), applicable test valve geometry parameters, the above worst case valve "available" stem thrust of 5533 lbs, minimized valve inlet pressure and valve differential pressure results in a <u>worst case apparent valve factor</u> of:

$$AVF = \frac{F_S - (P \cdot A_S)}{DP \cdot A_D}$$

where: AVF = Apparent Valve Factor

F_S = Worst Case Valve Stem Thrust (lbs)

DP = Minimized Valve Differential Pressure (psid)

A_S = Cross-sectional Area of the Valve Stem (in^2)

P = Minimized Test Valve Inlet Pressure (psig)

A_D = Valve Disc Area (in^2)

$$AVF = \frac{5533 - (2509 \cdot 0.994)}{(2518) \cdot (5.1996)} = 0.232$$

8.3 Required Valve Stem Thrust of In-plant Valves

8.3.1 In order to determine the required actuator output stem thrust at the design basis conditions established in Section 3.2, the standard industry valve equation will be combined with a conservative "apparent valve factor" and the standard industry stem packing friction load of 1500 lbs (for this valve stem size).

8.3.2 The standard valve thrust equation (neglecting stem packing friction load) for valve closing follows :

$$F_s = (AVF \cdot DP_{db} \cdot A_D) + (P_{db} \cdot A_s)$$

where: F_s = Required Valve Stem Thrust (lbs)

AVF = Apparent Valve Factor

DP_{db} = Design Basis Valve Differential Pressure (psid)

A_s = Cross-sectional Area of the Valve Stem (in^2)

P_{db} = Design Basis Valve Inlet Pressure (psig)

A_D = Valve Disc Area (in^2)

8.3.3 Measurements have not been taken on the in-plant PORV block valves, but the nominal "mean" seat diameter and valve stem diameter, as acquired from the prototype valve dimensional inspections, were utilized in the required stem thrust calculation since the test valve was manufactured to the original specifications.

Seat Diameter = 2.573 in.

$A_D = 5.1996\ in^2$

Stem Diameter = 1.125 in.

$A_s = 0.994\ in^2$

8.3.4 To account for aging and wear differences between the in-plant valve and the test valve, the apparent valve factor will be increased from 0.232 to a value of 0.3 (29% increase). This is considered conservative since the in-plant valves have never been operated under a steam blowdown differential pressure situation and therefore, material wear on the in-plant valves is considered minimal. This is confirmed by the fact that inspections of the prototype test valve showed insignificant wear after all testing was completed. Additionally, the worst case valve factor is already based upon steam conditions greater than the design basis conditions.

8.3.5 Substituting the appropriate values into the above required stem thrust equation results in the following required available stem thrust (above packing load):

$$F_s = (0.3 \cdot 2406 \cdot 5.1996) + (2406 \cdot 0.994)$$

$$F_s = 6145 \text{ lbf}$$

8.3.6 This value of 6145 lbs is the valve stem thrust, <u>above the stem packing friction load</u> (available stem thrust), required for valve operation at design basis conditions.

8.3.7 When assuming the 1500 lbs stem packing friction load, this results in a <u>total</u> required stem thrust of 7645 lbs.

8.4 Evaluation of Previous MOV Test Data

8.4.1 To show that an MOV has sufficient capability to operate a valve at the design basis conditions, the total measured valve stem thrust at torque switch trip (TST), including instrument inaccuracies and "rate-of-loading" effects penalties, must be greater than the valve stem thrust required for the valve to perform its safety function under differential pressure conditions (7645 lbf from Section 8.3.7).

8.4.2 The last MOV test data packages (from 1990) for the in-plant PORV block valves were examined and the following valve thrusts were noted:

VALVE TAG	ADJ. THRUST AT TST	RUNNING LOAD
HCV-150	8700 lbs	360 lbs
HCV-151	9150 lbs	700 lbs

8.4.3 The above running loads occurred during the entire valve stroke and are due to losses within the actuator. It is not possible to quantify valve stem packing friction loads using the ITI-MOVATS test methodology in use at Fort Calhoun Station. Therefore, the measured thrust at torque switch trip (TST) must be increased (adjusted as shown) by standard industry packing loads (1500 lbs for this valve stem size).

8.4.4 The test valve exhibited no reduction in thrust output at TST under dynamic (blowdown) test conditions as compared to static (no-flow) test conditions. If there would be a reduction, it is commonly referred to as a "rate-of-loading" effect.

8.4.5 For the above noted valve stem thrusts, a test equipment inaccuracy of 7.6% was utilized to show a "worst case" stem thrust measurement.

8.4.6 To determine the value of stem thrust at TST considering "rate-of-loading" effects and test equipment inaccuracies, the following application of these penalties will be utilized:

Measured Stem Thrust at TST - 7.6% - 0% - Packing Loads - Running Loads = Corrected Stem Thrust

8.4.7 The corrected stem thrusts for the in-plant PORV block valves are as follows:

VALVE TAG	CORRECTED STEM THRUST
HCV-150	61.8 lbs
HCV-151	6255 lbs

8.4.8 When comparing these corrected valve stem thrusts to the calculated <u>conservative required available</u> stem thrust of 6145 lbs, it is clear that margin exists at TST for satisfactory operation of the in-plant PORV block valves to isolate steam blowdown flow at design basis conditions. Even though the margin is not excessive, it is considered adequate since the use of 0.3 as the valve factor is based on a 29% increase of the <u>worst case</u> apparent valve factor measured by testing. Additionally, the use of 0.3 as a valve factor is consistent with industry practice and bounds all steam blowdown testing results.

8.5 Comparison of Test Valve Motor and Lubrication to In-plant Valves

8.5.1 There are two differences between the test valve and actuator and the existing in-plant PORV block valves and their actuators.

8.5.1.1 The test valve had a 10 ft-lb motor installed on its actuator while the existing motors on the in-plant PORV block valve actuators are 7½ ft-lb motors.

8.5.1.2 The test valve stem lubricant was Mobilux EP-1 grease, while the stem lubricant on the in-plant PORV block valve stems prior to the 1992 refueling outage was Never-Seez NG-165. Mobilux EP-1 stem lubricant will be used for the in-plant block valves subsequent to the 1992 refueling outage.

8.5.2 The following analysis was performed to evaluate these differences.

8.5.2.1 Determining the worst case <u>measured</u> valve stem thrust (from Section 8.2.2) and accounting for instrument inaccuracies results in:

$$5533 \times 1.015 = 5616 \text{ lbs}$$

8.5.2.2 To calculate the required motor torque to operate the valve at this stem thrust value, Limitorque Corporation's sizing procedure was utilized.

8.5.2.2.1 Valve stem thrust is converted to torque by the use of a "stem factor" (SF). Its application follows:

$$\text{Required Stem Thrust} \cdot \text{SF} = \text{Required Stem Torque}$$

8.5.2.2.2 A stem factor of 0.0158 was utilized in the conversion of stem thrust to torque (Ref. 10.19).

8.5.2.2.3 This stem factor value is based on <u>no</u> lubrication for a bronze actuator stem nut rotating on a 1.125 inch diameter steel valve stem with a pitch of ¼ and a lead of ½ (Ref. 10.19).

8.5.2.2.4 Using this stem factor with the required valve stem thrust results in a required actuator stem torque output of:

$$5616 \text{ lbs} \cdot 0.0158 = 88.73 \text{ ft-lb}$$

8.5.2.2.5 To calculate the required motor torque for this actuator output stem torque, the following formula was used.

$$\text{Required Motor Torque} = \frac{\text{Required Stem Torque}}{(\text{POE})\,(0.9)\,(\text{OAR})\,(\text{DVF})^2}$$

where POE = Pullout Efficiency (0.4 for these actuators)

0.9 = Application Factor (conservatism used by Limitorque Corporation)

OAR = Overall Actuator Ratio (46.8 for these actuators)

DVF = Degraded Voltage Factor (1.0 for these actuators)

8.5.2.2.6 Substituting the appropriate values results in a required motor torque of:

$$\text{Required Motor Torque} = \frac{88.73}{(0.4)\,(0.9)\,(46.8)\,(1.0)^2}$$

Required Motor Torque = 5.27 ft-lbs

8.5.3 When comparing the required motor torque of 5.27 ft-lb to the available motor torque of 7½ ft-lb for the in-plant PORV block valves, it is clear that a 7½ ft-lb motor would have successfully operated the test valve. Thus, the use of a 10 ft-lb motor on the test actuator is acceptable and similarity concerns between the 7½ ft-lb motor and the 10 ft-lb motor are irrelevant as discussed earlier in Section 4.2.

8.5.4 When performing the above calculation, it is significant to note that the required valve stem torque was determined assuming no lubrication between the actuator stem nut and valve stem. Thus, the lubrication differences between the test valve and the in-plant PORV block valves are acceptable since both the Never-Seez and the Mobilux EP-1 do provide some lubrication while the calculation assumes no lubrication.

8.5.5 To ensure the in-plant PORV block valves' actuator motors are sized appropriately, the calculated required valve available stem thrust (6145 lbs) is added to the highest assumed "packing load" (1500 lbs). This results in a maximum total required thrust of 7645 lbs.

8.5.5.1 Based upon the last MOV diagnostic test for the in-plant valves, the adjusted thrust (also accounting for test equipment errors) is:

VALVE TAG	ADJUSTED STEM THRUST
HCV-150	8039 lbs
HCV-151	8455 lbs

8.5.5.2 Thus, even when correcting for the test equipment accuracies, the installed in-plant actuators are providing more than the conservatively determined required total stem thrust. This proves that the installed motors are adequately sized.

9.0 CONCLUSIONS

9.1 Based on the discussion provided in the previous sections of the report, it can therefore be concluded:

9.1.1 The test valve and actuator accurately modeled the in-plant PORV block valves in performance characteristics.

9.1.2 The steam blowdown test conditions exceeded the maximum design basis conditions for the in-plant PORV block valves and are, therefcre, conservative and acceptable.

9.1.3 Based upon a conservative analysis, the in-plant PORV block valves have margin at actuator torque switch trip to perform their safety function of isolating steam blowdown flow through a "stuck-open" PORV.

9.2 Based on these conclusions, the in-plant PORV block valves will stroke closed in 10 seconds (or less) under the maximum expected differential pressure and flow conditions and therefore meet their most severe design basis function. As a result, all remaining NUREG-0737, Item II.D.1 issues have been addressed by this testing.

10.0 REFERENCES

10.1 NUREG-0737, Item II.D.1, page II.D.1-1, 3-72

10.2 NRC to OPPD letter of June 25, 1990, SUBJECT: Safety Evaluation of Additional Information on NUREG-0737 Item II.D.1, Performance Testing of Safety and Relief Valves, for Fort Calhoun Station (TAC No. 44582)

10.3 NRC to OPPD letter of March 4, 1992, SUBJECT: Power Operated Relief Valve (PORV) Block Valve Testing - Fort Calhoun Station, Unit 1 (TAC No. M75832)

10.4 ERIN Engineering Calculation C159-90-05.01, "Reactor Coolant System MOVs HCV-150/151", Revision 0, 9/17/91 **(Enclosure for NRC Technical Review)**

10.5 Combustion Engineering Report 602977-MPS-5EFPR-002, "Test Procedure Guideline for Out-of-Plant Testing of the PORV Block Valves at the Fort Calhoun Station," Revision 2 **(Enclosure for NRC Technical Review)**

10.6 OPPD to NRC letter of June 28, 1988, LIC-88-477, SUBJECT: Response to Request for Additional Information Concerning NUREG-0737, Item II.D.1

10.7 Telecopy from Bruce Harry (CRANE-ALOYCO, INC.) to Ralph Schwartzbeck (OPPD) dated 12-10-91, SUBJECT: PORV Test Valve, CAI S. O. SJ-212

10.8 CRANE-ALOYCO, INC. to OPPD letter of December 20, 1990, SUBJECT: OPPD Purchase Order S061012, CRANE Order #SJ-212

10.9 "Review of NRC/INEL Gate Valve Test Program," Electric Power Research Institute, Pre-publication Report NP-7065, Research Project 3433-03, January 1991

10.10 Idaho National Engineering Laboratory to ITI-MOVATS letter of December 6, 1991, SUBJECT: INEL Torque Measurements Position Paper (Draft)-RS-59-91.

10.11 CRANE-ALOYCO, INC. to OPPD letter of September 26, 1991, SUBJECT: P.O. Number S061012 (CAI SJ-212)

10.12 "Progress Report of the Validation Committee," MOV User's Group, July 1991

10.13 Telecopy from Bruce Harry (CRANE-ALOYCO, INC.) to Ralph Schwartzbeck (OPPD) dated 12-11-90, SUBJECT: Required Thrust and Torque for 2½" - 2500# Gate Valve Tag HCV-150 and HCV-151 (SMB-00-7½), OEM Crane S. O. 868464 **(Enclosure for NRC Technical Review)**

10.14 Engineering Report 5.0, Rev. 3, HENZE-MOVATS Incorporated, "Equipment Accuracy Summary," October 24, 1991

10.15 Limitorque Corporation Selection Procedure, SEL - 1, Page 1 of 1, 5/21/79

10.16 Limitorque Corporation Selection Procedure, SEL - 3, Page 3 of 4, 2/26/79

10.17 Limitorque Corporation Selection Procedure, SEL - 7, 11/79

10.18 WYLE Laboratories Scientific Services and Systems Group, Test Report 57411, Job FS-57411

10.19 Limitorque Corporation Selection Procedure, 900-00003, Sheet 2 of 3, 3/88

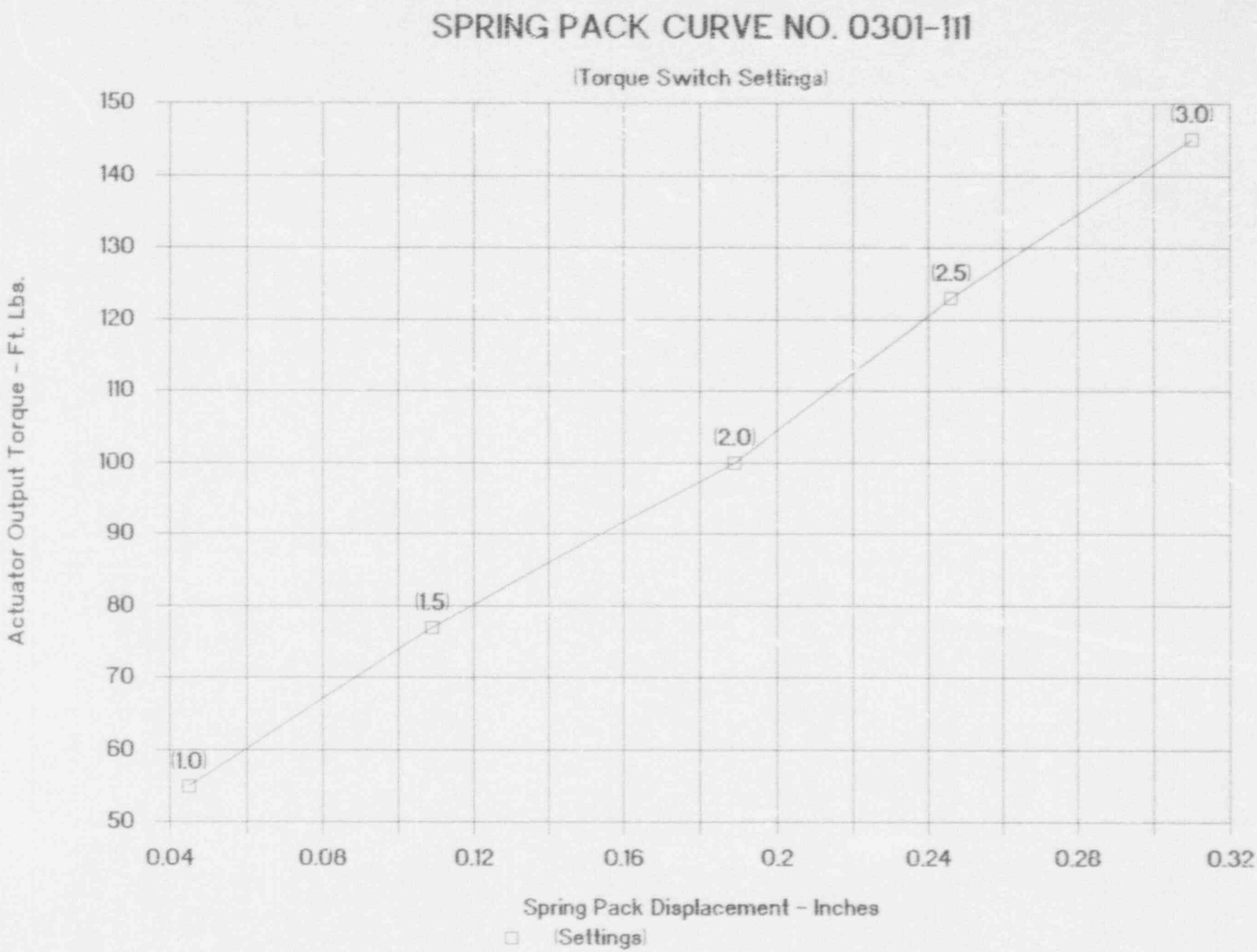
10.20 OPPD Internal Memorandum PED-FC-91-305 from R. L. Phelps to T. J. McIvor dated January 2, 1991, Subject: Degraded Voltage Operation of PORV Block Valves HCV-150 and HCV-151 (Enclosure for NRC Technical Review)

APPENDIX A

TORQUE SWITCH AND SPRING PACK CHARACTERISTICS

RELATIVE TORQUE SWITCH SETTINGS, SPRING PACK DISPLACEMENT, AND OUTPUT TORQUE OF A SMB-00 ACTUATOR WITH A 0301-111 SPRING PACK.

TORQUE SWITCH SETTING	SPRING PACK DISPLACEMENT (Inches)	OUTPUT TORQUE (Ft-lbs)
1.0	0.045	55
1.5	0.109	77
2.0	0.189	100
2.5	0.246	123
3.0	0.310	145


SPRING PACK CURVE NO. 0301-111
(Torque Switch Settings)
Actuator Output Torque - Ft. Lbs.
150
140
130
120
110
100
90
80
70
60
50
(1.0)
(1.5)
(2.0)
(2.5)
(3.0)
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
Spring Pack Displacement - Inches
(Settings)

APPENDIX B

GENERIC MOTOR PERFORMANCE CURVES FOR
7½ FT-LB MOTOR

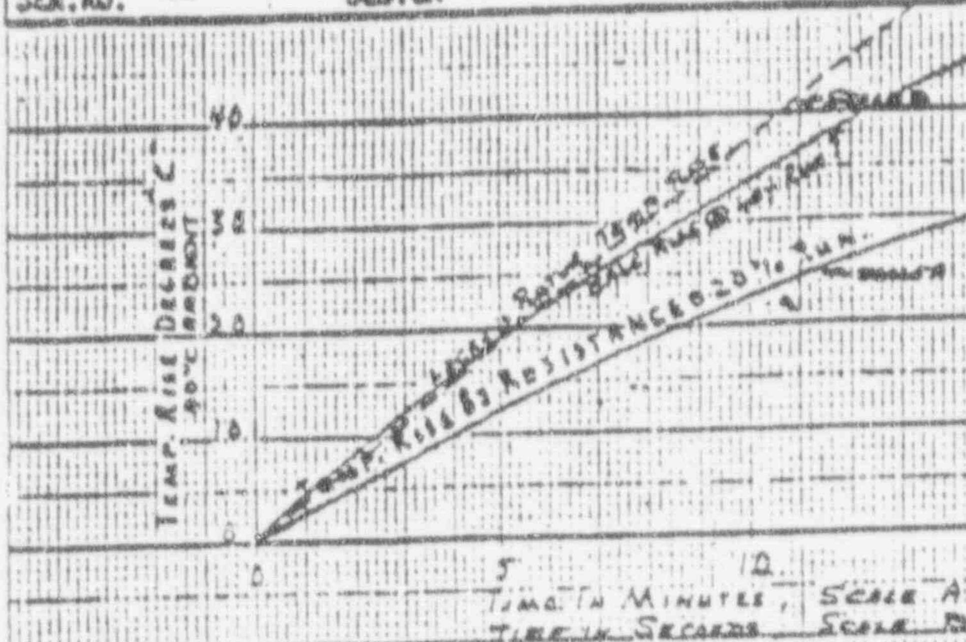
H. K. PORTER COMPANY, INC.

ELECTRICAL DIVISION — WARREN WORKS
WARREN, OHIO 44481

3 PHASE MOTOR PERFORMANCE CURVES

FRAME	PN568	H.P.	7.5 LB.FT.	RPM.	1750	ENCLOSURE	T.E.W.P.
VOLTS	220/440	HERTZ	60	AMPS.	3.0/1.5	ROTOR	48C-155
TIME	15 MIN.	PHASE	3	INS.	B	RES. AT 25°C	7.59@220VOLTS
DUTY	20% RUN.	CODE	—	RISE	75°C	TEST DATE	10-15-64
SER. NO.	—	DESIGN	—	AMB.	40°C	SPEC. NO.	23495

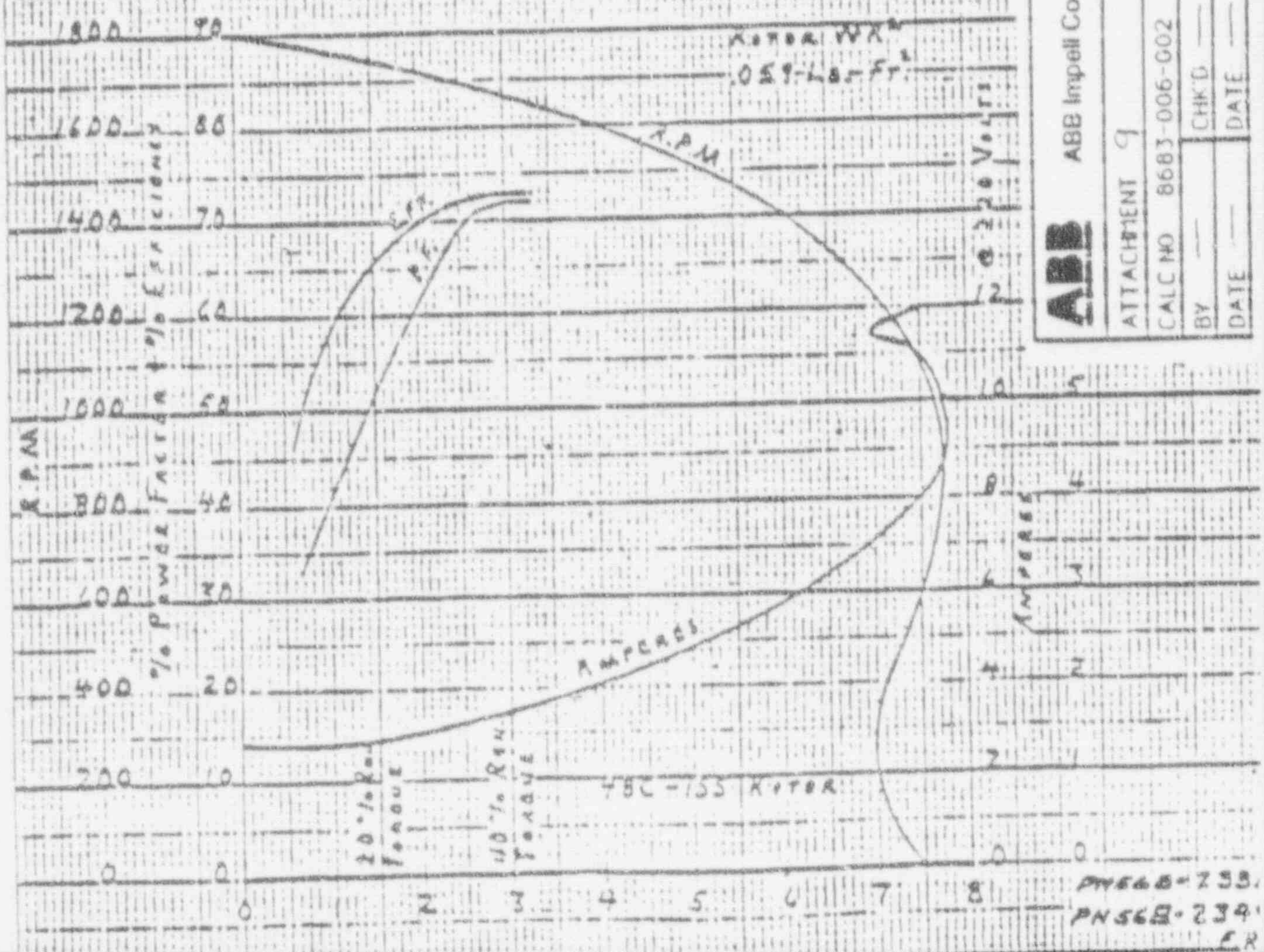
HCV-130 } EXISTING
HCV-131



VOLTS	--AMPERES--		
	N.L.	F.L.	L.R.
242	3.8	3.6	13
220	2.8	2.9	12
198	2.2	2.5	10
ROTOR WK^2 = 0.059 LB.FT			

ABB Impell Corporation

ATTACHMENT 9	PAGE 12 OF 12
CALC NO 8683-006-002	REV A
BY —	CHK'D —
DATE —	DATE —
JOB NO 8683-006-1351	



PN568-233
PN568-234
E.R.

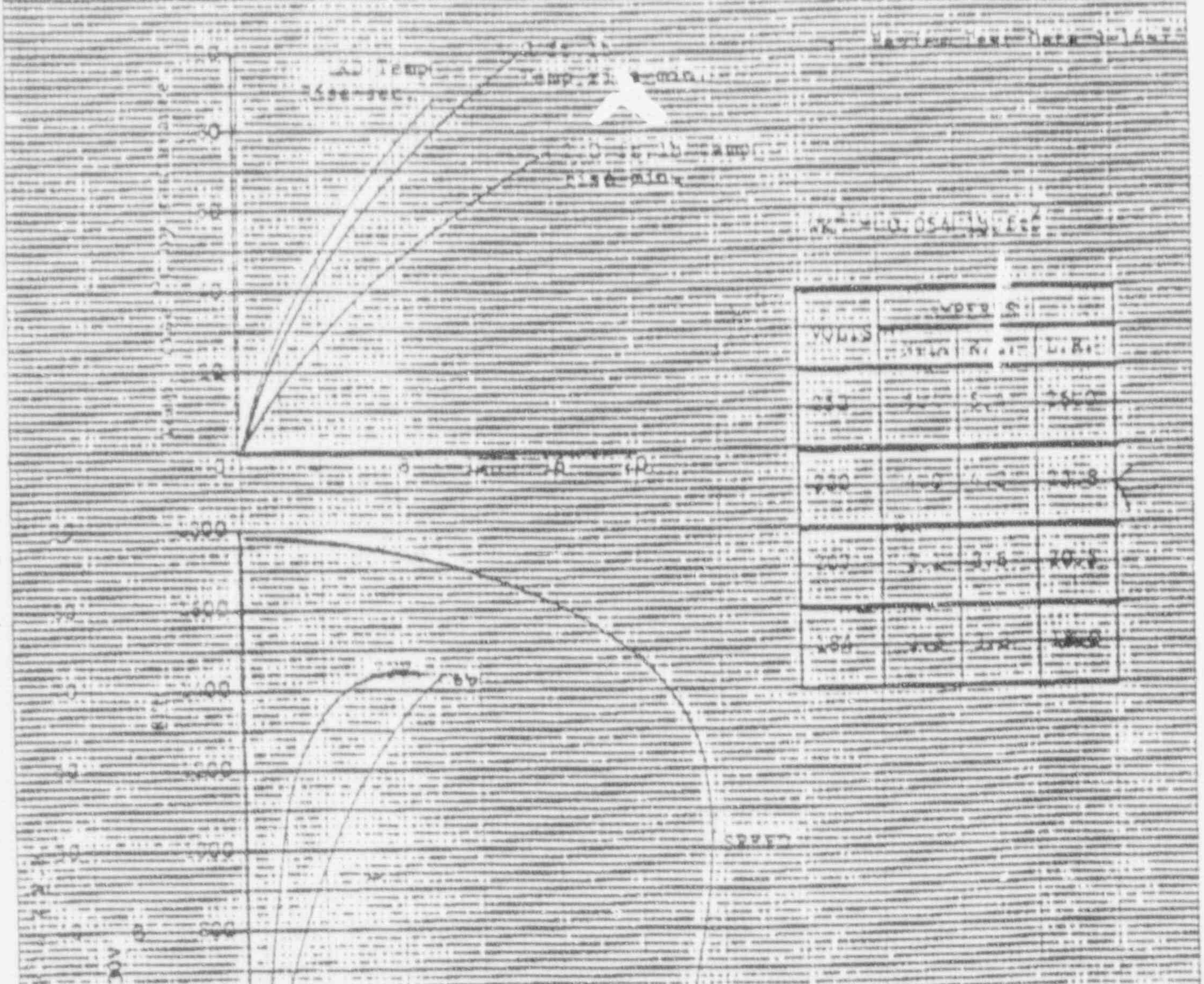
APPENDIX C

GENERIC MOTOR PERFORMANCE CURVES FOR 10 FT-LB MOTOR

PROTOTYPE PORV BLOCK VALVE
MOTOR CURVE

10/08/91 14:40 L 760 003

REL. S.O.	RPM 1700	S.F. 1.0	ROTOR 602006-09-E
FRAME L56	VOLTS 230/460	NEMA DESIGN	TEST S.O. 20700119
HP .7	AMPS 4.6/2.3	CODE LETTER R	TEST DATE 3-29-68
TYPE P	DUTY 15 Min.	ENCLOSURE TENV	STATOR RES. @ 25°C @230V
PHASE/HERTZ 3/60	AMB°C/INSUL 40° C/B	E/S 500226-02	4.71 OHMS (BETWEEN LINES)



VOLTS	AMPERES		
	[illegible]	[illegible]	L.R.
253	[illegible]	[illegible]	25.0
230	[illegible]	[illegible]	23.8
207	[illegible]	3.6	20.[illegible]
184	[illegible]	[illegible]	[illegible]

AMPERES SHOWN FOR 230V CONNECTION. IF OTHER VOLTAGE CONNECTIONS ARE AVAILABLE, THE AMPERES WILL VARY INVERSELY WITH THE RATED VOLTAGE.

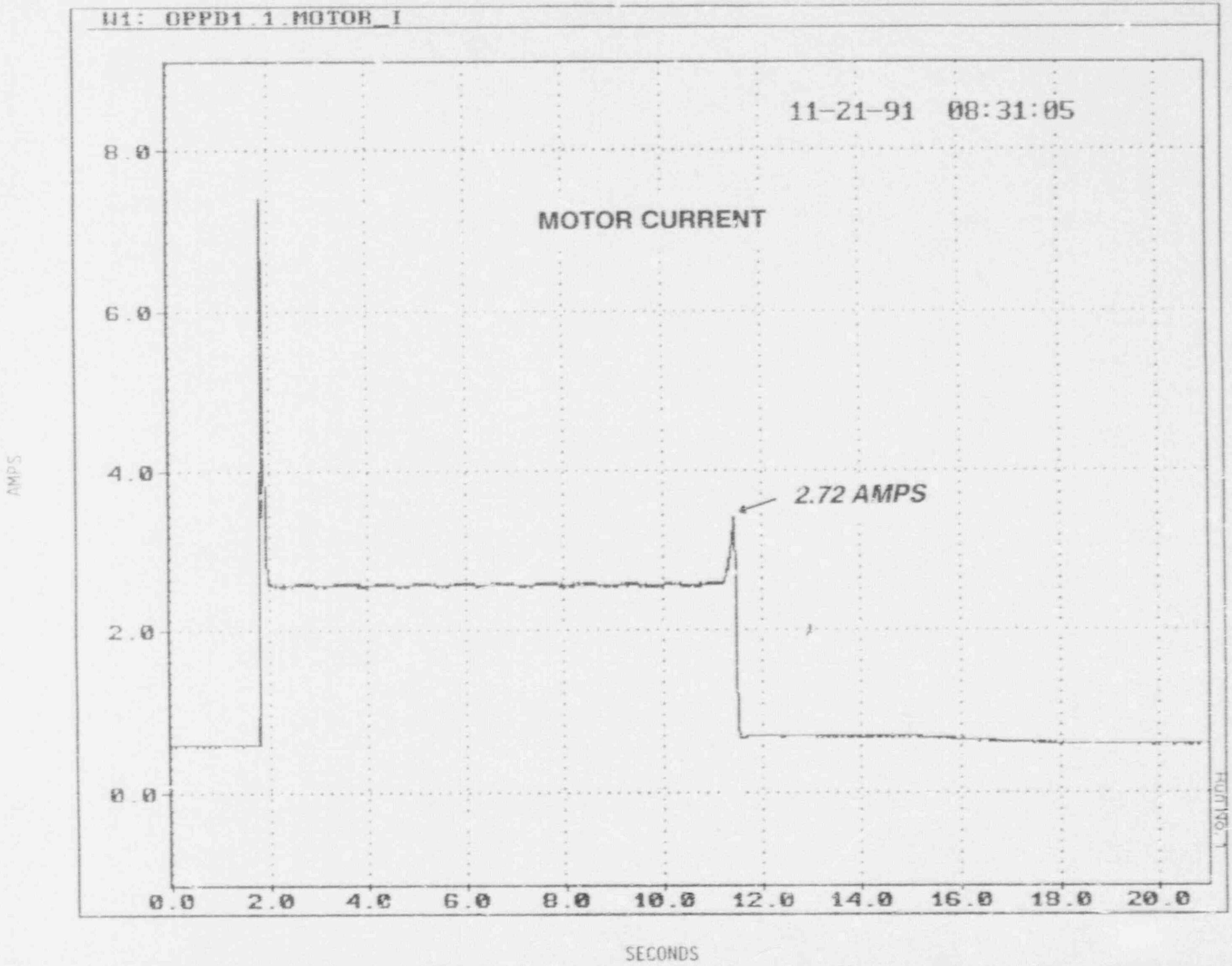
RELIANCE ELECTRIC COMPANY
CLEVELAND, OHIO 44117 U.S.A.

DR. BY JNR
CK. BY [illegible]
APP. BY [illegible]
DATE [illegible]

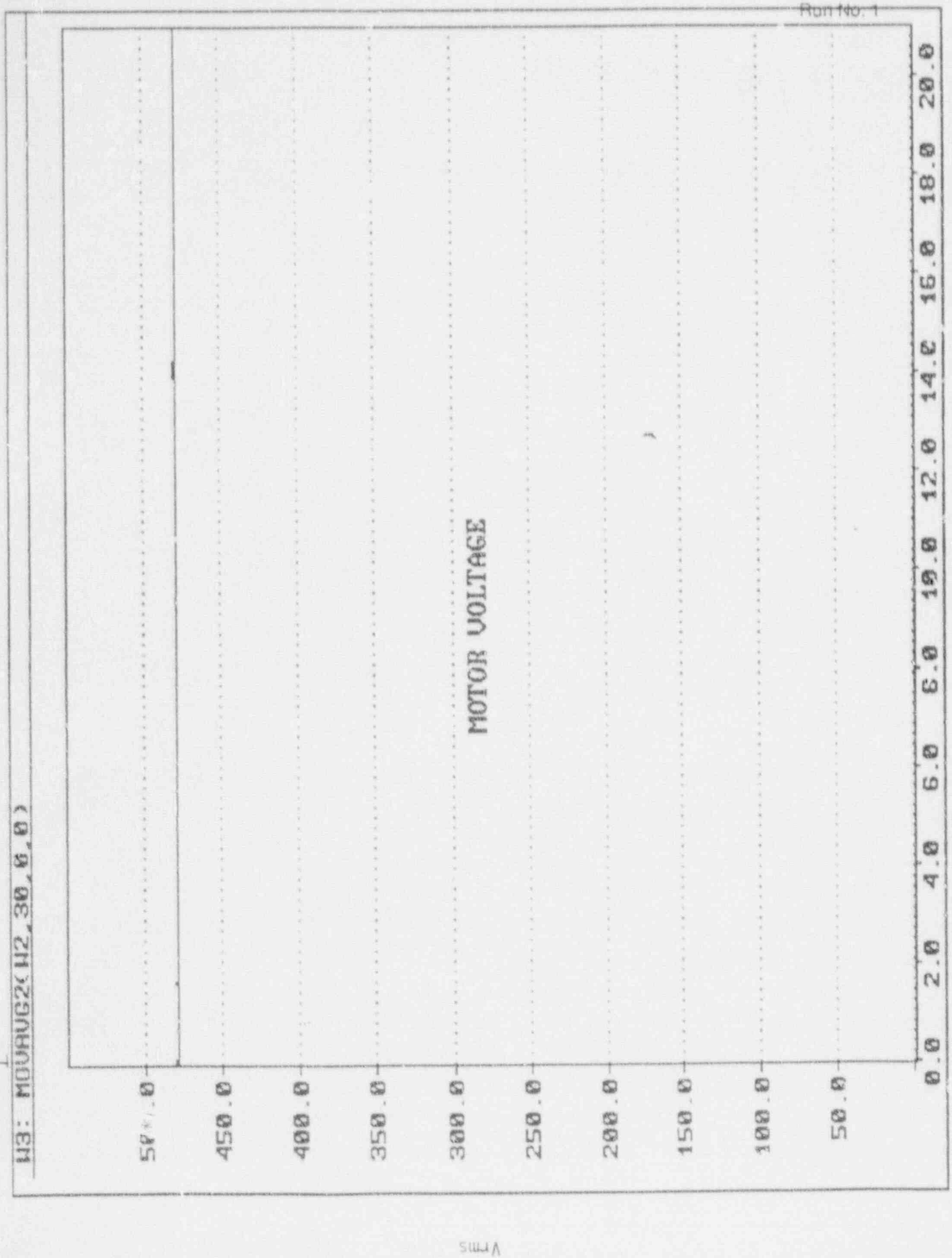
A-C MOTOR PERFORMANCE CURVES
M1468 (Updated 413018-03-AL)
ISSUE DATE 7/21/77

