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Informal Report on Activities in Progress at the
EPRI M&D Center

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CONTENTS

SUMMARY

An initial motor current signature analysis (MCSA) has been carried out on several motor-driven devices at the Eddystone power plant. An on-line automated data acquisition system has been installed and is now providing useful motor current signature information for eight Unit #2 extraction valves. This system has also been used to identify two significant (and apparently undesirable) extraction valve operational characteristics that are documented in this report.

Initial motor current signature examinations of other equipment (eight Unit #3 motor-operated valves, four boiler feed pumps, two induced-draft fans, and two mills) have provided interesting detailed baseline information that will be compared with subsequent test data in order to attempt to detect aging and service wear effects and signs of incipient failure.

Overall, a considerable amount of baseline motor current data has been acquired, examined, and now documented. Future work will focus on developing the capability of identifying parameter trends that are useful in detecting degradation and other abnormalities in the tested equipment.

1. INTRODUCTION

1.1 Background

The Oak Ridge National Laboratory (ORNL) has recently established the Advanced Diagnostic Engineering Research and Development Center (ADEC) in order to play a key role in the relatively new field of diagnostic engineering. ADEC is an organized multi-disciplinary diagnostics research program that brings together experts in many fields in order to develop and apply new advanced diagnostic technologies, especially within the power generation industry.

One of the most promising new machinery monitoring technologies, motor current signature analysis (MCSA), is the focus of several ADEC tasks. MCSA is based on the discovery that a conventional electric motor (ac or dc) driving a mechanical load acts as an efficient and permanently available transducer, detecting small time-dependent motor load variations generated anywhere within the mechanical system and converting them into electric-current noise signals that flow along the power cable.

MCSA technology was initially developed by ORNL as a means of determining the effects of aging and service wear on motor-operated valves (MOVs). Research carried out at ORNL identified several MOV motor current signature features that were affected by implanted defects and simulated degradation [1]. MCSA is recognized to be applicable not only to MOVs but also to a much broader range of machinery as well. One objective of ADEC is to demonstrate advanced monitoring and control techniques and applications that utilize MCSA, both on MOVs and on other equipment such as pumps, fans, compressors, and pulverizers.

The EPRI Monitoring and Diagnostics (M&D) Center at the Philadelphia Electric Company Eddystone Generating Station has provided ORNL/ADEC a unique opportunity to apply MCSA technology as an on-line MOV diagnostic monitoring technique.

1.2 ORNL Work Objectives at the EPRI M&D Center

The ORNL/ADEC work at the EPRI M&D Center (Eddystone power plant) is presently being carried out with these objectives in mind:

1. Demonstrate the workability of an automated data acquisition system in a real plant environment,
2. Obtain long-term performance data from service-aged MOVs,
3. Demonstrate the correspondence between parameter trends and performance problems or signs of degradation, and
4. Demonstrate the usefulness of MCSA on devices other than MOVs.

1.3 Equipment Tested

Several motor-driven devices at the Eddystone power plant have been the subject of motor current data acquisitions and analyses. A list of those devices that have been tested to date are shown in Table 1.

Table 1. Motor-Driven Equipment at the Eddystone Power Plant That Have Been Tested Using MCSA

Device	Number
Motor-Operated Valves	16
Induced-Draft Fans	2
Boiler Feed Pumps	4
Mills	2

The following sections in this report include additional information on these devices and provide the results obtained from their tests.

2. TEST RESULTS

2.1 Motor-Operated Steam Extraction Valves

A majority of the work done by ORNL/ADEC at the Eddystone power plant has focused on eight motor-operated valves in Unit #2 that are open during normal operation and whose function is to allow steam extraction from various turbine sections. This steam is routed through eight individual feedwater heaters (5A, 5B, 6A, 6B, 7A, 7B, 8A, 8B) to preheat the boiler feedwater. According to Eddystone, it is imperative that these extraction valves close if a significant feedwater heater tube leak occurs in order to avoid water induction back into the turbine sections.

2.1.1 Equipment Description

Based on valve information sheets provided by Eddystone, all eight extraction MOVs utilize Limitorque motor operators having motors rated for 3 phase, 60Hz, 208 volt power. Additional descriptive data for the extraction valves are shown in Table 2.

Table 2. Selected Descriptive Data for the Eight Unit #2 Extraction Valves

Valve ID	Motor Man. and S/N	Horse Power	RPM	Running Current	Motor Torque	Motor Operator	Order # Serial #
5A	Peerless EEK79044	1.00	1750	6.0 A	15.0 lb-ft	SMB-00	373109A 174659
6A	Peerless GJ72517	0.66	1750	4.4 A	10.0 lb-ft	SMA-00	88027 73495
7A	Peerless GJ72512	0.50	1750	4.0 A	7.5 lb-ft	SMA-00	40718D 75396
8A	Peerless GJ72520	1.00	1750	6.0 A	15.0 lb-ft	SMA-0	90782 75185
5B	Peerless MJ75911	0.50	1750	4.0 A	7.5 lb-ft	SMA-00	40699 76980
6B	Peerless GJ72537	0.66	1750	4.4 A	10.0 lb-ft	SMA-00	90779 75065
7B	Reliance Y122929A2	N/A	1675	4.2 A	10.0 lb-ft	SMA-00	76774 65925
8B	Peerless GJ72519	1.00	1750	6.0 A	15.0 lb-ft	SMA-0	90782 75186

As indicated by Table 2, all MOVs utilize SMA-type motor operators except valve 5A which uses a more recent vintage SMB-type operator.

2.1.2 ORNL On-Line Monitoring System - General Method of Operation

The following section provides a general description of the ORNL on-line MOV motor current monitoring system and how it has been utilized to obtain motor current signature information for the eight extraction valves at the Eddystone plant. Further detailed information with regard to the systems hardware and software elements will be made available after patent issues are resolved.

The ORNL-developed system is shown schematically in Figure 1. MOV motor current signals are acquired by 400:1 ratio toroidal current transformers, located near each motor control center. The ac current signals supplied by the secondary side of the current transformers are transmitted via coax cables to the first floor data acquisition room where they are connected to signal processing equipment developed especially for this application. At this location, each coax cable is terminated individually by a load resistor and the resulting voltages are summed, prior to undergoing signal conditioning (amplification, filtration, etc...).

When using this voltage summing technique, it is recognized that one major requirement for reliable operation of the ORNL system is that only one MOV be actuated at a time. If more than one MOV is running, the summed voltage signal contains elements of both MOVs and is usually unacceptable for analysis. As will be discussed later in this report, multiple valve actuations appear to have occurred occasionally.

During an MOV actuation, the signal processing equipment provides two outputs, one suitable for time-domain (waveform) analysis and one suitable for frequency-domain (spectral) analysis. In addition to the two analog signals, a digital signal is also generated by the signal processing equipment which reflects the identity of the MOV being actuated. The three analog and digital signals are carried by cables to the upstairs data display room where they are monitored continuously by a computer-based data acquisition system.

A general system operation flowchart is presented in Figure 2 and illustrates that the process of MOV signature development is presently a four-step process which includes data acquisition at Eddystone, data transfer to ORNL, and database construction and data analysis at ORNL. It is recognized that future system developments may ultimately streamline this process to the point where all necessary functions are carried out at the Eddystone plant.

The desktop computer monitors the analog and digital signals using a computer code called AUTOWAV. AUTOWAV acquires and stores data intelligently - that is, by keeping only the signature information that represents MOV actuations, and not storing unnecessary pre- and post- actuation signals. The rationale behind this data acquisition scheme is not simply to store MOV signatures efficiently, but rather is a response to the recognition that each MOV requires a different length of time to actuate through its entire stroke. As will be discussed later in this report, measured stroke times from valve to valve vary considerably (from less than 30 seconds to over 80 seconds). The AUTOWAV code also presently contains the capability to determine and display (on the computer screen) the valve stroke time, a potentially meaningful diagnostic parameter. It does this immediately after each MOV has completed an actuation.

The analog signals acquired by AUTOWAV are stored in binary-coded files on an internal hard disk according to a format that identifies valve number (e.g., 5A, 5B, ...), day and time acquired, and the sequence in which it is saved (e.g., first stroke, second stroke, ...). Stored data are then transferred to Oak Ridge (normally biweekly) by means of a modem, telephone line, and CARBON COPY PLUS (a software product of Meridian Technology, Inc.).

The received binary data files are then converted in Oak Ridge to analyzable MOV signatures in both time waveform and frequency spectrum formats. The data conversion utilizes an ORNL-developed computer program called WPDFIL which features a specially-developed algorithm that transforms the steady-state (non-transient) portion of a processed MOV motor current time signature to the frequency domain which provides a more sensitive and selective means to identify and trend periodic motor operator characteristics. The converted files are compatible (readable) by WAVEPAK (a software product of Computational Systems, Inc.).

The WAVEPAK subprograms, DATFIL and ANALYZ, are then utilized to read and display the extraction valve motor current signatures which are discussed in the following section.

2.1.3 Motor Current Test Data

During the month of October 1989, considerable motor current data were acquired from the eight Unit #2 steam extraction valves. These data were analyzed in both the time and frequency domains. The following sections describe the preliminary results from these analyses and offer possible explanations for a few of the trends observed. In view of the fact that these data represent baseline information from these MOVs, considerable effort was made to look at as much data in as many ways as was practical. Future data analyses (and the results presented in future reports) will undoubtedly not be as comprehensive, but will focus on those trends that appear to be most useful.

When studying the trend plots, it appeared that valve stroke direction was missed from time to time, resulting in an open-close data point being plotted within a grouping of data representing the close-open direction. Similarly, a close-open data point was occasionally plotted in close proximity to open-close data. It should be recognized that no attempt has been made by ORNL/ADEC to determine stroke direction directly, but rather to assume that in all cases, the first recorded stroke for a MOV on a given day is the open-close stroke since the valves are open during normal operation.

2.1.3.1 Time Domain

Analyses of extraction valve motor current time waveforms provided several insights; most notable was the observation that none of the eight valves showed any obvious signs of full closure (seating). This apparent lack of closure would be in contradiction to the functional requirements for these valves, stated earlier in this report. After this observation was initially described to the Eddystone plant personnel, it was identified that the mechanism for tripping all extraction valve motors in the closed valve position was the motor operator limit switch, which apparently trips the motor prior to valve closure and thus explains the absence of valve seating information.

Two major quantifiable signature characteristics were easily obtained from the time waveforms: stroke time and average running current. Both of these signature features were monitored over the month of October and are discussed in the following sections. In addition to those data acquired during October, stroke time and average running current data acquired on May 22, 1989, with portable MCSA equipment are also plotted for comparison.

2.1.3.1.1 Typical Time Waveforms

Figures 3 through 18 illustrate typical open-close and close-open time waveforms for the eight extraction valves during October. The lack of a discernible rise in motor current magnitude at the end of the open-close stroke of each extraction valve was indication that all valves failed to close fully.

2.1.3.1.2 Stroke Time Trends

Figures 19 through 26 present stroke time trend plots for each extraction valve and illustrate that, in general, the open-close stroke times were greater than the times measured for the close-open stroke. One possible explanation for this is that the running loads in the open-close direction were greater, which is understandable from the recognition that valve internal fluid pressure acts to oppose valve closure while assisting valve opening. Figures 19 through 26 also illustrate that valve stroke times varied considerably from valve to valve.

It is noted that no stroke time data was obtained for valve 7A. This resulted from an un-optimized trigger level setting in the AUTOWAV code. The trigger level has since been modified, resulting in acceptable data acquisition for that valve.

Recognizing that AUTOWAV computes stroke time automatically and displays the result on the computer screen, a comparison of manually determined stroke times and those measured by AUTOWAV was made. The results, shown in Figure 27, indicate that the stroke times computed by AUTOWAV are accurate and may thus be utilized for diagnostic purposes.

2.1.3.1.3 Average Running Current Trends

Figures 28 through 39 provide daily measurements of average running current during October for each extraction valve. Figures 28 through 31 present a valve-to-valve comparison within each train and show that from day to day, a decrease in average running current in one valve is usually matched by decreases in running current in other valves. One possible explanation for these daily increases and decreases in current is that line voltage fluctuates in a similar manner. It seems unlikely that internal valve pressure changes are responsible for this trend, since (as discussed earlier) an increase in pressure would generally increase open-close running current while decreasing running current in the close-open direction. An examination of Figures 28 through 31 shows that when open-close stroke current levels decrease, similar decreases in running current are observed in the close-open stroke. Hence, it appears that voltage, not pressure, may be the explanation for this observation.

Figures 32 through 39 show that open-close stroke average running current levels are generally greater than close-open stroke current levels - again reflecting the apparent increased running loads (due to internal valve pressure) that are present in the open-close stroke.

Figures 40 and 41 illustrate, for two valves, one potentially useful data analysis technique - the determination of the difference in running current between stroke directions. This measurement may generally reflect the change in internal fluid pressure from day to day, recognizing that a substantial increase in internal pressure would result in greater open-close current and less close-open current, and thus an increase in the difference in current between the two strokes.

2.1.3.1.4 Stroke Time vs. Running Current

A potentially useful analysis technique is the cross-plotting of stroke time and running current. ORNL tests have been carried out recognizing that the relationship between MOV motor slip and motor current is predictable for a given line voltage. Those tests have shown that by monitoring motor current alone, a determination can be made as to whether a change in running current is a result of a change in actual running loads or simply a result of a change in line voltage.

Figures 42 and 43 illustrate the relationship between stroke time (which is a function of motor slip) and running current for two valves. Assuming that valve stroke (distance) remains constant from day to day, the significant data scatter observed in Figures 42 and 43 suggests that day to day line voltage fluctuations were present.

2.1.3.1.5 Unusual Signature Features

Two MOVs exhibited unusual time waveform features worth noting. Occasionally, the valve 5A open-close signature contained evidence of a motor trip and restart at the exact same time (1.30 seconds) from the beginning of the valve stroke. Figure 44 illustrates this observed anomaly which has initially been identified as a relay problem. Another unusual feature was present on several close-open stroke signatures for valve 8A. Figure 45 shows that variations in running load have occurred during October near the beginning of the valve stroke. Both the 5A and 8A anomalies will be monitored closely during the next month and Eddystone personnel will be kept advised as to their status.

2.1.3.2 Frequency Domain

Analyses of extraction valve motor current signals in the frequency domain were carried out, although only limited conclusive results can be presented at this time due to the existence of non-MOV related spectral peaks that tended to "cover up" the MOV-related spectral peaks. Initial attempts to remove this "noise" from the MOV information provided some improvement in spectral appearance; however, additional refinements in the technique is needed before substantial useful MOV information may be routinely extracted from the frequency domain.

A brief discussion of results is presented in the following sections.

2.1.3.2.1 Motor Current Spectra

Figures 46 and 47 are frequency spectra from both open-close and close-open actuations of valves 8A and 8B, respectively and are illustrative of the frequency domain signatures obtained from the extraction valves in October. The predominant 2 Hz, 4Hz, 6Hz, 8Hz, ..., peaks appear to be characteristics of the power line, and are discussed briefly in the next section. A comparison of open-close and close-open signatures identify differences in spectra that are apparently MOV-related, assuming the power line spectra are stable during a full valve cycle. Once extraction valve spectra are more clearly understood, trending of key features will be carried out.

2.1.3.2.2 Dummy Load Spectra

A test was carried out to verify that the power line was indeed responsible for some frequency components. To do this, current through a fixed resistive "dummy load" was monitored on two separate occasions. A dummy load was installed at the extraction valve motor control centers for both train A and train B. Frequency spectra are presented in Figures 48 and 49 and illustrate that the power line noise was not only different between trains (train B was generally noisier than train A) but also varied between the two days it was acquired as well.

2.1.4 Monitoring System Performance and Anomalies

The on-line MOV monitoring system, for the most part, worked very well throughout October. In addition to recording "normal" MOV motor current signatures, however, there were many instances where the system recorded "partial", "multiple starts", "end-begin", and "off-on" signatures. Examples of each signature type are shown in Figures 50 through 54. Anomalies are described and explained below.

The first anomaly, the partial run, was where the first part of the signature was missing. With only the last part of the actuation being recorded and the start up peak not present, the stroke time could not be determined from these plots. The average running current was still readable on the partial runs and the final current drop off (motor trip) could be inspected for seating indication. The most probable cause of the partial runs was that the computer trigger level was set too high or a strong transient was fooling the computer, which resulted in missed data. The number of partial runs decreased significantly after modifying the AUTOVAV trigger level.

When two or more start-up peaks occurred during the same valve signature, it was identified as a multiple starts anomaly. These multiple valve operations interfered with the stroke time measurements of the signatures to the point of making them undeterminable. The only useful information that was usually determined from this type signature was the average running current, and sometimes, even that was obscured. These anomalies can be eliminated if valves are simply actuated one at a time.

In several cases, the end of one run and the beginning of another were together and stored as one valve signature. These plots were considered part of the third type of anomaly, the end-begin. In a few cases, the end of one run was followed by a complete next run. Like the partial run, the end-begin signature appeared to be a result of an unoptimized trigger level.

For each of the days when data were recorded by the system, two actuations of each valve were expected to be present. If a signature was missing for one or both actuations, this was recorded under the fourth anomaly, not taken. If only the second actuation of a valve is missing, the first actuation was usually a multiple start or a end-begin.

The last anomaly, off-on, was for those valve signatures that start out appearing normal, but during the run, the motor shuts off for a period of one to five seconds and is restarted. While the average running current was easily read, the stroke time could not be determined since the run was never completed. There were not many cases (only 5) of this during October.

2.2 Motor-Operated Valves in Unit #3

On August 29, 1989, eight Eddystone plant Unit 3 MOVs were tested using portable MCSA equipment. Recognizing an interest on the part of both Eddystone plant personnel and ORNL/ADEC to acquire motor current signatures on these MOVs again, the results from the tests are presented here in detail. The descriptions of those valves tested as well as the results obtained from the tests are described in the next few sections.

2.2.1 Valve Descriptions

Not as much information is presently known about the Unit 3 MOVs as is known about the extraction valves. A selection of information that was supplied by Eddystone is presented in Table 3 below.

Table 3. Selected Descriptive Data for the Eight Unit #3 Valves

Valve ID	Motor Man. and S/N	Horse Power	RPM	Running Current	Motor Torque	Motor Operator	Order # Serial #
VE7	Limitorque YA57476	0.133	1750	0.55	2.0 lb-ft	SMB-000	n/a
VE9	Limitorque 447026-6Y	1.0	1700	2.80	15.0 lb-ft	SMB-00	n/a
VP0	Limitorque XA59095	0.66	1750	2.2	10.0 lb-ft	SMB-00	n/a
VP1	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VP2	Limitorque XA59108	0.66	1750	2.2	10.0 lb-ft	SMB-00	n/a
VP3	Limitorque 447026-MX	0.66	1700	2.8	15 lb-ft	SMB-00	n/a
VP5	Limitorque YA57464	0.133	1750	0.55	2.0 lb-ft	SMB-000	n/a

VP6	Limitorque YA57457	0.133	1750	0.55	2.0 lb-ft	SMB-000	n/a

2.2.2 ORNL Portable Test Method

Motor current monitoring of the Unit #3 MOVs was carried out using a clamp-on current transformer (Fluke 80i-600) at the motor control center (MCC) of each valve. The current transformer provided a 1000:1 current attenuation with a secondary coil signal level suitable for test instruments. Other equipment used included a portable motor current signal conditioner (ORNL development), and a portable tape recorder (TEAC R61). Motor current signal recordings were later displayed and analyzed off-site by a portable computer (COMPAQ Portable 2 model 4) using a hardware and software package that provided digital oscilloscope and spectrum analyzer emulation (WAVEPAK).

During the acquisition of motor current data for some valves (VE9, VP2, and VP5), the signal conditioning electronics were not set up properly due to not knowing beforehand the rated current for each MOV motor. Shortly after these MOVs were started, the signal conditioning parameters were changed, which resulted in several apparent current level changes and transients. These features should be disregarded when viewing the close-open time waveforms for these valves. Due to the procedure used in generating the frequency spectra, these signatures were not affected by the signal conditioning artifacts.

2.2.3 Motor Current Test Data

Motor current data are presented in the next sections in both time domain and frequency domain signatures. As will be evident from the signatures described below, both average running current and stroke time varied considerably from valve to valve. Other time domain and frequency domain characteristics were seen to vary as well.

2.2.3.1 Time Domain

The recorded Unit #3 MOV motor current data were analyzed in the time domain in order to obtain average running current and stroke time information, as well as to determine additional details with regard to MOV operational characteristics. Figures 55 through 70 illustrate the overall motor current time waveforms for the open-close and close-open valve strokes.

The most obvious difference between the open-close signatures for the Unit #3 valves and previously described extraction valves was that several of the Unit #3 valves showed signs of seating. Only VP0, VP1, and VP6 showed no obvious signs of valve seating. Valves VE7 and VP1 contained an anomaly during their close-open valve strokes that appeared to resemble a momentary change in line voltage rather than a change in running load since a similar feature was not observed on the accompanying open-close stroke signatures. Valve VP1 running current magnitudes decreased slightly during its operational cycle (close-open-close) and appeared similar to valve signatures previously analyzed by ORNL that were from MOVs left idle for some period of time.

One interesting observation was that the valve VP6 close-open stroke time was shorter (31.8 seconds vs. 34.1 seconds) than the accompanying open-close stroke time. One possible explanation for this difference was that more inertial coasting (after the motor tripped) occurred in the close-open stroke direction which resulted in a longer open-close valve stroke than that required to open the valve. The inertial coasting in the open-close direction may have been terminated by contact between the valve obturator and seat during closure. Differences in stroke times were even greater for valve VPO. The most likely explanation for the > 12 second difference in actuation times between open-close and close-open strokes was that the valve was not closed completely. Stroke times and average running currents are summarized for the eight Unit #3 valves in figures 71 and 72.

2.2.3.2 Frequency Domain

Motor current frequency spectra were obtained from the eight Unit #3 valves and were seen to be void of any power line artifacts, contrary to the Unit #2 extraction valves. Figures 73 through 88 illustrate that motor current noise characteristics varied not only from valve to valve but also from stroke to stroke for each valve. This is understandable since, as a motor operator opens or closes a valve, internal gears mesh on different tooth surfaces (dependent on direction). Some valve spectra contained more harmonic and sideband content of suspected worm gear tooth meshing frequencies that would suggest that some motor operator worm gears and/or stem nuts are worn more than others. All MOV characteristic frequencies will be conclusively identified once actual gear teeth numbers are obtained. As additional motor current data are acquired on these valves, more substantial results will be obtained as a result of tracking several key spectral peaks over time, and/or before and after controlled MOV modifications (e.g., tightened packing, changed stem nut lubrication, ...)

2.3 MCSA Applied to Other Equipment

Motor current signature analysis has been applied at the Eddystone power plant to other non-valve motor-driven devices as well. On August 9, 1989, motor current data were acquired on the following equipment:

2A Induced-Draft Fan
2B Induced-Draft Fan

C Mill
D Mill

2A Intermediate-Pressure Boiler Feed Pump
2B Intermediate-Pressure Boiler Feed Pump
2A Low-Pressure Boiler Feed Pump
2B Low-Pressure Boiler Feed Pump

Figures 89 through 100 provide individual spectral displays for each machine tested as well as comparison plots between similar machines. Identified on the bottom of each individual spectra is the average running current measured during testing. The primary purpose for including these spectra in this report is to provide "baseline" information to which subsequent spectra can be compared to.

3. Plans for Future Work

There are several areas worthy of future work including:

1. Continued testing of familiar equipment (e.g., previously tested MOVs, pumps, fans, and mills)

2. Initial testing of other equipment (esp. air compressors)

3. Investigating the possibility of data coloration attributable to the acquisition of signals from the secondary (meter) side of the Eddystone current transformers.

4. Making improvements in the on-line MOV monitoring system:

   (a) Optimization of AUTOWAV trigger level
   (b) Improvement of MOV frequency domain information through identification and removal of power line noise
   (c) Upgrading Eddystone-resident programming such as improving real-time screen display, adding trend plot capabilities, and implementing low level automated diagnostics.

The timetable for this work is not clear; however, with continued interaction with M&D Center personnel, priorities can be determined based on the relative importance of each task to the objectives of ORNL/ADEC, EPRI, and the Eddystone plant.

4. Summary and Interim Conclusions

An initial motor current signature analysis (MCSA) has been carried out on several motor-driven devices at the Eddystone power plant. The on-line automated data acquisition system for eight Unit #2 extraction valves has been installed and is now working well. The extraction valve data analyses carried out thus far have resulted in the identification of several trends that will be further examined both by continued motor current signature feature monitoring and by additional discussions with Eddystone personnel. With the modification of the AUTOWAV trigger level on October 31, the MOV data acquisitions appear to be proceeding at an improved level of reliability.

Two significant extraction valve operational characteristics were identified and have been discussed with Eddystone personnel. Perhaps the most significant was that none of the eight extraction valves showed signs of complete closure. A second notable observation was the occasional motor trip and restart observed on valve 5A.

Frequency domain examinations of extraction valve motor current signals and the subsequent dummy load tests identified the existence of a significant level of power line noise. Initial attempts to separate power line and MOV characteristics from the MOV motor current spectra were encouraging but need further refinement.

Tests of the Unit #3 MOVs provided clean frequency domain spectra (no power line noise), a significant observation in itself. The resulting MOV spectra were thus examined and found to contain typical spectral characteristics although verification of peak identities requires the knowledge of specific gear teeth numbers. The most significant finding observed from the time waveform analyses was that several of the Unit #3 valves showed obvious signs of seating, a feature not seen in the Unit #2 extraction valves.

Motor current signature examinations of other equipment (boiler feed pumps, induced-draft fans, mills) have provided interesting detailed spectral peak information, although peak identification will require additional discussions with Eddystone plant personnel and further testing.

Overall, a considerable amount of motor current data has been acquired, examined, and now documented in this first progress report. With continued effort on the part of ORNL/ADEC, EPRI, and Eddystone plant personnel, motor current signature analysis can be implemented in a way that benefits us all.

REFERENCES

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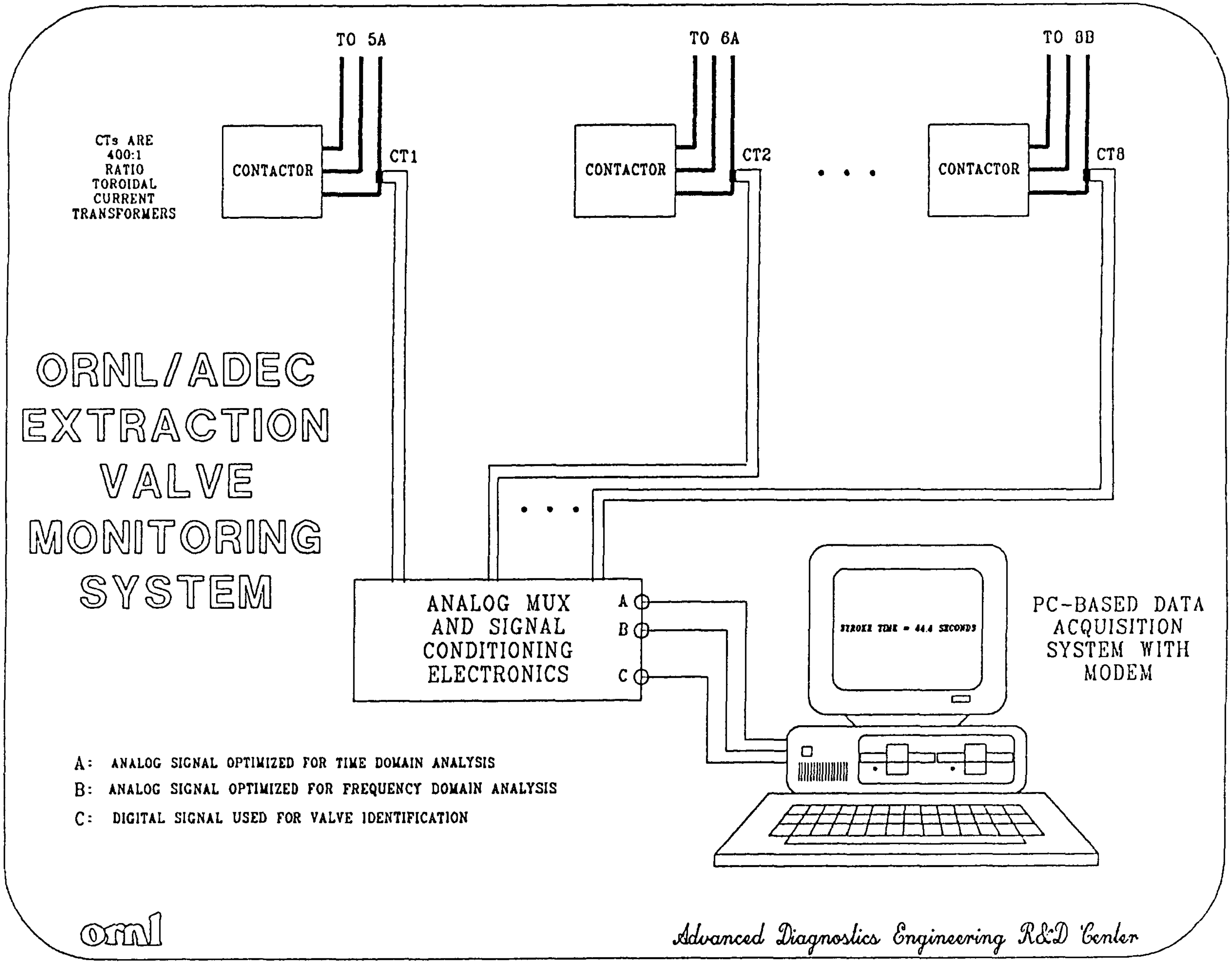

TO 5A
TO 6A
TO 8B
CTs ARE 400:1 RATIO TOROIDAL CURRENT TRANSFORMERS
CONTACTOR
CT1
CONTACTOR
CT2
CONTACTOR
CT8
ORNL/ADEC EXTRACTION VALVE MONITORING SYSTEM
ANALOG MUX AND SIGNAL CONDITIONING ELECTRONICS
A
B
C
STROKE TIME = 44.4 SECONDS
PC-BASED DATA ACQUISITION SYSTEM WITH MODEM
A: ANALOG SIGNAL OPTIMIZED FOR TIME DOMAIN ANALYSIS
B: ANALOG SIGNAL OPTIMIZED FOR FREQUENCY DOMAIN ANALYSIS
C: DIGITAL SIGNAL USED FOR VALVE IDENTIFICATION
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 1

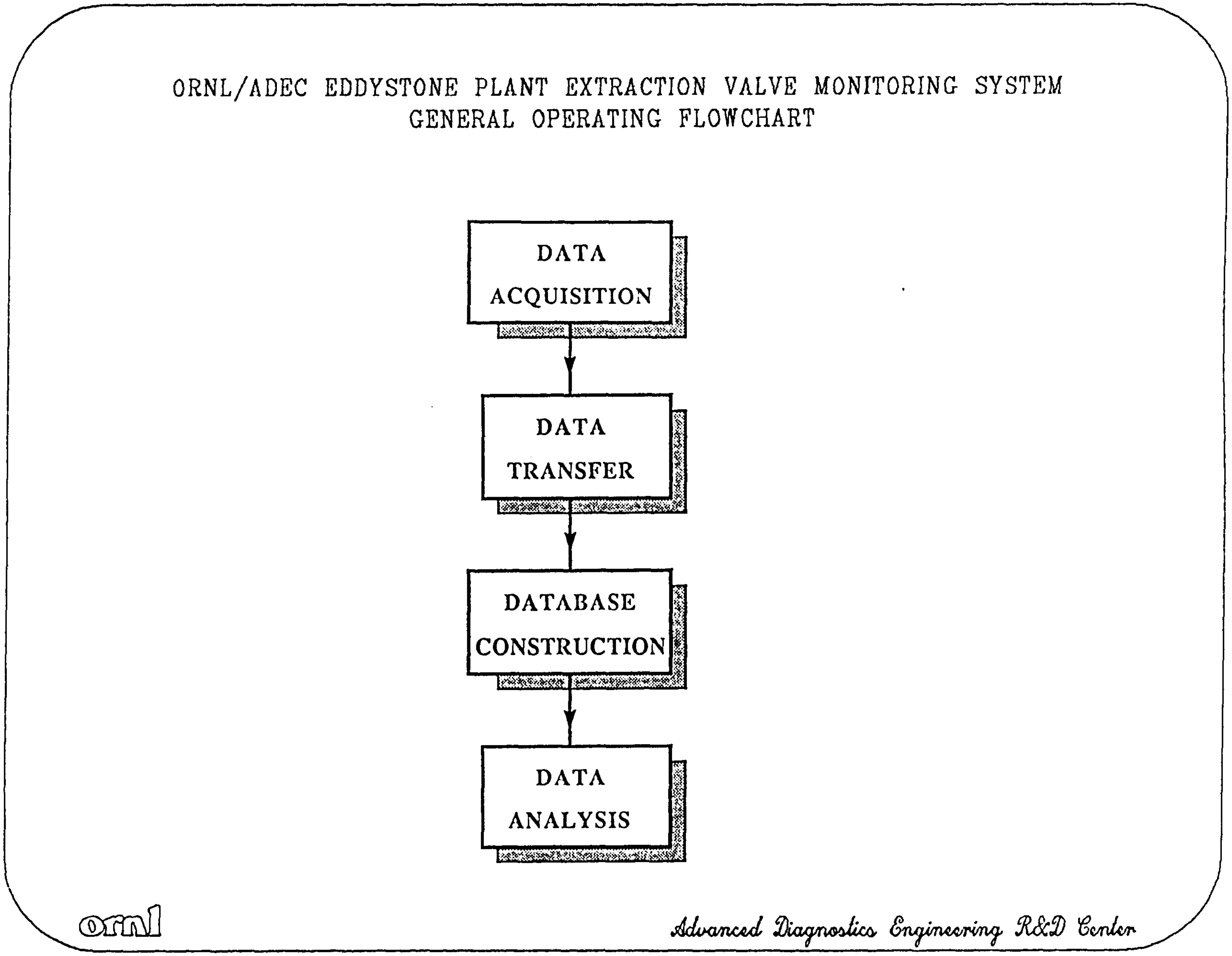
ORNL/ADEC EDDYSTONE PLANT EXTRACTION VALVE MONITORING SYSTEM
GENERAL OPERATING FLOWCHART
DATA ACQUISITION
DATA TRANSFER
DATABASE CONSTRUCTION
DATA ANALYSIS
ornl
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FIGURE 2

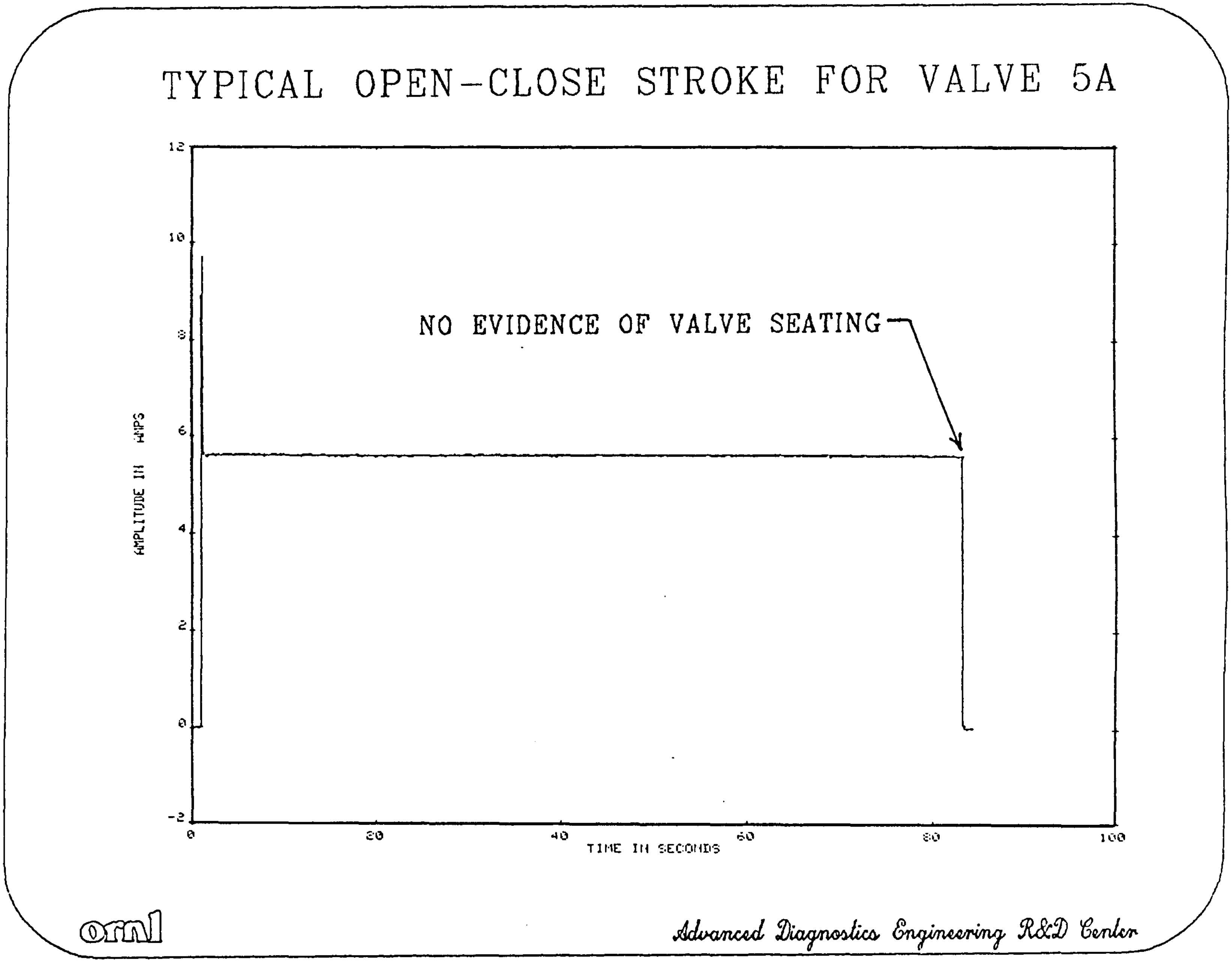
TYPICAL OPEN-CLOSE STROKE FOR VALVE 5A
NO EVIDENCE OF VALVE SEATING
AMPLITUDE IN AMPS
TIME IN SECONDS
12
10
8
6
4
2
0
-2
0
20
40
60
80
100
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FIGURE 3

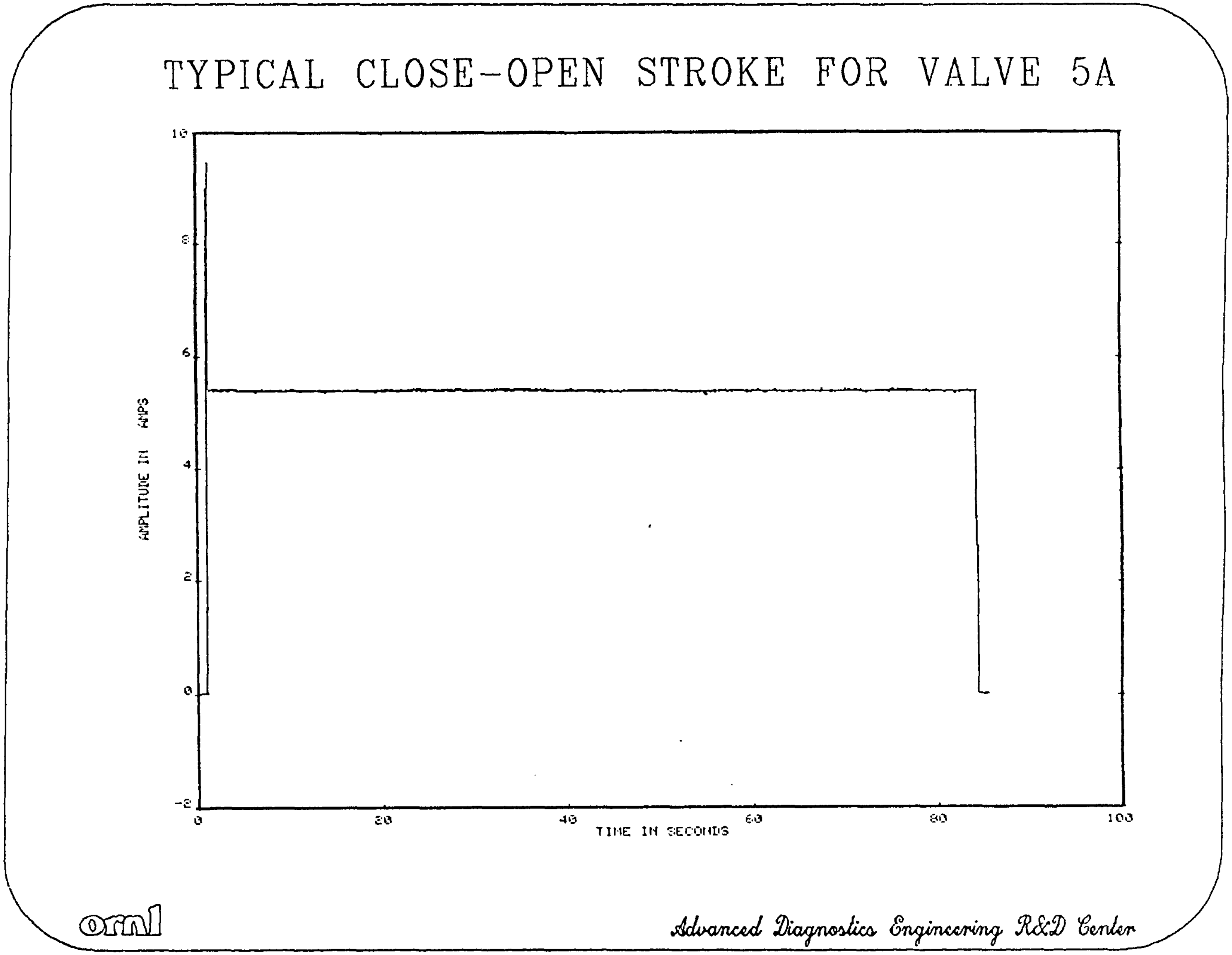
TYPICAL CLOSE-OPEN STROKE FOR VALVE 5A
AMPLITUDE IN AMPS
TIME IN SECONDS
10
8
6
4
2
0
-2
0
20
40
60
80
100
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 4

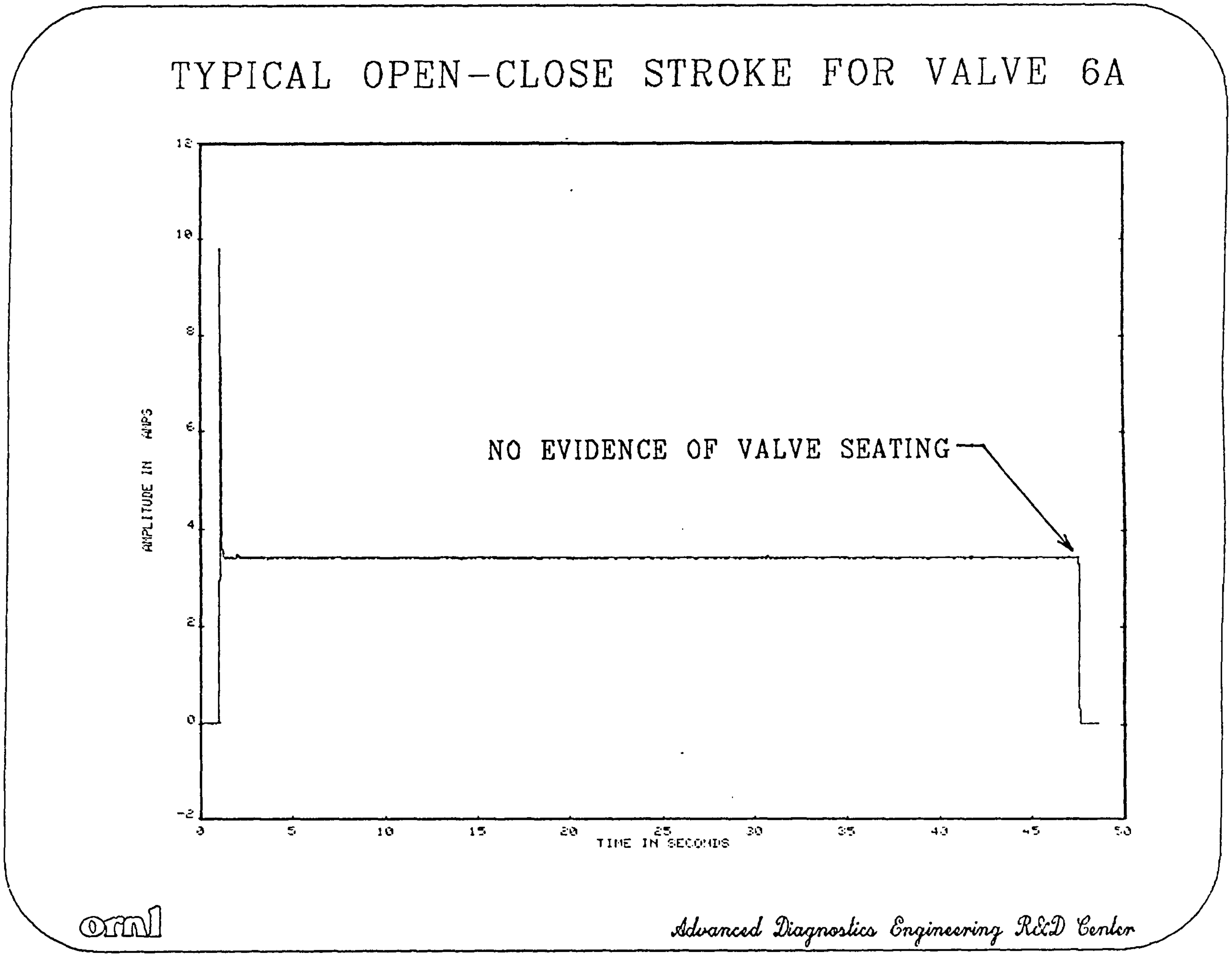
TYPICAL OPEN-CLOSE STROKE FOR VALVE 6A
12
10
8
6
4
2
0
-2
AMPLITUDE IN AMPS
NO EVIDENCE OF VALVE SEATING
0
5
10
15
20
25
30
35
40
45
50
TIME IN SECONDS
Advanced Diagnostics Engineering R&D Center

FIGURE 5

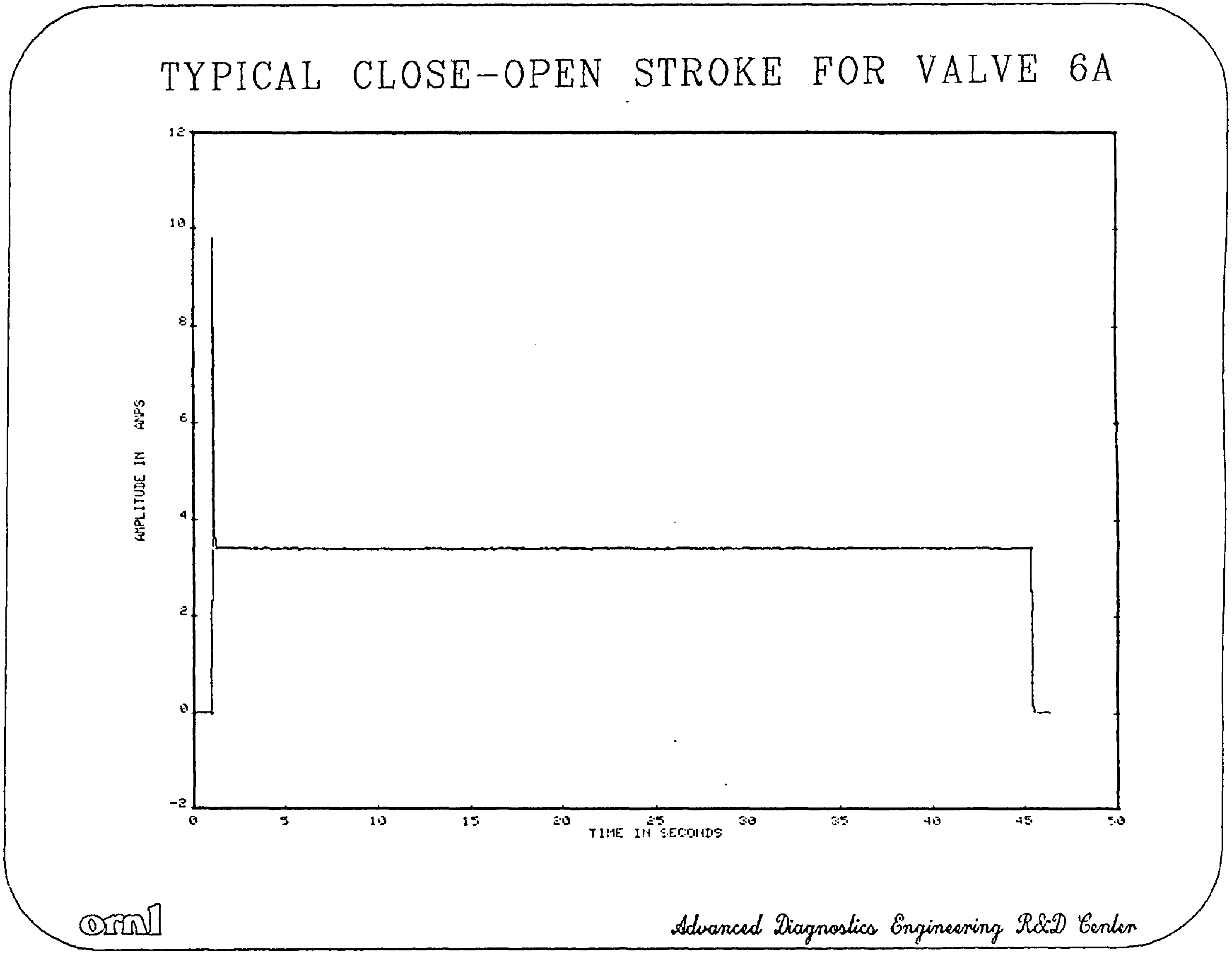
TYPICAL CLOSE-OPEN STROKE FOR VALVE 6A
AMPLITUDE IN AMPS
TIME IN SECONDS
12
10
8
6
4
2
0
-2
0
5
10
15
20
25
30
35
40
45
50
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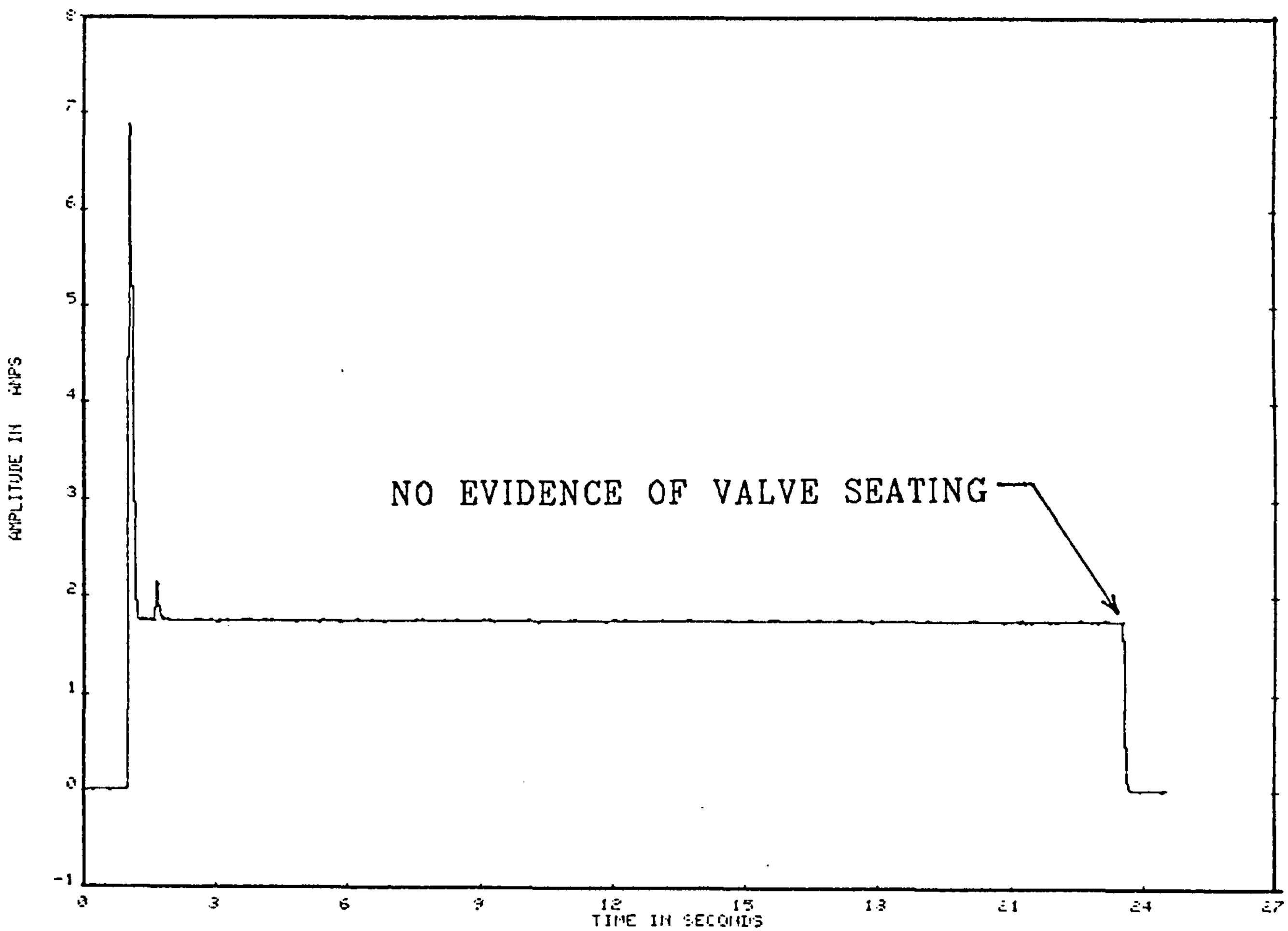
FIGURE 6

