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INTERNAL TECHNICAL REPORT

Title: ANALYSIS OF A TRANSIENT LOAD MEASURING SYSTEM

Organization: LOFT EXPERIMENTAL MEASUREMENTS BRANCH

Author: R. R. Good/T. R. Meachum

Checked By: L. D. Goodrich/D. J. Hanson

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EG&G Idaho, Inc.

LOFT TECHNICAL REPORT
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Analysis of a Transient Load Measuring System

REPORT NO.
LTR-LO-87-80-132

AUTHOR
Robert Good TRM
R. R. Good, T. R. Meachum

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ABSTRACT

An analysis of the performance of a load measuring system is presented. The load system was designed to measure the weight of a pressure vessel containing high pressure and temperature water. The uncertainty and frequency response of the system are quantified for both steady state and dynamic conditions as is the repeatability of the test rig. Computation of the mass flow exiting the system during explosive decompression of the system is also presented.

DISPOSITION OF RECOMMENDATIONS

No disposition required.

SUMMARY

An analysis of the weight measuring system used in a series of transient steam water flow tests is herein presented. The analysis yields two sigma static uncertainties of 0.59% RG and dynamic uncertainties of 7.8% RG. The system frequency response is flat to 0.3 hz, and not quantified at any higher frequencies. The purpose of the weight measuring system is to provide a reference mass flow for assessing the performance of a variety of experimental mass flow transducers. The experimental transducers are currently used in the Loss-of-Fluid Test (LOFT) program. Thus in addition to the uncertainty in system weight, this analysis quantifies the repeatability of the test rig, and describes in detail the computation of mass flow given the time history of system weight.

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I. INTRODUCTION

A transient steam water calibration facility was constructed to test Loss of Fluid Test (LOFT) mass flow instrumentation. The primary design criterion of the facility was the capability to calibrate LOFT instrumentation under fluid conditions identical to those in LOFT. Achievement of the design goal required that the geometry and initial fluid conditions of LOFT be duplicated and that a reliable reference mass flow instrument be installed in the calibration system. There exists no standard reference instrumentation for multiphase calibration facilities, thus all mass flow sensing methods were considered. The requirements for an acceptable reference were severe. The reference must survive a high pressure (15.5 MPa) temperature (550 K) environment, measure the global mass flow through the blowdown piping, and be unaffected by the multi-phase nature of the flow. The only instrument which met these requirements was a load cell based weighing system. This paper presents an analysis of the frequency response, static and dynamic uncertainties of the load cell system.

The quantification of the uncertainty in mass flow measurement was achieved through a combination of experimental and analytic techniques. The lack of a recognized standard for multiphase mass flow calibration forces all uncertainty estimates to be compared to single phase standards, this creates uncertainties quantifiable only be engineering judgement. The stochastic nature of fluid requires that averaging techniques be applied to the data to produce repeatable results. The selection of appropriate averaging methods also requires engineering judgement to be utilized. Thus, the assessment of the accuracy of the reference instrumentation was a combination of engineering judgement and standard single phase calibration techniques.

Uncertainty was quantitative both for static and dynamic conditions. The static uncertainty limits the uncertainty in the total mass flow and provides a lower bound for the dynamic uncertainty if no filtering is applied. The dynamic uncertainty quantifies the frequency response of the mass flow measurement and the uncertainty in the measurement at each frequency. The mass measurement repeatability between tests is addressed both in the static and dynamic analyses.

II. WEIGH SYSTEM DESCRIPTION

The design goal of the WTT load cell weigh system was to weigh the WTT system during explosive decompression. The weigh system consisted of two primary subsystems, the load system, and the data processing system. The load system produced a filtered electrical output proportional to the system weight. The data processing system used the electrical output of the load system to produce system weight and rate of change of system weight in engineering units. Figures 1 and 2 respectively present schematic representations of the weight and data processing subsystems.

The pertinent aspects of the load system are the load cells, the sway bracing and the air bag supports for the blowdown piping. The design concept was to support the weight of the blowdown vessel and fluid on the load cells and the weight of the blowdown piping and stabilizing mass on the air bag support system. Computer analysis, Reference 3, indicated that a negligible (< 15 Kg) amount of load sharing would occur between the load cells and the air bag support. Unfortunately this computer analysis neglected long term thermal effects as initially only short duration blowdowns were anticipated. The long term thermal effects problem resulted in a redesign of the load cell system. The primary change was the addition of another load cell. The weigh system configuration change and its effect on overall system uncertainty will be documented in a later report. This report addresses only fast transients (< 300 sec) for which the computer analysis was assumed valid.

The load cells were selected with fast transient capability. The load cells were manufactured by Interface. Appendix A contains the manufacturer's specifications. Briefly each load cell has a range of 0 - 226.82 Kilonewtons and a frequency response of not less than 100 Hz. The load cells are a strain gauge shear web design. Each load cell has a dual bridge; one is inputted to the data acquisition system, and the other is displayed in real time. The system consisted of three load cells spaced at 120 degree intervals around the vessel as shown in Figure 3. The output of the load cells was algebraically summed which produced an output directly proportional to load.

The air bag support system was the only other major load bearing component in the weight system. The air bag support system consisted of two separate supports, one located next to the vessel, and one at the end of the blowdown leg. Air bags were supplied by Firestone and Lord Kinematic. Firestone air bags were located closest to the vessel and the Lord Kinematic supported the stabilizing mass at the end of the blowdown leg. Manufacturer's specifications and schematic diagrams, for these components are given in Appendix B. The relative stiffness of the air bag and load cell supports determines the amount of load sharing which will occur. The ratio of stiffness of load cells to air bag (See Reference 2) support is at least 1000; thus, the load cell support system would acquire at least 1000 newtons of load for every 1 newton the air bag system acquires. The load sharing described assumes no major structural changes occur in the system.

The only major non vertical load bearing component of the weigh system were the sway braces. The design goal of sway brace system was to restrain all horizontal motion of the vessel. The design concept was to restrain the vessel with large mechanical braces. Implementation of this system resulted in the sway braces absorbing some of the vertical loading of the vessel. This system was redesigned for the second series of tests.

The software system for producing mass flow data is documented in Appendix C. The essentials of the software process are (1) 50 sample/sec sampling rate, (2) optional low pass digital filter, (3) differentiating by computation of finite differences, (4) output of data. Additionally, the program documented in Appendix C computes the mass flow based on information from the vessel differential pressure cells and compares the differential pressure and load cell data. The program is written in Fortran IV and is implemented on a CYBER 173-176 system. Provision has been made for reproduction of higher frequency load cell data via 5000 Hz analog recording of the load cell bridge output.

III. STATIC LOAD CALIBRATION

The WTT load system was statically calibrated. The static load tests consisted of a series of fill, hydrostatic, and heatup tests. The fill tests established the load cells accuracy, the degree of load sharing between the load cells and airbag supports, and the effects of asymmetric loads on the vessel. The hydrostatic pressure tests and heatup tests quantified the WTT system sensitivity to pressure and temperature. The fill tests were conducted prior to and during the actual blowdown testing period. The pressure sensitivity of the weigh system was not suspected until after testing began; thus the pressure tests were conducted during the transient testing period. Attempts at quantifying the temperature sensitivity were made prior to and during transient testing. The results of the static load testing were in general satisfactory.

The fill tests consisted of metering water into the WTT system and recording the output of the load cells. The load cells were dual bridge devices. One set of bridges was summed analog and the output displayed. The second set of bridges was inputed to the data acquisition system. A total of six cold fill tests were conducted on the WTT system. The tests spanned a two and one half month interval. Table I summarizes the data from these tests and Figure 4 is a plot of a typical series of data sets. The reference instrument for each fill test was a Foxboro Mark 1 F1-16-SB full flow turbine serial number 31064. The uncertainty of this turbine was <0.2% RG as determined by single phase flow testing by the Foxboro Company.

The procedure for conducting a cold fill test involved metering water into the WTT system and recording the output of the load cell system and the amount of water metered into the vessel. Appendix D is the test procedure used to perform the fill tests. The data used to calculate the WTT system static uncertainty was acquired by the Wyle computer system and therefore incorporates the uncertainties due to quantization, signal transmission, and computer system effects.

The effect of asymetric system loading was quantified during the fill tests and by subjecting the load ring to point loads of approximately 1250 newtons. Asymetric loads of approximately 4406 newtons were placed on the system during the fill tests due to the mass distributed in the blowdown piping. No measurable change in the sum of the load cell outputs was detected while asymetric loads were placed on the system; therefore, the effect of asymetric loads on system uncertainty is deemed neglible, <0.05% RG.

The WTT system static load uncertainty design requirement was 1% RG. Range was 40800 newtons. Range was determined by the mass of water required to fill the WTT system at 15.5 MPa and 550 K. The required uncertainty of the weigh system was achieved after modification of the air regulating system and the turbine meter fill system. The static system weigh uncertainty was 0.59% RG (241 newtons).

The long term drift uncertainty of the weigh system was established by repeating the calibrated fill tests approximately two months later. Figure 5 is a comparison of two calibration tests taken two months apart. There is no statistically significant (95% confidence) difference in the calibration coefficient (the offset varies but this is removed on a test by test basis). Thus, long term drift uncertainty is deemed negligible (<0.05% RG).

Uncertainty in system load due to pressure effects was quantified in a series of cold and hot hydrostatic tests. The results of these tests are tabulated in Table II. Figures 6 and 7 represent the range of results obtained. A total of four cold pressure tests and two hot pressure tests were conducted. In general, the system load appeared sensitive to pressure; however, no repeatable functional relationship could be derived. Investigation of system load at decompression initiation revealed a step change in load occurring simultaneously with system subcooled depressurization to saturation and no detectable load sensitivity to pressure during the remaining depressurization. Figure 8 is a typical load cell blowdown trace illustrating the initial step change. Analysis of data gathered during transient testing indicated that the sway brace system was assuming significant vertical load during system pressurization and was releasing that load when the depressurization shock wave propagated through the system. A hot hydrostatic test and system depressurization was conducted with the sway brace system removed to verify the analysis. Figure 9 presents the hot hydro with sway brace removed data. The data indicate a slight increase in load with pressure. The increase in system load is commensurate with the mass required to raise the system pressure by 7.5 MPa. Thus, the removal of sway braces removed any system pressure sensitivity. The weigh system uncertainty due to pressure changes was deemed negligible (<0.05%) if a mechanical shock sufficient to remove any friction vertical load bearing in the sway brace system occurs prior to measurement. If a mechanical shock does not occur, the uncertainty is approximately 27% RG.

The weigh system uncertainty due to temperature fluctuations was not fully quantified. Tests were conducted to reveal system sensitivity to small (20 K) temperature fluctuations. Those tests demonstrated no significant weigh system temperature sensitivity. WTT system design precluded varying system temperature significantly while maintaining system mass constant. Thus, no quantitative large scale system temperature sensitivity was calculated. System temperature sensitivity was judged neglible for transients less than 300 seconds.

The static weigh system uncertainty consists only of the uncertainty in the force measurement of the load cells as all other uncertanties are less than 0.05% RG assuming that the effects of the sway bracing have been nullified. The uncertainty in system weight under static conditions is therefore ± 255 newtons (± 25.5 kg or 0.59% RG).

IV. DYNAMIC LOAD UNCERTAINTY

The quantification of the Wyle Transient Test system's dynamic uncertainty requires both experimental and analytic methods. The experimental methods allow the direct measurement of the system's response to physical excitation. The analytic approach yields estimates of the system uncertainty given the system's static response and the filtering applied to the output. Thus estimates of the system's frequency response have been obtained experimentally and quantification of the system uncertainty has been obtained analytically.

The experimental analyses involve the load cells and their structural support system. The support system acts as a complex damped spring mass system, the spring constants, etc. of which are unknown. The experiments performed to quantify the system frequency response included low frequency excitation of the system and broad band system excitation via explosive decompression of the system. The lowest frequency observed during either explosive decompression or low frequency excitation was 3 Hz. Figures 10 through 13 are power spectral densities (PSD's) of the individual load cells and their electronic summation. There is a clear peak evident in the PSD's of load cells 002 and 242 and a slightly more ill defined peak in load cell 122 and the net load. All of these peaks occur within 0.2 hz of 3 hz. Figures 14 and 15 present PSD's of the output of a velocity and momentum flux instrument respectively. These instruments are located in the center of the blowdown piping 2 meters from the blowdown vessel. Neither the velocity nor momentum flux PSD exhibits any clearly defined peaks. Thus since these two measurements incorporate both density and velocity measurements it is evident that the 3 Hz phenomena measured by the load cell system is an artifact of the load cells and their support system, not a real oscillation in mass flow. The experimental data then provides the basis for engineering judgment in establishing the upper bound of frequency response for mass flow computed using the load cells. This upper bound is set at 0.3 Hz, one decade below the lowest measured load cell system resonant frequency.

The computational software system provided the means for extracting the desired frequency range and calculating the mass flow given system mass. Analysis of the software system provided an estimate of the uncertainty in mass flow after the signal had been processed. Signal processing consisted of analog and digital filtering. The analog filtering consisted of a 4 pole 10 Hz filter. The digital filter was a convolution of a 112 term low pass filter and a 25 term derivative filter. The digital filters were implemented as a weighted sum of finite differences. Figure 16 is the transfer function of the digital filter. All signals used to calculate the static uncertainties were passed through the analog filter, hence any uncertainty associated with the analog filter is integral to the static uncertainty estimate. Uncertainties associated with the digital filter are calculated via Equation (1) (see Reference 4).

$$\sigma_f^2 = \sigma_u^2 \sum_{K=-K}^{K} C_K^2 \qquad (1)$$

where

σ_f^2 = uncertainty in filtered output

σ_u^2 = uncertainty in unfiltered output

C_K = coefficients of digital filter.

Equation (1) yields an estimated uncertainty in mass flow of 2.16×10^{-3} newtons/sec (0.22 grams/sec) given the static uncertainty of (25.5 kilograms). A basic assumption of Equation (1) is that the system being filtered is a linear time invariant system. This assumption is probably invalid when considering signal magnitudes of the order of 1 newton or less. Thus a reasonable engineering estimate of the uncertainty in system mass flow is 0.5 kg/sec (2σ), assuming that the digital filter described in Appendix C is applied to the data.

The dynamic uncertainty within any single test has now been analytically quantified. The dynamic repeatability however remains unknown. The dynamic repeatability is a function of many independent variables. These variables include initial system pressure, water temperature, metal temperature, and temperature distribution. Few of these parameters are well defined, thus an experimental approach must be employed to obtain meaningful estimates of the system's dynamic repeatability.