APPENDIX D

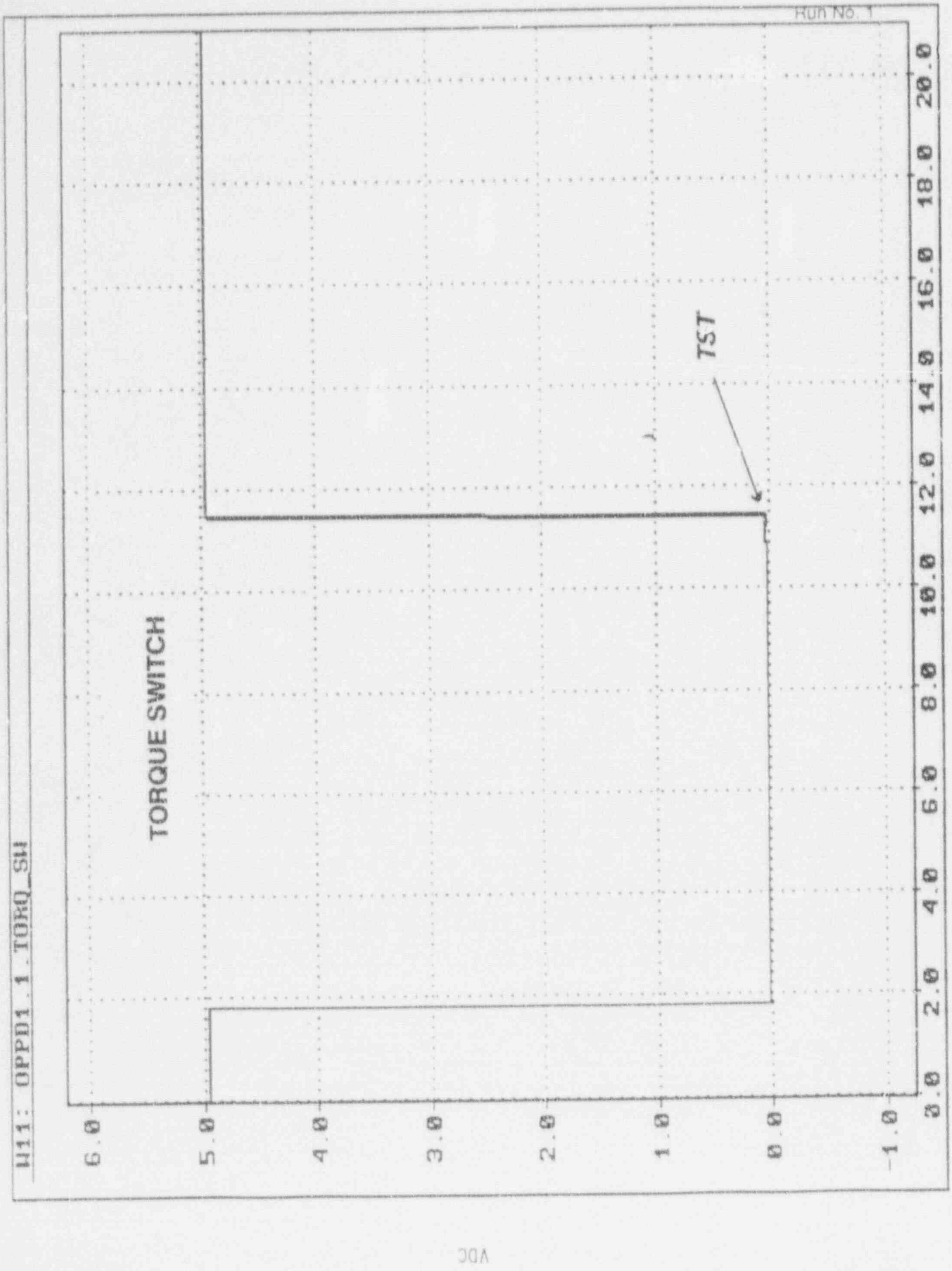
DATA PLOTS FOR TEST RUN 1



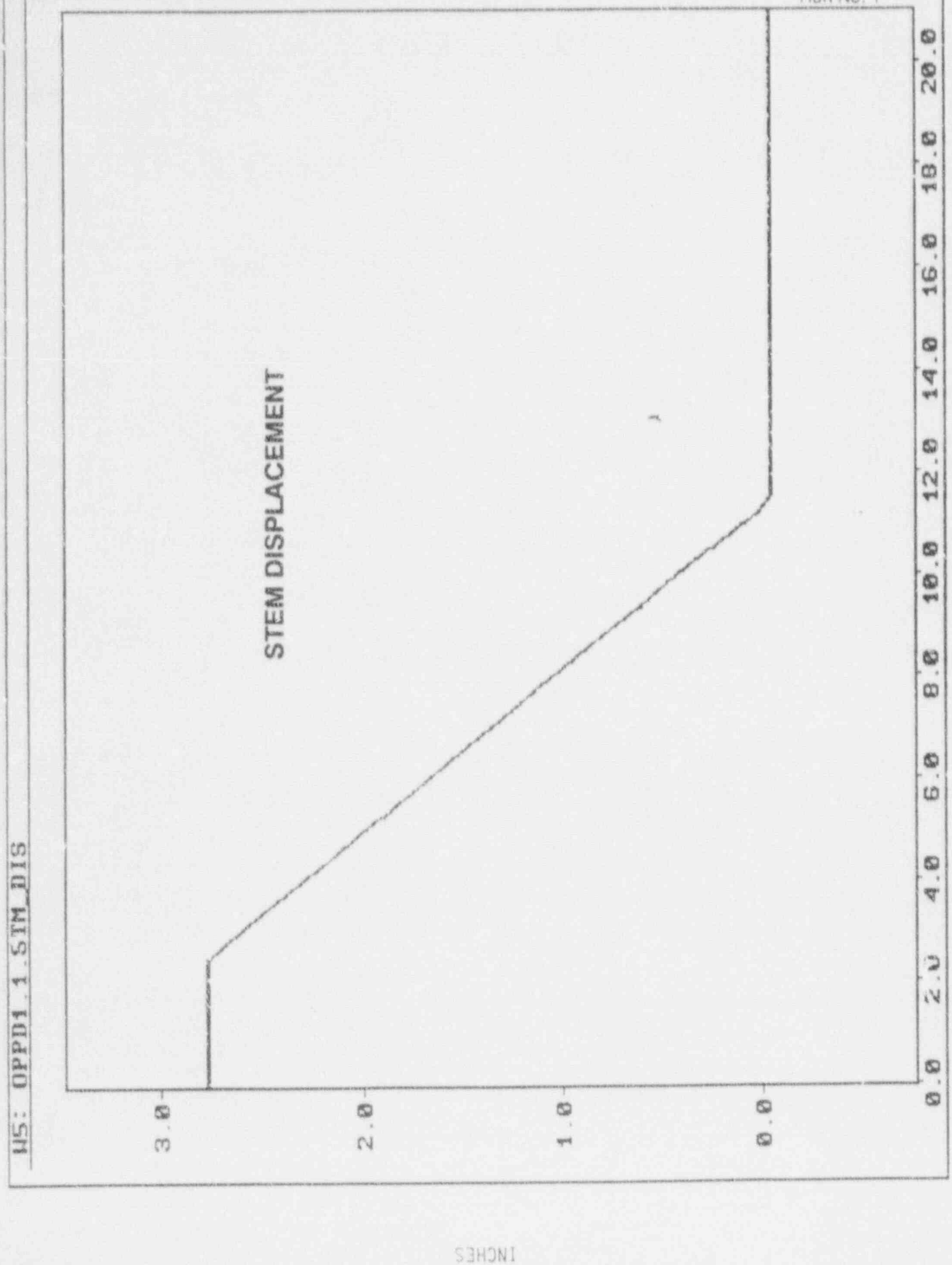
Report No. 57411
Page No. A-2

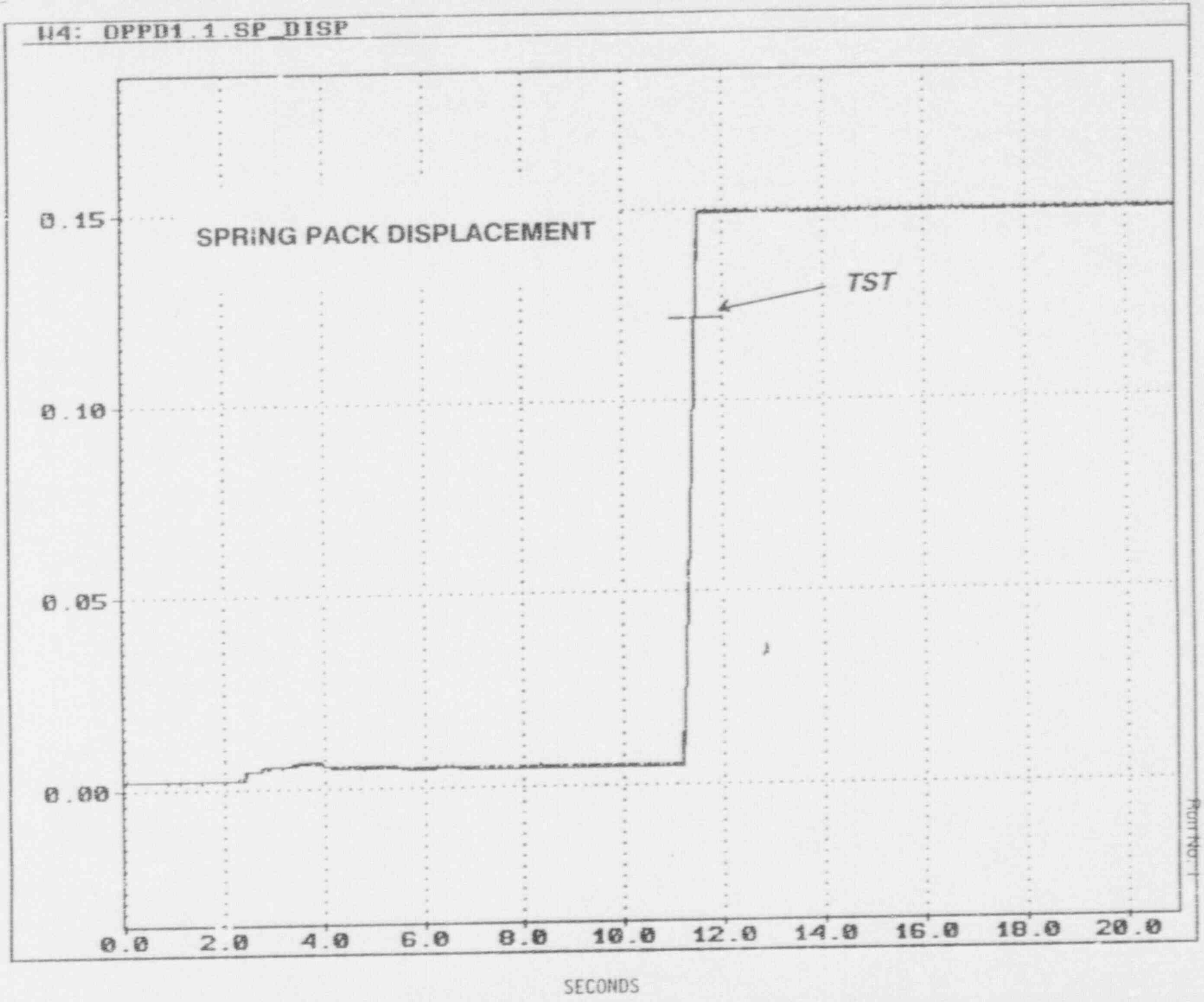

W3: MOVAVG2(W2,30,0,0)
MOTOR VOLTAGE
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2.0
4.0
6.0
10.0
12.0
14.0
16.0
18.0
20.0
SECONDS
Vrms

Run No. 1

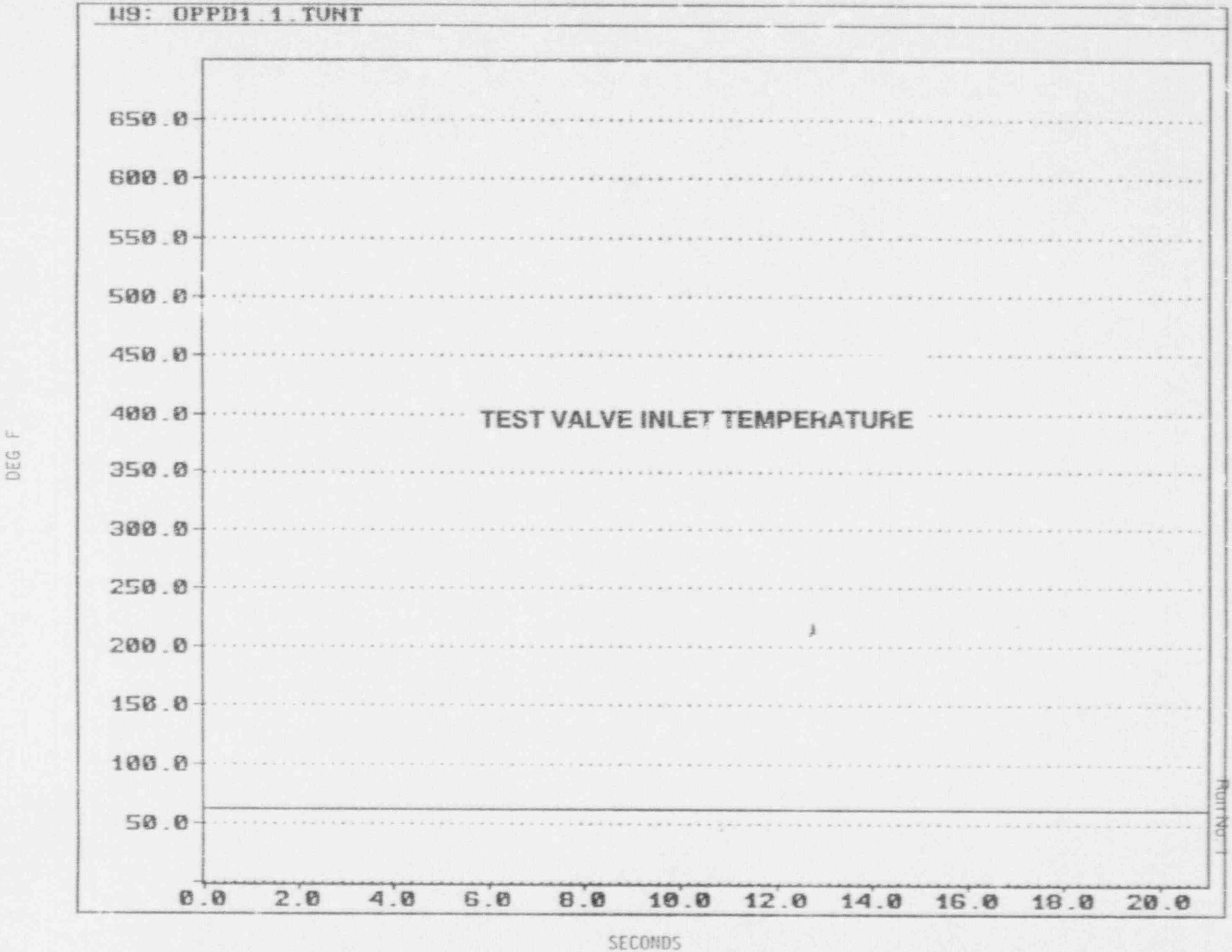

W11: OPPD1_1_TORQ_SW
TORQUE SWITCH
TST
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
SECONDS
VDC

Run No. 1

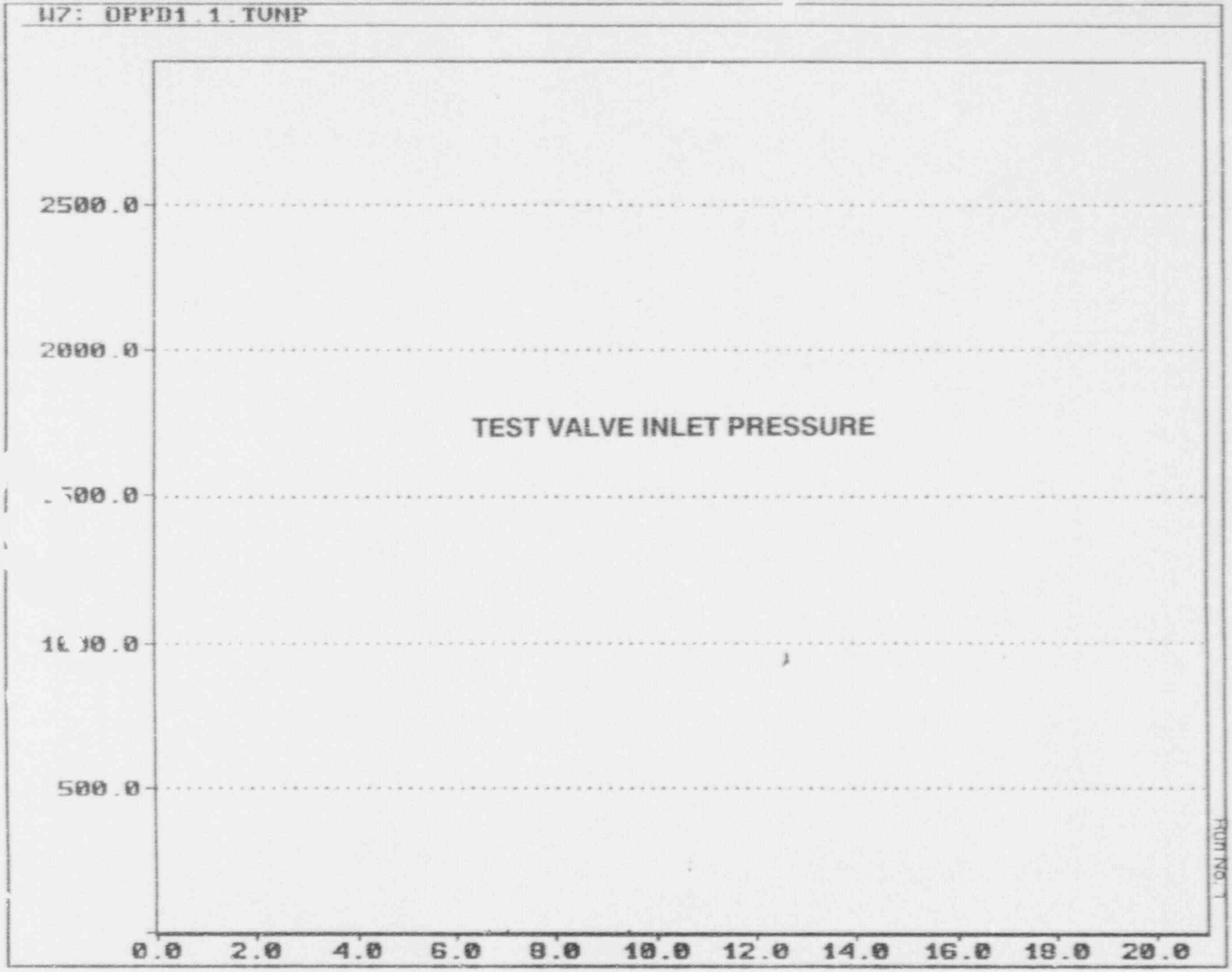

H5: OPPD1_1.STM_DIS
STEM DISPLACEMENT
0.0
1.0
2.0
3.0
INCHES
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
SECONDS



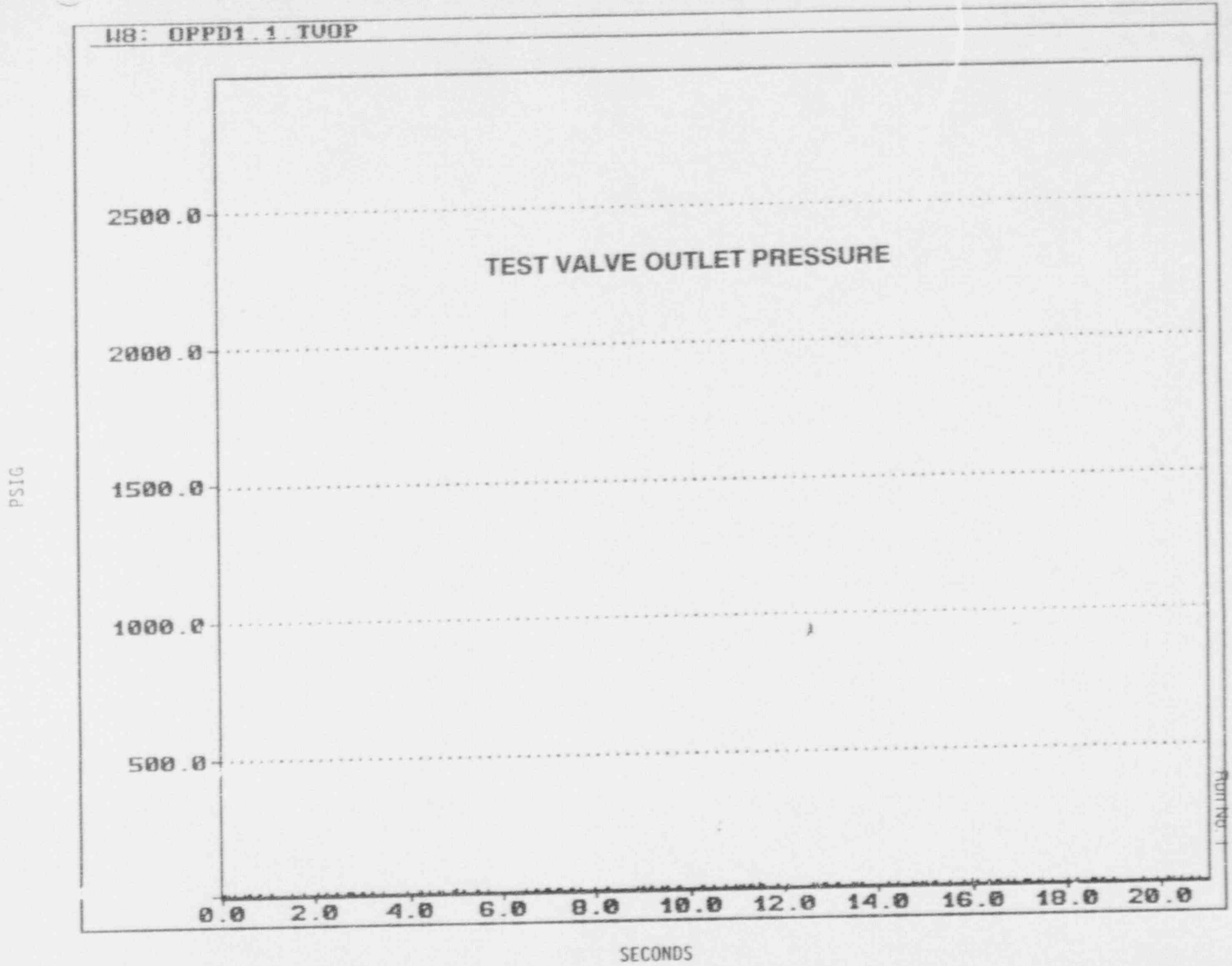
Report No. 57411
Page No. A-7
Run No. 1



Report No. 57411
Page No. A-8

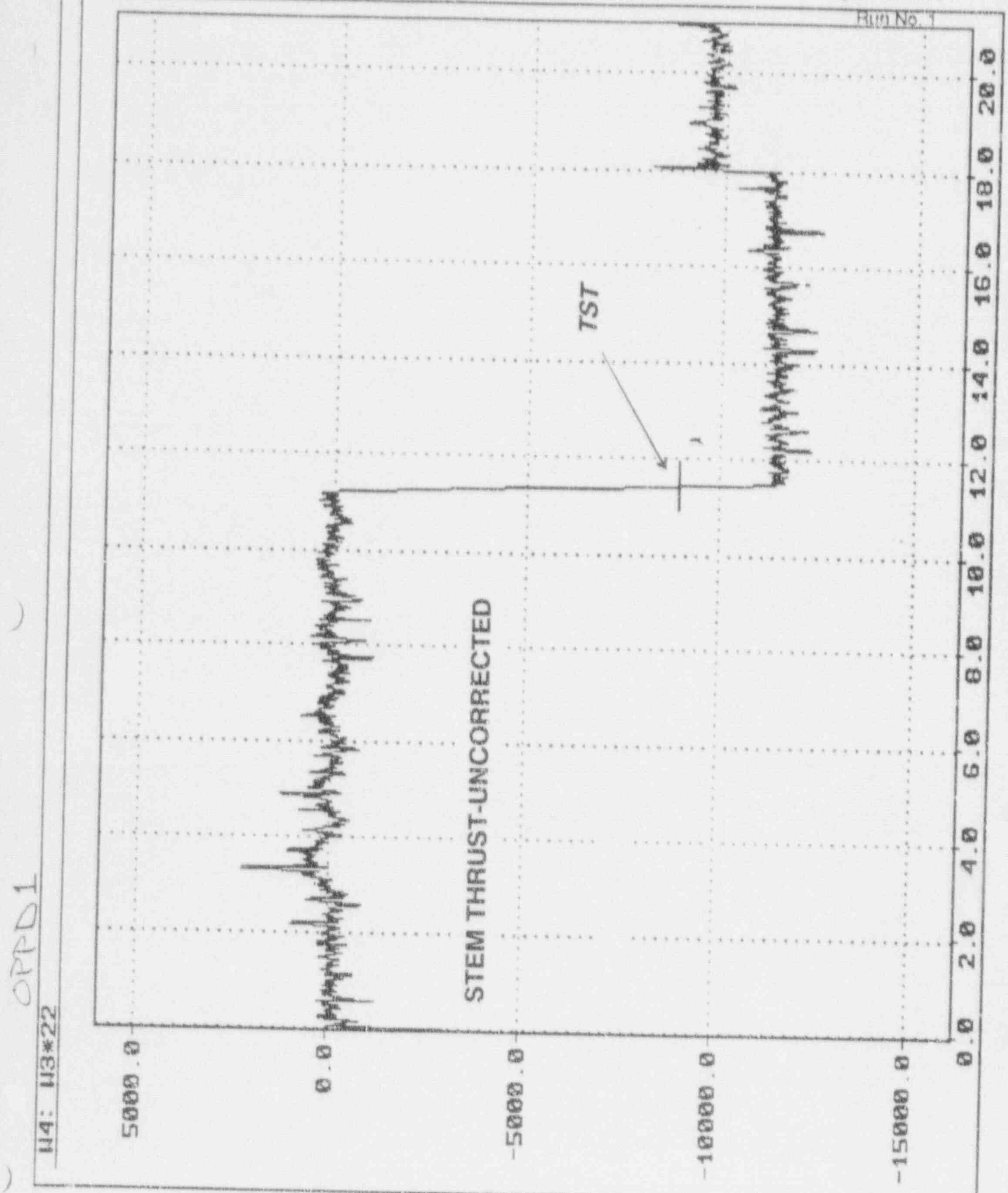


Report No. 57411
Page No. A-9



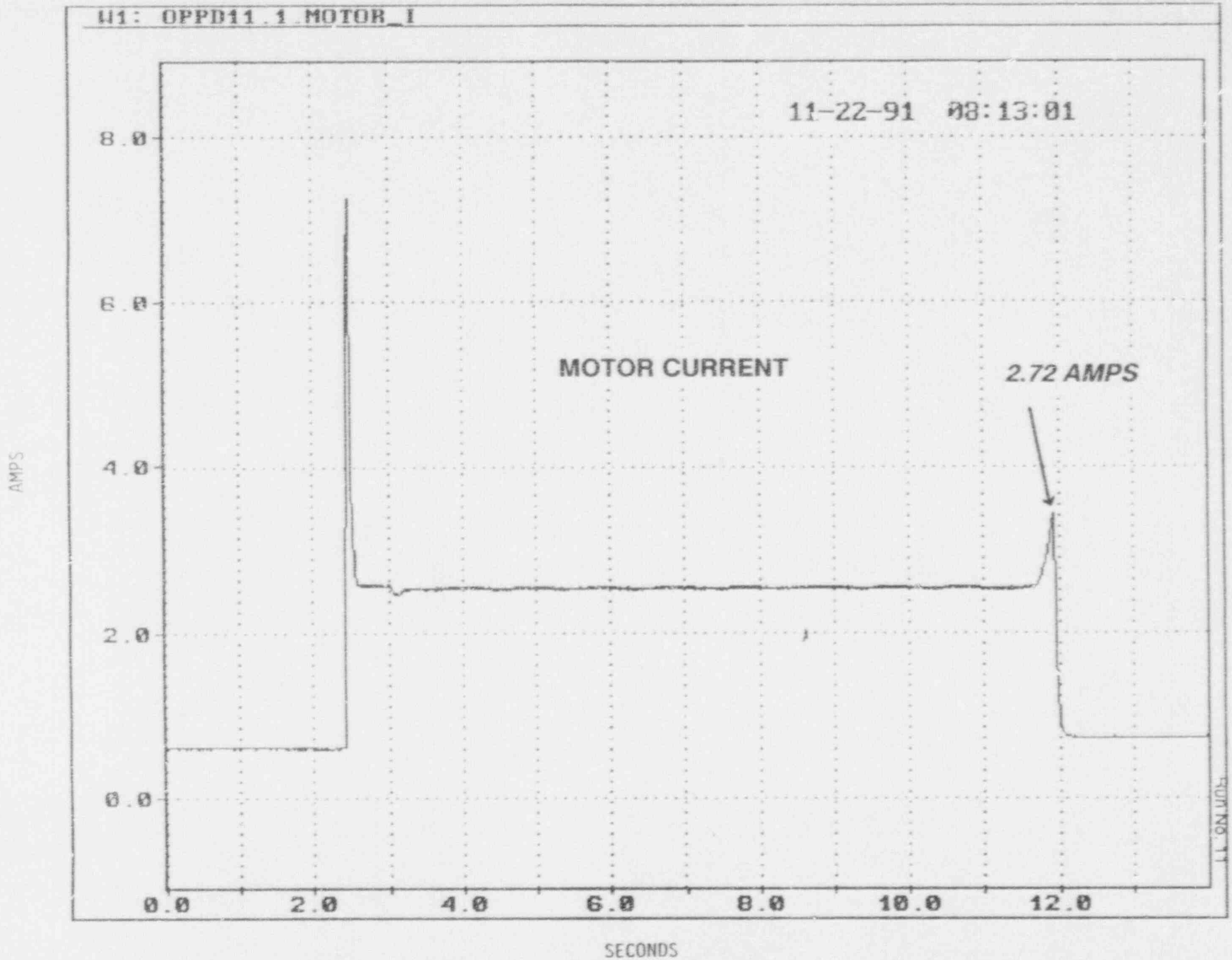
Report No. 57411
Page No. A-10

Report No. 57411
Page No. A-11

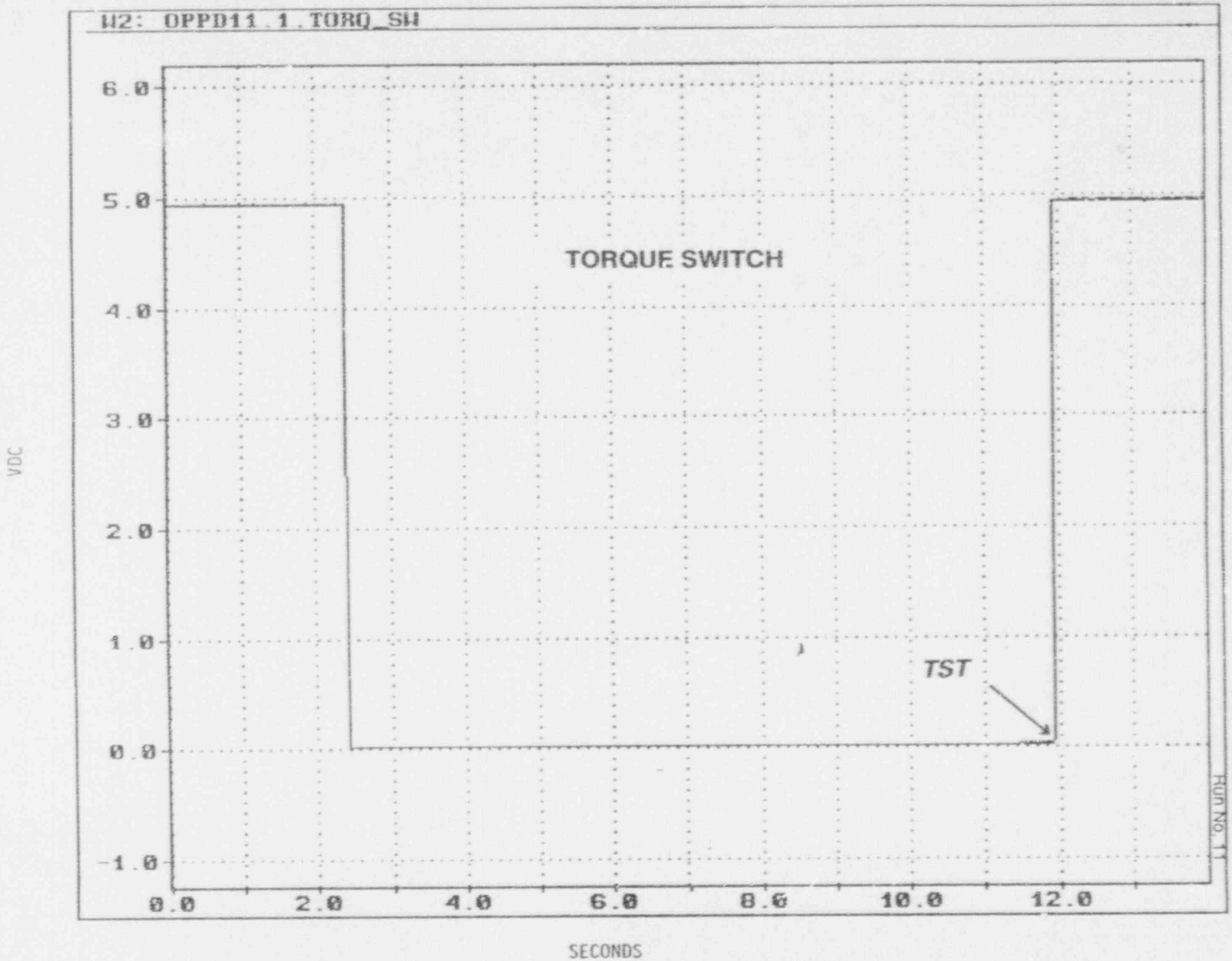


APPENDIX E

DATA PLOTS FOR TEST RUN 11

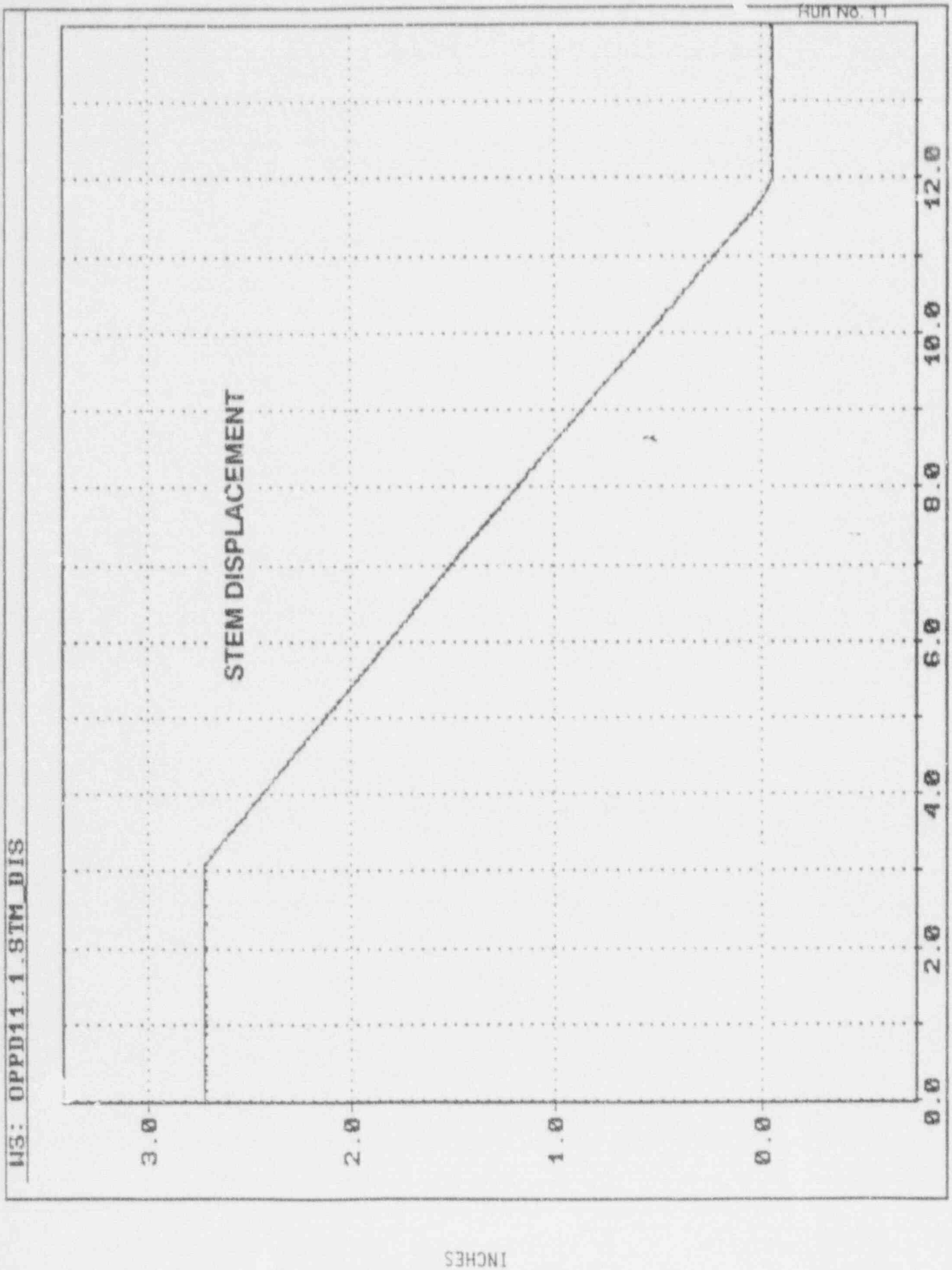

W1: OPPD11.1.MOTOR_I
11-22-91 08:13:01
MOTOR CURRENT
2.72 AMPS
8.0
6.0
4.0
2.0
0.0
AMPS
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS
Run No. 11

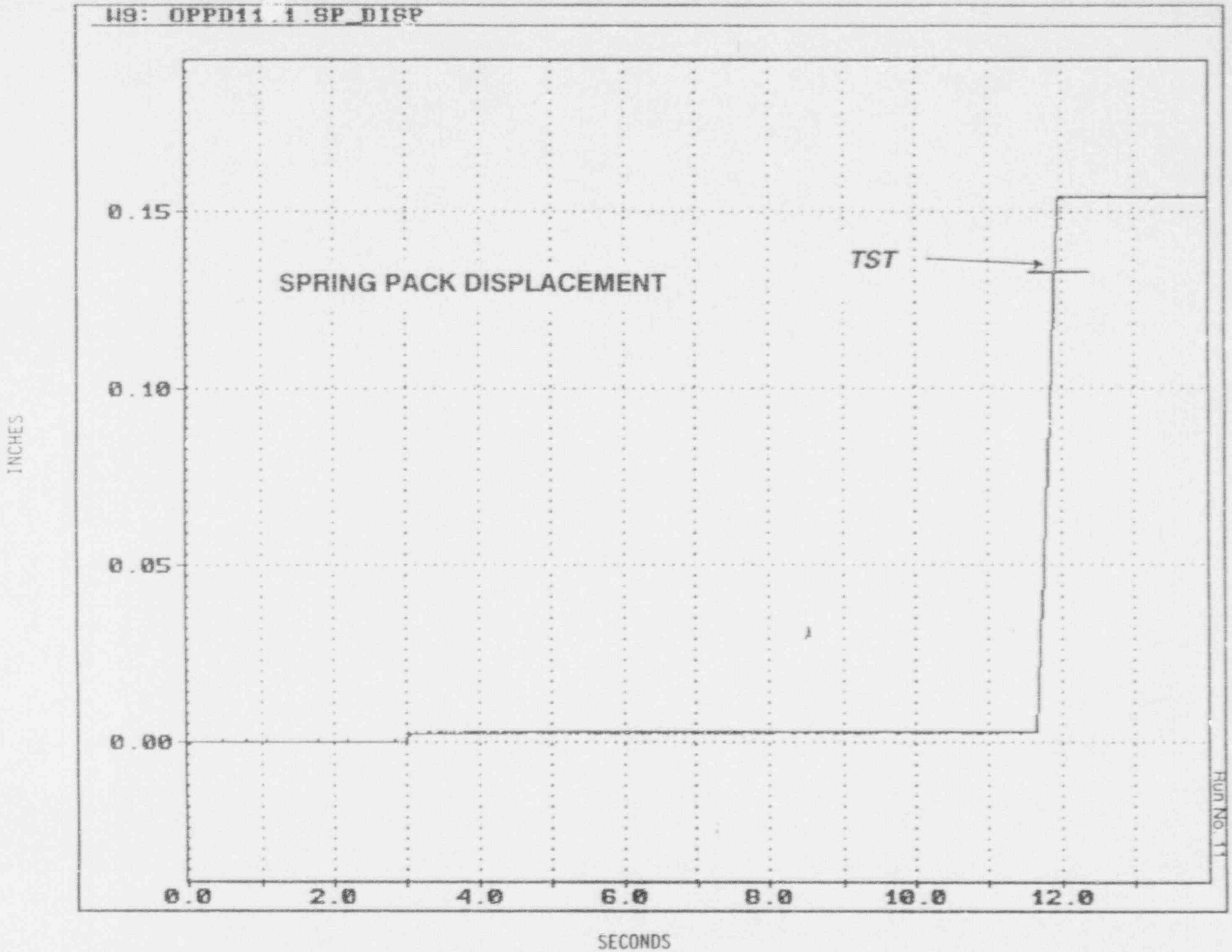

W6: MOVAVG2(W5,30,0,0)
MOTOR VOLTAGE
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
Vrms
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS