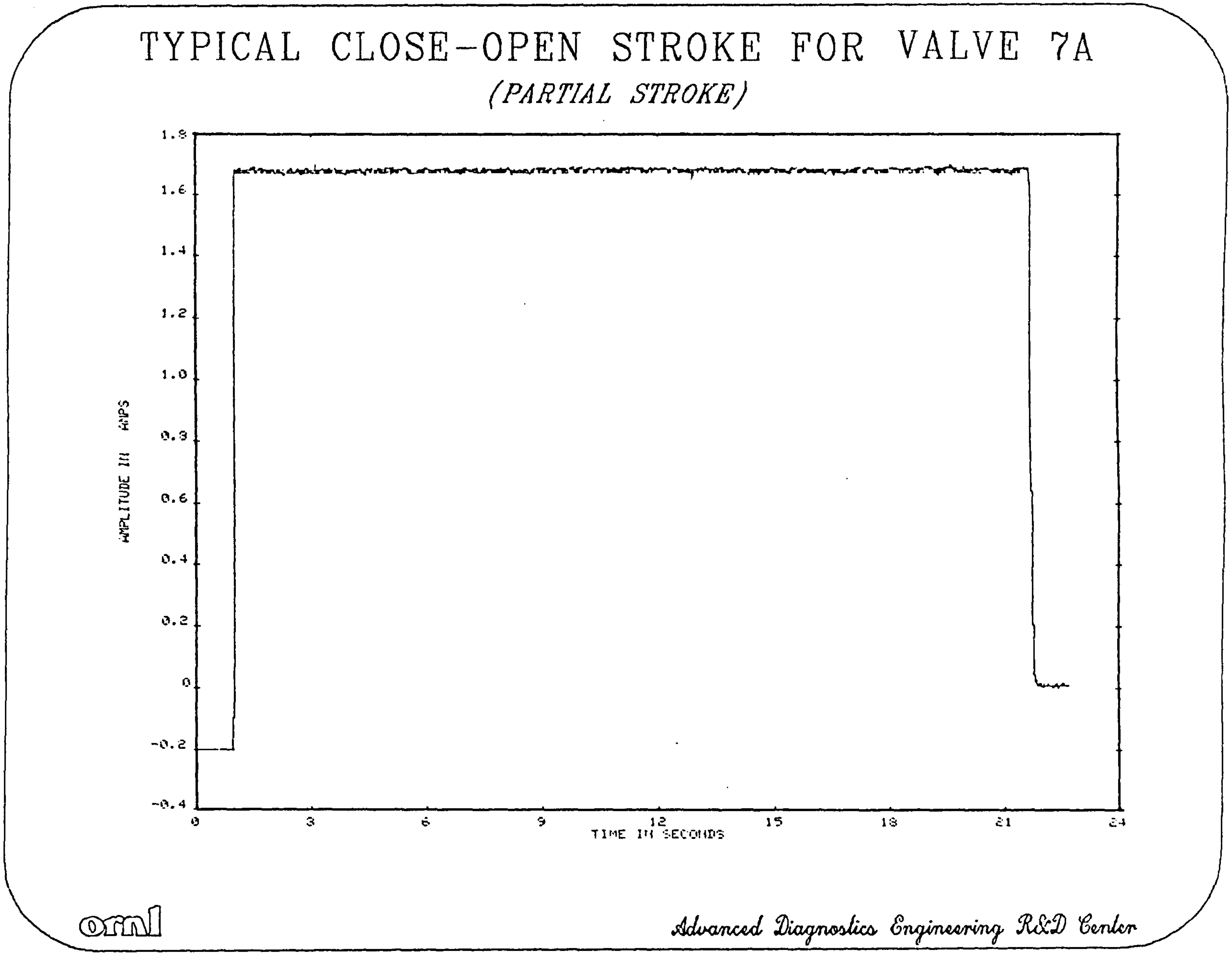
TYPICAL OPEN-CLOSE STROKE FOR VALVE 7A



ornl

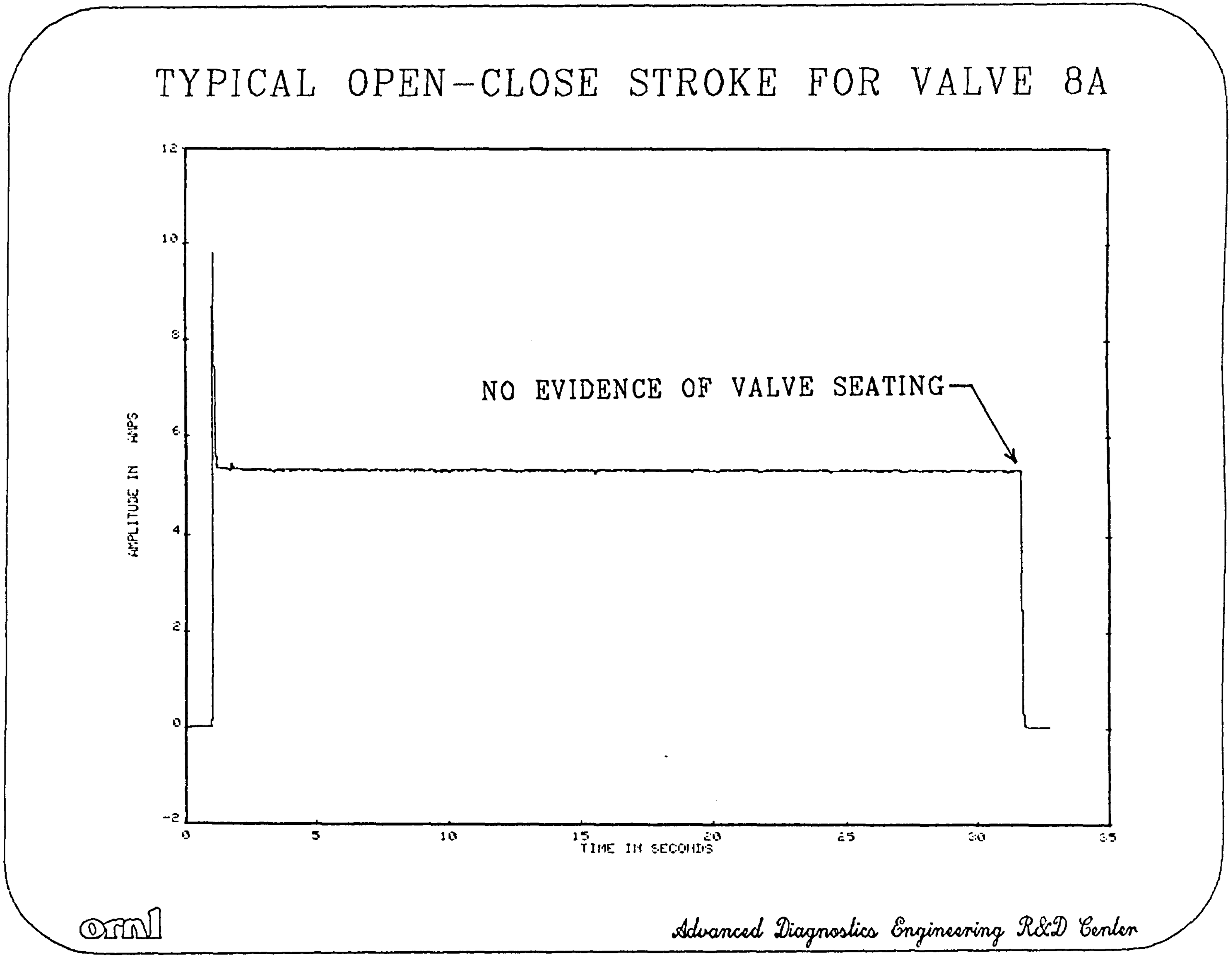
Advanced Diagnostics Engineering R&D Center

FIGURE 7



TYPICAL CLOSE-OPEN STROKE FOR VALVE 7A
(PARTIAL STROKE)
AMPLITUDE IN AMPS
TIME IN SECONDS
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0
3
6
9
12
15
18
21
24
Advanced Diagnostics Engineering R&D Center

FIGURE 8



TYPICAL OPEN-CLOSE STROKE FOR VALVE 8A
NO EVIDENCE OF VALVE SEATING
AMPLITUDE IN AMPS
TIME IN SECONDS
12
10
8
6
4
2
0
-2
0
5
10
15
20
25
30
35
Advanced Diagnostics Engineering R&D Center

FIGURE 9

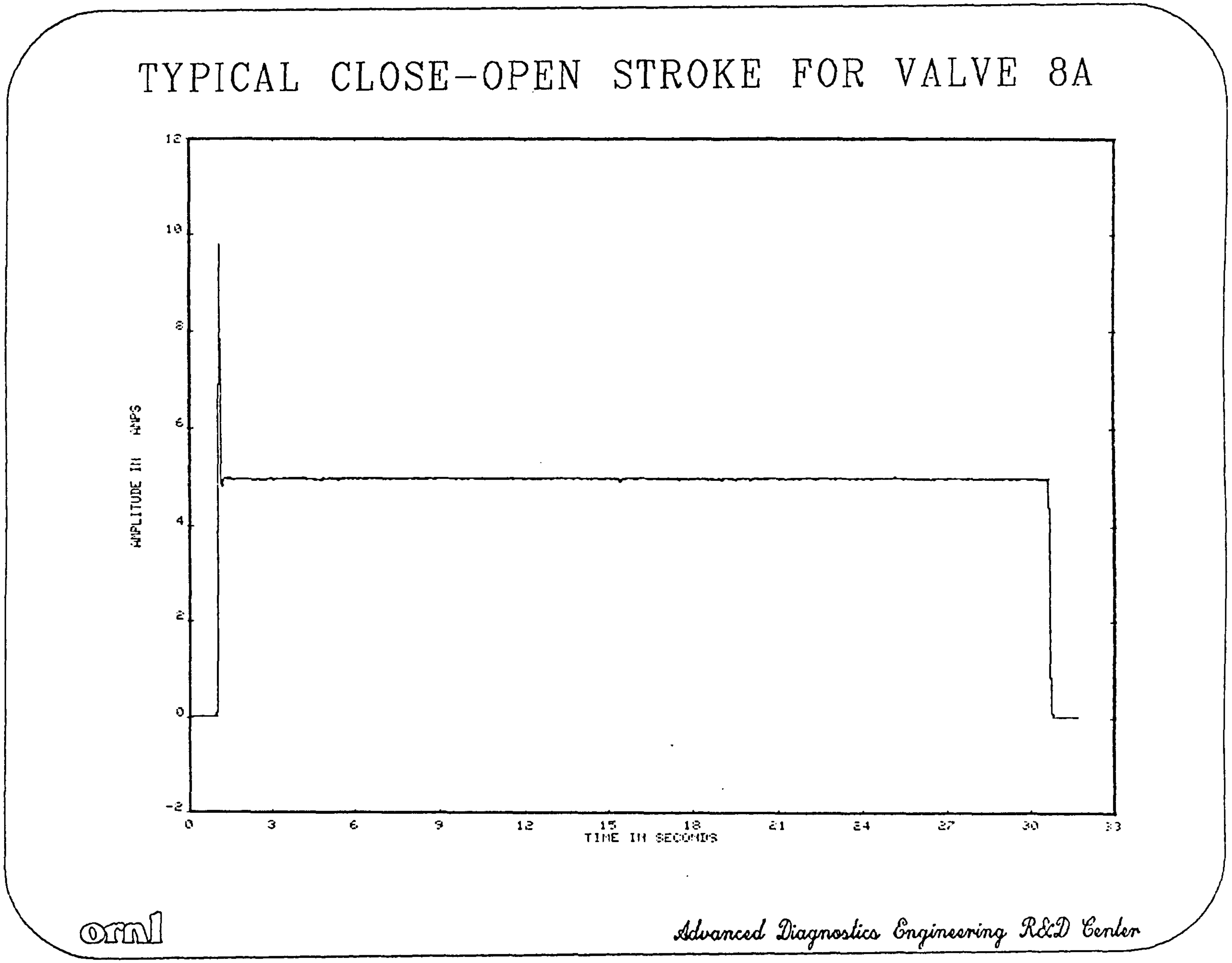
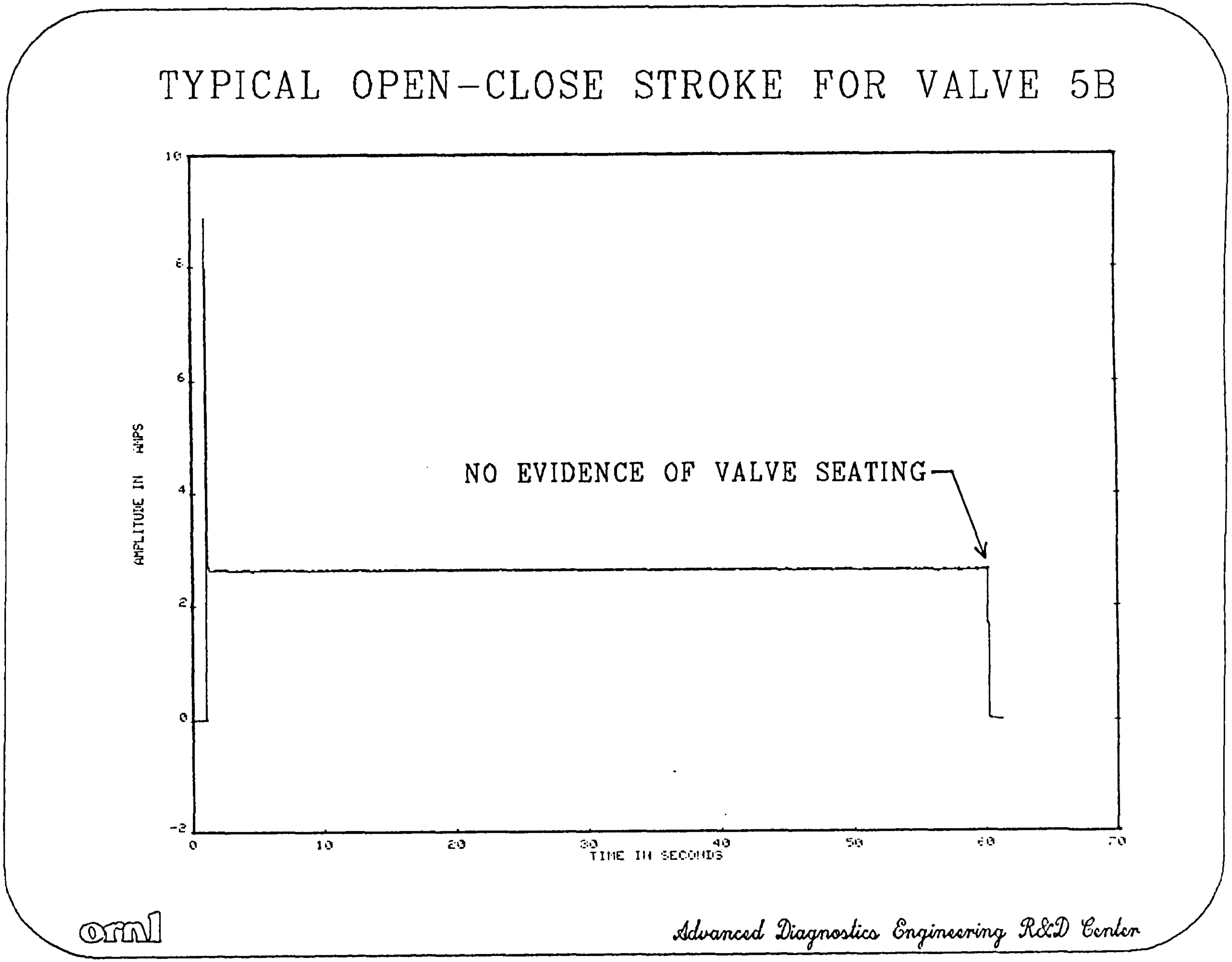

TYPICAL CLOSE-OPEN STROKE FOR VALVE 8A
AMPLITUDE IN AMPS
12
10
8
6
4
2
0
-2
0
3
6
9
12
15
18
21
24
27
30
33
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

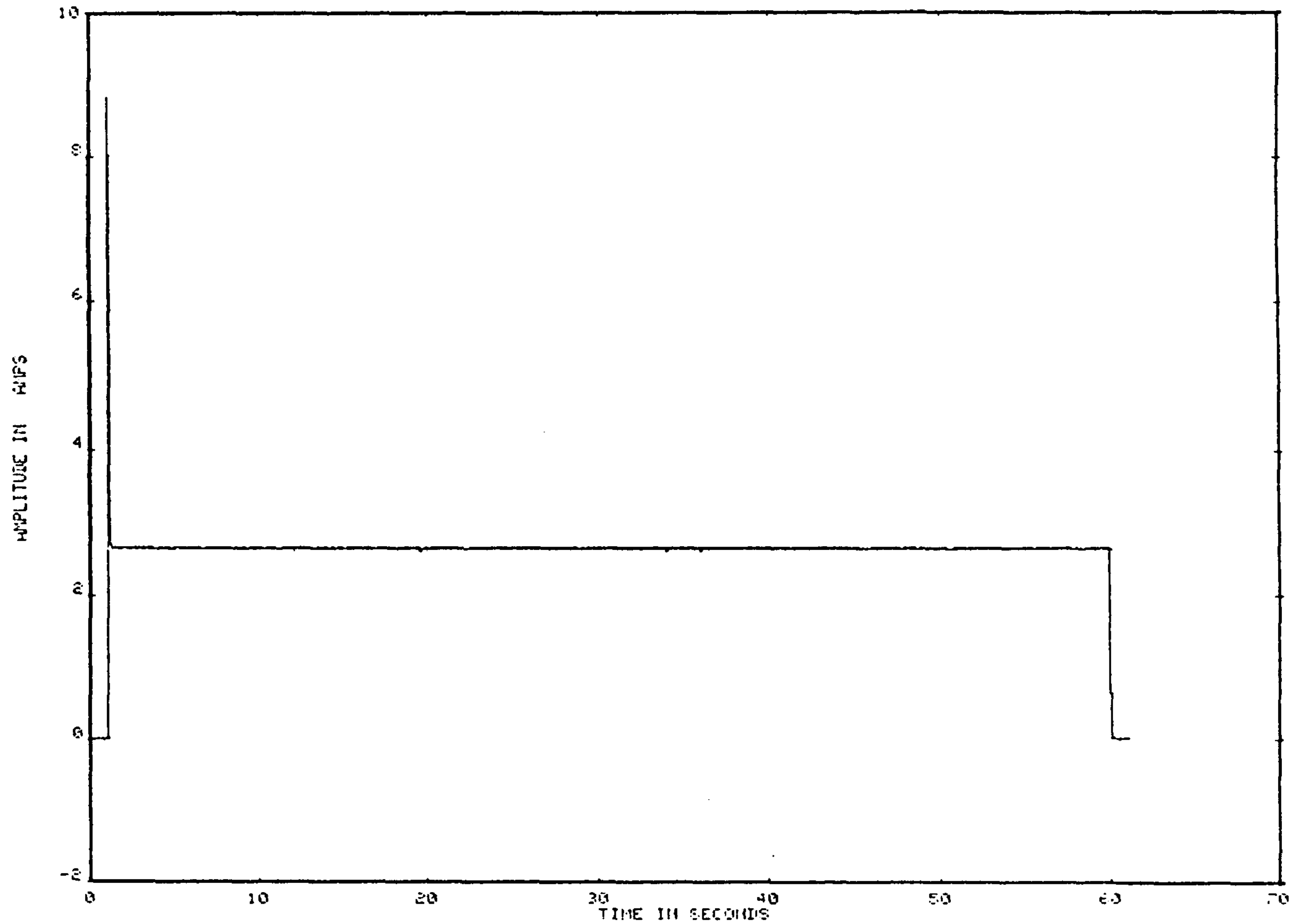
FIGURE 10



TYPICAL OPEN-CLOSE STROKE FOR VALVE 5B
NO EVIDENCE OF VALVE SEATING
AMPLITUDE IN AMPS
TIME IN SECONDS
10
8
6
4
2
0
-2
0
10
20
30
40
50
60
70
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 11

TYPICAL CLOSE-OPEN STROKE FOR VALVE 5B



ornl

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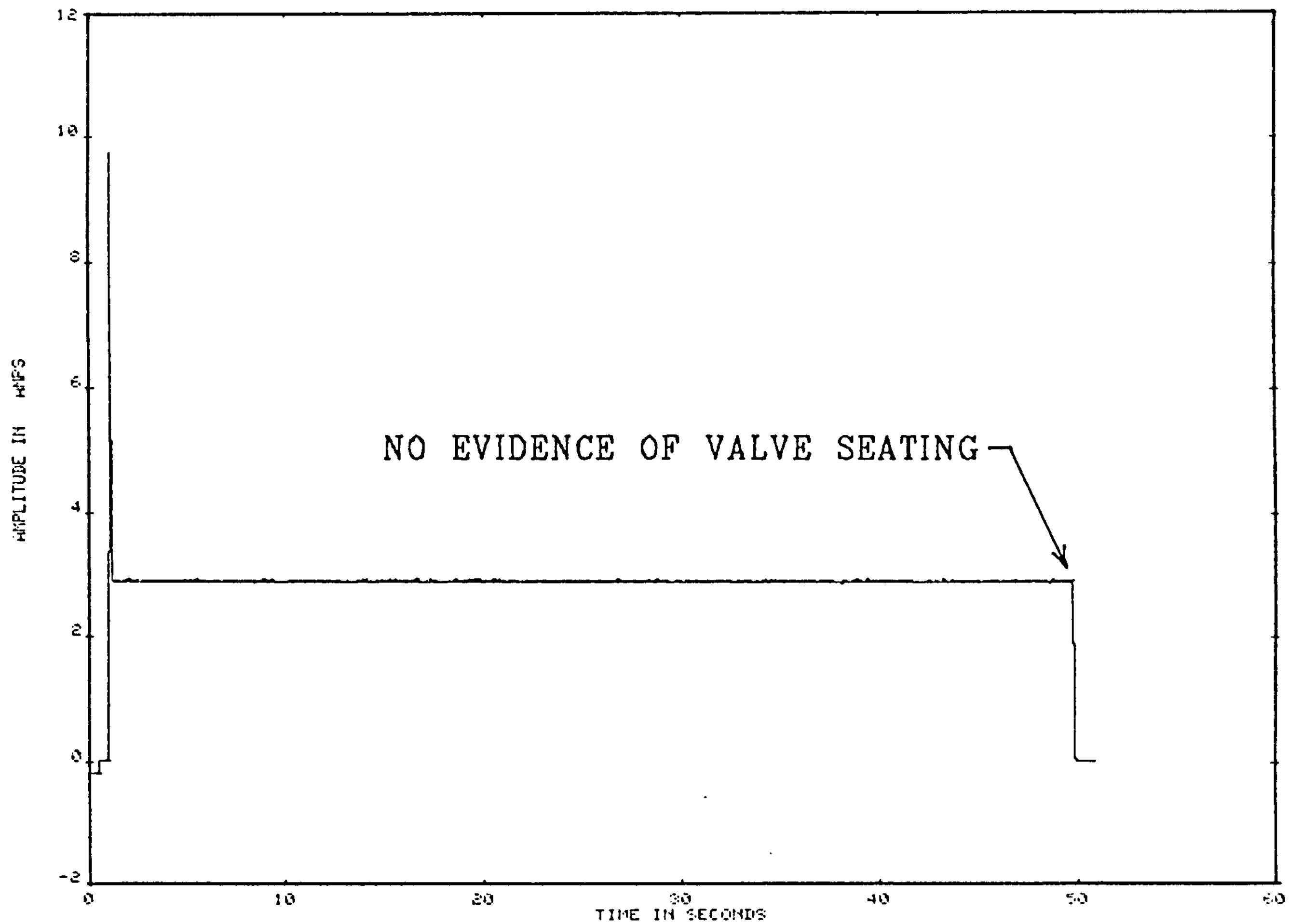
FIGURE 12

TYPICAL OPEN-CLOSE STROKE FOR VALVE 6B



ornl

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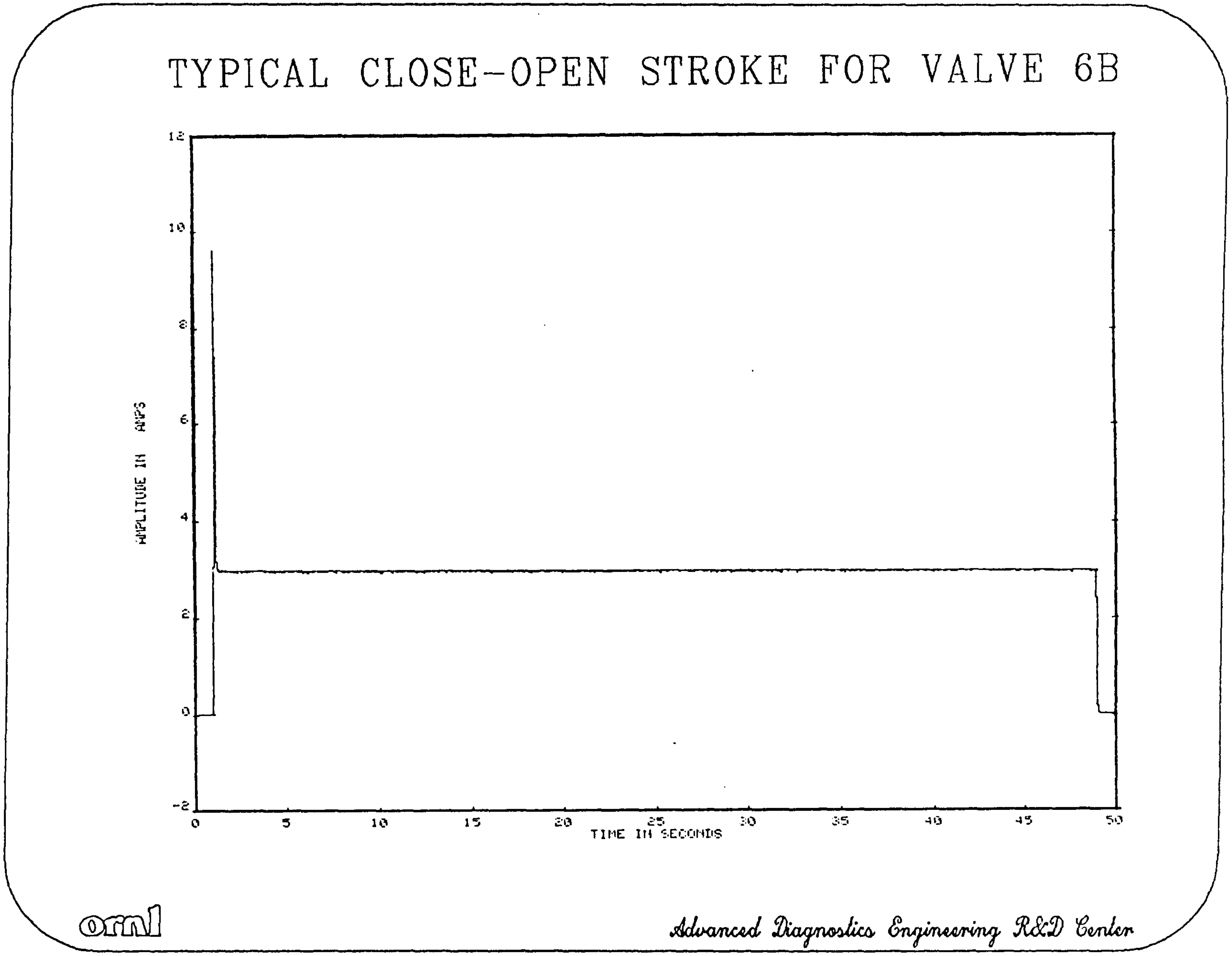
FIGURE 13



TYPICAL CLOSE-OPEN STROKE FOR VALVE 6B
AMPLITUDE IN AMPS
12
10
8
6
4
2
0
-2
0
5
10
15
20
25
30
35
40
45
50
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 1 4

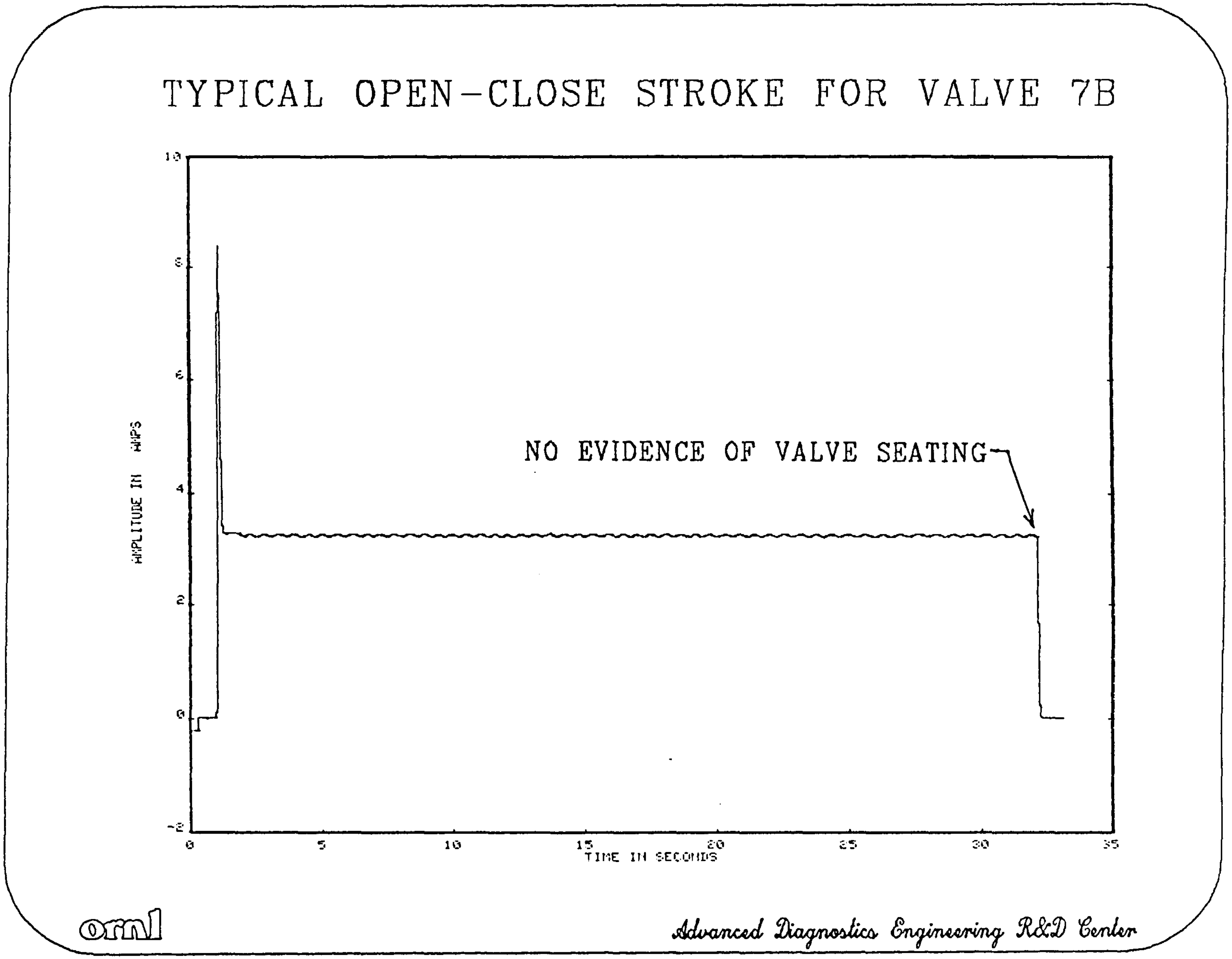
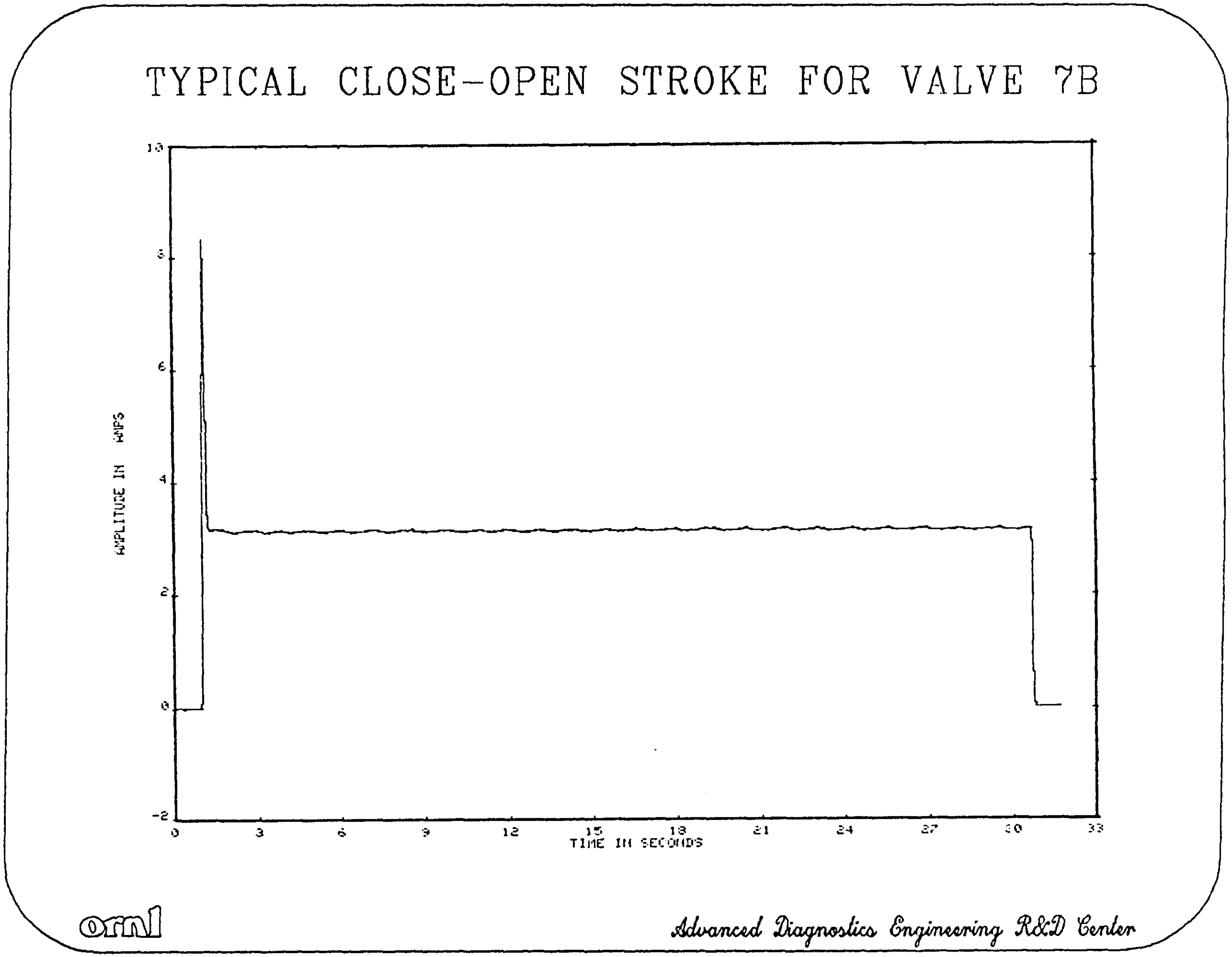

TYPICAL OPEN-CLOSE STROKE FOR VALVE 7B
NO EVIDENCE OF VALVE SEATING
AMPLITUDE IN AMPS
TIME IN SECONDS
10
8
6
4
2
0
-2
0
5
10
15
20
25
30
35
Advanced Diagnostics Engineering R&D Center

FIGURE 1 5



TYPICAL CLOSE-OPEN STROKE FOR VALVE 7B
AMPLITUDE IN AMPS
TIME IN SECONDS
10
8
6
4
2
0
-2
0
3
6
9
12
15
18
21
24
27
30
33
Advanced Diagnostics Engineering R&D Center

FIGURE 16

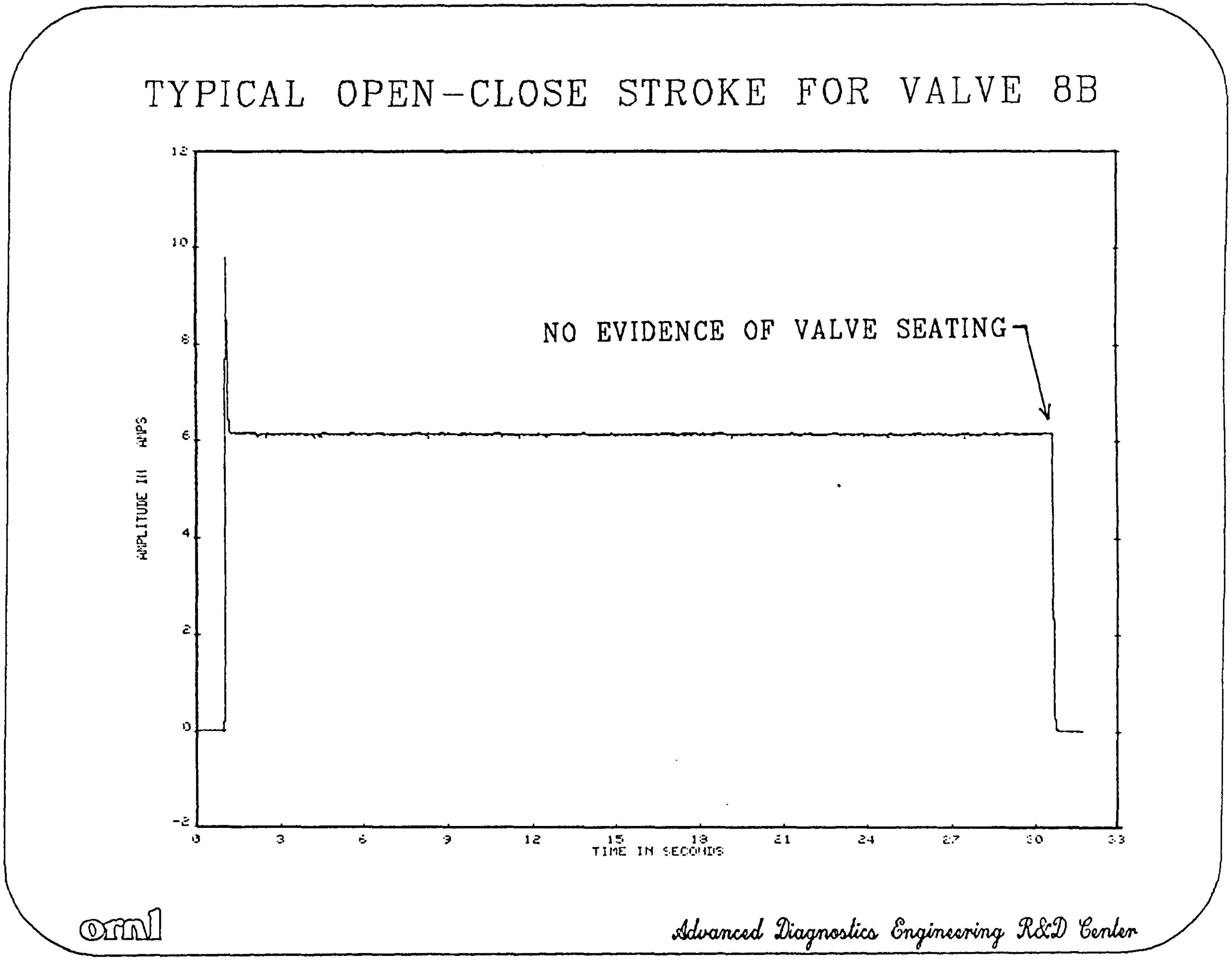
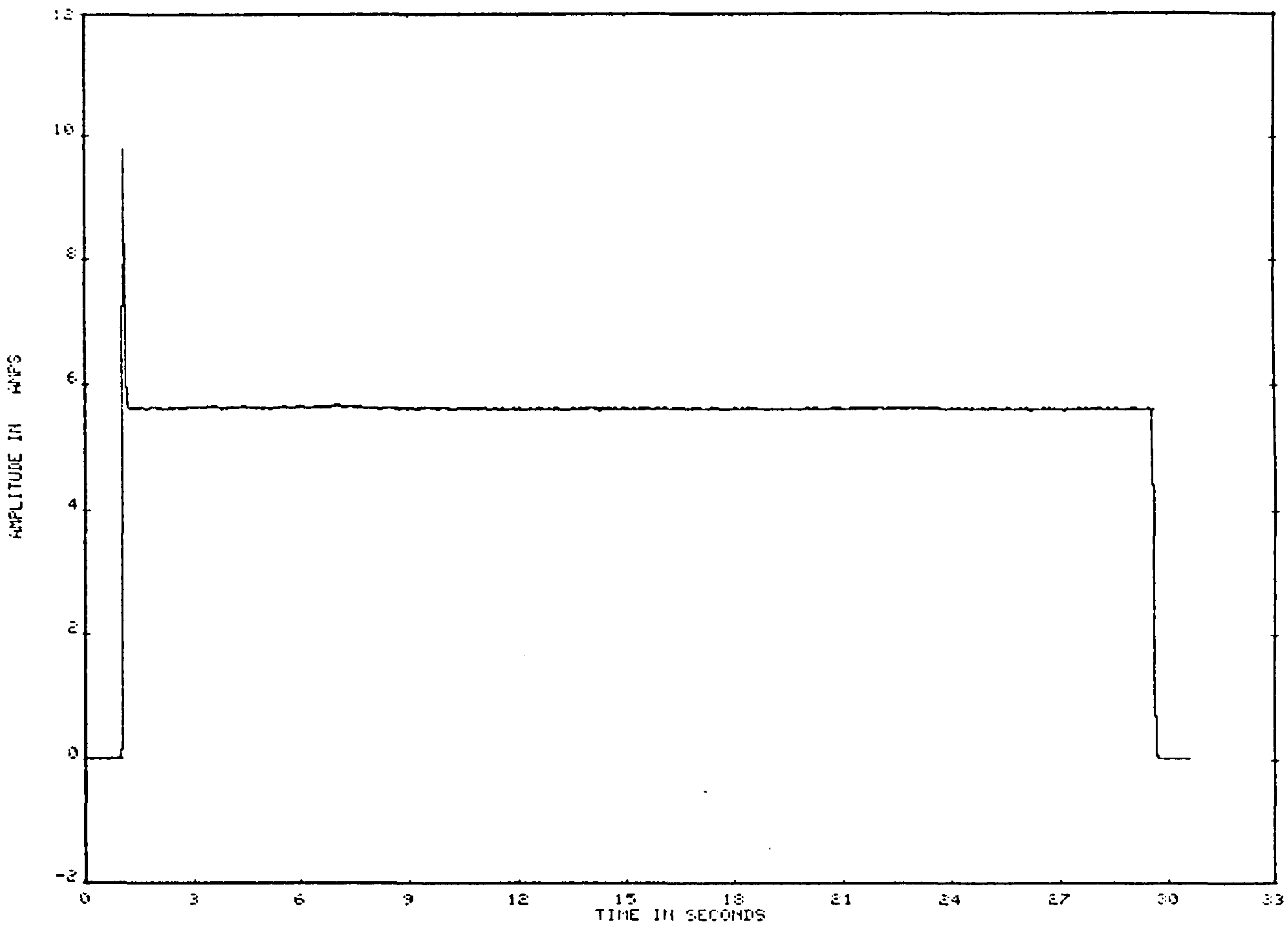

TYPICAL OPEN-CLOSE STROKE FOR VALVE 8B
NO EVIDENCE OF VALVE SEATING
AMPLITUDE IN AMPS
12
10
8
6
4
2
0
-2
0
3
6
9
12
15
18
21
24
27
30
33
TIME IN SECONDS
Advanced Diagnostics Engineering R&D Center

FIGURE 17

TYPICAL CLOSE-OPEN STROKE FOR VALVE 8B



ornl

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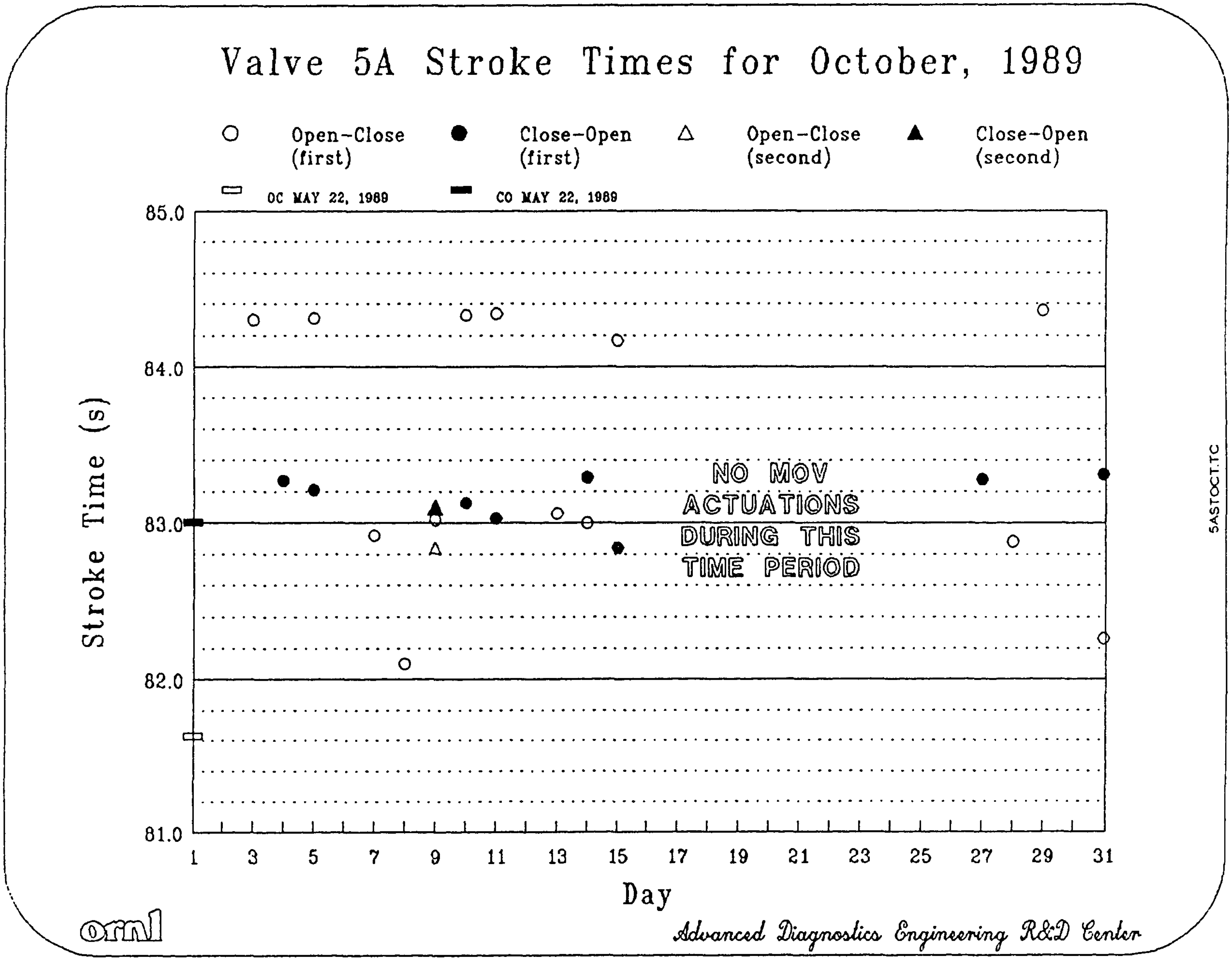
FIGURE 18



Valve 5A Stroke Times for October, 1989
Open-Close (first)
Close-Open (first)
Open-Close (second)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
85.0
84.0
83.0
82.0
81.0
Stroke Time (s)
NO MOV ACTUATIONS DURING THIS TIME PERIOD
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Day
5ASTOCT.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 19

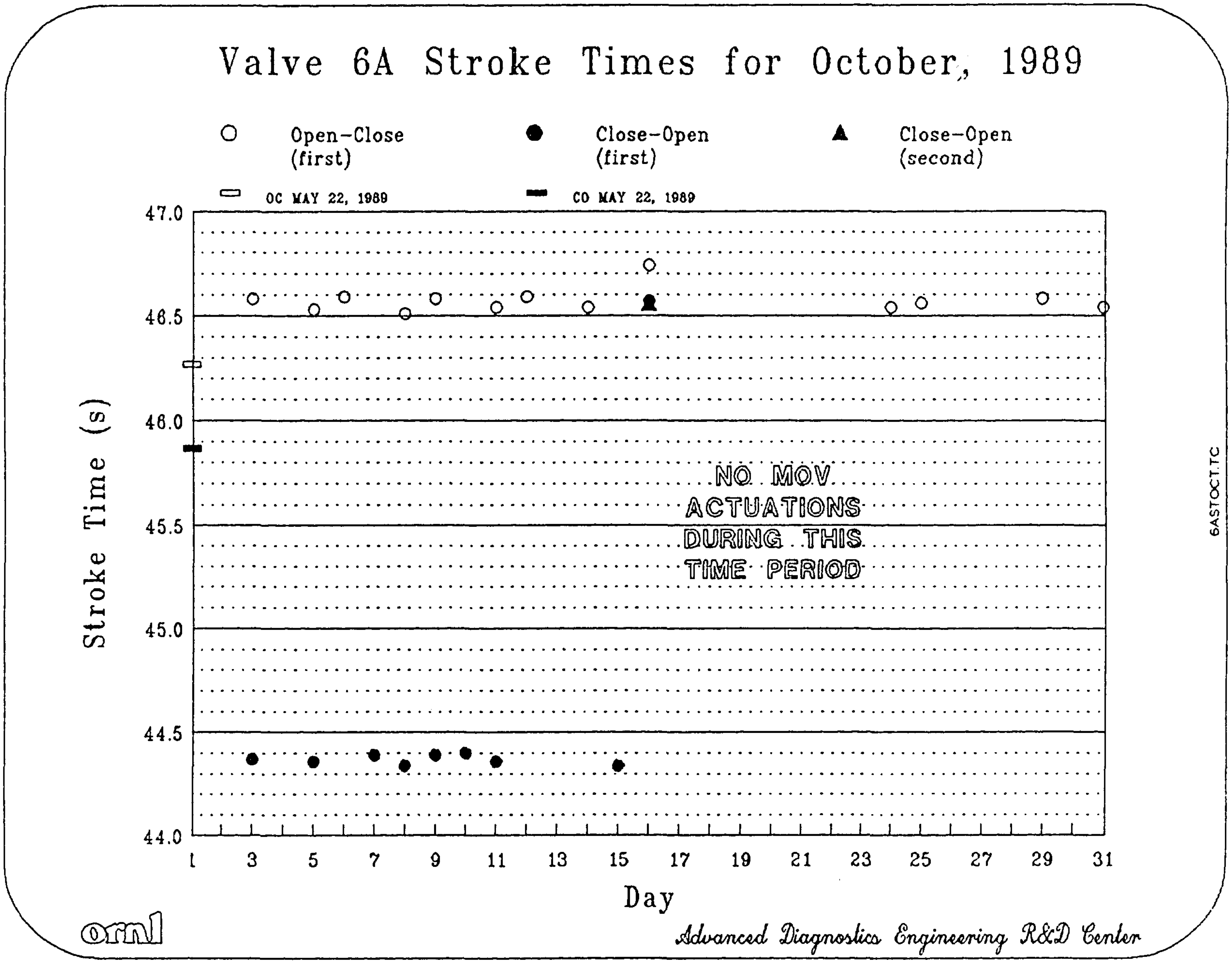

Valve 6A Stroke Times for October, 1989
Open-Close (first)
Close-Open (first)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
Stroke Time (s)
47.0
46.5
46.0
45.5
45.0
44.5
44.0
NO MOV ACTUATIONS DURING THIS TIME PERIOD
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
6ASTOCT.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 20