The WTT experimental series included several replications of identical pretest configurations. Table III presents the results of comparing the first and second test series. Figure 17 is an overlay of the mass flow for three identical blowdown tests. Estimates of the instantaneous repeatability between tests were obtained by computing the deviation from the first test of the test series. All tests started at time zero as defined by the time a 5.0 MPa drop occurred across an orifice in the blowdown piping. Equation (2) was used to compute system instantaneous repeatability as well as integrated mass repeatability.

$$\sqrt{\sigma_I} = \sqrt{\frac{\sum_{j=2}^{n} (X_1 - X_j)^2}{n-1}} \tag{2}$$

where

X_1 = reference channel

X_j = all other channels

$\sqrt{\sigma_I}$ = instantaneous standard deviation

Figure 18 is a plot of instantaneous repeatability of mass flow for the first test series. System instantaneous repeatability varies widely during the blowdowns with the largest levels occurring during the subcooled portion of the blowdowns and at approximately 20 to 25 seconds. The time period of 20 to 25 seconds corresponds to the time when the downcomer uncovers. The mean instantaneous repeatability in mass flow for time segment is given in Table III.C.

V. CONCLUSION

The transient steam water calibration facility's reference mass flow system has proven to be an accurate, repeatable and durable system. The isolation of the transducers from the internal environment of the system has allowed the mass flow system to perform reliably for more than twenty experiments. The nature of the transducers, being they measure system weight directly, has contributed to their accuracy and has eased the computational requirements to reduce mass flow rate. The uncertainty in static system weight is ± 25.5 Kg, the uncertainty in mass flow (assuming filtering is applied to the signal) is 0.5 Kg/sec. The weight systems frequency response is flat to 0.3 Hz and has not been quantified for greater frequencies. Additionally the transient facility's repeatability has been quantified. The repeatability of the weigh system is an integral part of the transient system's repeatability but has not been quantified separately. The transient systems worst case repeatability is ± 20.1 Kg/sec, 7.8% of range.

It is the recommendation of the authors that load cell based systems be considered for all future transient two phase systems and that weigh systems be recommended as a standard reference for the industry.

TABLE I

CALIBRATED FILL TESTS OF THE WYLE TRANSIENT TEST FACILITY

Test No.	Date	Calibration Coefficient		Correlation Coefficient	Standard Deviation of Y on X		# of Points
		Kg/Volt**	Newtons/Volt		Kg	Newtons	
1	6/26/79	1731.6	17282	0.9997	23.7	237	21
2	6/28/79	1690.5	16871	1.0000	10.0	100	22
3	6/28/79	1689.5	16861	1.0000	12.7	127	19
4	7/2/79	1434.5*	14316	1.0000	66.2	661	9
5	7/25/79	1699.5	16961	0.9999	8.8	88	27
6	8/29/79	1702.7	16993	1.0000	8.7	87	24

* Flow meter partially bypassed thus this point is not used in any analyses.

** Volts = sum of output of loadcells 1, 2, & 3 from data acquisition system output.

TABLE II

WYLE TRANSIENT TEST SYSTEM PRESSURE SENSITIVITY

Test #	Pressure Range MPa	Maximum Force Range Newtons	Data	Temperature K
1	15	1355	8-6-79	350
2	14	9108	8-22-79	350
3	15	1014	8-28-79	350
4	5	3401	8-30-79	500
5	7.5	1181	9-5-79	500
6	17	1866	7-25-79	350

TABLE III

COMPARISON OF INSTANTANEOUS REPEATABILITY

A. RMS ERROR (Kg/sec)

TIME INTERVALS (SECONDS)

Test Series	0-10	10-20	20-25	25-40	40-60
IA1	20.1	9.4	17.2	10.3	2.1
IA2	22.8	7.4	16.6	5.0	1.9

B. MASS FLOW (Kg/sec)

TIME INTERVALS (SECONDS)

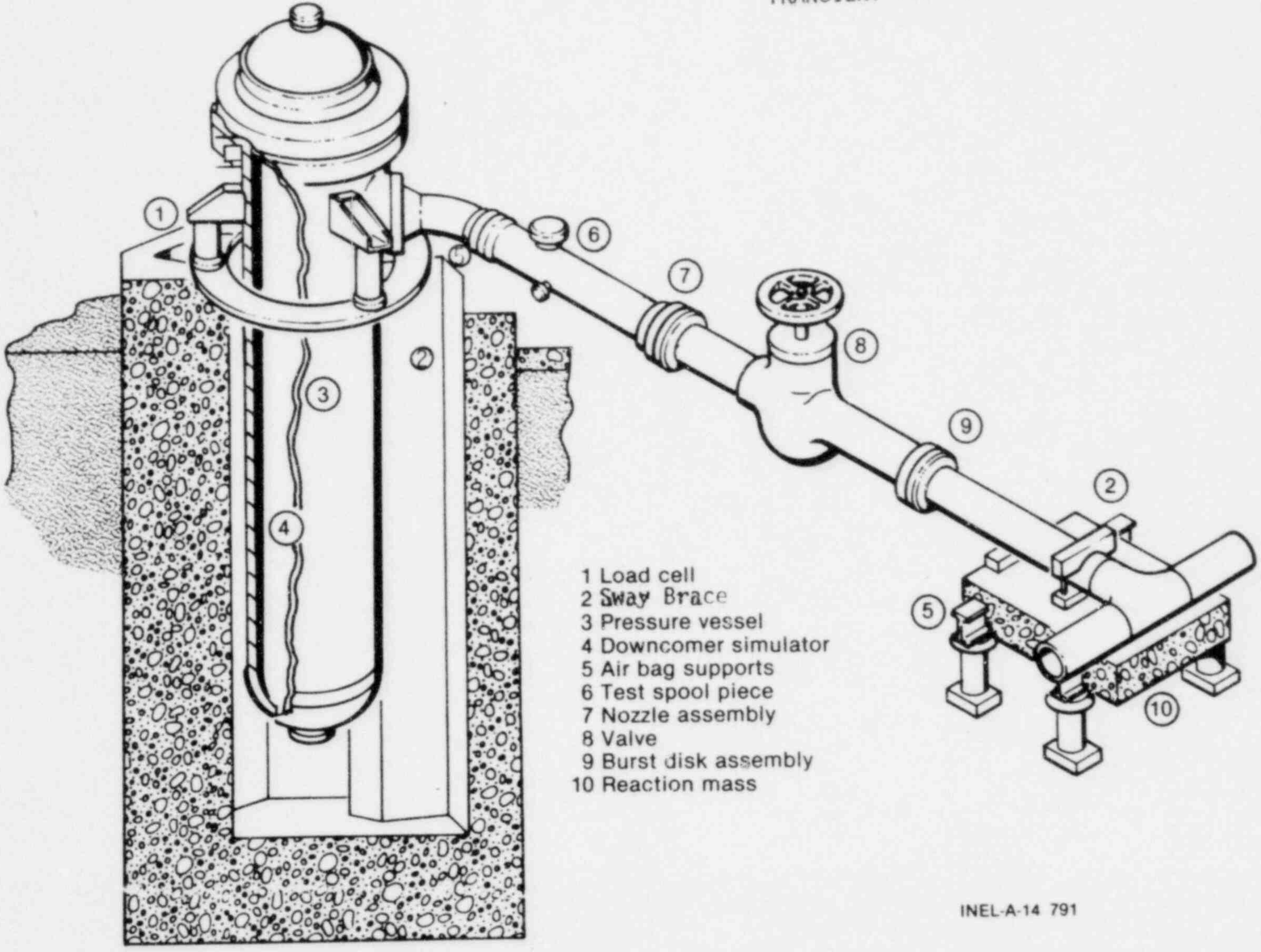
Test Number	0-10	10-20	20-25	25-40	40-60
IA101	175.7	128.9	59.6	18.2	3.6
IA102	188.0	126.3	83.7	28.5	2.6
IA103	175.6	130.1	83.7	30.8	4.0
IA1 Series (Avg)	179.8	128.4	75.7	25.8	3.4
IA201	178.2	129.5	85.9	29.5	3.5
IA202	169.4	130.3	74.2	24.9	2.6
IA2 Series (Avg)	173.8	129.9	80.1	27.2	3.1

C. % OF RD UNCERTAINTY IN MASS FLOW

TIME INTERVALS (SECONDS)

Test Number	0-10	10-20	20-25	25-40	40-60
IA101	11	7	29	57	58
IA102	11	7	21	36	81
IA103	11	7	21	33	53
IA1 Series (Avg)	11	7	23	40	62
IA201	13	6	19	17	54
IA202	13	6	22	20	73
IA2 Series (Avg)	13	6	21	18	61
Mean	12	7	23	32	63

SCHEMATIC OF WYLE
TRANSIENT TEST SYSTEM



1 Load cell
2 Sway Brace
3 Pressure vessel
4 Downcomer simulator
5 Air bag supports
6 Test spool piece
7 Nozzle assembly
8 Valve
9 Burst disk assembly
10 Reaction mass

INEL-A-14 791

FIGURE 1

FLOW CHART OF DATA PROCESSING

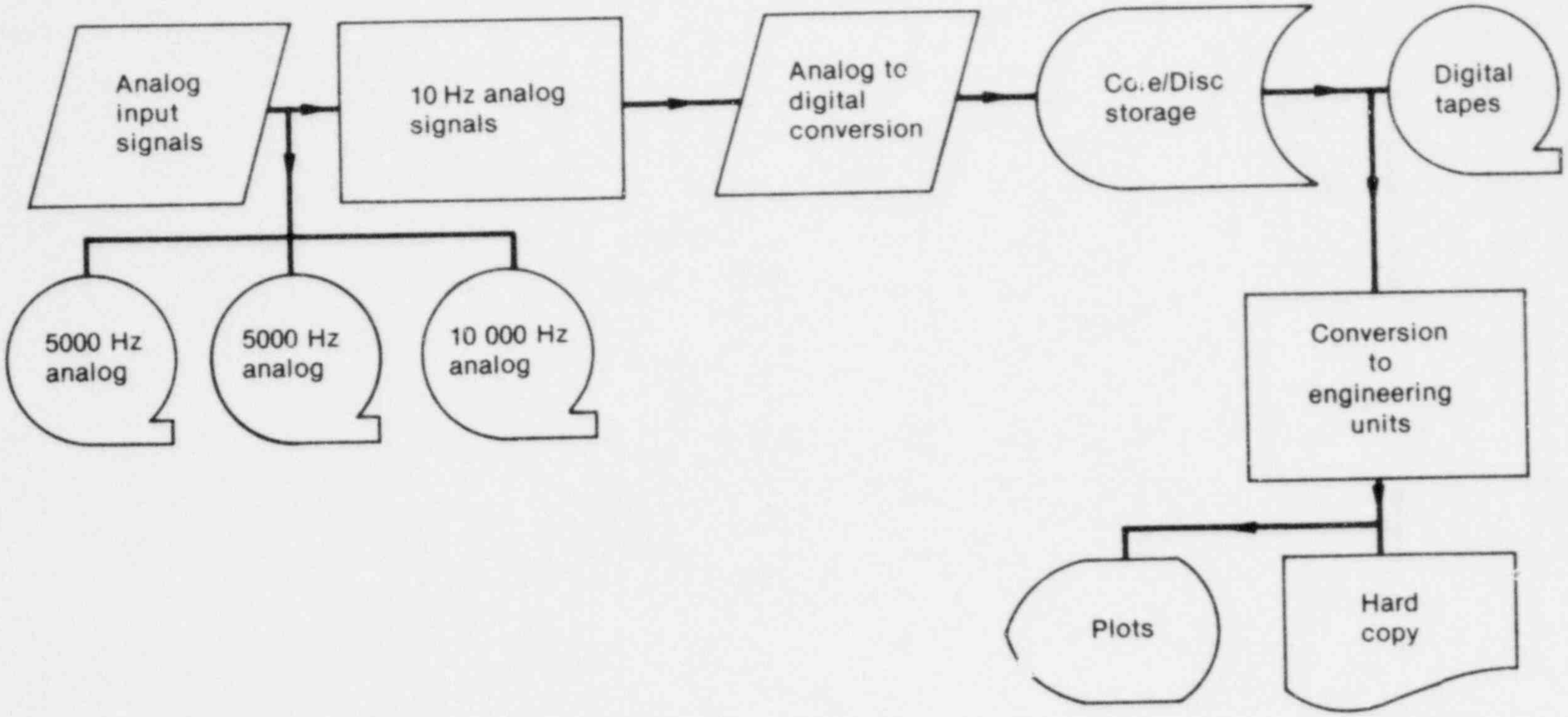


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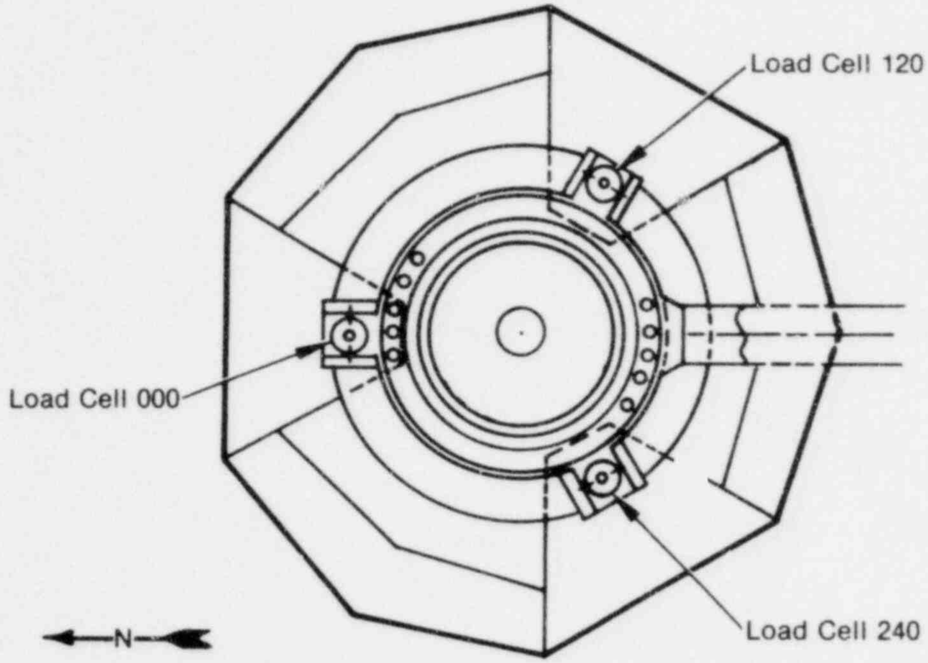
FIGURE 2