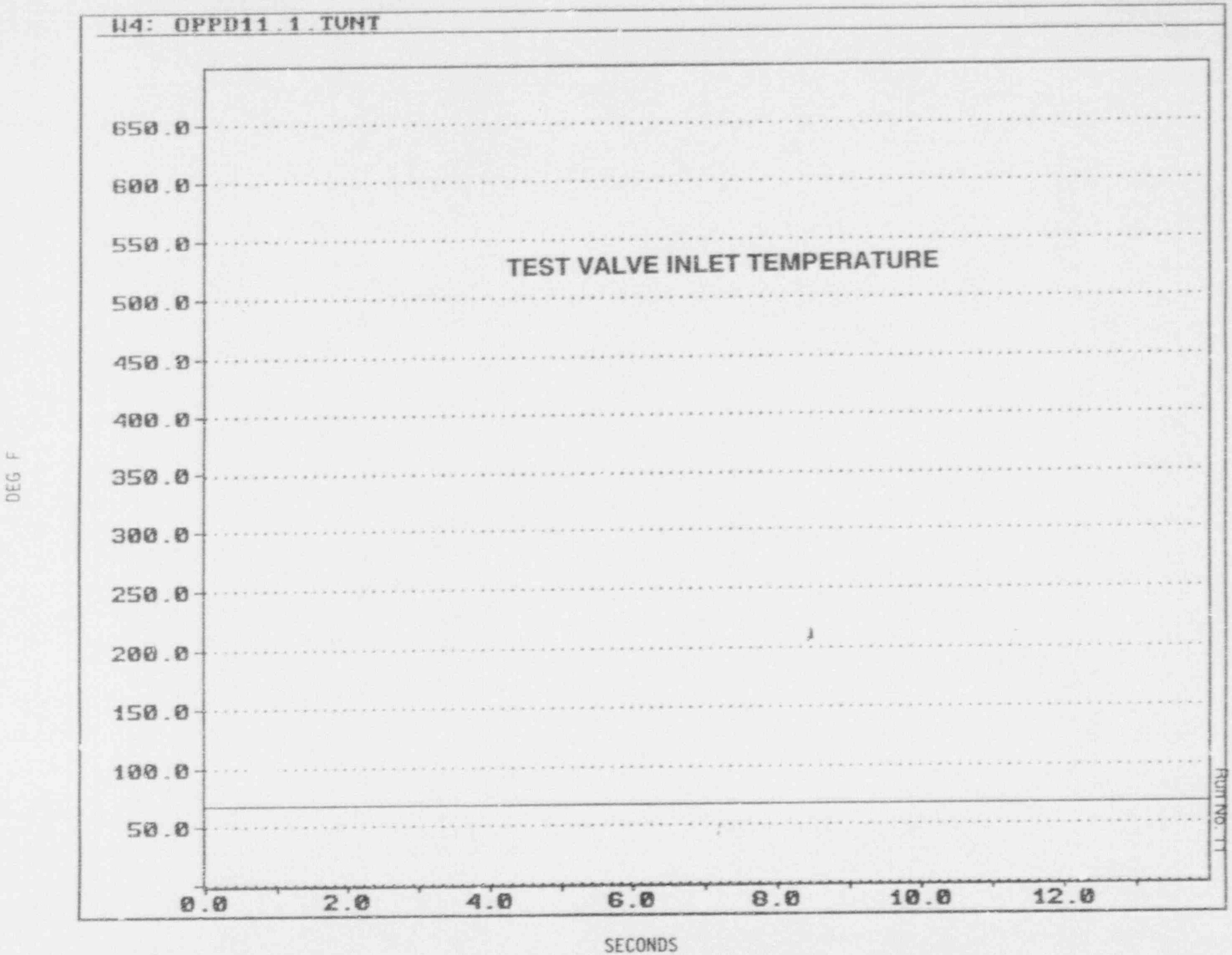
Report No. 57411
Page No. A-128

Run No. 11


W5: OPPD11_1_STM_DIS
STEM DISPLACEMENT
3.0
2.0
1.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS
INCHES

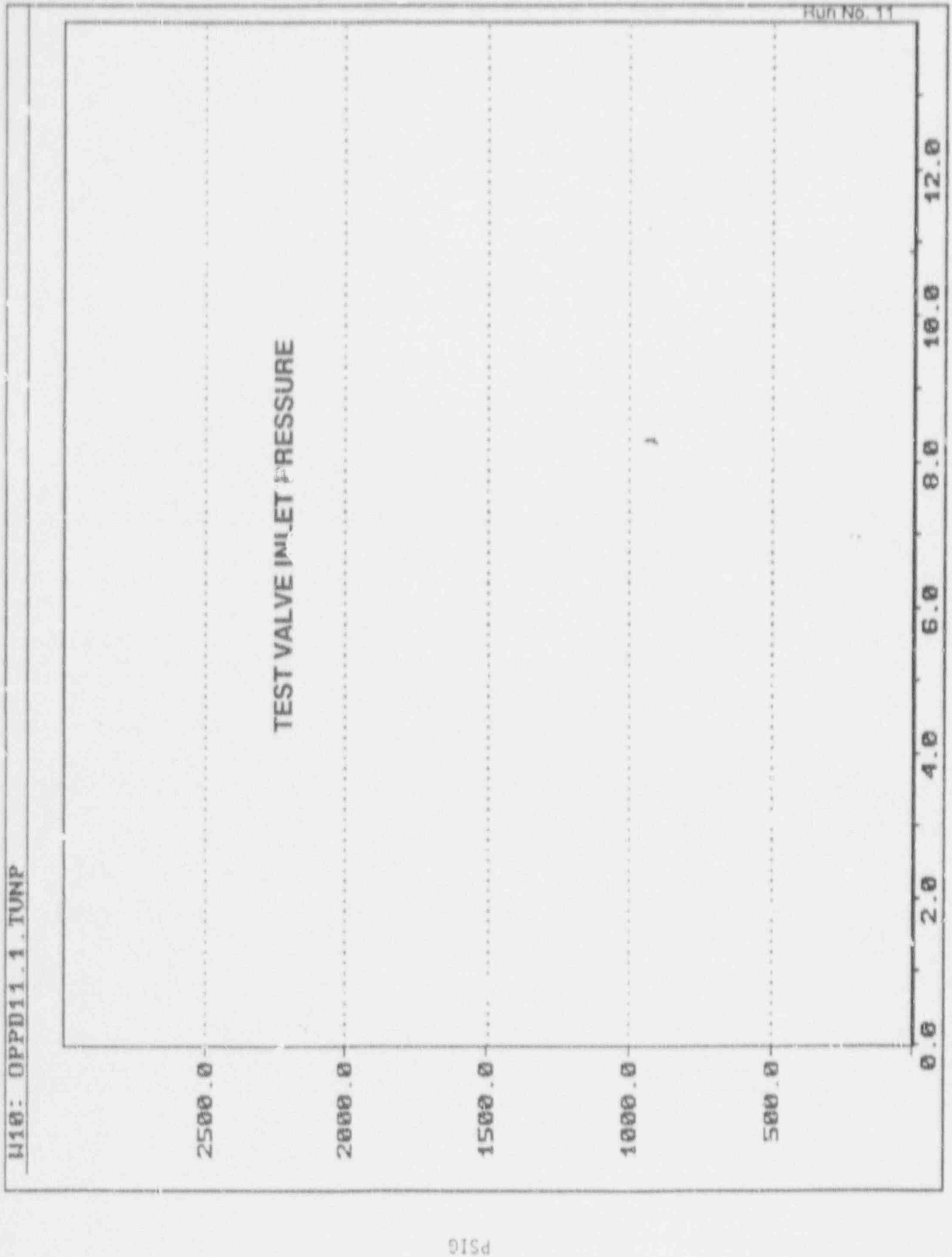


Report No. 57411
Page No. A-131

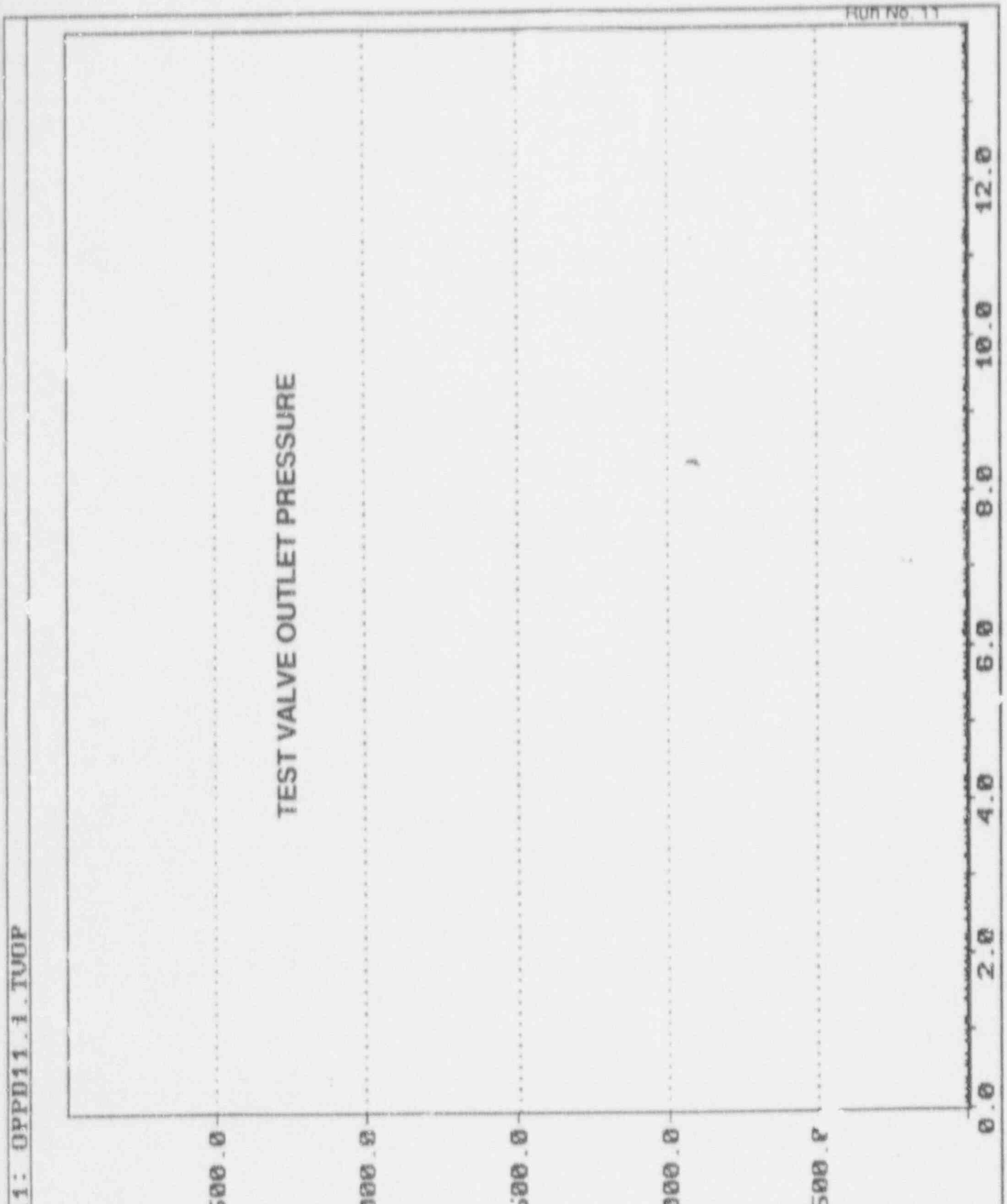


Report No. 57411
Page No. A-132

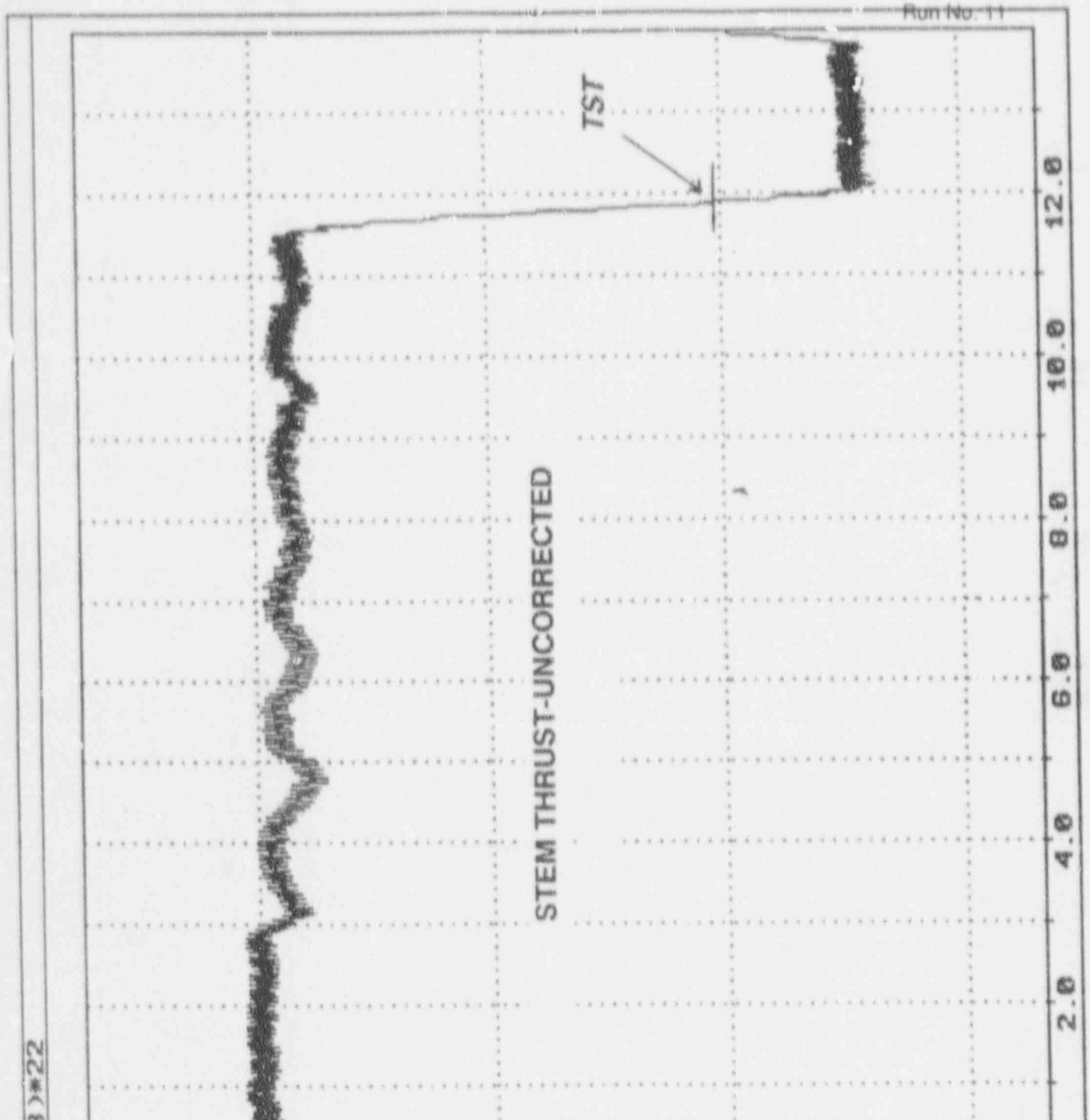
Run No. 11


W10: OPPD11.1.TUNP
TEST VALVE INLET PRESSURE
2500.0
2000.0
1500.0
1000.0
500.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS
PSIG

Run No. 11


W11: OPPD11.1.TVOP
TEST VALVE OUTLET PRESSURE
2500.0
2000.0
1500.0
1000.0
500.0
PSIG
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS

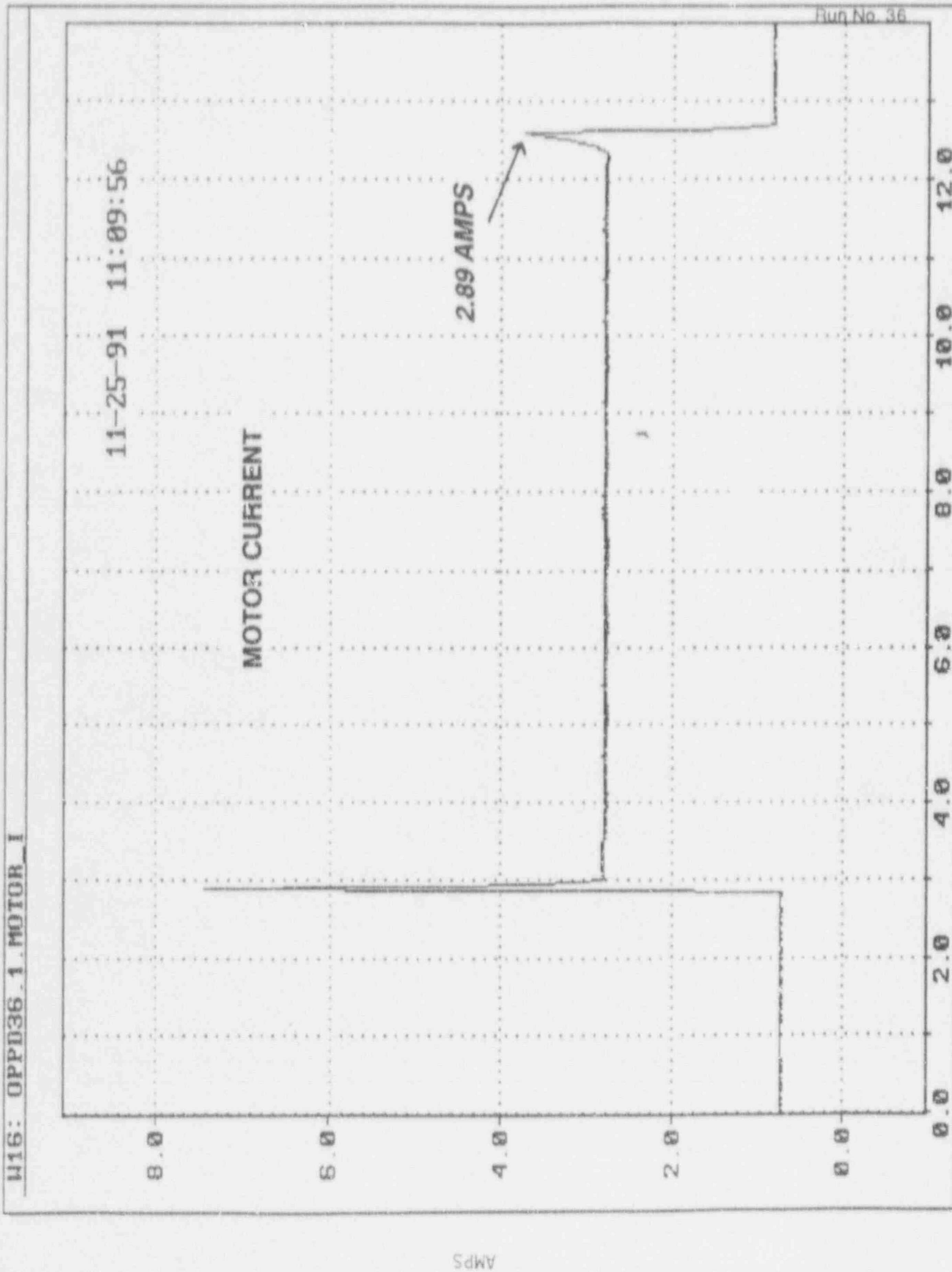
Report No. 57411
Page No. A-135
Run No. 11

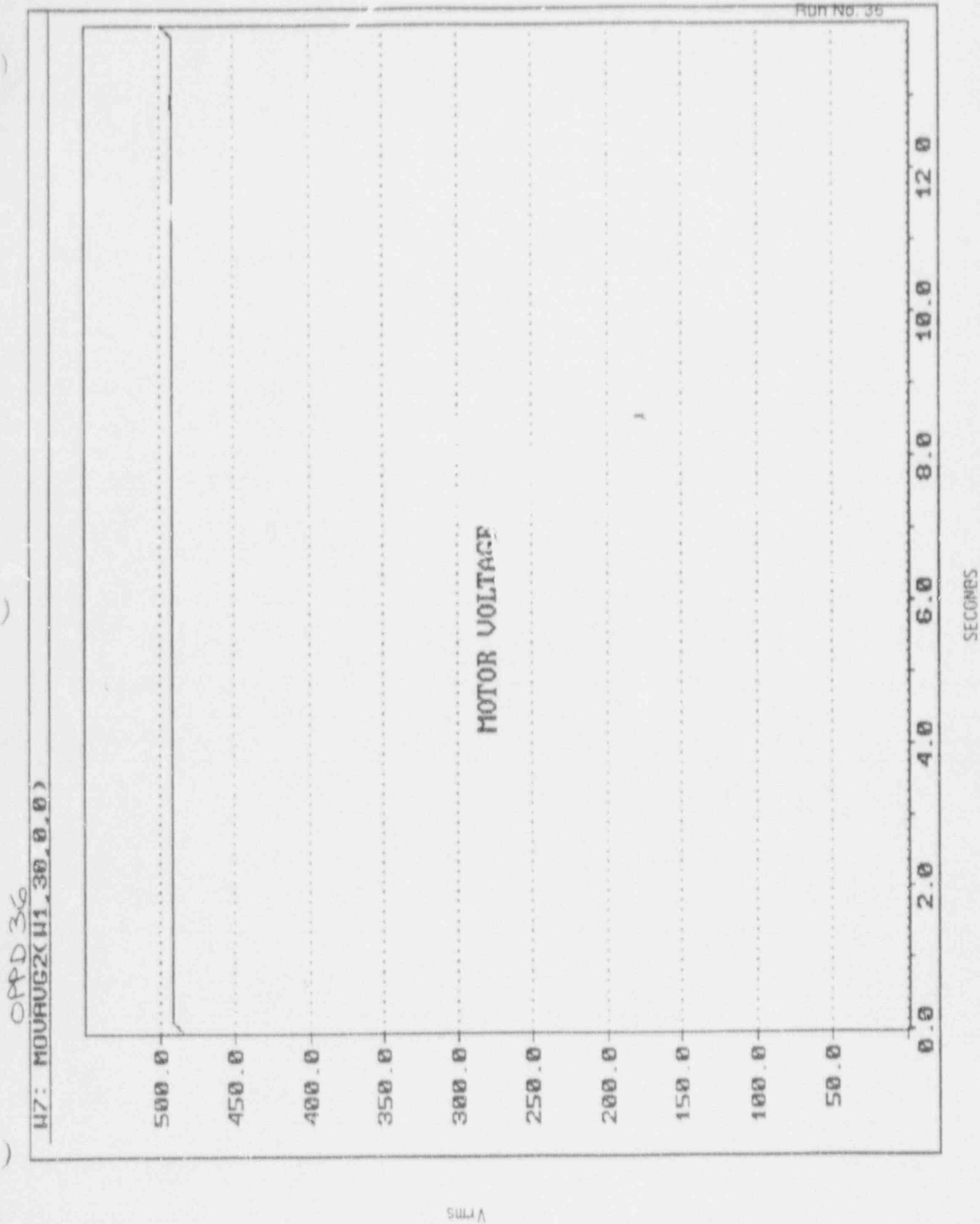


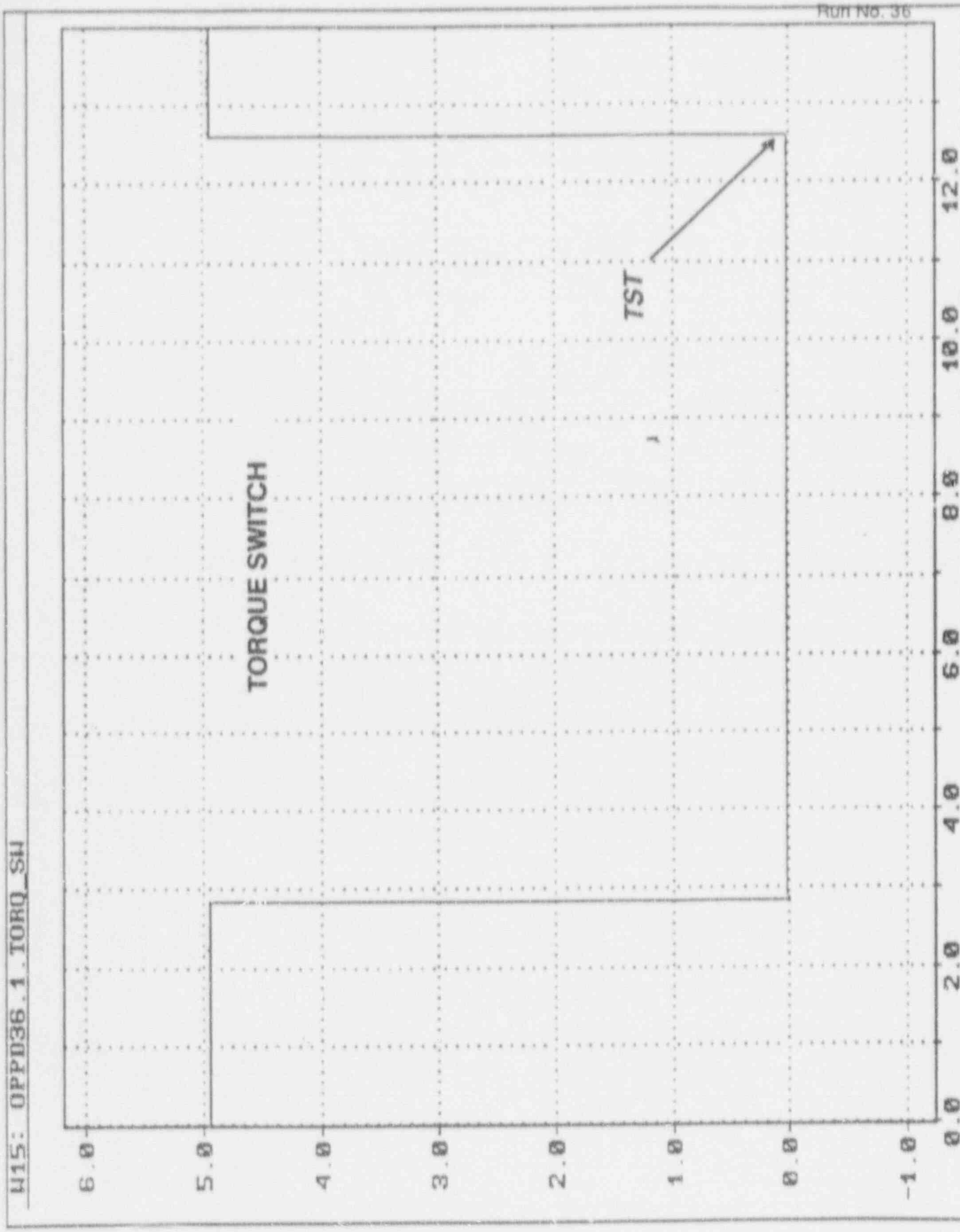
APPENDIX F

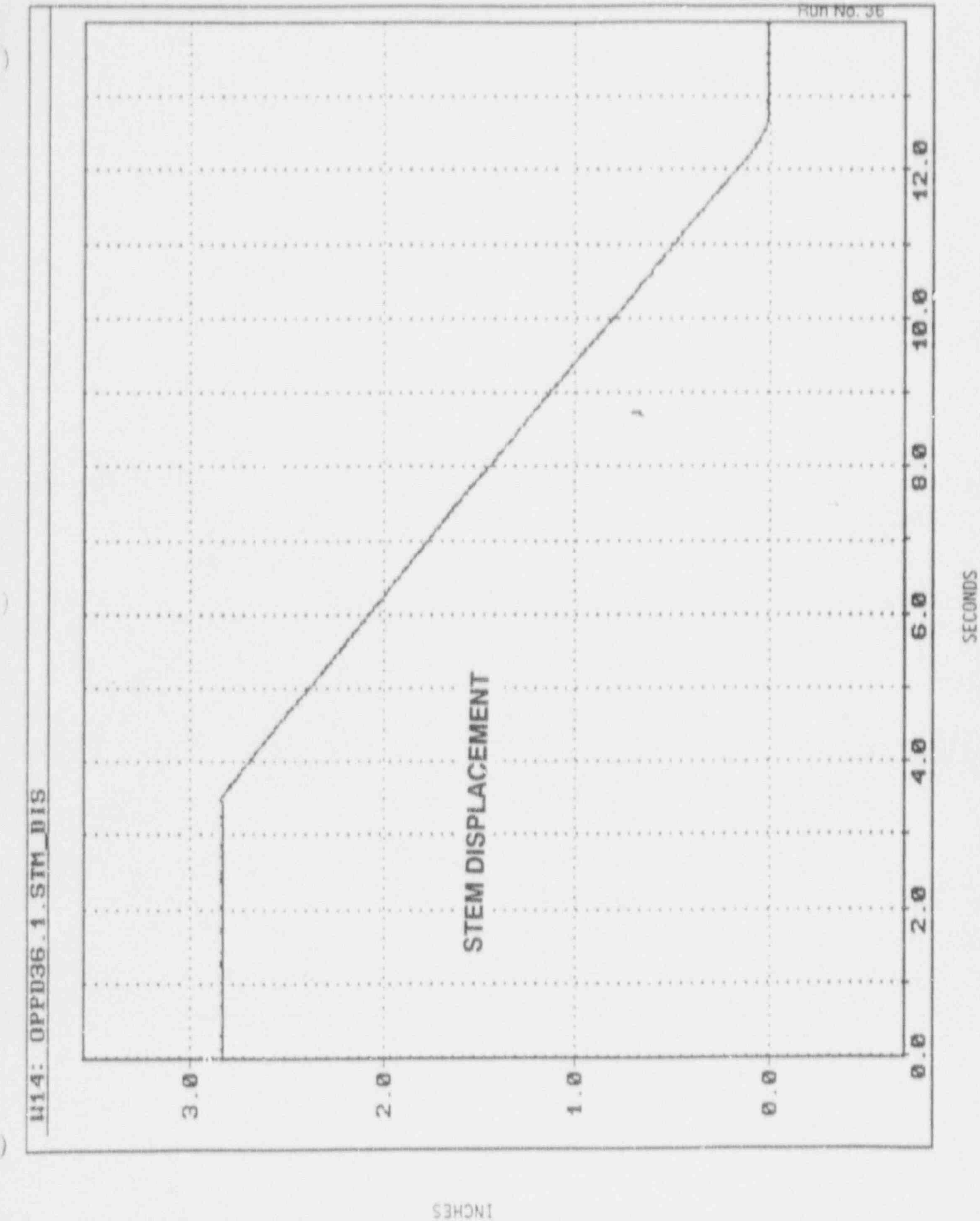
DATA PLOTS FOR TEST RUN 27

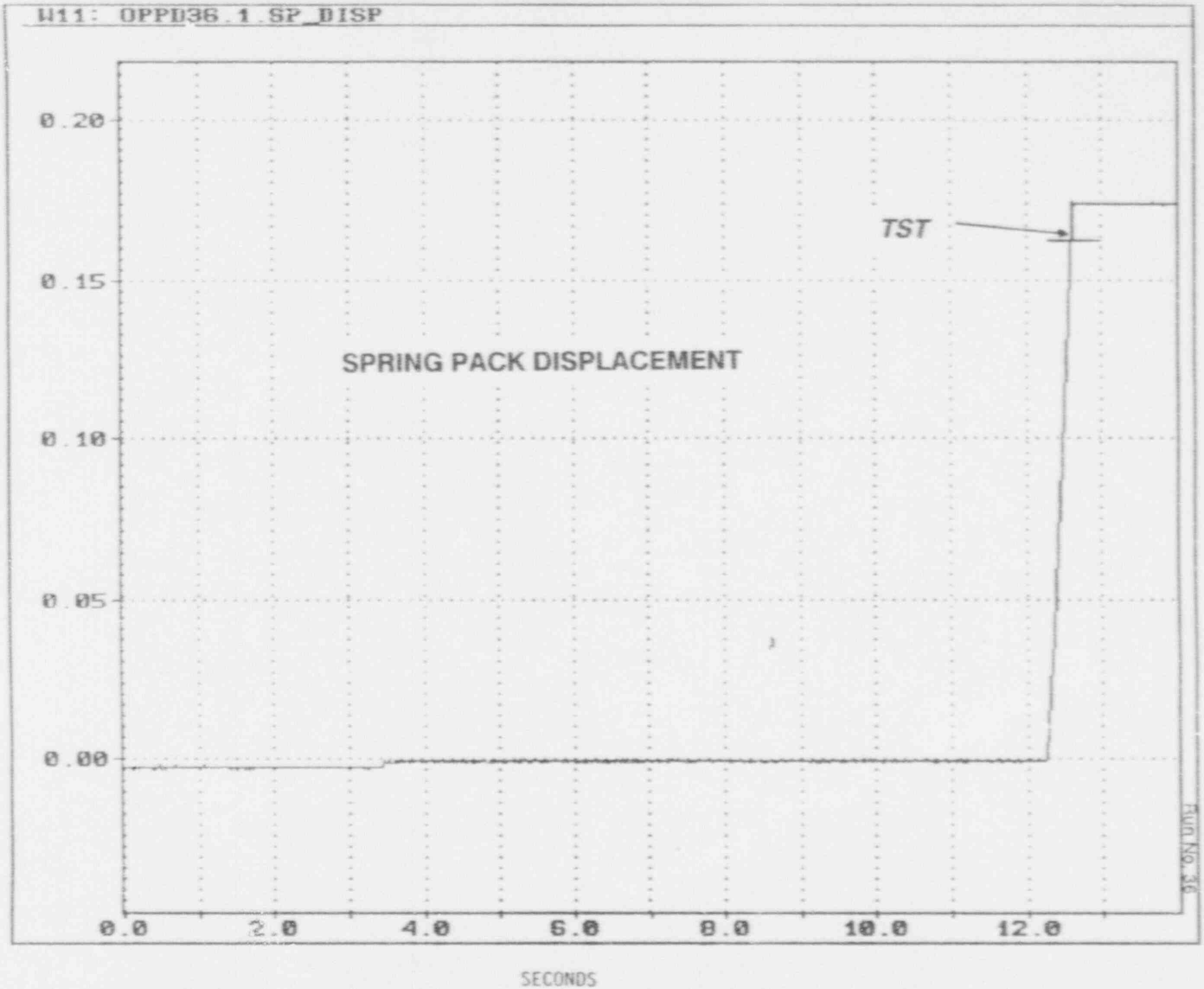
Run No. 36

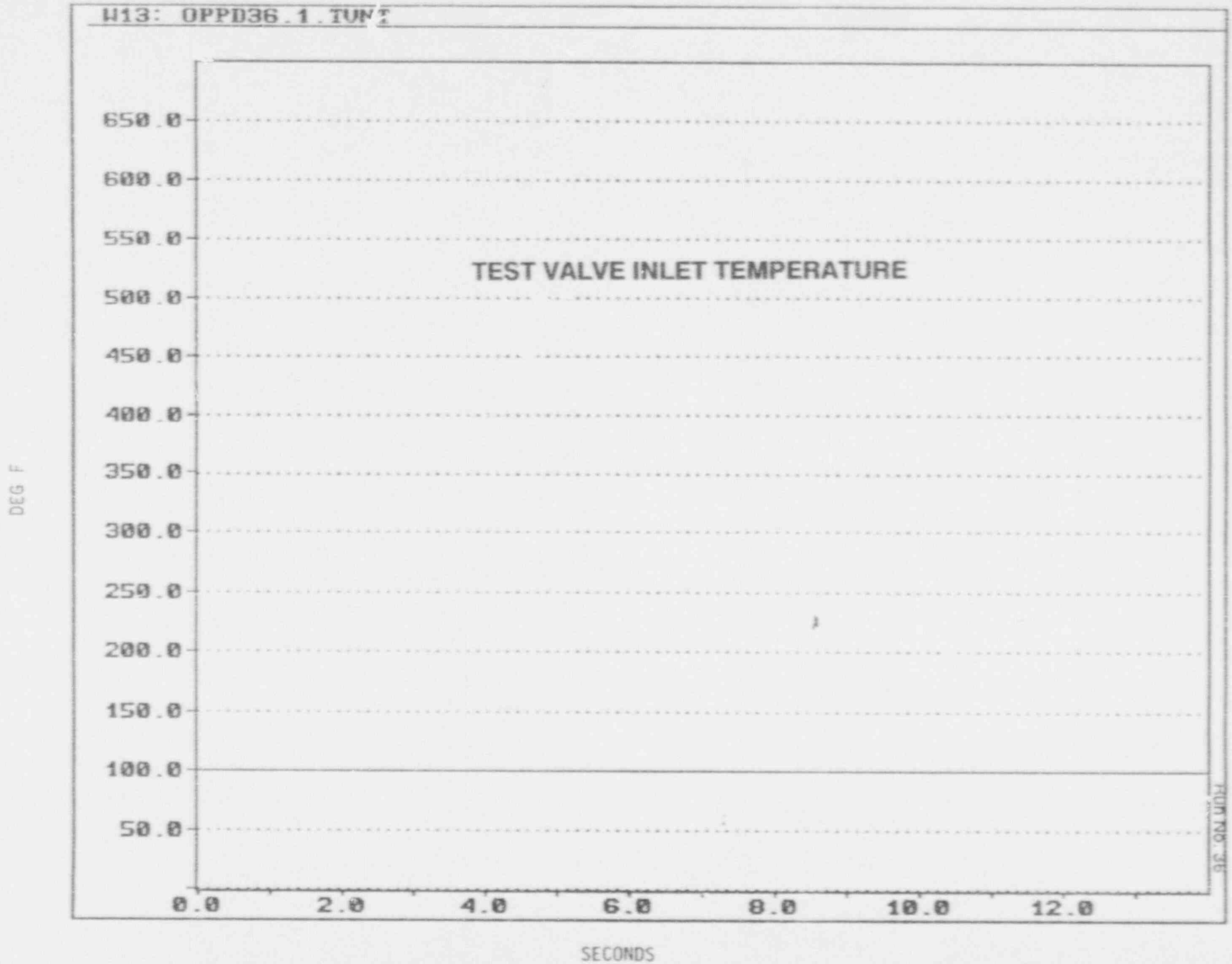

W16: OPPD36.1.MOTOR_I
11-25-91 11:09:56
MOTOR CURRENT
2.89 AMPS
8.0
6.0
4.0
2.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS
AMPS


OPPD 36
W7: MOVAVG2(W1,30,0,0)
MOTOR VOLTAGE
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS
Vrms

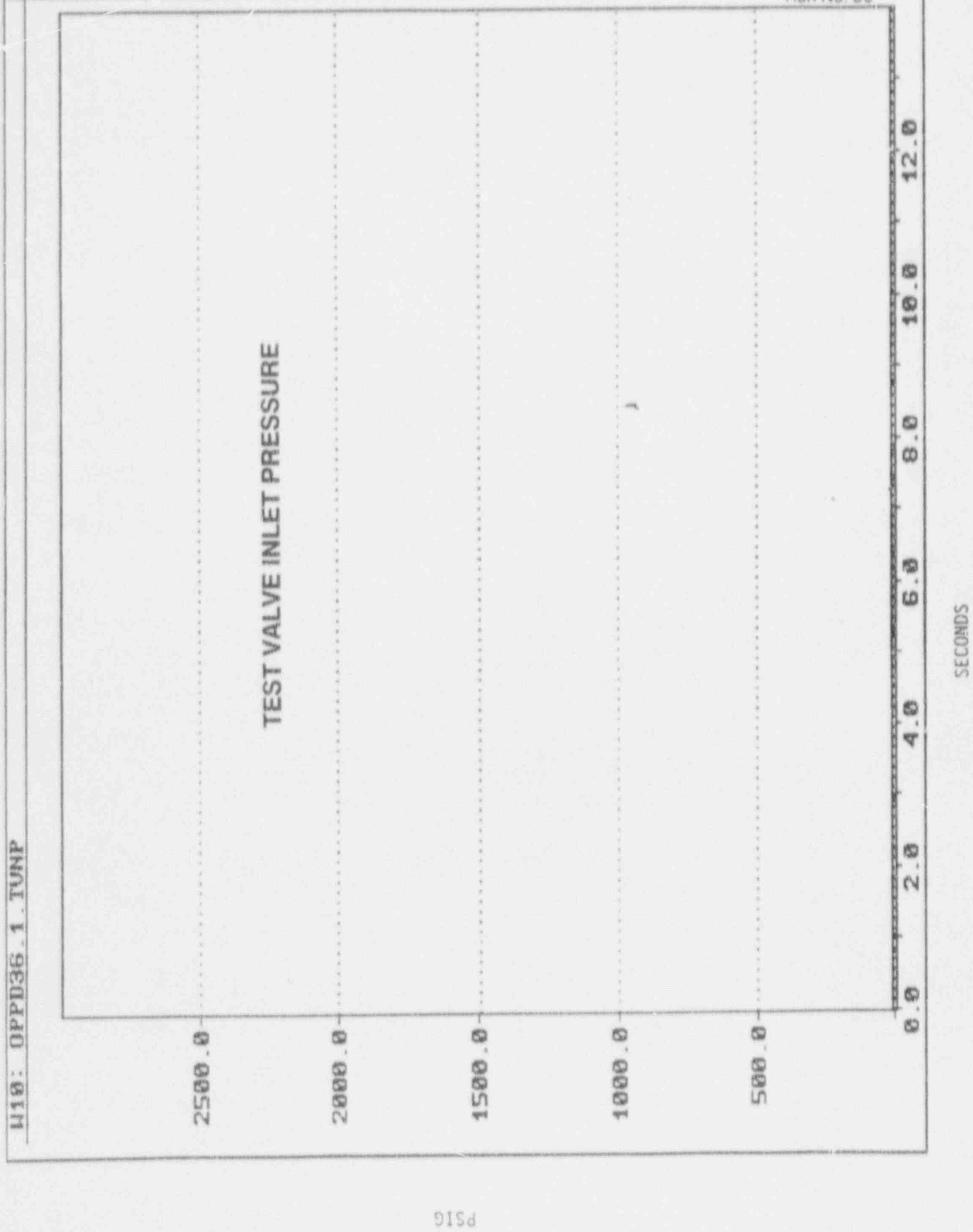

W15: OPPD36.1 TORQ_SW
TORQUE SWITCH
TST
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS
VDC