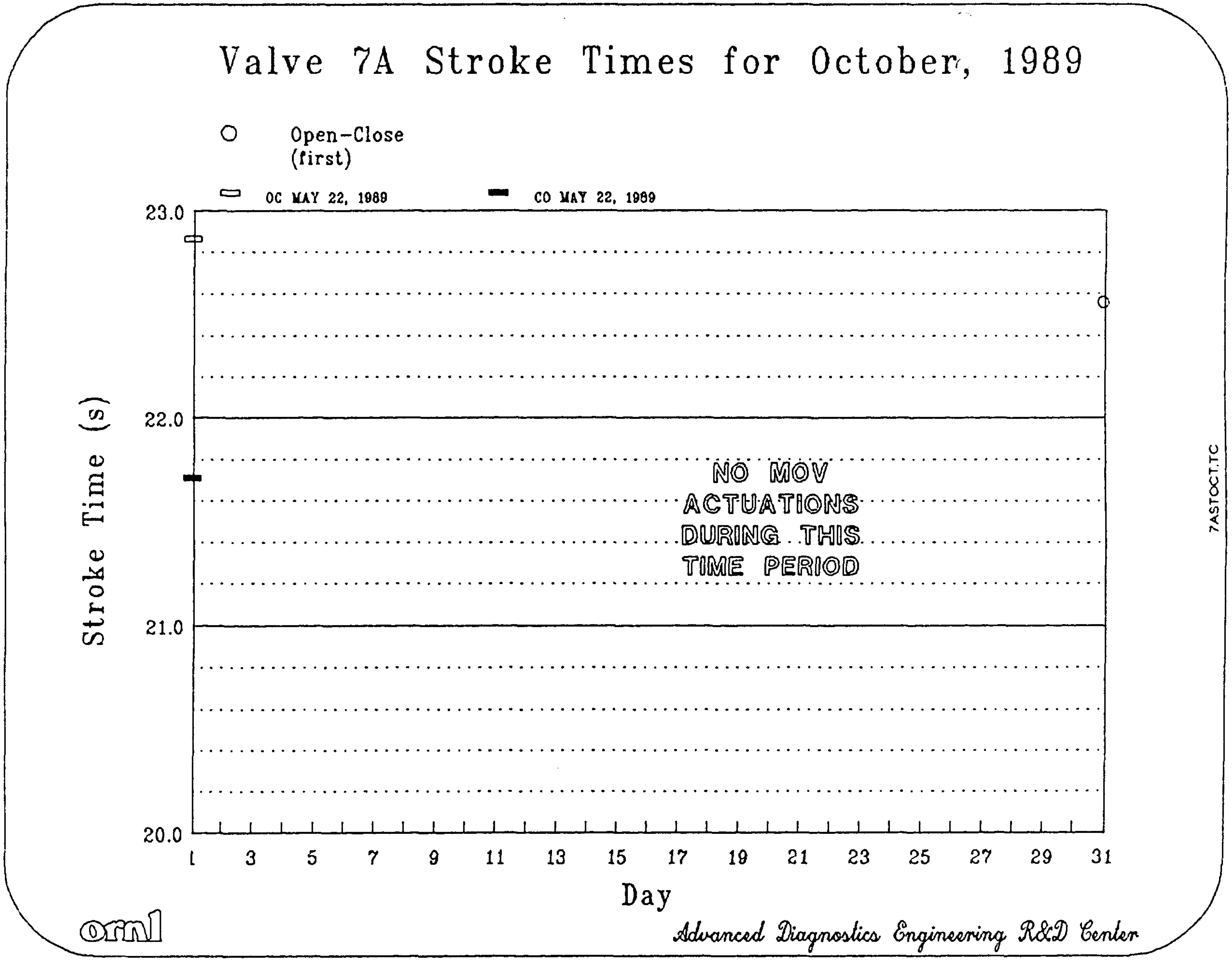

Valve 7A Stroke Times for October, 1989
Open-Close
(first)
OC MAY 22, 1989
CO MAY 22, 1989
23.0
22.0
21.0
20.0
Stroke Time (s)
NO MOV
ACTUATIONS
DURING THIS
TIME PERIOD
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
7ASTOCT.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 2 1

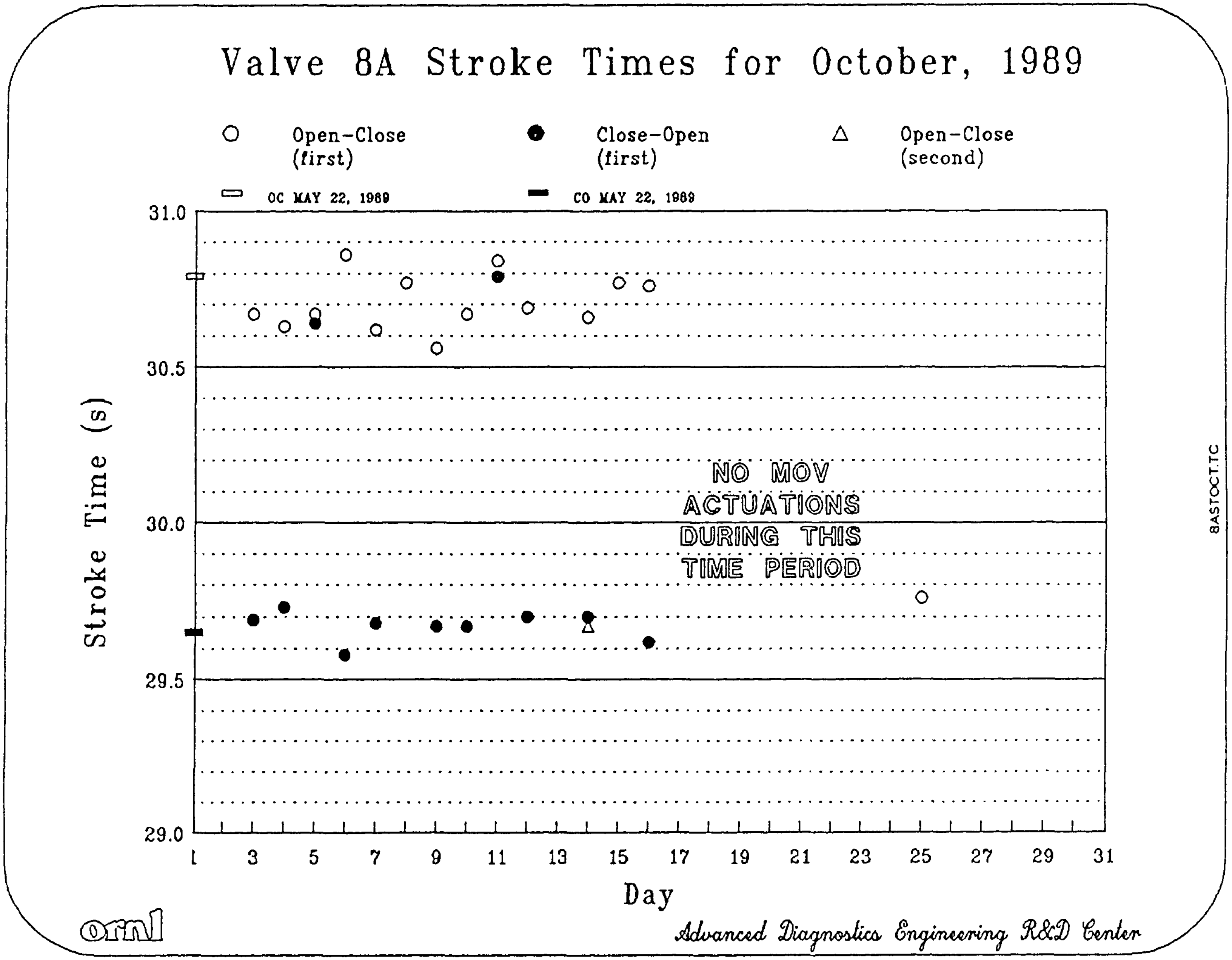

Valve 8A Stroke Times for October, 1989
Open-Close (first)
Close-Open (first)
Open-Close (second)
OC MAY 22, 1989
CO MAY 22, 1989
31.0
30.5
30.0
29.5
29.0
Stroke Time (s)
NO MOV ACTUATIONS DURING THIS TIME PERIOD
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
8ASTOCT.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 2 2

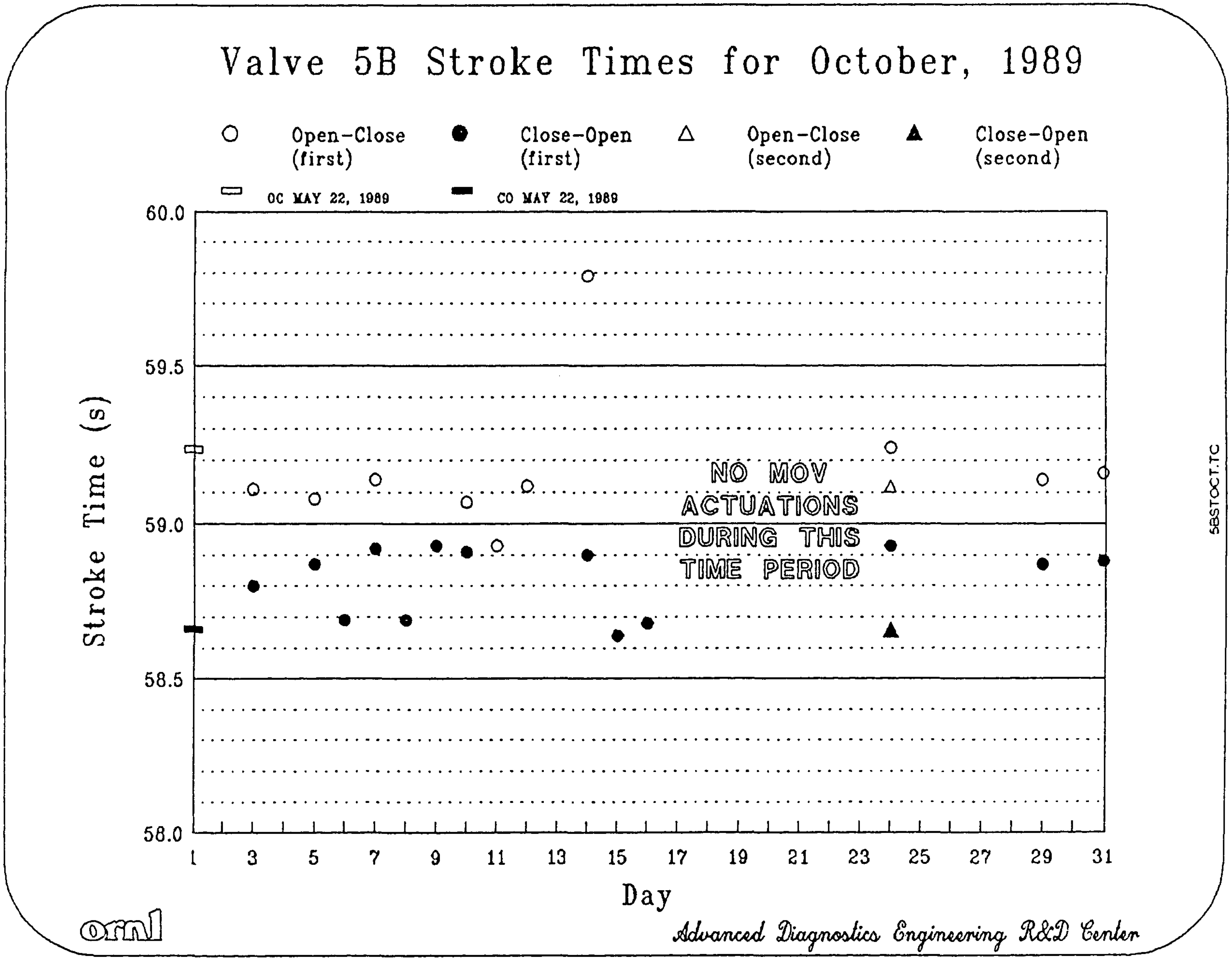

Valve 5B Stroke Times for October, 1989
Open-Close (first)
Close-Open (first)
Open-Close (second)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
Stroke Time (s)
60.0
59.5
59.0
58.5
58.0
Day
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
NO MOV ACTUATIONS DURING THIS TIME PERIOD
5BSTOCT.TC
Advanced Diagnostics Engineering R&D Center

FIGURE 2 3

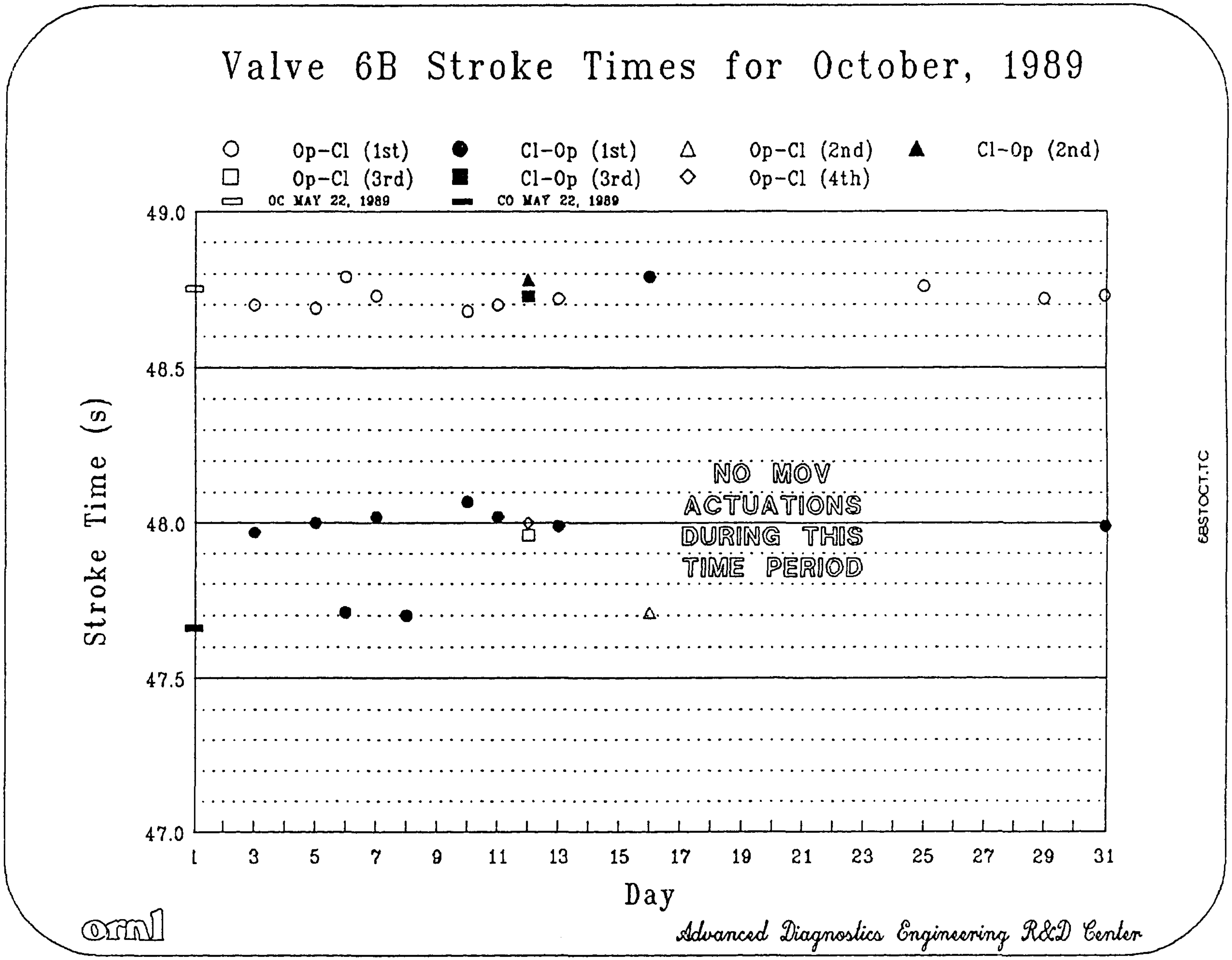
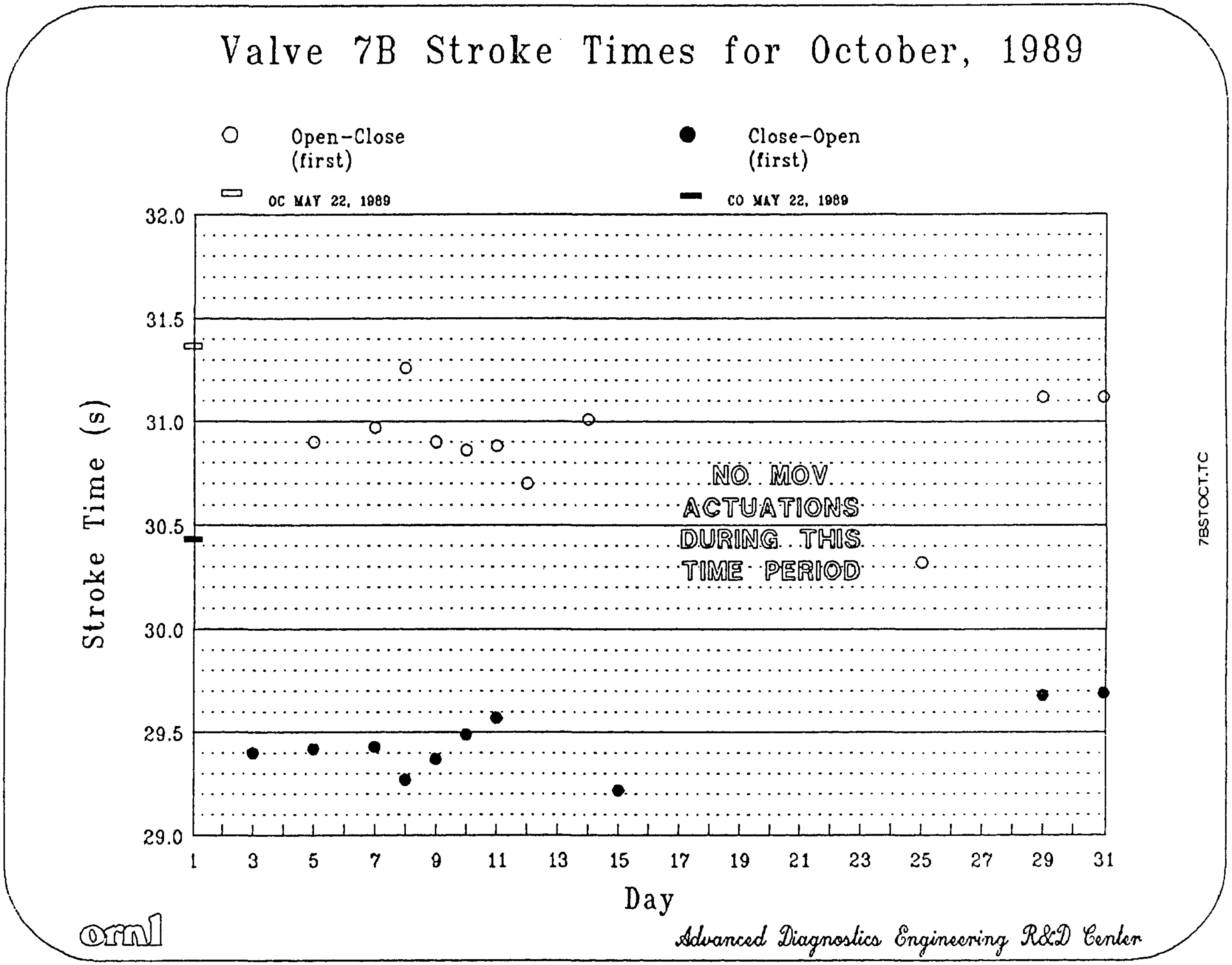

Valve 6B Stroke Times for October, 1989
Op-Cl (1st)
Cl-Op (1st)
Op-Cl (2nd)
Cl-Op (2nd)
Op-Cl (3rd)
Cl-Op (3rd)
Op-Cl (4th)
OC MAY 22, 1989
CO MAY 22, 1989
49.0
48.5
48.0
47.5
47.0
Stroke Time (s)
NO MOV ACTUATIONS DURING THIS TIME PERIOD
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
6BSTOCT.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 24



Valve 7B Stroke Times for October, 1989
Open-Close (first)
Close-Open (first)
OC MAY 22, 1989
CO MAY 22, 1989
32.0
31.5
31.0
30.5
30.0
29.5
29.0
Stroke Time (s)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
NO MOV ACTUATIONS DURING THIS TIME PERIOD
7BSTOCT.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 2 5

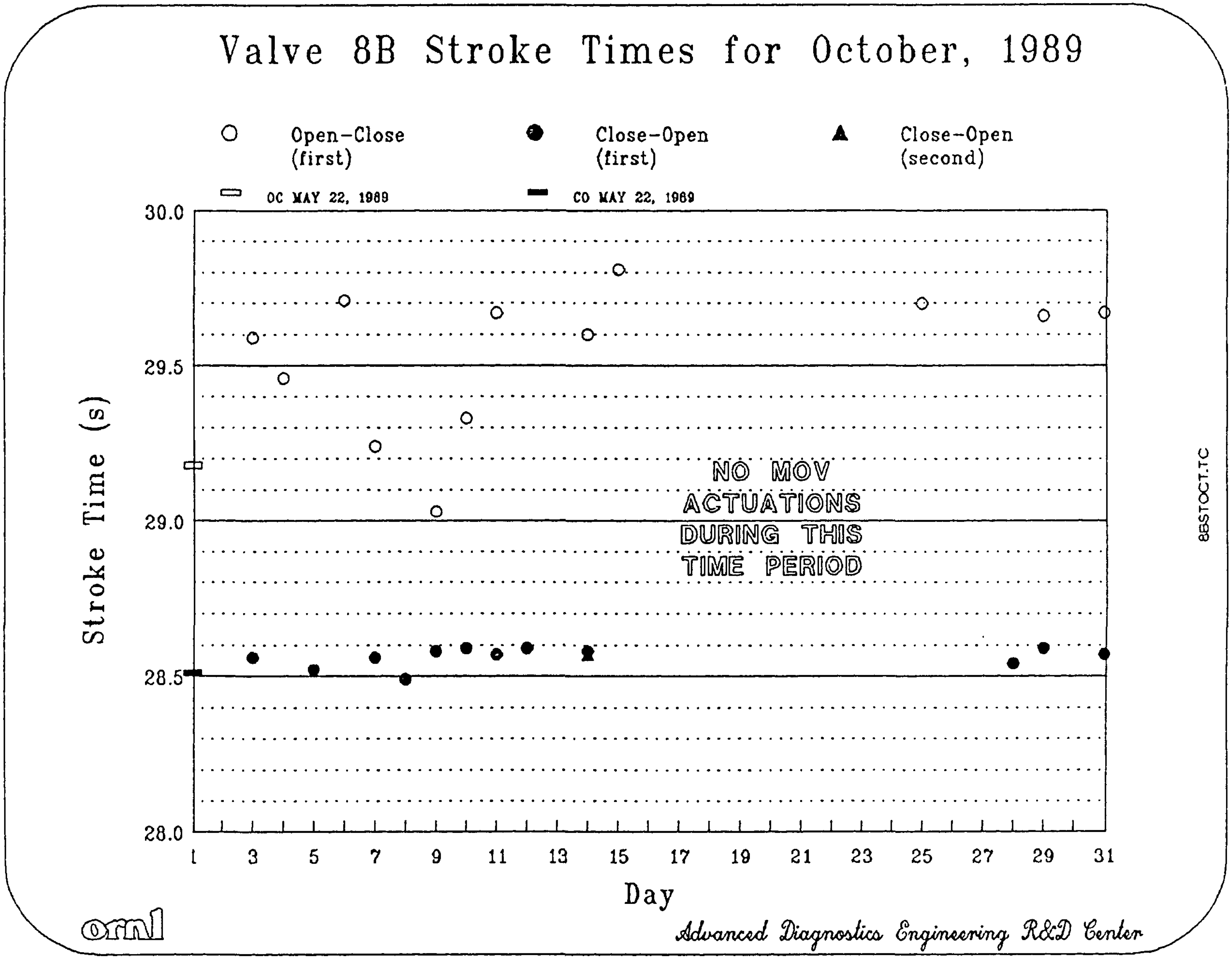
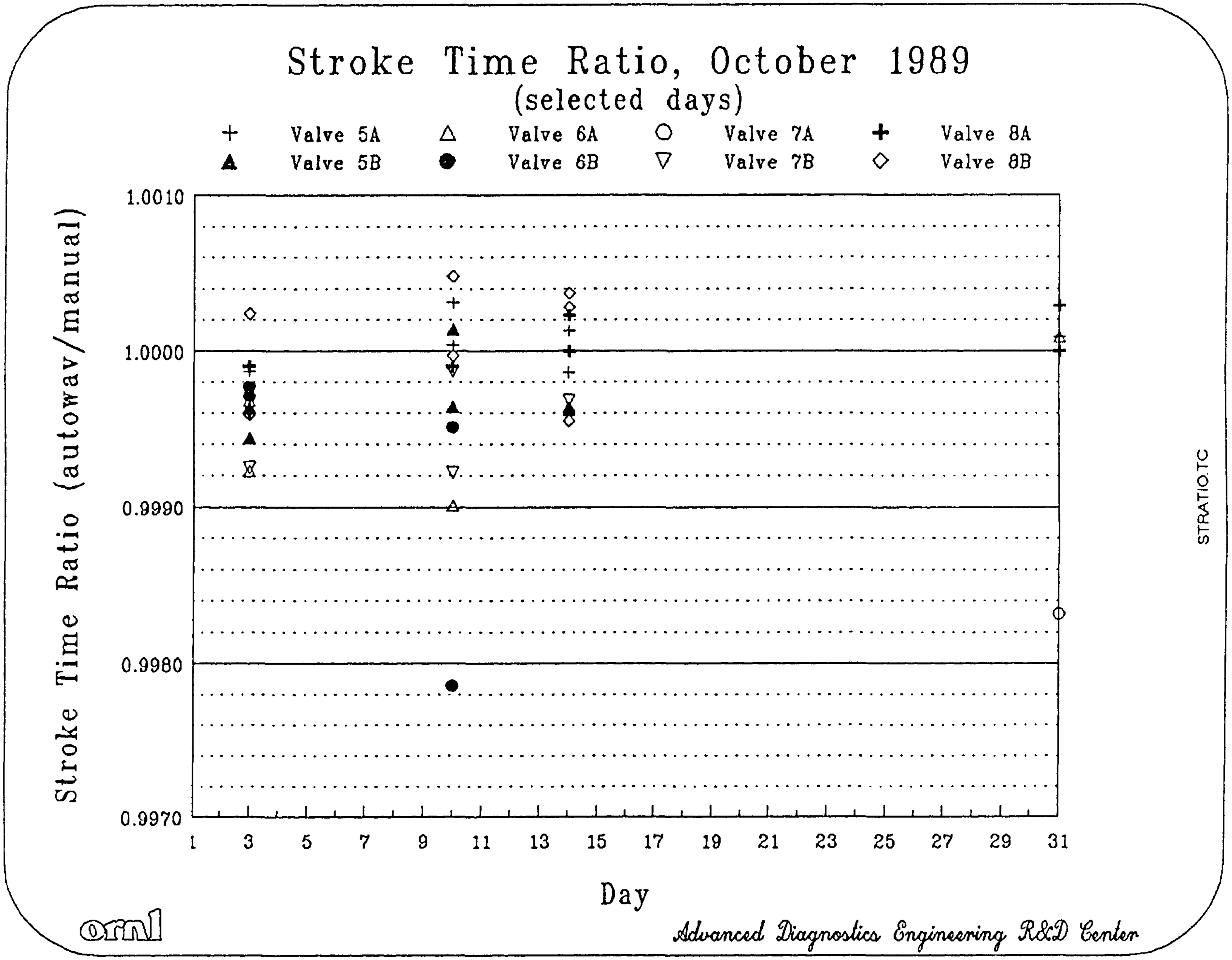
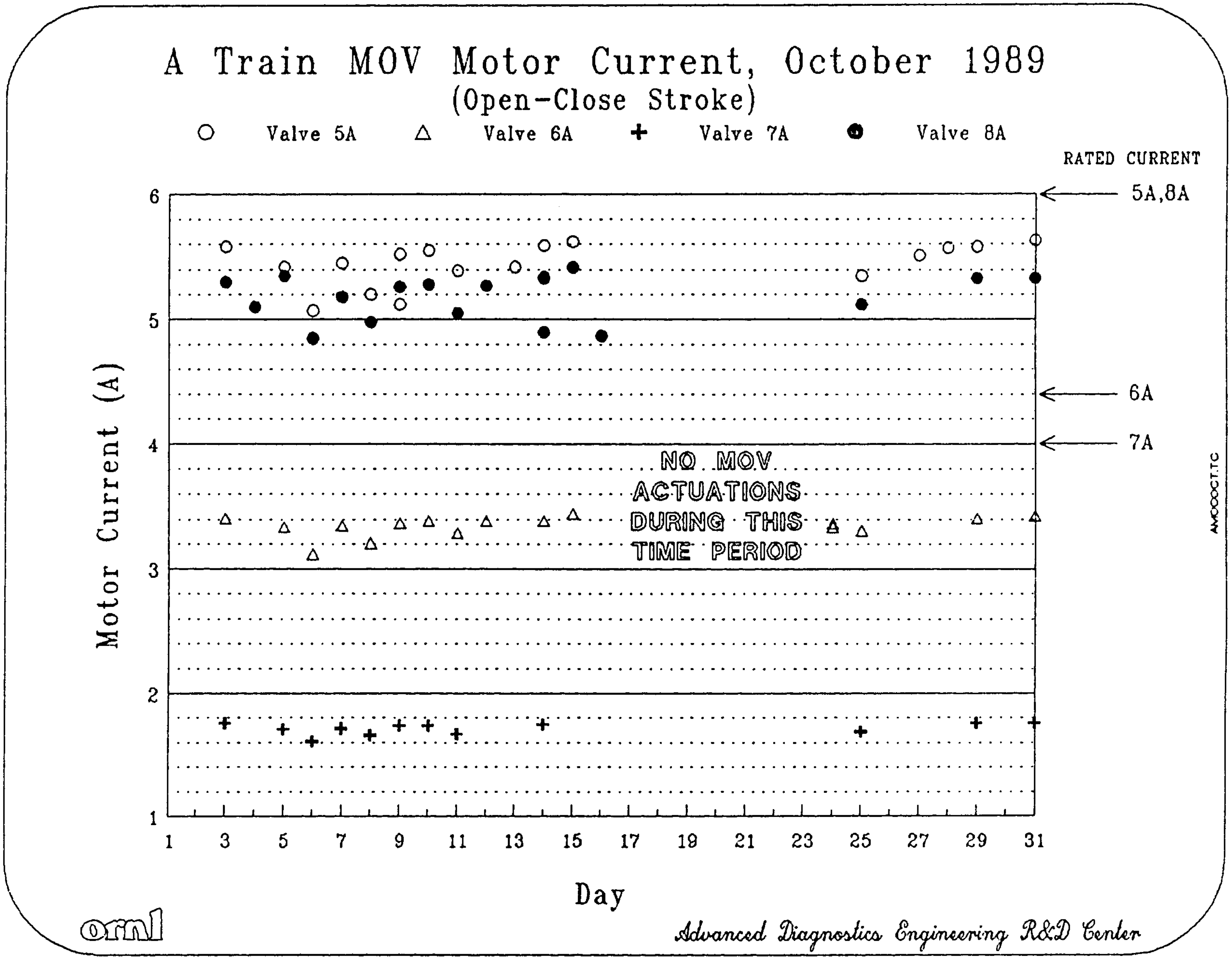

Valve 8B Stroke Times for October, 1989
Open-Close (first)
Close-Open (first)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
30.0
29.5
29.0
28.5
28.0
Stroke Time (s)
NO MOV ACTUATIONS DURING THIS TIME PERIOD
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
8BSTOCT.TC
Advanced Diagnostics Engineering R&D Center

FIGURE 26



Stroke Time Ratio, October 1989
(selected days)
Valve 5A
Valve 5B
Valve 6A
Valve 6B
Valve 7A
Valve 7B
Valve 8A
Valve 8B
Stroke Time Ratio (autowav/manual)
1.0010
1.0000
0.9990
0.9980
0.9970
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
STRATIO.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 27



A Train MOV Motor Current, October 1989
(Open-Close Stroke)
Valve 5A
Valve 6A
Valve 7A
Valve 8A
RATED CURRENT
5A,8A
6A
7A
NO MOV ACTUATIONS DURING THIS TIME PERIOD
Motor Current (A)
Day
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
6 5 4 3 2 1
AMOOOCT.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 2 8

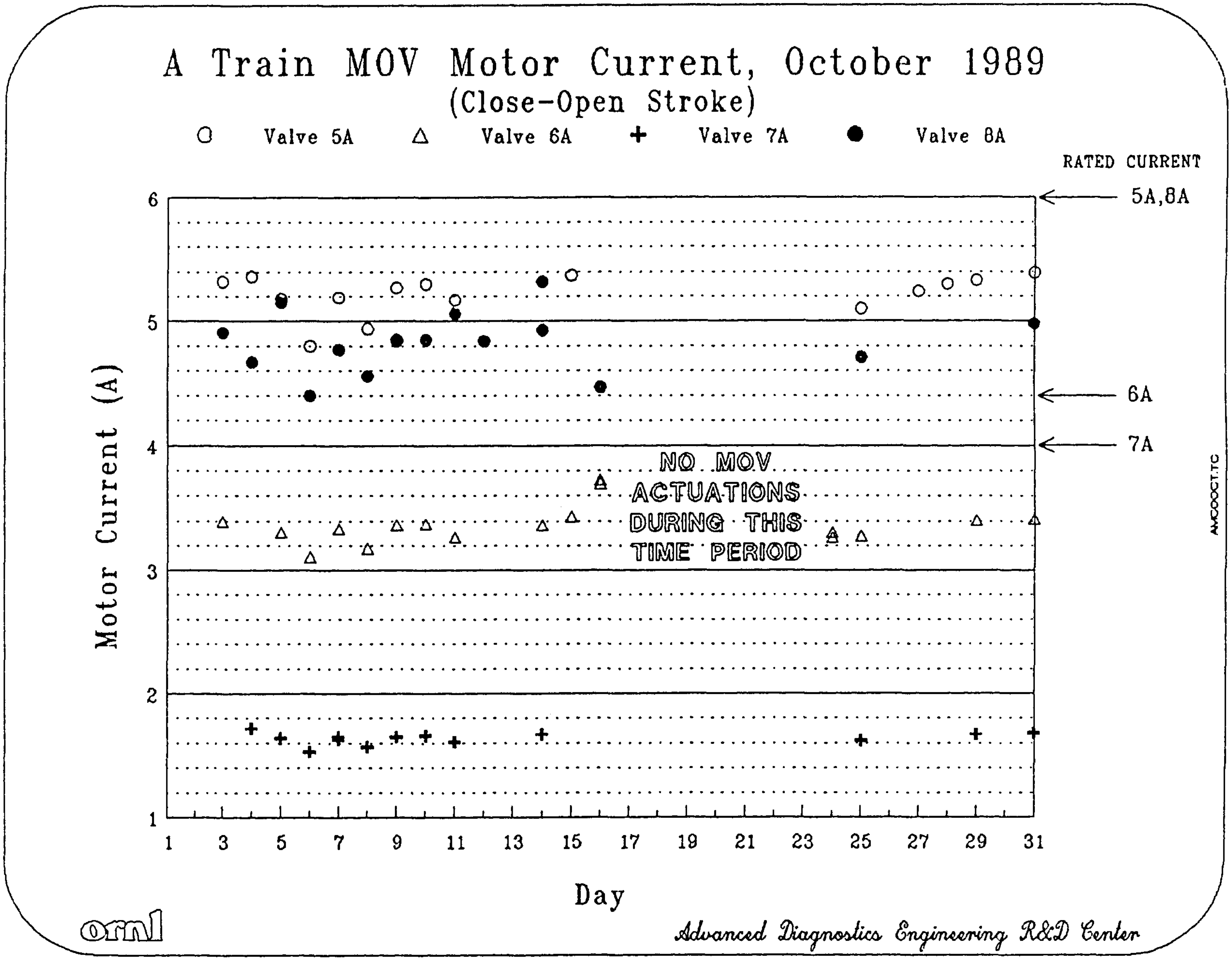
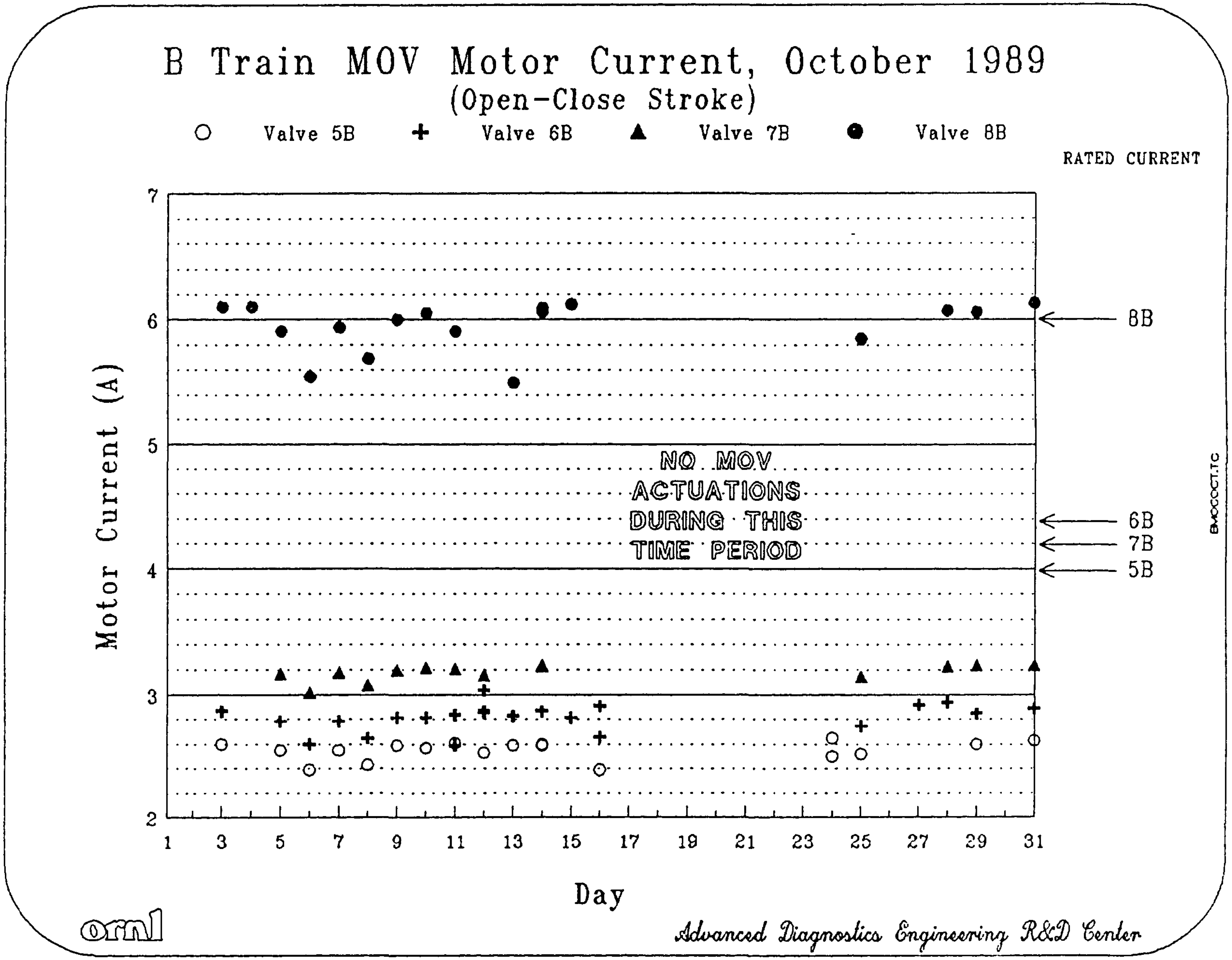

A Train MOV Motor Current, October 1989
(Close-Open Stroke)
Valve 5A
Valve 6A
Valve 7A
Valve 8A
RATED CURRENT
5A,8A
6A
7A
NO MOV ACTUATIONS DURING THIS TIME PERIOD
Motor Current (A)
Day
1
2
3
4
5
6
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
AMCOOCT.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 2 9



B Train MOV Motor Current, October 1989
(Open-Close Stroke)
Valve 5B
Valve 6B
Valve 7B
Valve 8B
RATED CURRENT
Motor Current (A)
7
6
5
4
3
2
8B
6B
7B
5B
NO MOV
ACTUATIONS
DURING THIS
TIME PERIOD
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
BMOCOCT.TC
Advanced Diagnostics Engineering R&D Center

FIGURE 3 0

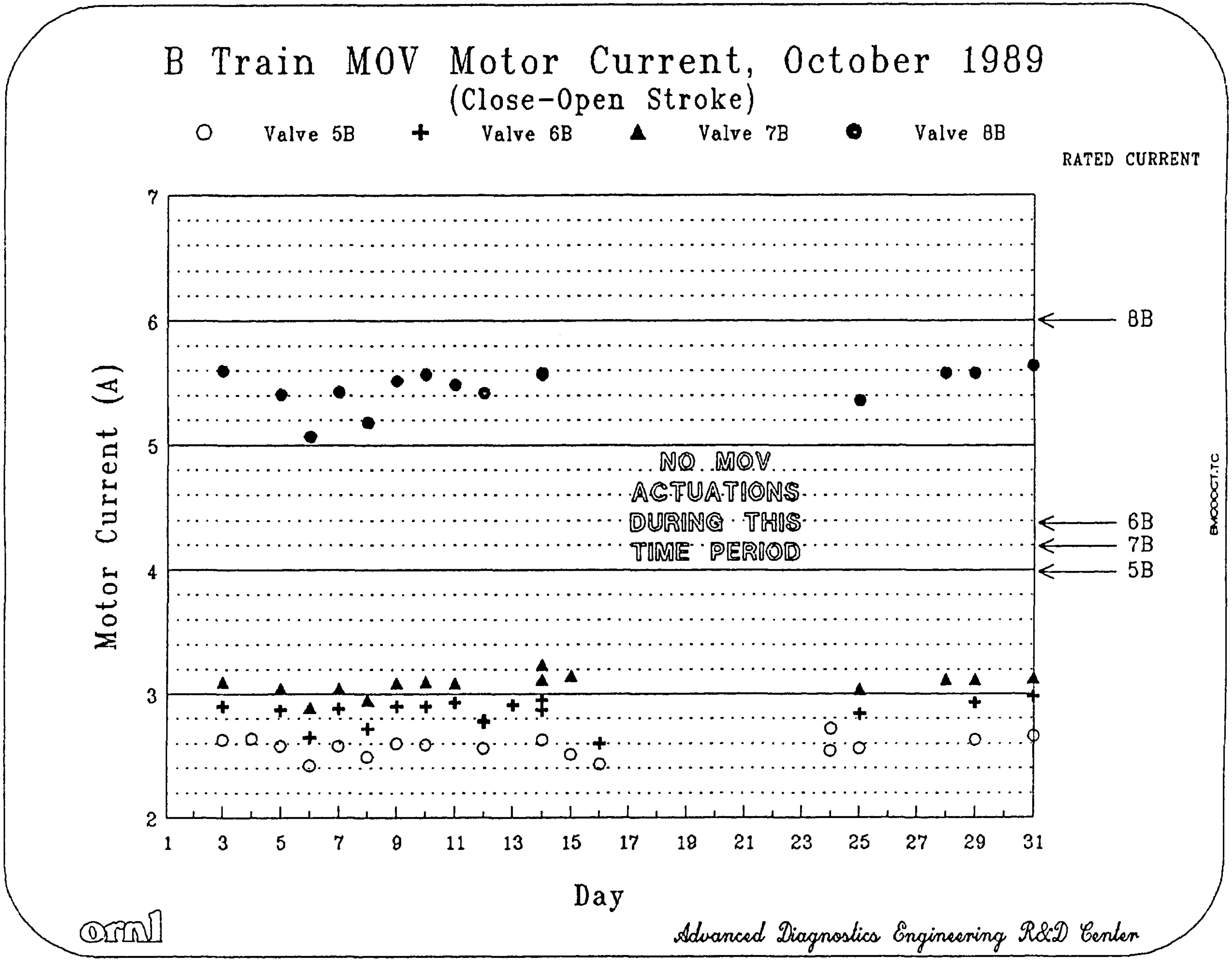
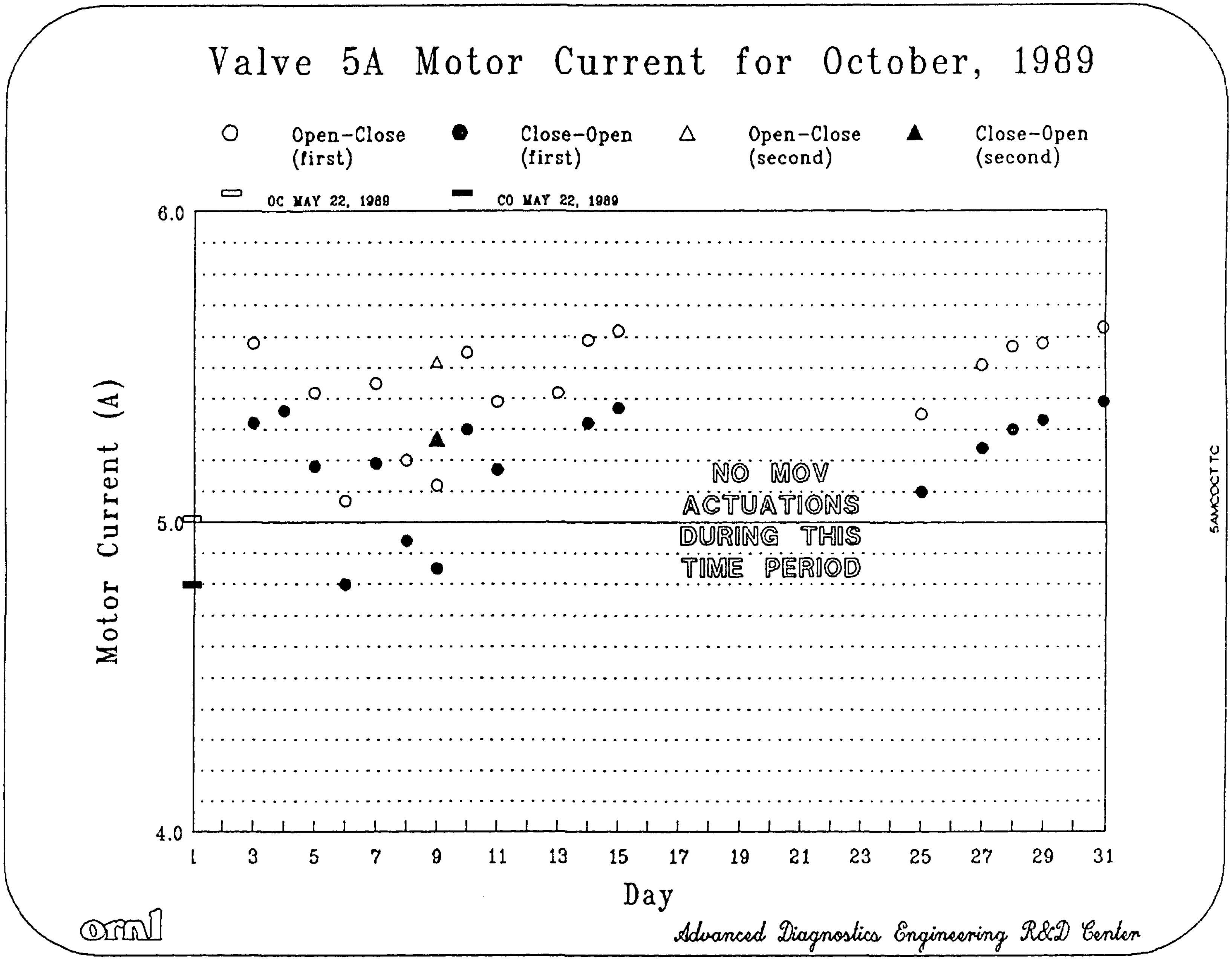
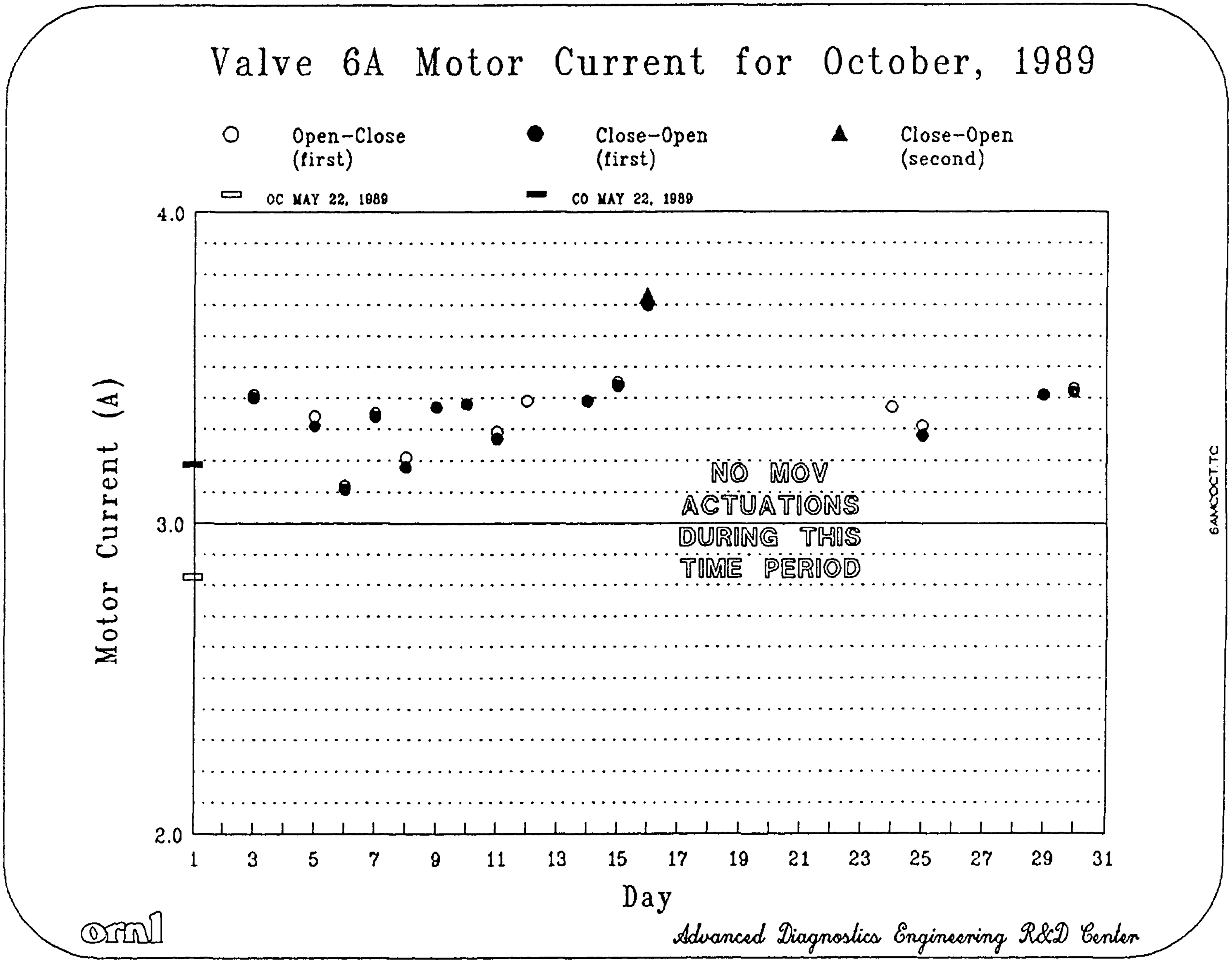

B Train MOV Motor Current, October 1989
(Close-Open Stroke)
Valve 5B
Valve 6B
Valve 7B
Valve 8B
RATED CURRENT
Motor Current (A)
Day
NO MOV ACTUATIONS DURING THIS TIME PERIOD
8B
6B
7B
5B
Advanced Diagnostics Engineering R&D Center

FIGURE 3 1



Valve 5A Motor Current for October, 1989
Open-Close (first)
Close-Open (first)
Open-Close (second)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
6.0
5.0
4.0
Motor Current (A)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
NO MOV ACTUATIONS DURING THIS TIME PERIOD
5AMCOCT TC
Advanced Diagnostics Engineering R&D Center

FIGURE 3 2



Valve 6A Motor Current for October, 1989
Open-Close (first)
Close-Open (first)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
4.0
3.0
2.0
Motor Current (A)
NO MOV ACTUATIONS DURING THIS TIME PERIOD
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
6AMCOCT.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 3 3