OVERHEAD VIEW OF LOAD CELL POSITIONS



Overhead view of load cell positions

INEL-A-14 802

FIGURE 3

WYLE LOAD CELL CAL SUM OF LOAD
CELLS VERSUS REF MASS

10-8-79

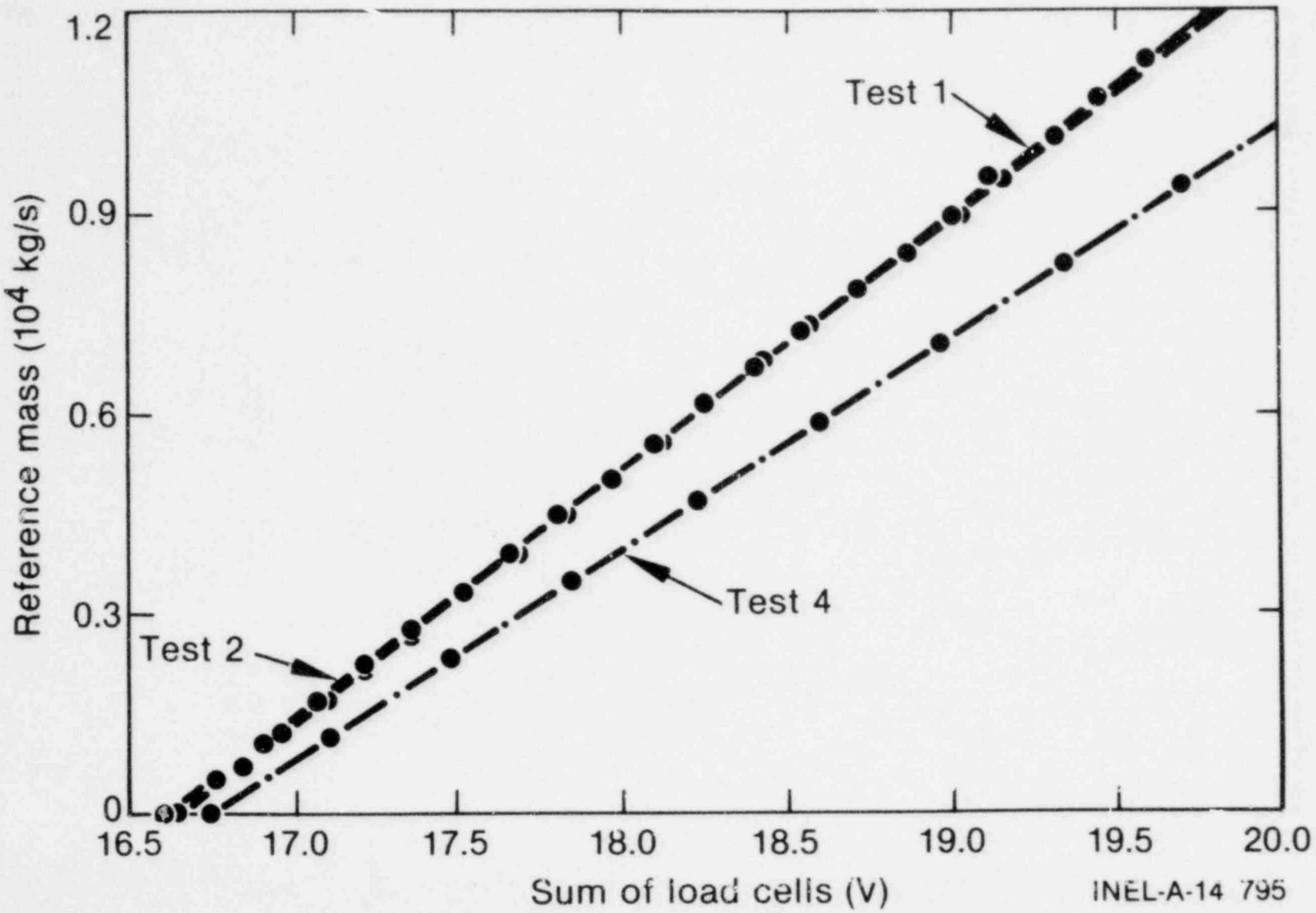


FIGURE 4

WYLE LONG TERM DRIFT TEST
SUM OF LOAD CELLS VERSUS REF MASS

11-28-79

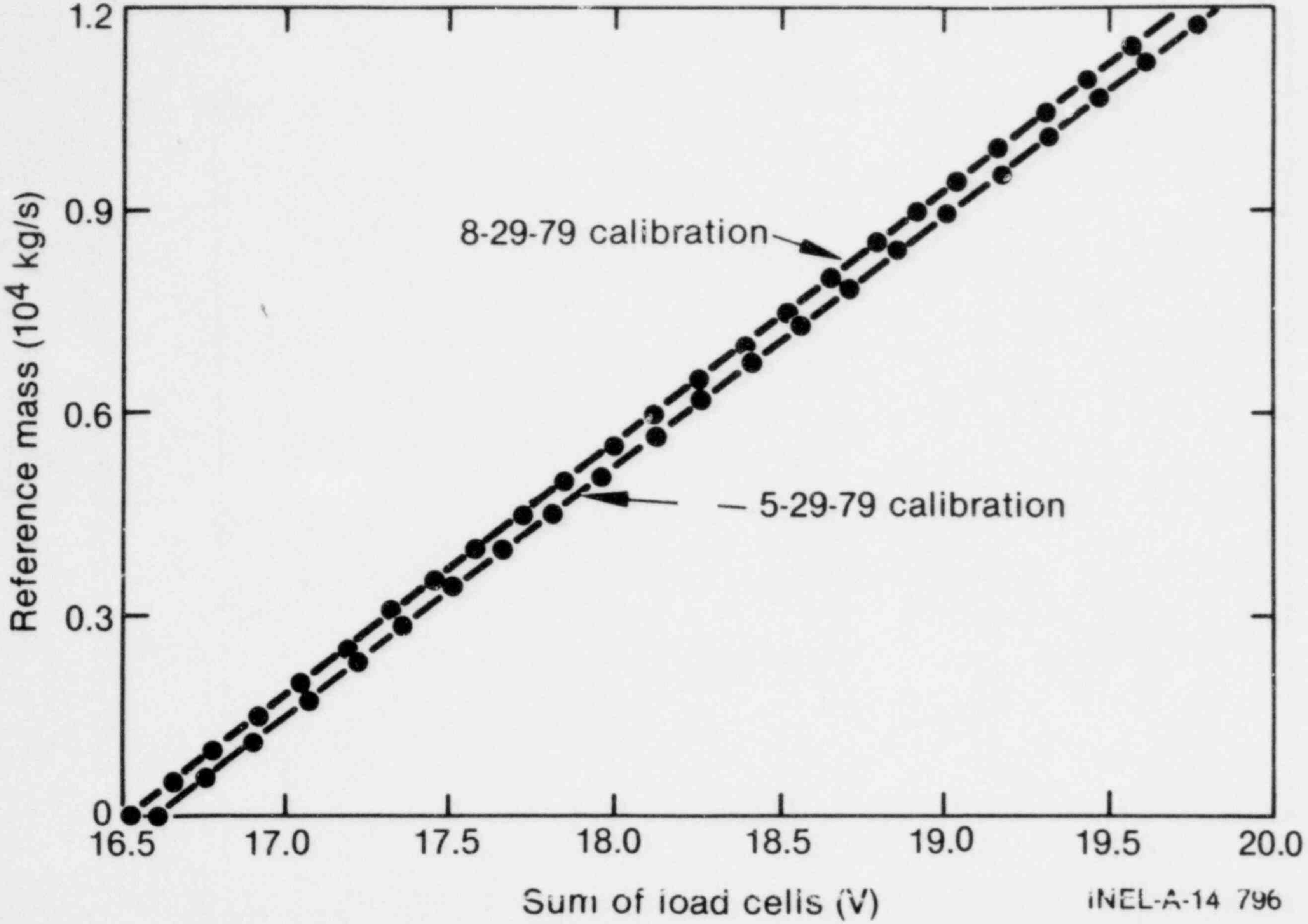


FIGURE 5

WYLE LOAD CELL PRESSURE SENSITIVITY
HYDRO

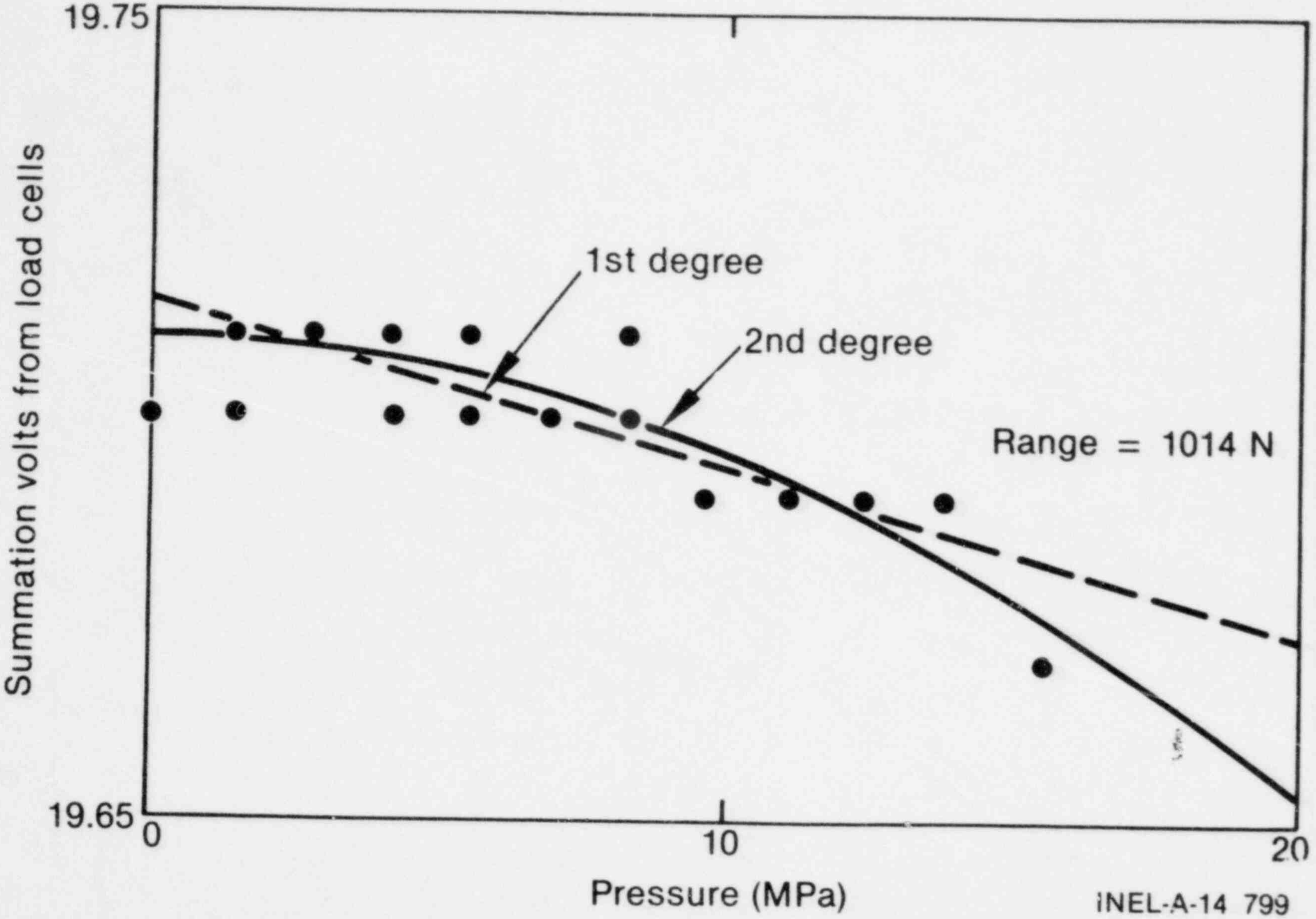


FIGURE 6

8-22-79

WYLE LOAD CELL PRESSURE SENSITIVITY

IB2SP01

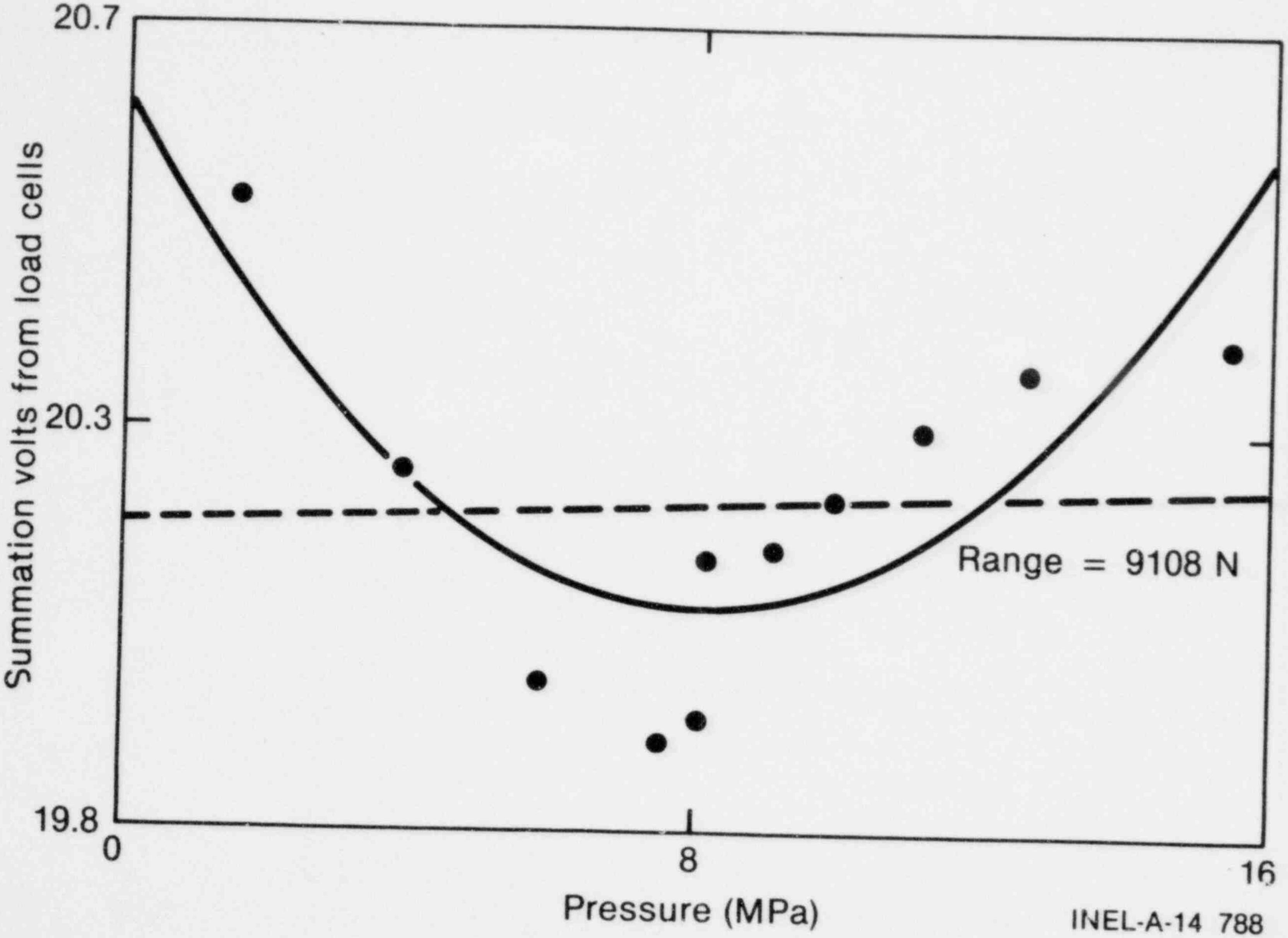


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FIGURE 7