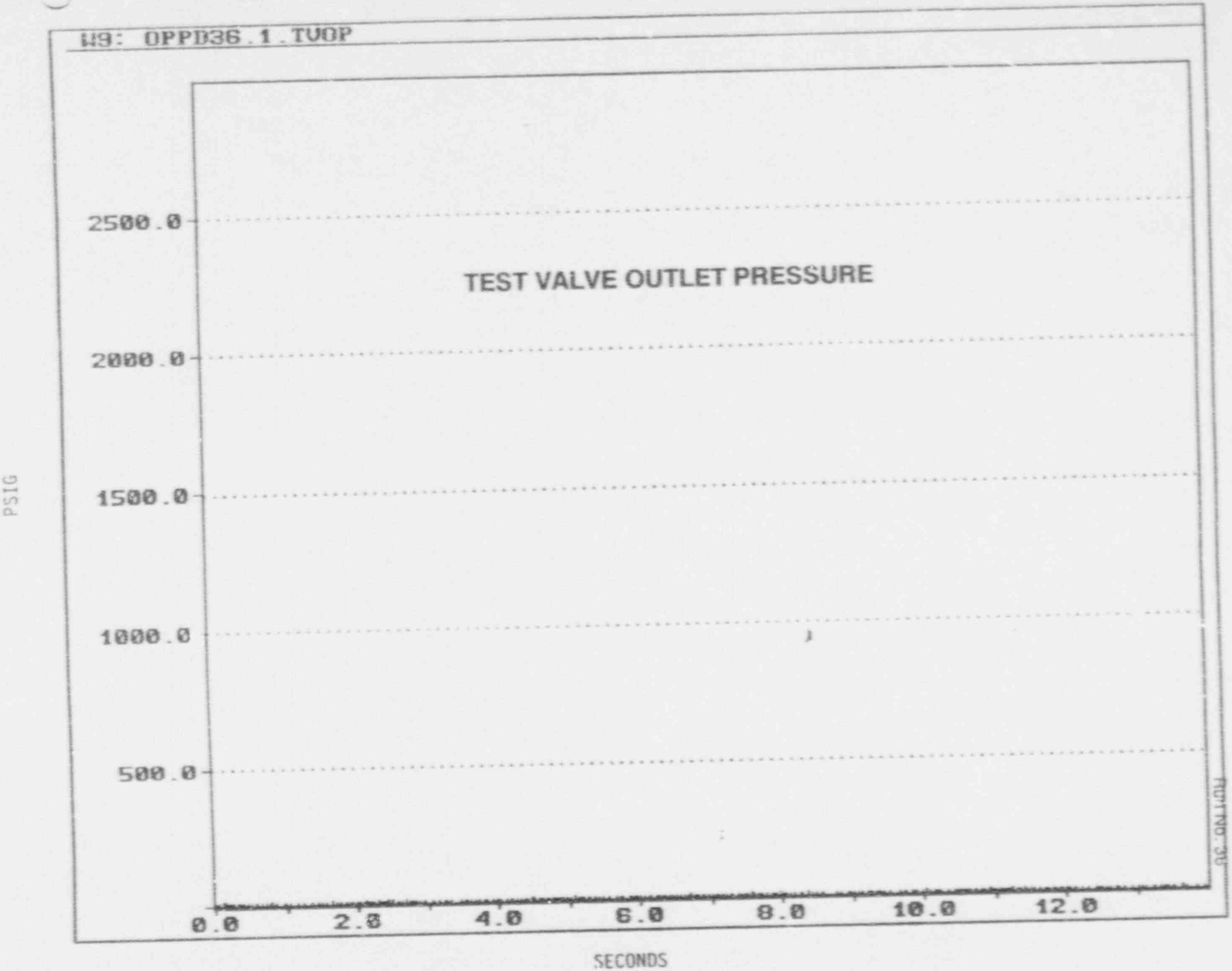

U14: OPPD36.1.STM_DIS
STEM DISPLACEMENT
3.0
2.0
1.0
0.0
INCHES
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS


W11: OPPD36.1.SP_DISP
0.20
0.15
0.10
0.05
0.00
INCHES
SPRING PACK DISPLACEMENT
TST
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS
Run No. 36

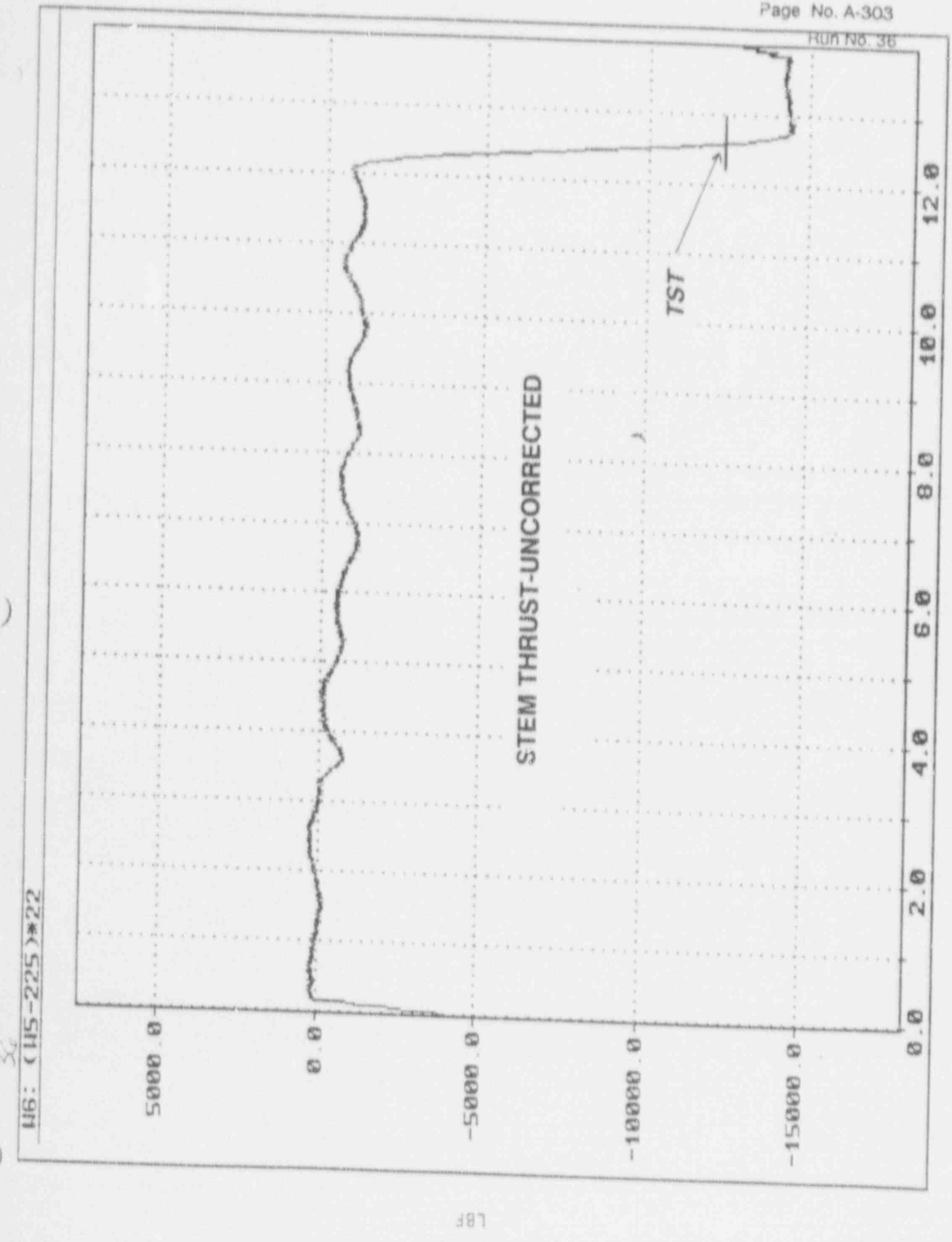


Report No. 57411
Page No. A-300


W10: OPPD36.1 TUNP
TEST VALVE INLET PRESSURE
2500.0
2000.0
1500.0
1000.0
500.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS
PSIG



Report No. 57411
Page No. A-302
Run No. 36



W6: (W5-225)*22
STEM THRUST-UNCORRECTED
TST
5000.0
0.0
-5000.0
-10000.0
-15000.0
LBF
0.0
2.0
4.0
6.0
8.0
10.0
12.0
SECONDS

APPENDIX G

MOTOR CURRENT TRACES FROM THE
LATEST MOV DIAGNOSTIC TESTS

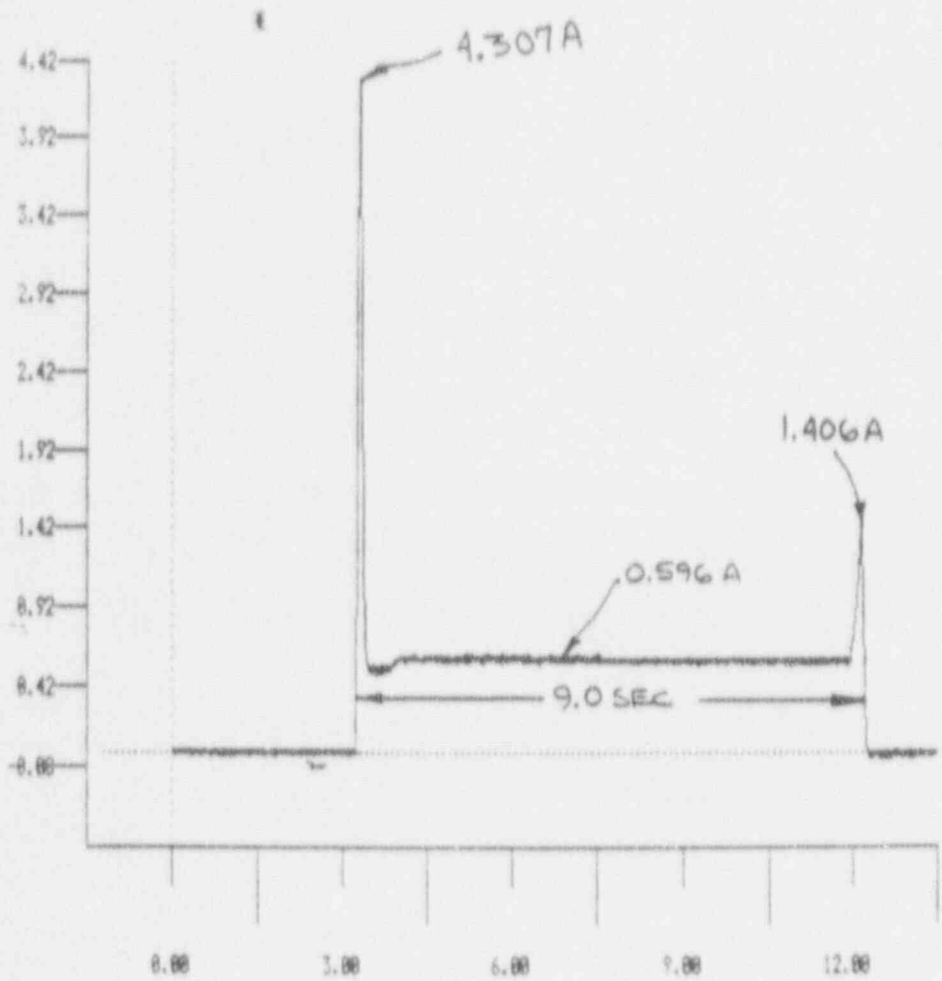
DATIS by Impell Corporation
MOV Test & Analysis Application
Version 3A. 01/06/89
Analysis Date & Time
04/05/90 10:31:12 AM
MWO - 894530

File: 03209BAL
Test Date: 03/20/90
Test Number: 1
Test Status: AS LEFT

OPPD

Fort Calhoun Station

Motor Current vs Stroke Time (CLOSE)



CURSOR

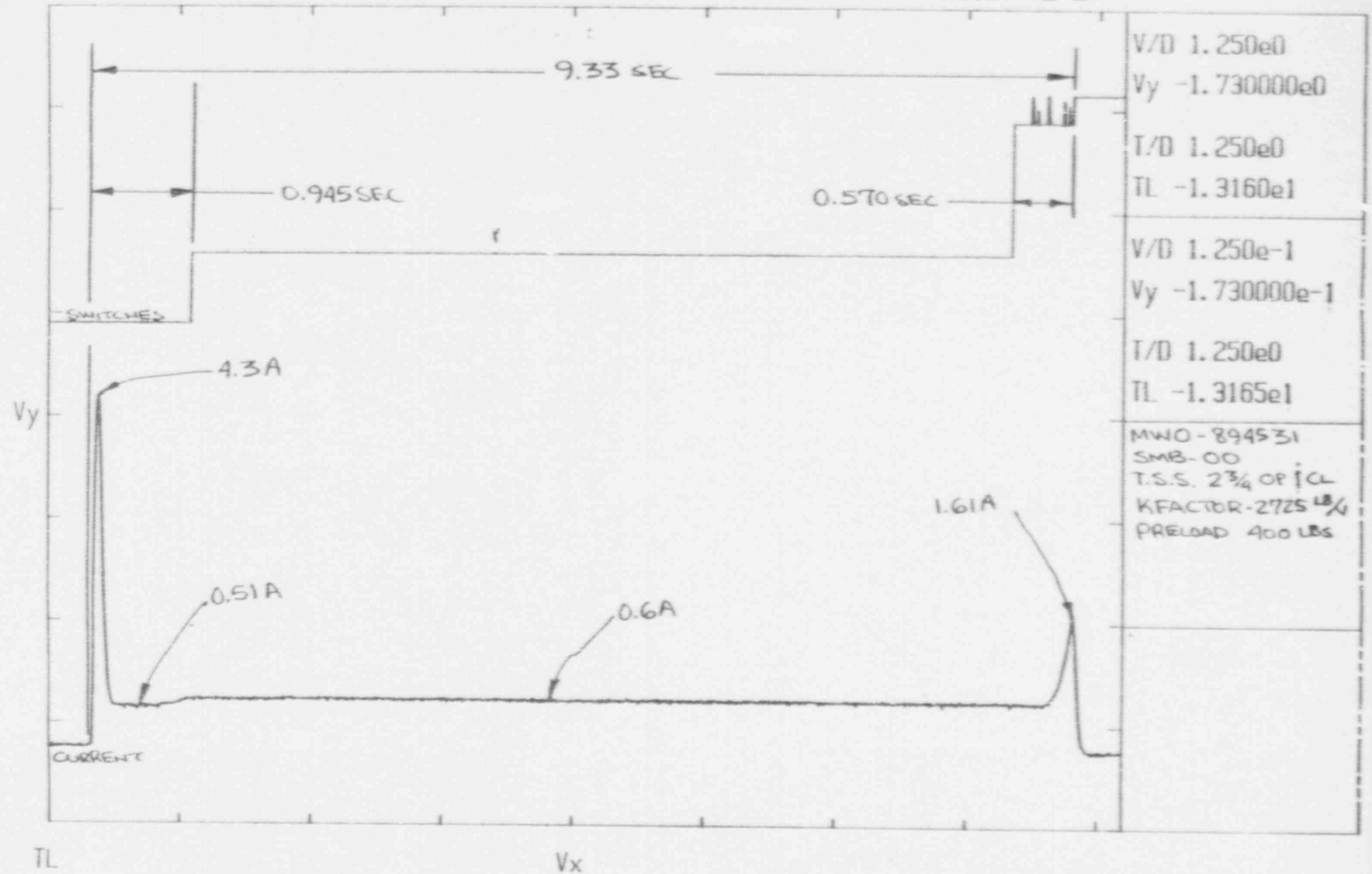
Secs	0.000
Amp	0.000

SWITCH TIME

TS	NOTR
BPS	NOTR
RLS	1.485

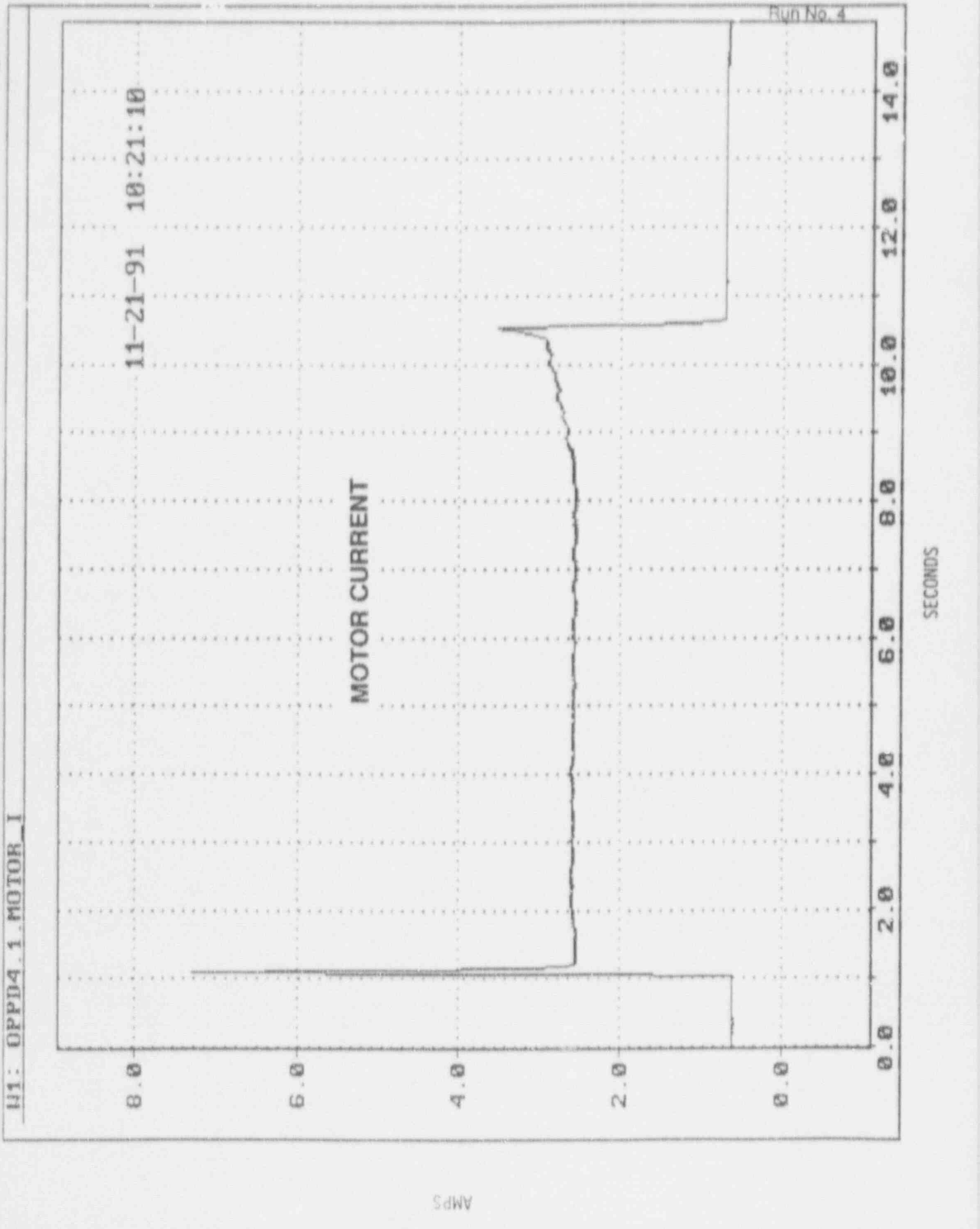
Valve: HCV-150 Test # 1 File: 03209BAL

AL CS-OC HCV-151 3/22/90

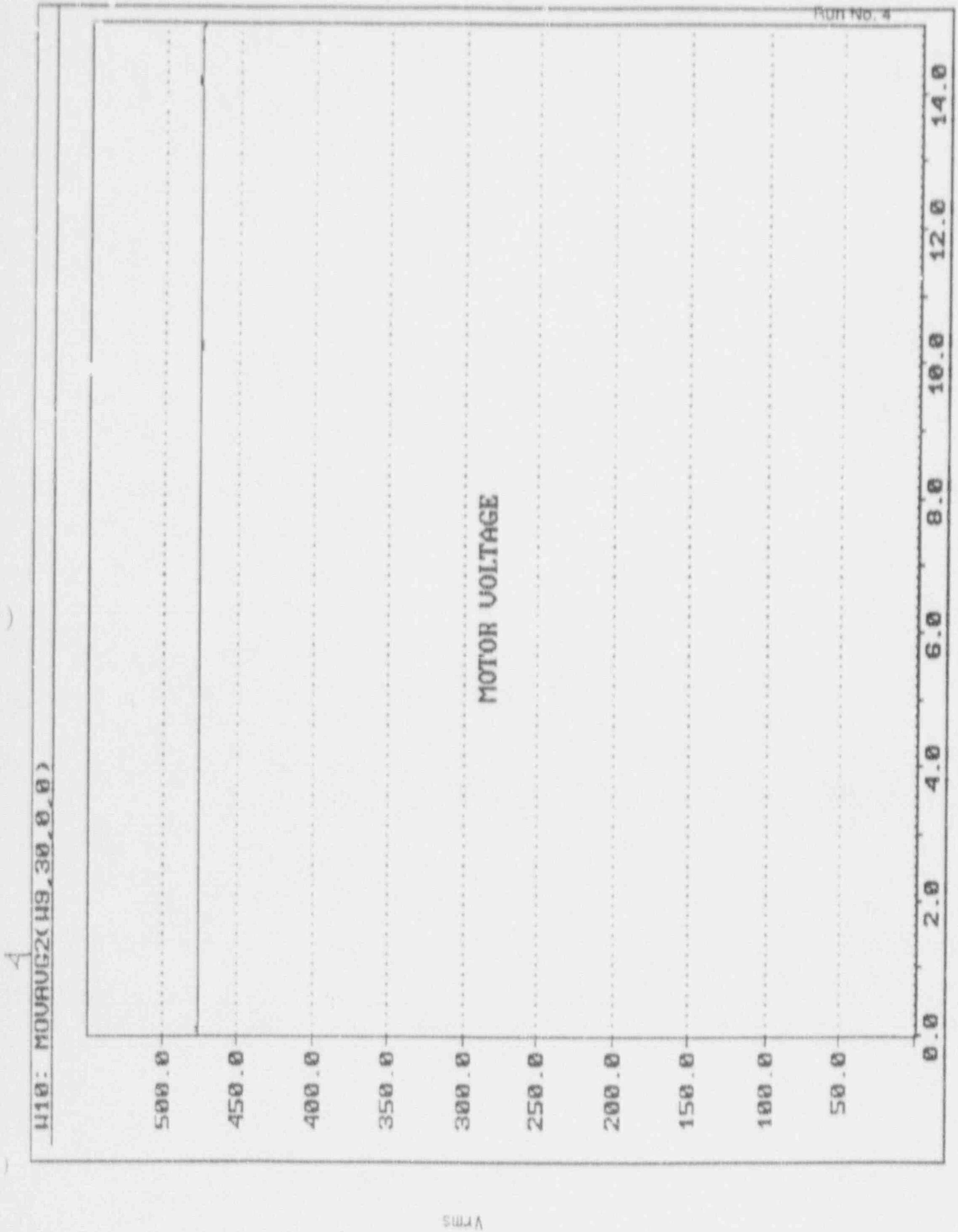


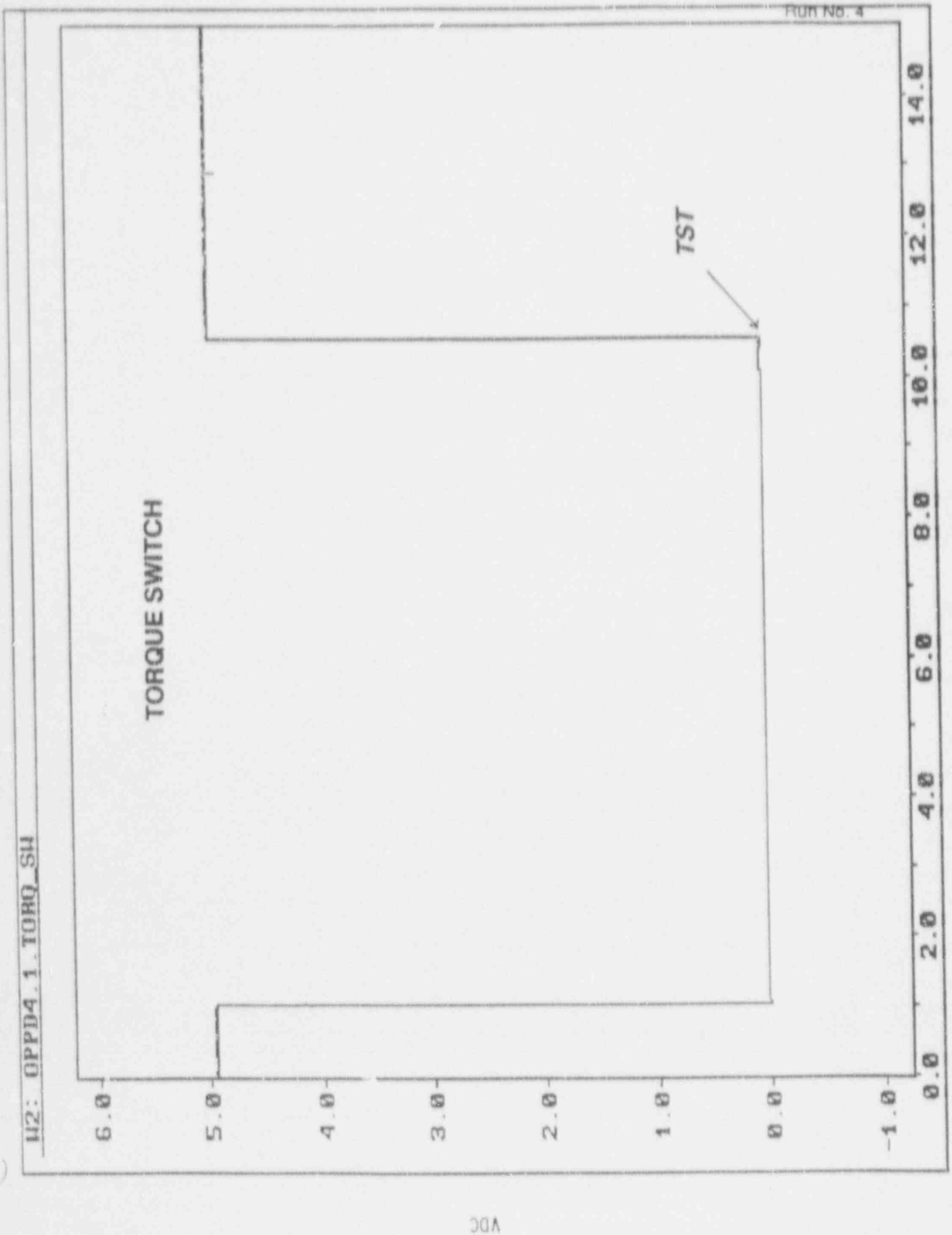
APPENDIX H

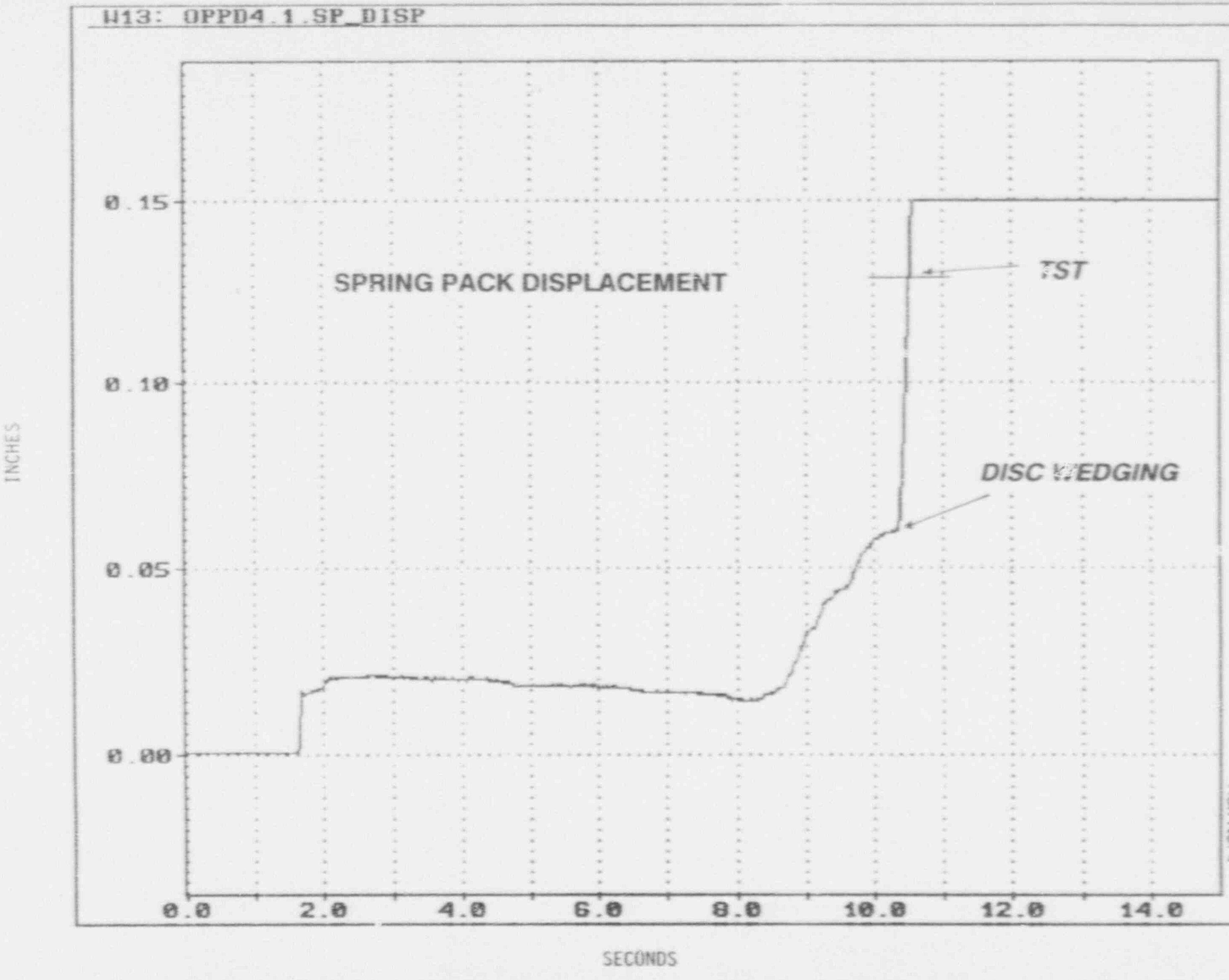
DATA PLOTS FOR TEST RUN 4


Run No. 4
01: OPPD4_1.MOTOR_I
11-21-91 10:21:10
MOTOR CURRENT
8.0
6.0
4.0
2.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
SECONDS
AMPS

Run No. 4

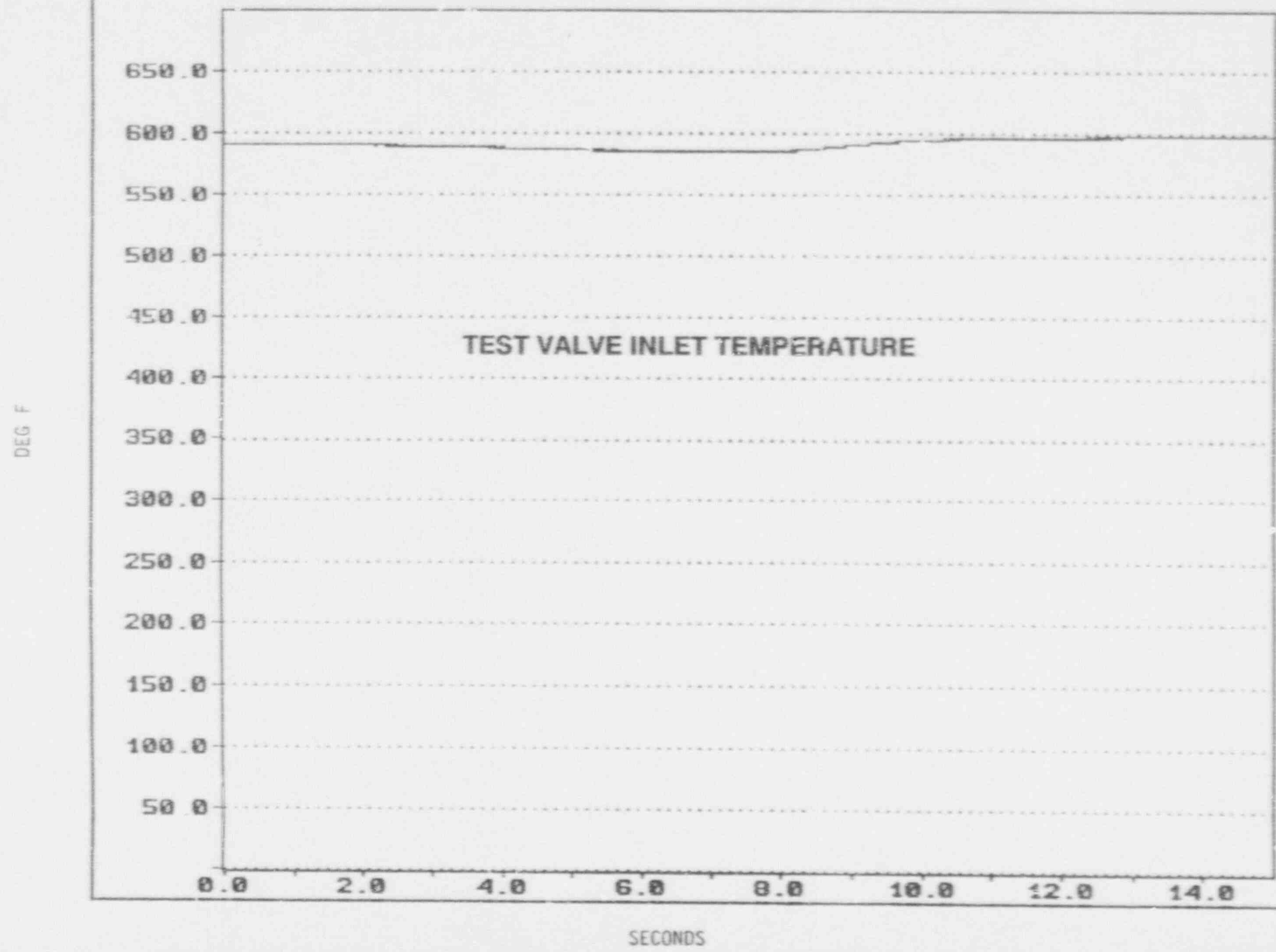

W10: MOVAVG2(W9,30,0,0)
MOTOR VOLTAGE
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
SECONDS
Vrms


W2: OPPD4.1.TORQ_SW
TORQUE SWITCH
TST
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
SECONDS
VDC



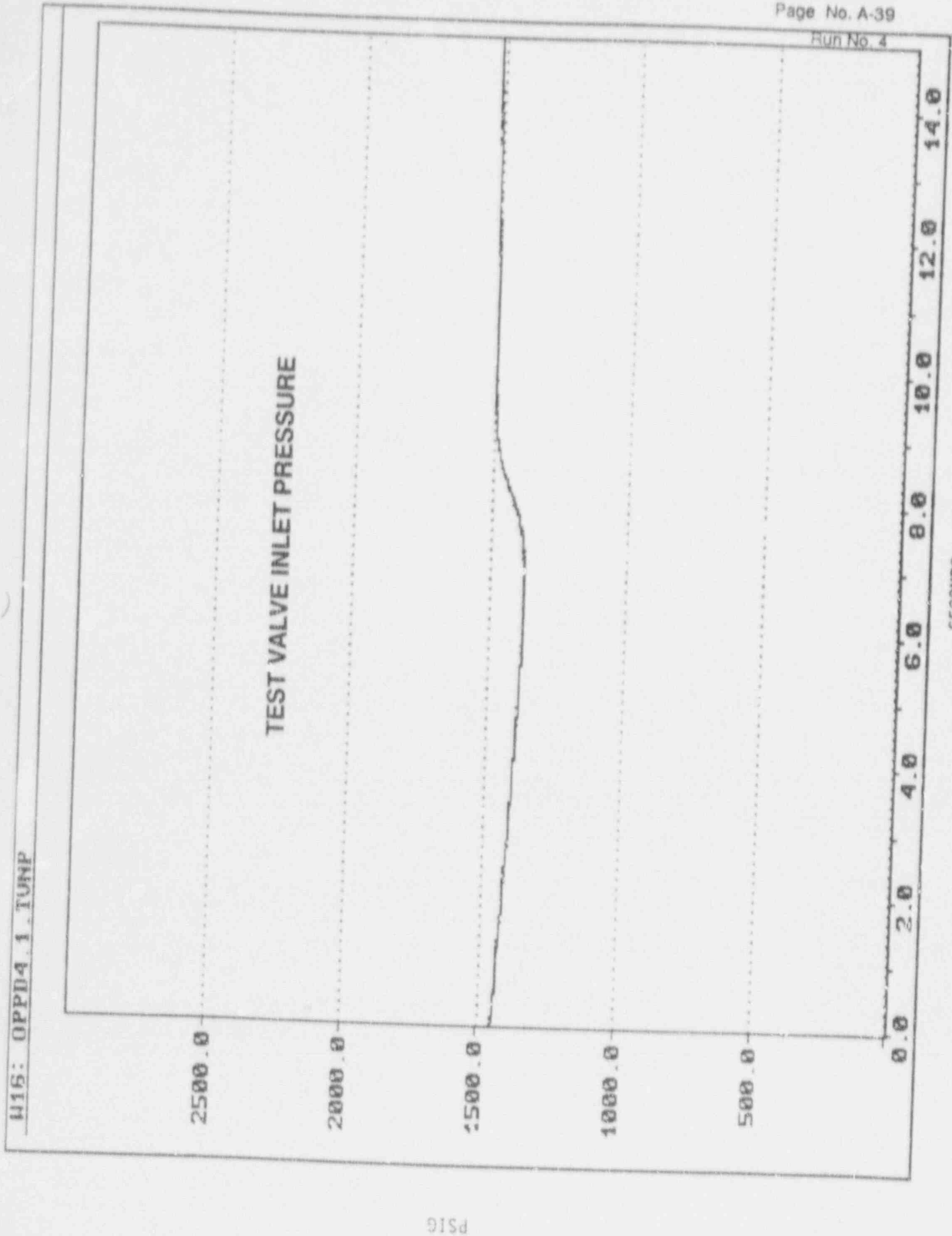
Report No. 57411
Page No. A-37
Run No. 4