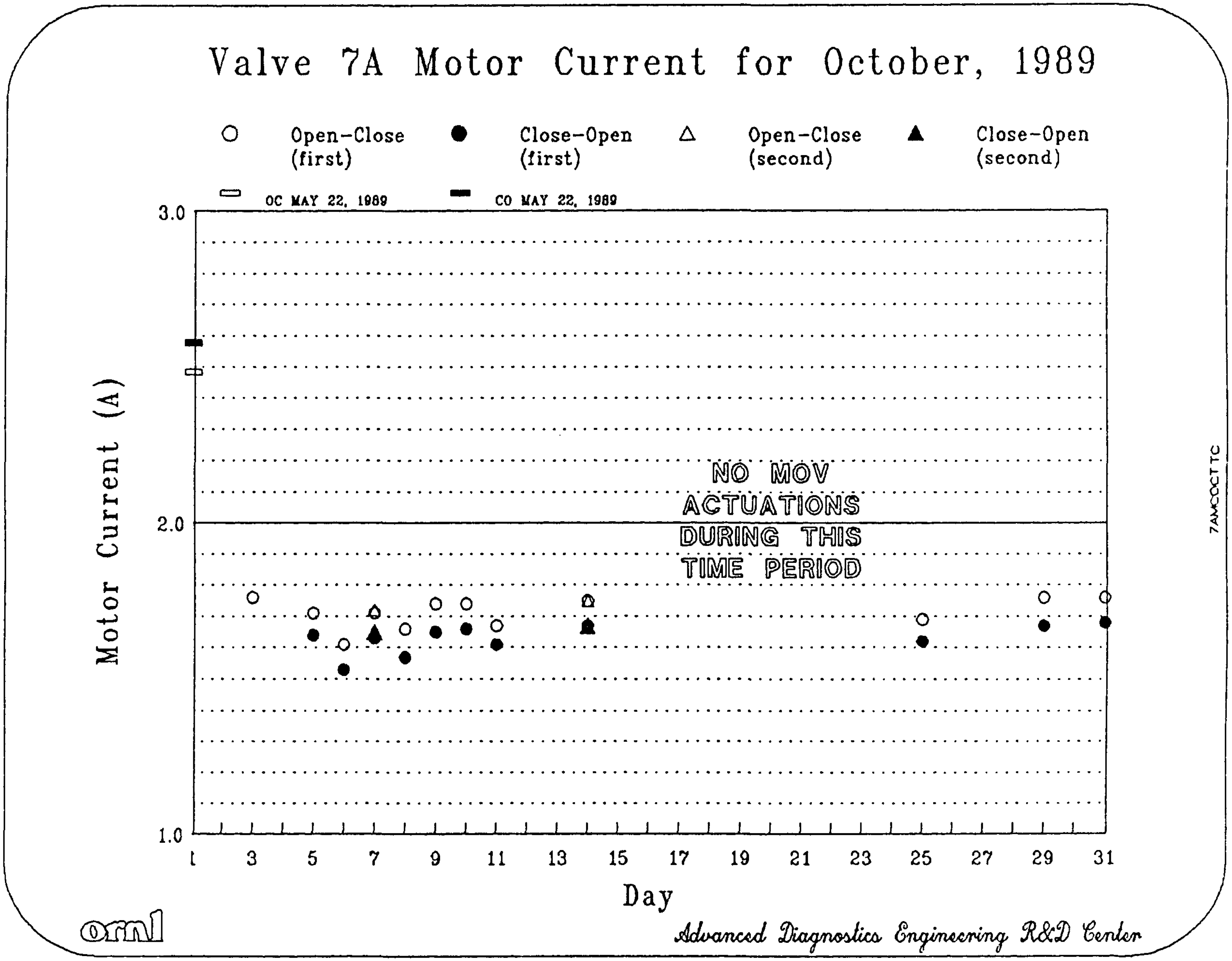
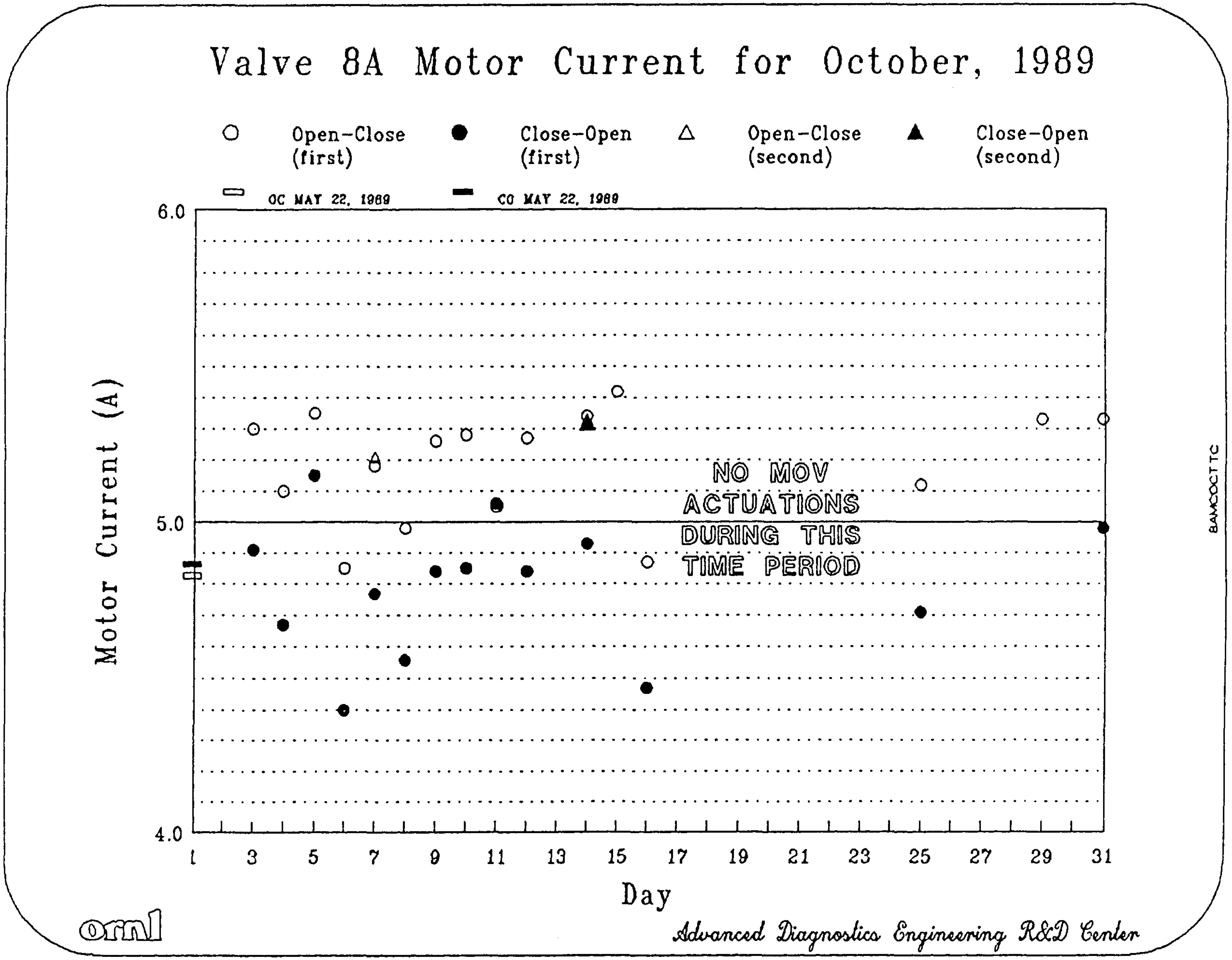

Valve 7A Motor Current for October, 1989
Open-Close (first)
Close-Open (first)
Open-Close (second)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
Motor Current (A)
3.0
2.0
1.0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
NO MOV ACTUATIONS DURING THIS TIME PERIOD
7AMCOCTTC
Advanced Diagnostics Engineering R&D Center

FIGURE 3 4



Valve 8A Motor Current for October, 1989
Open-Close (first)
Close-Open (first)
Open-Close (second)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
Motor Current (A)
6.0
5.0
4.0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
NO MOV ACTUATIONS DURING THIS TIME PERIOD
BAMOOCT TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 3 5

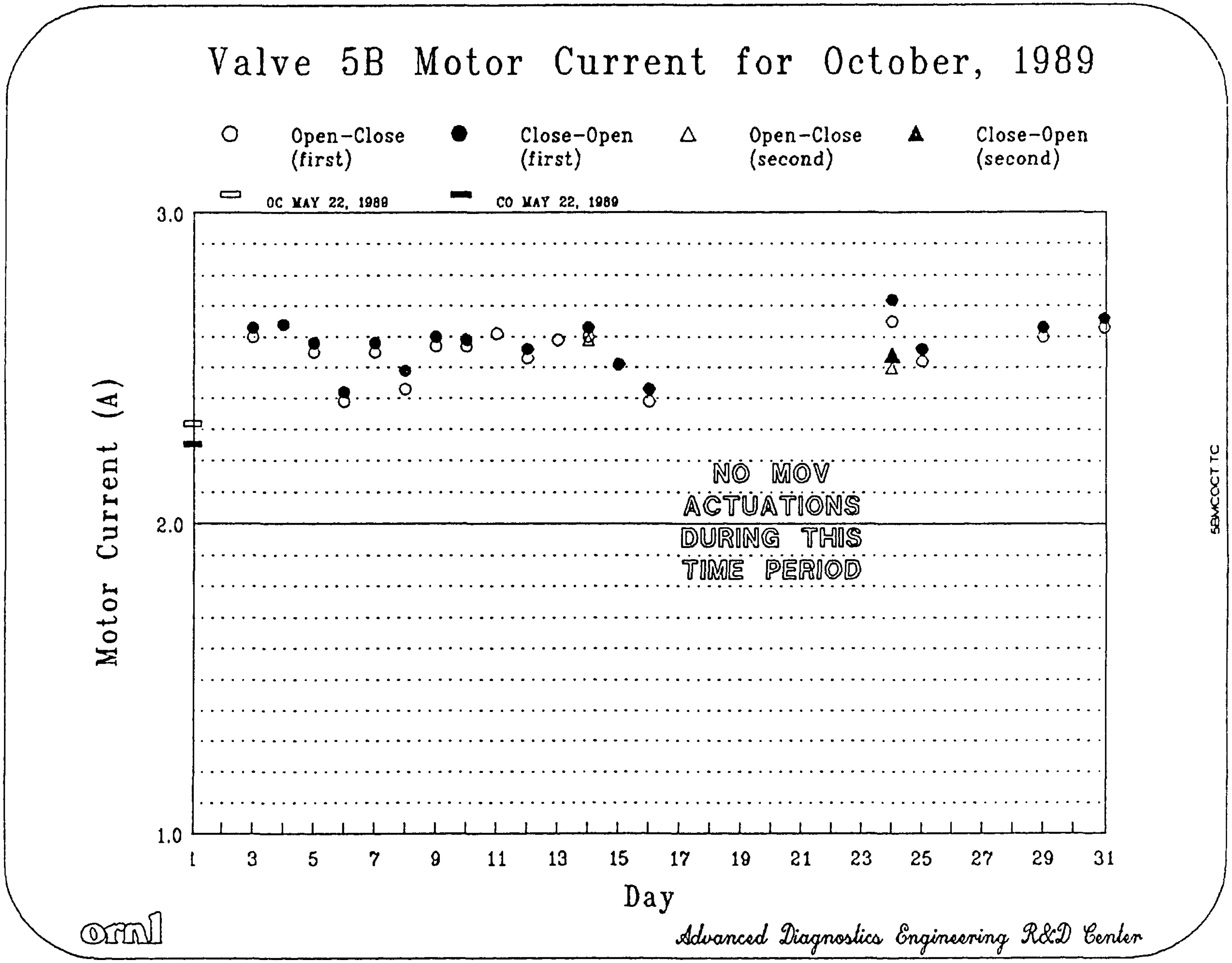
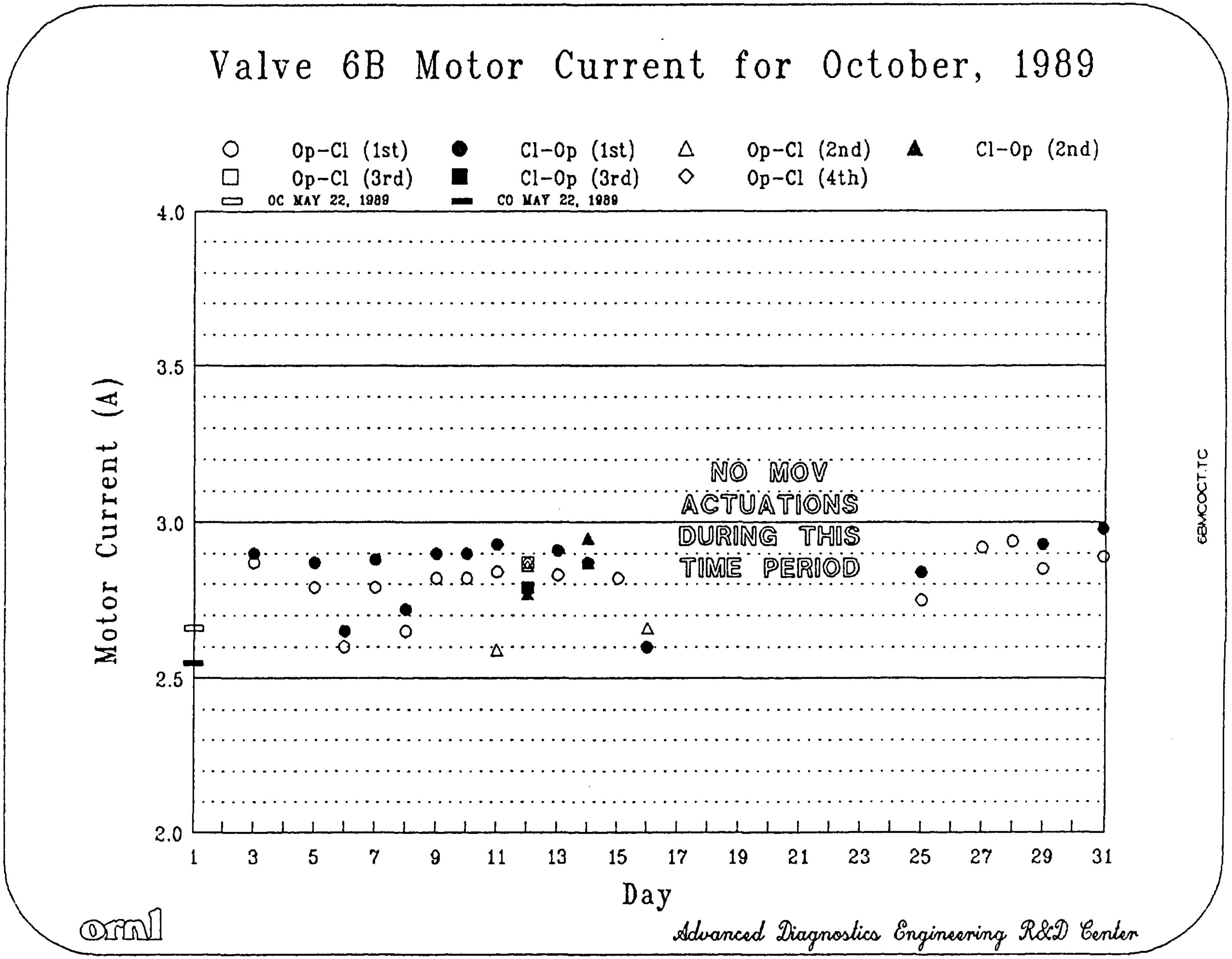

Valve 5B Motor Current for October, 1989
Open-Close (first)
Close-Open (first)
Open-Close (second)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
3.0
2.0
1.0
Motor Current (A)
NO MOV ACTUATIONS DURING THIS TIME PERIOD
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
5BMCOCT TC
Advanced Diagnostics Engineering R&D Center

FIGURE 3 6



Valve 6B Motor Current for October, 1989
Op-Cl (1st)
Cl-Op (1st)
Op-Cl (2nd)
Cl-Op (2nd)
Op-Cl (3rd)
Cl-Op (3rd)
Op-Cl (4th)
OC MAY 22, 1989
CO MAY 22, 1989
Motor Current (A)
4.0
3.5
3.0
2.5
2.0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
NO MOV ACTUATIONS DURING THIS TIME PERIOD
6BMCOCT.TC
Advanced Diagnostics Engineering R&D Center

FIGURE 37

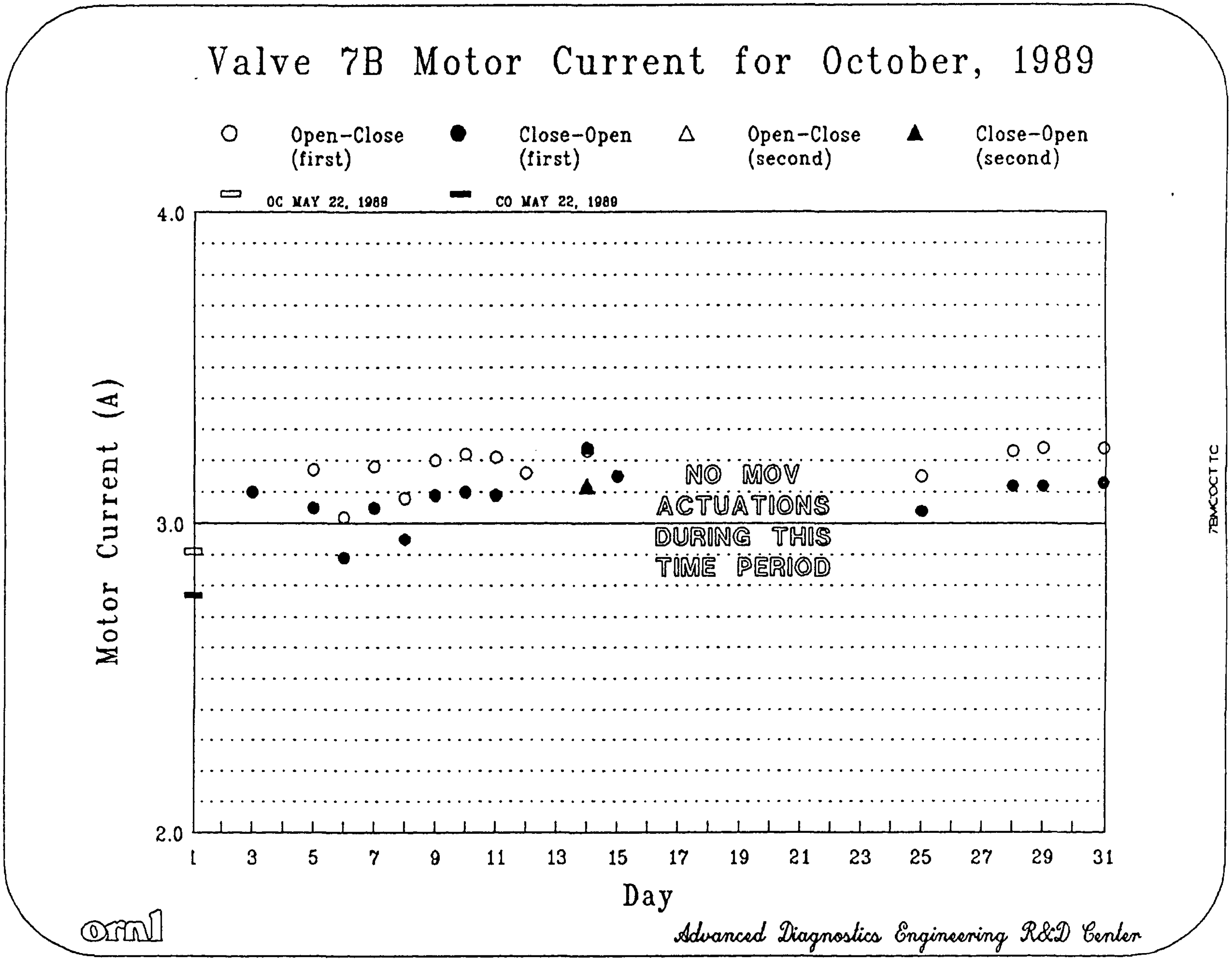

Valve 7B Motor Current for October, 1989
Open-Close (first)
Close-Open (first)
Open-Close (second)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
4.0
3.0
2.0
Motor Current (A)
NO MOV ACTUATIONS DURING THIS TIME PERIOD
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
7BMOCT TC
Advanced Diagnostics Engineering R&D Center

FIGURE 3 8

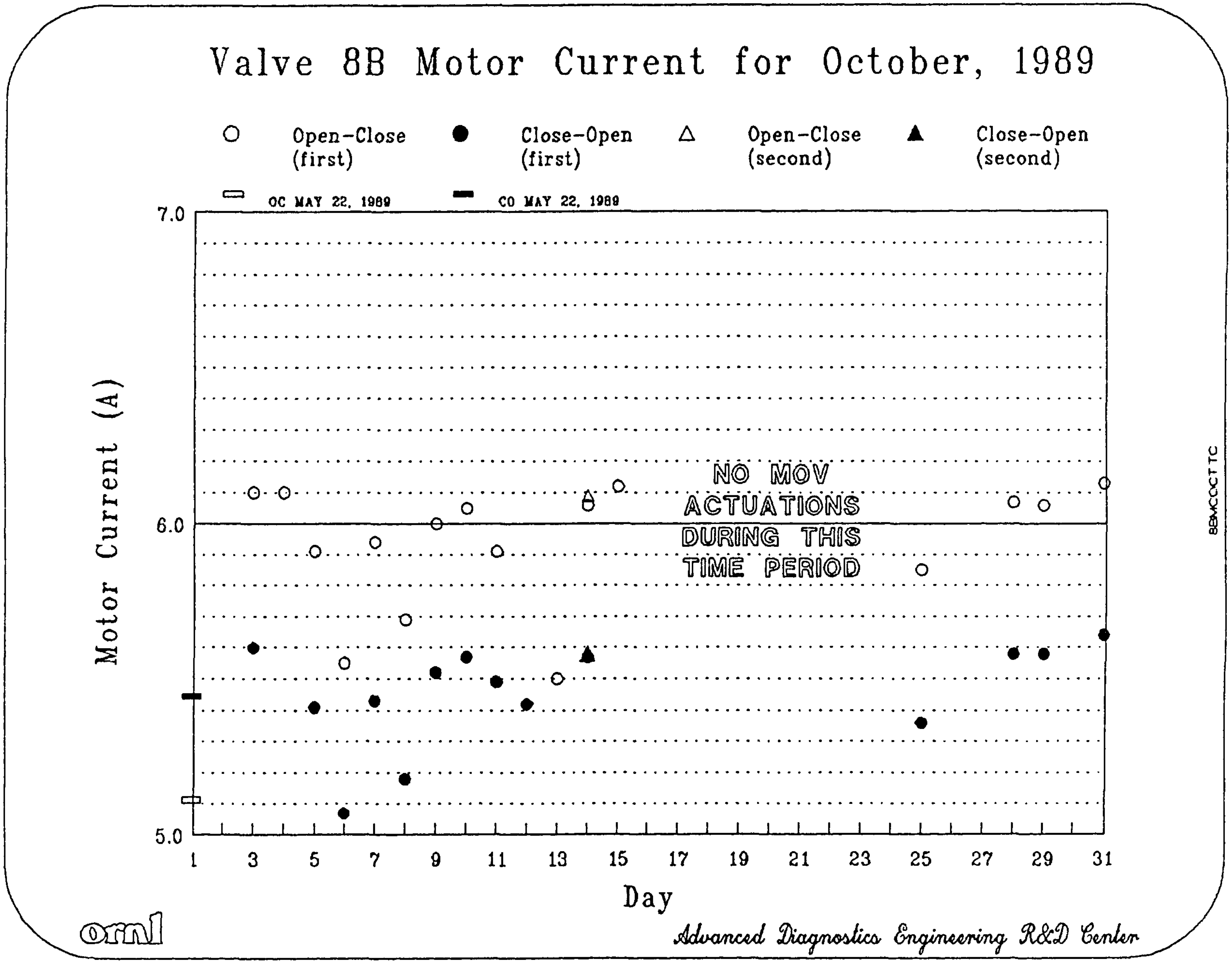

Valve 8B Motor Current for October, 1989
Open-Close (first)
Close-Open (first)
Open-Close (second)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
Motor Current (A)
7.0
6.0
5.0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
NO MOV ACTUATIONS DURING THIS TIME PERIOD
Advanced Diagnostics Engineering R&D Center

FIGURE 39

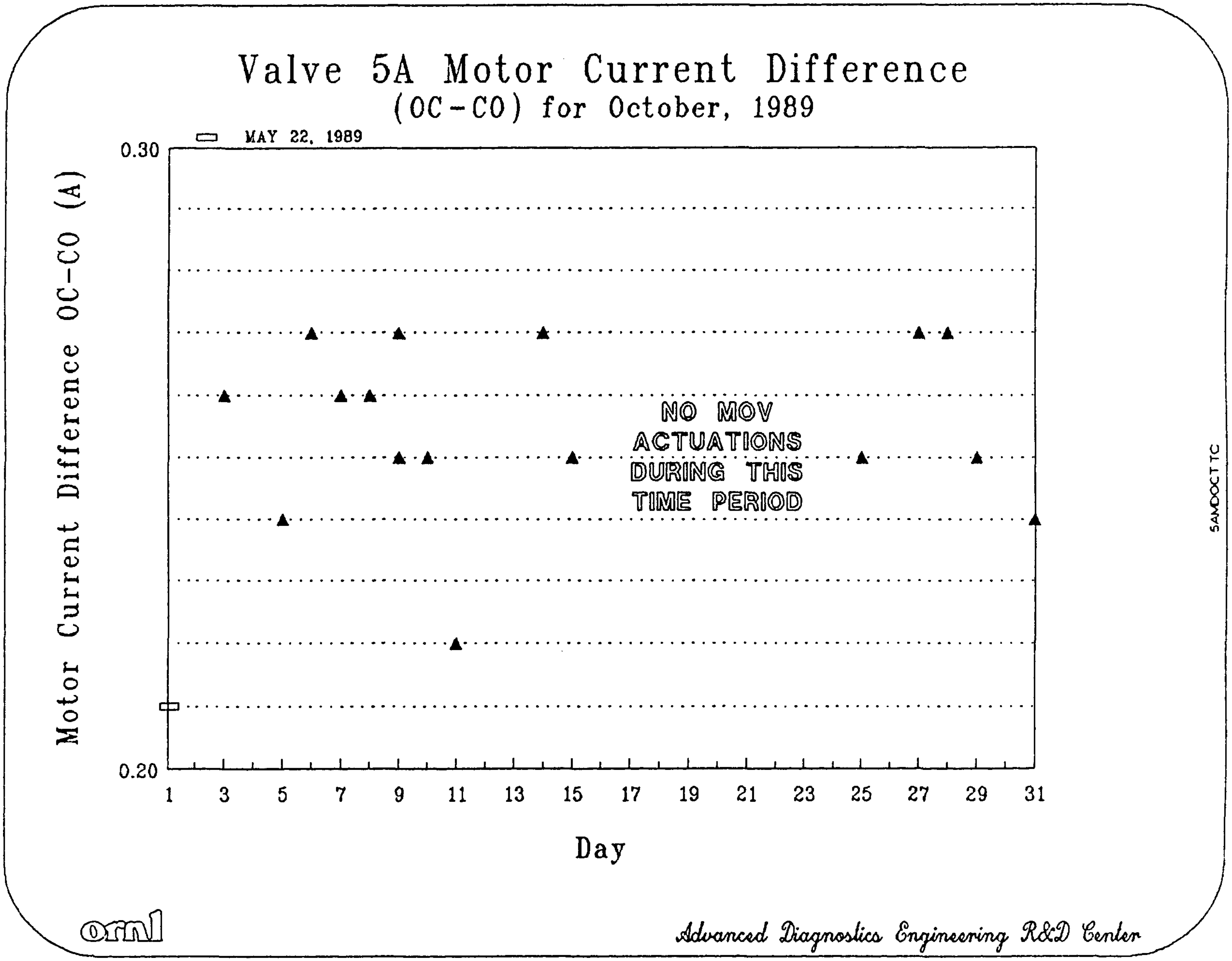

Valve 5A Motor Current Difference
(OC-CO) for October, 1989
MAY 22, 1989
0.30
0.20
Motor Current Difference OC-CO (A)
NO MOV ACTUATIONS DURING THIS TIME PERIOD
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Day
5AMOCT TC
Advanced Diagnostics Engineering R&D Center

FIGURE 40

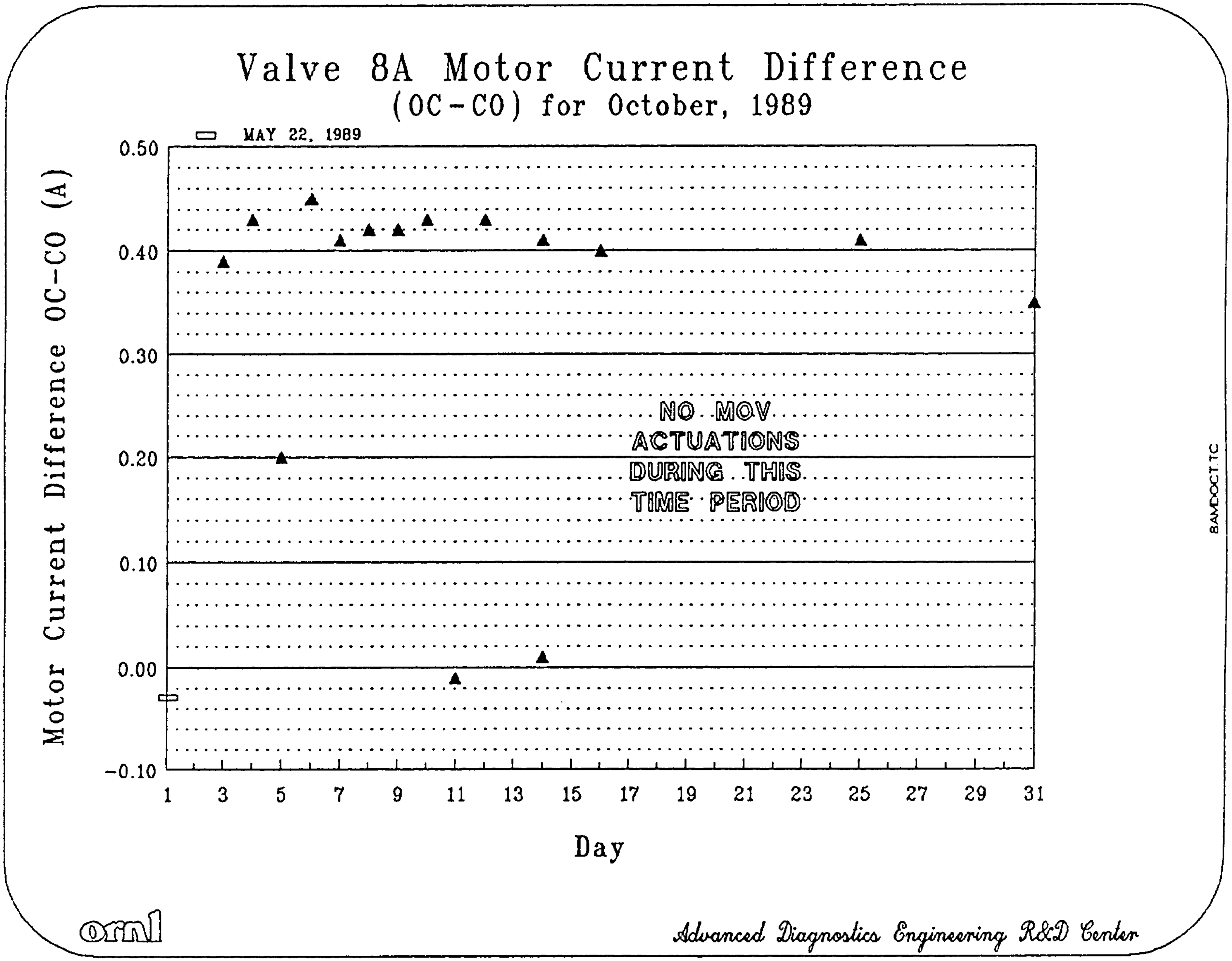

Valve 8A Motor Current Difference
(OC-CO) for October, 1989
MAY 22, 1989
Motor Current Difference OC-CO (A)
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
NO MOV
ACTUATIONS
DURING THIS
TIME PERIOD
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day
Advanced Diagnostics Engineering R&D Center
8AMDOCT TC

FIGURE 4 1

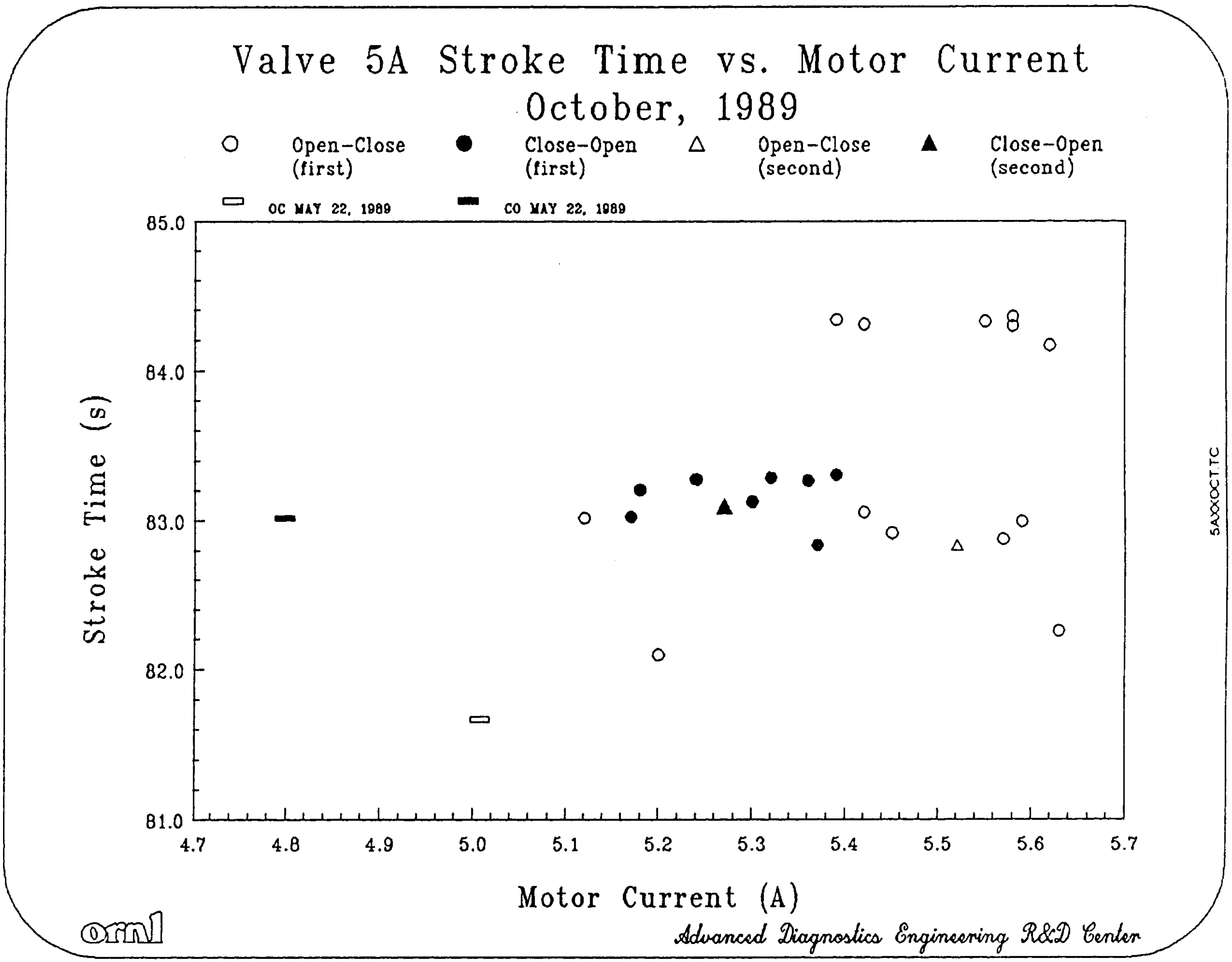
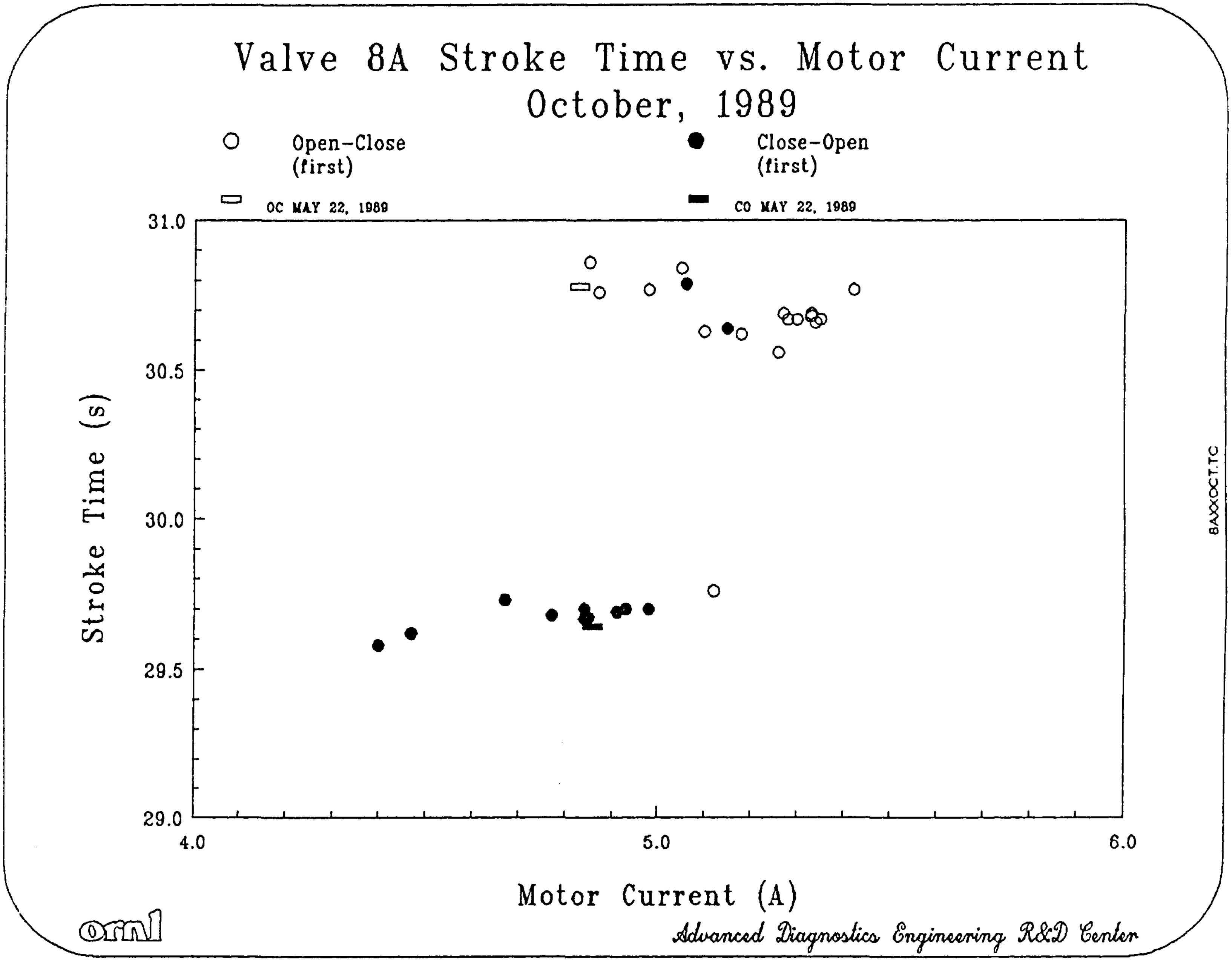

Valve 5A Stroke Time vs. Motor Current
October, 1989
Open-Close (first)
Close-Open (first)
Open-Close (second)
Close-Open (second)
OC MAY 22, 1989
CO MAY 22, 1989
85.0
84.0
83.0
82.0
81.0
Stroke Time (s)
4.7
4.8
4.9
5.0
5.1
5.2
5.3
5.4
5.5
5.6
5.7
Motor Current (A)
5AXXOCT.TC
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 4 2

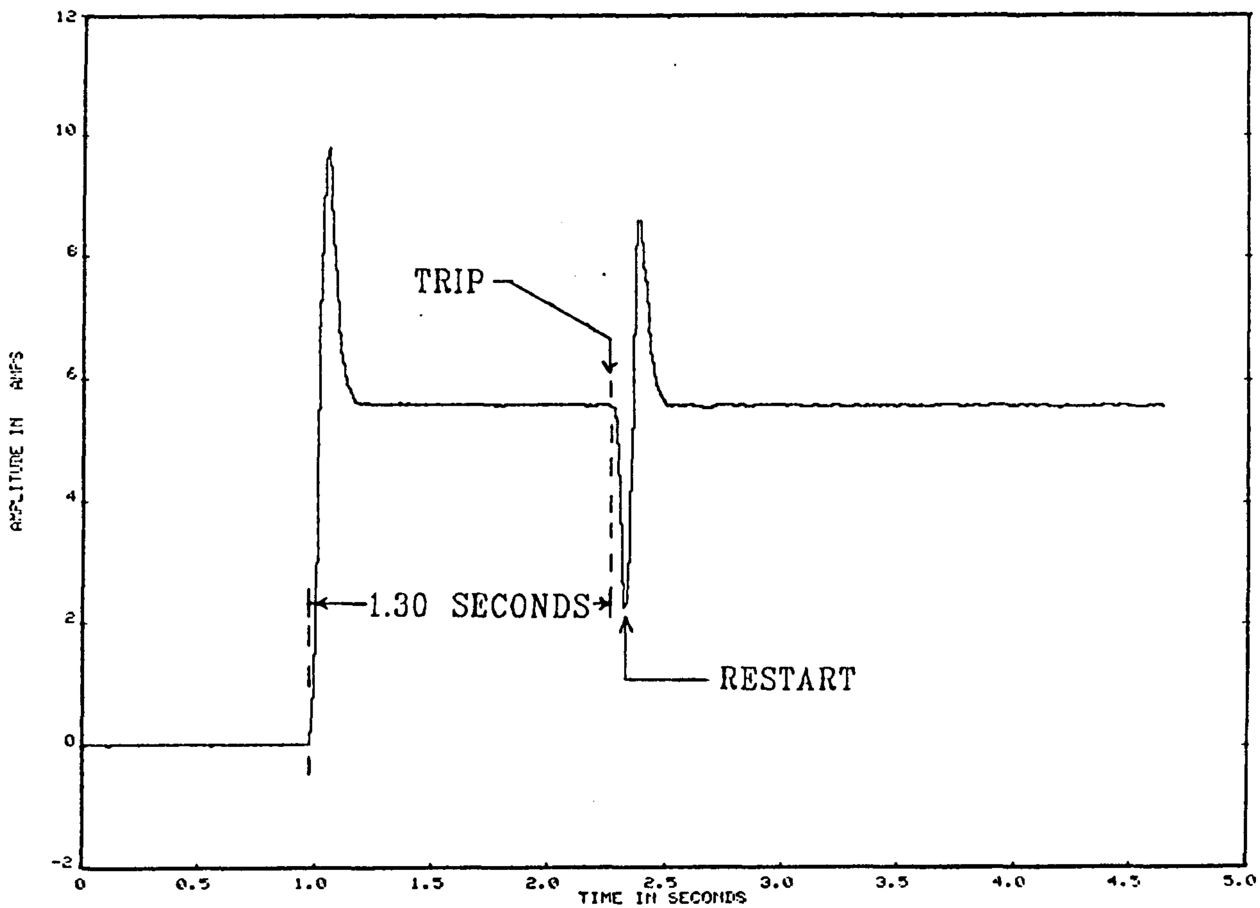


Valve 8A Stroke Time vs. Motor Current
October, 1989
Open-Close
(first)
Close-Open
(first)
OC MAY 22, 1989
CO MAY 22, 1989
31.0
30.5
30.0
29.5
29.0
Stroke Time (s)
4.0
5.0
6.0
Motor Current (A)
8AXXOCT.TC
Advanced Diagnostics Engineering R&D Center

FIGURE 4 3

APPARENT MOTOR TRIP AND RESTART OBSERVED ON VALVE 5A (O-C STROKE) - OCTOBER 29, 1989

(Also observed on September 24, and October 3, 5, 10, and 11)



ornl

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FIGURE 4 4

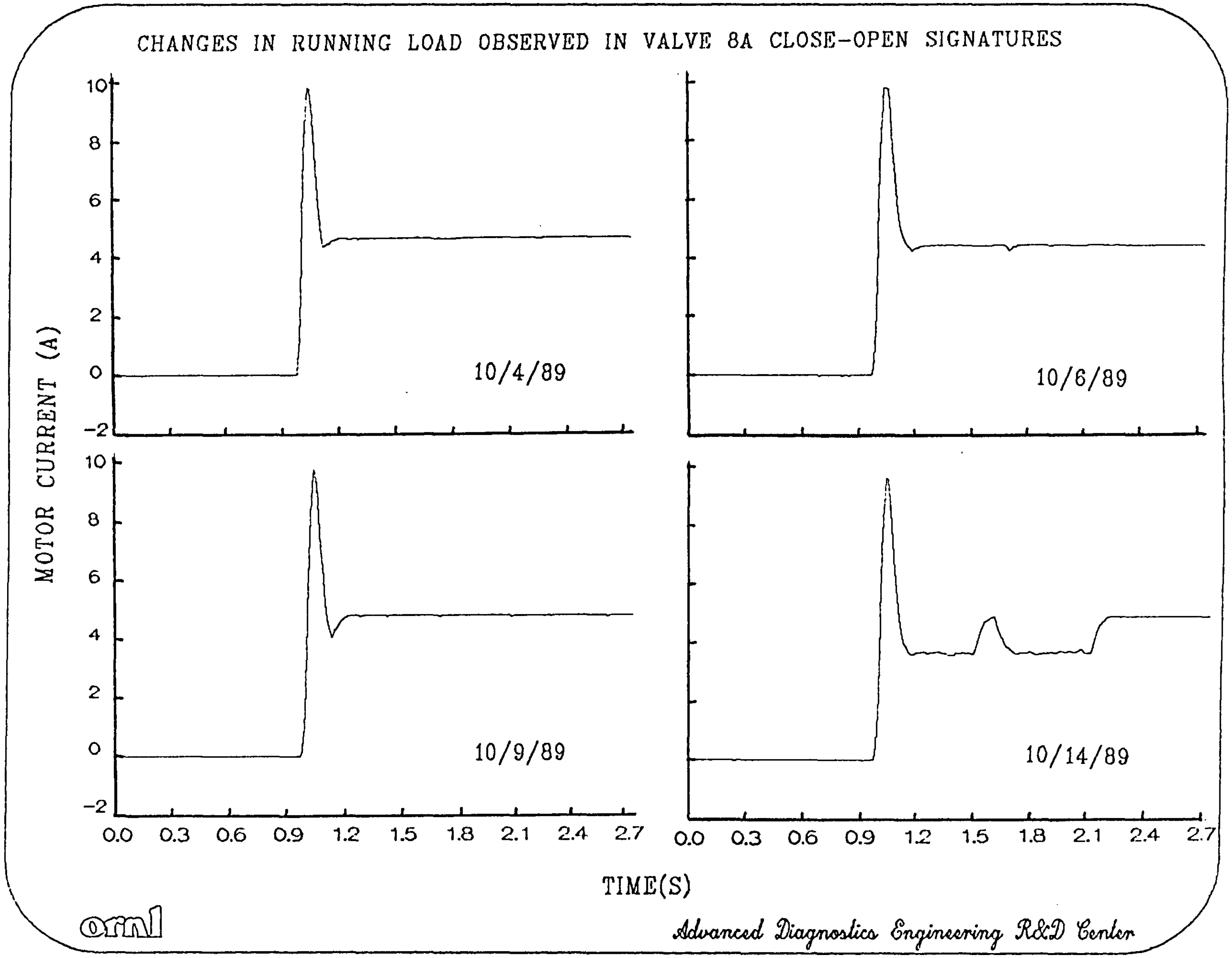

CHANGES IN RUNNING LOAD OBSERVED IN VALVE 8A CLOSE-OPEN SIGNATURES
MOTOR CURRENT (A)
10
8
6
4
2
0
-2
10/4/89
10/6/89
10/9/89
10/14/89
0.0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4 2.7
TIME(S)
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 4 5

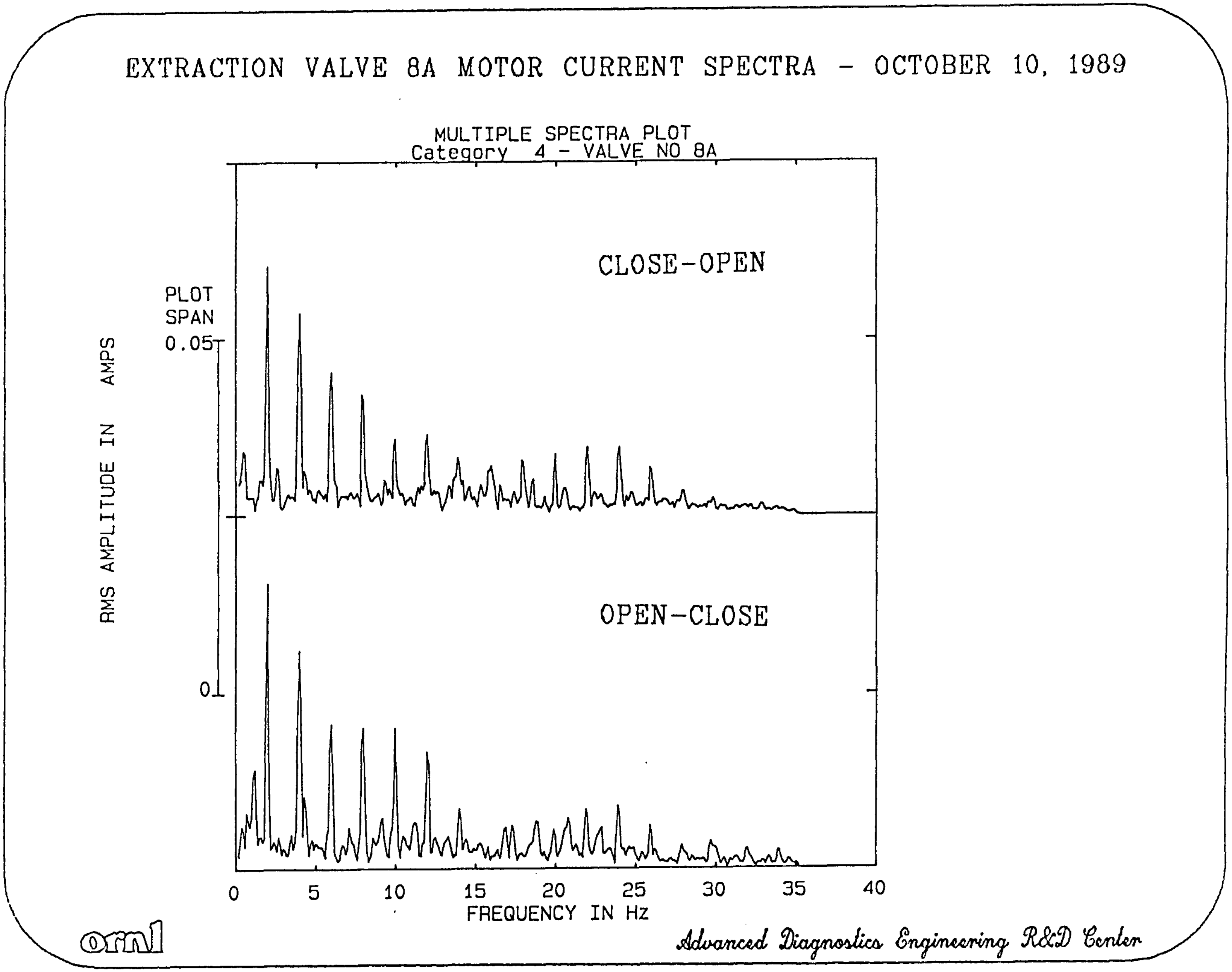

EXTRACTION VALVE 8A MOTOR CURRENT SPECTRA - OCTOBER 10, 1989
MULTIPLE SPECTRA PLOT
Category 4 - VALVE NO 8A
CLOSE-OPEN
OPEN-CLOSE
PLOT
SPAN
0.05
0
RMS AMPLITUDE IN AMPS
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
Advanced Diagnostics Engineering R&D Center

FIGURE 4 6

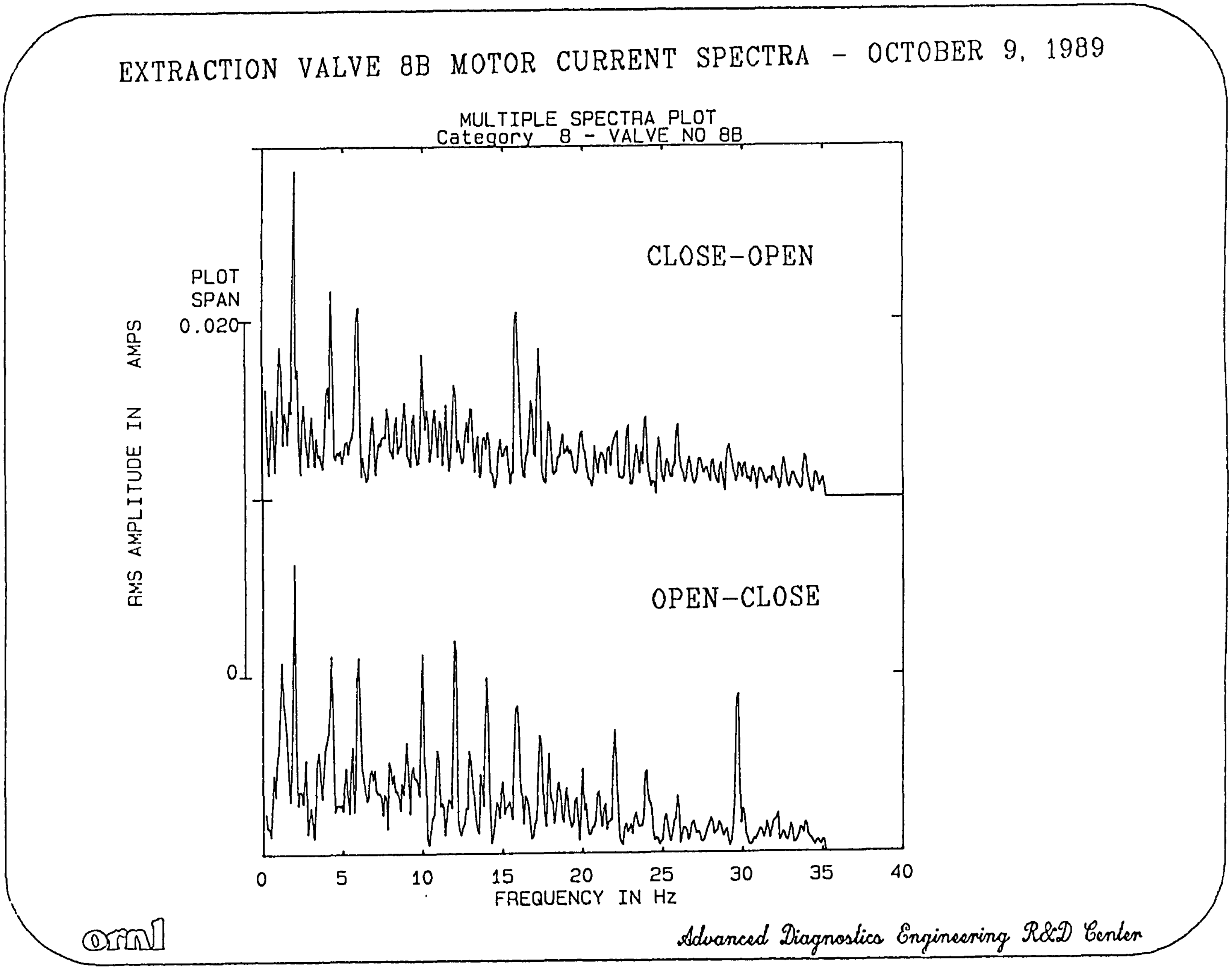

EXTRACTION VALVE 8B MOTOR CURRENT SPECTRA - OCTOBER 9, 1989
MULTIPLE SPECTRA PLOT
Category 8 - VALVE NO 8B
CLOSE-OPEN
OPEN-CLOSE
PLOT SPAN
0.020
0
RMS AMPLITUDE IN AMPS
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
Advanced Diagnostics Engineering R&D Center