TYPICAL LOAD CELL BLOWDOWN
VOLTAGE TRACE

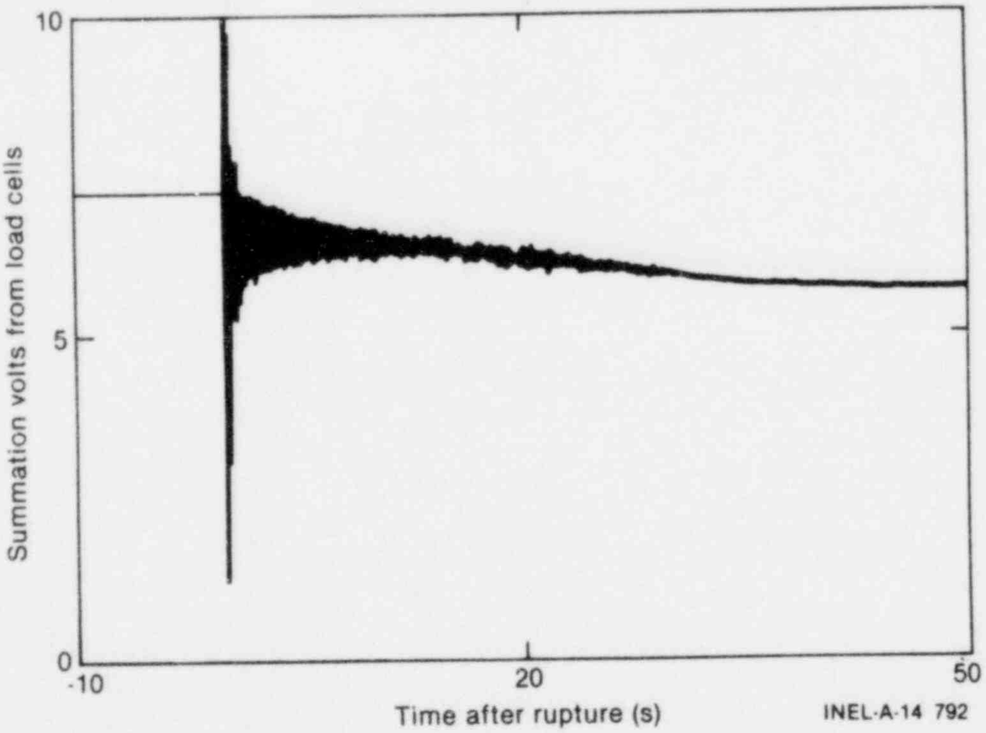


FIGURE 8

9-5-79

WYLE LOAD CELL PRESSURE SENSITIVITY
HYDRO

(SWAY BRACE REMOVED)

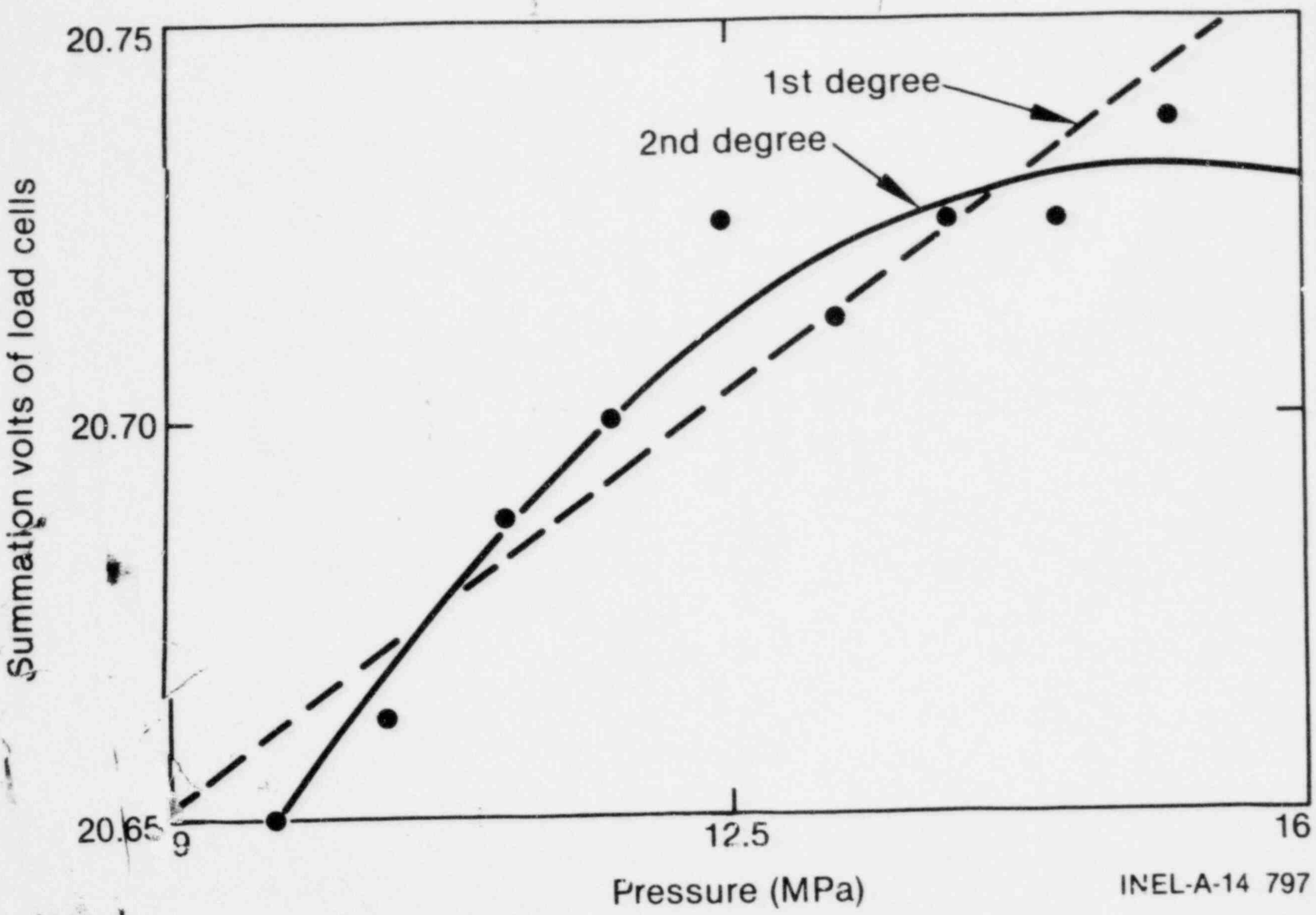


FIGURE 9

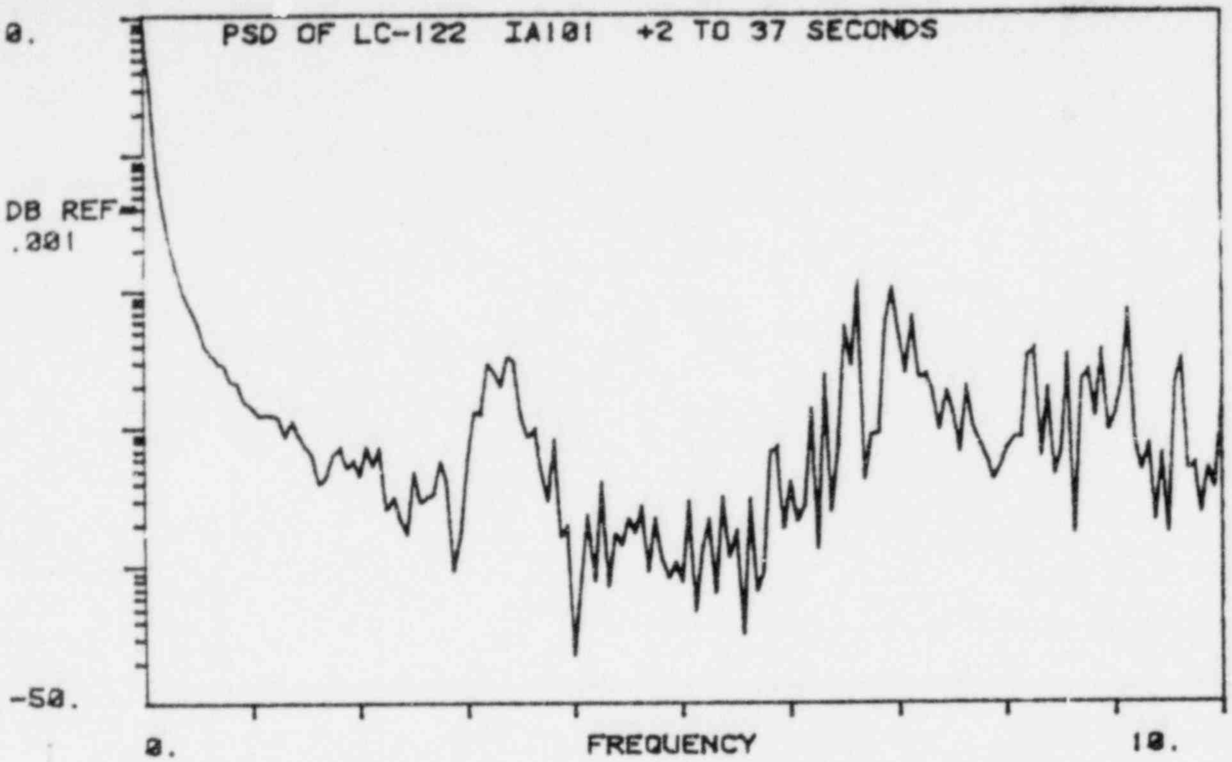


FIGURE 10

SAMPLING FREQUENCY = 32. E0. FILTER FREQUENCY =10.
FRAME COUNT = 2. APS ACCURACY = +-70.71%
INPUT RANGE = +-4.VOLTS RESOLUTION =.0625 HZ/LINE

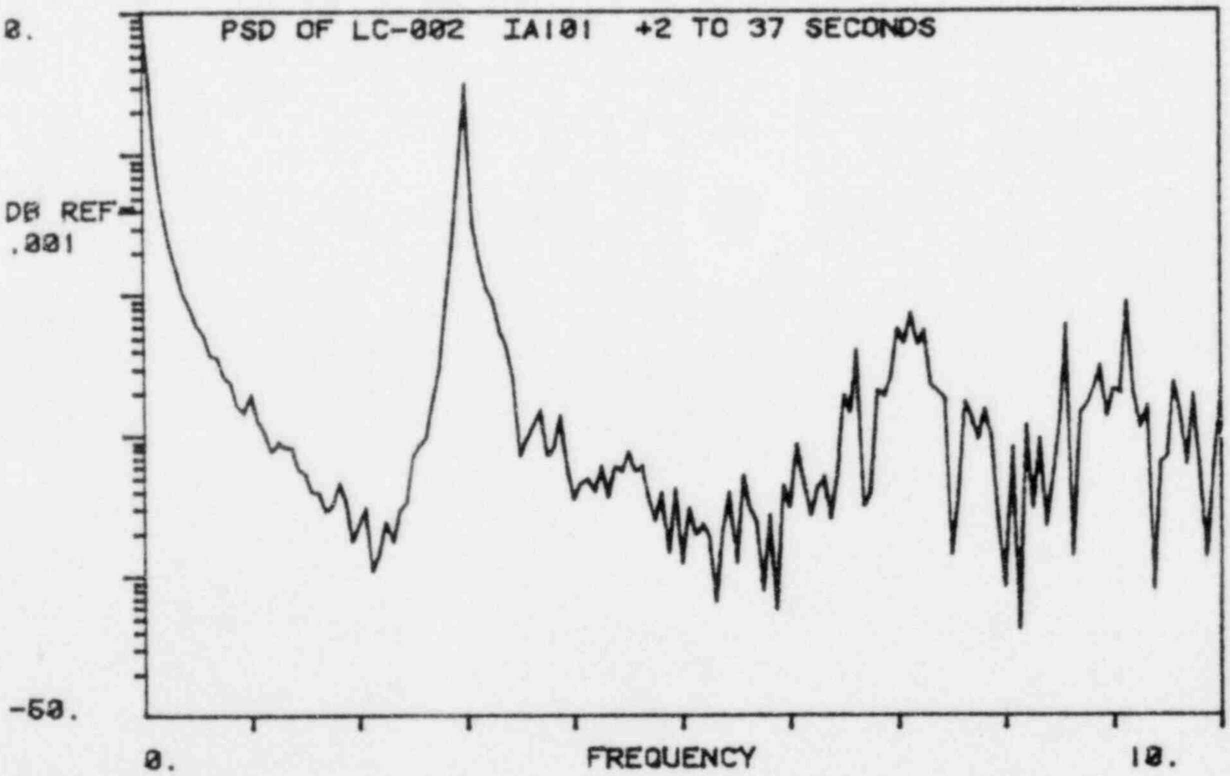


FIGURE 11

SAMPLING FREQUENCY = 32. E0. FILTER FREQUENCY =10.
FRAME COUNT = 2. APS ACCURACY = +-70.71%
INPUT RANGE = +-4.VOLTS RESOLUTION =.0625 HZ/LINE