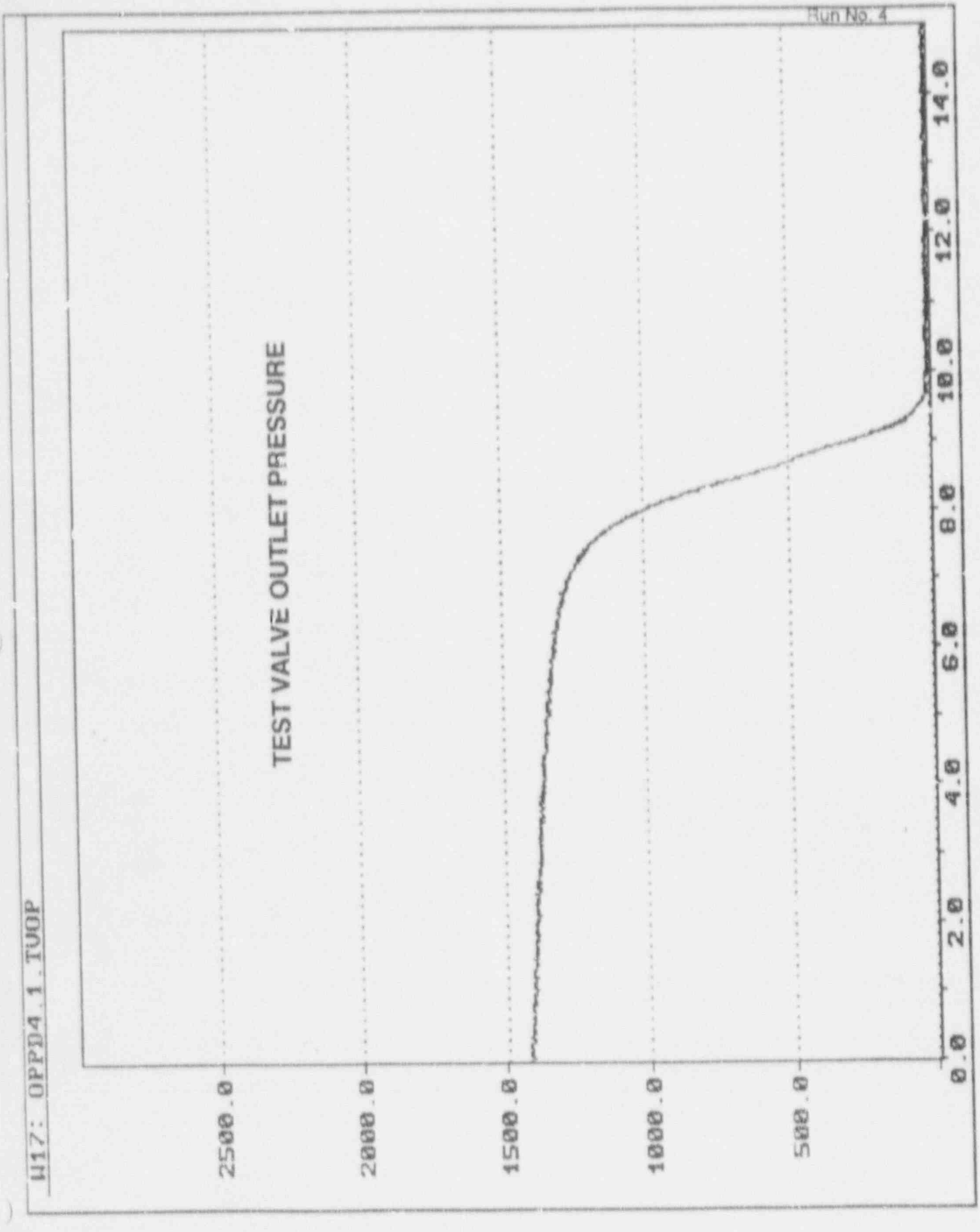
W8: OPPD4.1.TVNT

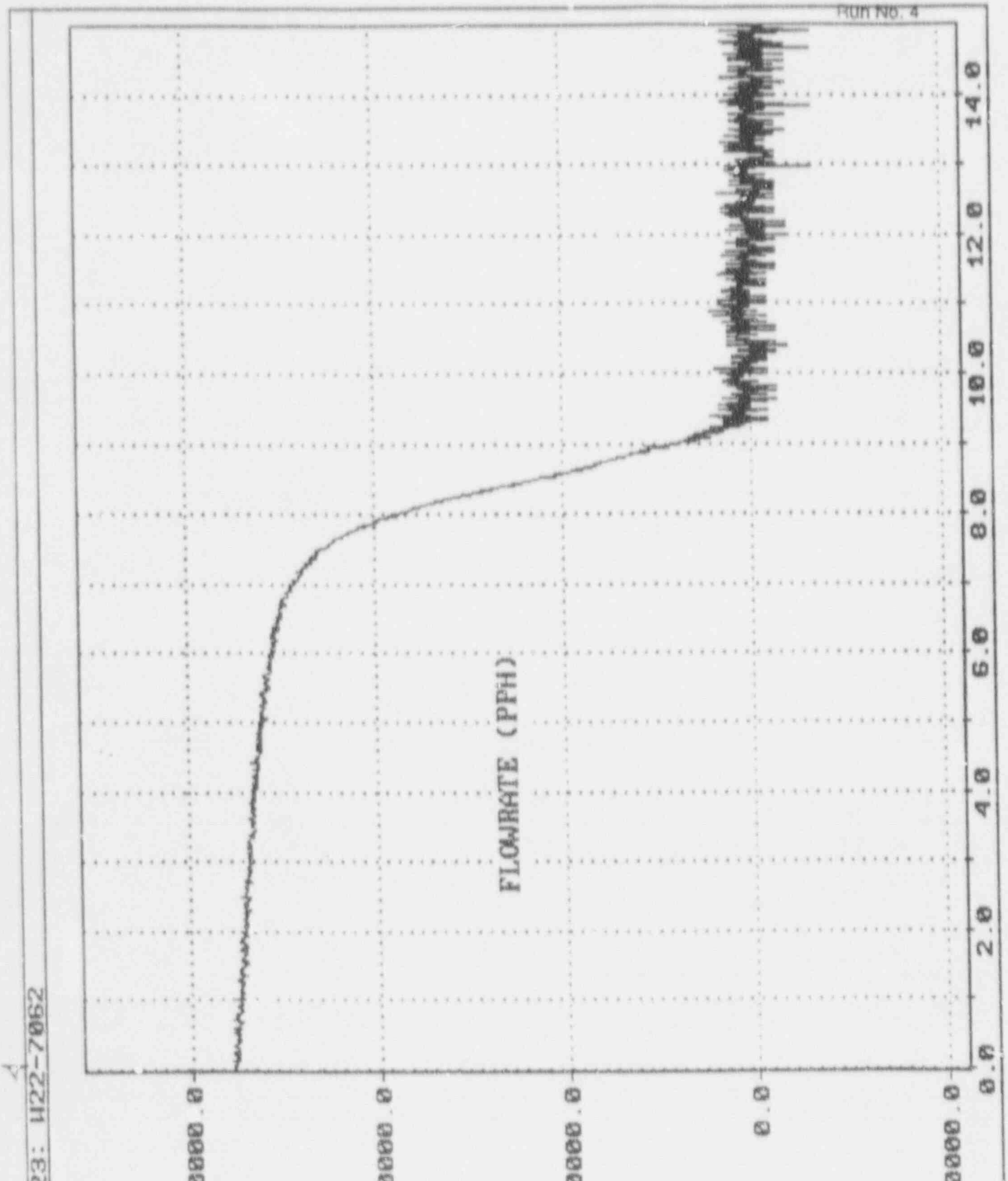


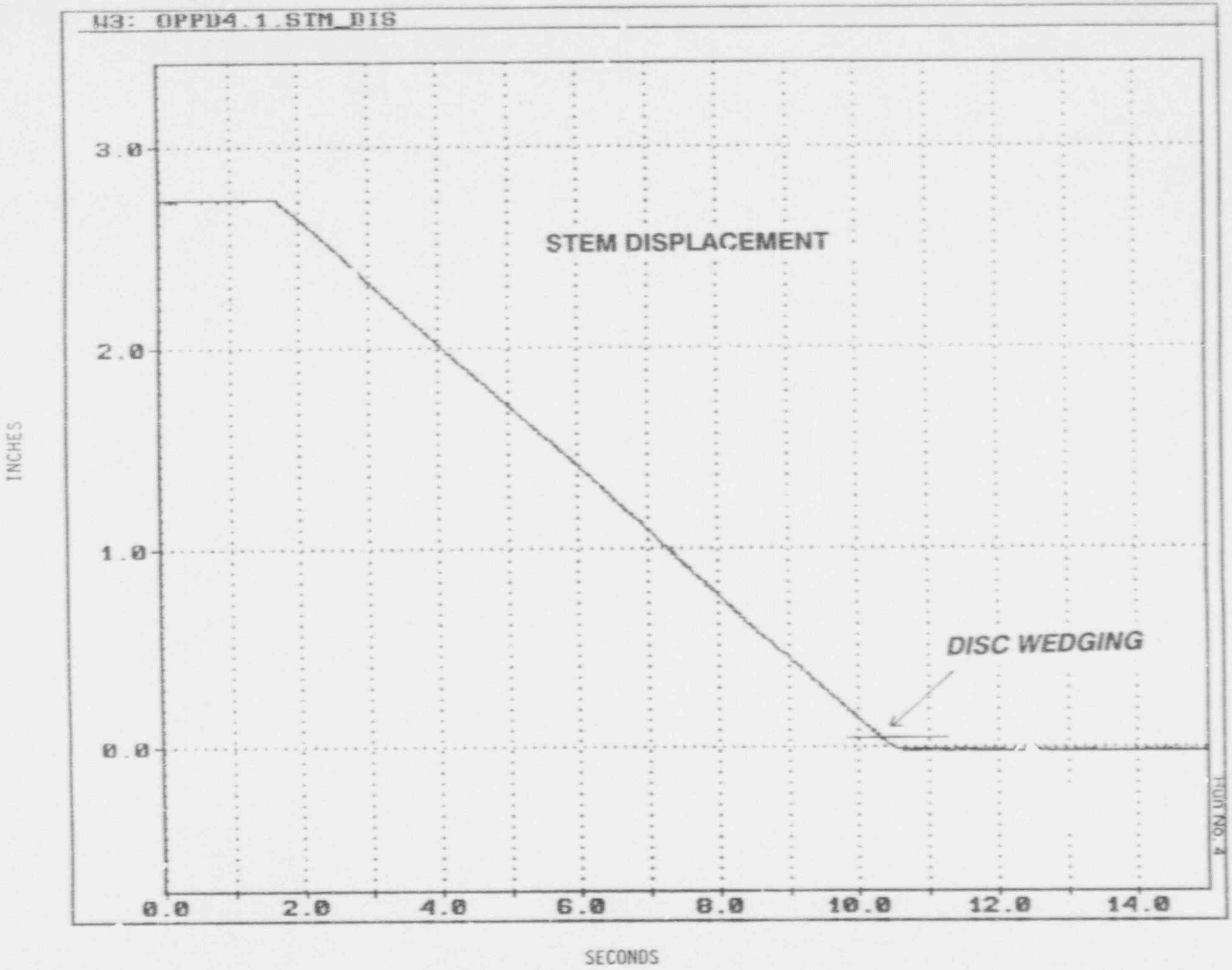
Run No. 4

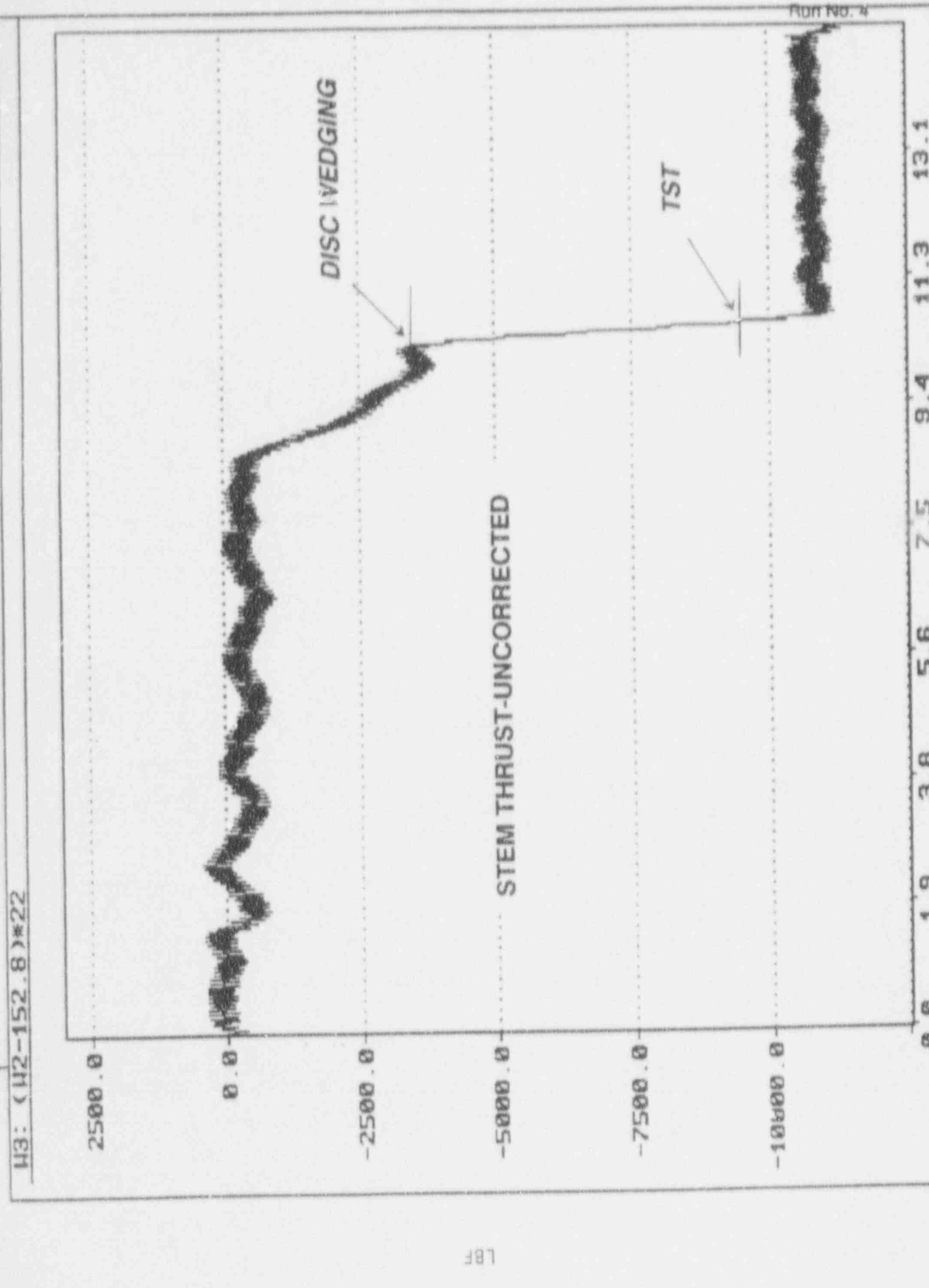
Report No. 57411
Page No. A-38


Run No. 4
W16: OPPD4 1 TUNP
TEST VALVE INLET PRESSURE
2500.0
2000.0
1500.0
1000.0
500.0
PSIG
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
SECONDS


Run No. 4
W17: OPPD4_1_TUOP
TEST VALVE OUTLET PRESSURE
2500.0
2000.0
1500.0
1000.0
500.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
SECONDS
PSIG


W23: W22-7062
FLOWRATE (PPH)
60000.0
40000.0
20000.0
0.0
-20000.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
SECONDS
PPH

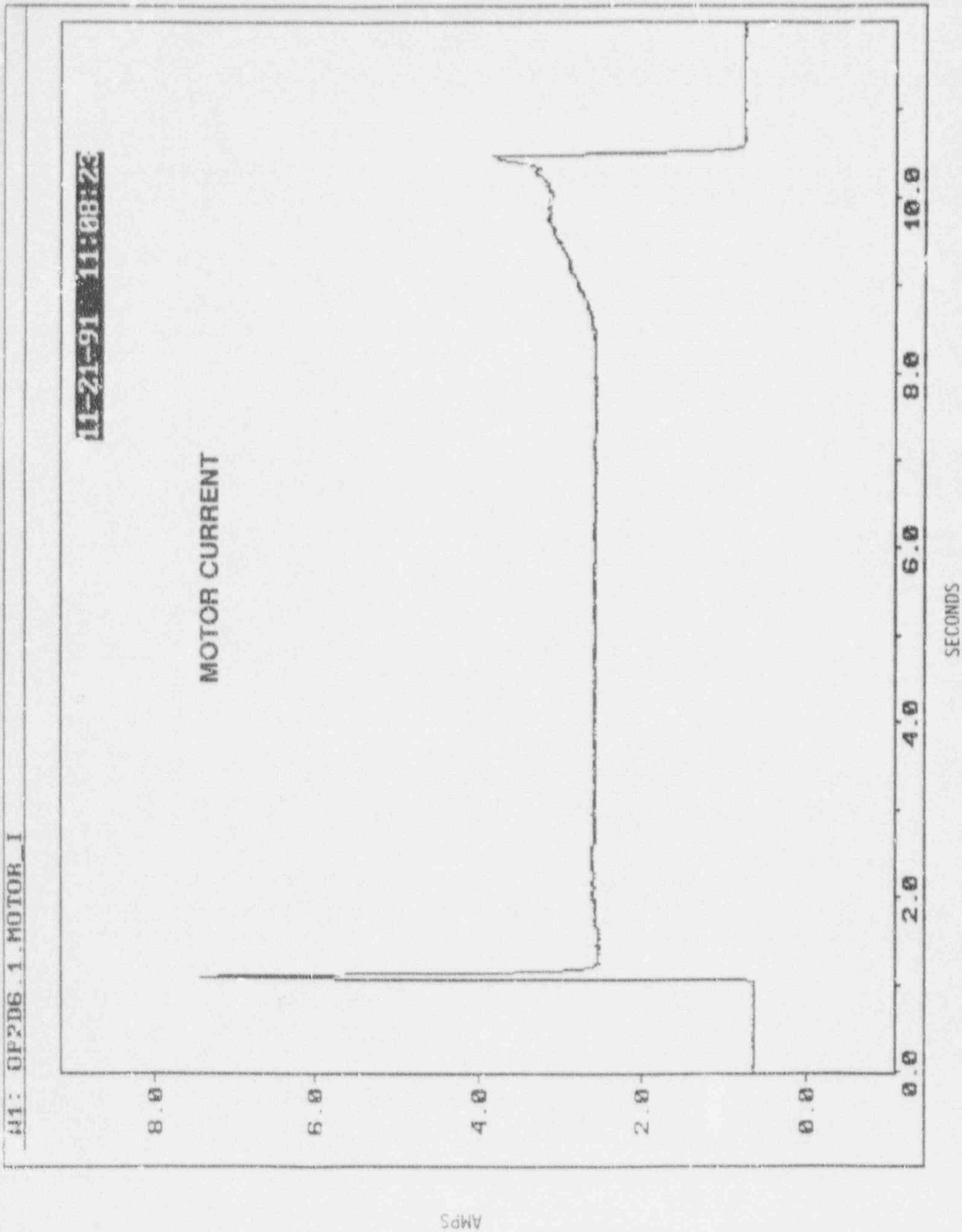

W3: OPPD4.1.STM_DIS
STEM DISPLACEMENT
DISC WEDGING
INCHES
3.0
2.0
1.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
SECONDS
Run No. 4

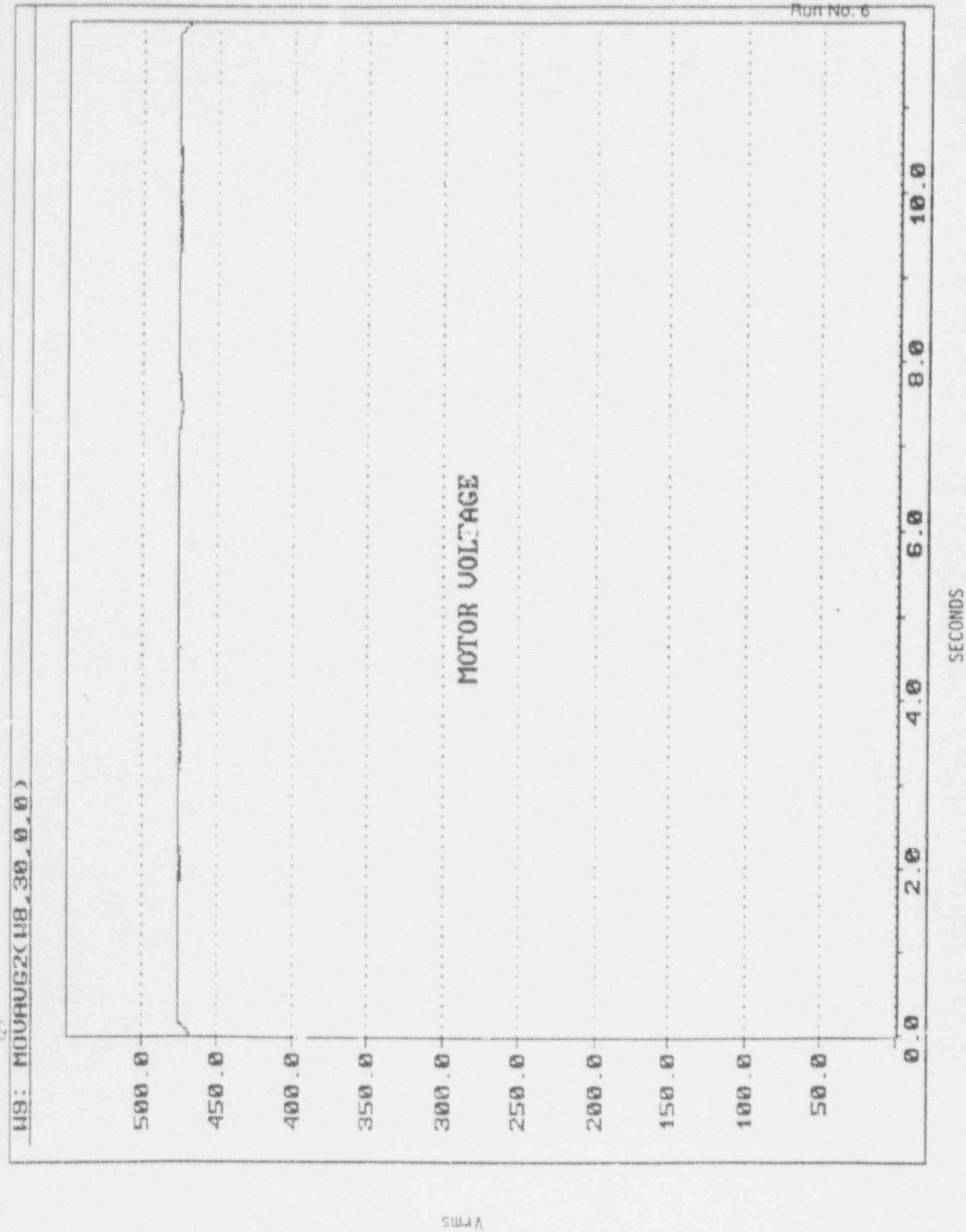

H3: (H2-152.8)*22
2500.0
0.0
-2500.0
-5000.0
-7500.0
-10000.0
LBF
0.0
1.9
3.8
5.6
7.5
9.4
11.3
13.1
SECONDS
DISC WEDGING
TST
STEM THRUST-UNCORRECTED

APPENDIX 1

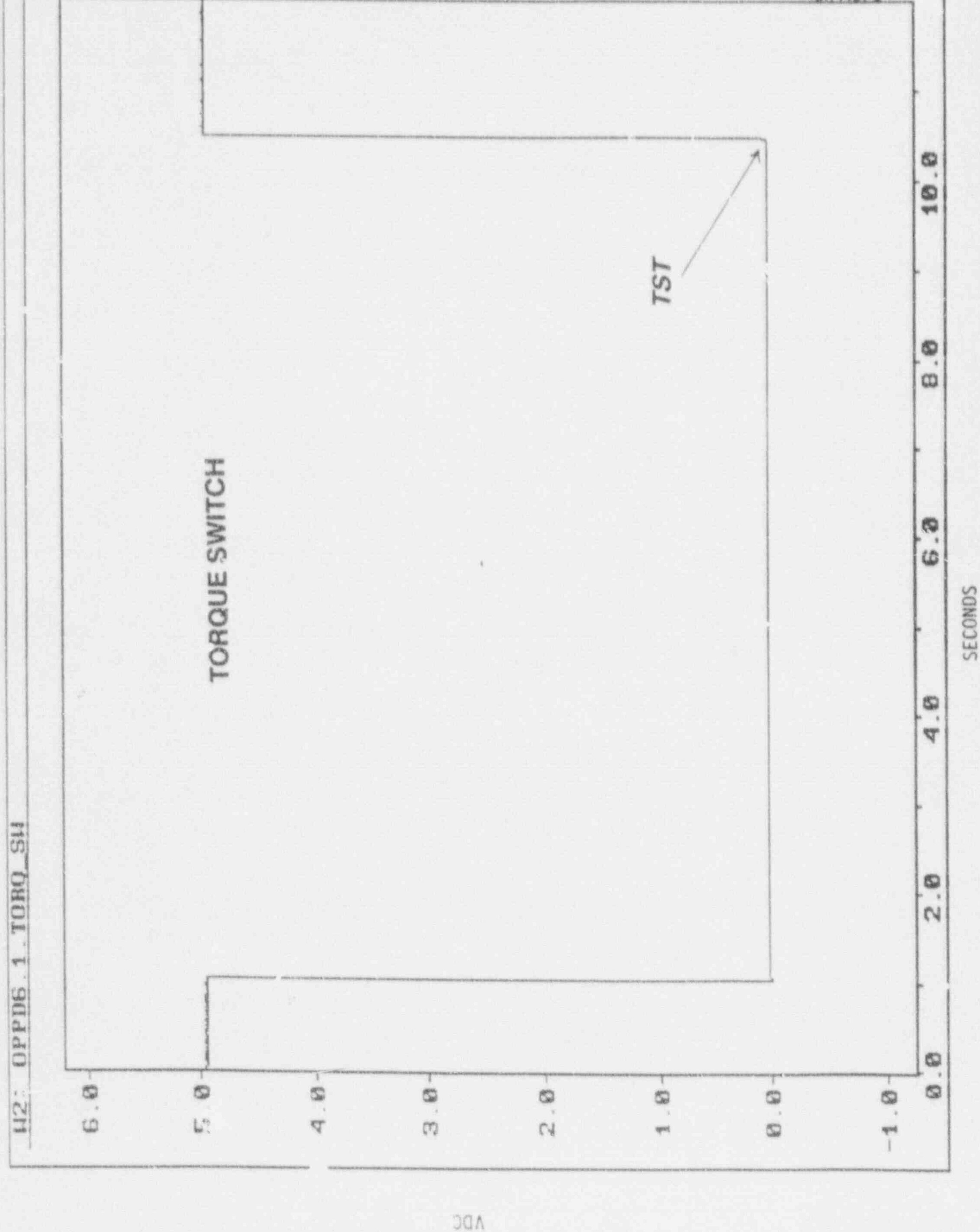
DATA PLOTS FOR TEST RUN 6

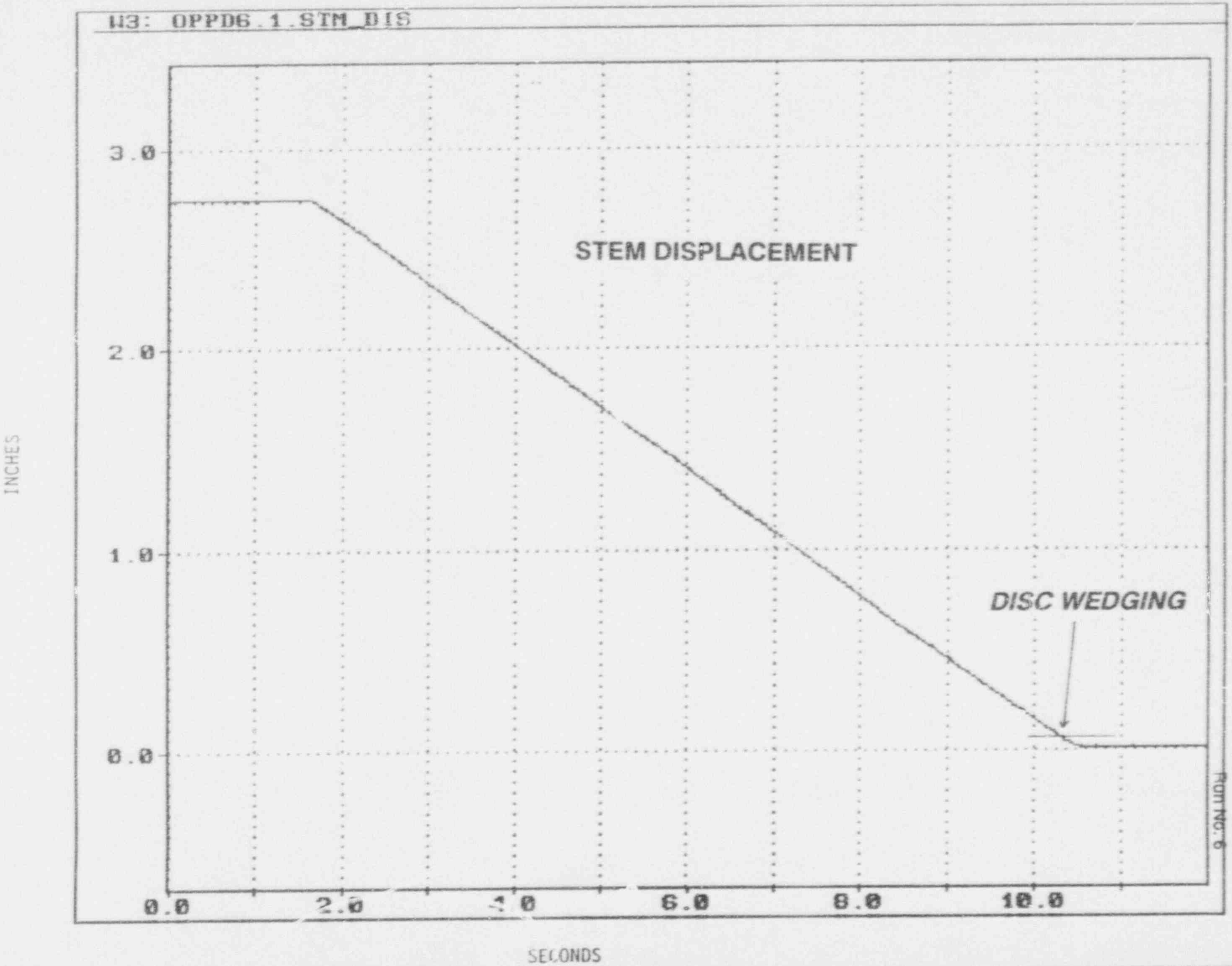
Report No. 57411
Page No. A-58
Run No. 6

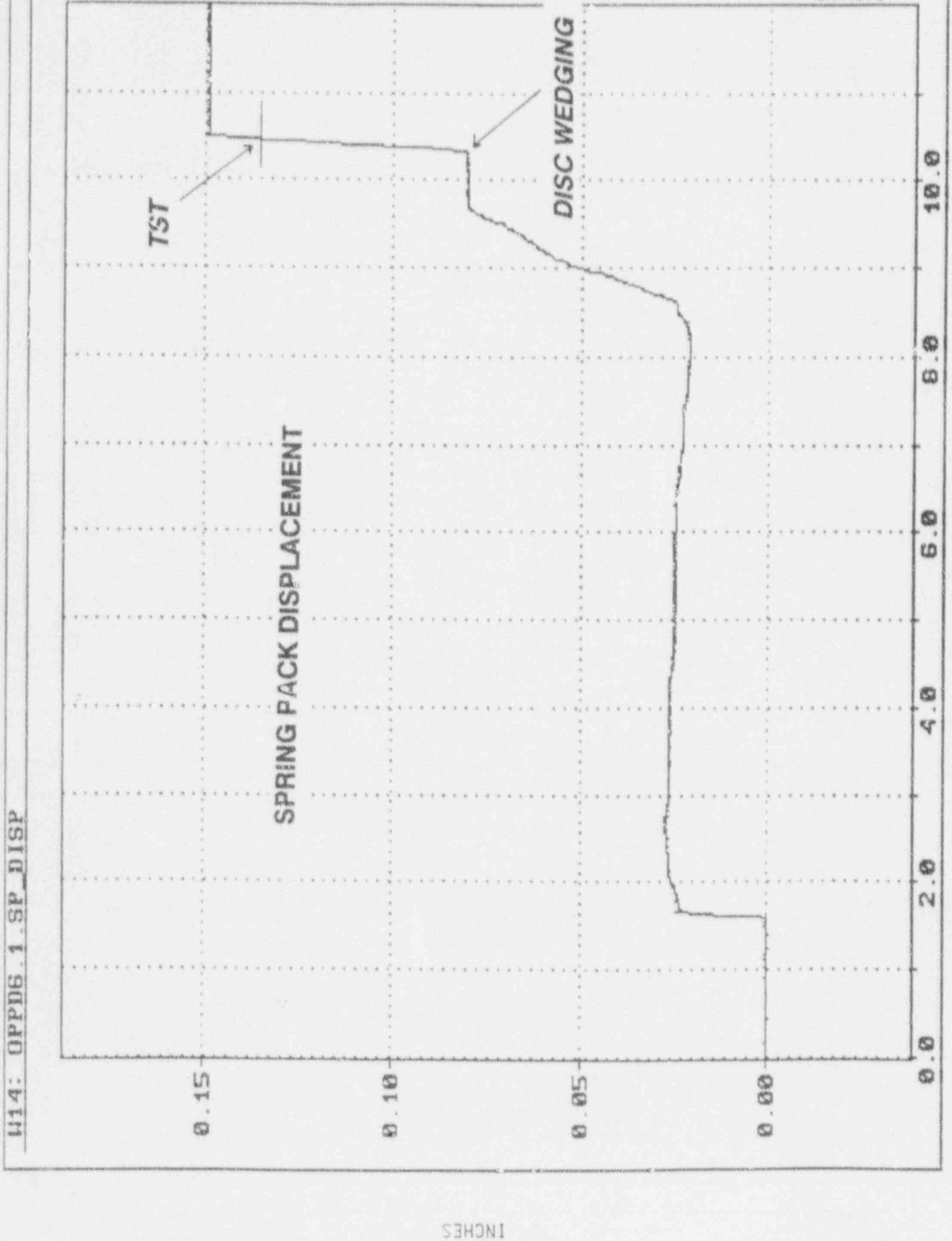


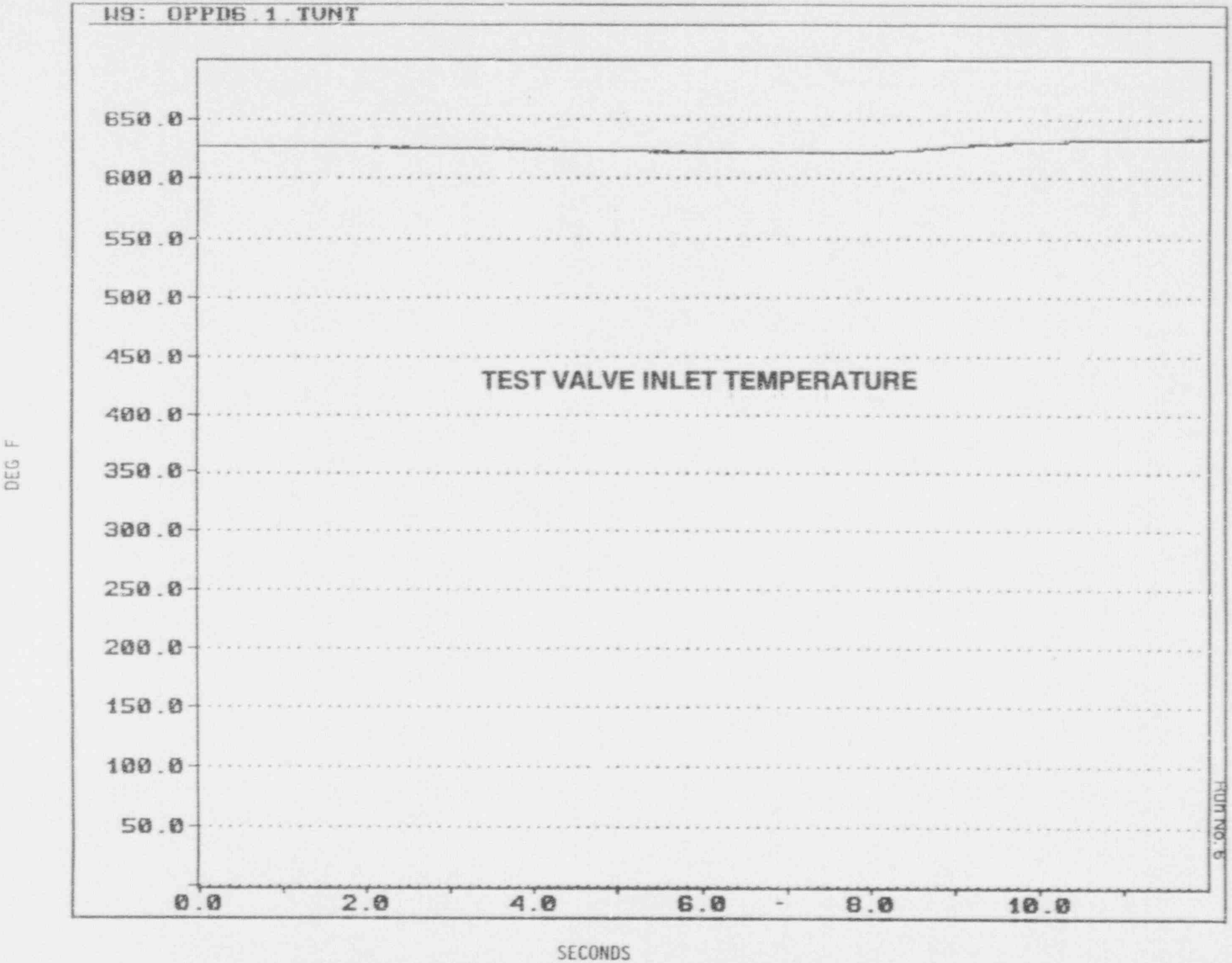

W9: MOVAVG2(W8,30,0,0)
MOTOR VOLTAGE
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS
Vrms

Report No. 57411
Page No. A-60
Run No. 6

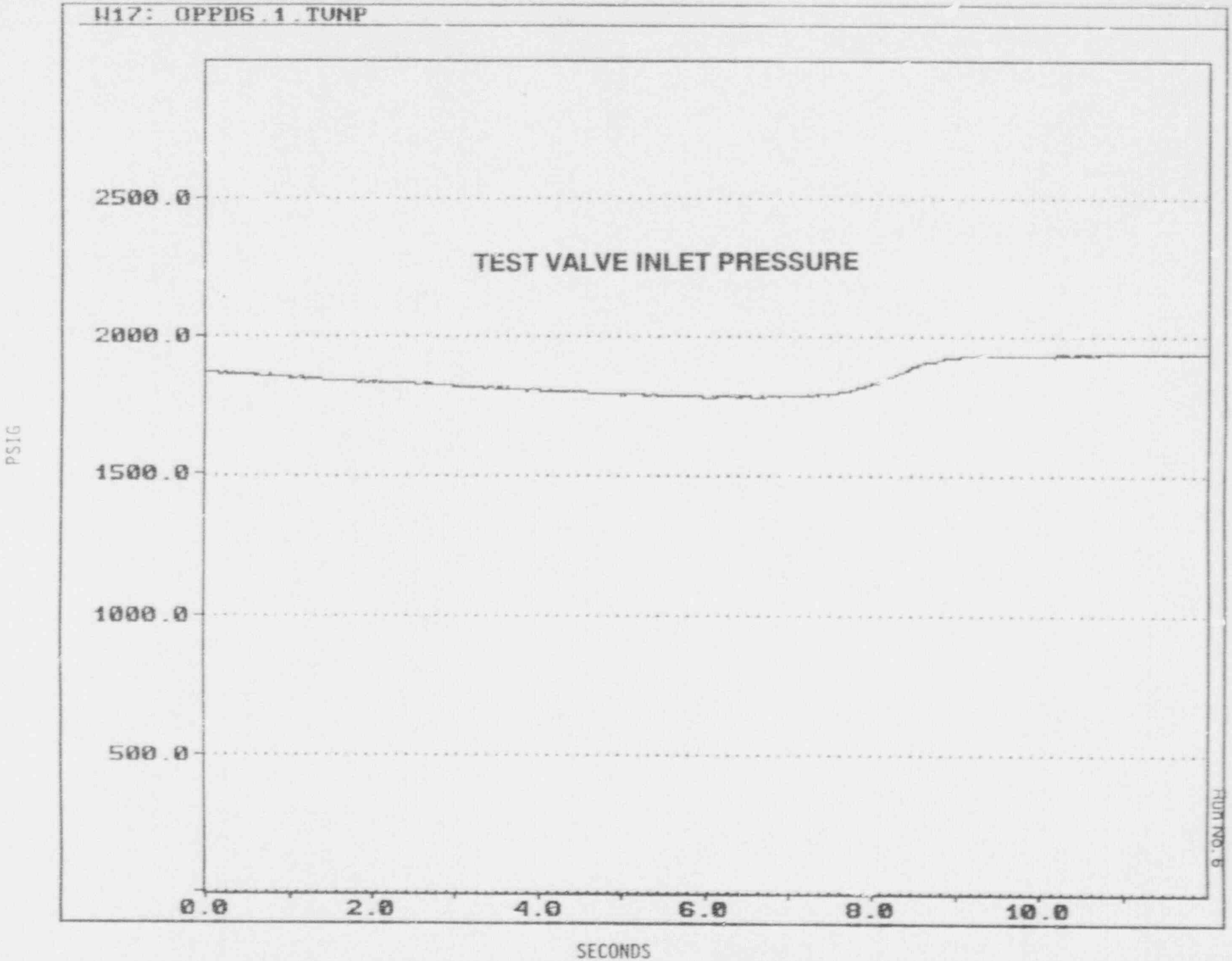



W3: OPPD6.1.STM_DIS
STEM DISPLACEMENT
DISC WEDGING
INCHES
SECONDS
3.0
2.0
1.0
0.0
2.0
6.0
8.0
10.0
Run No. 6

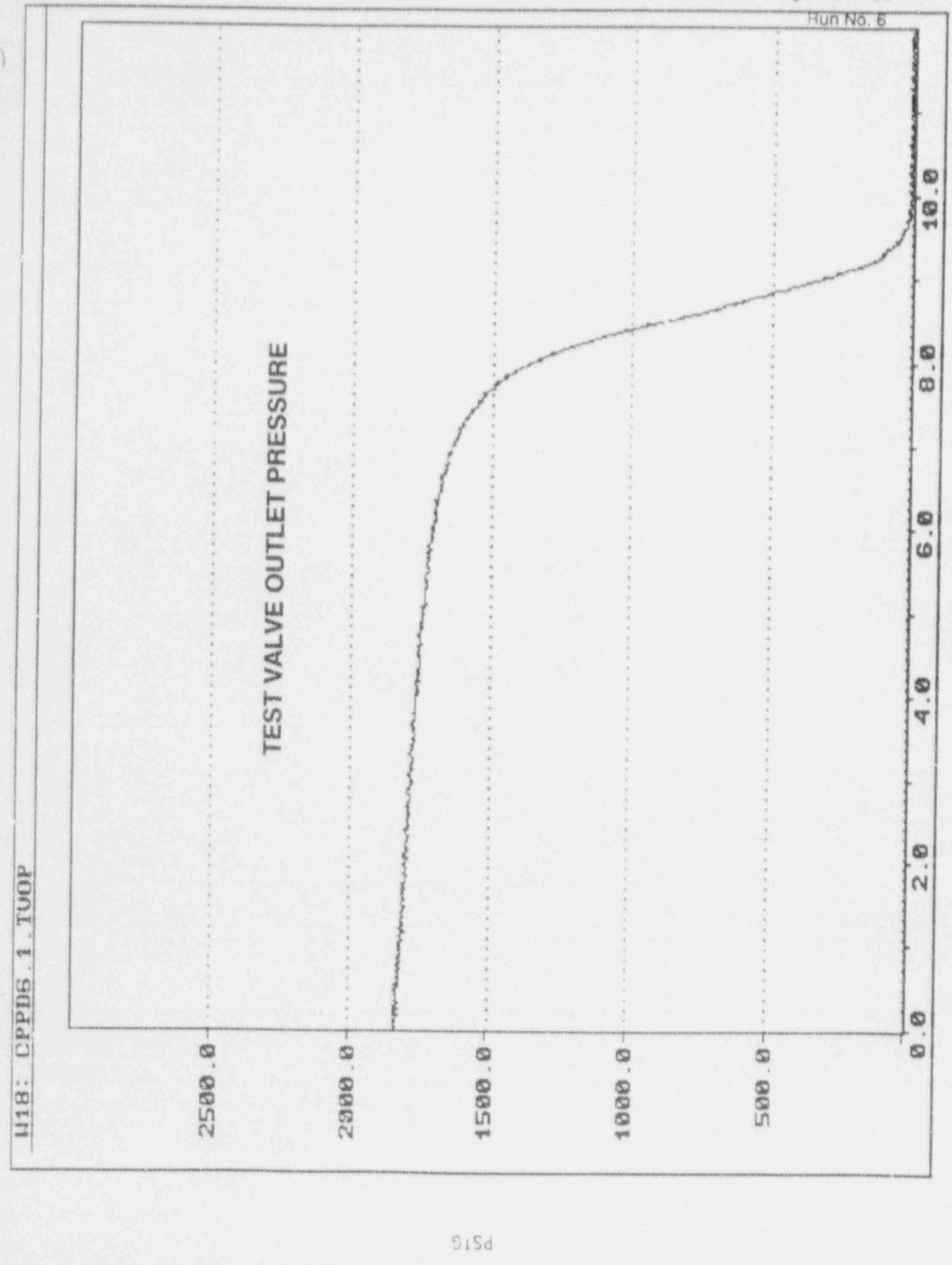

W14: OPPD6.1.SP_DISP
SPRING PACK DISPLACEMENT
TST
DISC WEDGING
0.15
0.10
0.05
0.00
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS
INCHES