FIGURE 4 7

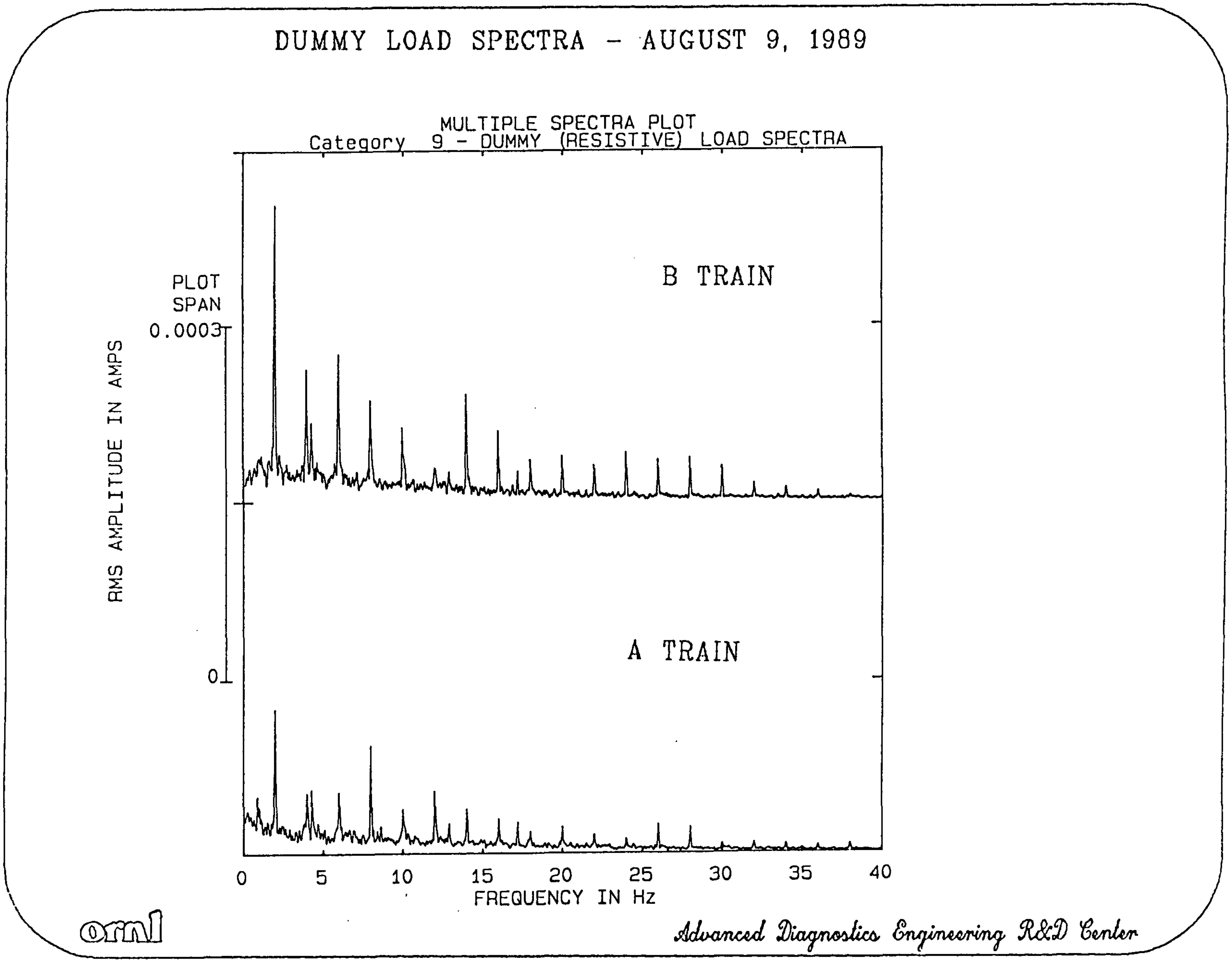

DUMMY LOAD SPECTRA - AUGUST 9, 1989
MULTIPLE SPECTRA PLOT
Category 9 - DUMMY (RESISTIVE) LOAD SPECTRA
PLOT
SPAN
0.0003
0
RMS AMPLITUDE IN AMPS
B TRAIN
A TRAIN
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
Advanced Diagnostics Engineering R&D Center

FIGURE 4 8

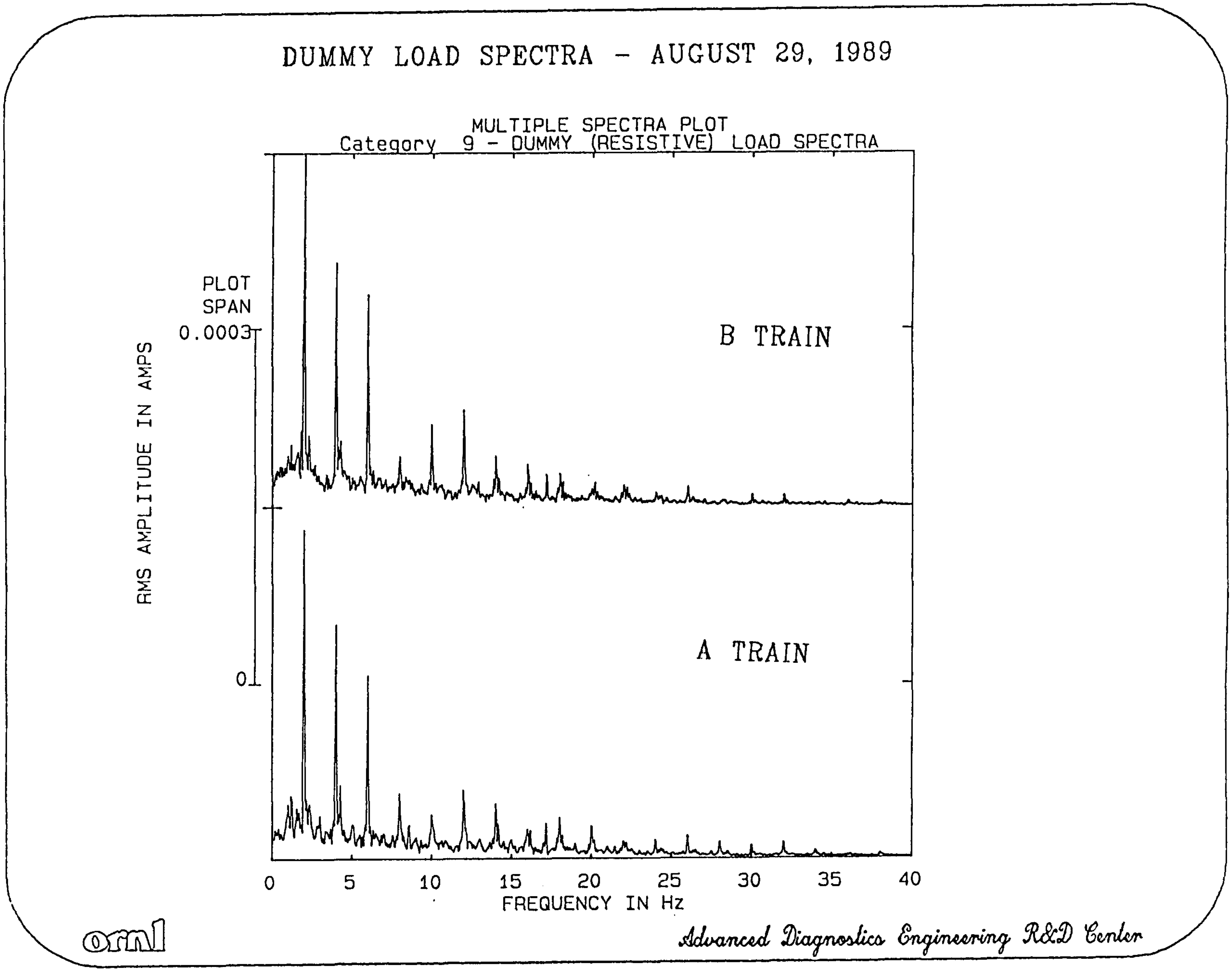

DUMMY LOAD SPECTRA - AUGUST 29, 1989
MULTIPLE SPECTRA PLOT
Category 9 - DUMMY (RESISTIVE) LOAD SPECTRA
PLOT
SPAN
0.0003
0
RMS AMPLITUDE IN AMPS
B TRAIN
A TRAIN
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 4 9

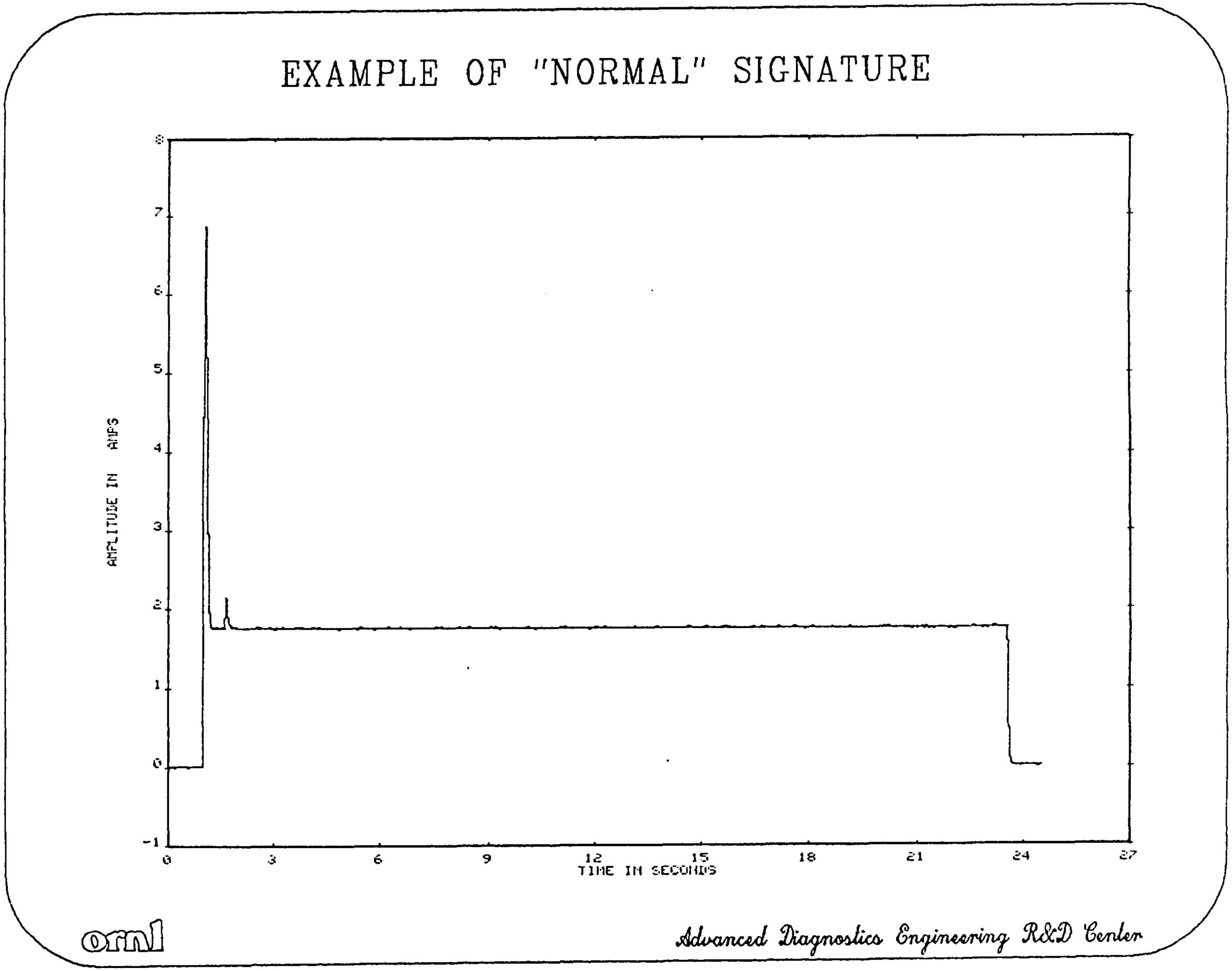

EXAMPLE OF "NORMAL" SIGNATURE
AMPLITUDE IN AMPS
TIME IN SECONDS
8
7
6
5
4
3
2
1
0
-1
0
3
6
9
12
15
18
21
24
27
Advanced Diagnostics Engineering R&D Center

FIGURE 50

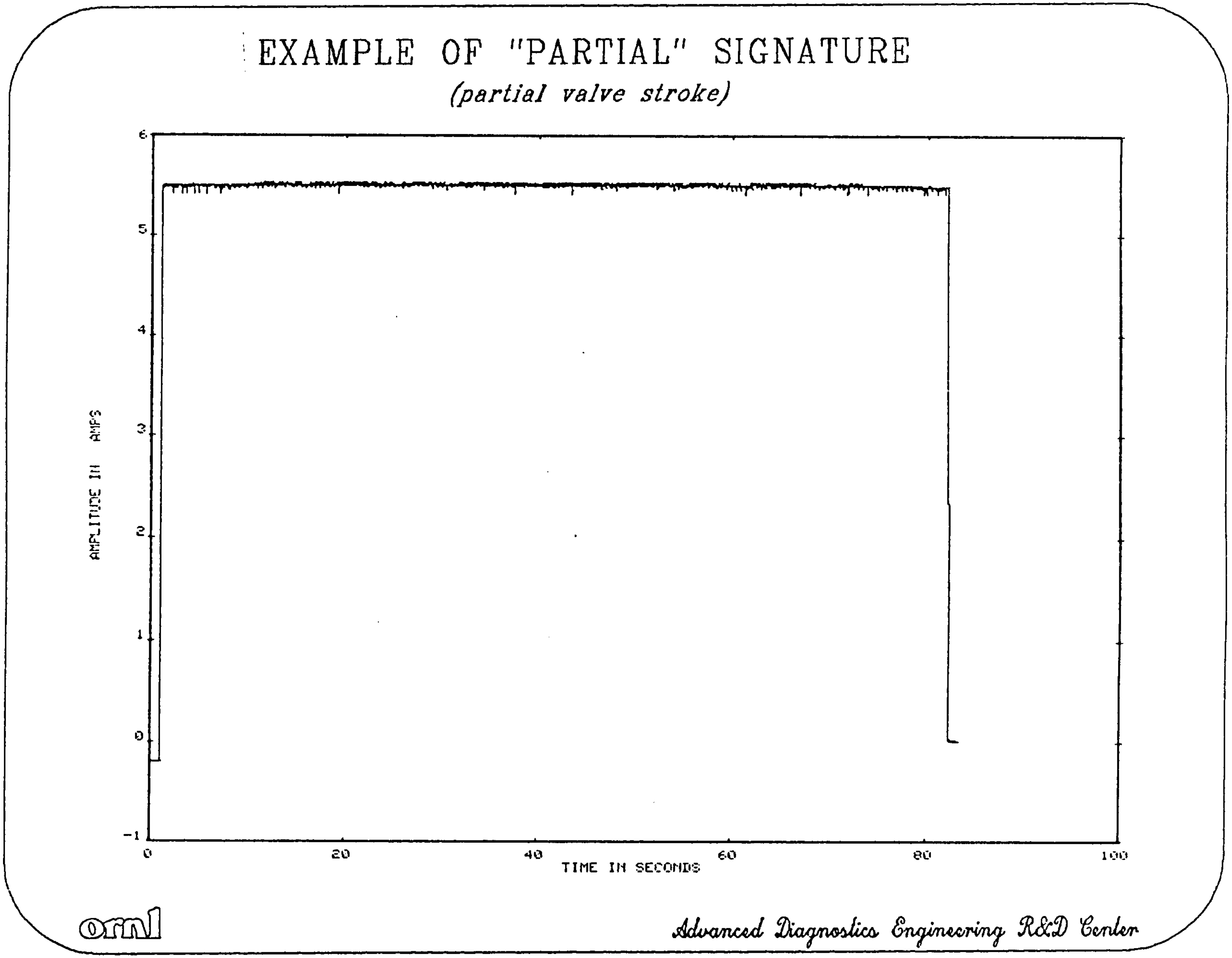

EXAMPLE OF "PARTIAL" SIGNATURE
(partial valve stroke)
AMPLITUDE IN AMPS
TIME IN SECONDS
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
Advanced Diagnostics Engineering R&D Center

FIGURE 5 1

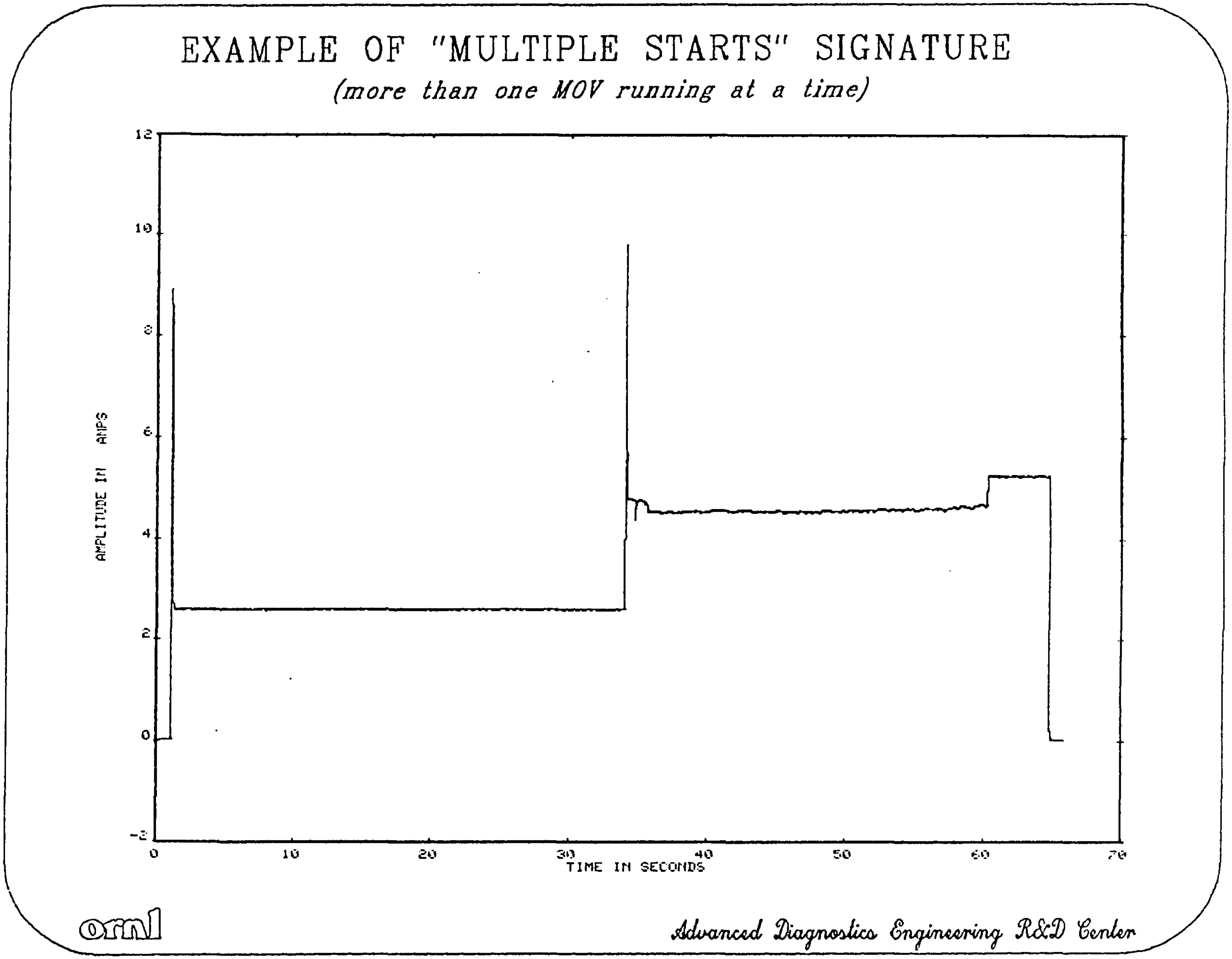

EXAMPLE OF "MULTIPLE STARTS" SIGNATURE
(more than one MOV running at a time)
12
10
8
6
4
2
0
-2
AMPLITUDE IN AMPS
0
10
20
30
40
50
60
70
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 5 2

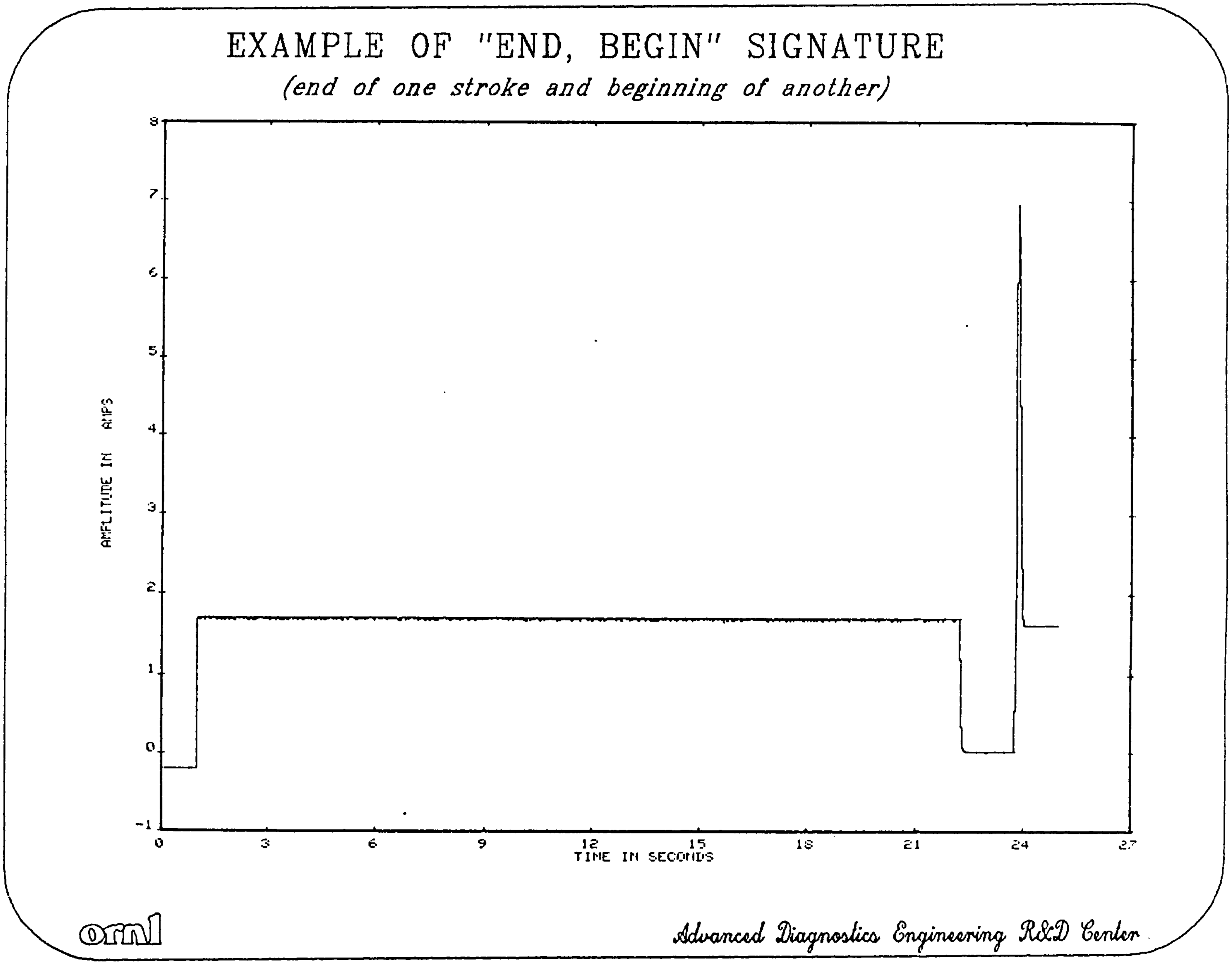
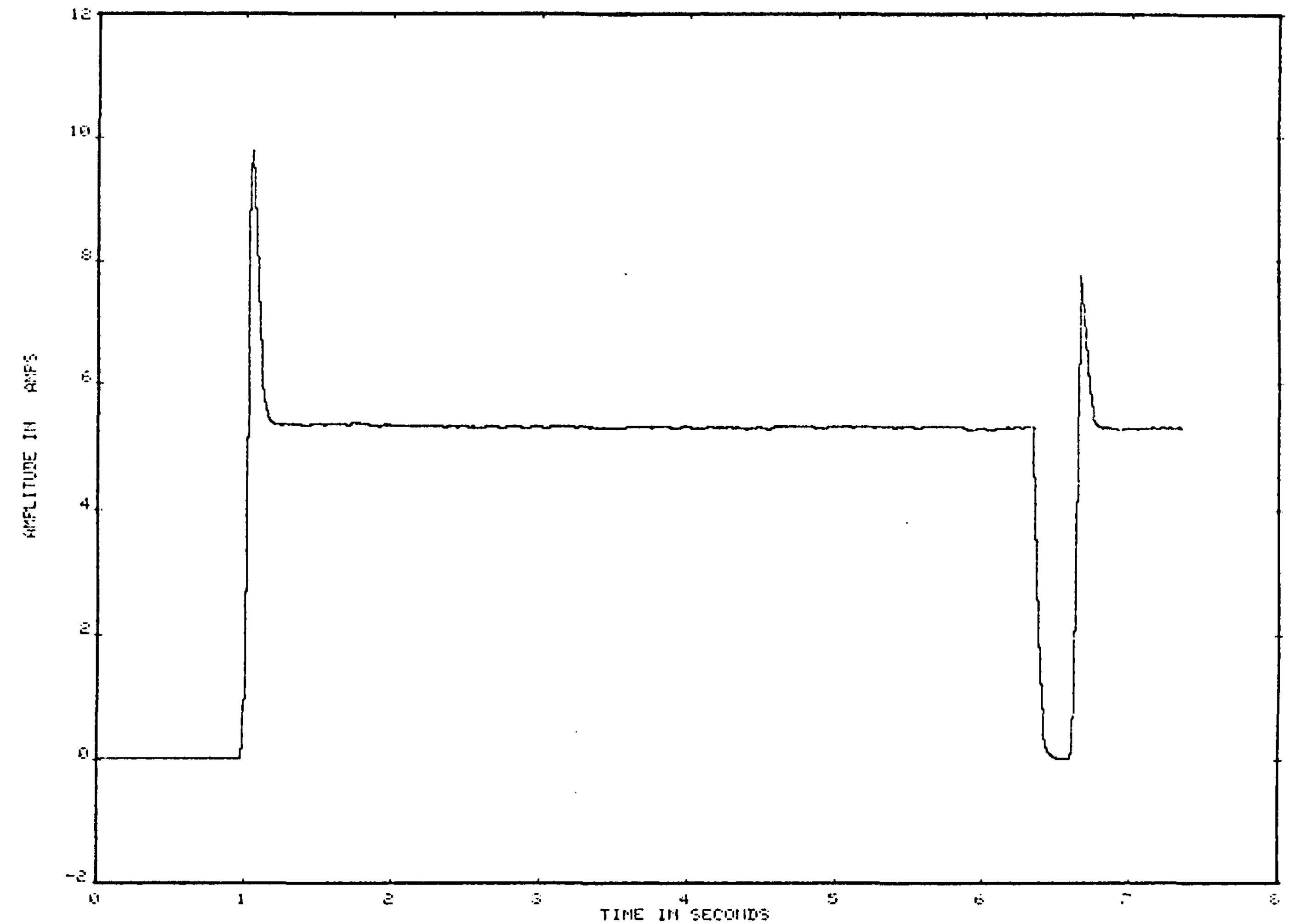

EXAMPLE OF "END, BEGIN" SIGNATURE
(end of one stroke and beginning of another)
AMPLITUDE IN AMPS
8
7
6
5
4
3
2
1
0
-1
0
3
6
9
12
15
18
21
24
27
TIME IN SECONDS
Advanced Diagnostics Engineering R&D Center

FIGURE 5 3

EXAMPLE OF "OFF, ON" SIGNATURE

(MOV shuts off and is restarted)



ornl

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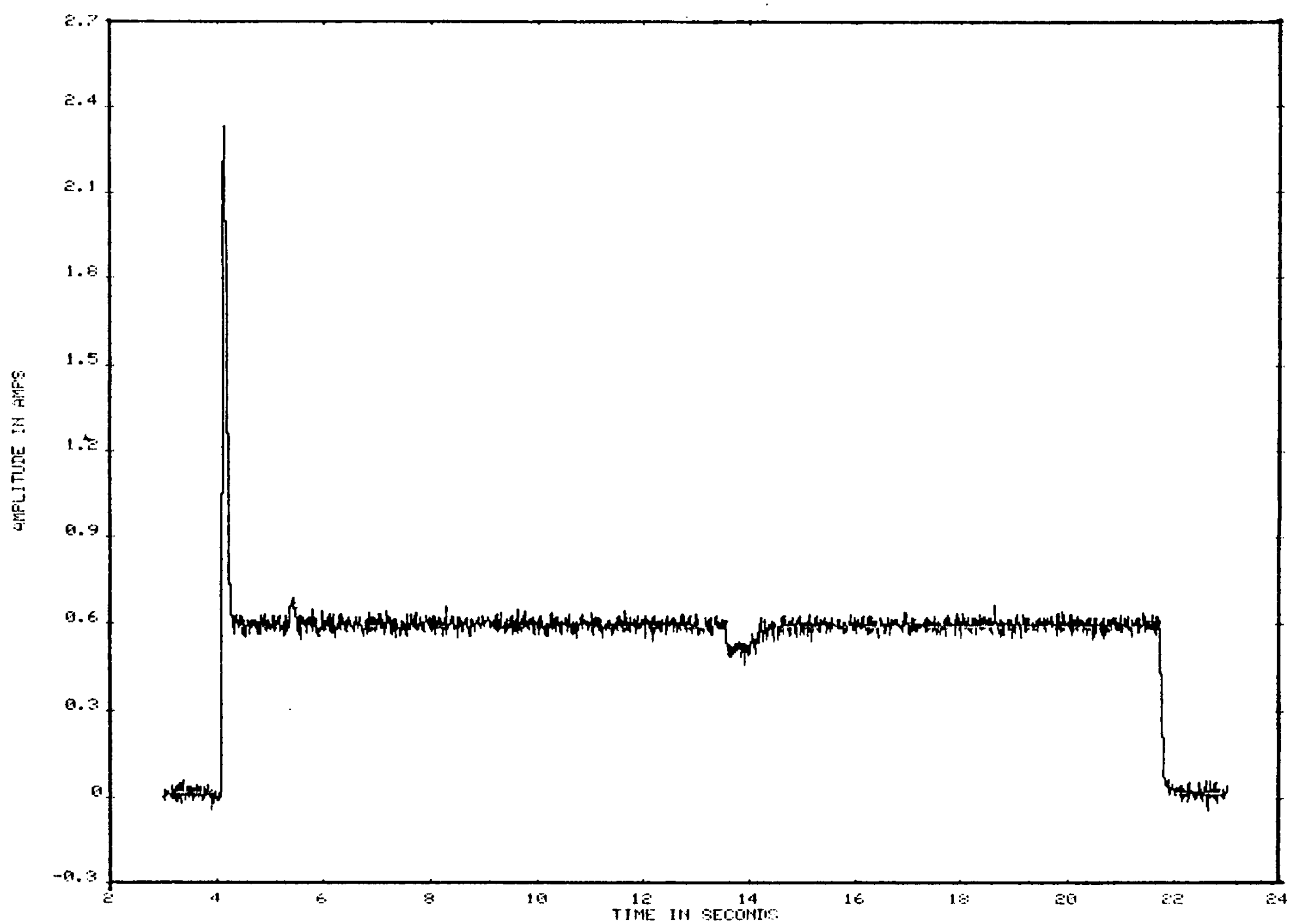
FIGURE 5 4

UNIT 3: VALVE VE7 (CLOSE TO OPEN) - AUGUST 29, 1989



ornl

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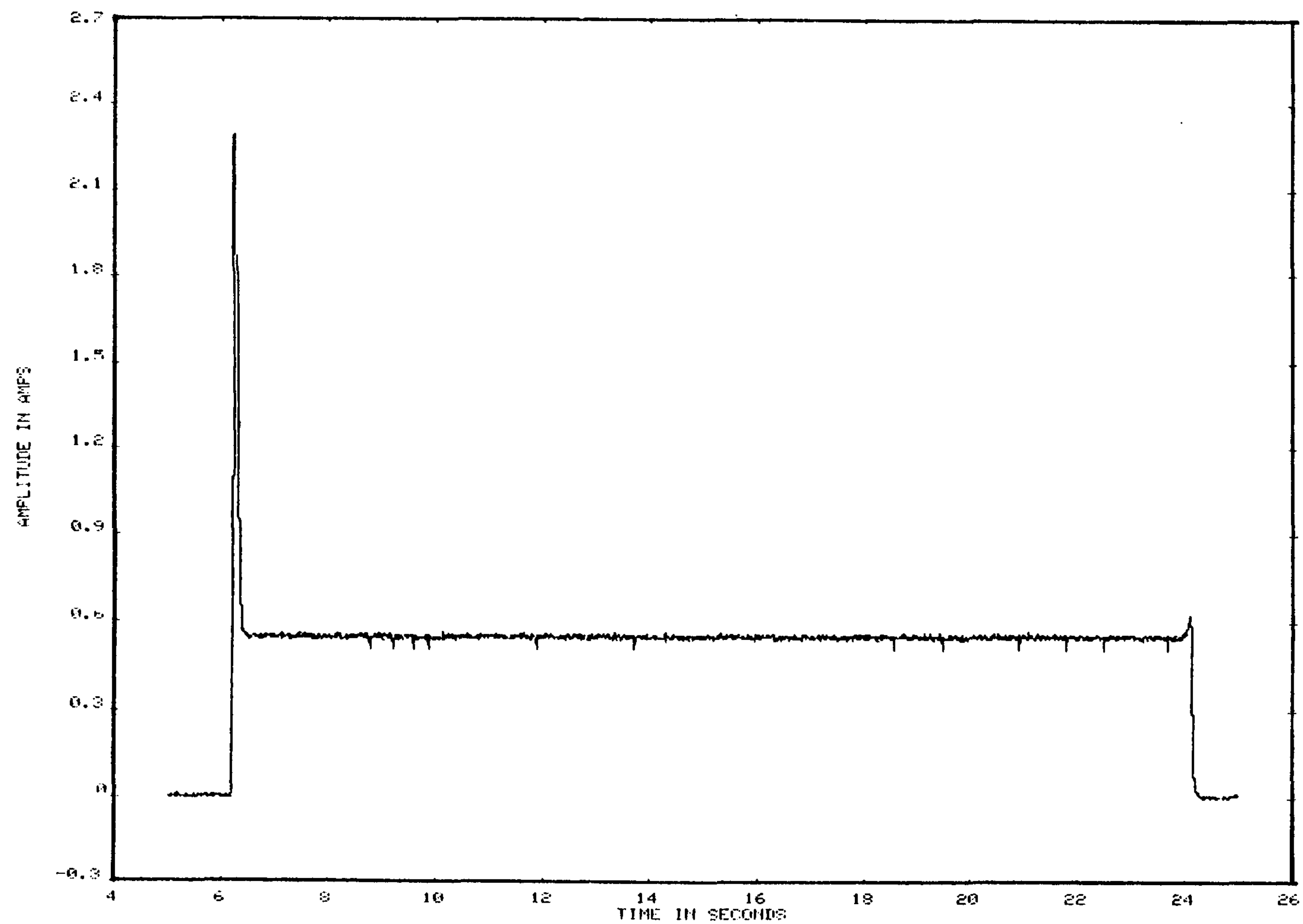
FIGURE 55

UNIT 3: VALVE VE7 (OPEN TO CLOSE) - AUGUST 29, 1989



ornl

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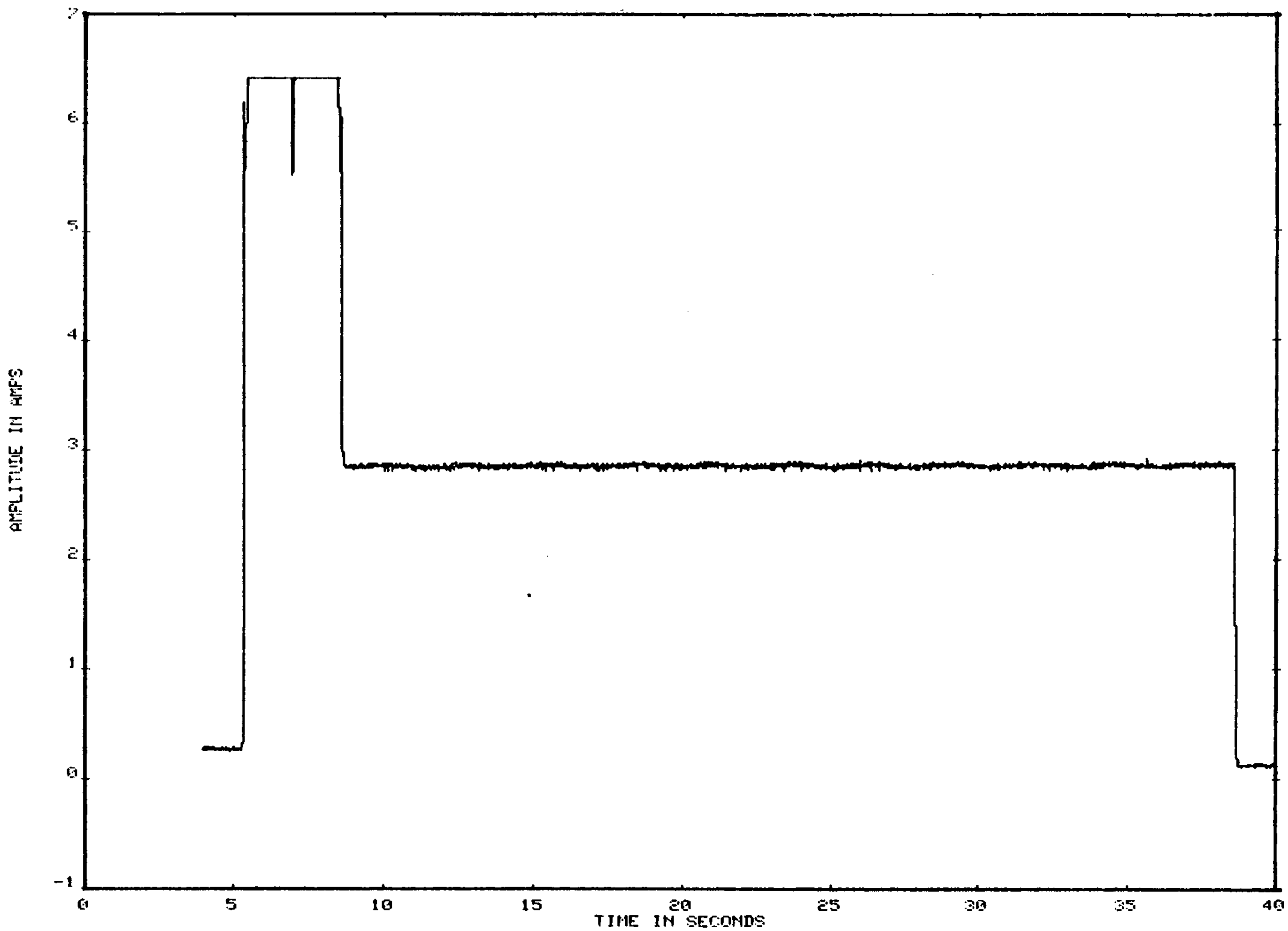
FIGURE 56

UNIT 3: VALVE VE9 (CLOSE TO OPEN) - AUGUST 29, 1989



ornl

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FIGURE 57

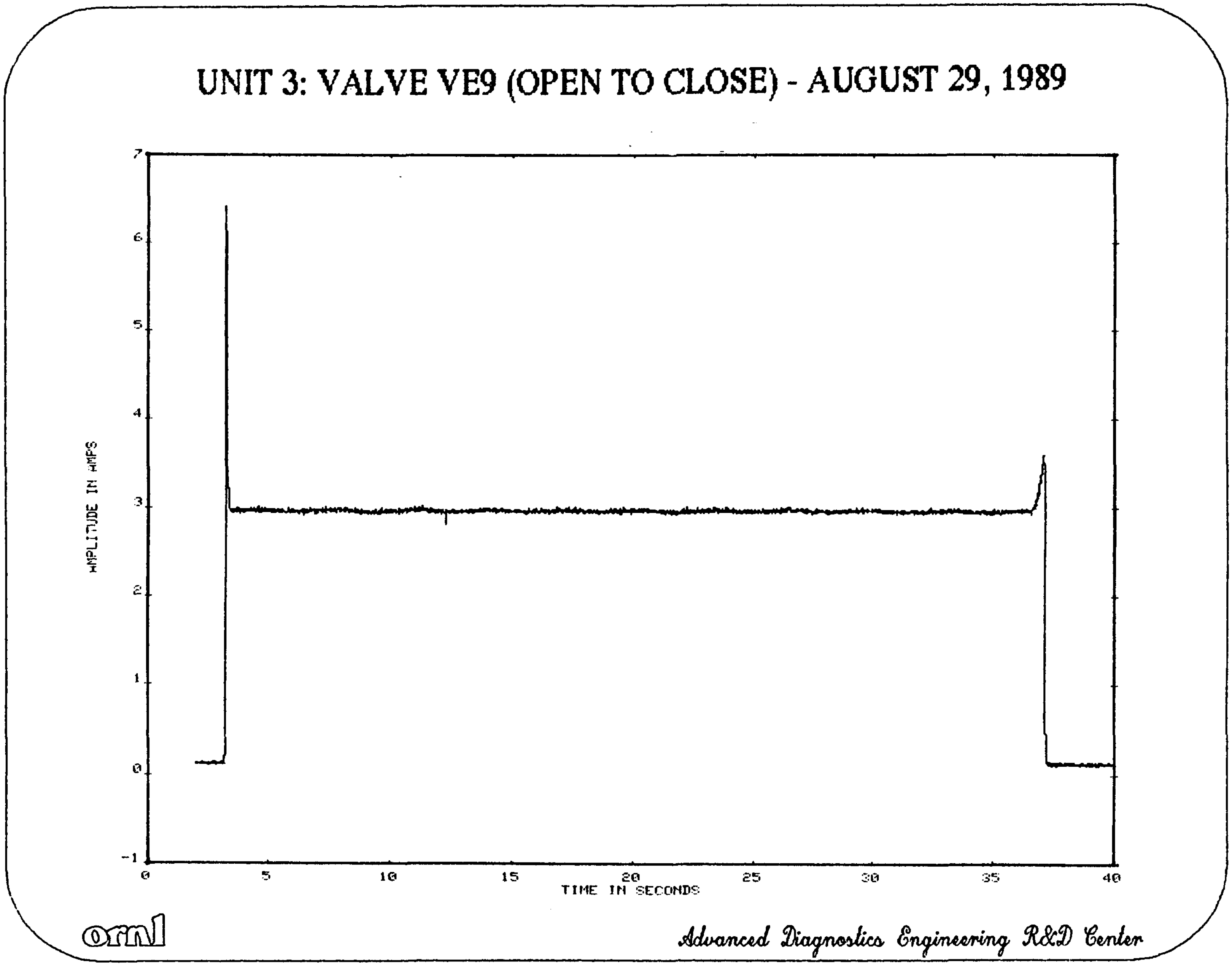

UNIT 3: VALVE VE9 (OPEN TO CLOSE) - AUGUST 29, 1989
AMPLITUDE IN AMPS
TIME IN SECONDS
7
6
5
4
3
2
1
0
-1
0
5
10
15
20
25
30
35
40
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 58

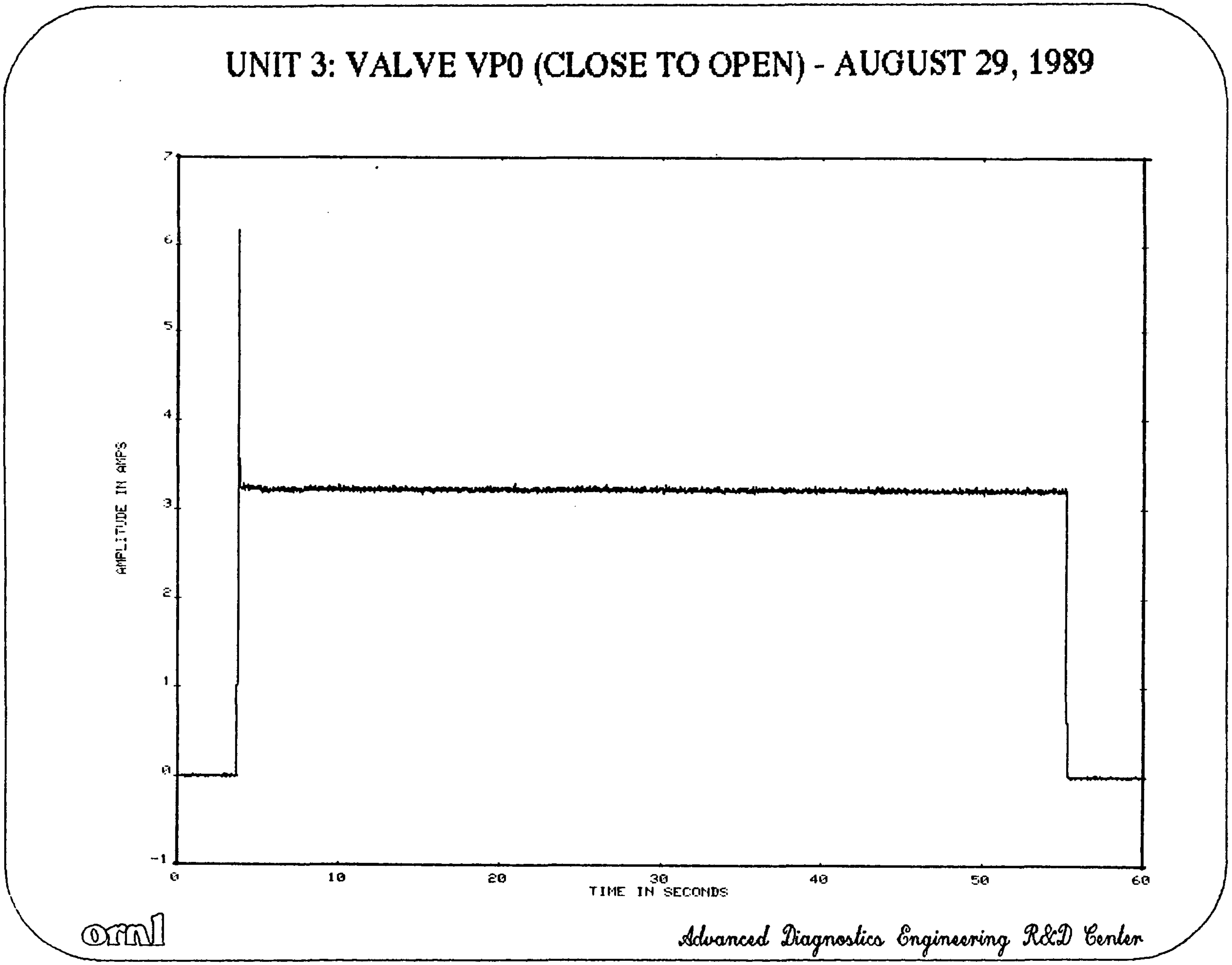
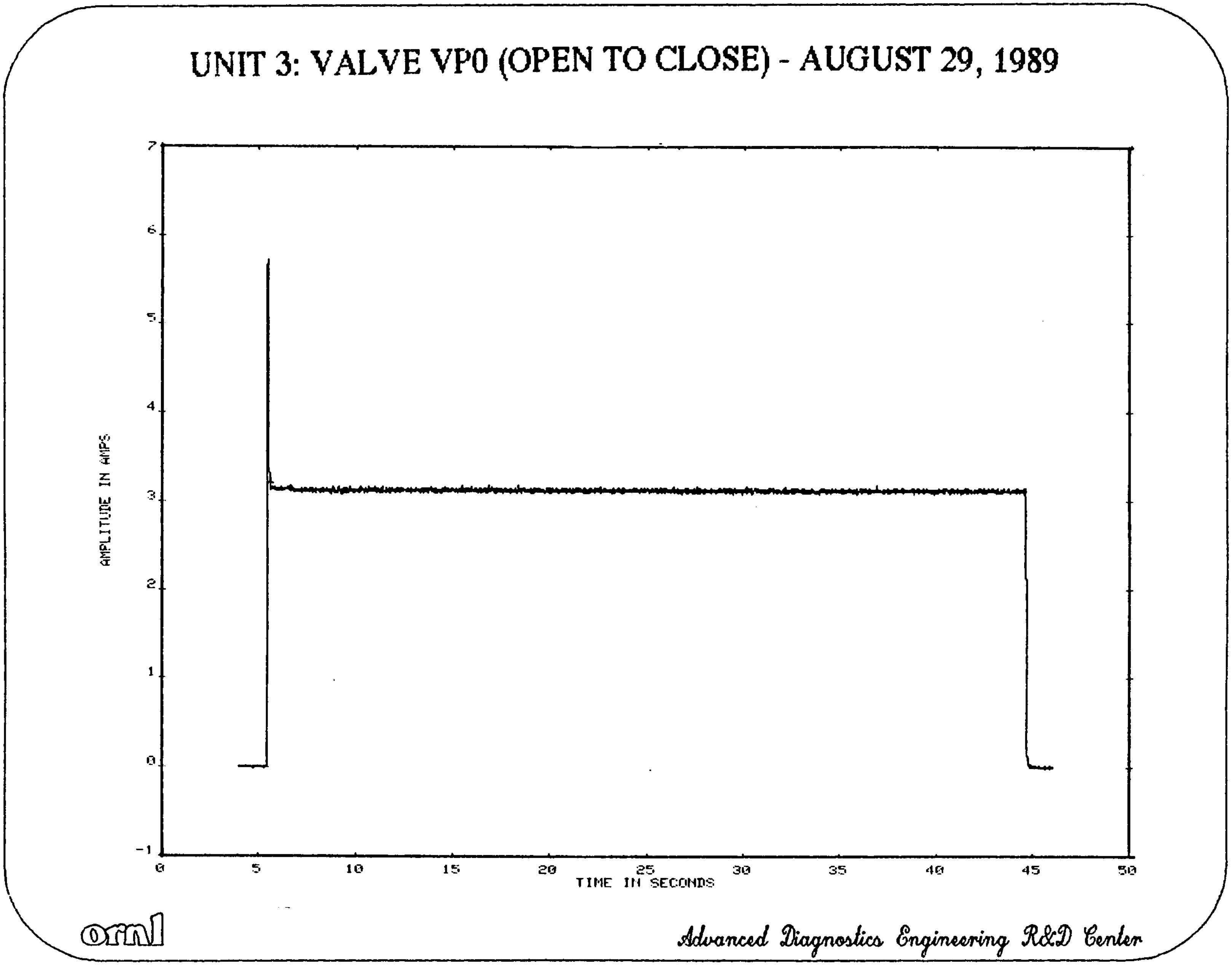

UNIT 3: VALVE VP0 (CLOSE TO OPEN) - AUGUST 29, 1989
AMPLITUDE IN AMPS
7
6
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 59



UNIT 3: VALVE VP0 (OPEN TO CLOSE) - AUGUST 29, 1989
AMPLITUDE IN AMPS
7
6
5
4
3
2
1
0
-1
0
5
10
15
20
25
30
35
40
45
50
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 60