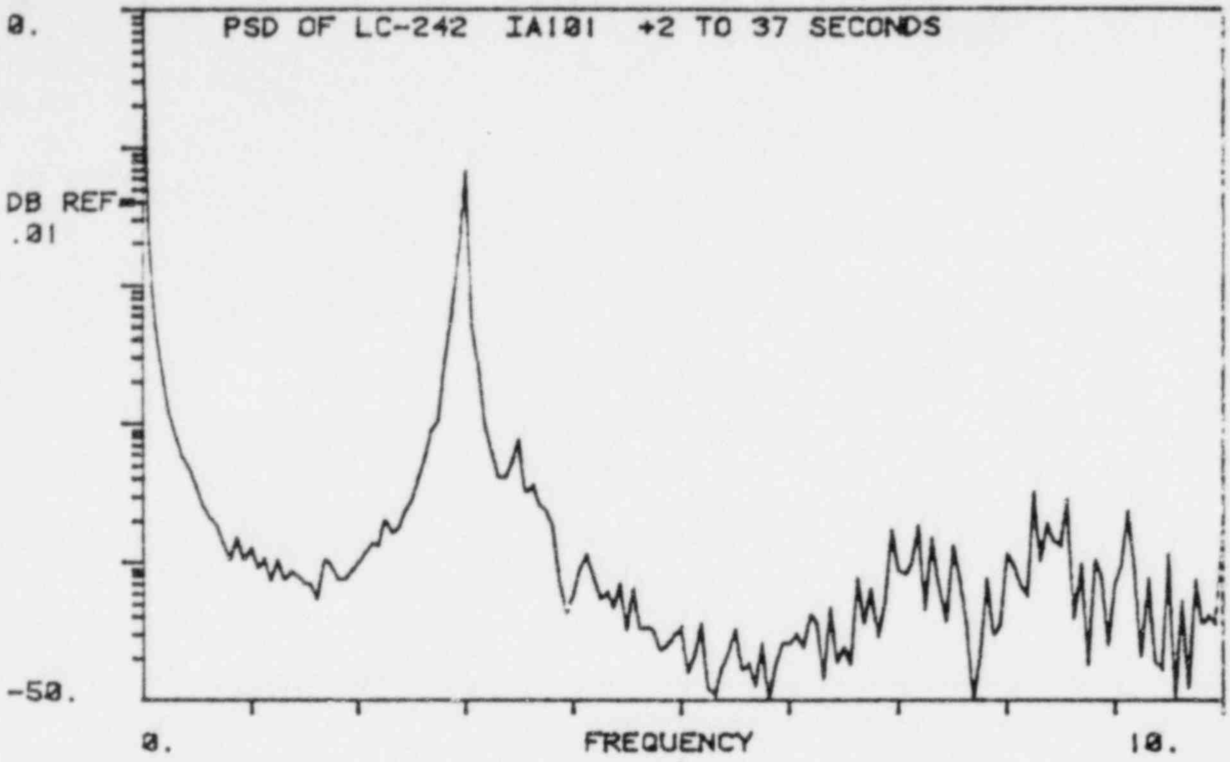


FIGURE 12

SAMPLING FREQUENCY = 32. E0. FILTER FREQUENCY =10.
FRAME COUNT = 2. APS ACCURACY = +-70.71%
INPUT RANGE = +-4.VOLTS RESOLUTION =.0625 HZ/LINE

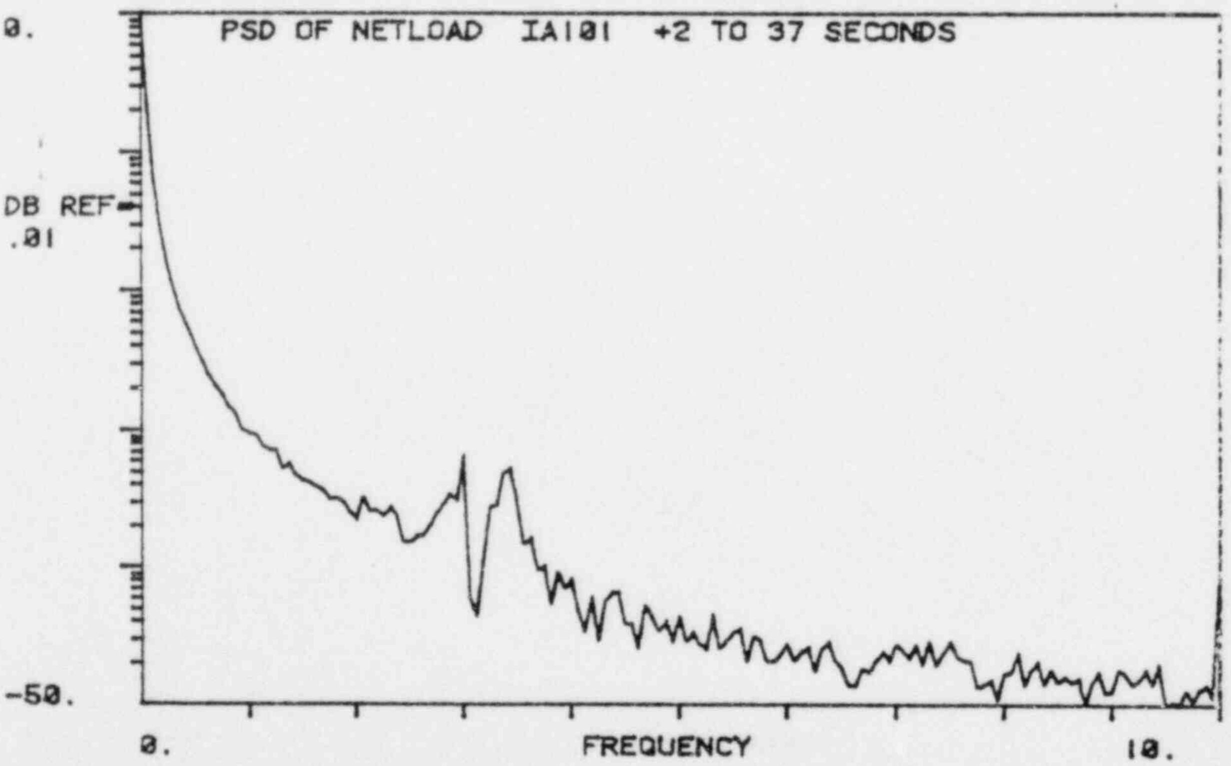
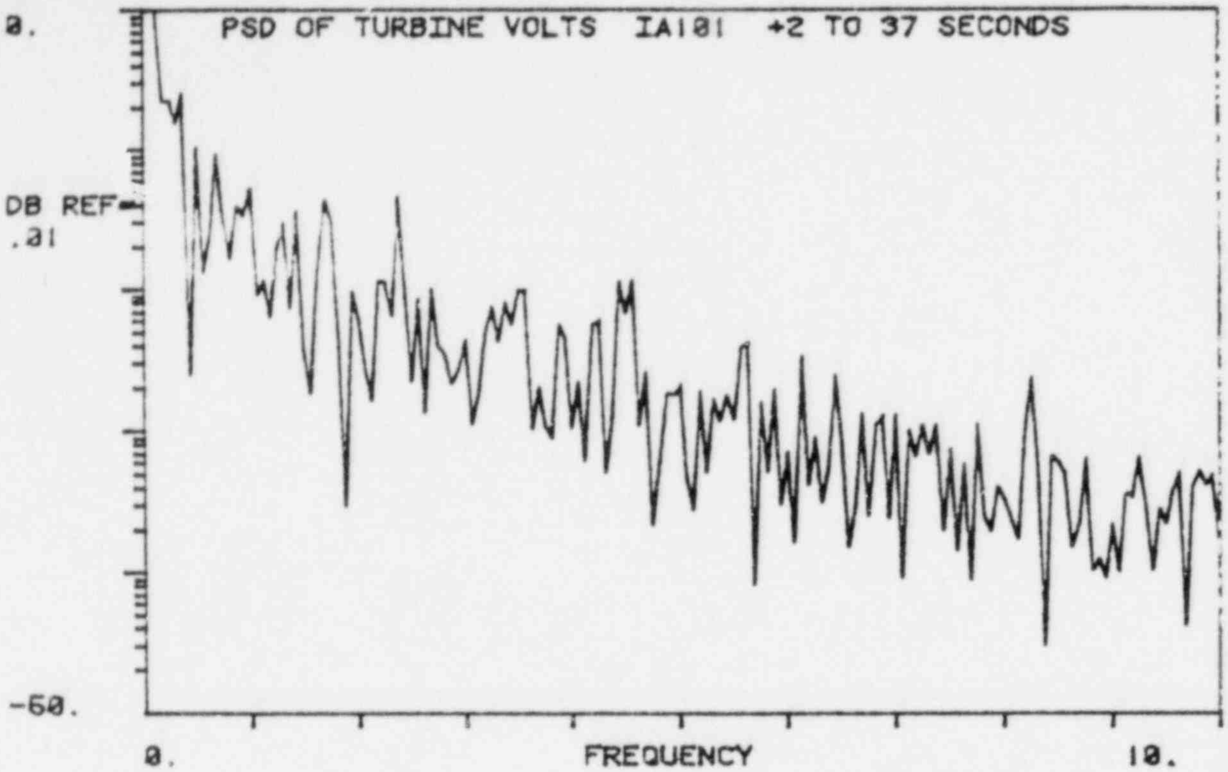


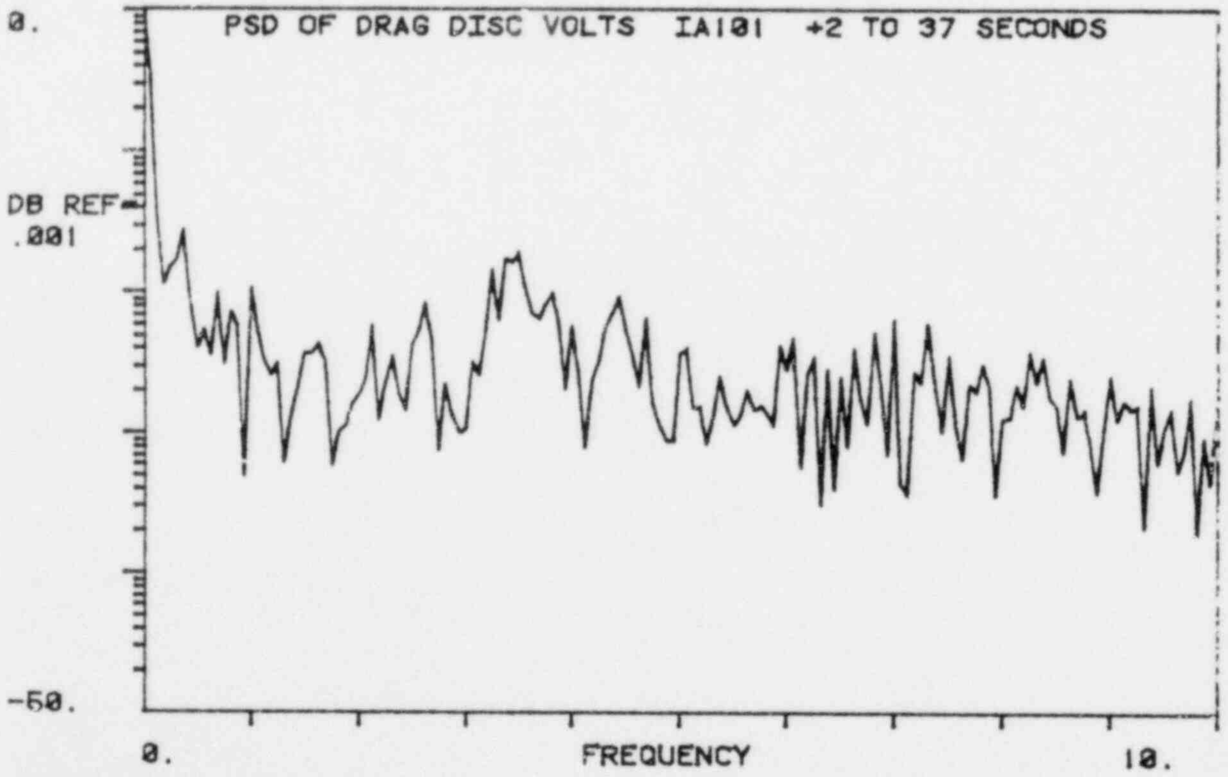
FIGURE 13

SAMPLING FREQUENCY = 32. E0. FILTER FREQUENCY =10.
FRAME COUNT = 2. APS ACCURACY = +-70.71%
INPUT RANGE = +-4.VOLTS RESOLUTION =.0625 HZ/LINE


PSD OF TURBINE VOLTS IA101 +2 TO 37 SECONDS

SAMPLING FREQUENCY = 32. E0. FILTER FREQUENCY =10.
FRAME COUNT = 2. APS ACCURACY = +-70.71%
INPUT RANGE = +-4.VOLTS RESOLUTION =.0625 HZ/LINE

FIGURE 14


PSD OF DRAG DISC VOLTS IA101 +2 TO 37 SECONDS

SAMPLING FREQUENCY = 32. E0. FILTER FREQUENCY =10.
FRAME COUNT = 2. APS ACCURACY = +-70.71%
INPUT RANGE = +-4.VOLTS RESOLUTION =.0625 HZ/LINE