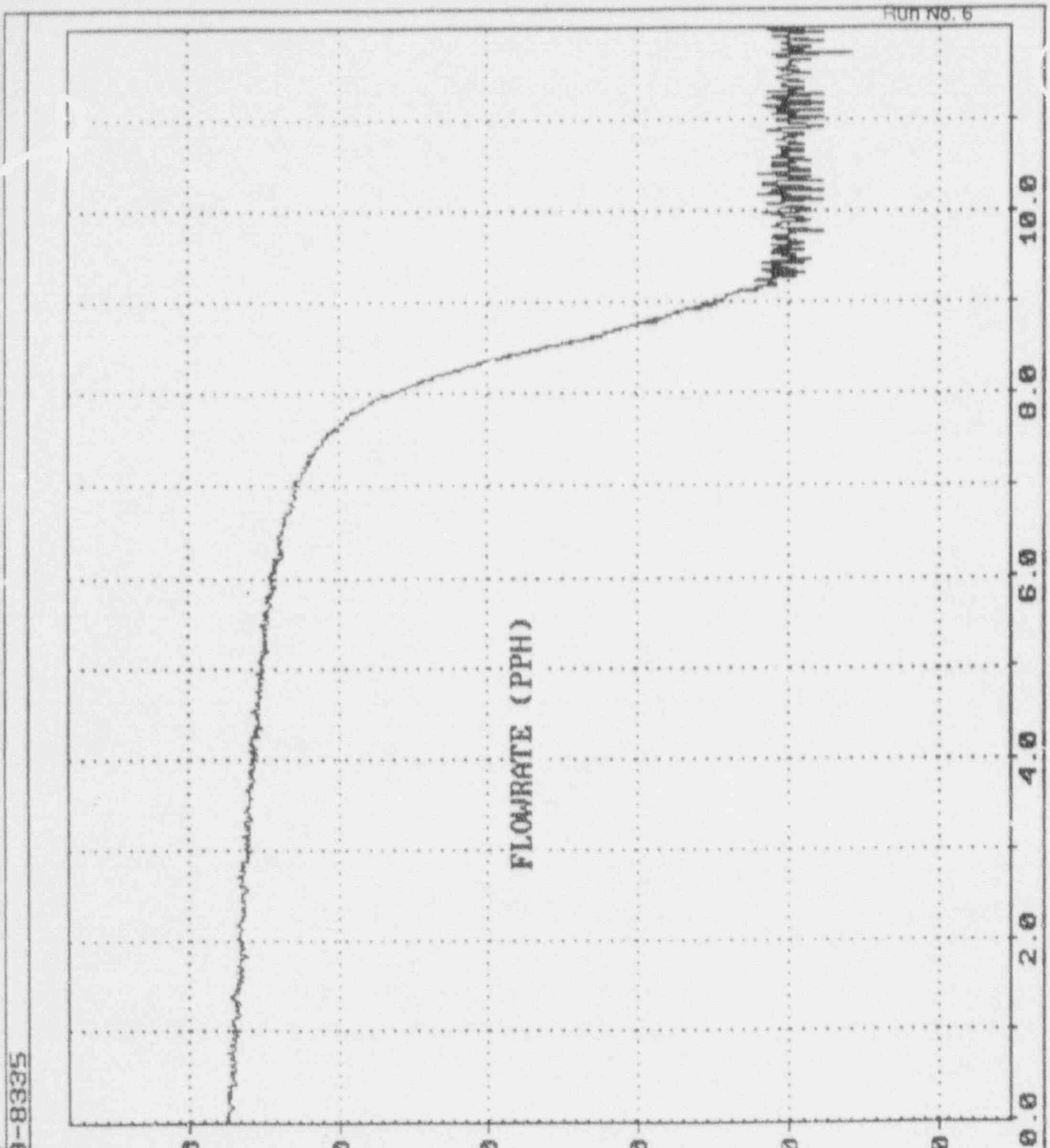
Report No. 57411
Page No. A-64

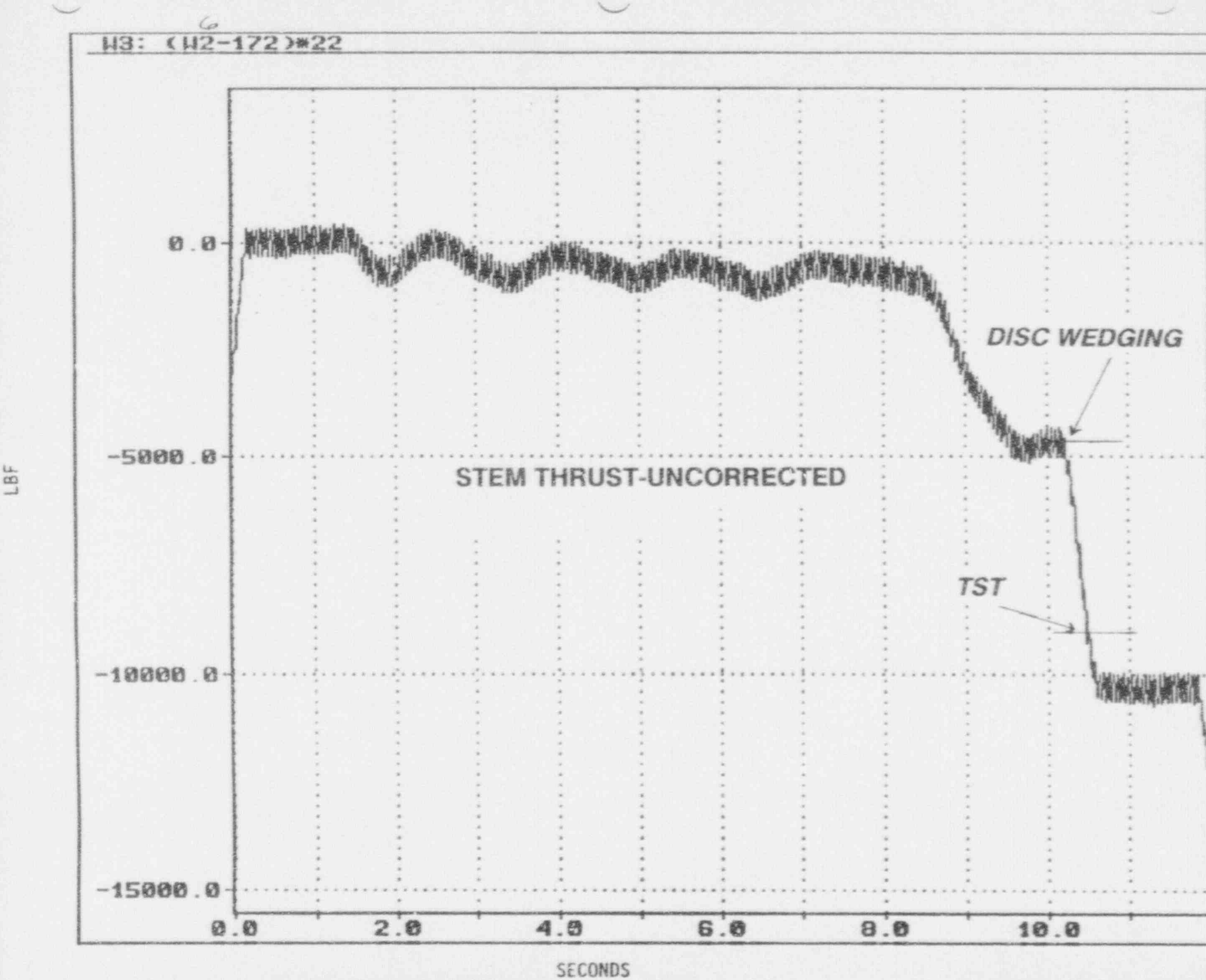

W17: OPPD6.1.TVNP
TEST VALVE INLET PRESSURE
PSIG
2500.0
2000.0
1500.0
1000.0
500.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS
RUN NO. 6

Run No. 6


H18: CPPD6.1.TUOP
TEST VALVE OUTLET PRESSURE
2500.0
2000.0
1500.0
1000.0
500.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS
PSIG

Run No. 6

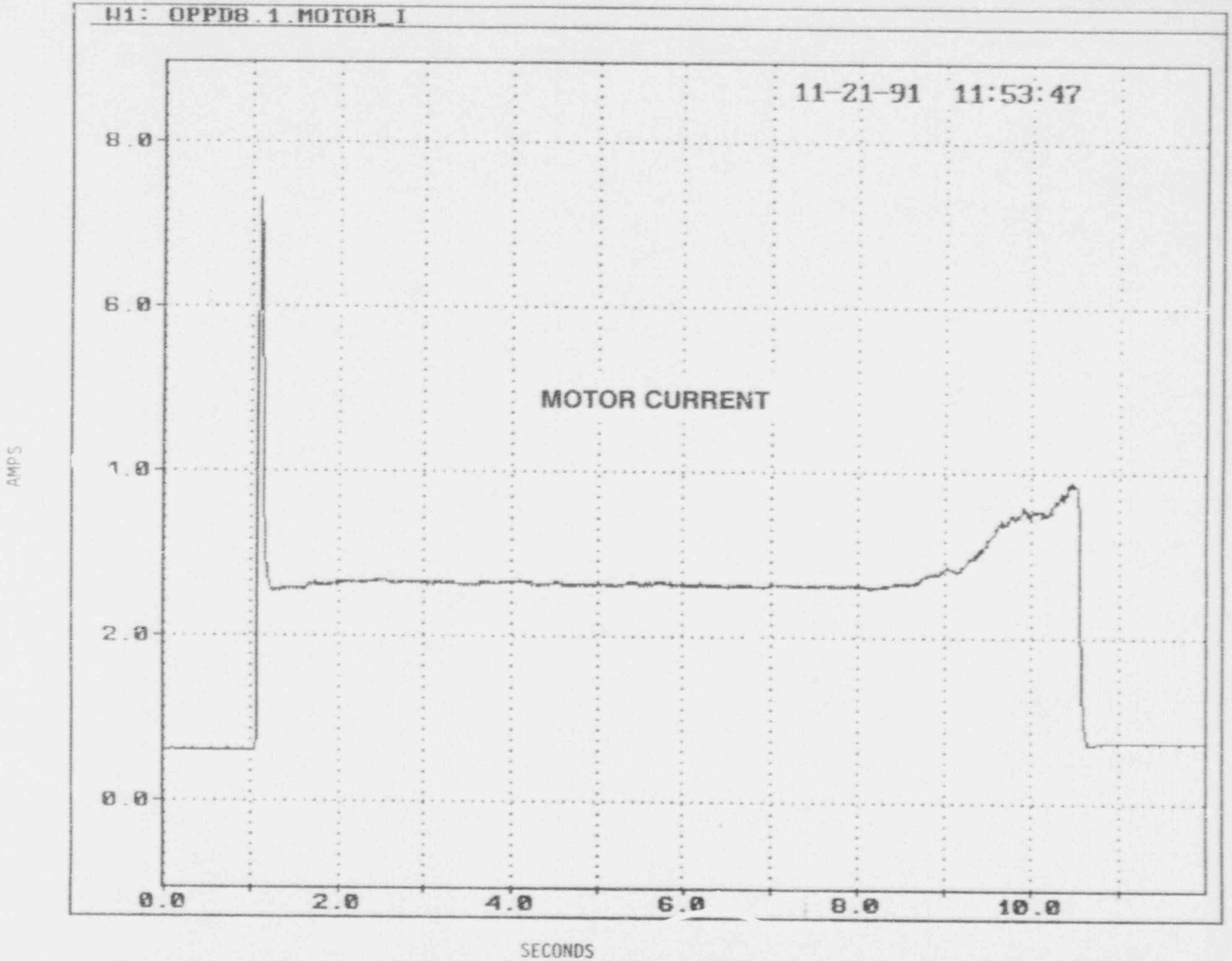

W20: W19-8335
FLOWRATE (PPH)
80000.0
60000.0
40000.0
20000.0
0.0
-20000.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS
PPH

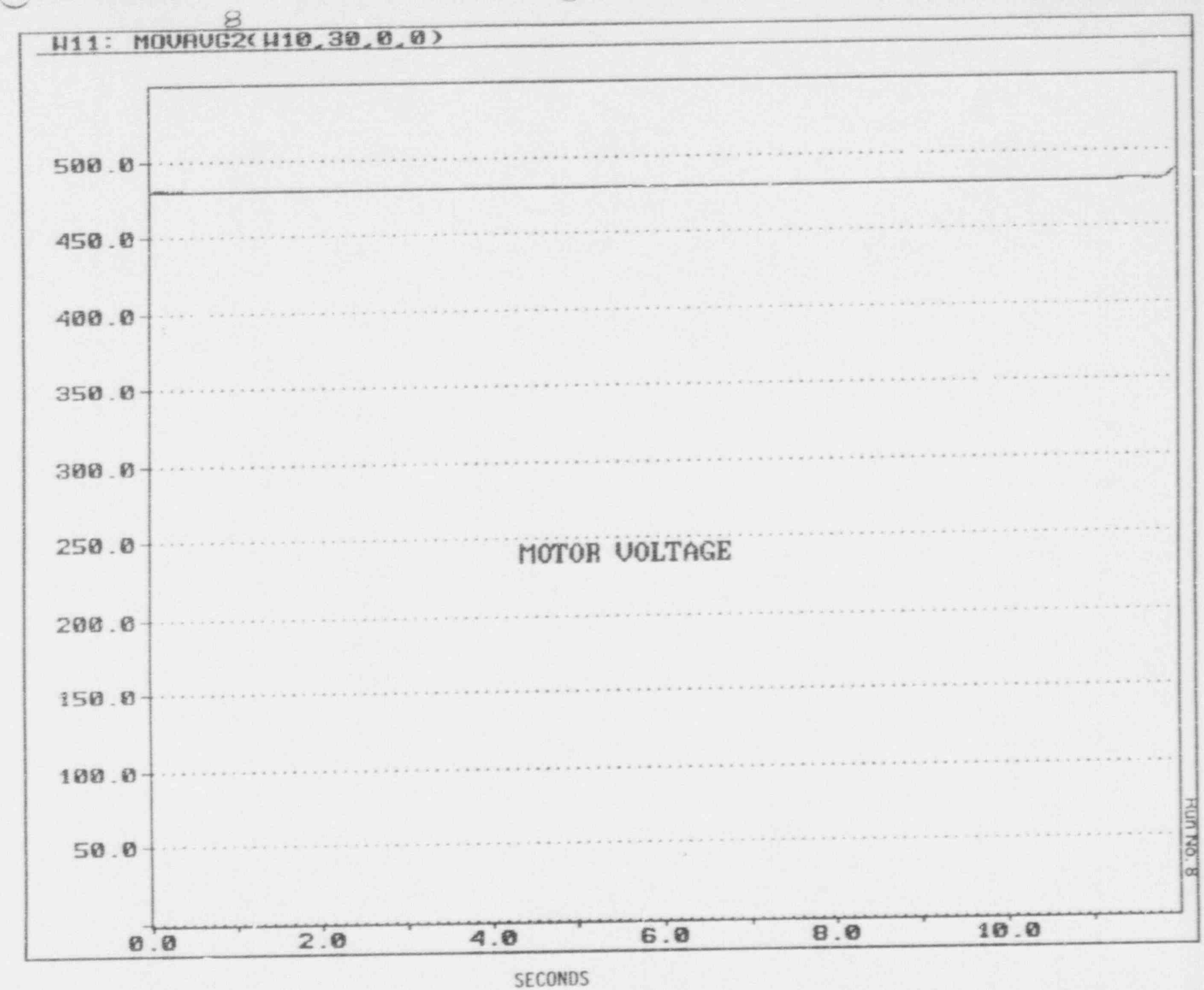


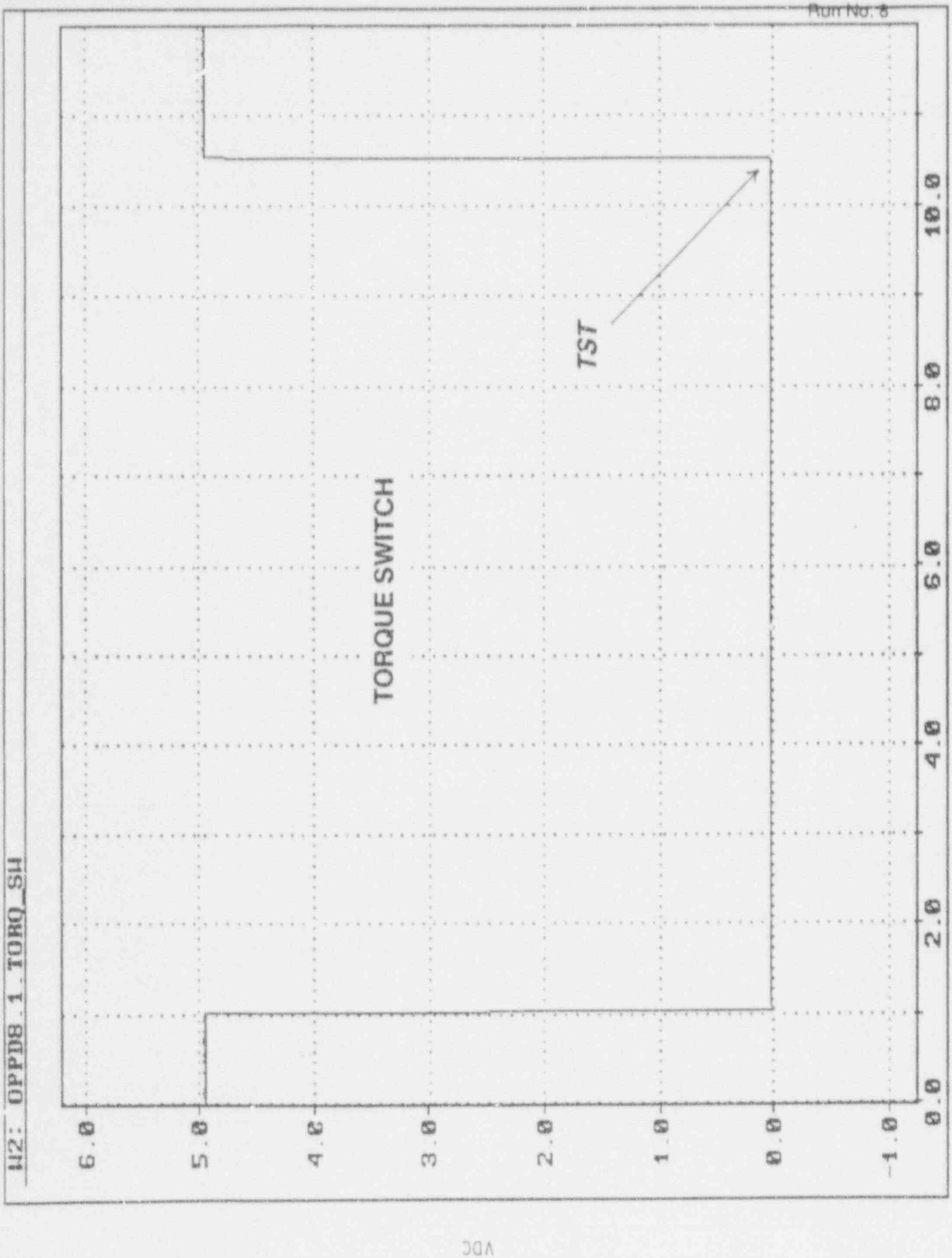
Report No. 57411
Page No. A-73
Run No. 6

APPENDIX J

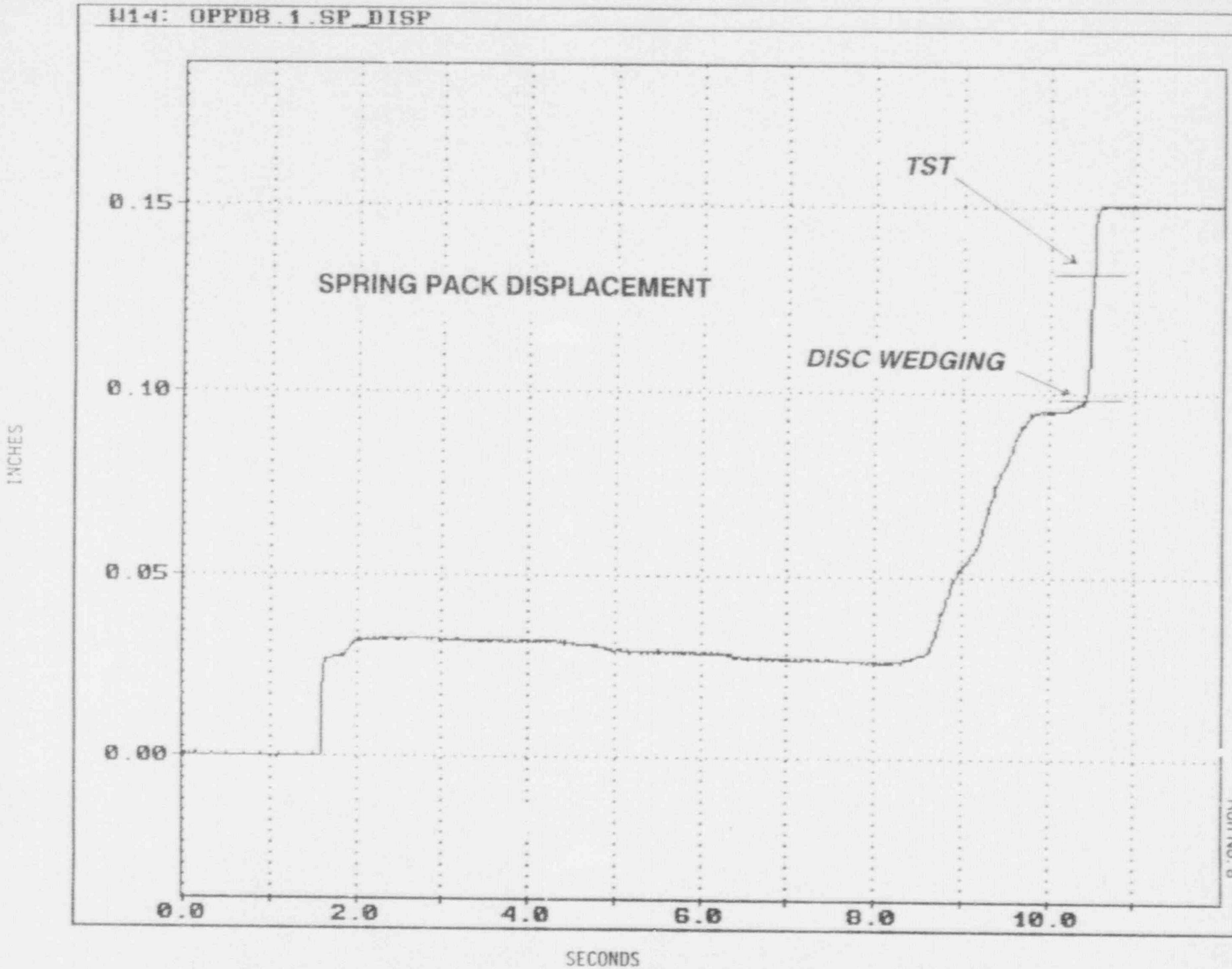
DATA PLOTS FOR TEST RUN 8


W1: OPPD8.1.MOTOR_I
11-21-91 11:53:47
MOTOR CURRENT
AMPS
8.0
6.0
4.0
2.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS


8
W11: MOVAVG2(W10,30,0,0)
MOTOR VOLTAGE
Vrms
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS
Run No. 8


H2: OPPD8_1_TORQ_SW
TORQUE SWITCH
TST
SECONDS
VDC
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
0.0
2.0
4.0
6.0
8.0
10.0

W3: OPPD8.1.STM_DIS
STEM DISPLACEMENT
DISC WEDGING
INCHES
3.0
2.0
1.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS
Run No. 8



Run No. 8

Report No. 57411
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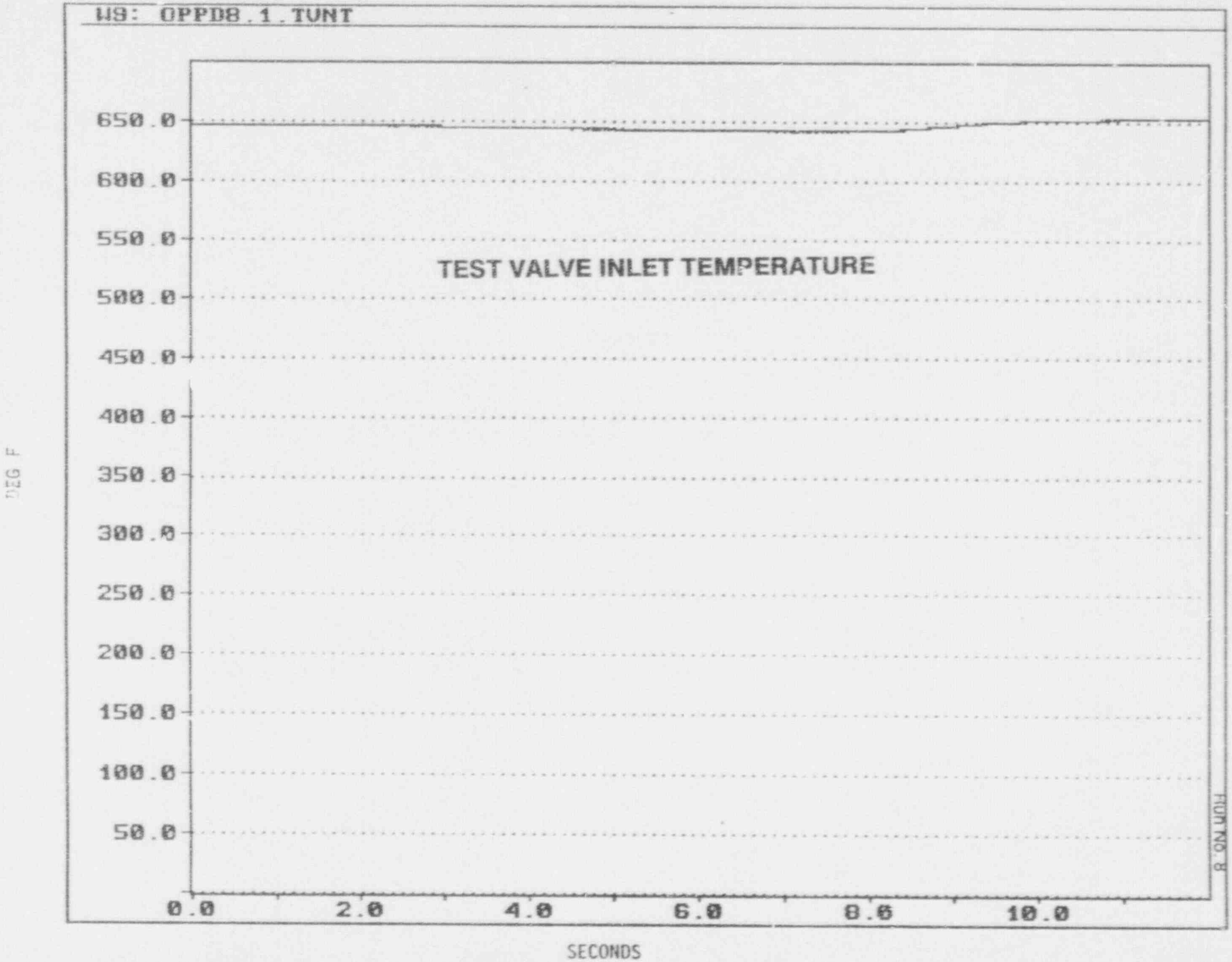
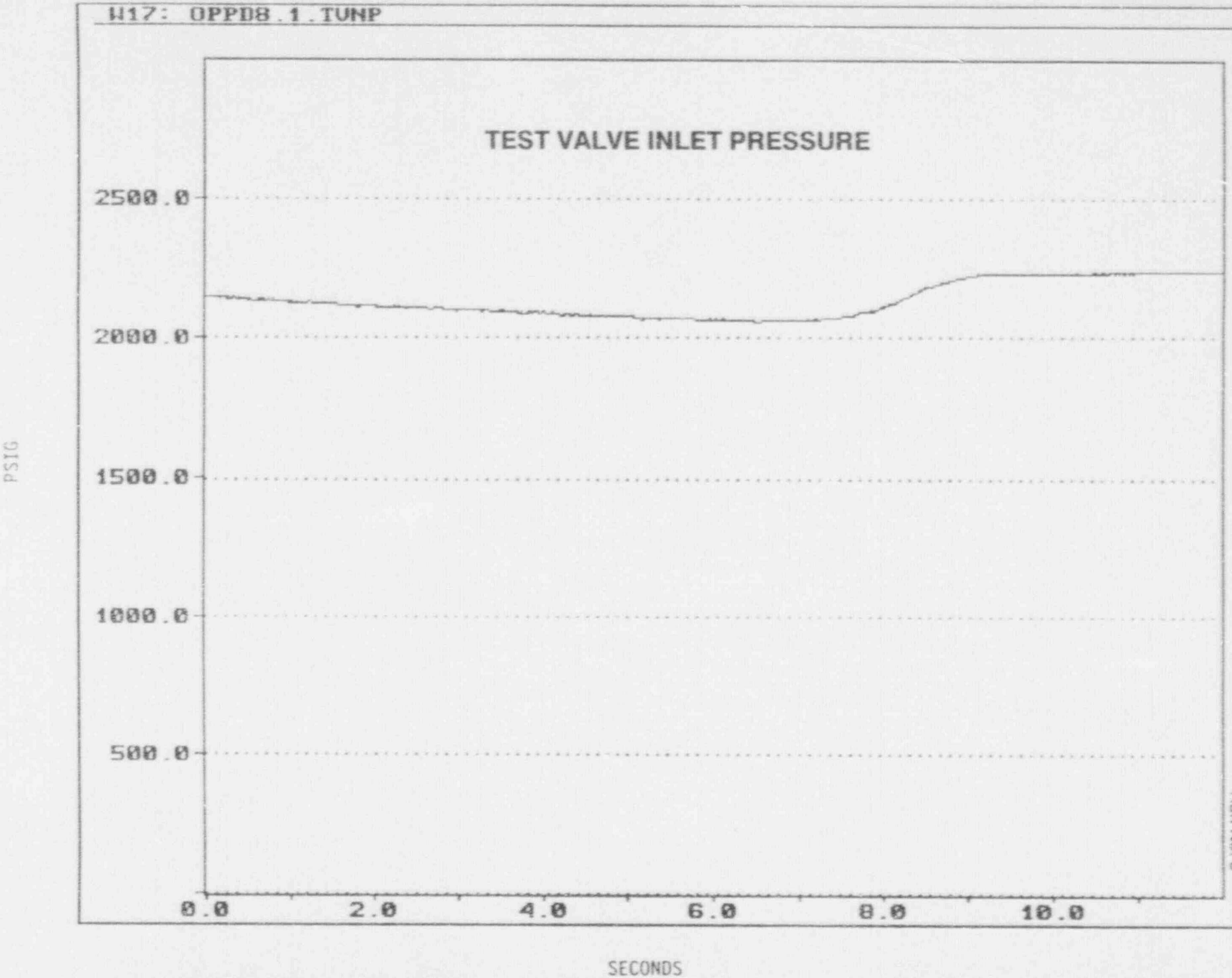


W9: OPPD8.1.TVNT
TEST VALVE INLET TEMPERATURE
DEG F
650.0
600.0
550.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS
RUN No. 8



Report No. 57411
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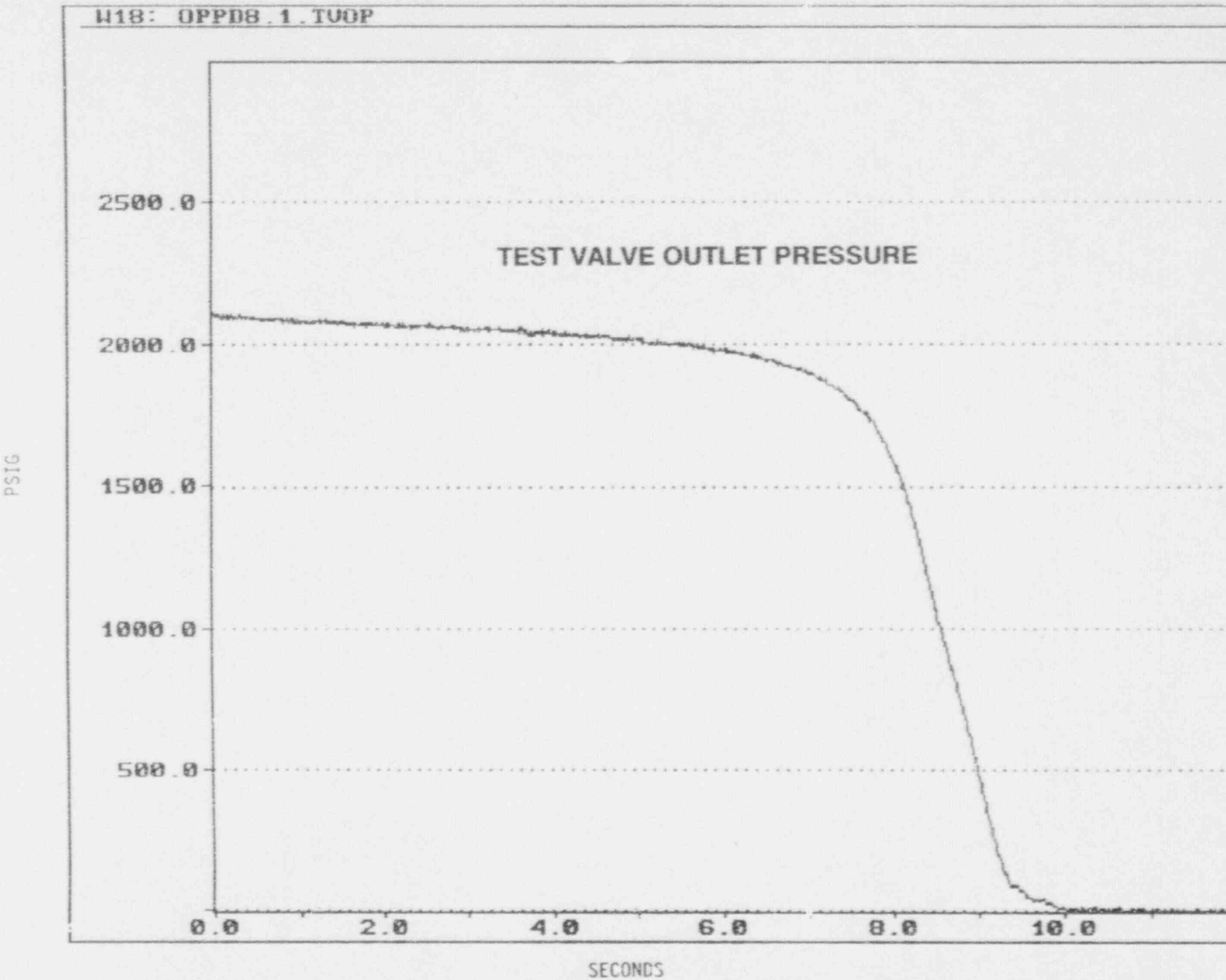
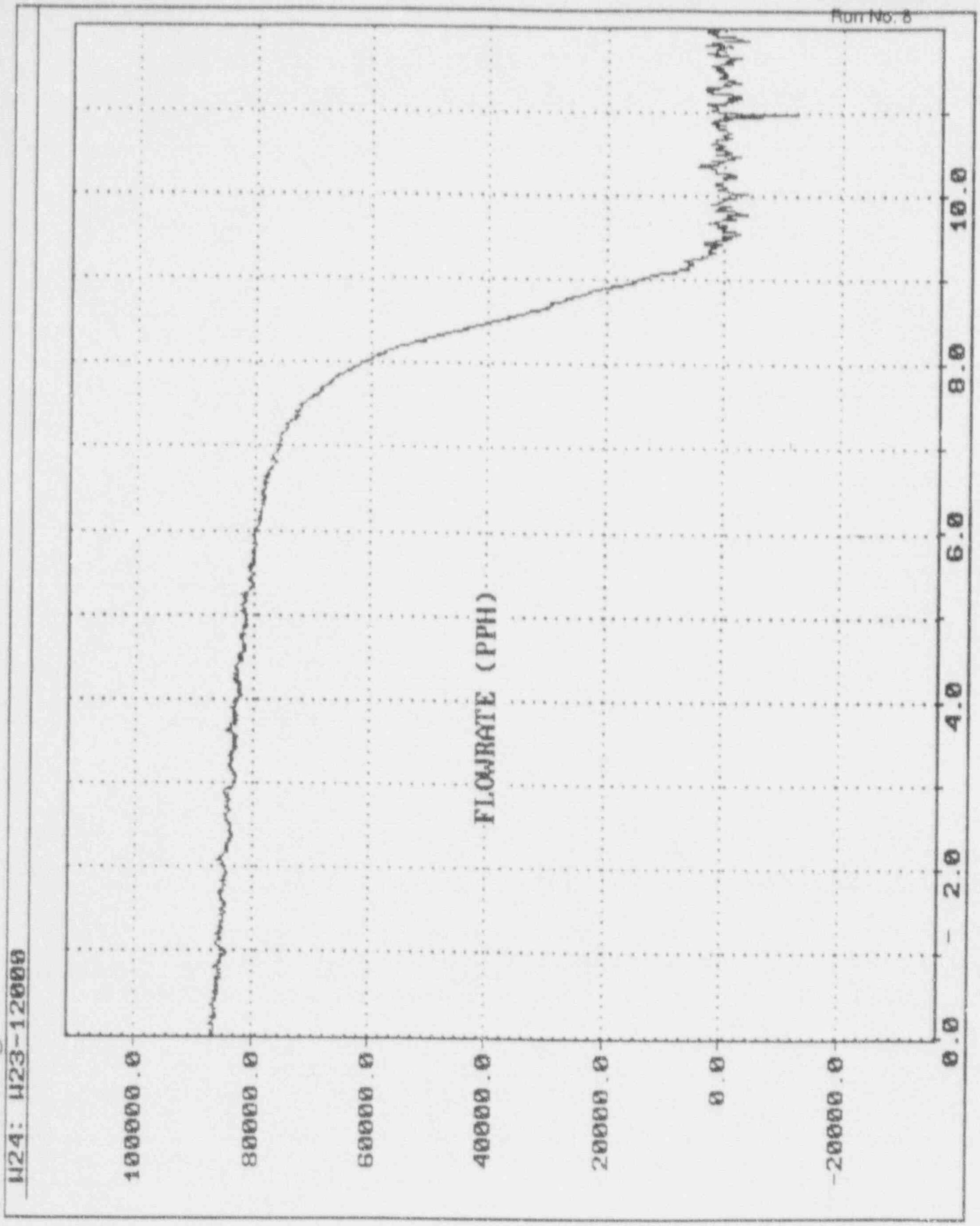
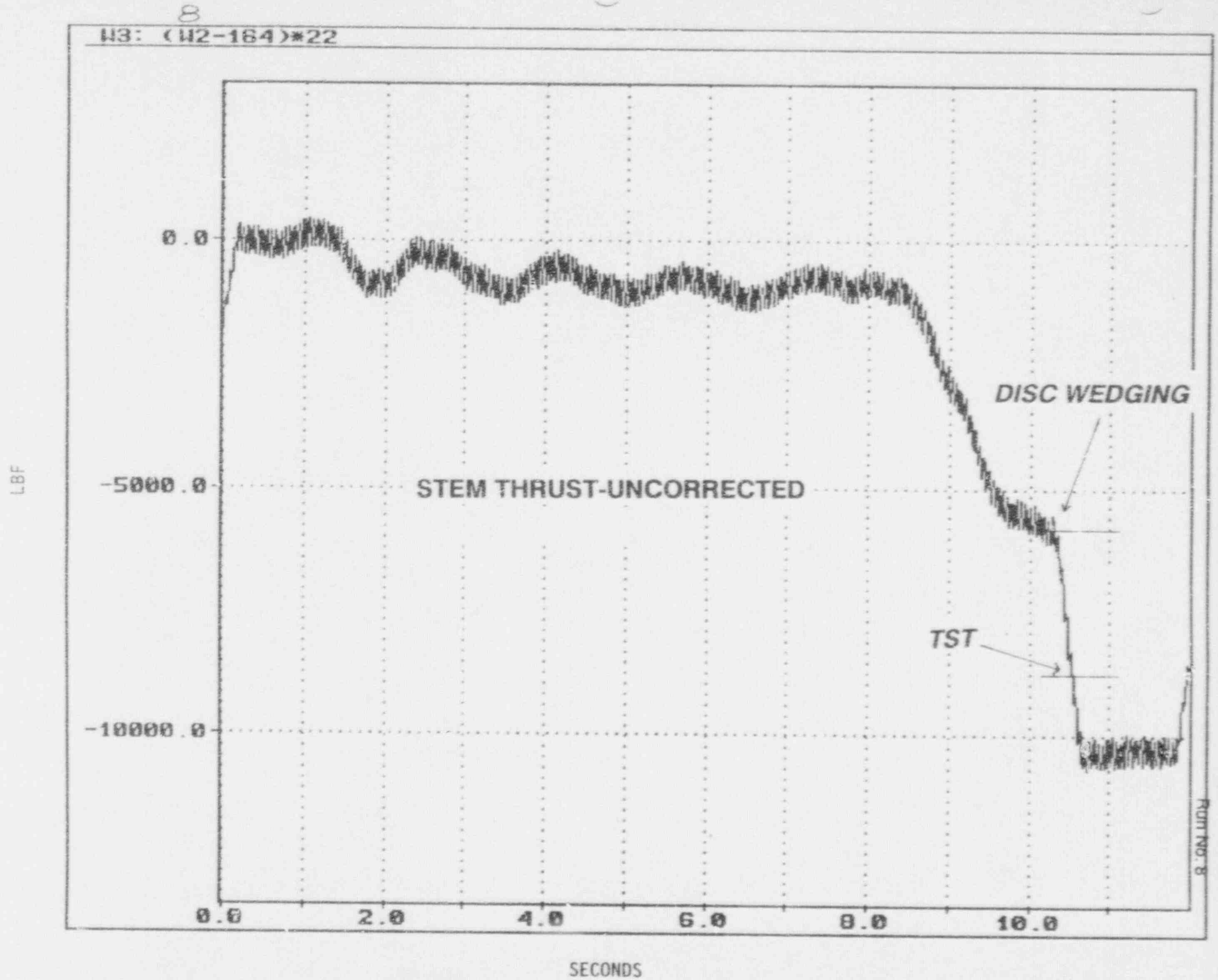
Run No. 8