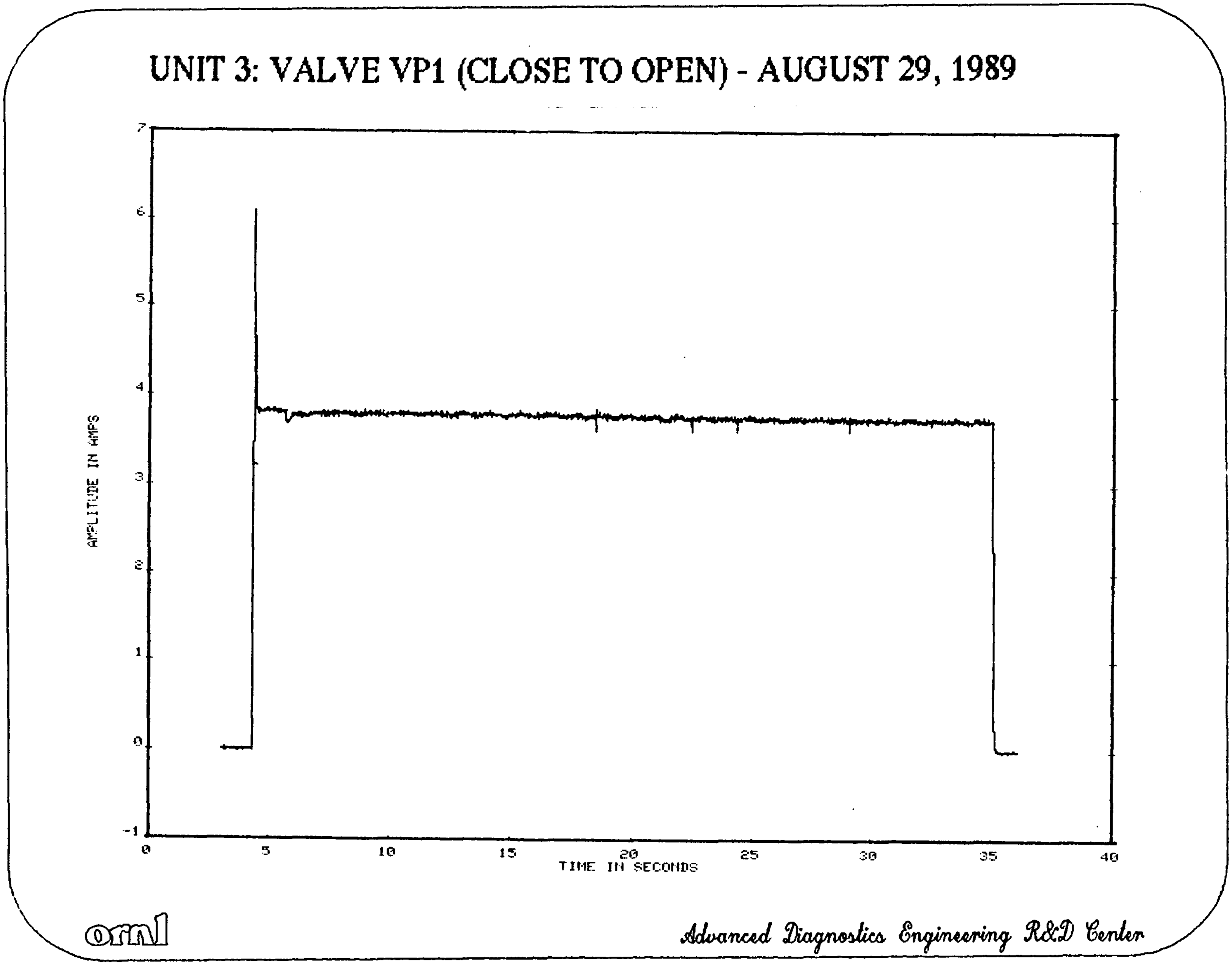

UNIT 3: VALVE VP1 (CLOSE TO OPEN) - AUGUST 29, 1989
AMPLITUDE IN AMPS
TIME IN SECONDS
7
6
5
4
3
2
1
0
-1
0
5
10
15
20
25
30
35
40
Advanced Diagnostics Engineering R&D Center

FIGURE 61

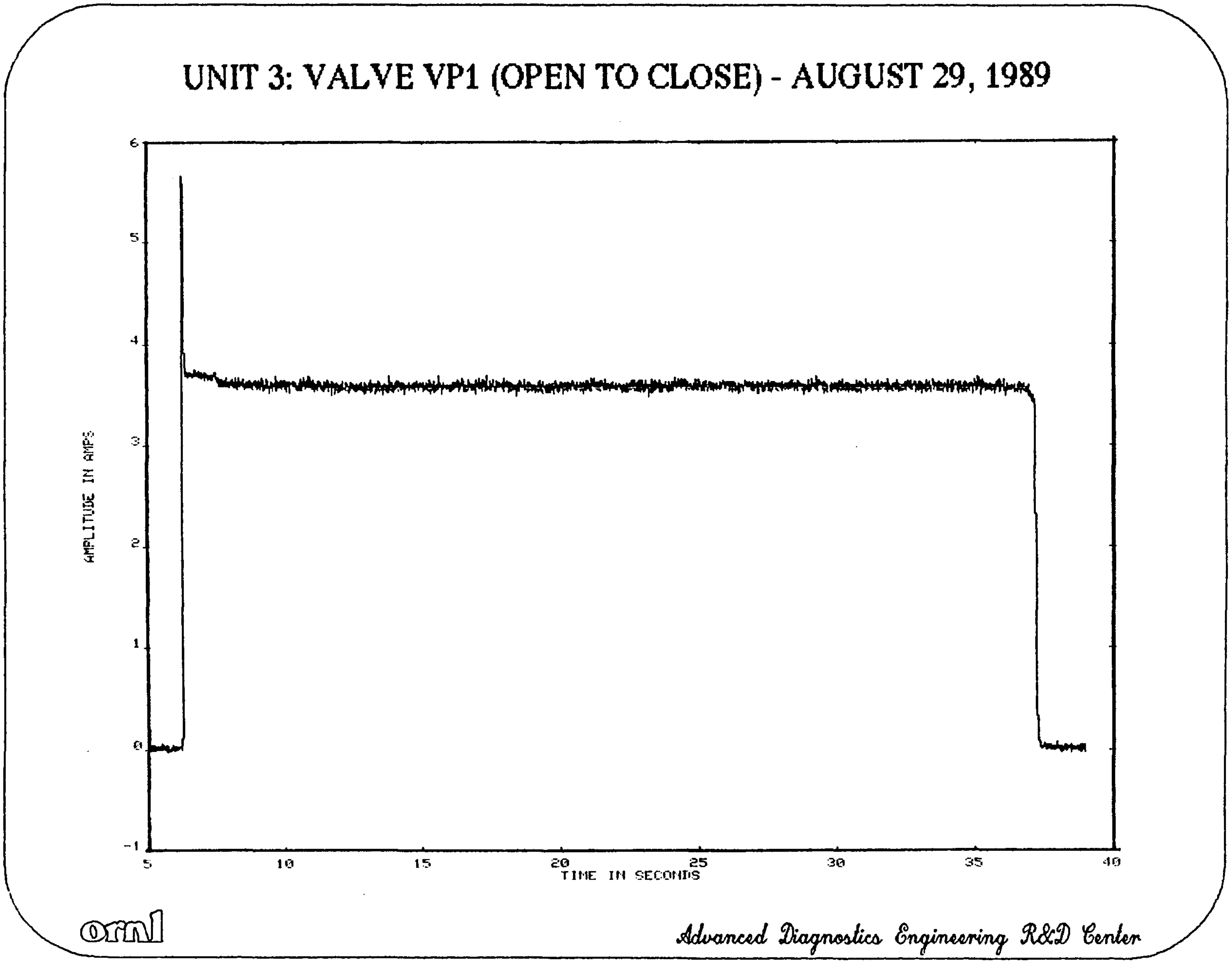
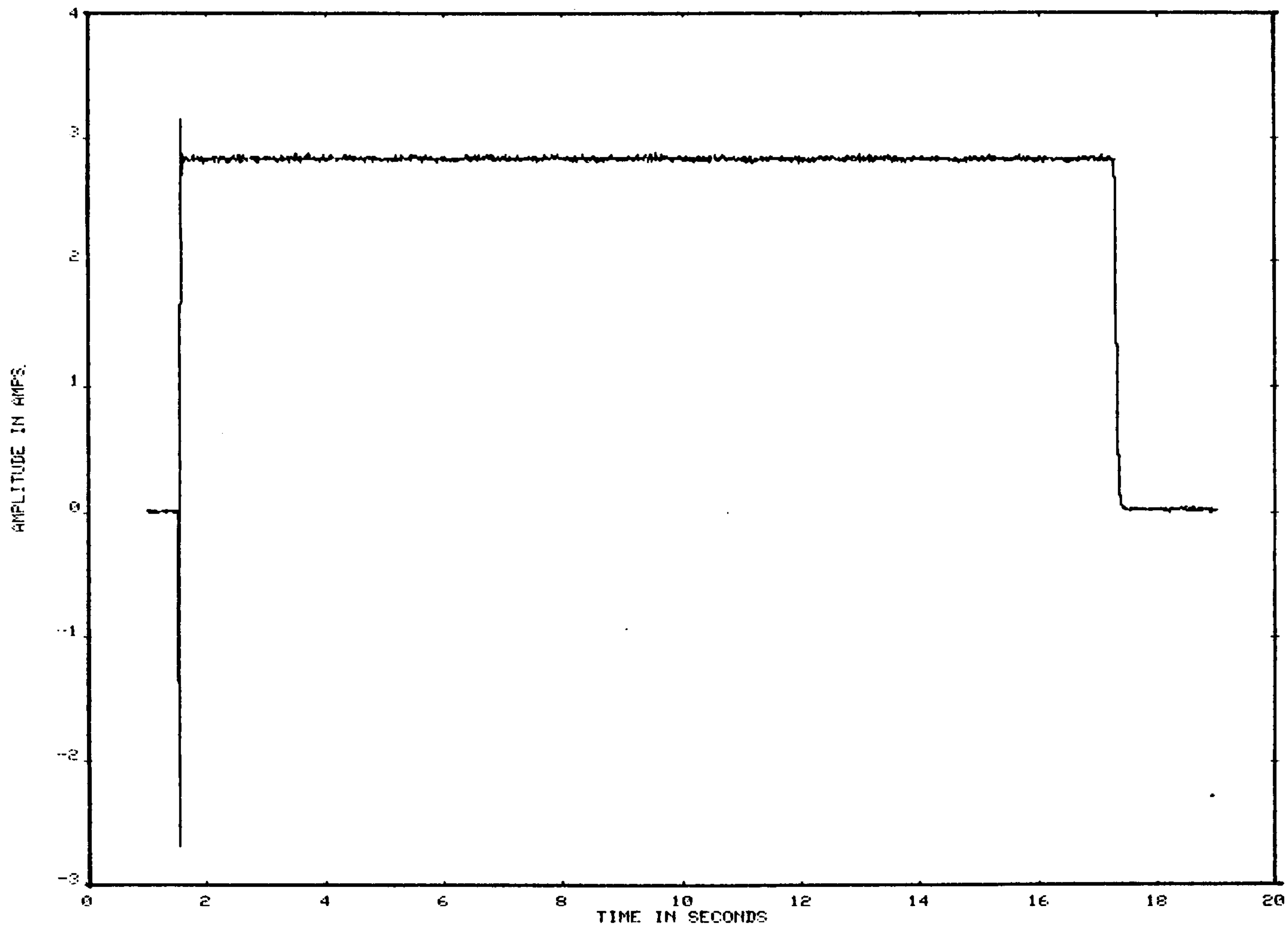

UNIT 3: VALVE VP1 (OPEN TO CLOSE) - AUGUST 29, 1989
AMPLITUDE IN AMPS
6
5
4
3
2
1
0
-1
5
10
15
20
25
30
35
40
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 62

UNIT 3: VALVE VP2 (CLOSE TO OPEN) - AUGUST 29, 1989



ornl

Advanced Diagnostics Engineering R&D Center

FIGURE 63

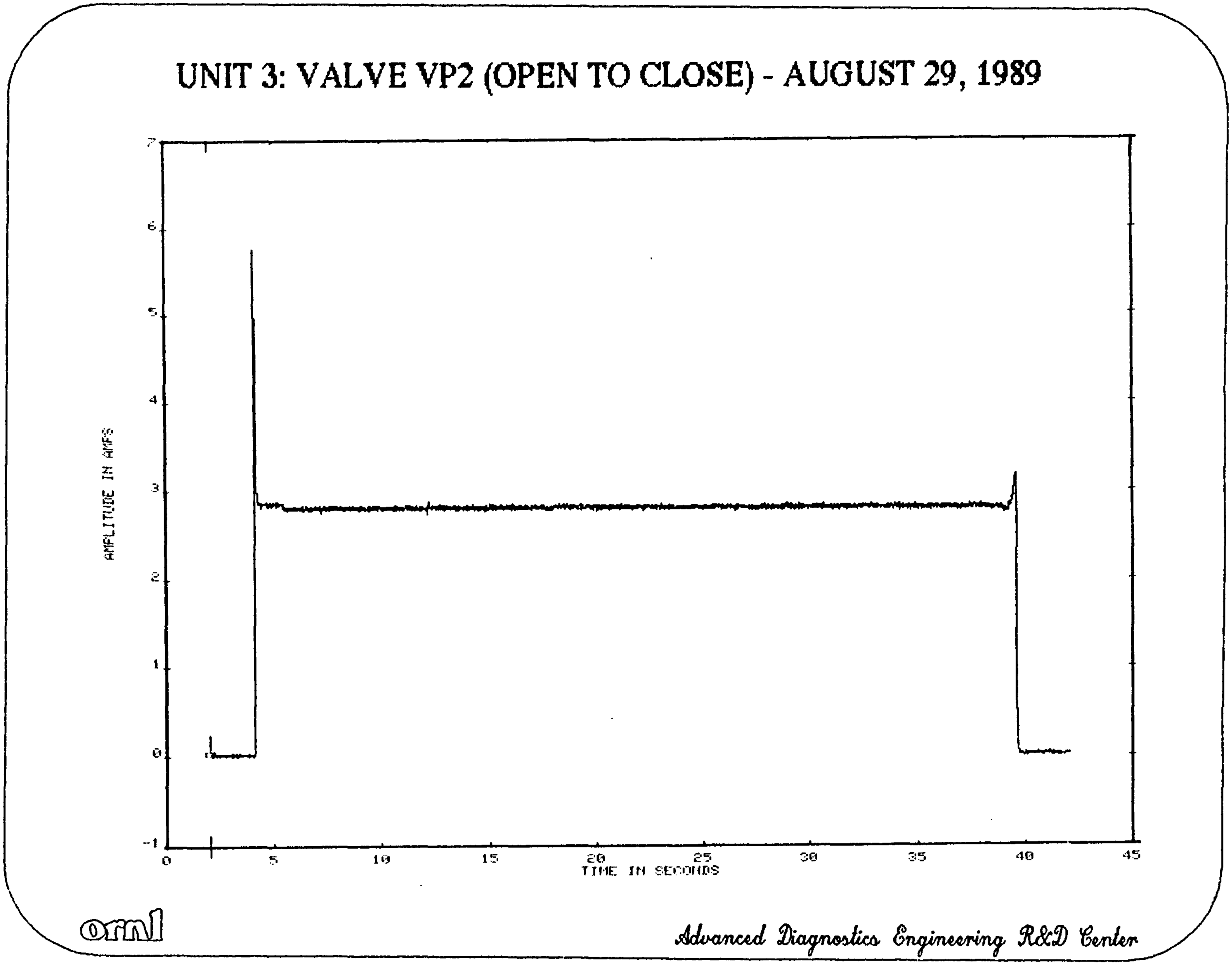
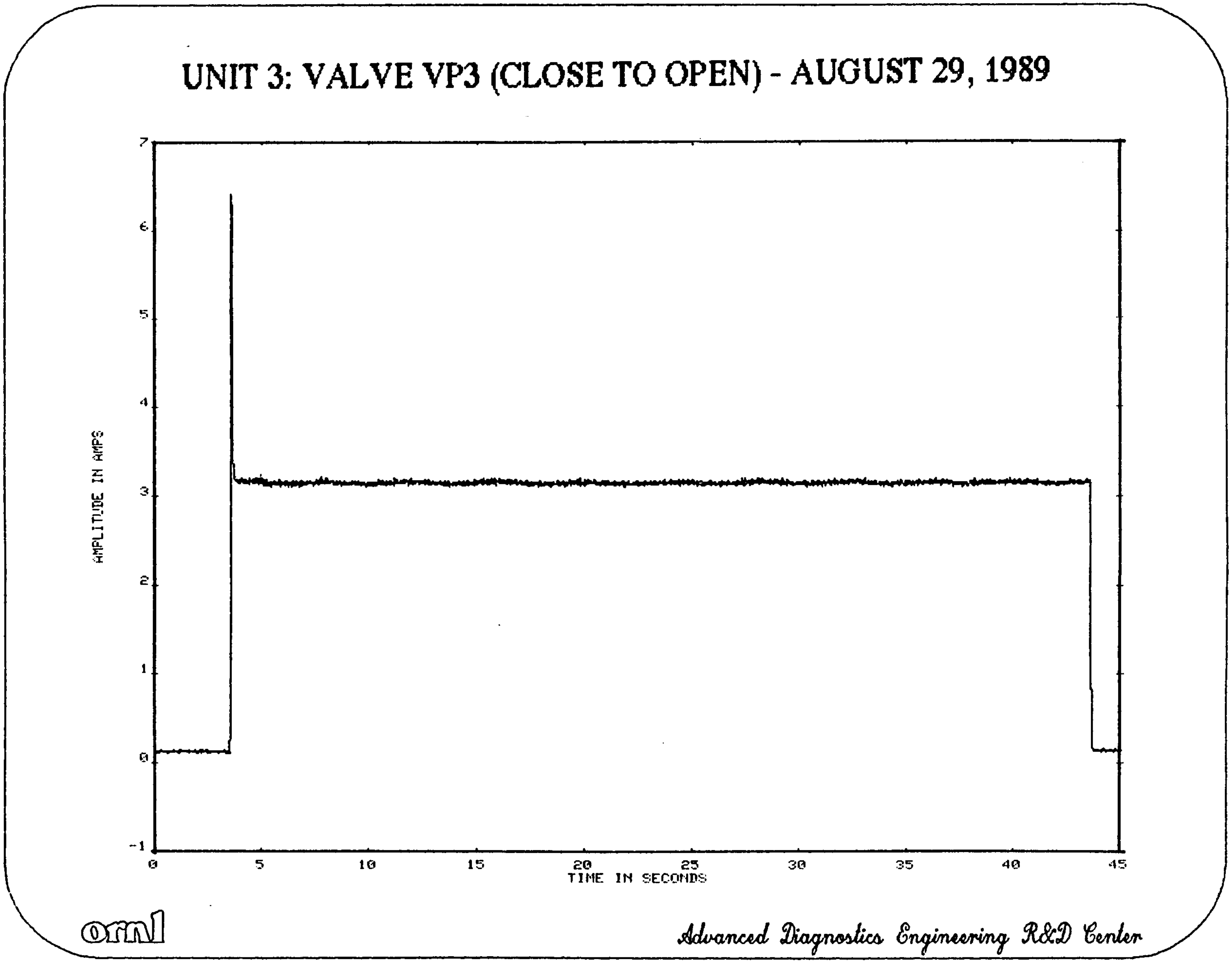

UNIT 3: VALVE VP2 (OPEN TO CLOSE) - AUGUST 29, 1989
7
6
5
4
3
2
1
0
-1
AMPLITUDE IN AMPS
0
5
10
15
20
25
30
35
40
45
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 64



UNIT 3: VALVE VP3 (CLOSE TO OPEN) - AUGUST 29, 1989
AMPLITUDE IN AMPS
7
6
5
4
3
2
1
0
-1
0
5
10
15
20
25
30
35
40
45
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 65

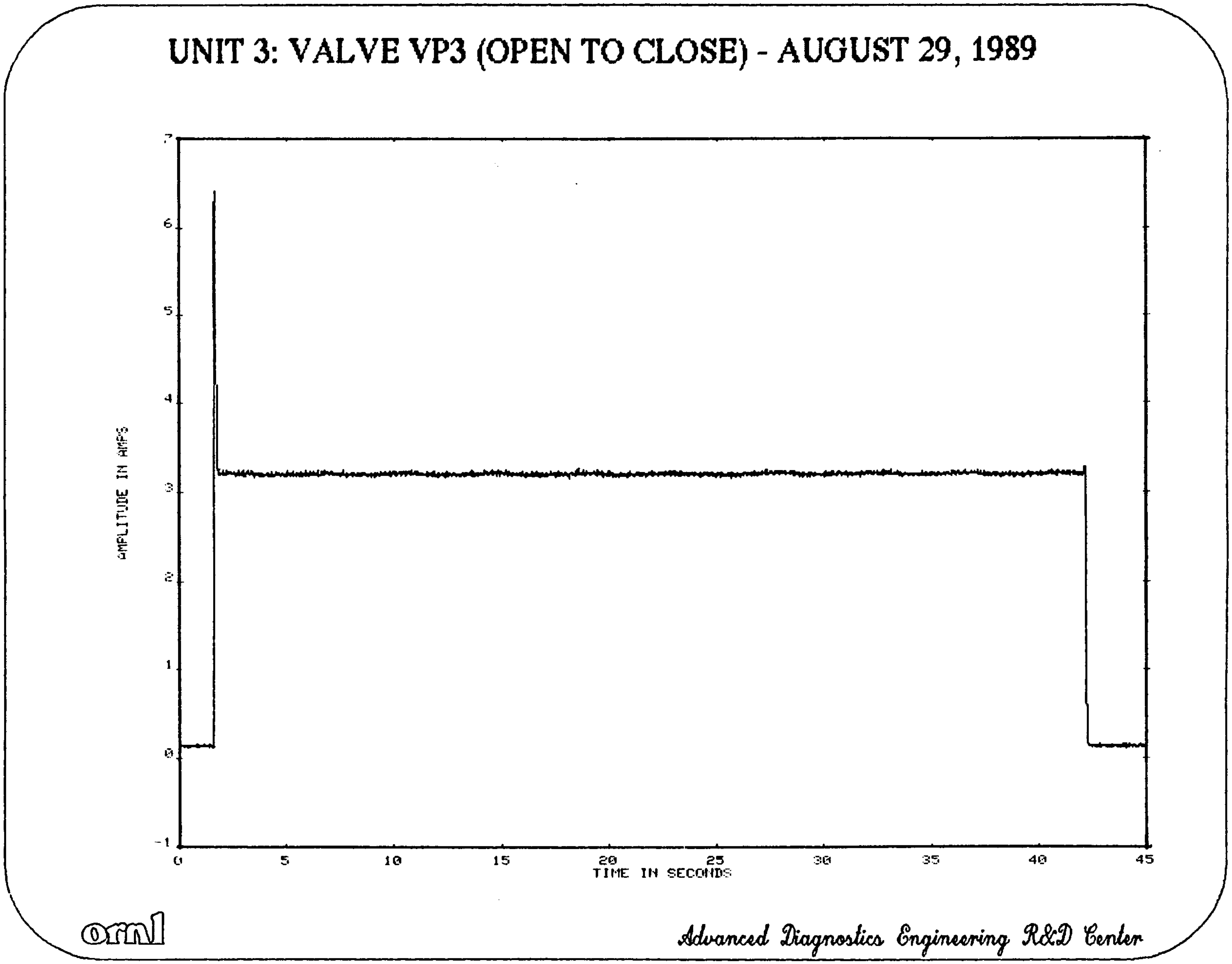
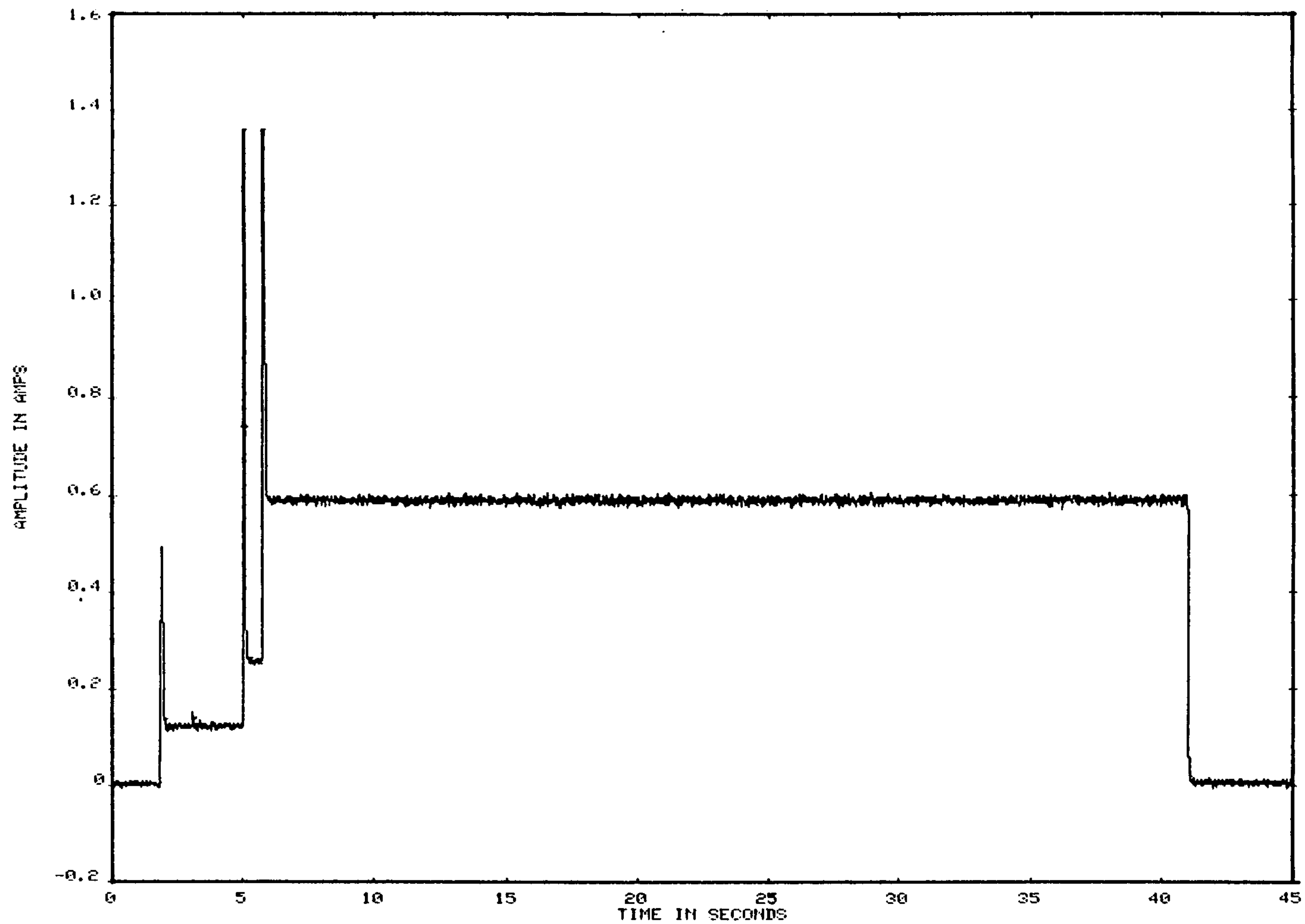

UNIT 3: VALVE VP3 (OPEN TO CLOSE) - AUGUST 29, 1989
AMPLITUDE IN AMPS
7
6
5
4
3
2
1
0
-1
0
5
10
15
20
25
30
35
40
45
TIME IN SECONDS
orml
Advanced Diagnostics Engineering R&D Center

FIGURE 66

UNIT 3: VALVE VP5 (CLOSE TO OPEN) - AUGUST 29, 1989



ornl

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FIGURE 67

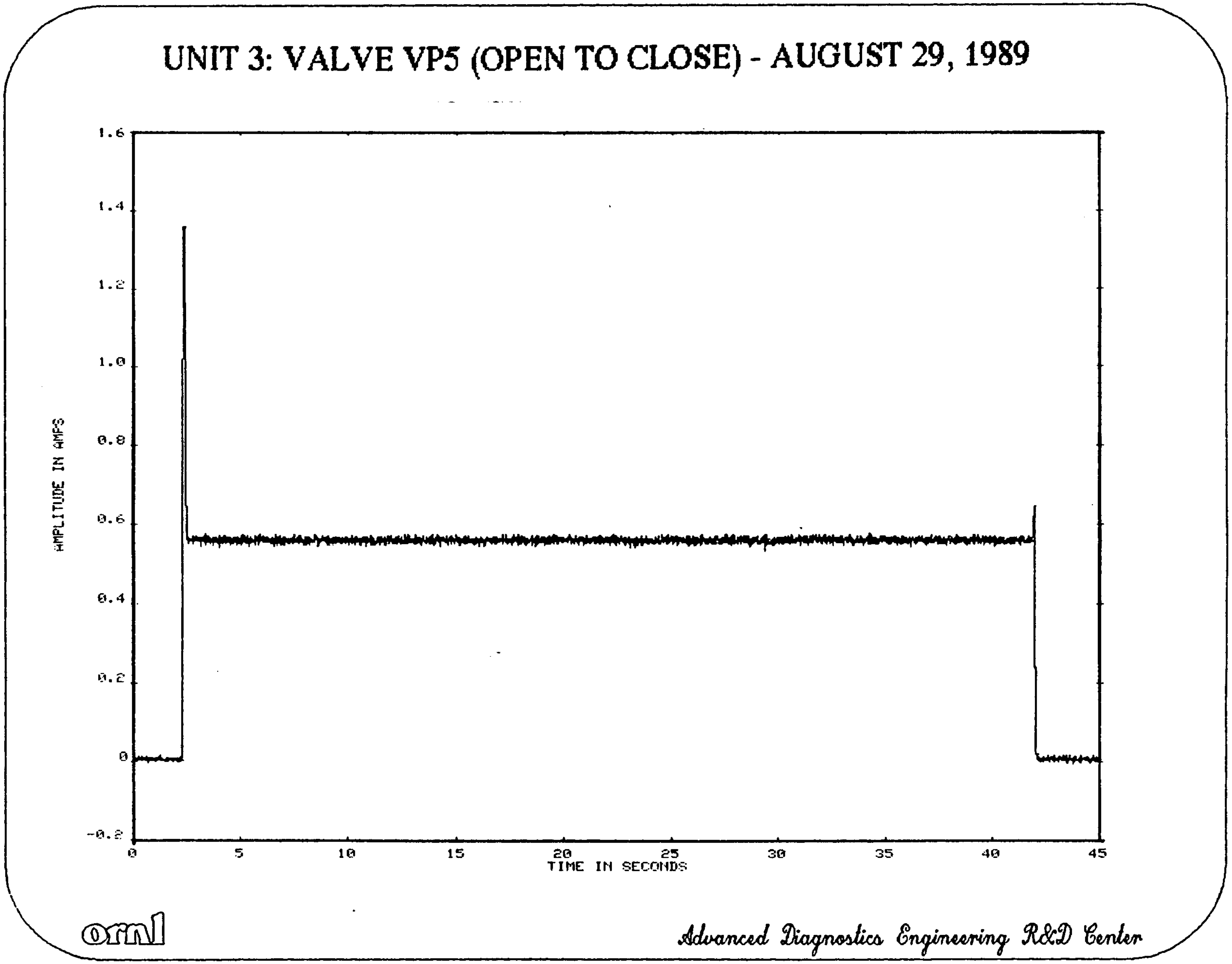

UNIT 3: VALVE VP5 (OPEN TO CLOSE) - AUGUST 29, 1989
AMPLITUDE IN AMPS
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
0
5
10
15
20
25
30
35
40
45
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 68

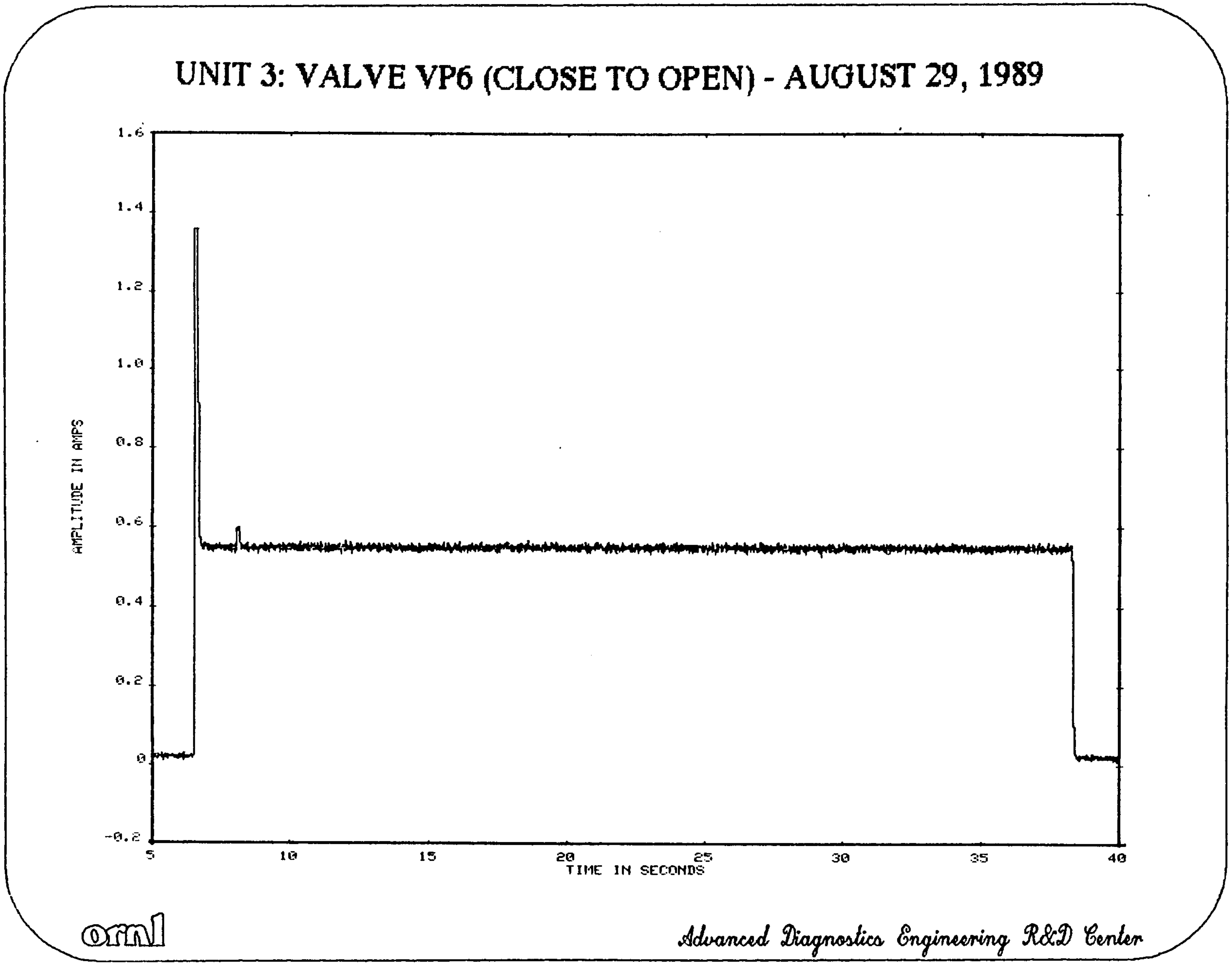

UNIT 3: VALVE VP6 (CLOSE TO OPEN) - AUGUST 29, 1989
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
AMPLITUDE IN AMPS
5
10
15
20
25
30
35
40
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 69

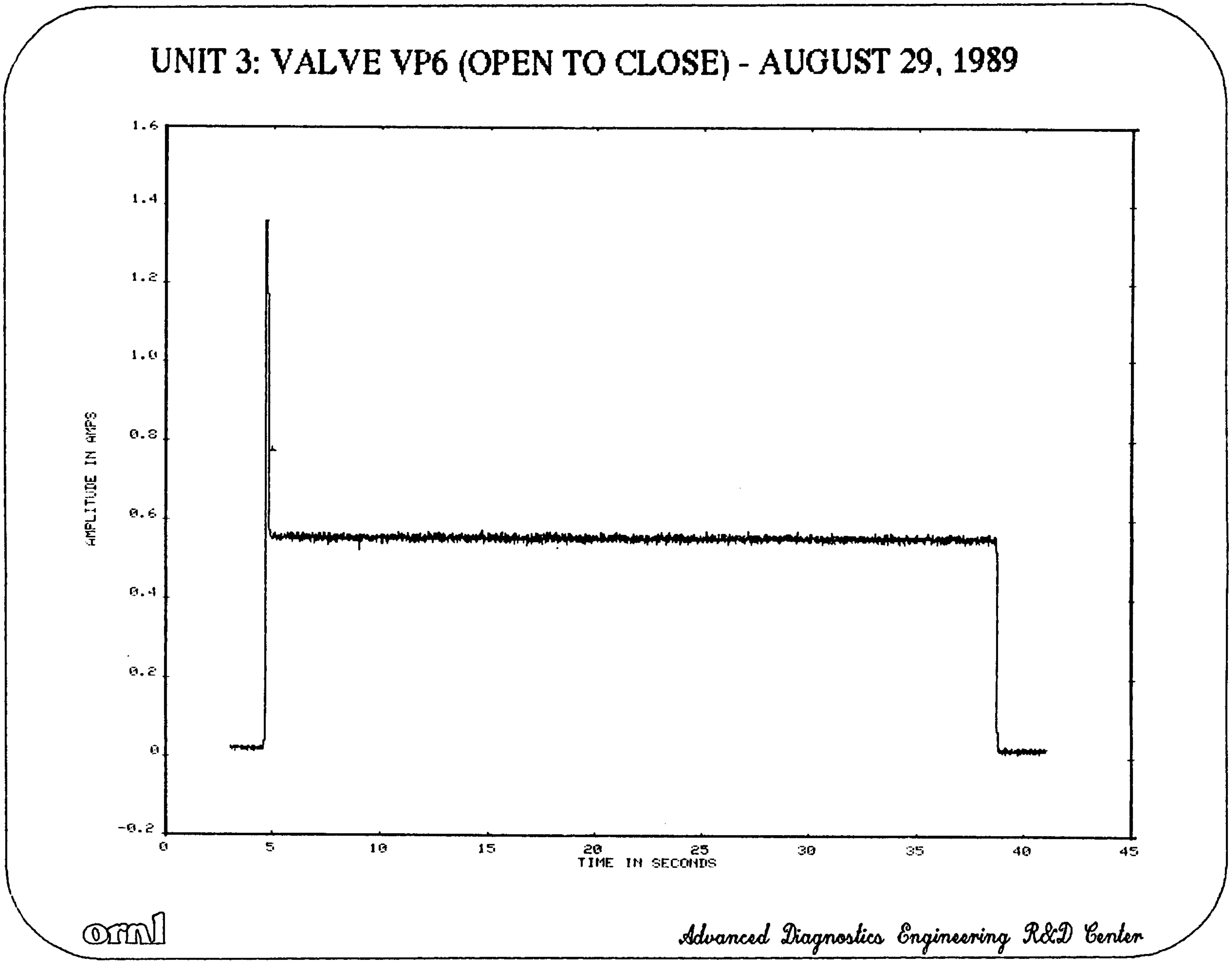
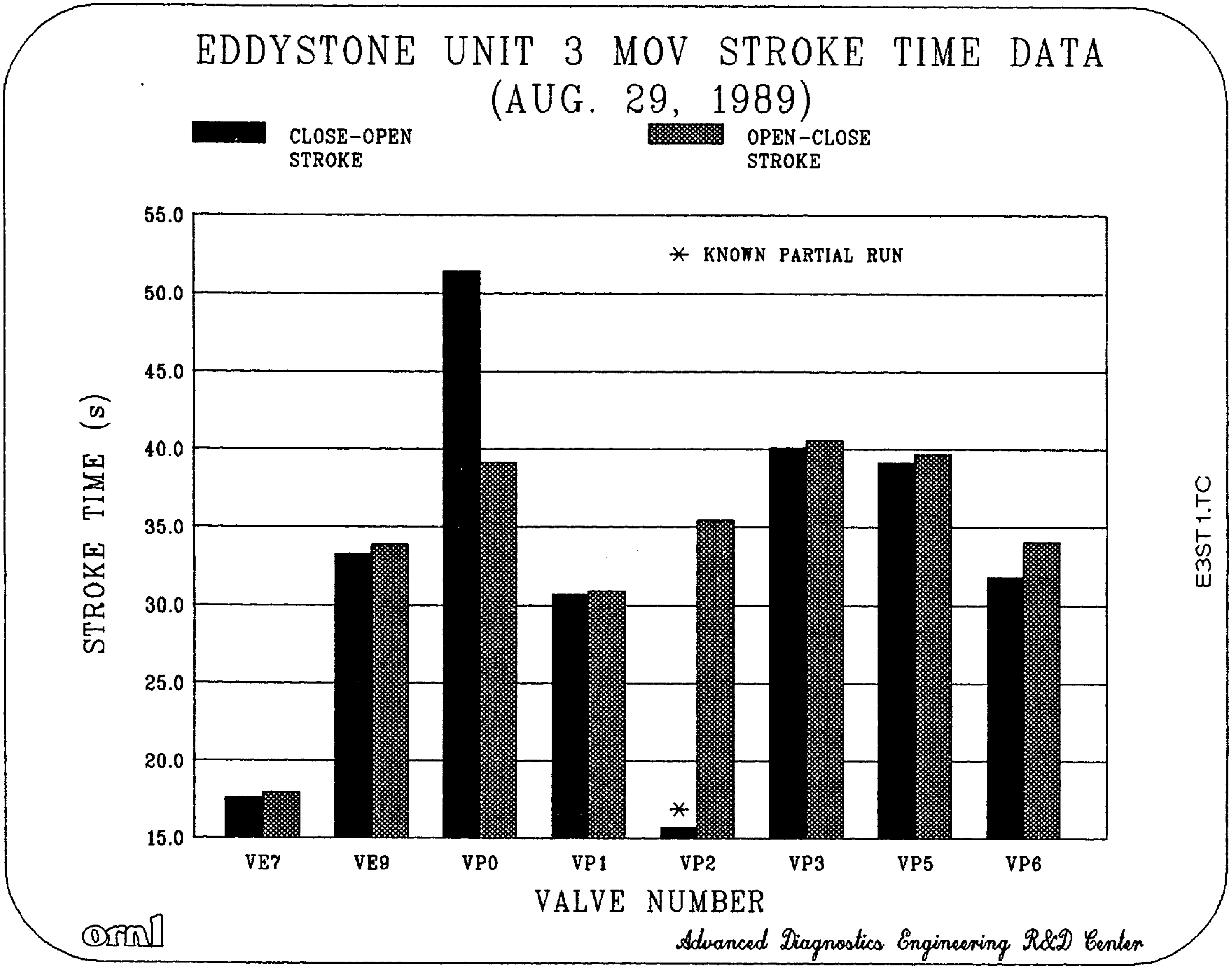

UNIT 3: VALVE VP6 (OPEN TO CLOSE) - AUGUST 29, 1989
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
AMPLITUDE IN AMPS
0
5
10
15
20
25
30
35
40
45
TIME IN SECONDS
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 70



EDDYSTONE UNIT 3 MOV STROKE TIME DATA
(AUG. 29, 1989)
CLOSE-OPEN STROKE
OPEN-CLOSE STROKE
* KNOWN PARTIAL RUN
STROKE TIME (s)
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
VE7
VE9
VP0
VP1
VP2
VP3
VP5
VP6
VALVE NUMBER
E3ST1.TC
Advanced Diagnostics Engineering R&D Center

FIGURE 71

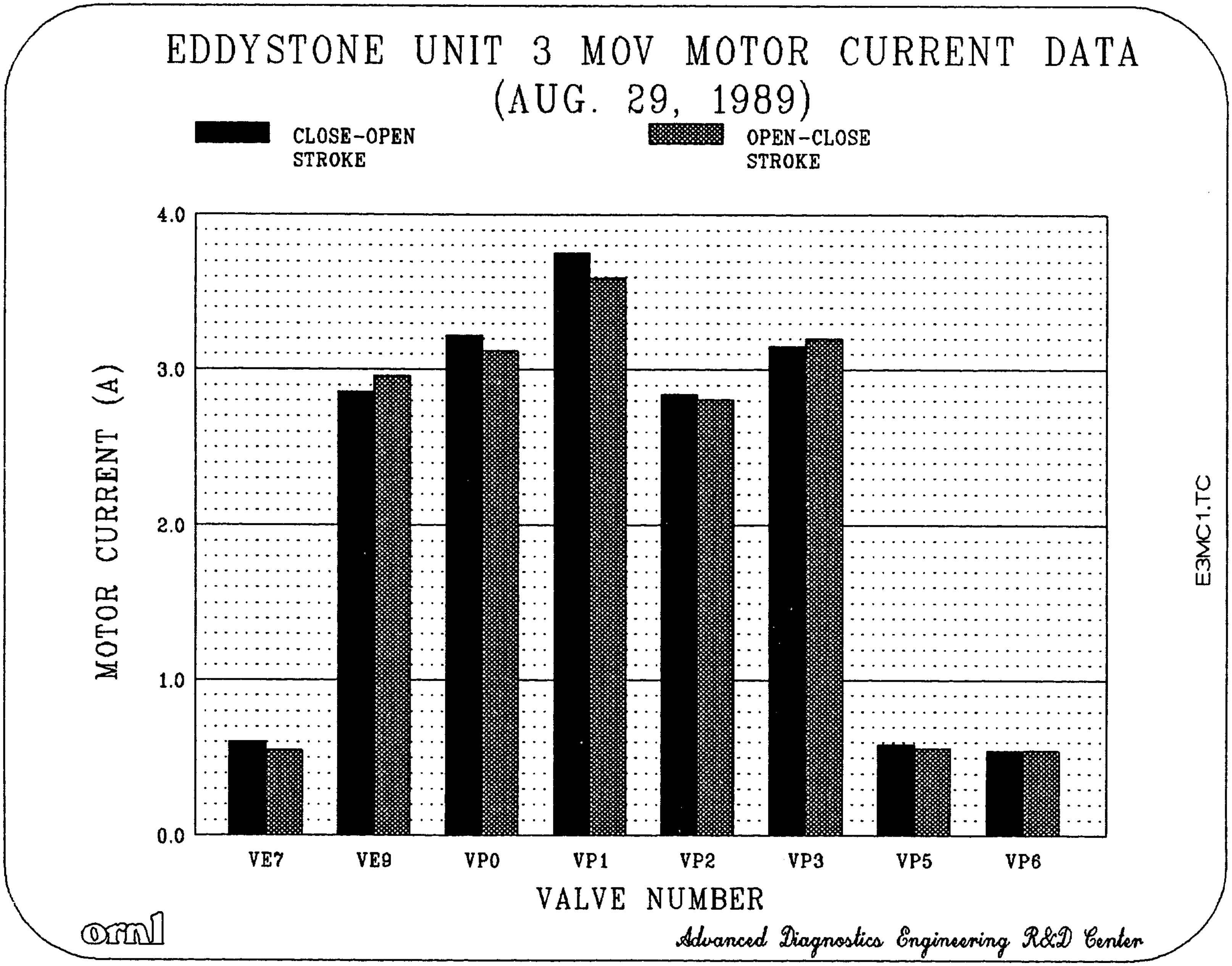

EDDYSTONE UNIT 3 MOV MOTOR CURRENT DATA
(AUG. 29, 1989)
CLOSE-OPEN STROKE
OPEN-CLOSE STROKE
MOTOR CURRENT (A)
4.0
3.0
2.0
1.0
0.0
VE7
VE9
VP0
VP1
VP2
VP3
VP5
VP6
VALVE NUMBER
ornl
Advanced Diagnostics Engineering R&D Center
E3MC1.TC

FIGURE 72

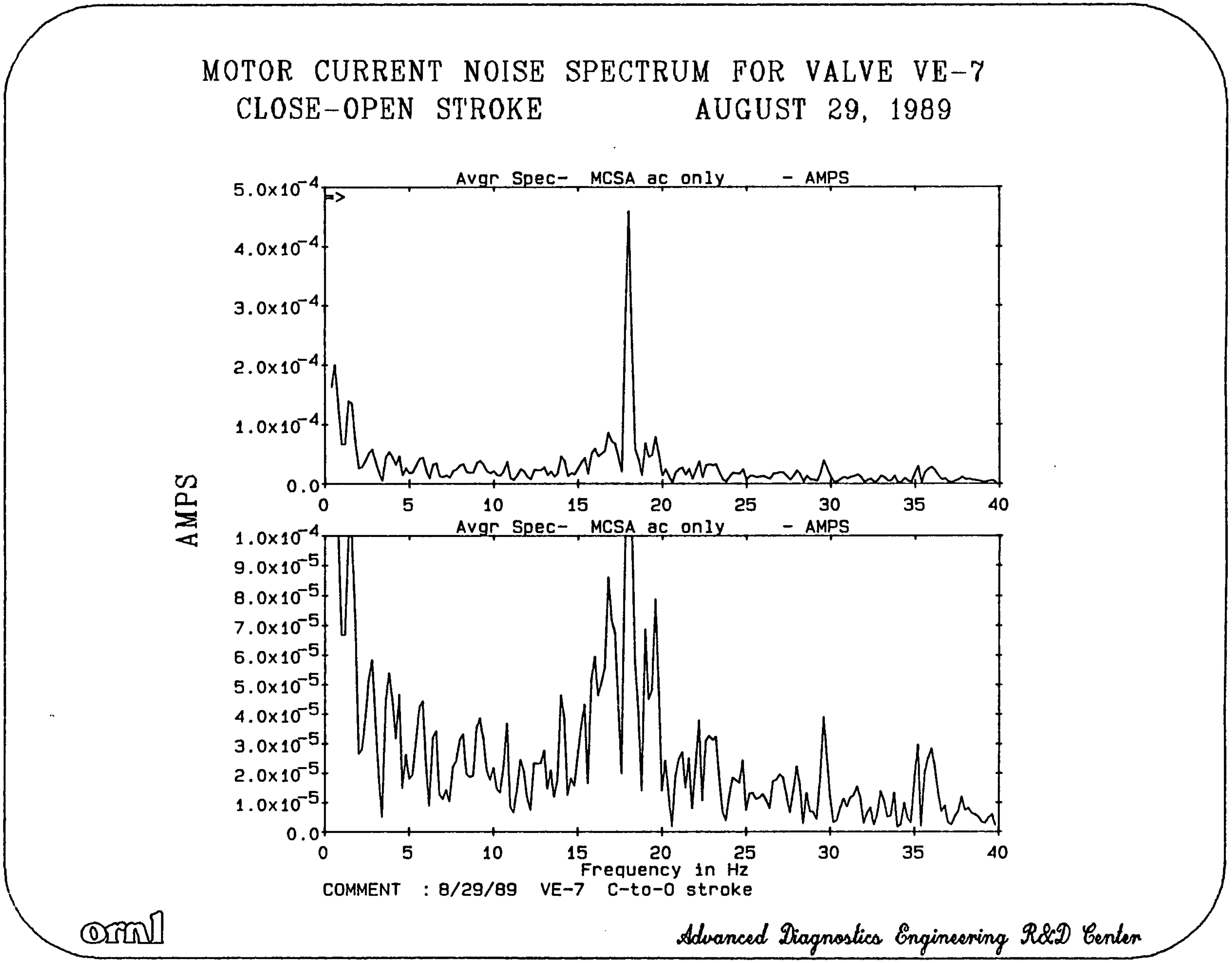
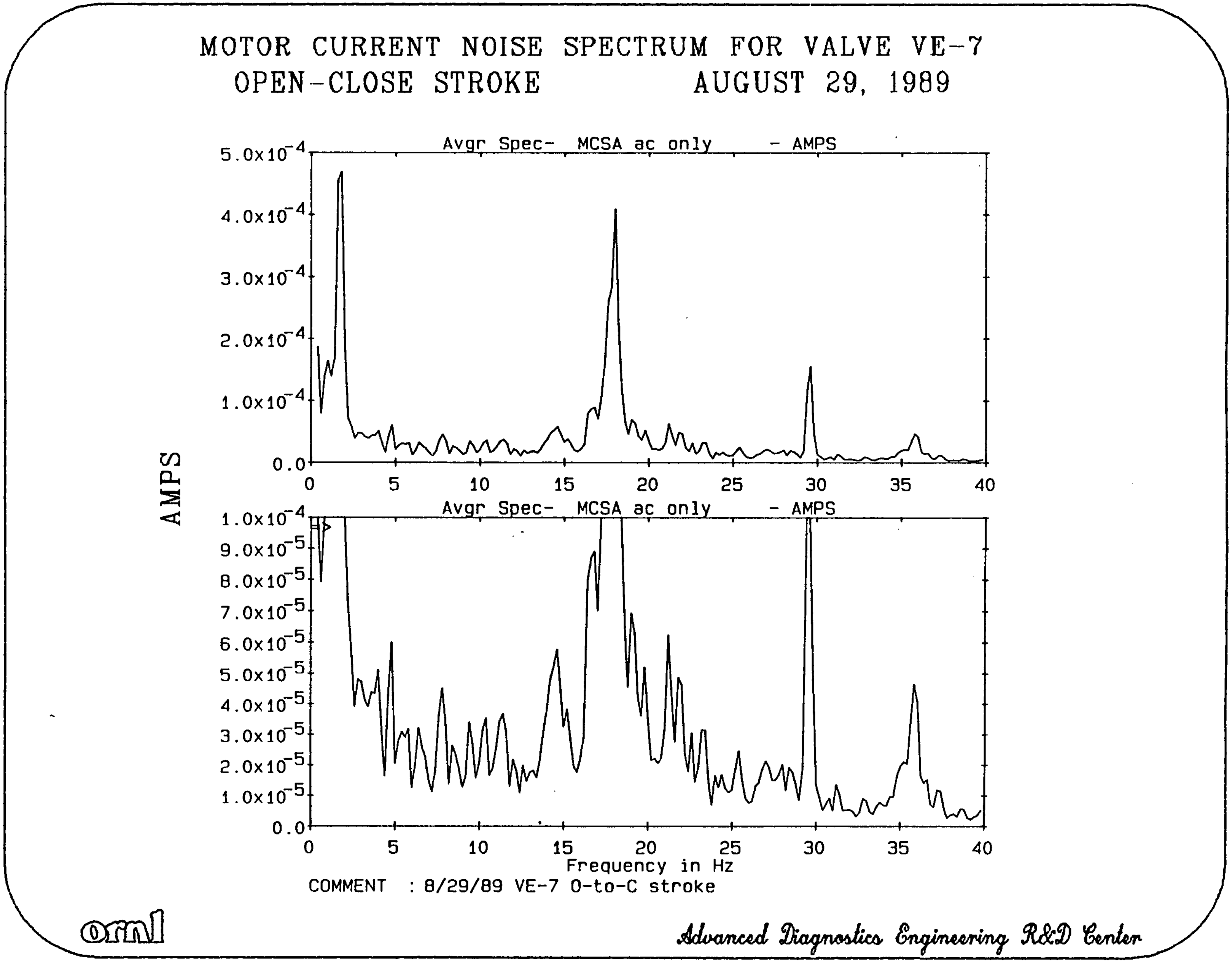