FIGURE 15

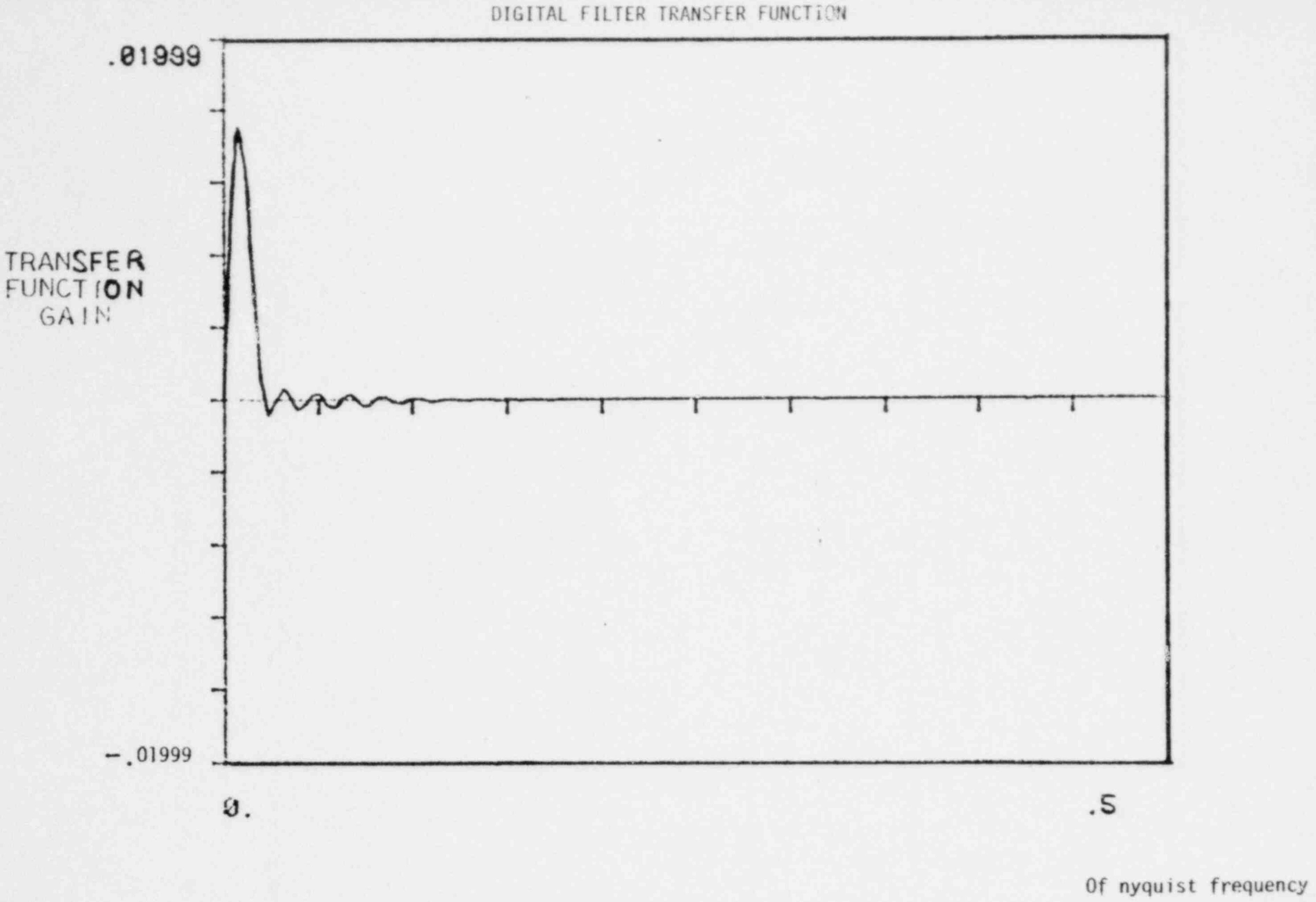

DIGITAL FILTER TRANSFER FUNCTION
.01999
TRANSFER FUNCTION GAIN
-.01999
0.
.5
Of nyquist frequency

FIGURE 16

OVERLAY OF WYLE IA1 SERIES
(3 TESTS)

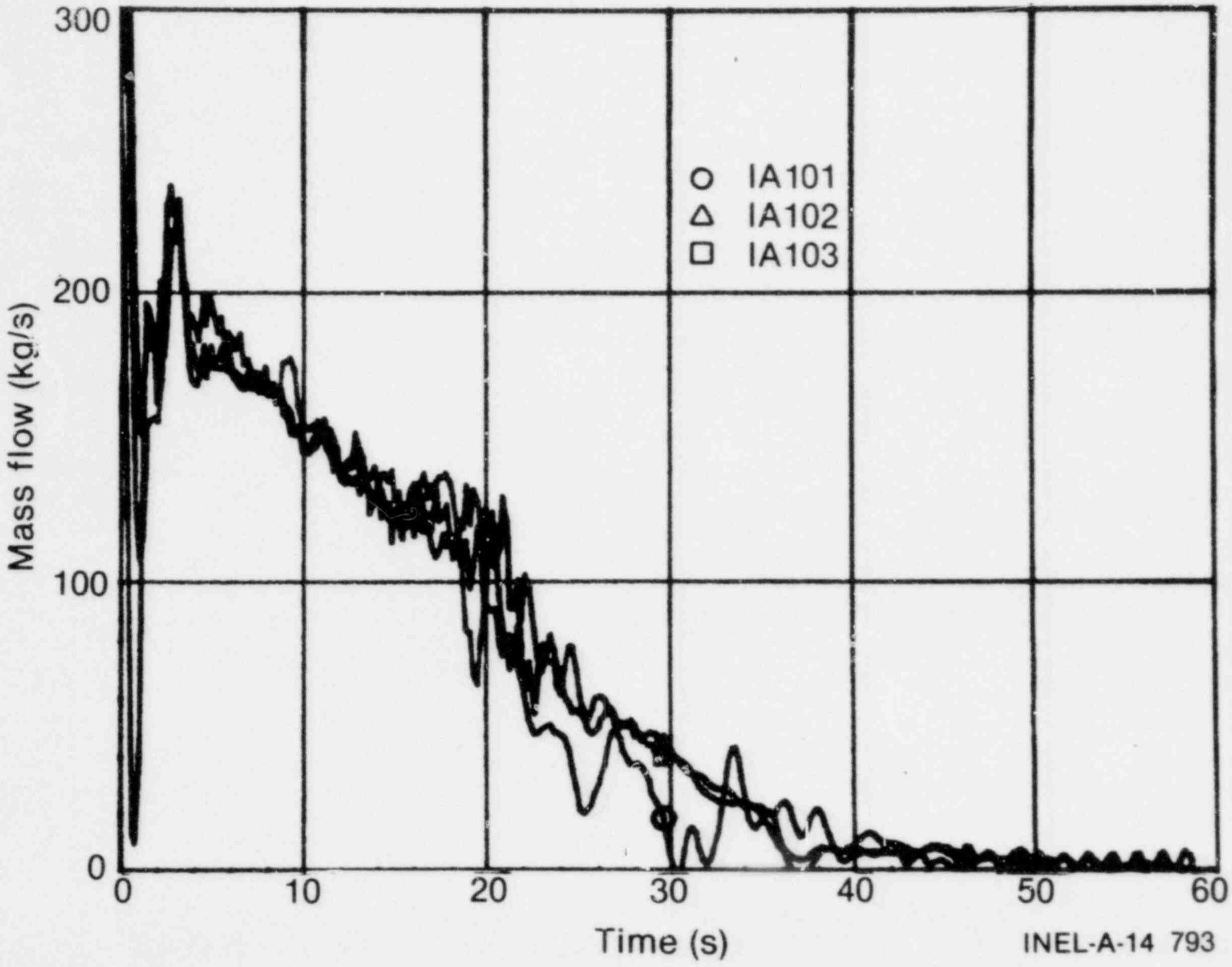


FIGURE 17

WYLE IA1 SERIES
(3 TESTS)

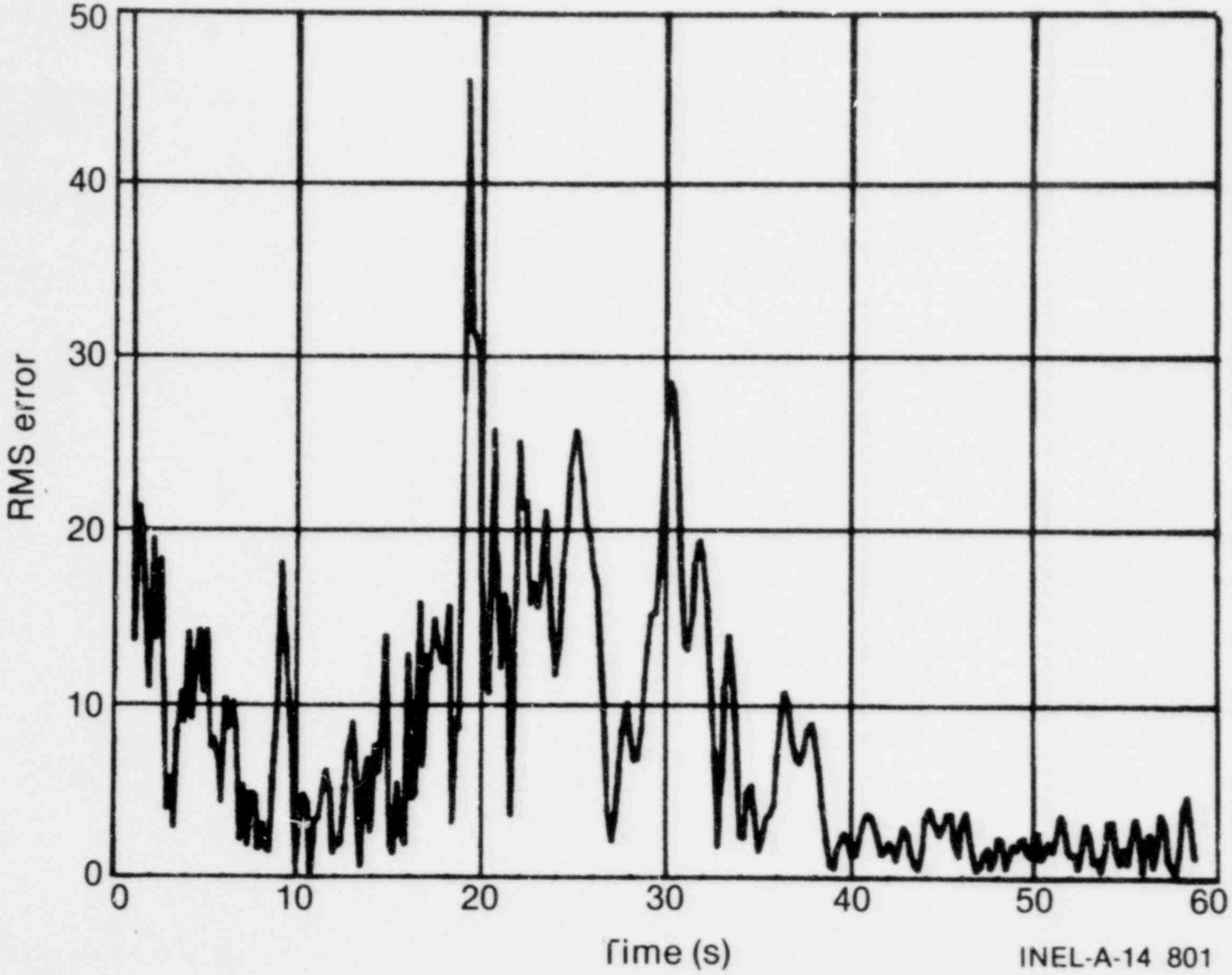


FIGURE 18

WYLE VESSEL

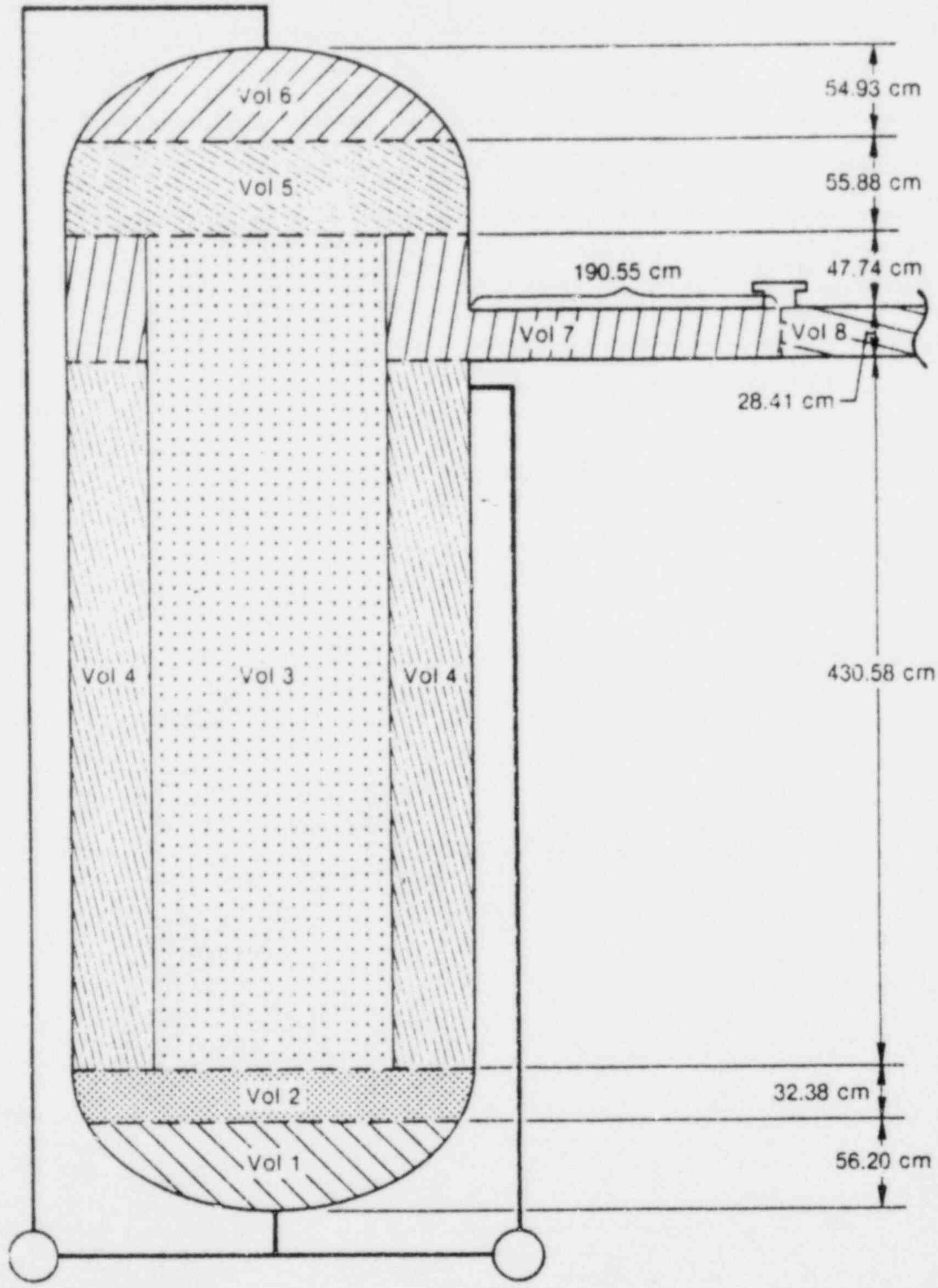


FIGURE 19

VII. REFERENCES

1. D. L. Reeder, LOFT System and Test Description (5.5 ft Nuclear Core 1 LOCEs), NUREG/CR-0247, TREE-1208 (July 1978).

2. Jacqui Wambach et al., Wyle Transient Test EDR (December 1979).

3. John Martinell et al., "Performance Assessment of Mass Flow Rate Measurement Capabilities in the Large Scale Transient Two-Phase Flow Test System," 2nd Multiphase Flow and Heat Transfer Workshop, Miami, Florida, April 1979.