W18: OPPD8.1.TVOP
TEST VALVE OUTLET PRESSURE
PSIG
2500.0
2000.0
1500.0
1000.0
500.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS


W24: W23-120000
FLOWRATE (PPH)
100000.0
80000.0
60000.0
40000.0
20000.0
0.0
-20000.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS



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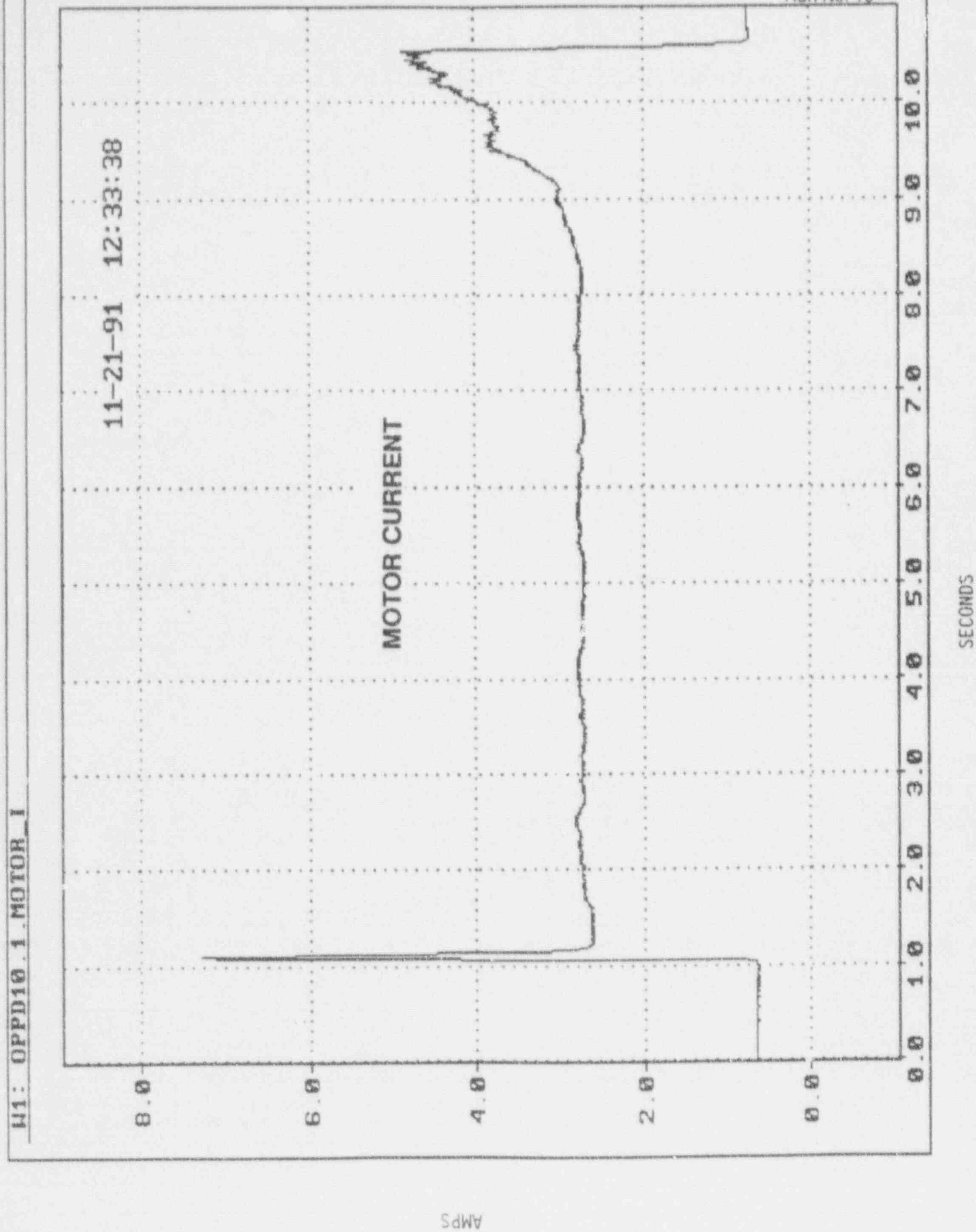
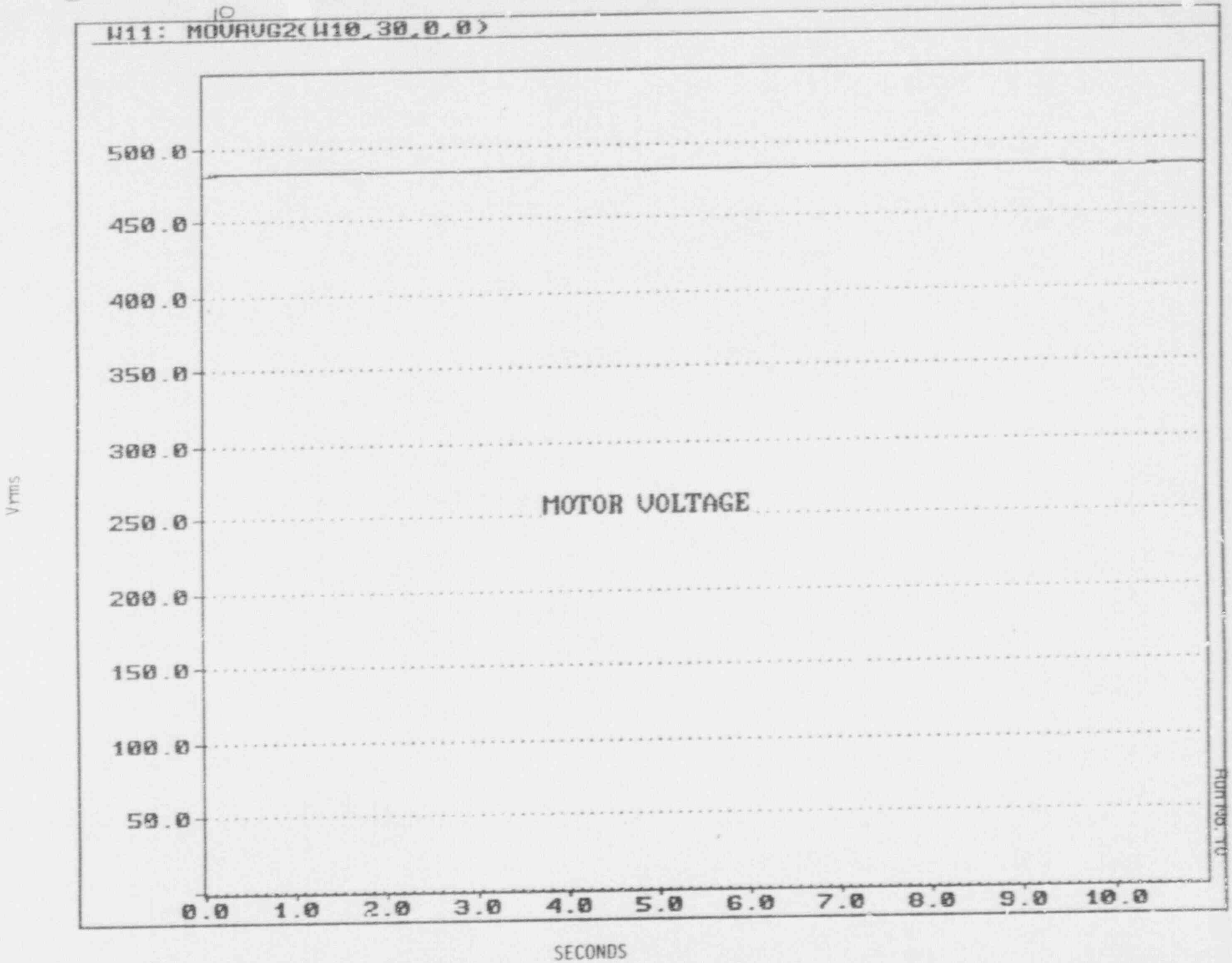
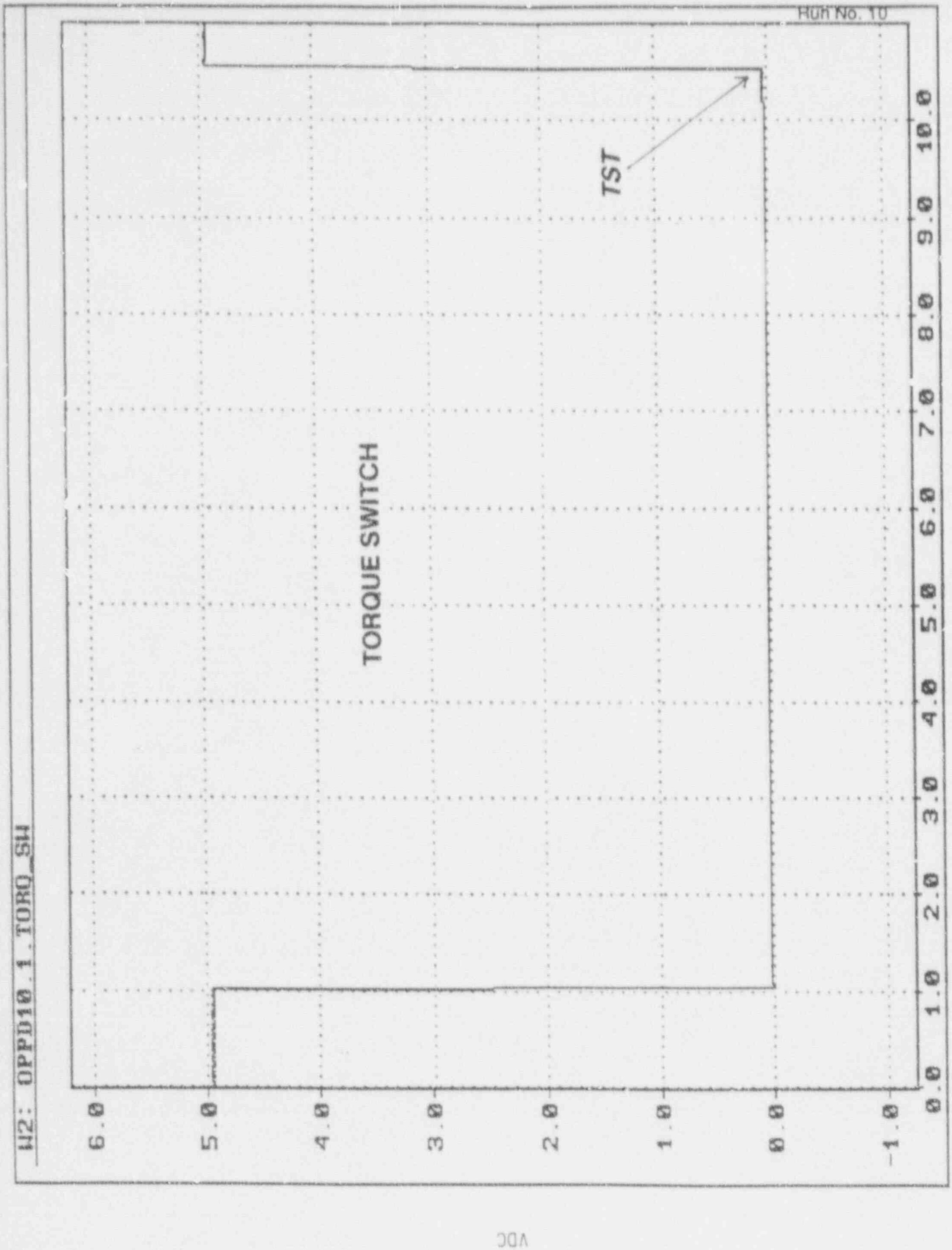
APPENDIX K

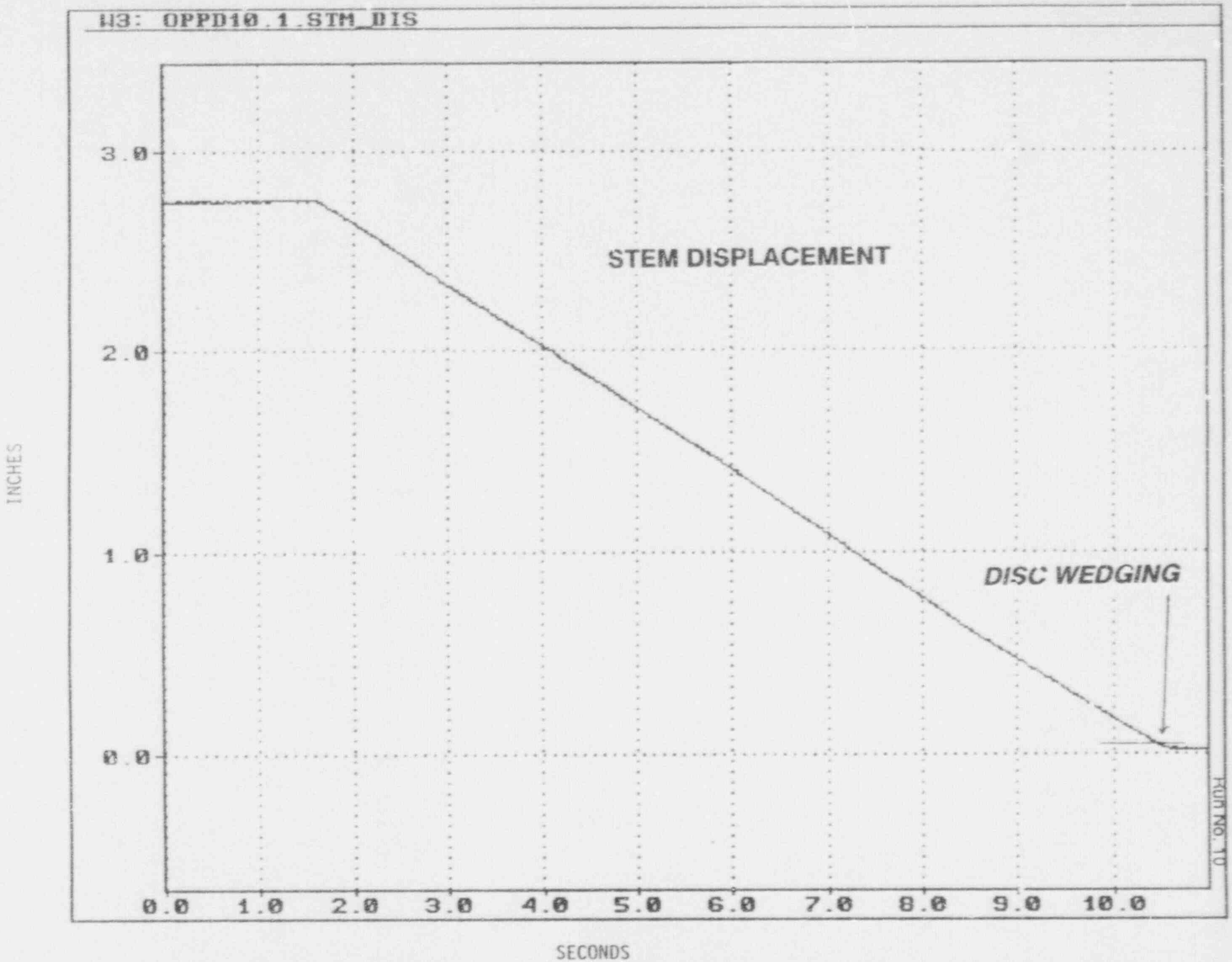
DATA PLOTS FOR TEST RUN 10


W1: OPPD10.1.MOTOR_I
11-21-91 12:33:38
MOTOR CURRENT
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
SECONDS
8.0
6.0
4.0
2.0
0.0
AMPS



W11: MOVAVG2(W10,30,0,0)
MOTOR VOLTAGE
Vrms
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
SECONDS
Run No. 10


W2: OPPD10.1.TORQ_SW
TORQUE SWITCH
TST
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
VDC
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
SECONDS



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Report No. 57411
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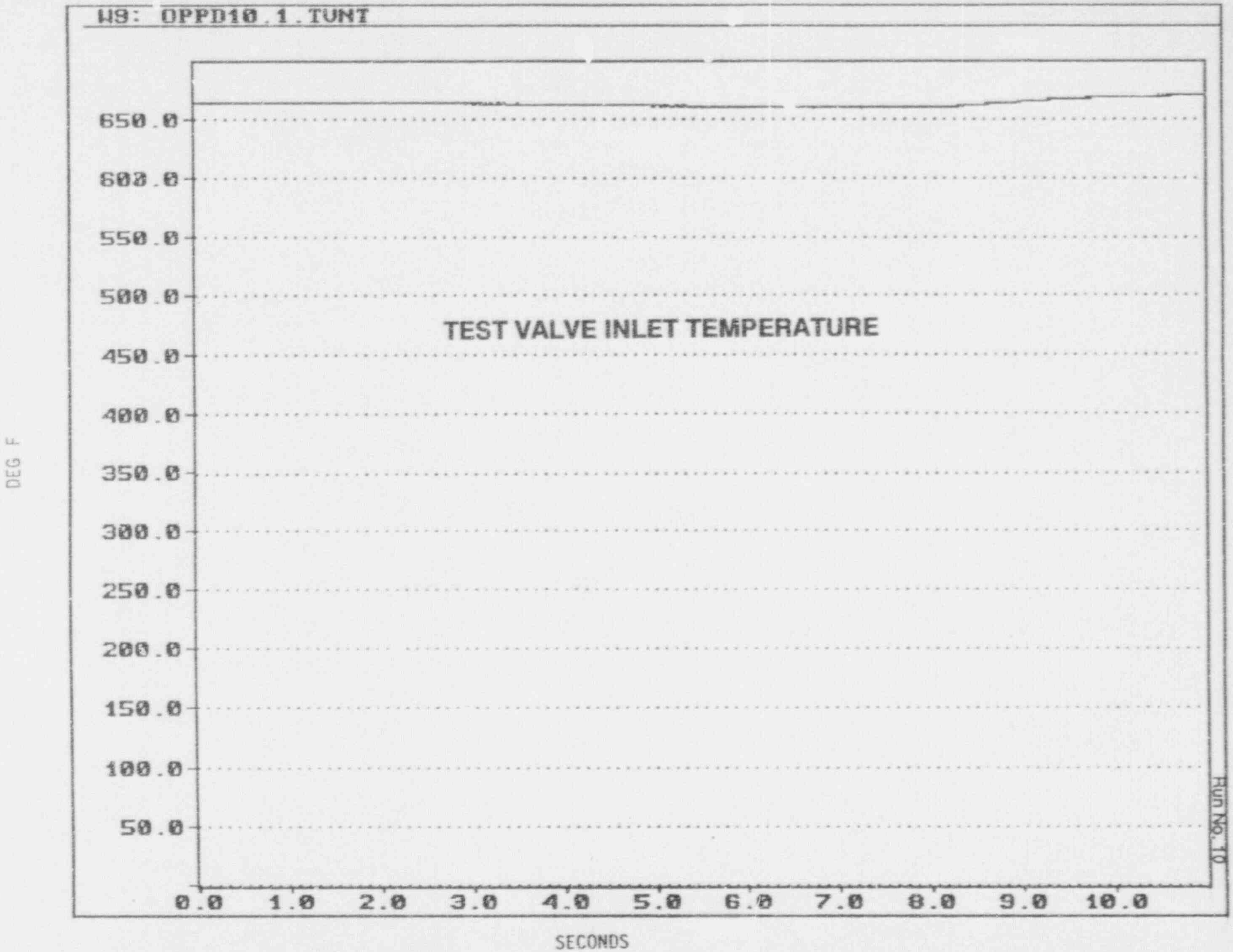

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Report No. 57411
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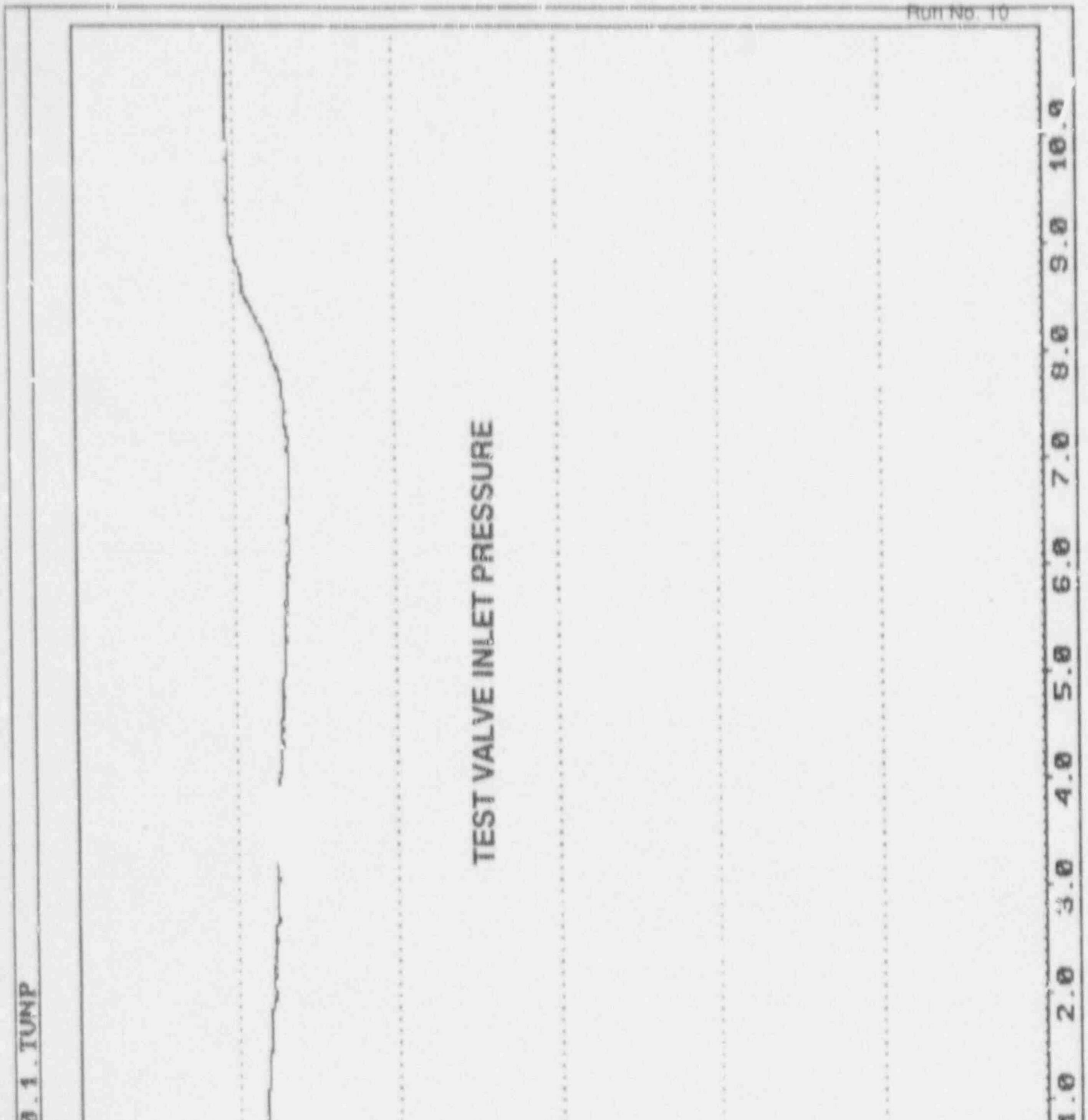
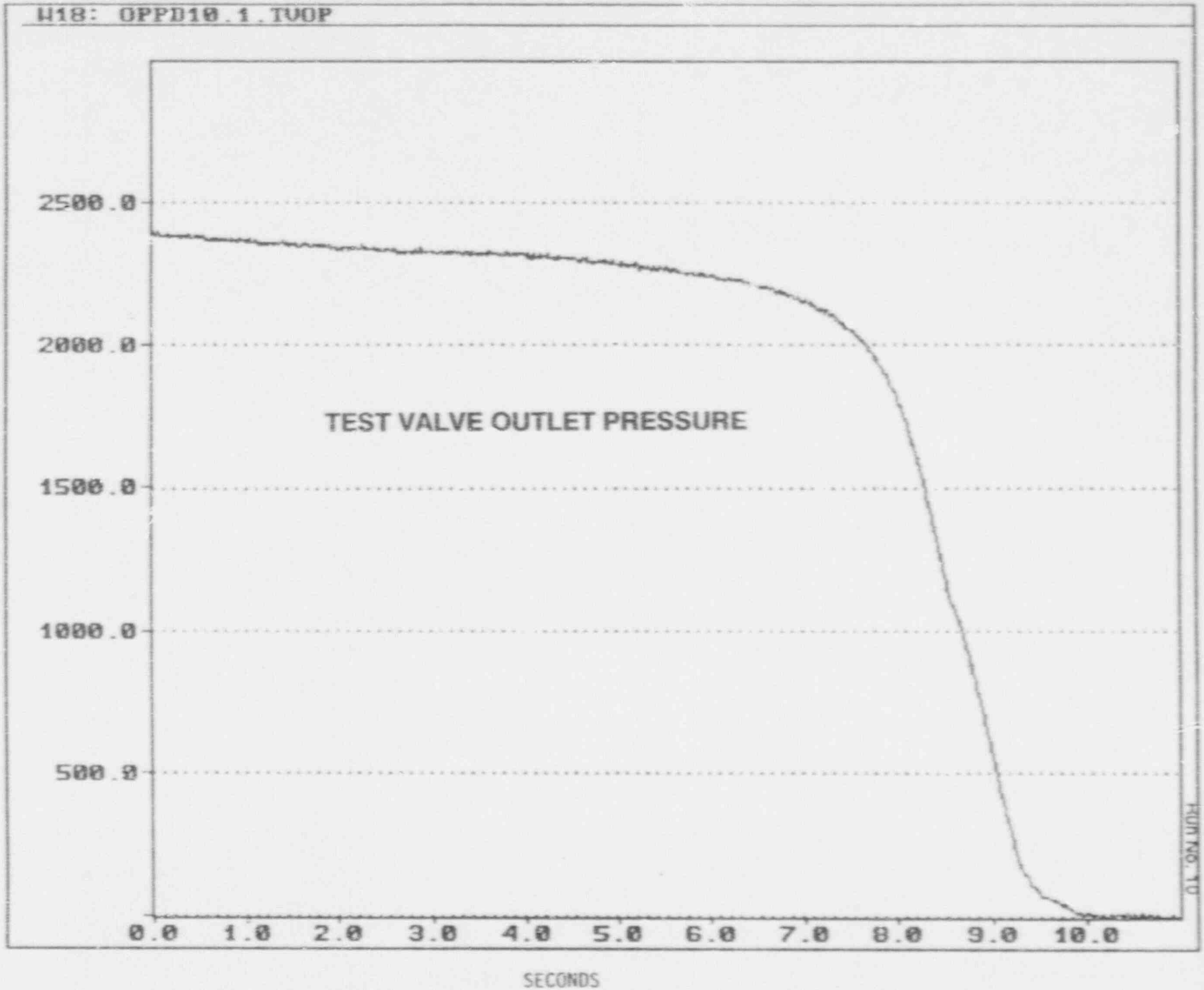
Run No. 10





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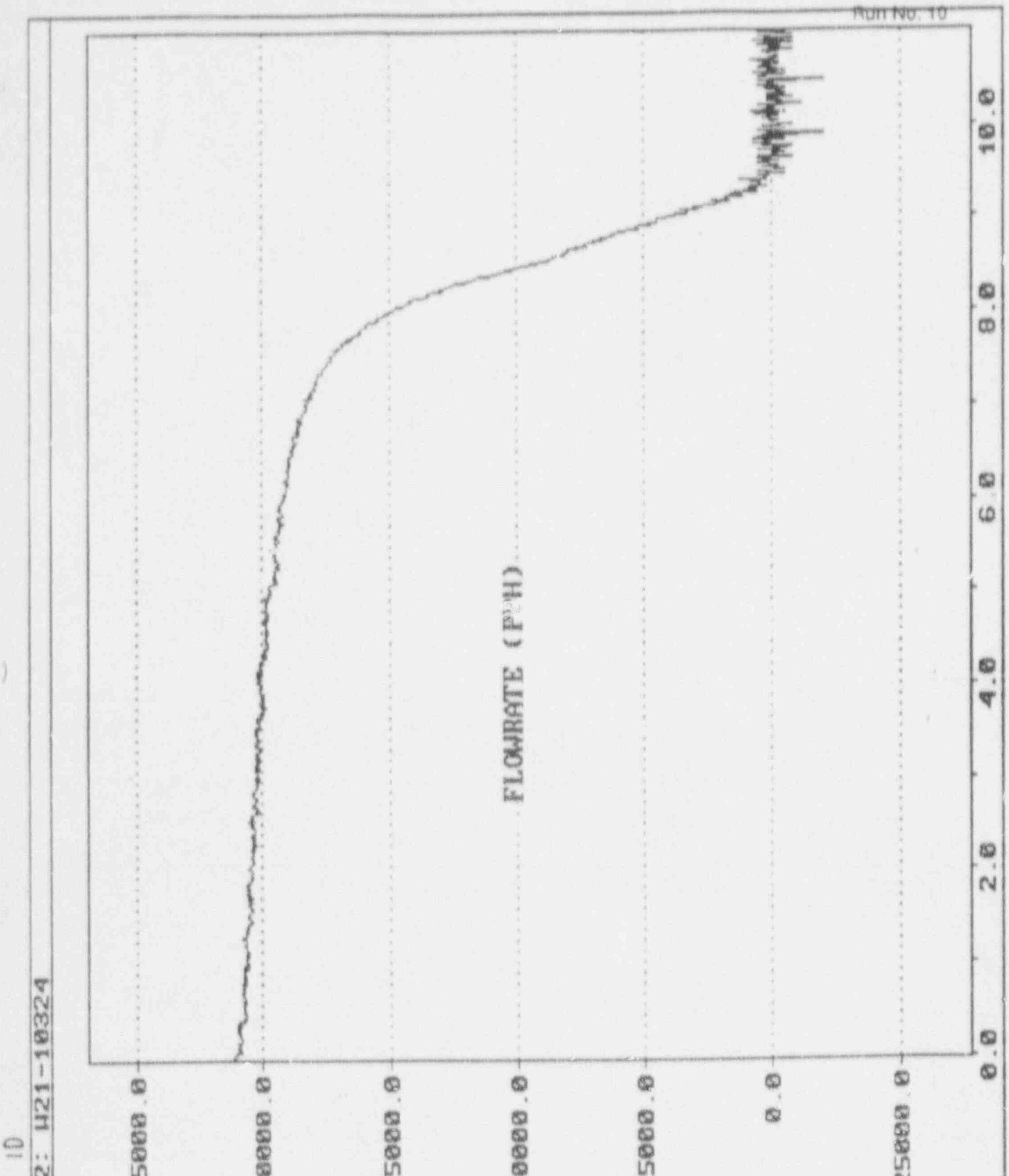
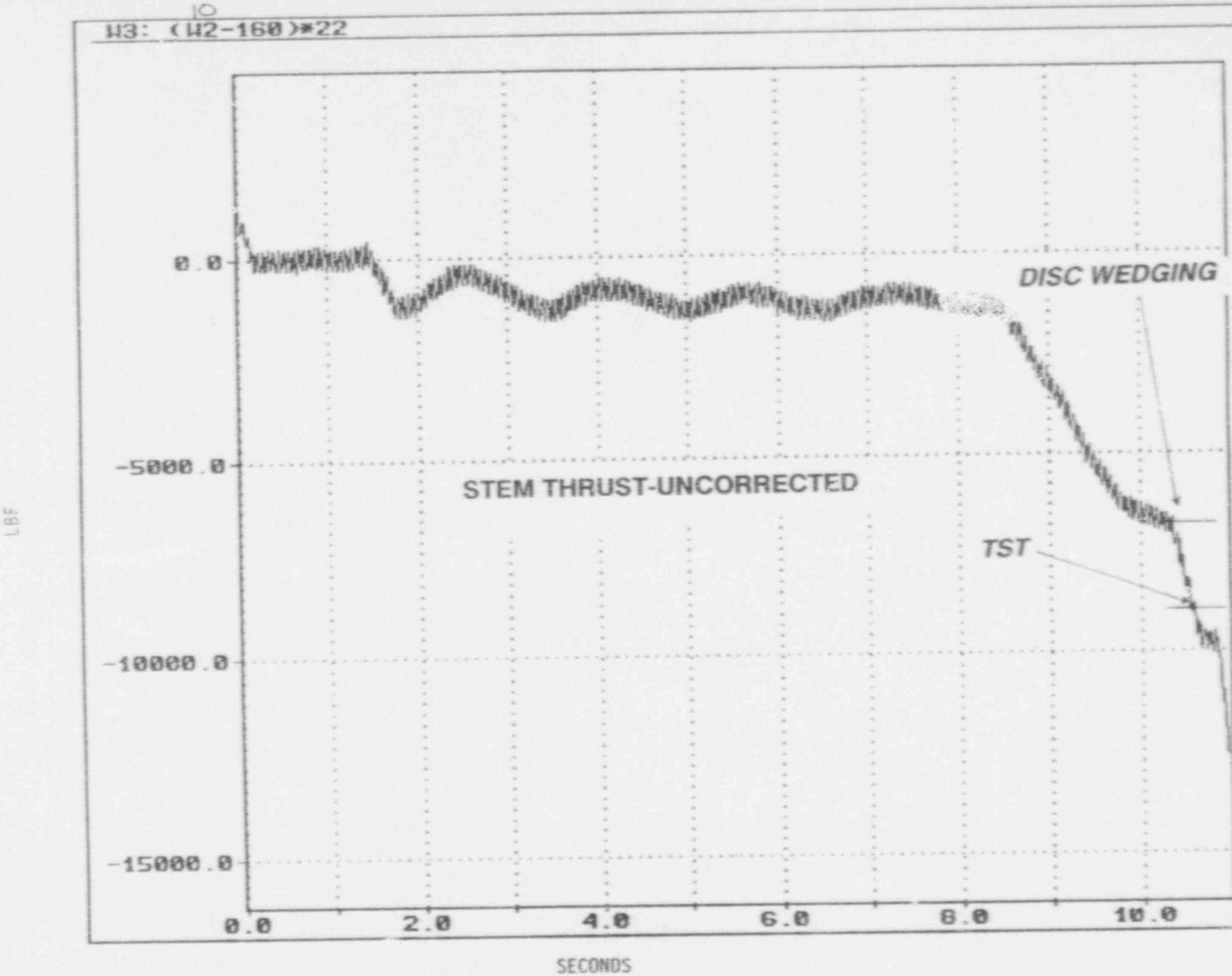
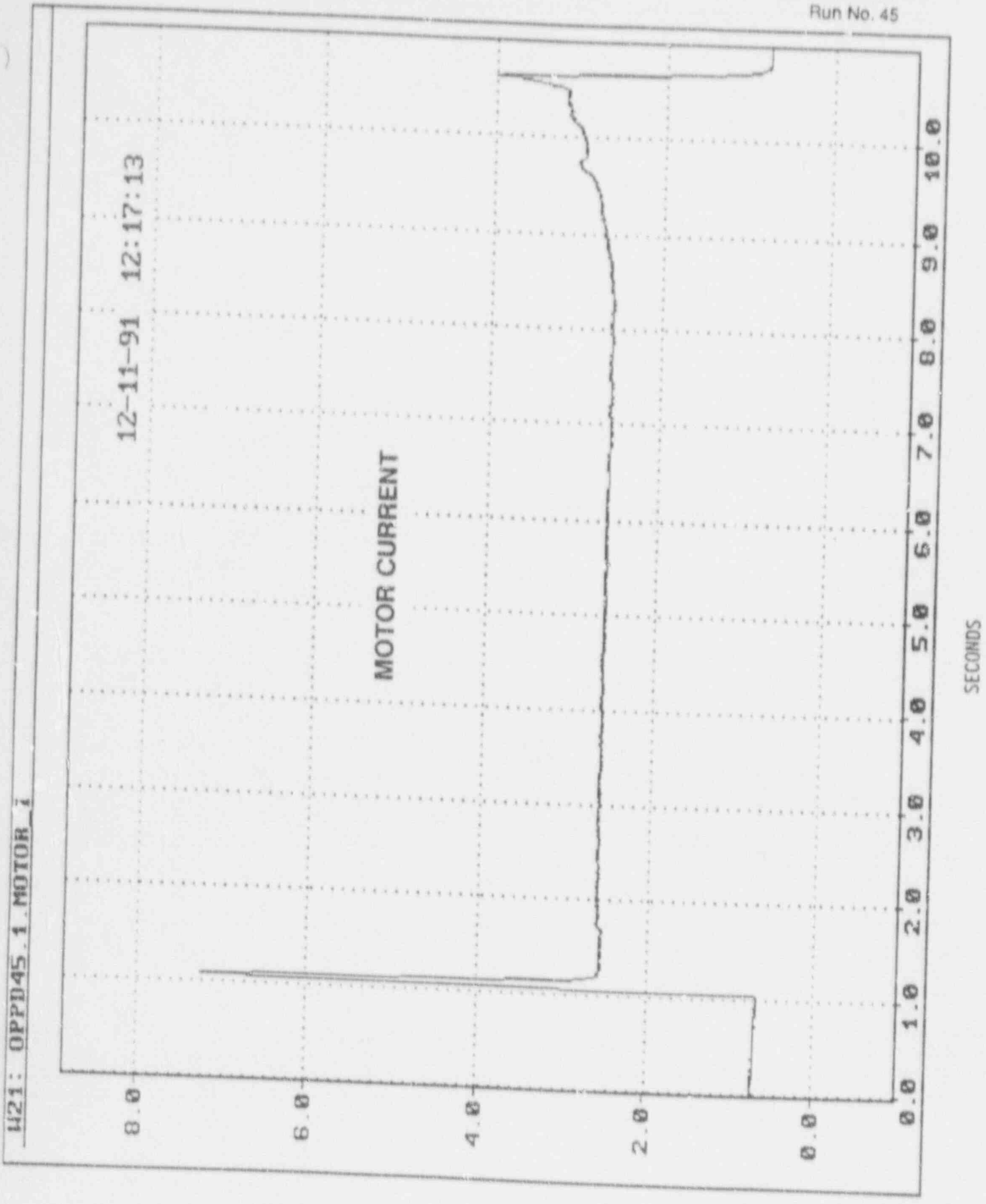