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VE-7
CLOSE-OPEN STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
AMPS
Frequency in Hz
COMMENT : 8/29/89 VE-7 C-to-O stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 73



MOTOR CURRENT NOISE SPECTRUM FOR VALVE VE-7
OPEN-CLOSE STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
5.0x10^-4
4.0x10^-4
3.0x10^-4
2.0x10^-4
1.0x10^-4
0.0
0 5 10 15 20 25 30 35 40
AMPS
Avgr Spec- MCSA ac only - AMPS
1.0x10^-4
9.0x10^-5
8.0x10^-5
7.0x10^-5
6.0x10^-5
5.0x10^-5
4.0x10^-5
3.0x10^-5
2.0x10^-5
1.0x10^-5
0.0
0 5 10 15 20 25 30 35 40
Frequency in Hz
COMMENT : 8/29/89 VE-7 O-to-C stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 74

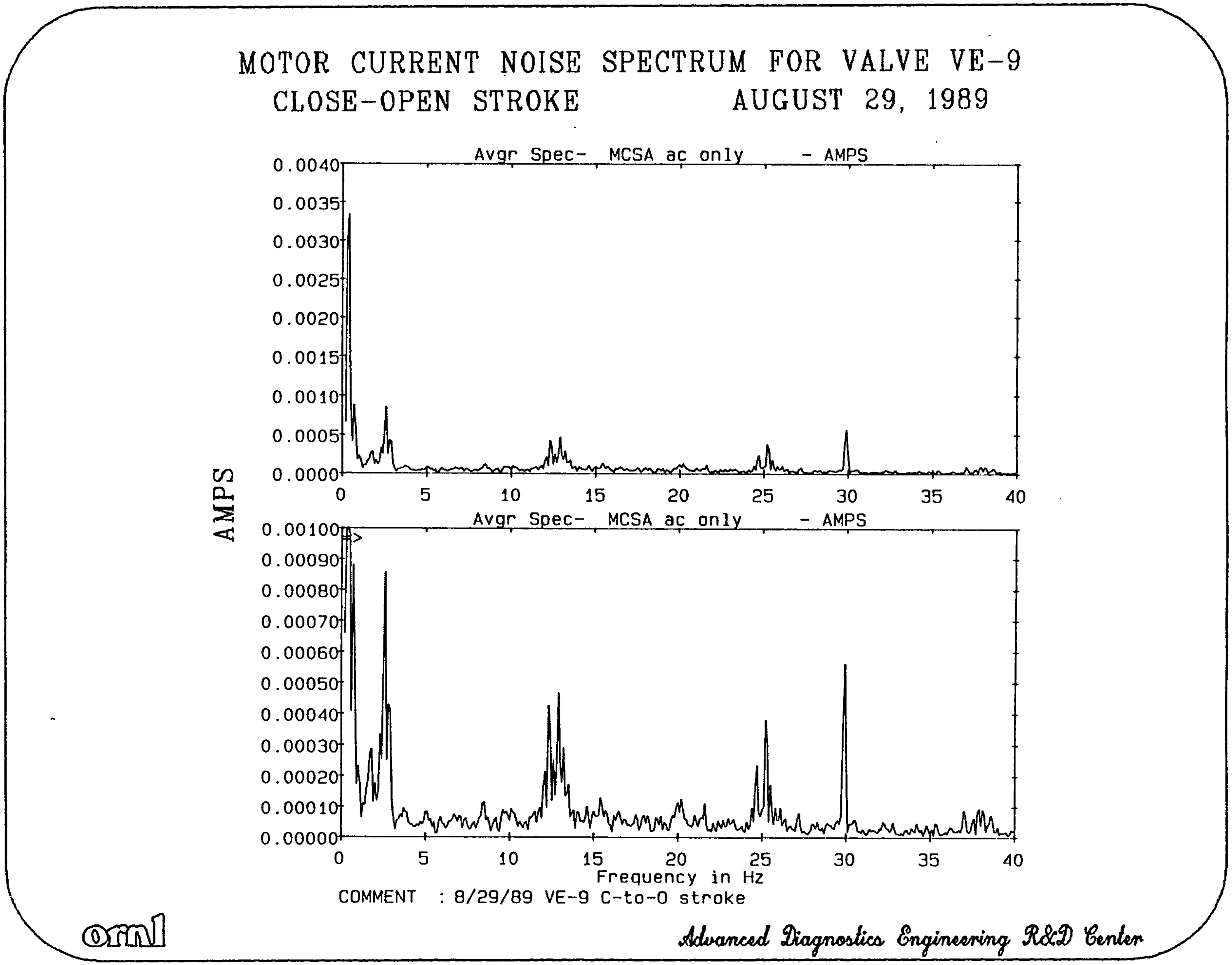

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VE-9
CLOSE-OPEN STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
AMPS
Frequency in Hz
COMMENT : 8/29/89 VE-9 C-to-O stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 75

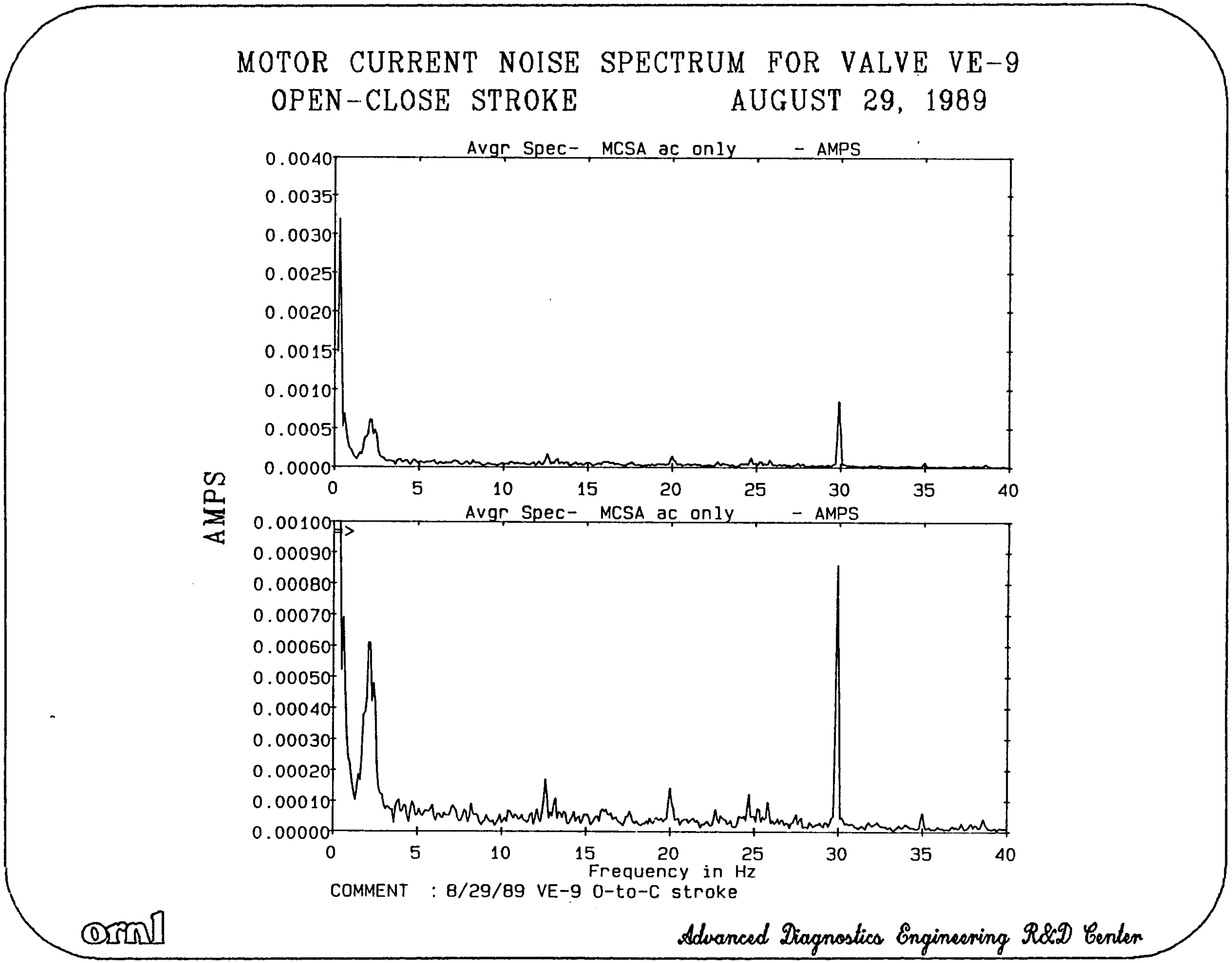

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VE-9
OPEN-CLOSE STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
AMPS
Frequency in Hz
COMMENT : 8/29/89 VE-9 O-to-C stroke
Advanced Diagnostics Engineering R&D Center

FIGURE 76

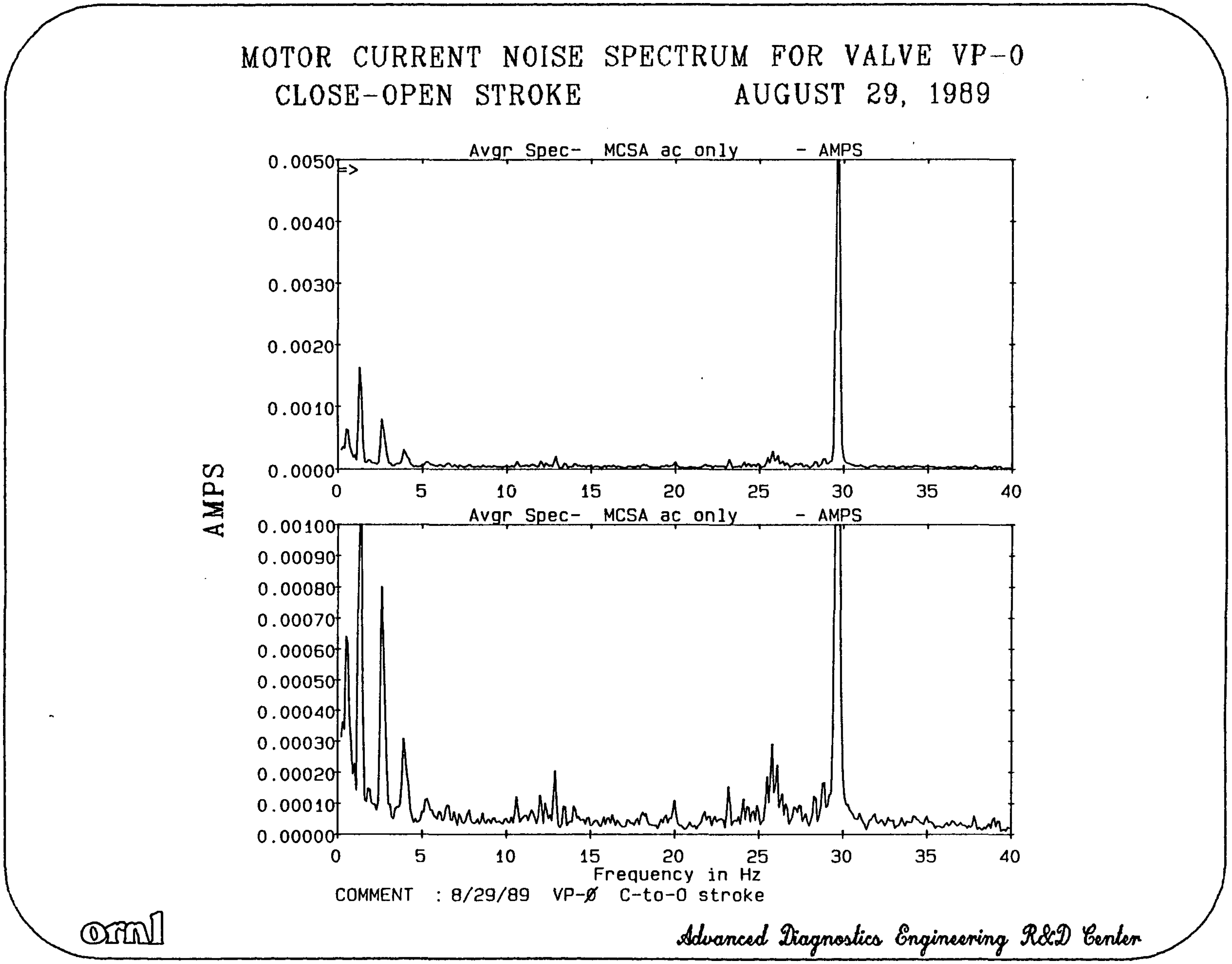

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-0
CLOSE-OPEN STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
0
5
10
15
20
25
30
35
40
Avgr Spec- MCSA ac only - AMPS
AMPS
0.00100
0.00090
0.00080
0.00070
0.00060
0.00050
0.00040
0.00030
0.00020
0.00010
0.00000
Frequency in Hz
COMMENT : 8/29/89 VP-Ø C-to-O stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 77

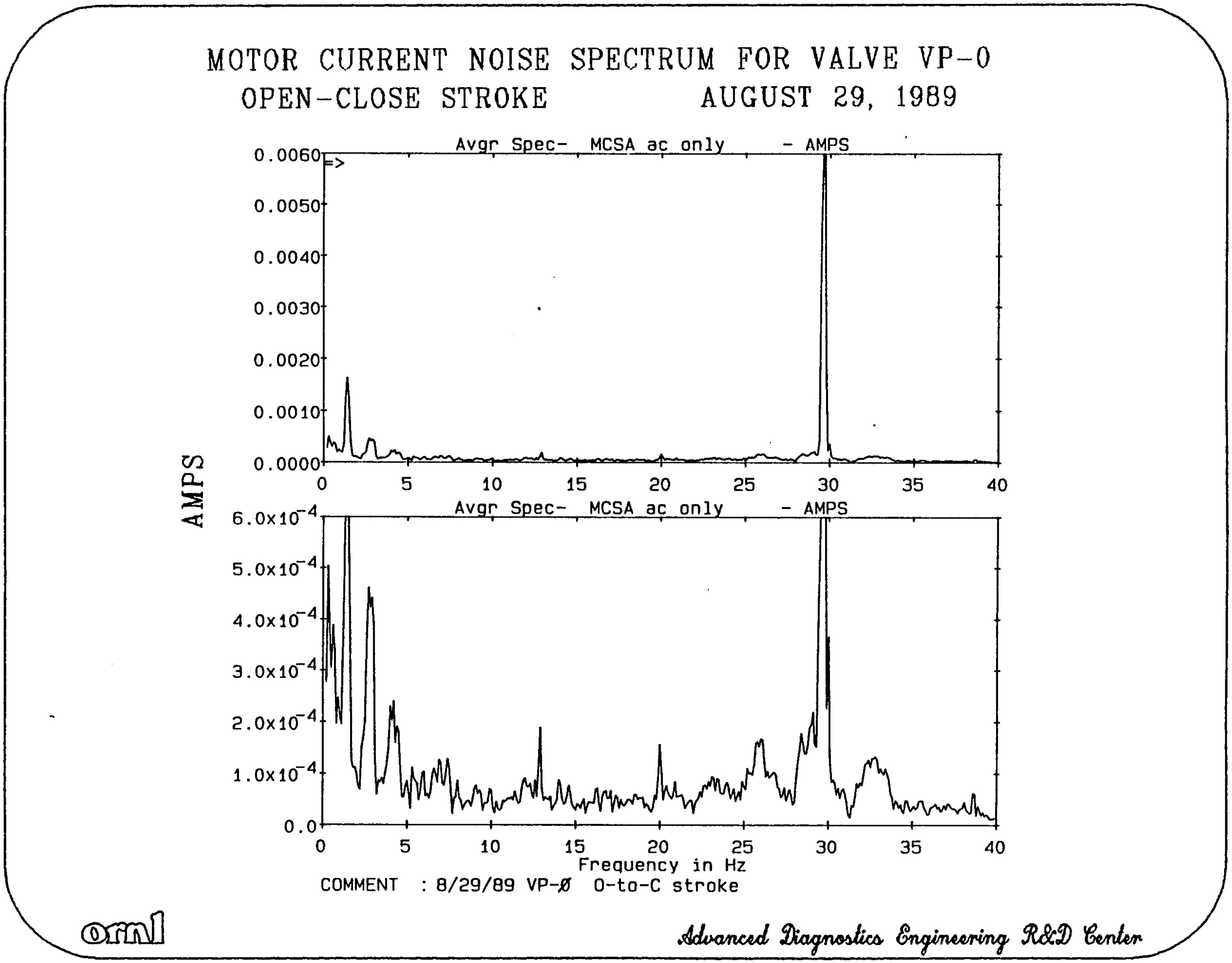

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-0
OPEN-CLOSE STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
0
5
10
15
20
25
30
35
40
AMPS
Avgr Spec- MCSA ac only - AMPS
6.0x10^-4
5.0x10^-4
4.0x10^-4
3.0x10^-4
2.0x10^-4
1.0x10^-4
0.0
Frequency in Hz
COMMENT : 8/29/89 VP-Ø O-to-C stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 78

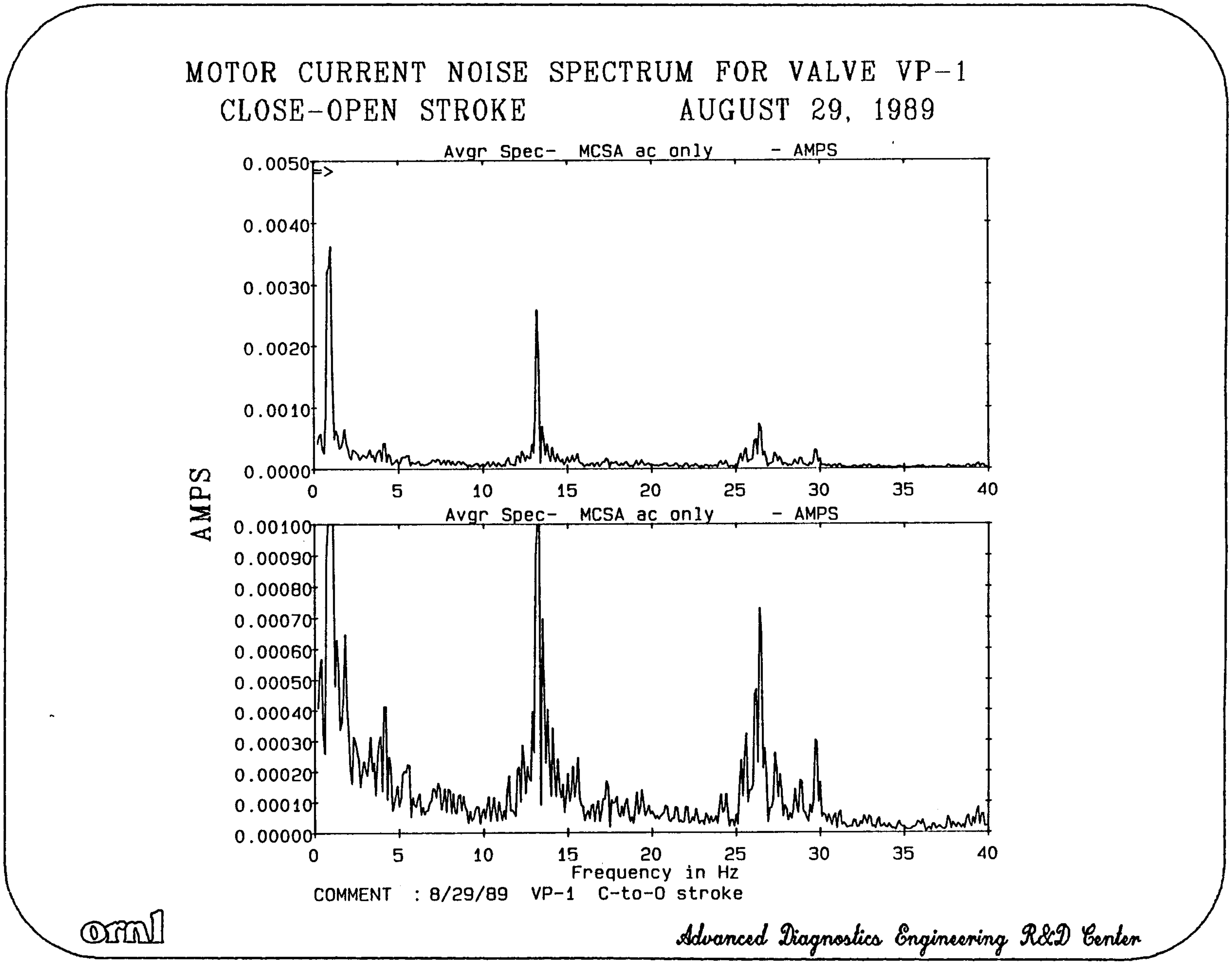

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-1
CLOSE-OPEN STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
0 5 10 15 20 25 30 35 40
AMPS
Avgr Spec- MCSA ac only - AMPS
0.00100
0.00090
0.00080
0.00070
0.00060
0.00050
0.00040
0.00030
0.00020
0.00010
0.00000
0 5 10 15 20 25 30 35 40
Frequency in Hz
COMMENT : 8/29/89 VP-1 C-to-O stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 79

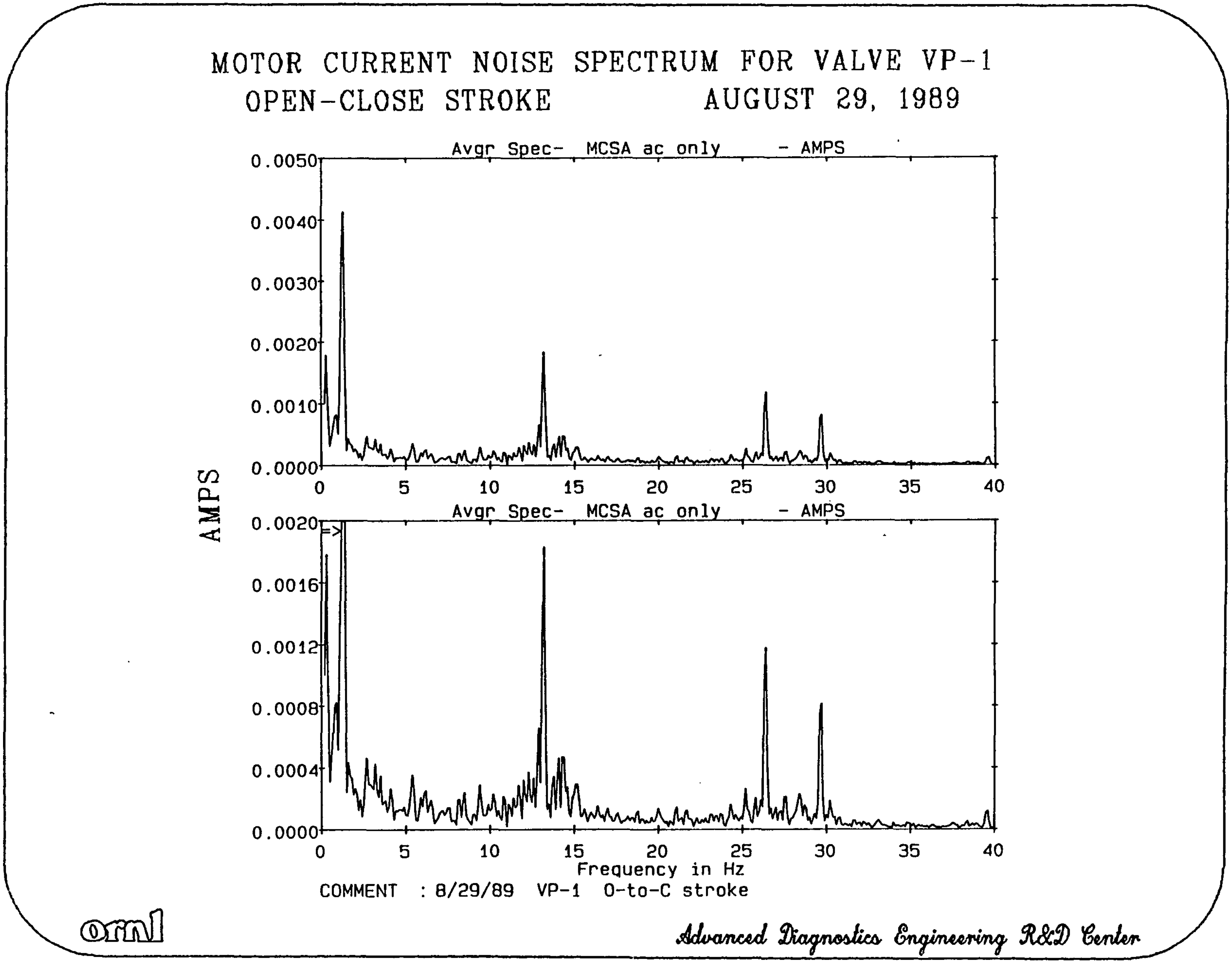

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-1
OPEN-CLOSE STROKE
AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
0
5
10
15
20
25
30
35
40
AMPS
Avgr Spec- MCSA ac only - AMPS
0.0020
0.0016
0.0012
0.0008
0.0004
0.0000
Frequency in Hz
COMMENT : 8/29/89 VP-1 O-to-C stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 80

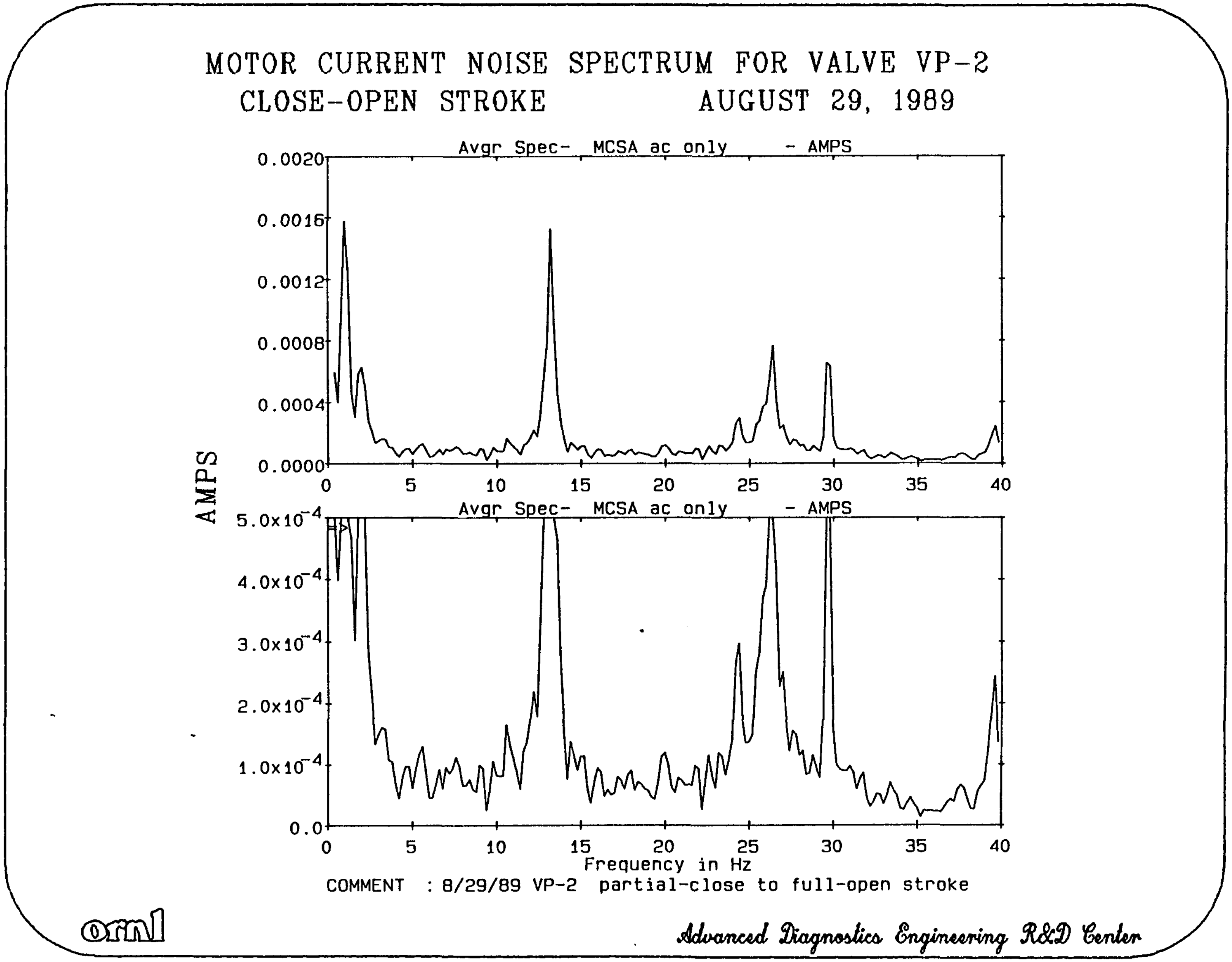
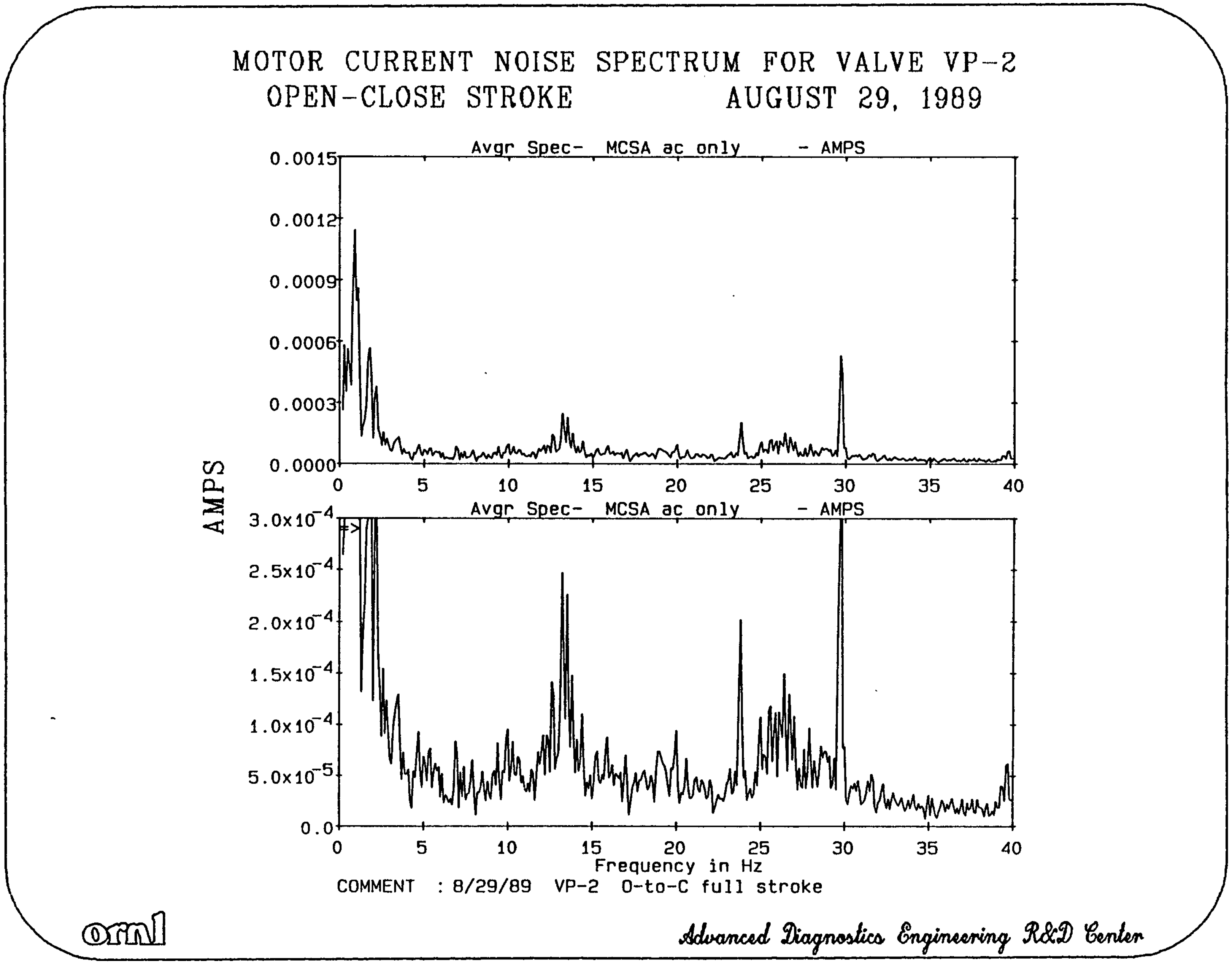
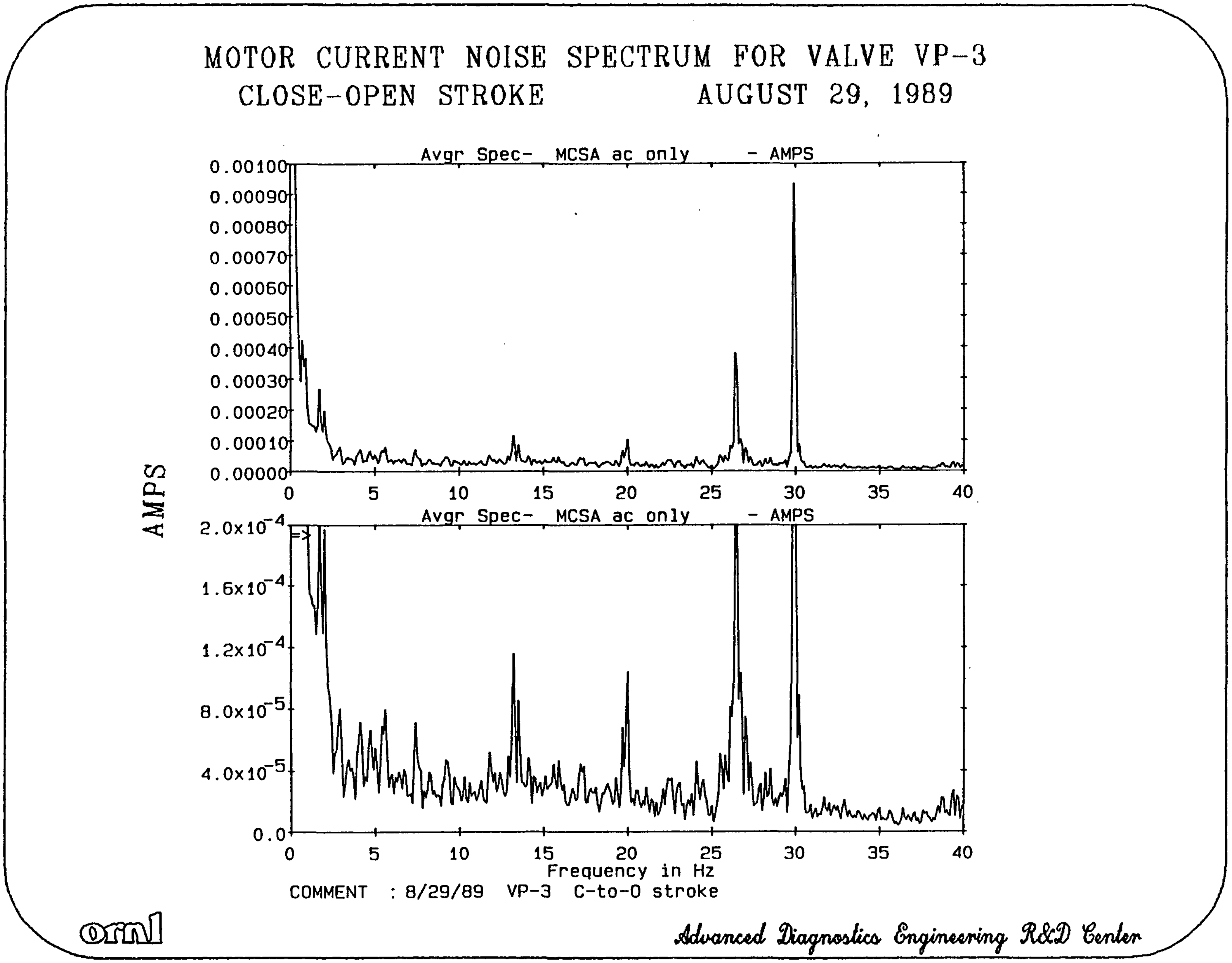

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-2
CLOSE-OPEN STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
AMPS
0.0020
0.0016
0.0012
0.0008
0.0004
0.0000
0 5 10 15 20 25 30 35 40
Avgr Spec- MCSA ac only - AMPS
5.0x10^-4
4.0x10^-4
3.0x10^-4
2.0x10^-4
1.0x10^-4
0.0
0 5 10 15 20 25 30 35 40
Frequency in Hz
COMMENT : 8/29/89 VP-2 partial-close to full-open stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 81



MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-2
OPEN-CLOSE STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
AMPS
0.0015
0.0012
0.0009
0.0006
0.0003
0.0000
0 5 10 15 20 25 30 35 40
Avgr Spec- MCSA ac only - AMPS
3.0x10-4
2.5x10-4
2.0x10-4
1.5x10-4
1.0x10-4
5.0x10-5
0.0
0 5 10 15 20 25 30 35 40
Frequency in Hz
COMMENT : 8/29/89 VP-2 O-to-C full stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 82



MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-3
CLOSE-OPEN STROKE
AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
AMPS
Frequency in Hz
COMMENT : 8/29/89 VP-3 C-to-O stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 83

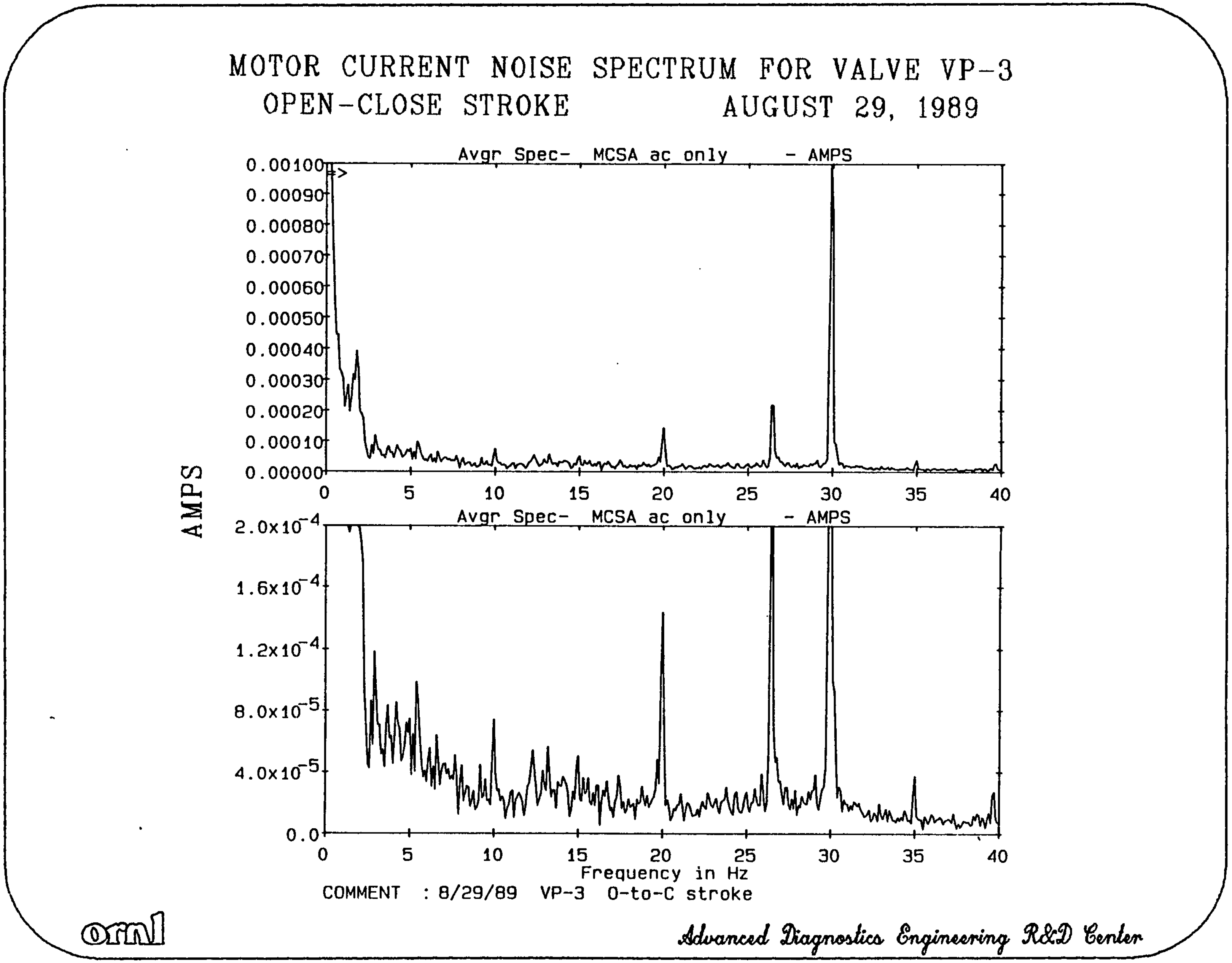

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-3
OPEN-CLOSE STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
0.00100
0.00090
0.00080
0.00070
0.00060
0.00050
0.00040
0.00030
0.00020
0.00010
0.00000
0 5 10 15 20 25 30 35 40
AMPS
Avgr Spec- MCSA ac only - AMPS
2.0x10^-4
1.6x10^-4
1.2x10^-4
8.0x10^-5
4.0x10^-5
0.0
0 5 10 15 20 25 30 35 40
Frequency in Hz
COMMENT : 8/29/89 VP-3 O-to-C stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 84

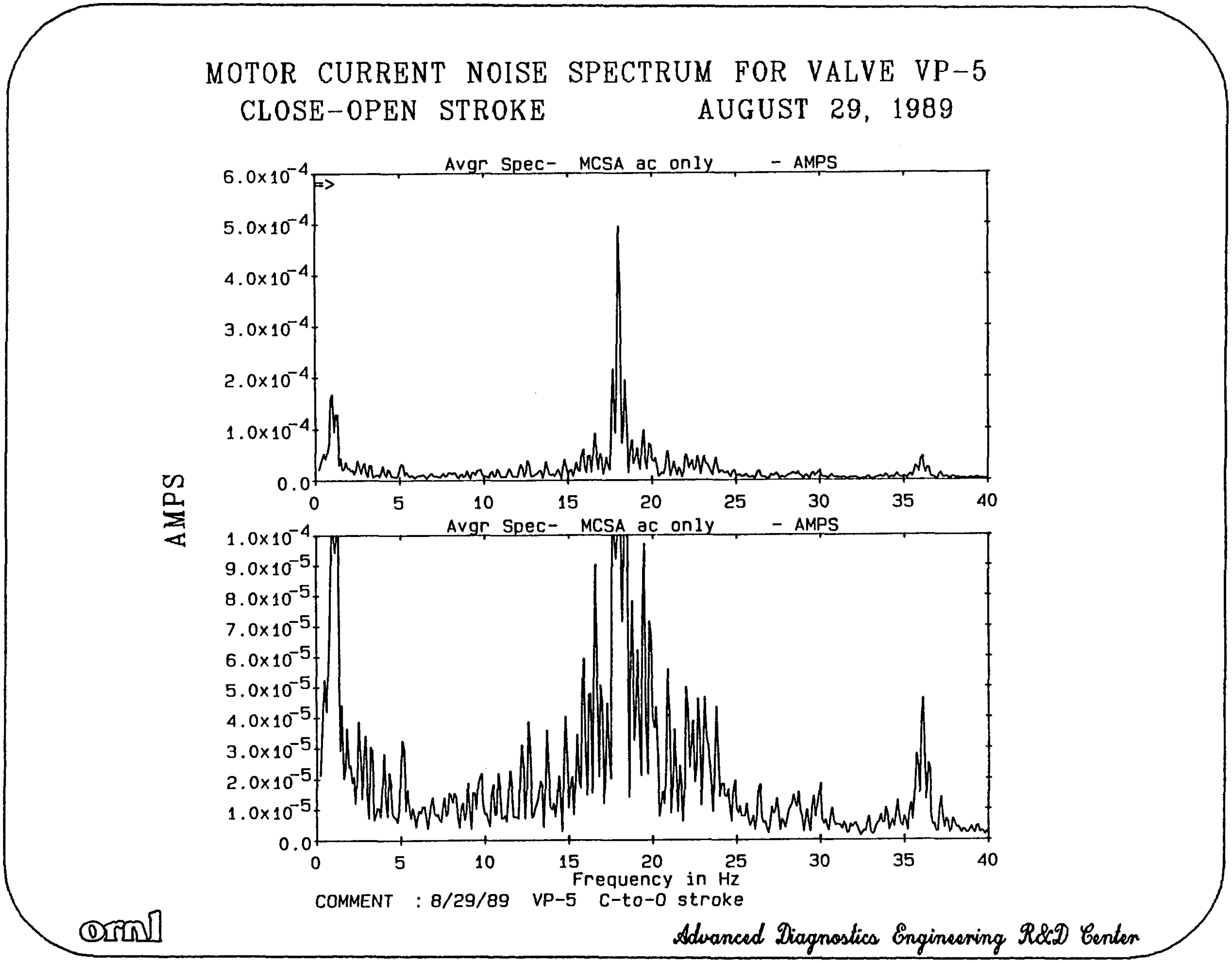

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-5
CLOSE-OPEN STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
AMPS
Frequency in Hz
COMMENT : 8/29/89 VP-5 C-to-O stroke
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 85

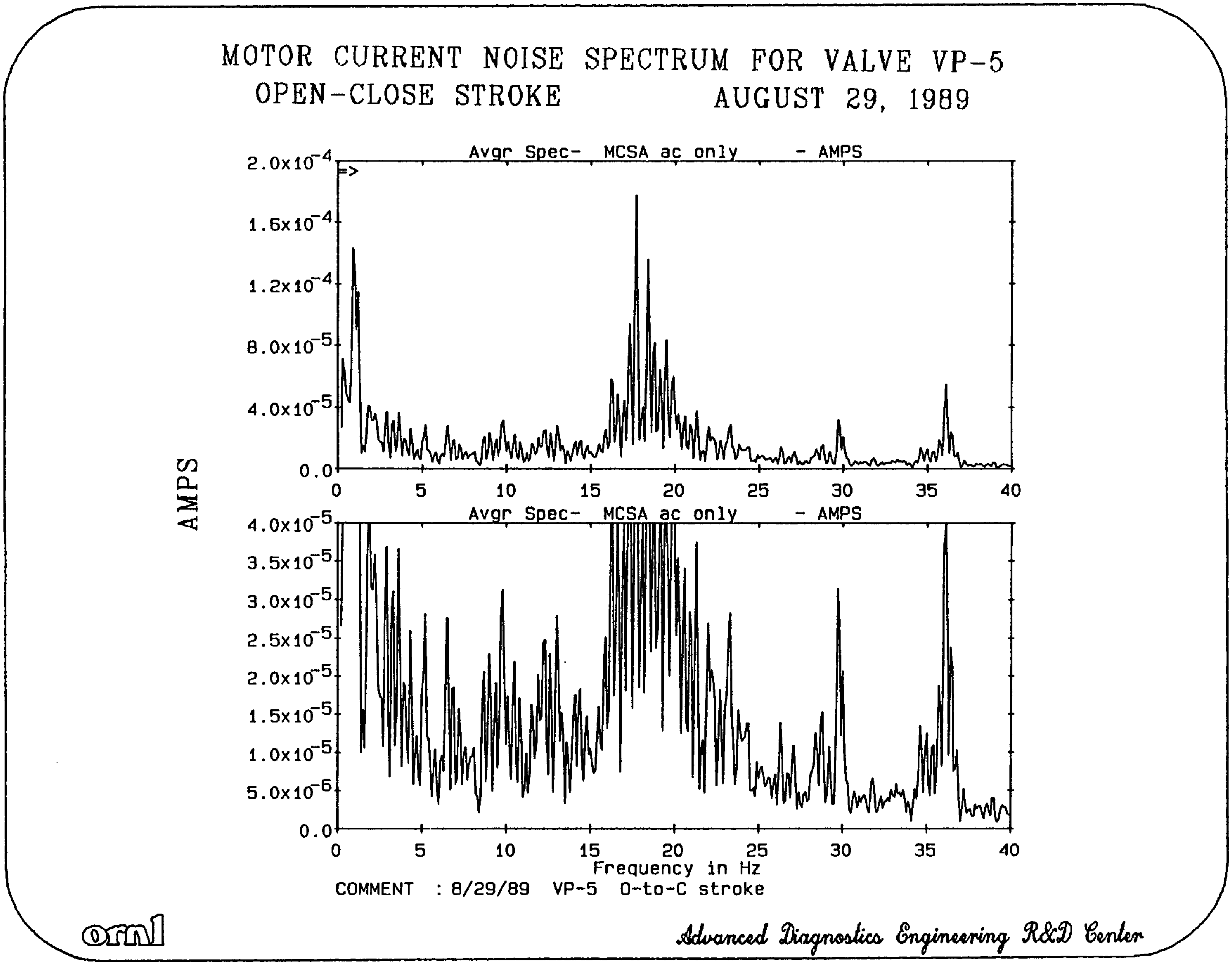

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-5
OPEN-CLOSE STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
AMPS
Frequency in Hz
COMMENT : 8/29/89 VP-5 O-to-C stroke
Advanced Diagnostics Engineering R&D Center

FIGURE 86

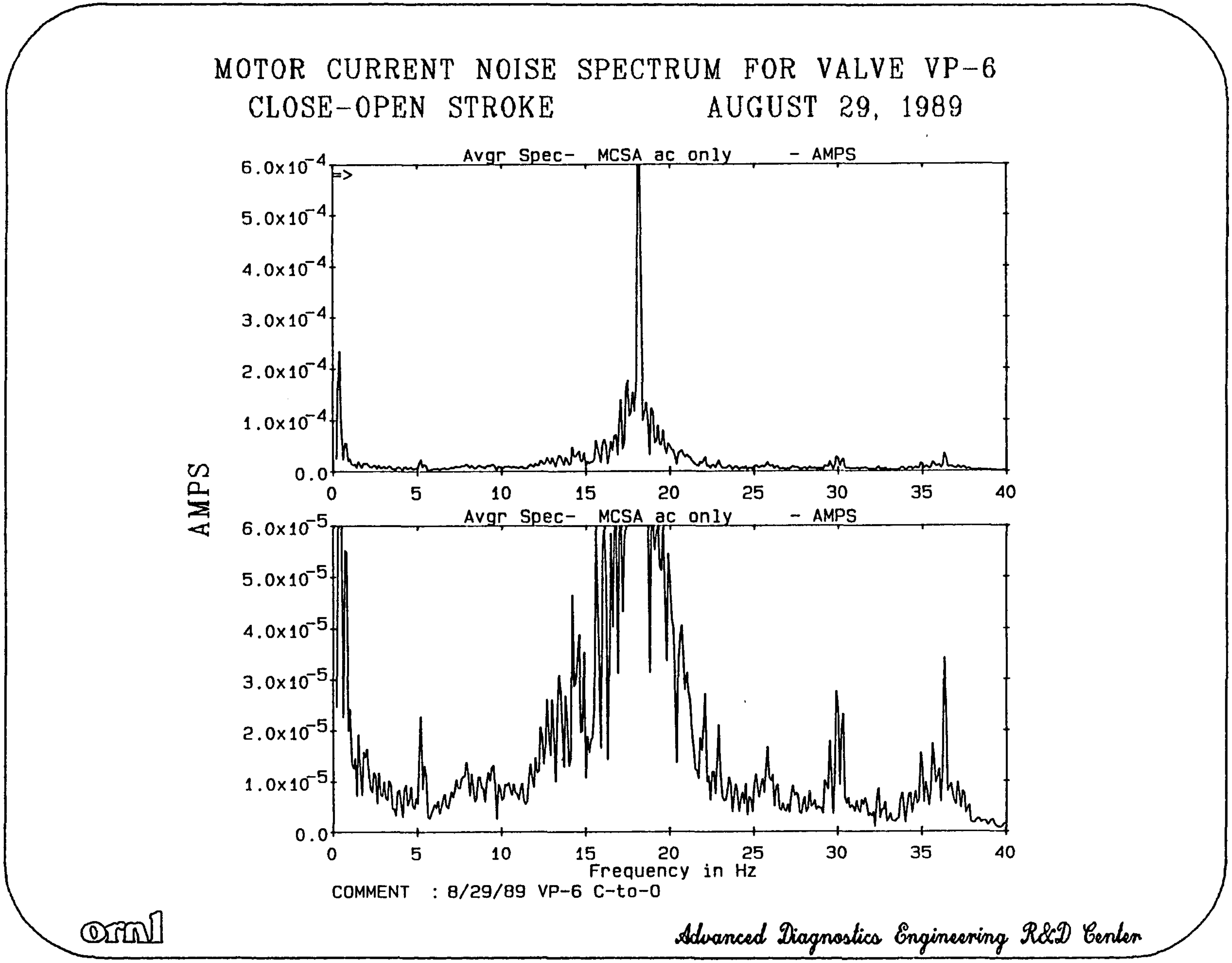

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-6
CLOSE-OPEN STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
6.0x10^-4
5.0x10^-4
4.0x10^-4
3.0x10^-4
2.0x10^-4
1.0x10^-4
0.0
AMPS
0 5 10 15 20 25 30 35 40
Avgr Spec- MCSA ac only - AMPS
6.0x10^-5
5.0x10^-5
4.0x10^-5
3.0x10^-5
2.0x10^-5
1.0x10^-5
0.0
0 5 10 15 20 25 30 35 40
Frequency in Hz
COMMENT : 8/29/89 VP-6 C-to-O
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 87