4. R. W. Hamming, Digital Filters, Prentice Hall, Inc. 1977.

APPENDIX A

LOAD CELL SPECIFICATIONS

interface
ADVANCED FORCE MEASUREMENT

CALCULATED NATURAL FREQUENCIES (AXIAL) FOR INTERFACE LOAD CELLS

	MODEL	NATURAL FREQUENCIES (H_z)	
	1010-500	6950	H_z
	1010-1K	9850	"
	1010-2.5K	6600	"
	1010-5K	9350	"
	1020-12.5K	6450	"
	1020-25K	7000	"
	1032-50K	5800	"
	1040-100K	4950	"
	1110-1K	6950	"
	1110-2K	9850	"
	1110-5K	6600	"
	1110-10K	9350	"
	1120-25K	6450	"
	1120-50K	7000	"
	1111-1K	6350	"
	1111-2K	9000	"
	1111-5K	6050	"
	1111-10K	8600	"
	1121-25K	5850	"
	1121-50K	6550	"
	1210-1K	6950	"
	1210-2K	9850	"
	1210-5K	6600	"
	1210-10K	9350	"
Model Used	1220-25K	6450	"
	1220-50K	7000	"
	1232-100K	5800	"
	1240-200K	4950	"
	MB-5	950	"
	MB-10	1300	"
	MB-25	2250	"
	MB-50	3300	"
	MB-75	3900	"
	MB-100	4000	"
	MB-150	4750	"
	MB-250	4400	"

MODEL	NATURAL FREQUENCIES (H_z)	
1211-1K	6350	H_z
1211-2K	9000	"
1211-5K	6050	"
1211-10K	8600	"
1221-25K	8200	"
1221-50K	11650	"
1231-100K	7550	"
1241-200K	6700	"
1310-1K	6950	"
1310-2K	9850	"
1310-5K	6600	"
1310-10K	9350	"
1320-25K	6450	"
1320-50K	7000	"
1330-100K	7550	"
1311-1K	6350	"
1311-2K	9000	"
1311-5K	6050	"
1311-10K	8600	"
1321-25K	8200	"
1321-50K	11650	"
1410-50	2550	"
1410-100	3600	"
1420-250	4350	"
1420-500	6000	"
1921-30K	5350	"
SM-10	600	"
SM-25	1000	"
SM-50	1550	"
SM-100	1850	"
SM-250	2350	"
SM-500	2150	"
SM-1000	3350	"
SSM-500	2150	"
SSM-1000	3350	"
SSB-100	1750	"
SSB-250	2050	"

2/24/78
RB #31-B

MAXIMUM ERROR BAND, COMPUTED ON A BEST STRAIGHT LINE THROUGH ZERO BASIS, INCLUDING NON-LINEARITY HYSTERESIS AND REPEATABILITY. ±.018 (% Full scale R-cal 6/13)

SYSTEMS CALIBRATION

with DS-300-T2 indicator
S/N 02751
R-cal = 34920 lbs.

Resonant Frequency = 11650 Hz

INTERFACE, INC
7401 EAST BUTHERUS DRIVE • SCOTTSDALE, ARIZONA 85260
TLX 668 394 TELEPHONE 602 - 948-5555 USA

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interface

Load Cell

CALIBRATION CERTIFICATE

L99893

WARRANTY

INSTALLATION INFORMATION

TWO YEAR WARRANTY

Interface, Inc. hereby warrants all products of its manufacture as follows: Commencing with the date of shipment of each load cell to the original purchaser, and for a period expiring two years from said date, Interface, Inc. unconditionally warrants that each unit shall remain free from defects in parts, materials, and workmanship.

The warranties herein shall not obligate Interface, Inc. in any manner whatsoever with respect to, and shall not be applicable to, any defects which after inspection by Interface, Inc. are not to Interface, Inc.'s reasonable satisfaction demonstrably the result of defective parts, materials or workmanship. Interface, Inc. is not liable for consequential damages. All transportation charges for returned merchandise are to be prepaid and borne by customer.

CERTIFICATION

Interface, Inc. certifies that this load cell was thoroughly tested and inspected and found to meet its published specifications when shipped from the factory. Interface, Inc. further certifies that its calibration measurements are traceable to NBS.

INSTALLATION

The load cell should be mounted on a surface which is flat and parallel within 0.0002 T.I.R. for Universal, and within 0.0005 T.I.R. for compression units. It should be mounted to the surface with grade 8 bolts evenly tightened to the following torques:

Bolt Size	8-32	10-32	1/4-28
Installation Torque (ft.-lbs.)	2	4	5 (Alum. Load Cell) 10 (Steel Load Cell)

Bolt Size	5/16-24	3/8-24	7/16-20	5/8-18
Installation Torque (ft.-lbs.)	25	55	100	300

The load cell matching thread should be class 3.

Customer Wyle Laboratories

Sales Order 9743 Model 1221-32

Purchase Order

CALIBRATION

Bridge* A Date 12-15-78

Range 50,000 lbs. Serial No. 12291

Input Resistance	367.2 ohms
Output Resistance	350.7 ohms
Recommended Excitation	10 VDC or VAC
Maximum Excitation	20 VDC or VAC
Non-Linearity (terminal)	REFER TO % FS
Hysteresis	"NOTES" % FS
Compensated Temp. Range	+15 °F to +115 °F
Thermal Zero Shift	.0008 % FS/°F
Zero Balance	.04 % FS
Tension Output	— MV/V
Compression Output	4.002 MV/V

WIRING

Function	Pin	Pigtail
+ Excitation		RED - WH/RED
+ Output		WH - WH/YEL.
— Output		GRN
— Excitation		BLK - WH/BLK
Shield		

Polarity shown results in positive output for:

(compression) (~~tension~~)

SHUNT CALIBRATION

— ohms – Exc. to – Out. — lbs.

30K to .01% WH/RED - WH/YEL. ~~ohms + Exc. to + Out.~~ 34551.9 lbs.

Calibrated by

*For multiple bridge load cells.

MAXIMUM ERROR BAND, COMPUTED ON A BEST STRAIGHT LINE THROUGH ZERO BASIS, INCLUDING NON-LINEARITY HYSTERESIS AND REPEATABILITY. +.026

SYSTEMS CALIBRATION

with DS-300-T2 indicator

S/N 62751

R-cal. = 34930

INTERFACE, INC

7401 EAST BUTHERUS DRIVE • SCOTTSDALE, ARIZONA 85260

TLX 668-394 TELEPHONE 602 - 948-5555 USA

---

interface

Load Cell

CALIBRATION CERTIFICATE

L99894

WARRANTY

INSTALLATION INFORMATION

TWO YEAR WARRANTY

Interface, Inc. hereby warrants all products of its manufacture as follows: Commencing with the date of shipment of each load cell to the original purchaser, and for a period expiring two years from said date, Interface, Inc. unconditionally warrants that each unit shall remain free from defects in parts, materials, and workmanship.

The warranties herein shall not obligate Interface, Inc. in any manner whatsoever with respect to, and shall not be applicable to, any defects which after inspection by Interface, Inc. are not to Interface, Inc.'s reasonable satisfaction demonstrably the result of defective parts, materials or workmanship. Interface, Inc. is not liable for consequential damages. All transportation charges for returned merchandise are to be prepaid and borne by customer.

CERTIFICATION

Interface, Inc. certifies that this load cell was thoroughly tested and inspected and found to meet its published specifications when shipped from the factory. Interface, Inc. further certifies that its calibration measurements are traceable to NBS.

INSTALLATION

The load cell should be mounted on a surface which is flat and parallel within 0.0002 T.I.R. for Universal, and within 0.0005 T.I.R. for compression units. It should be mounted to the surface with grade 8 bolts evenly tightened to the following torques:

Bolt Size	8-32	10-32	1/4-28
Installation Torque (ft.-lbs.)	2	4	5 (Alum. Load Cell) 10 (Steel Load Cell)

Bolt Size	5/16-24	3/8-24	7/16-20	5/8-18
Installation Torque (ft.-lbs.)	25	55	100	300

The load cell mating thread should be class 3.

Customer Wyle Laboratories
Sales Order 9745 Model 1221-32

Purchase Order

CALIBRATION

Bridge* A Date 12-19-78
Range 50,000 lbs. Serial No. 12292

Input Resistance	367.4	ohms
Output Resistance	350.7	ohms
Recommended Excitation	10	VDC or VAC
Maximum Excitation	20	VDC or VAC
Non-Linearity (terminal)	REFER TO	% FS
Hysteresis	"NOTES"	% FS
Compensated Temp. Range	+15 °F to +115 °F	
Thermal Zero Shift	.0008	% FS/°F
Zero Balance	.13	% FS
Tension Output	—	MV/V
Compression Output	4.000	MV/V

WIRING

Function	Pin	Pigtail
+ Excitation		RED-WH/RED
+ Output		WH-WH/GR.
— Output		GRN
— Excitation		BLK-WH/BLK
Shield		

Polarity shown results in positive output for:

(compression) (~~tension~~)

SHUNT CALIBRATION

— ohms – Exc. to – Out. — lbs.
30K to 0.01% WH/RED-WH/GR. ~~ohms – Exc. to – Out.~~ 34637.3 lbs

Calibrated by

*For multiple bridge load cells.

BAND, COMPUTED ON A
BEST STRAIGHT LINE THROUGH ZERO BASIS,
INCLUDING NONLINEARITY HYSTERESIS AND
REPEATABILITY, ± .05

SYSTEMS CALIBRATION

with DS-300-T2 indicator

S/N 62751

R-cal = 34830 lbs

INTERFACE, INC

7401 EAST BUTHERUS DRIVE • SCOTTSDALE, ARIZONA 85260

TLX 668-394 TELEPHONE 602 - 948-5555 USA

---

interface

Load Cell

CALIBRATION CERTIFICATE

L99395

WARRANTY

INSTALLATION INFORMATION

TWO YEAR WARRANTY

Interface, Inc. hereby warrants all products of its manufacture as follows: Commencing with the date of shipment of each load cell to the original purchaser, and for a period expiring two years from said date, Interface, Inc. unconditionally warrants that each unit shall remain free from defects in parts, materials, and workmanship.

The warranties herein shall not obligate Interface, Inc. in any manner whatsoever with respect to, and shall not be applicable to, any defects which after inspection by Interface, Inc. are not to Interface, Inc.'s reasonable satisfaction demonstrably the result of defective parts, materials or workmanship. Interface, Inc. is not liable for consequential damages. All transportation charges for returned merchandise are to be prepaid and borne by customer.

CERTIFICATION

Interface, Inc. certifies that this load cell was thoroughly tested and inspected and found to meet its published specifications when shipped from the factory. Interface, Inc. further certifies that its calibration measurements are traceable to NBS.

INSTALLATION

The load cell should be mounted on a surface which is flat and parallel within 0.0002 T.I.R. for Universal, and within 0.0005 T.I.R. for compression units. It should be mounted to the surface with grade 8 bolts evenly tightened to the following torques:

Bolt Size	8-32	10-32	1/4-28
Installation Torque (ft.-lbs.)	2	4	5 (Alum. Load Cell) 10 (Steel Load Cell)

Bolt Size	5/16-24	3/8-24	7/16-20	5/8-18
Installation Torque (ft.-lbs.)	25	55	100	300

The load cell mating thread should be class 3.

Customer WYLE LABORATORIES

Sales Order 4743 Model 1221-JZ

Purchase Order

CALIBRATION

Bridge* A Date 12-20-78

Range 50000 lbs. Serial No. 12283

Input Resistance 368.6 ohms

Output Resistance 350.9 ohms

Recommended Excitation 10 VDC or VAC

Maximum Excitation 20 VDC or VAC

Non-Linearity (terminal) REFER TO % FS

Hysteresis "NOTES" % FS

Compensated Temp. Range +15 °F to +115 °F

Thermal Zero Shift .0008 % FS/°F

Zero Balance .05 % FS

Tension Output —— MV/V

Compression Output 4.000 MV/V

WIRING

Function	Pin	Pigtail
+ Excitation	——	RED - WHT/RED
+ Output	——	WHT - WHT/YEL
— Output	——	GRN
— Excitation	——	BLK - WHT/BLK
Shield		

Polarity shown results in positive output for:

(compression) ~~(tension)~~

SHUNT CALIBRATION

—— ohms – Exc. to – Out. —— lbs.

301.0 K ohms WHT/RED - WHT/YEL – Exc. to + Out. 34528.5 lbs.

Calibrated by Kevin A. Moore

*For multiple bridge load cells.

APPENDIX B

AIR BAG SPECIFICATIONS

Lord Kinemati

Vibration, Shock, Noise Control Prod

LORD

LTR-87-80-132

Industrial Product Sales

Lord Kinematics
Lord Corporation
2730 West 12th Street
Erie, Pa. 16505
Telephone 800 458-0456
814 456-8511
Telex 914-478

Air Springs
Actuators

REACTION MASS SUPPORT

Pneuride Air-Bellows are effective air springs and air actuators which have numerous industrial applications. Their rugged construction of reinforced neoprene flexing element, sealed with metal end plates, assures reliable long service life even under the most severe conditions. Available in six diameters and one, two, or three convolutions, they meet a wide range of operating conditions. Each size can be used for a variety of loads and disturbing frequencies by varying the air pressure.

Ideal Vibration Isolators

Vibration isolation efficiency ranging to above 99 percent is attainable depending upon the disturbing frequency. They provide protection for adjacent surroundings from machinery shock and vibration, and they protect sensitive machinery from external disturbances. Typical applications for Air Bellows as vibration isolators include machinery mounts, platform vibration isolation systems, and especially systems requiring suspension system with variable frequency. The low natural frequency (95 to 200 cycles per minute) of Air Bellows systems makes them an exceptionally versatile isolator. Special systems can be designed with lower natural frequencies if required.

Effective Actuators

There is no smoother actuator than an Air Bellow. Easily installed and no wearing parts to lubricate or require maintenance. Air Bellows will withstand cocking when inherent in the application thereby eliminating the need for cleves or other misalignment accommodation. The same parts are used for isolators are recommended for actuators. This wide variety make Air Bellows suitable for many industrial applications such as: automatic lift/lower rams, constant load cells, stitching machines and many others.