W22: W21-103324
ID
FLOWRATE (PPH)
PPH
SECONDS
125000.0
100000.0
75000.0
50000.0
25000.0
0.0
-25000.0
0.0
2.0
4.0
6.0
8.0
10.0

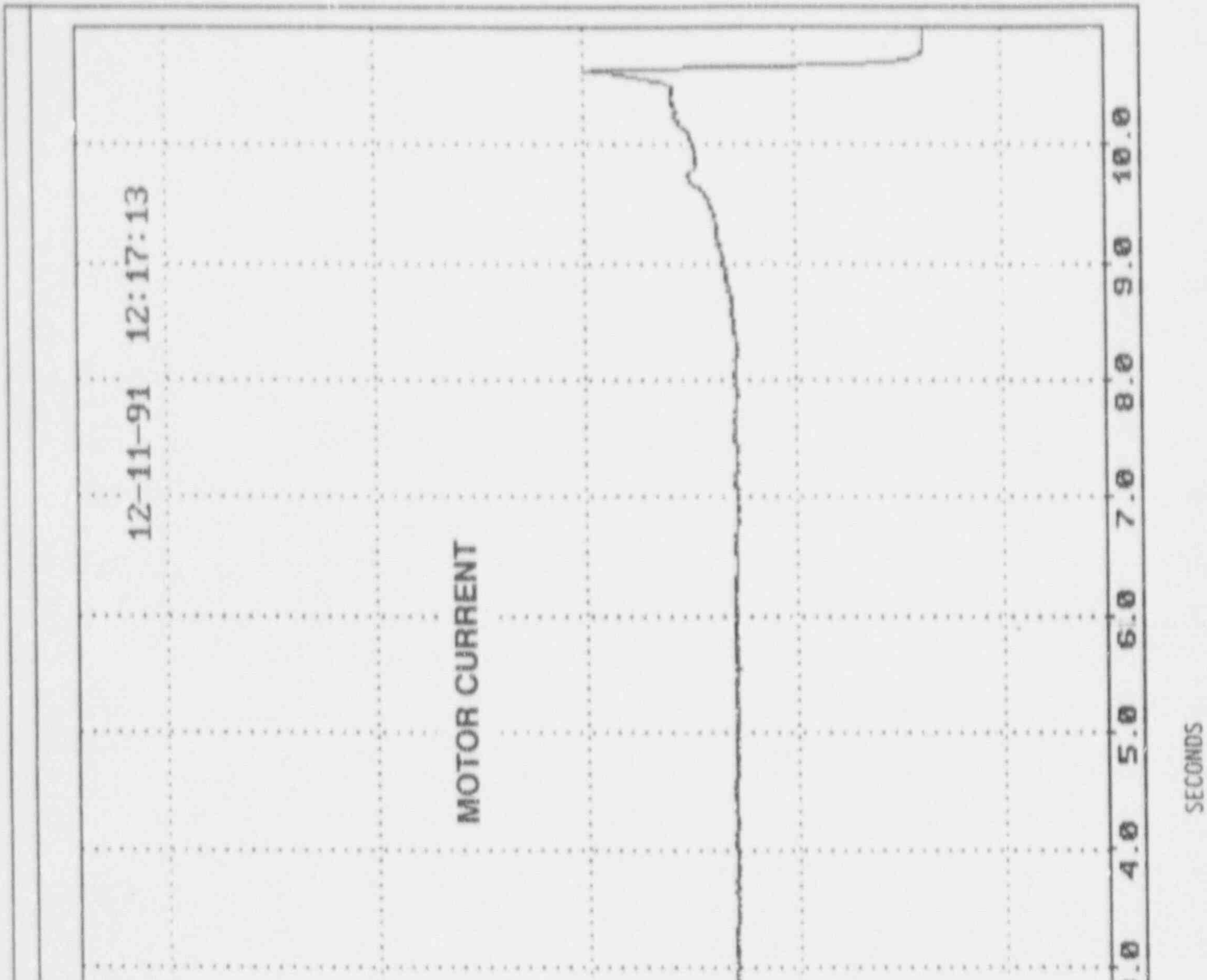

W3: (W2-160)*22
LBF
0.0
-5000.0
-10000.0
-15000.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS
STEM THRUST-UNCORRECTED
DISC WEDGING
TST

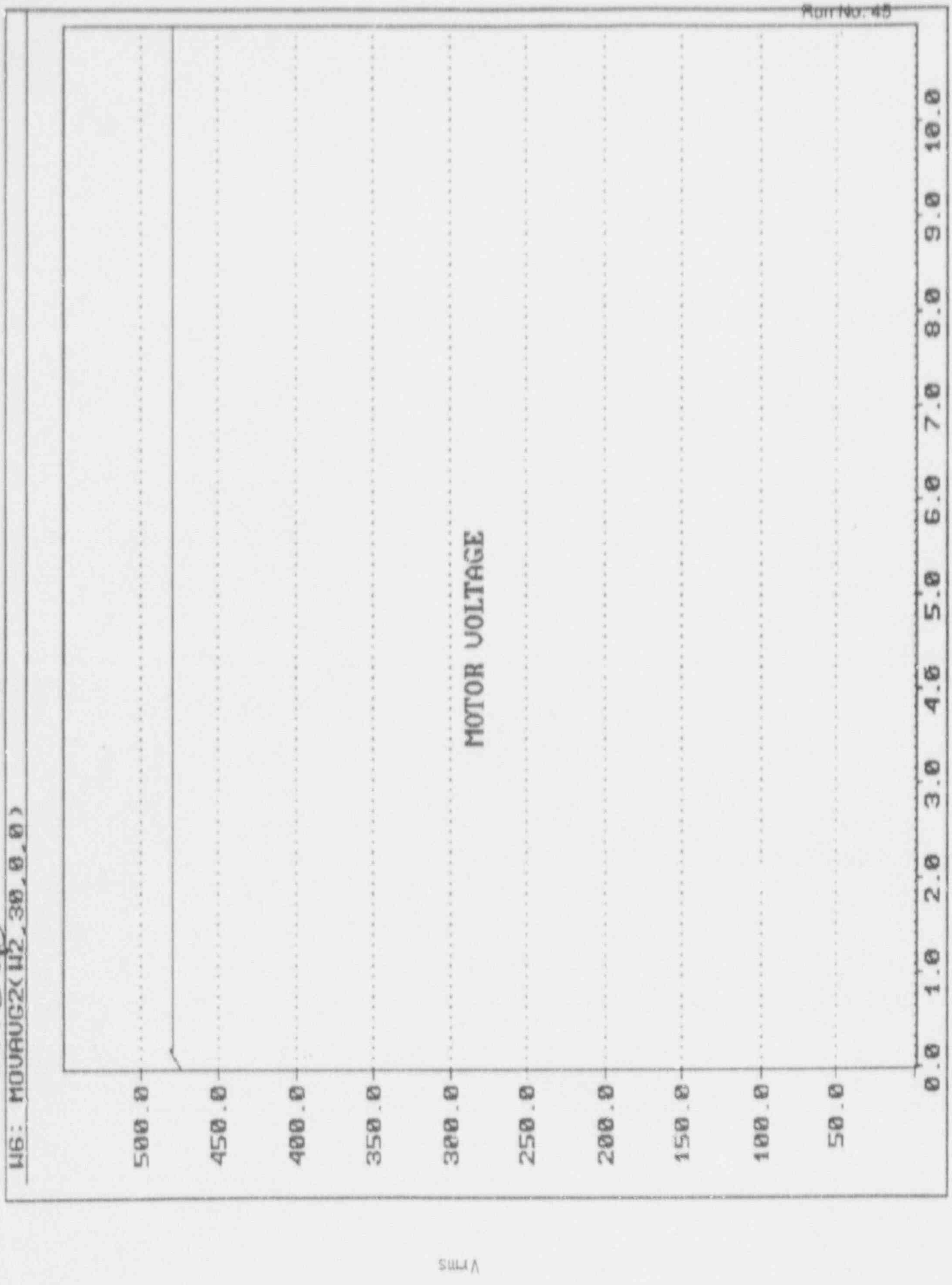
APPENDIX L

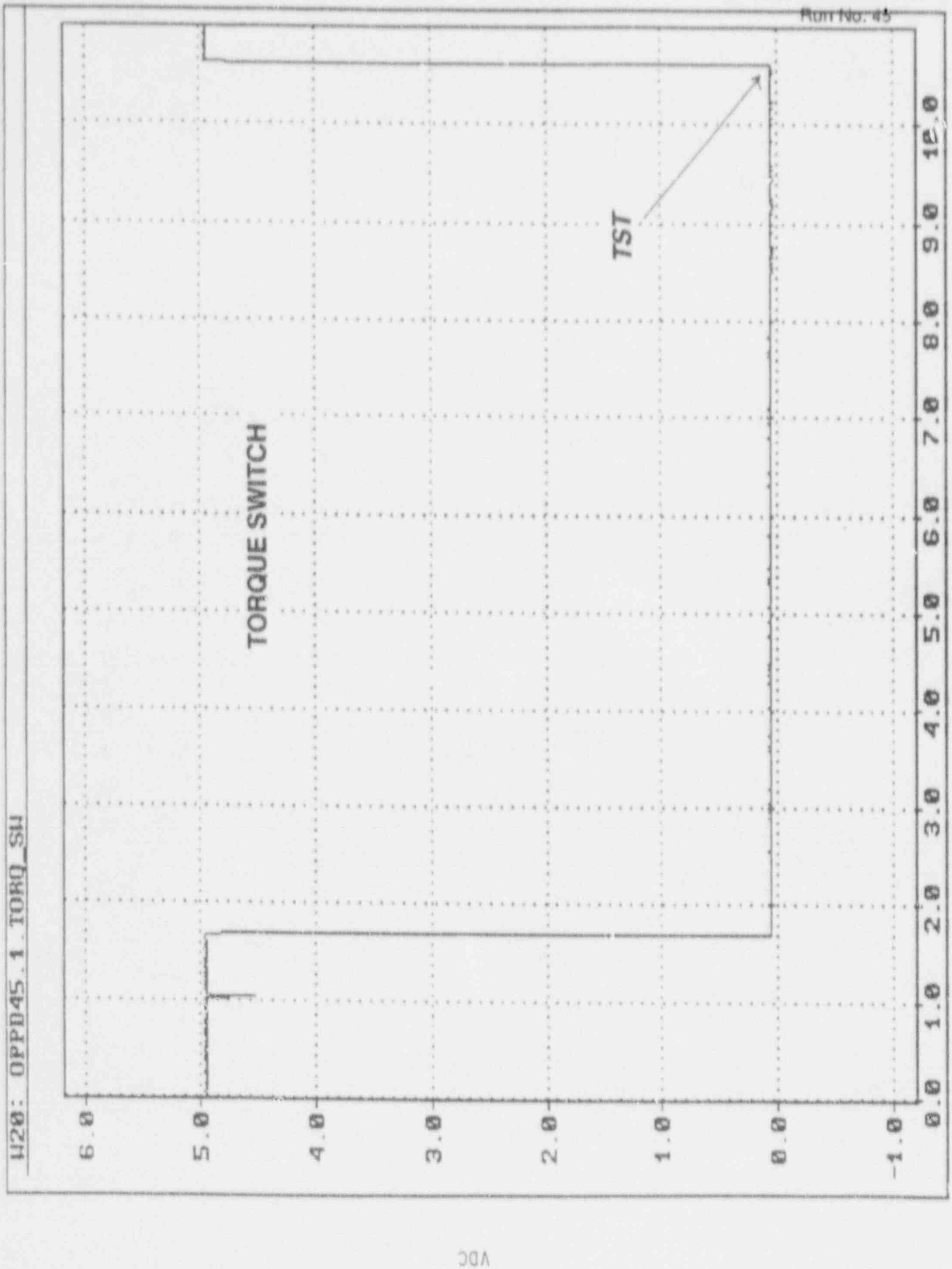
DATA PLOTS FOR TEST RUN 36

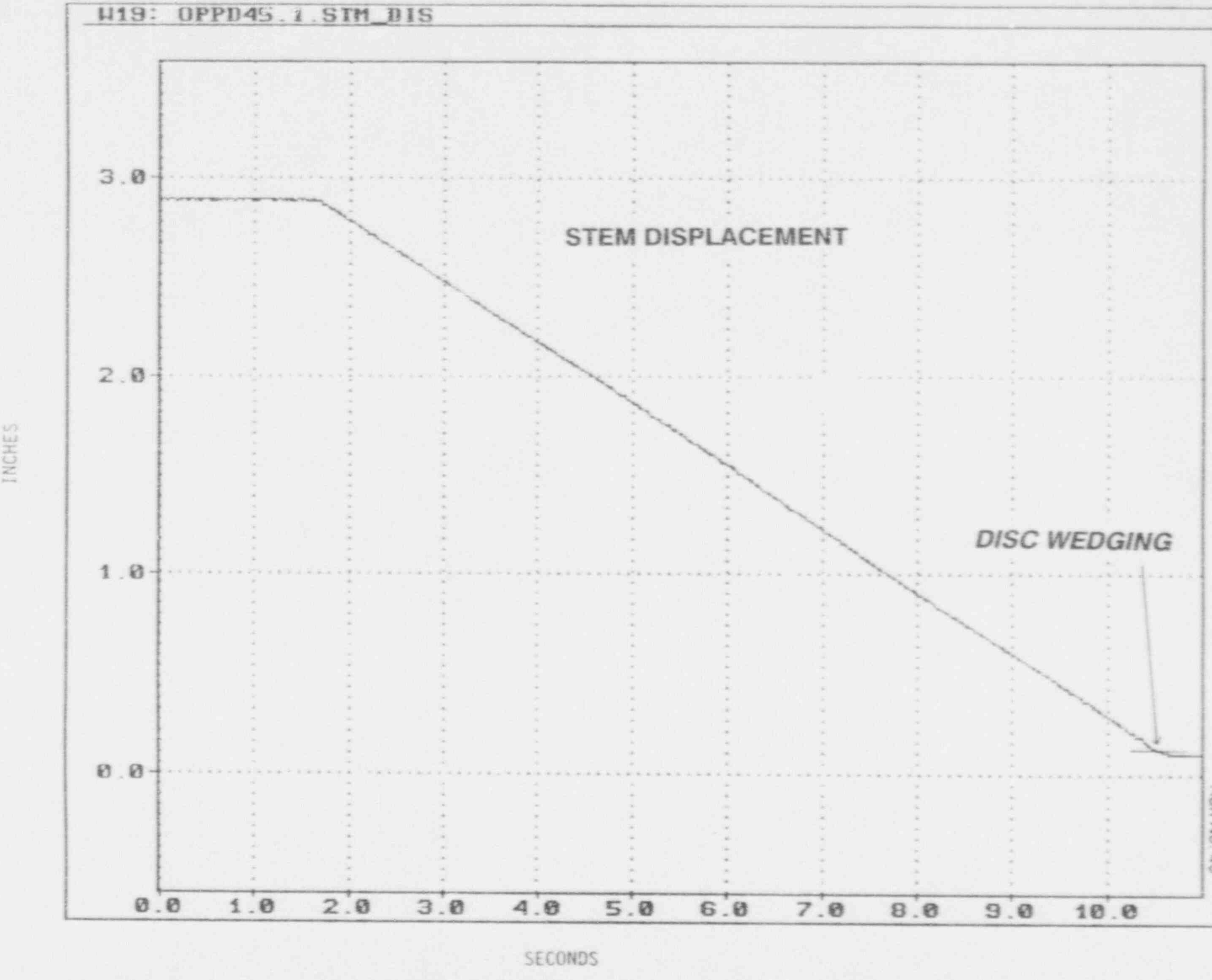

W21: OPPD45.1.MOTOR I
12-11-91 12:17:13
MOTOR CURRENT
8.0
6.0
4.0
2.0
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
SECONDS
AMPS

Report No. 57411
Page No. A-406
Run No. 45

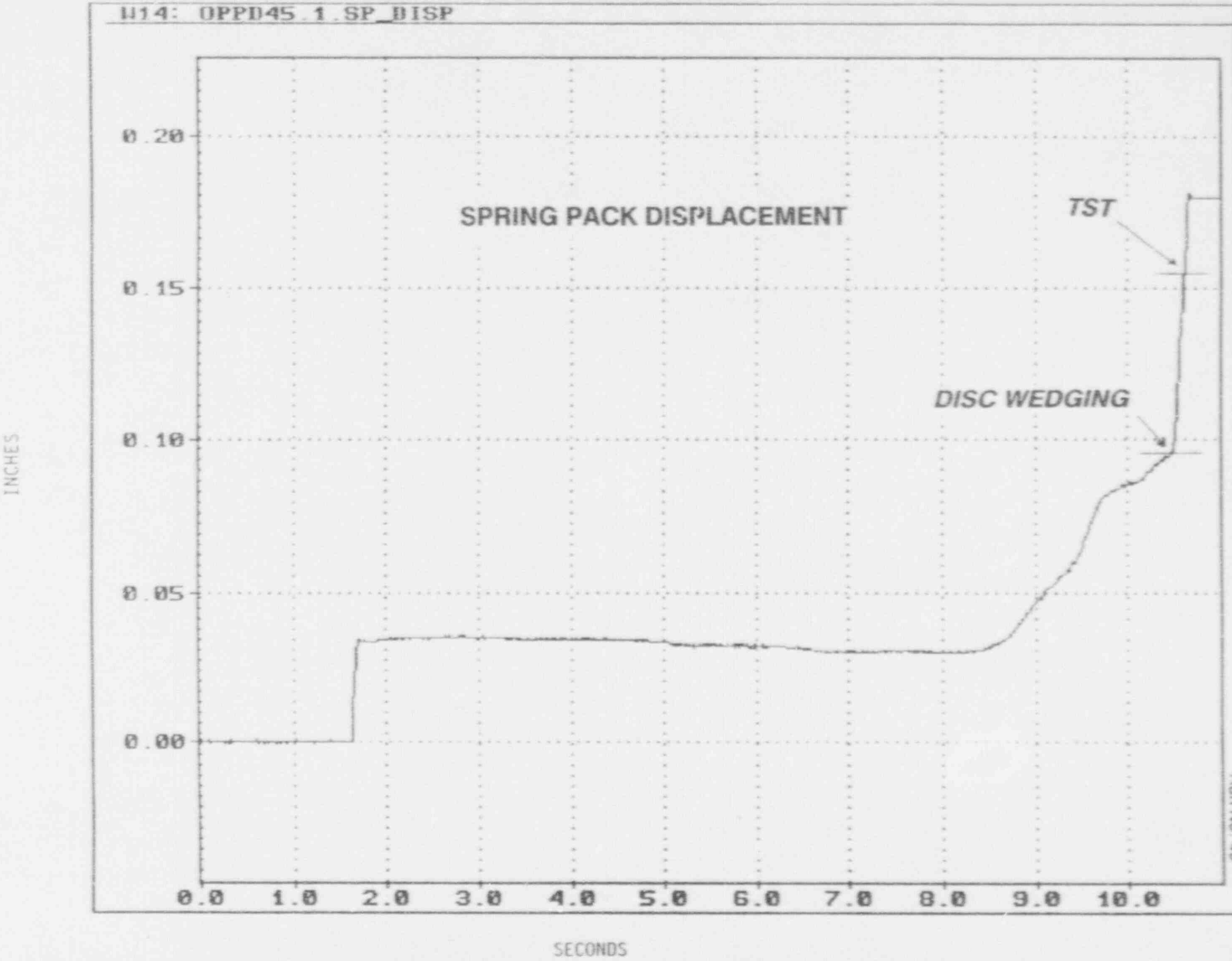



OPPD 45
W6: MOVAVG2(W2,30,0,0)
MOTOR VOLTAGE
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
SECONDS
Vrms

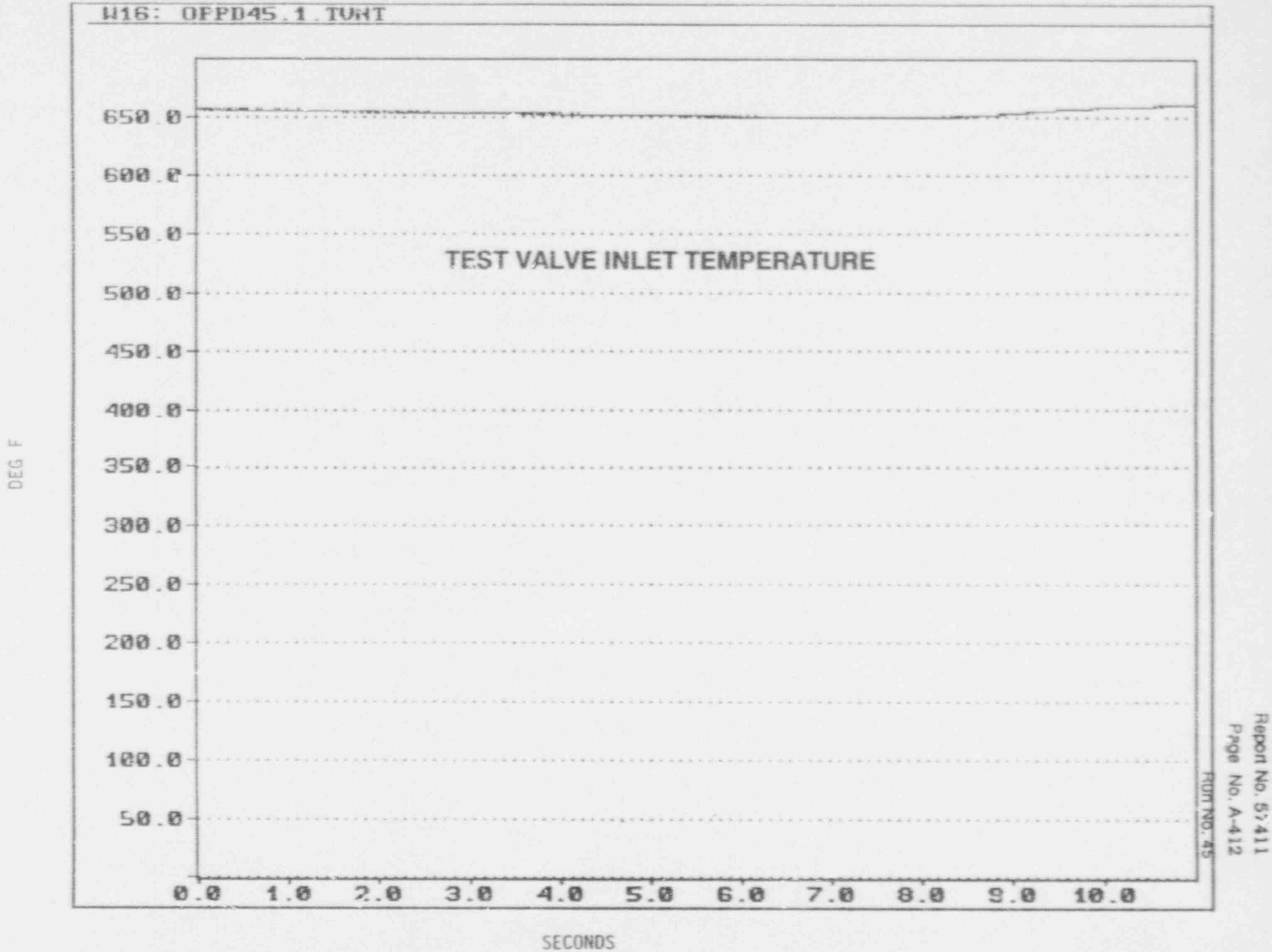

W20: OPPD45.1 TORQ_SW
TORQUE SWITCH
TST
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
SECONDS
VDC

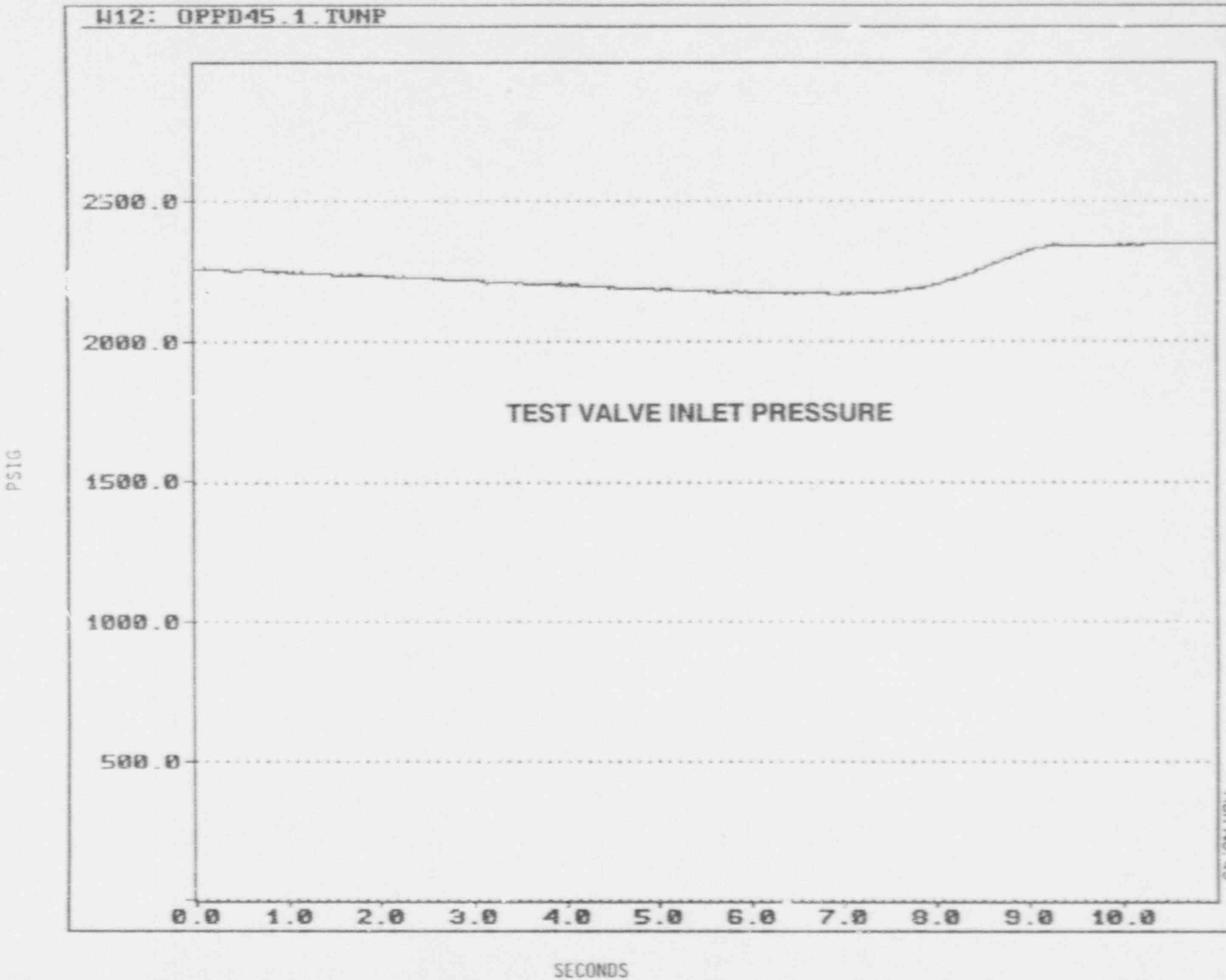


Report No. 57411
Page No. A-410
Run No. 45



Report No. 57411
Page No. A-411
Run No. 45


W16: OFPD45.1.TVRT
TEST VALVE INLET TEMPERATURE
DEG F
650.0
600.0
550.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
SECONDS
Run No. 45
Report No. 57411
Page No. A-412



Report No. 57411
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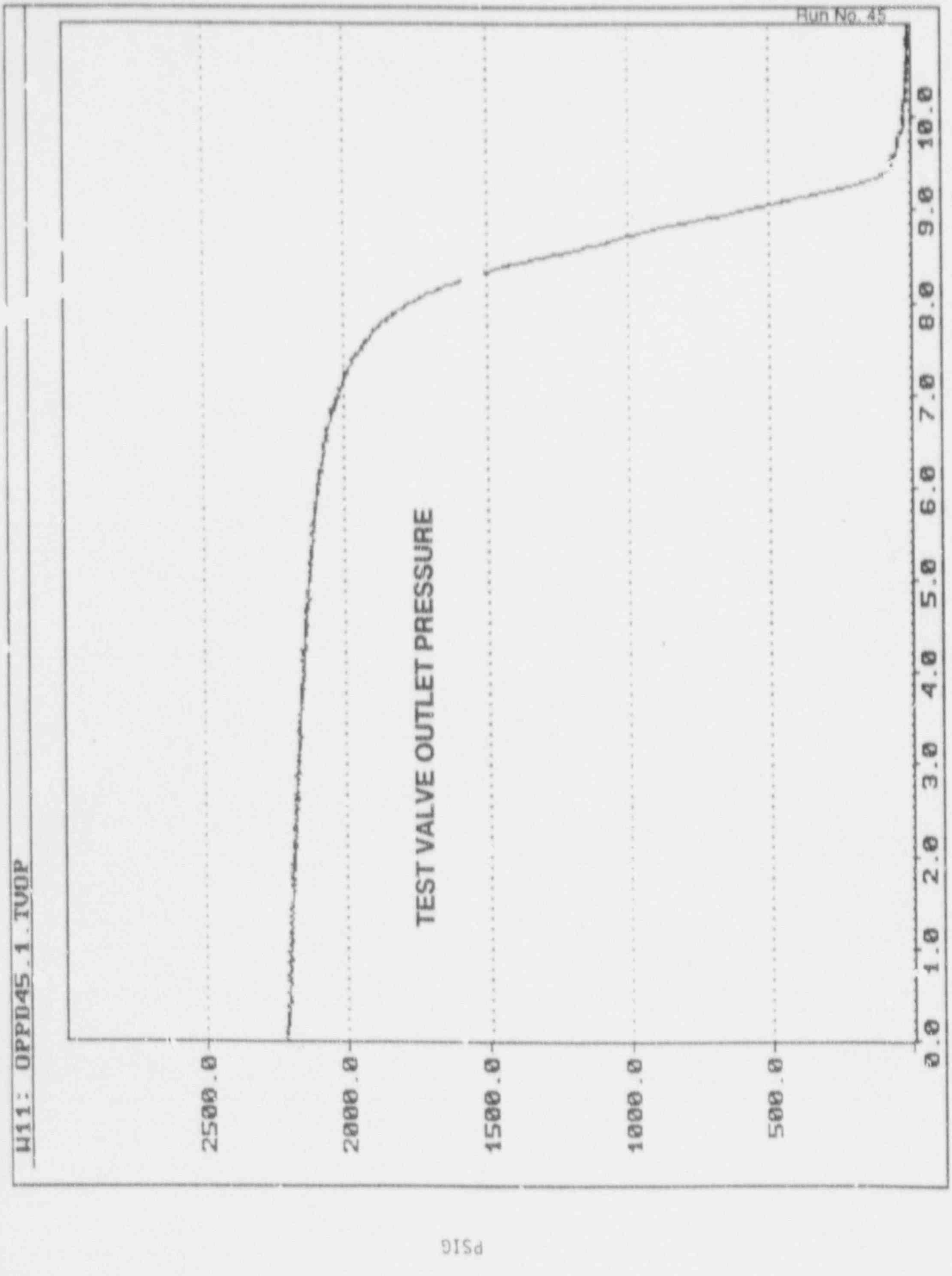
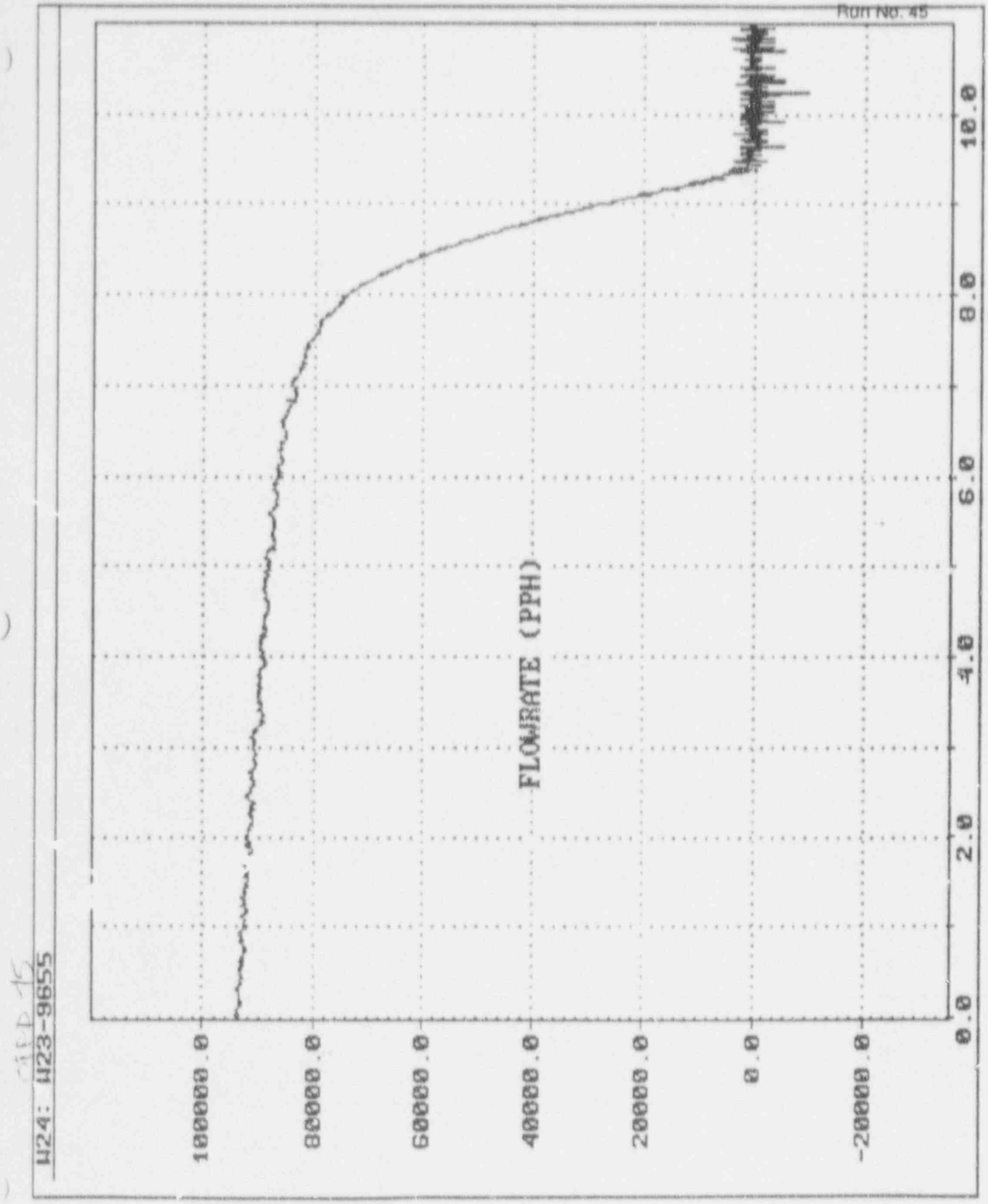
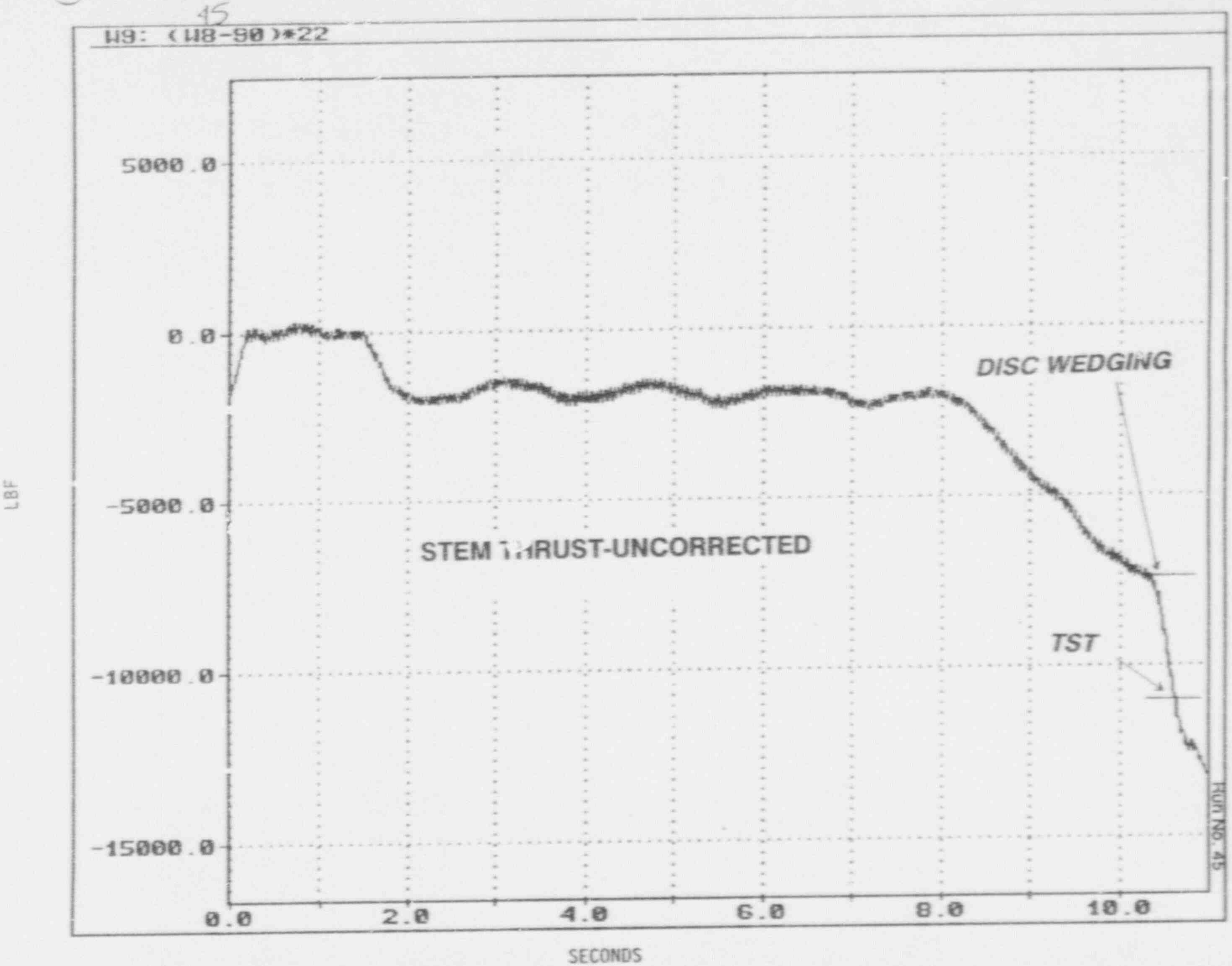

Run No. 45
W11: OPPD45_1_TVOP
TEST VALVE OUTLET PRESSURE
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
SECONDS
PSIG


W24: W23-9655
FLOWRATE (PPH)
100000.0
80000.0
60000.0
40000.0
20000.0
0.0
-20000.0
0.0
2.0
4.0
6.0
8.0
10.0
SECONDS
PPH



Report No. 57411
Page No. A-422

APPENDIX M

STEM THRUST STRAIN GAUGE CALIBRATION CURVE

MICROSTRAIN VS COMPRESSIVE LOAD
(Actual Test Data)

u Microstrain (Times 1,000)	Compressive Load (Pounds)
+ 48	- 1,000
- 157	- 3,300
- 253	- 4,800
- 328	- 6,000

MICROSTRAIN VS COMPRESSIVE LOAD
(Calculated Calibration Curve)

Compressive Load = 13.176u - 1502.2

u Microstrain (Times 1,000)	Compressive Load (Pounds)
0	- 1,502
- 400	- 6,773
- 800	- 12,043
- 1,000	- 14,678

CALIBRATION CURVE

(13.176u - 1502.2)