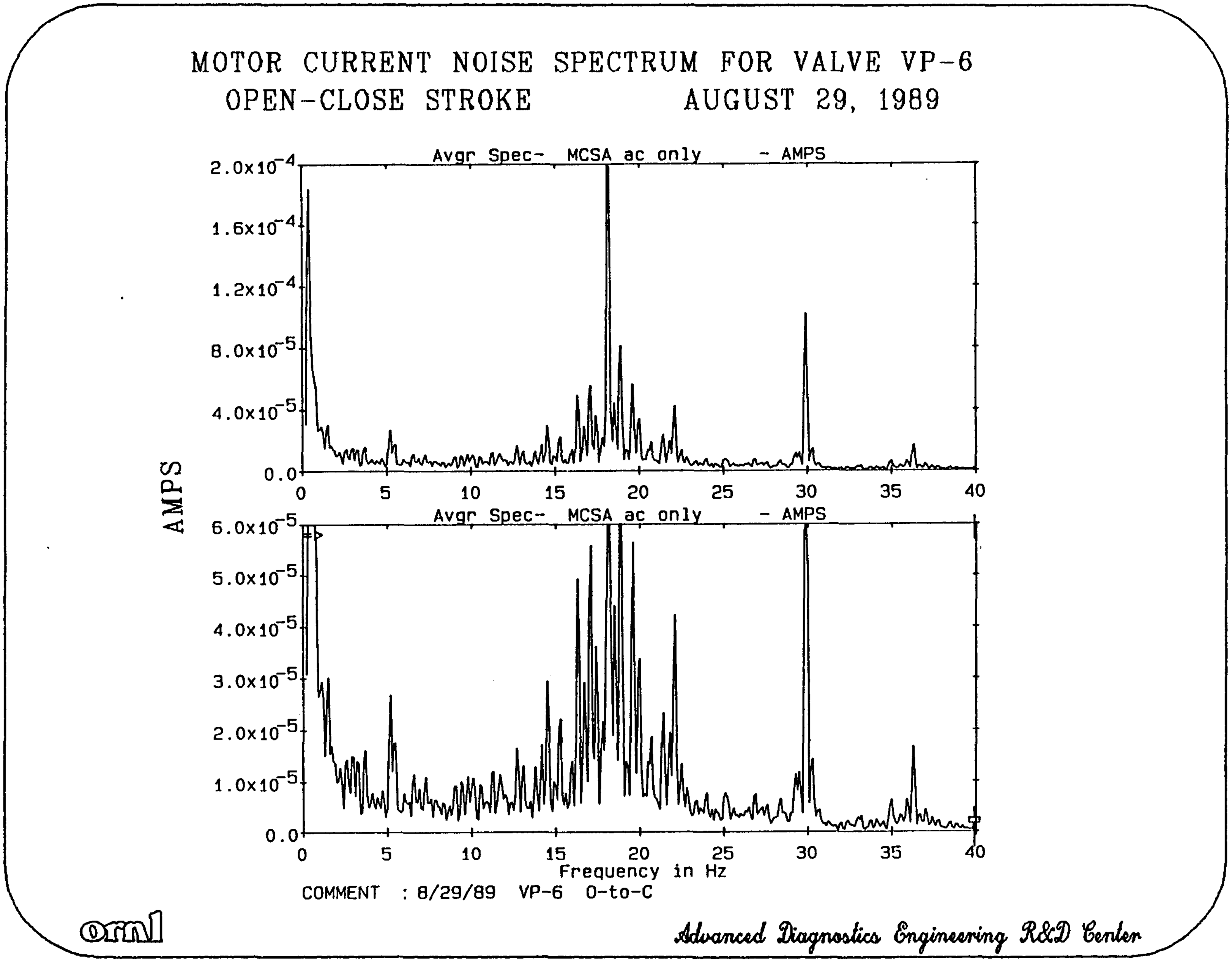

MOTOR CURRENT NOISE SPECTRUM FOR VALVE VP-6
OPEN-CLOSE STROKE AUGUST 29, 1989
Avgr Spec- MCSA ac only - AMPS
2.0x10^-4
1.6x10^-4
1.2x10^-4
8.0x10^-5
4.0x10^-5
0.0
0 5 10 15 20 25 30 35 40
AMPS
Avgr Spec- MCSA ac only - AMPS
6.0x10^-5
5.0x10^-5
4.0x10^-5
3.0x10^-5
2.0x10^-5
1.0x10^-5
0.0
0 5 10 15 20 25 30 35 40
Frequency in Hz
COMMENT : 8/29/89 VP-6 O-to-C
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 88

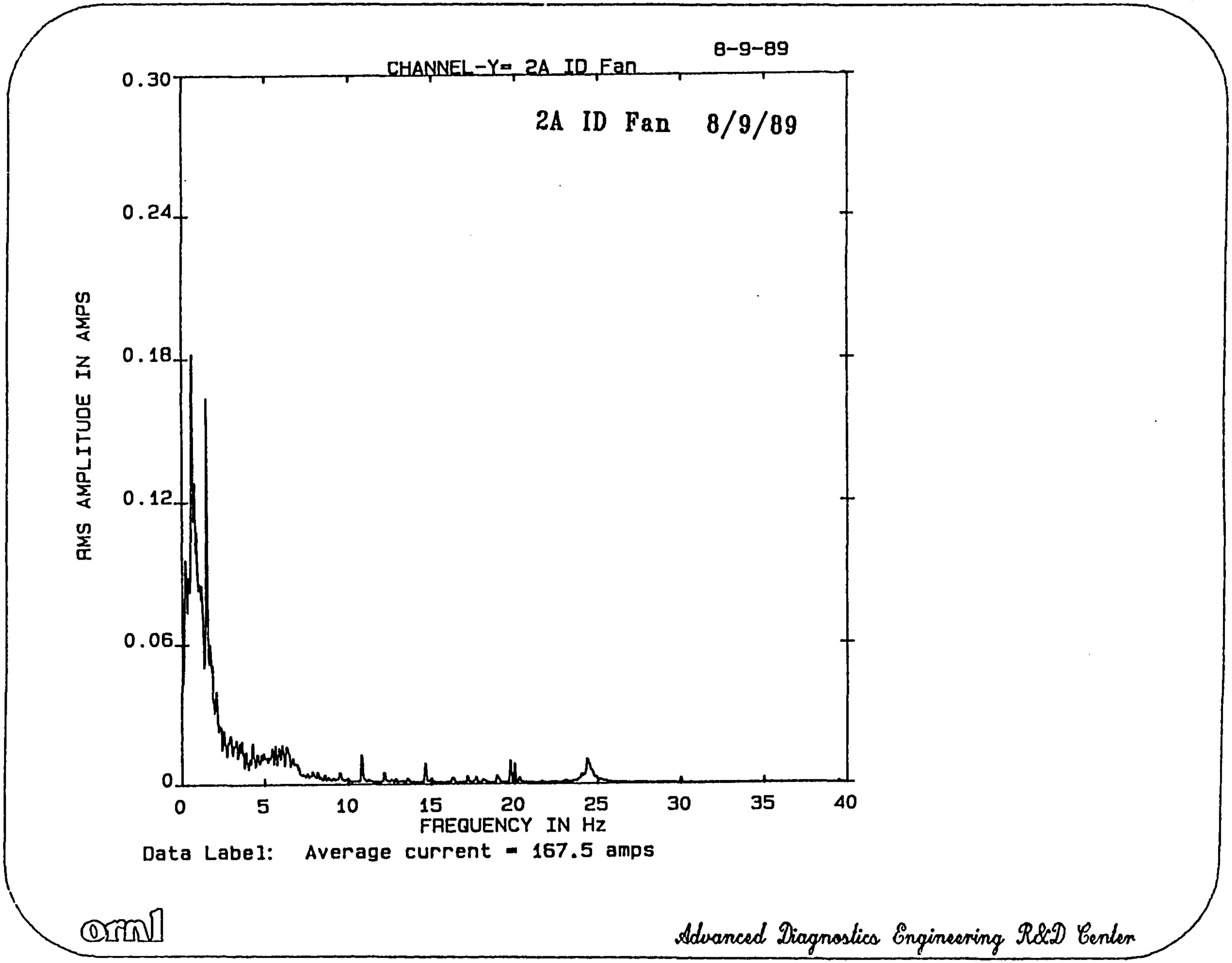
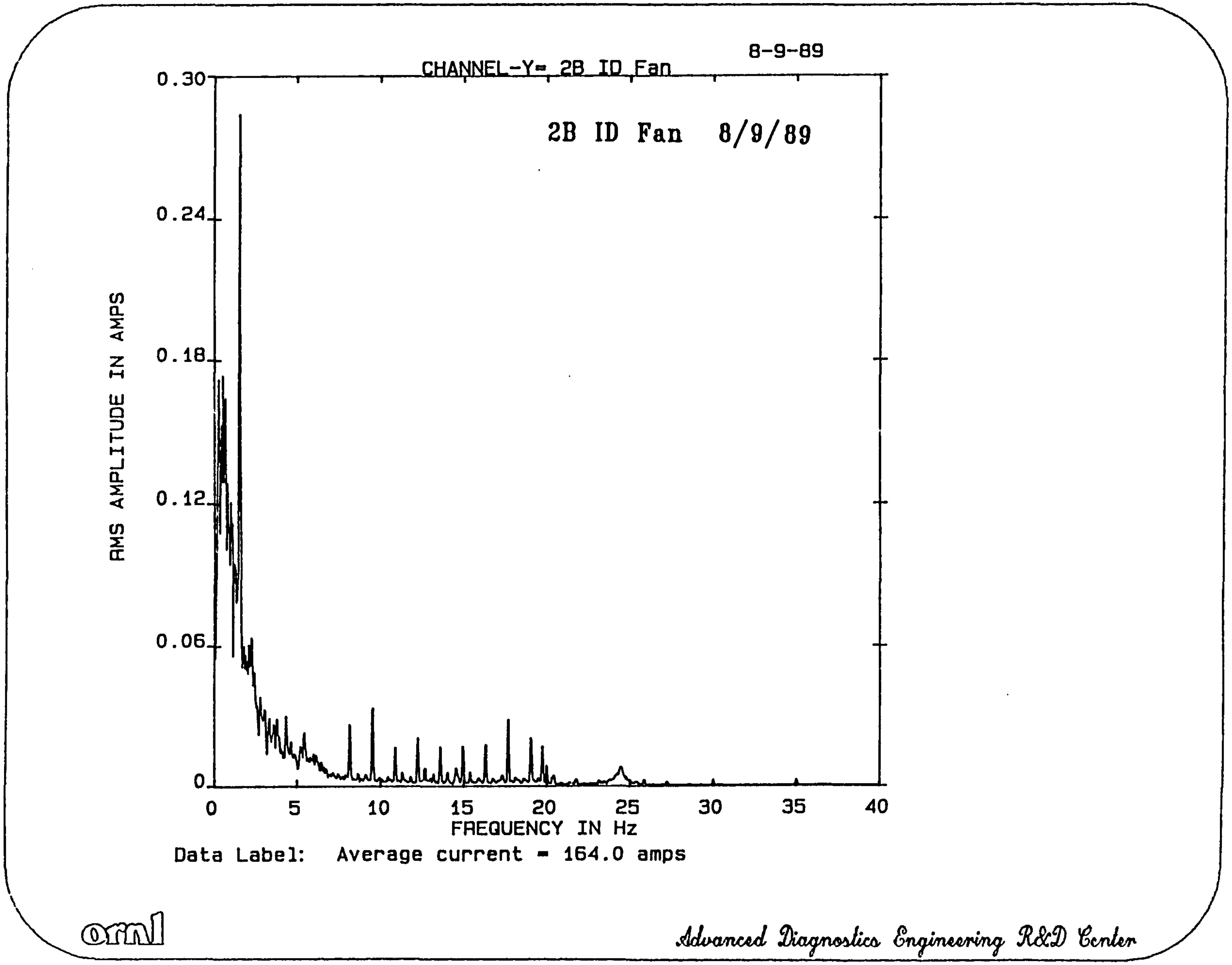
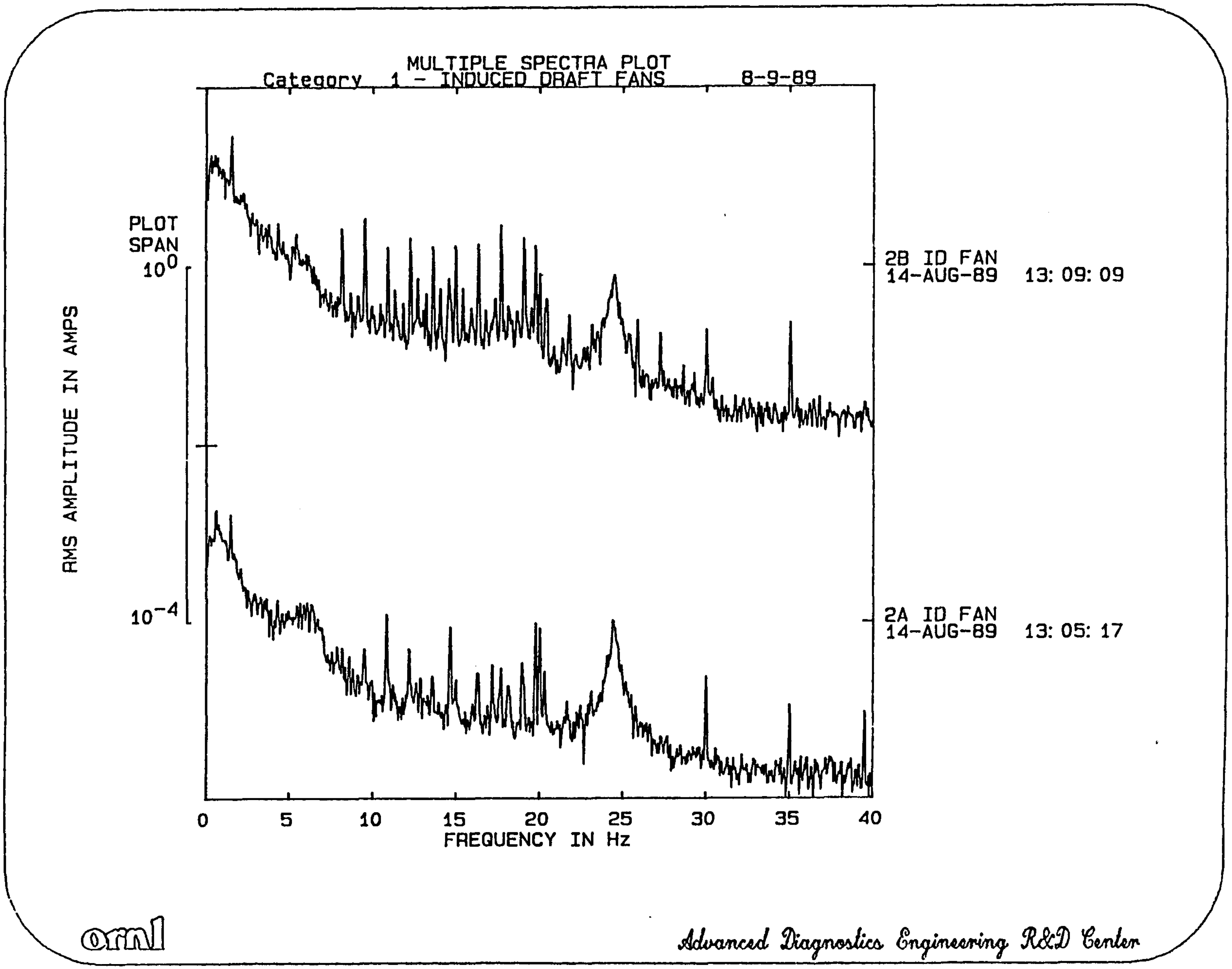

8-9-89
CHANNEL-Y= 2A ID Fan
2A ID Fan 8/9/89
RMS AMPLITUDE IN AMPS
0.30
0.24
0.18
0.12
0.06
0
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
Data Label: Average current = 167.5 amps
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 89



8-9-89
CHANNEL-Y= 2B ID Fan
2B ID Fan 8/9/89
0.30
0.24
0.18
0.12
0.06
0
RMS AMPLITUDE IN AMPS
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
Data Label: Average current = 164.0 amps
Advanced Diagnostics Engineering R&D Center

FIGURE 90



MULTIPLE SPECTRA PLOT
Category 1 - INDUCED DRAFT FANS 8-9-89
PLOT SPAN
10^0
10^-4
RMS AMPLITUDE IN AMPS
2B ID FAN
14-AUG-89 13: 09: 09
2A ID FAN
14-AUG-89 13: 05: 17
0 5 10 15 20 25 30 35 40
FREQUENCY IN Hz
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 91

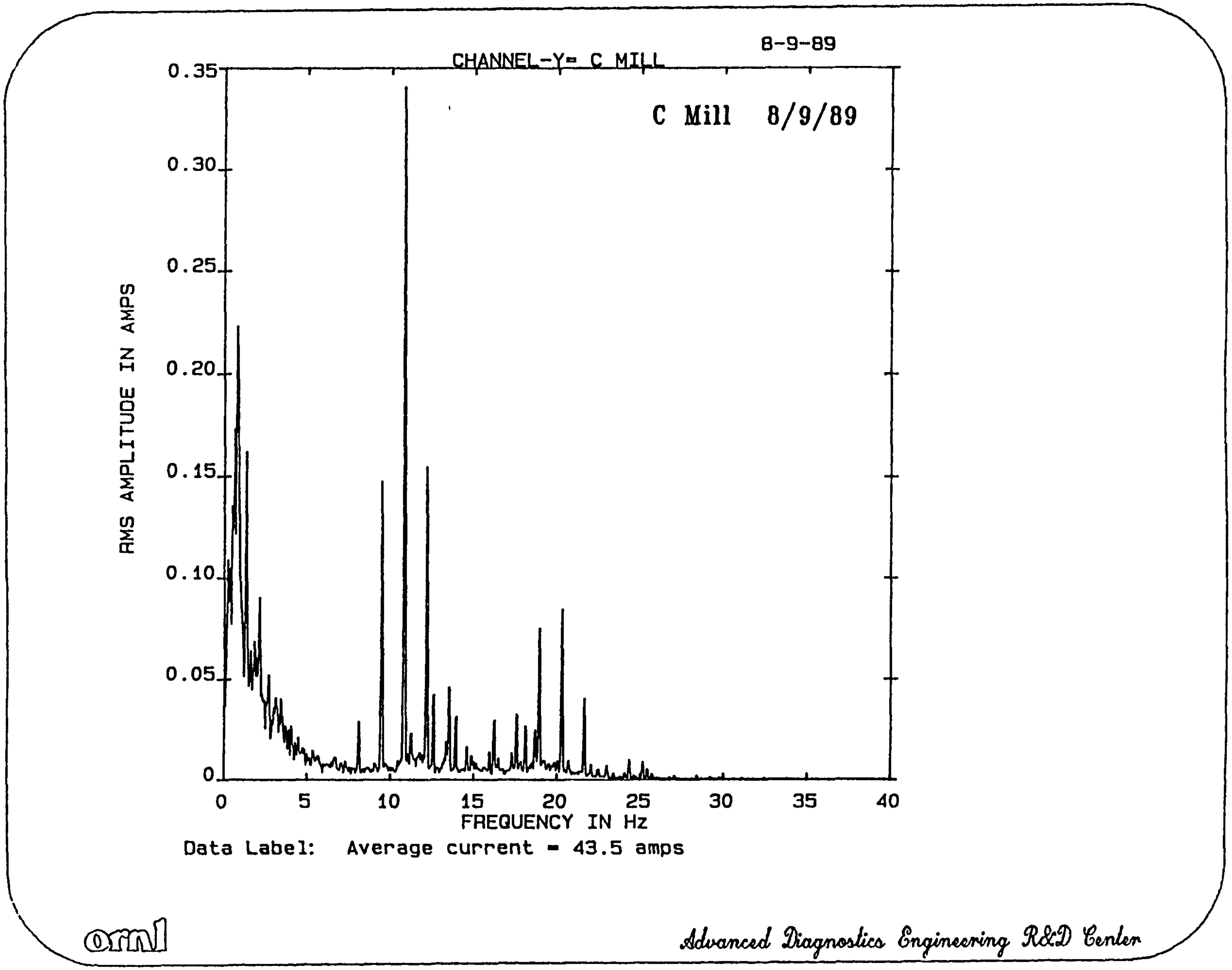

8-9-89
CHANNEL-Y= C MILL
C Mill 8/9/89
RMS AMPLITUDE IN AMPS
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
Data Label: Average current = 43.5 amps
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 92

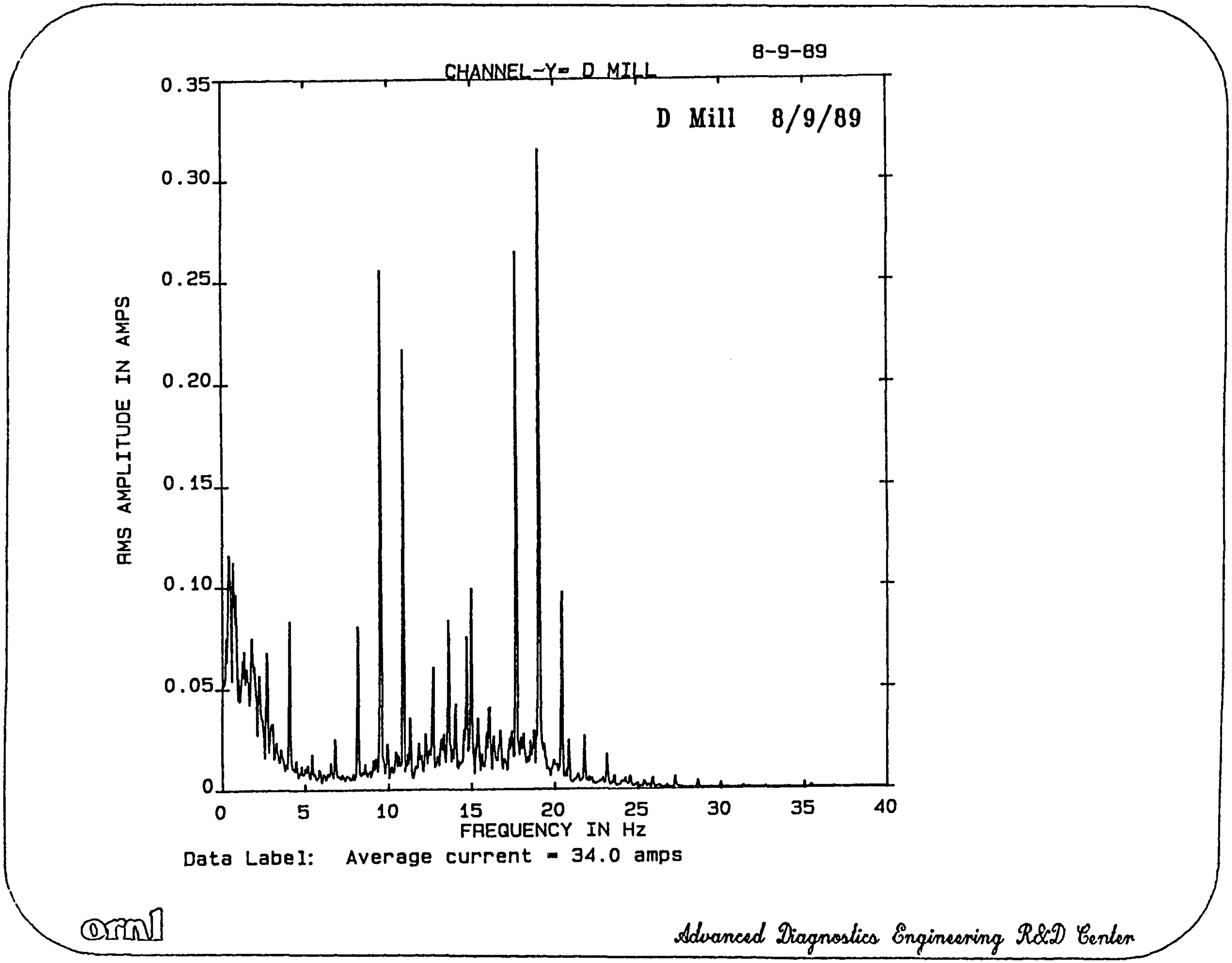

8-9-89
CHANNEL-Y= D MILL
D Mill 8/9/89
RMS AMPLITUDE IN AMPS
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0 5 10 15 20 25 30 35 40
FREQUENCY IN Hz
Data Label: Average current = 34.0 amps
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 93

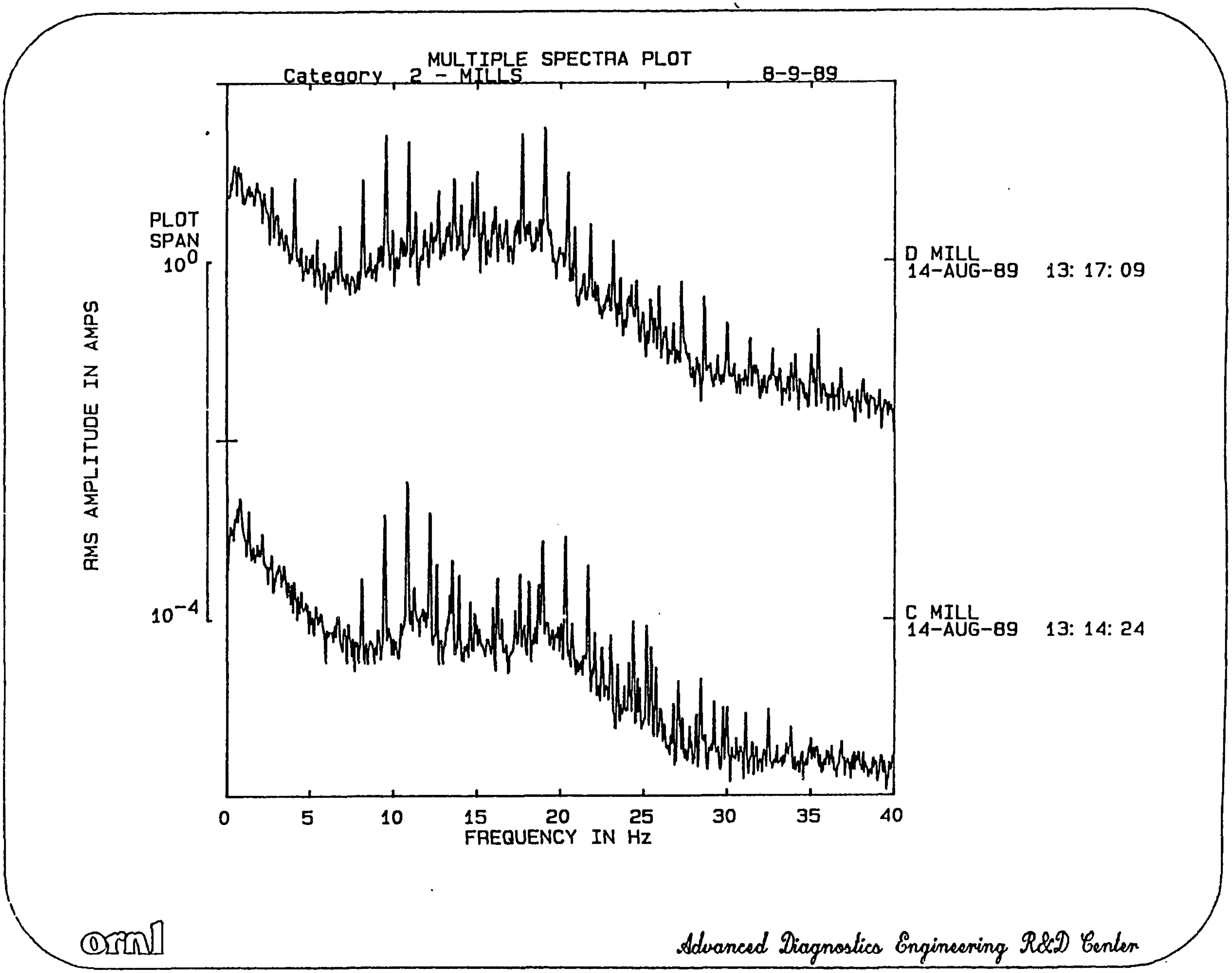

MULTIPLE SPECTRA PLOT
Category 2 - MILLS
8-9-89
PLOT SPAN
10^0
10^-4
RMS AMPLITUDE IN AMPS
D MILL
14-AUG-89 13: 17: 09
C MILL
14-AUG-89 13: 14: 24
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 94

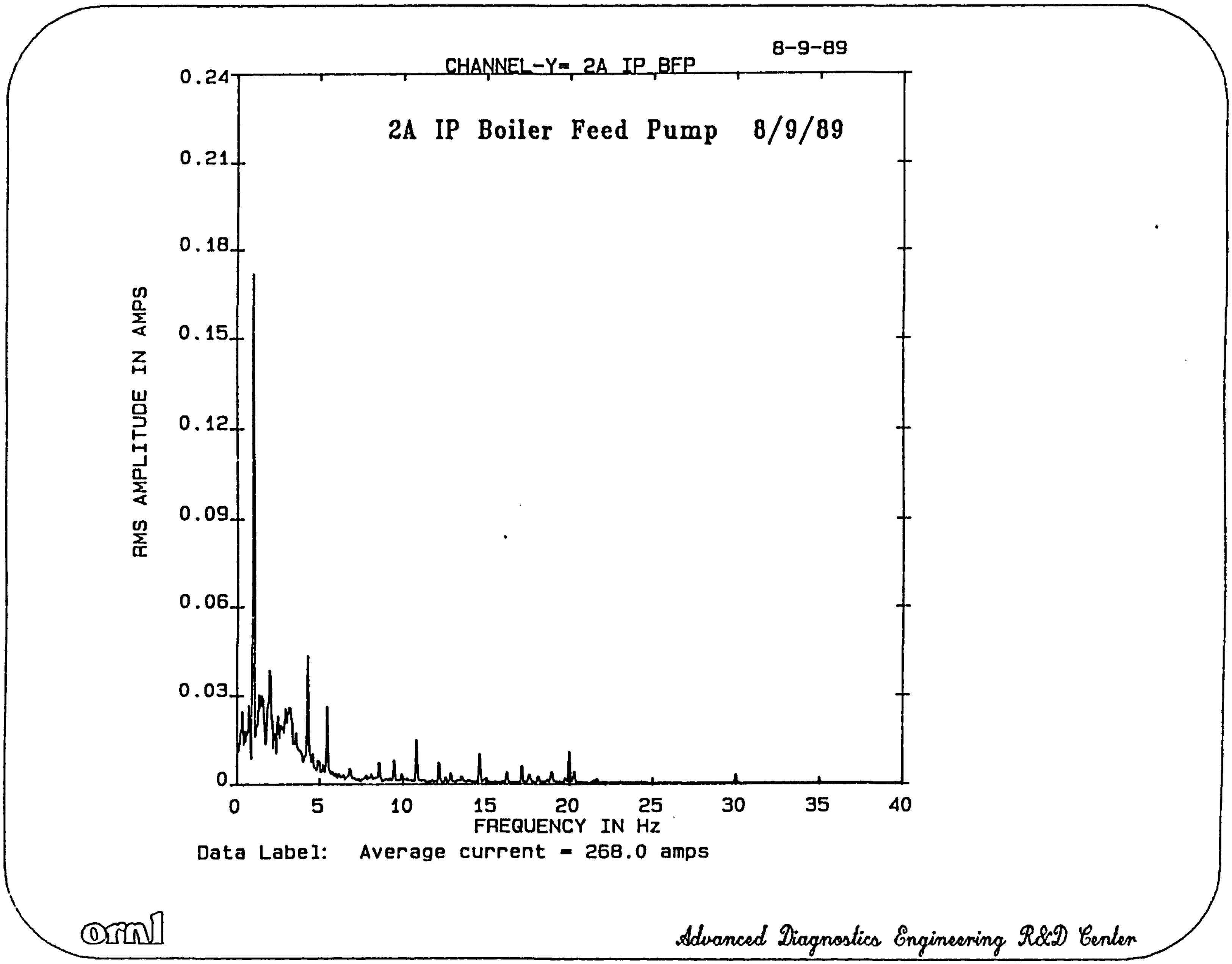

8-9-89
CHANNEL-Y= 2A IP BFP
2A IP Boiler Feed Pump 8/9/89
RMS AMPLITUDE IN AMPS
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
0
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
Data Label: Average current = 268.0 amps
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 95

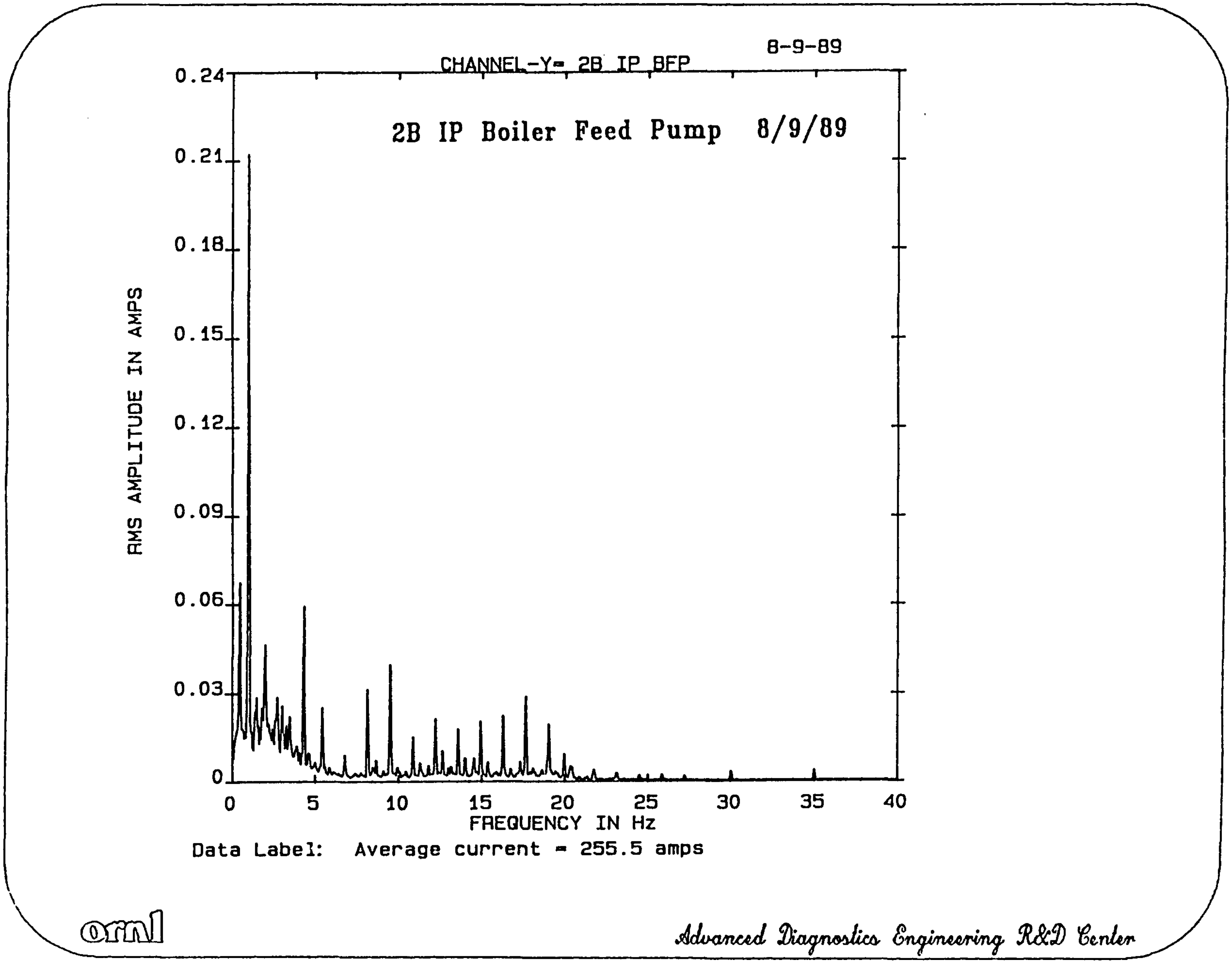
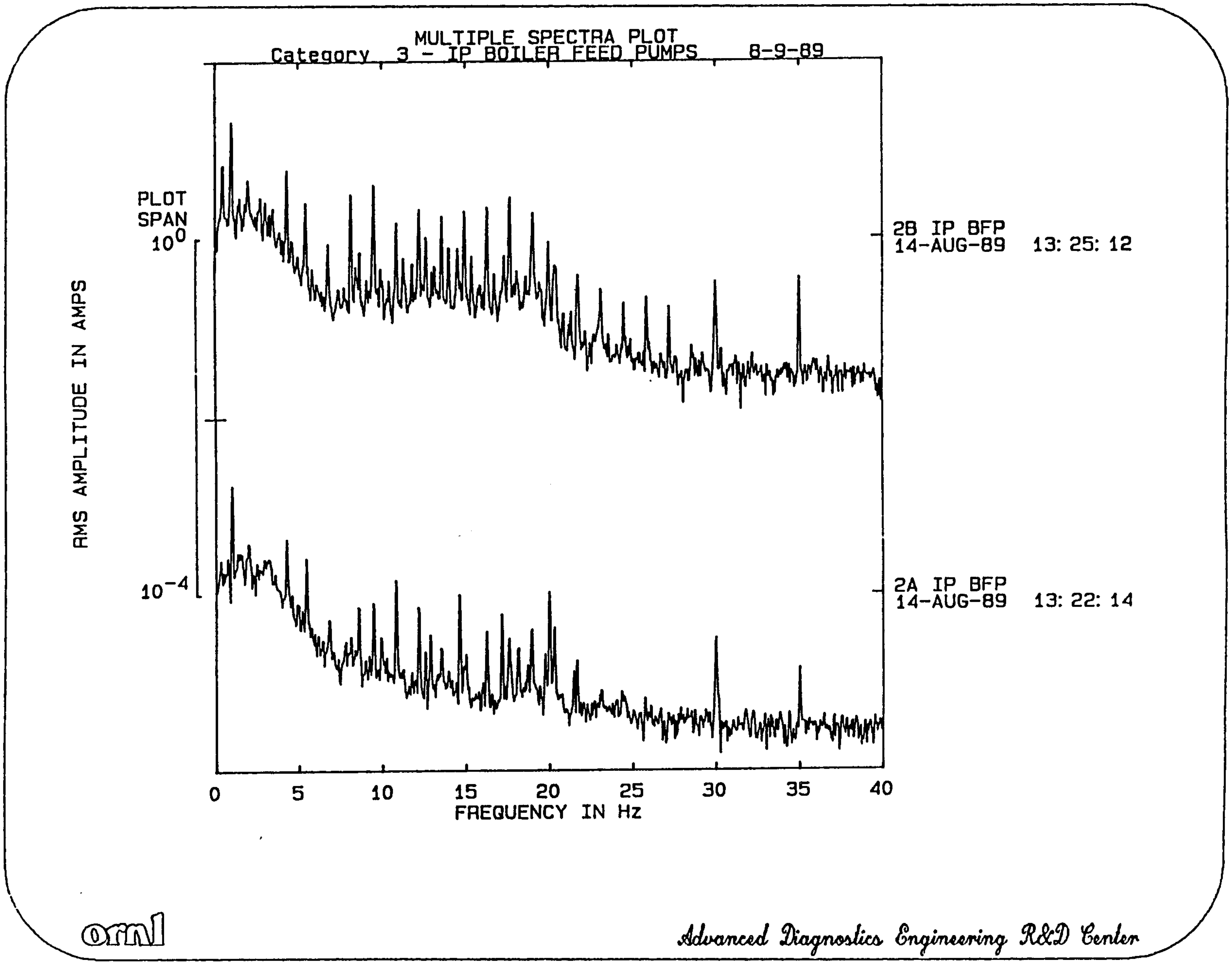

8-9-89
CHANNEL-Y= 2B IP BFP
2B IP Boiler Feed Pump 8/9/89
RMS AMPLITUDE IN AMPS
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
0
0 5 10 15 20 25 30 35 40
FREQUENCY IN Hz
Data Label: Average current = 255.5 amps
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 96



MULTIPLE SPECTRA PLOT
Category 3 - IP BOILER FEED PUMPS 8-9-89
PLOT
SPAN
10^0
10^{-4}
RMS AMPLITUDE IN AMPS
2B IP BFP
14-AUG-89 13: 25: 12
2A IP BFP
14-AUG-89 13: 22: 14
0 5 10 15 20 25 30 35 40
FREQUENCY IN Hz
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 97

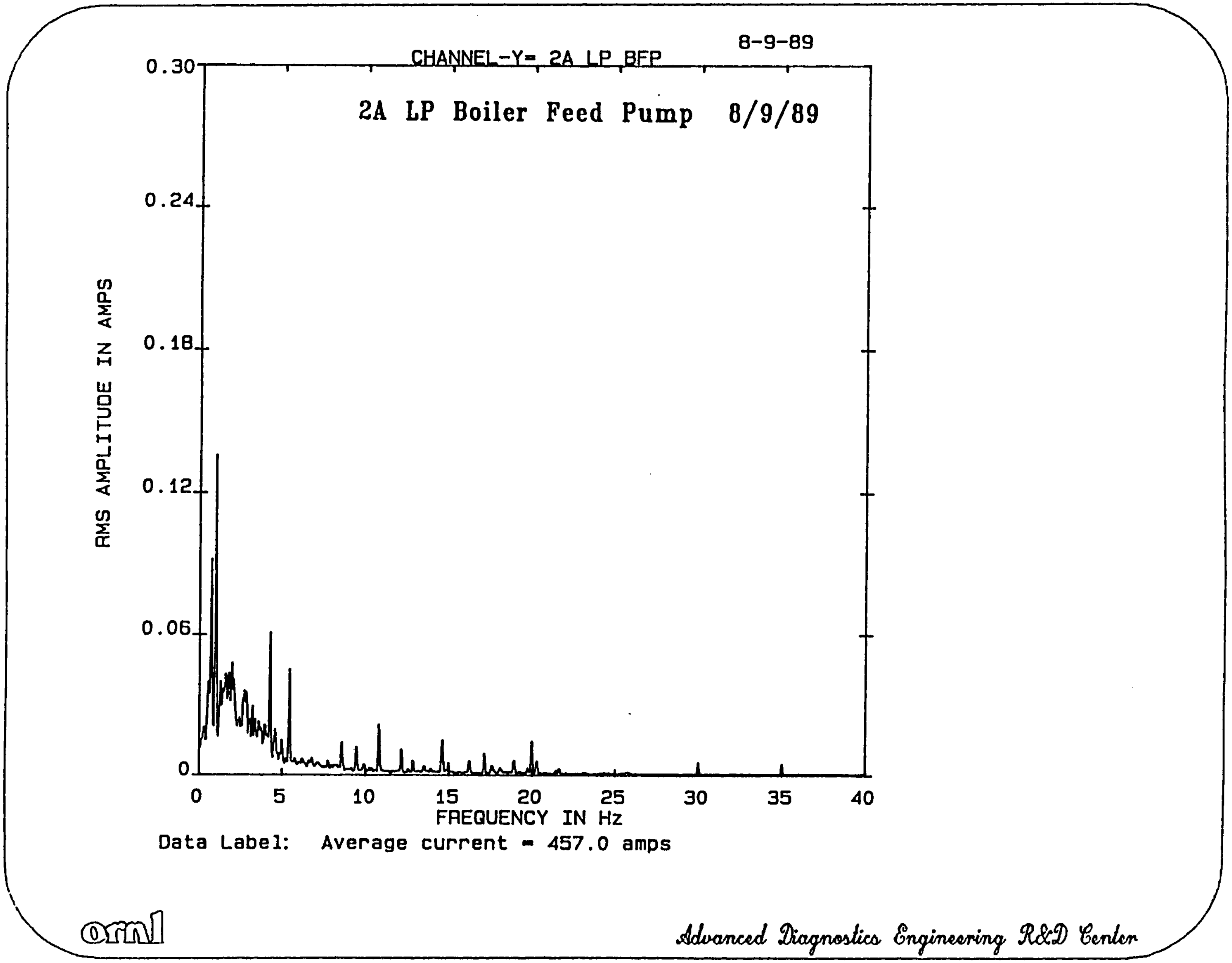

8-9-89
CHANNEL-Y= 2A LP BFP
2A LP Boiler Feed Pump 8/9/89
RMS AMPLITUDE IN AMPS
0.30
0.24
0.18
0.12
0.06
0
0 5 10 15 20 25 30 35 40
FREQUENCY IN Hz
Data Label: Average current = 457.0 amps
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FIGURE 98

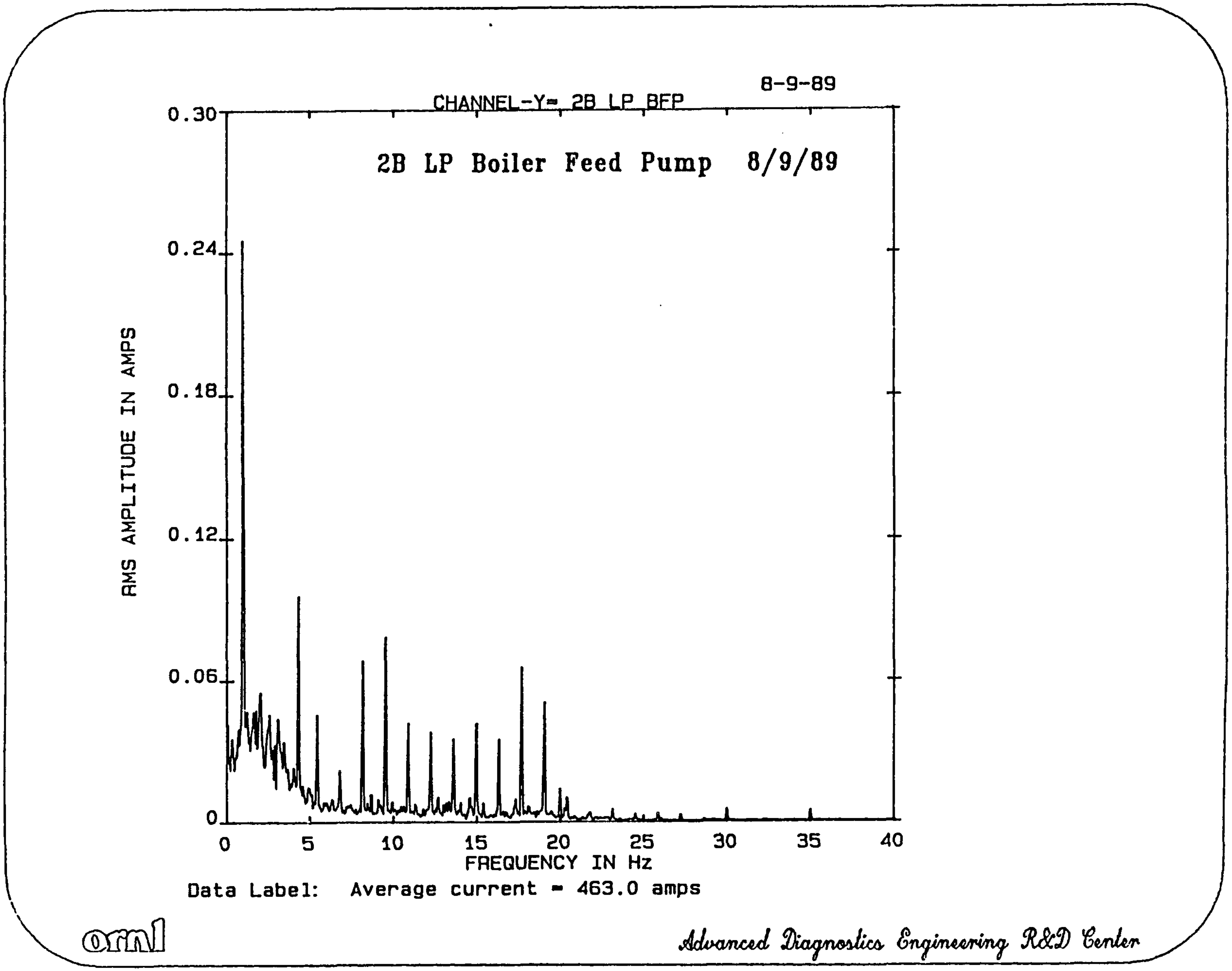
8-9-89
CHANNEL-Y= 2B LP BFP
2B LP Boiler Feed Pump 8/9/89
0.30
0.24
0.18
0.12
0.06
0
RMS AMPLITUDE IN AMPS
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
Data Label: Average current = 463.0 amps
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 99

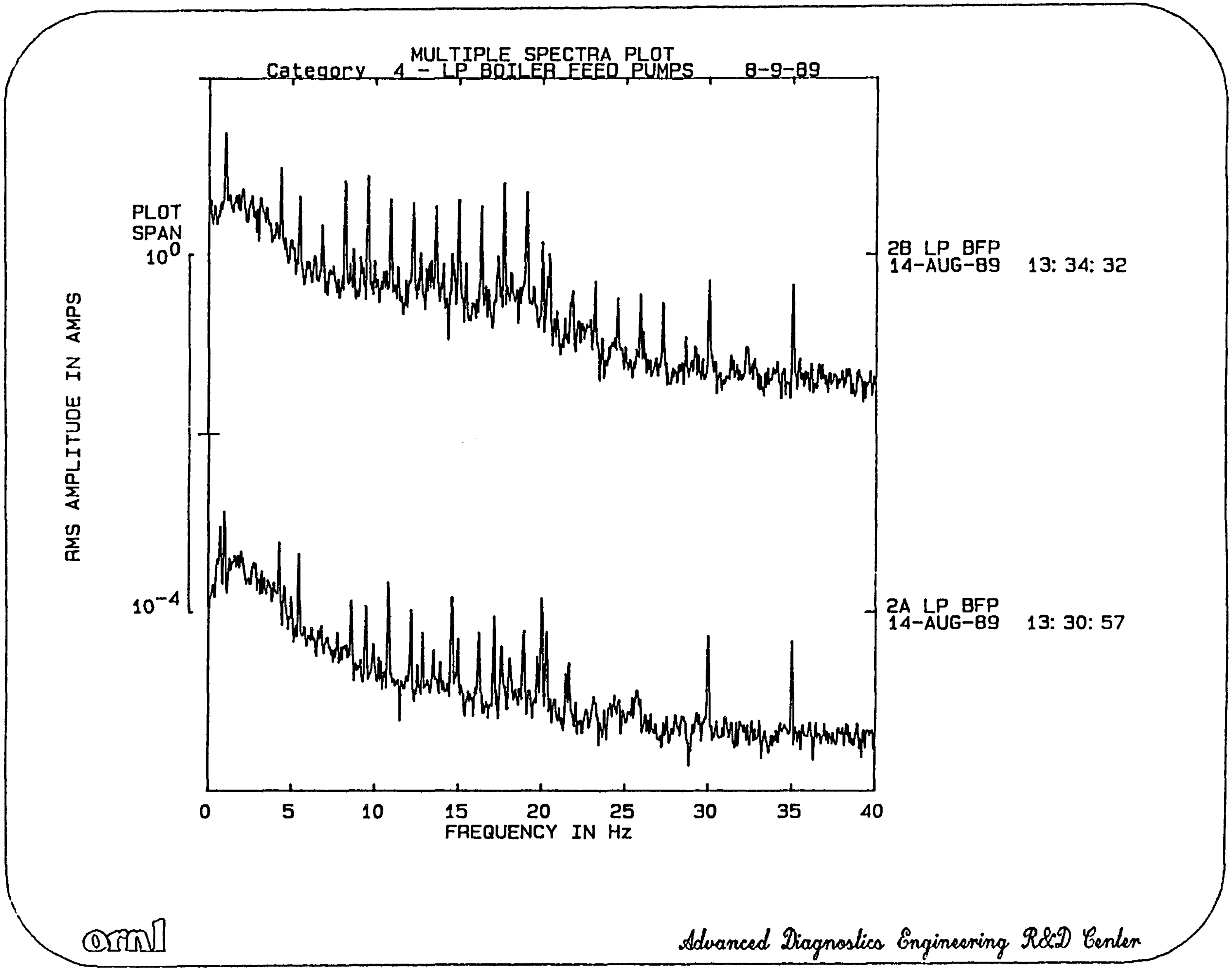
MULTIPLE SPECTRA PLOT
Category 4 - LP BOILER FEED PUMPS 8-9-89
PLOT
SPAN
10^0
10^{-4}
RMS AMPLITUDE IN AMPS
2B LP BFP
14-AUG-89 13: 34: 32
2A LP BFP
14-AUG-89 13: 30: 57
0
5
10
15
20
25
30
35
40
FREQUENCY IN Hz
ornl
Advanced Diagnostics Engineering R&D Center

FIGURE 100