LORD Lord
Kinematics

TABLE 1

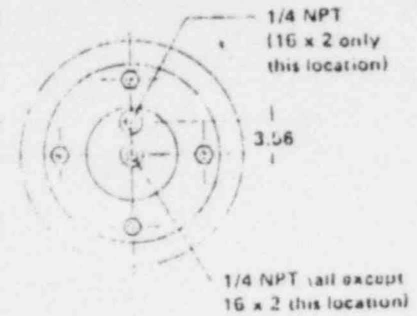
CHARACTERISTICS

	ISOLATOR DATA				ACTUATOR DATA(3)		
Lord Kinematics P/N	Size Dia. (in.) x No. Conv.	Rated Static Load Cap. (lbs.)	(1) Effect. Area ($in.^2$)	(2) Nat. Freq. (cpm)	Max. Recom. Stroke (in.)	Force at Max. Stroke (lbs.)	Force at 1" Stroke (lbs.)
ASA-06C2-1-1	6 x 2	1500	18.8	151	3.5	1200	2230
ASA-08C1-1-1	8 x 1	2125	26.6	178	3.5	1000	3300
ASA-08C2-1-1	8 x 2	2375	29.7	138	6.0	1750	4210
ASA-08C3-1-1	8 x 3	2350	29.4	105	9.5	1300	4350
ASA-10C2-1-1	10 x 2	4200	52.5	117	6.0	3250	6400
ASA-10C3-2-1	10 x 3	3740	46.8	96	10.0	3000	6400
ASA-12C1-1-1 ✓	12 x 1	6500	81.3	148	2.75	5500	9300
ASA-12C2-1-1	12 x 2	6390	79.9	116	6.5	5550	10000
ASA-12C3-1-1	12 x 3	6200	77.5	95	10.0	5500	10000
ASA-14C1-1-1	14-1/2 x 1	9130	114.1	153	4.0	8200	14000
ASA-14C2-1-1	14-1/2 x 2	9540	119.2	110	7.5	8100	14000
ASA-16C2-2-1	16 x 2	11500	143.8	105	7.5	10800	14800

(1) At static height and 80 psi air pressure

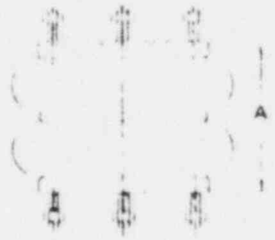
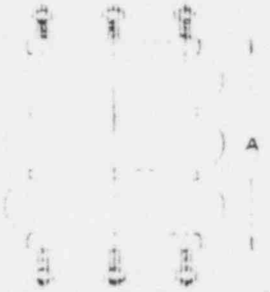
(2) At static height and static load

(3) Based on 100 psi air pressure



Specification and Installation

Air Bellows are available in six diameters and one, two, and three convolution designs. Air supply up to 120 psi is acceptable. Design data is based on 80 psi to the Air Spring or Actuator. Clearance must be allowed for maximum diameter of loaded or retracted Air Bellows. Attachment studs are 3/8-24 UNF by 1 inch long. The air inlet is 1/4 N.P. Air Bellows can be operated with water based fluid (with anti-freeze or rust inhibitor additive) or a brake fluid. Petroleum-based fluids should not be employed.



STABILITY CONSIDERATIONS

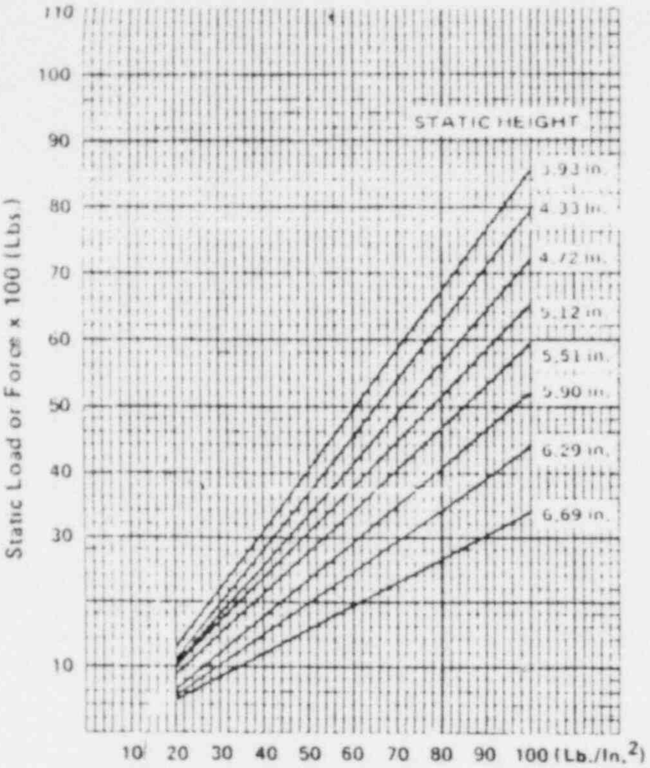
The inherent softness of the Air Bellow isolator makes it necessary to consider the lateral stability of the system. When the center of gravity is very high above the mounting plane, instability might be a problem. For best results, the C.G. should be no higher above the mounting plane than the narrowest mount spacing. It is also important to consider lateral forces present. Air Bellows exhibit a characteristic change in effective area with stroke, decreasing as the static height increases. This effect can be determined from the static load-pressure curves.

TABLE 2

DIMENSIONS

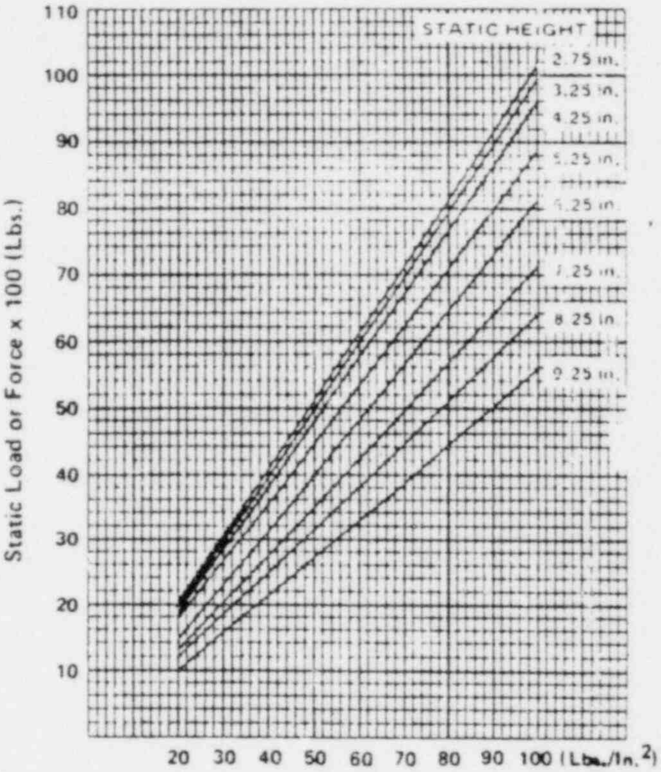
Lord Kinematics P/N	A (1) Static Height (S.H.) (in.)	Max. Height (in.)	Min. Height (in.)	B Max. Dia. Dia. (in.)	C End Plate Dia. (in.)	D Stud Spacing B.C. Dia. (in.)
ASA-06C2-1-1	4.75	6.75	2.75	7	6.00	5.000
ASA-08C1-1-1	3.75	5.75	1.75	9	7.25	6.125
ASA-08C2-1-1	5.75	8.75	2.75	9	7.25	6.125
ASA-08C3-1-1	8.50	13.50	3.50	9	7.25	6.125
ASA-10C2-1-1	6.25	9.50	3.00	11	8.25	7.125
ASA-10C3-2-1	9.25	14.25	3.50	11	8.25	7.125
ASA-12C1-1-1✓	5.00	6.75	4.00	13	10.25	9.125
ASA-12C2-1-1	6.25	9.25	2.75	13	10.25	9.125
ASA-12C3-1-1	8.75	13.75	3.50	13	10.25	9.125
ASA-14C1-1-1	4.25	6.50	2.50	15	12.25	11.125
ASA-14C2-1-1	7.00	11.00	2.75	15	12.25	11.125
ASA-16C2-2-1	7.00	11.00	3.00	17	12.25	11.125

(1) At rated static load

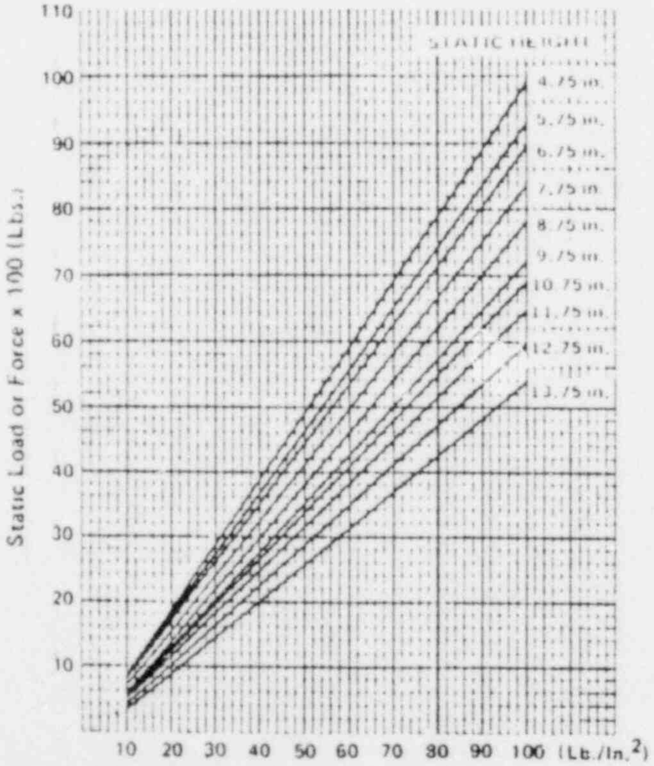


REACTION
MASS
SUPPORT

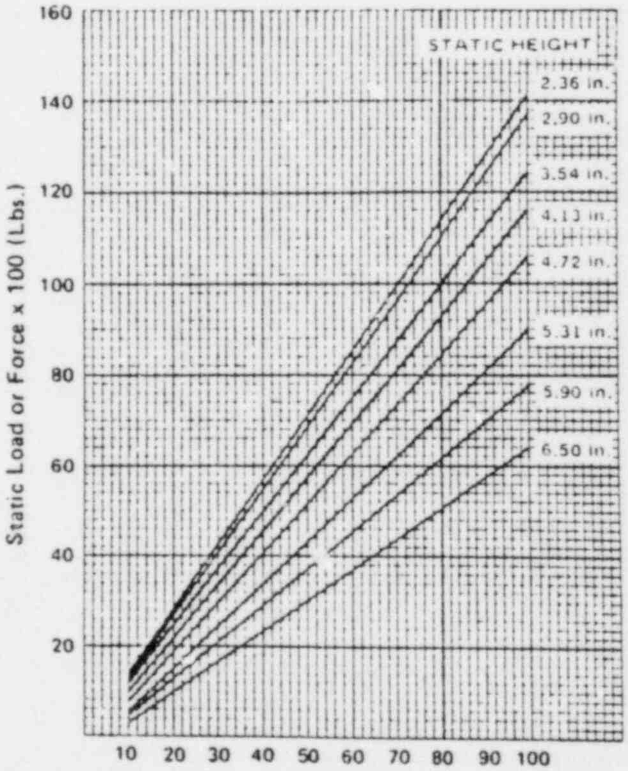
Pressure
12" x 1 Bellow
Lord P/N ASA-12C1-1-1



Pressure
12" x 2 Bellow
Lord P/N ASA-12C2-1-1

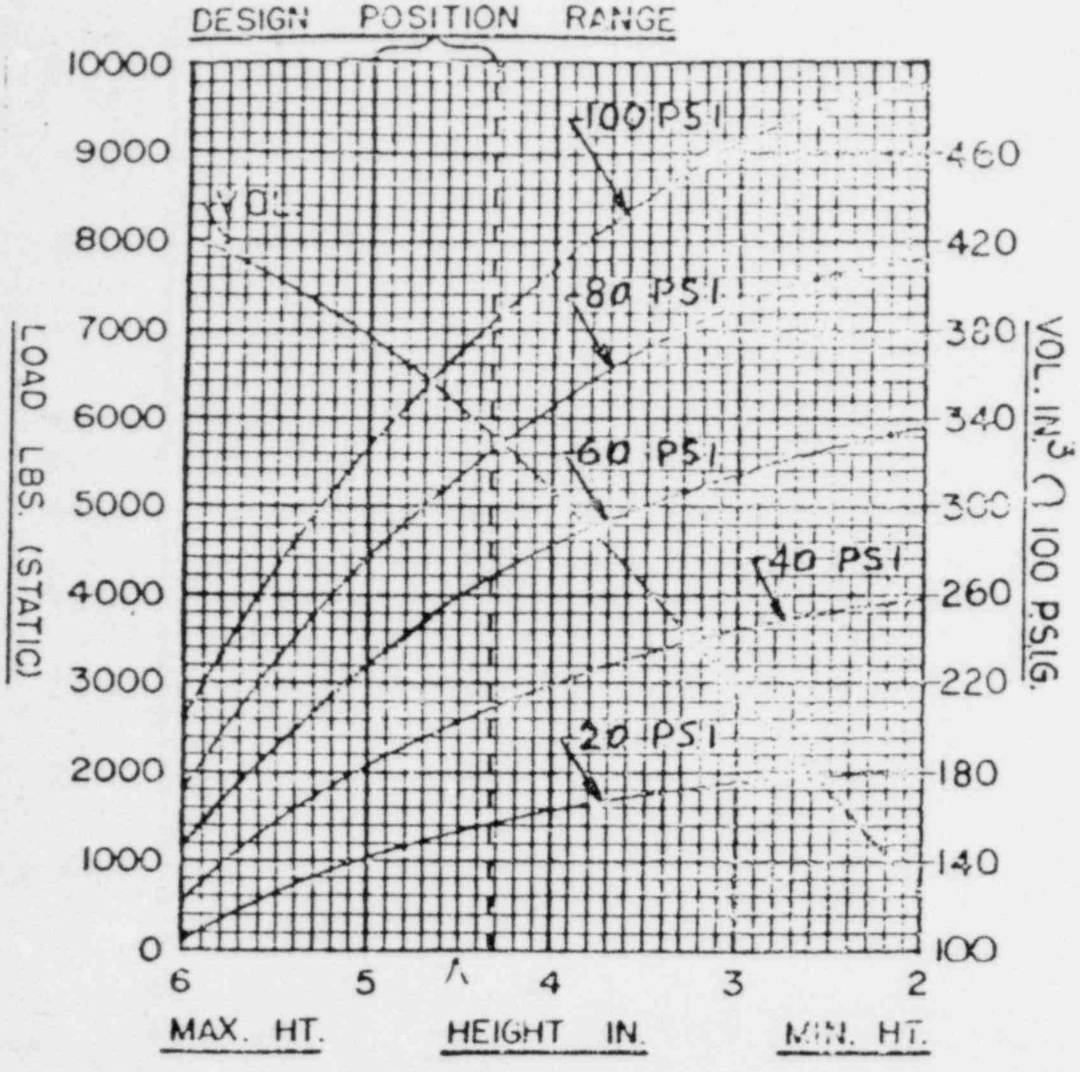


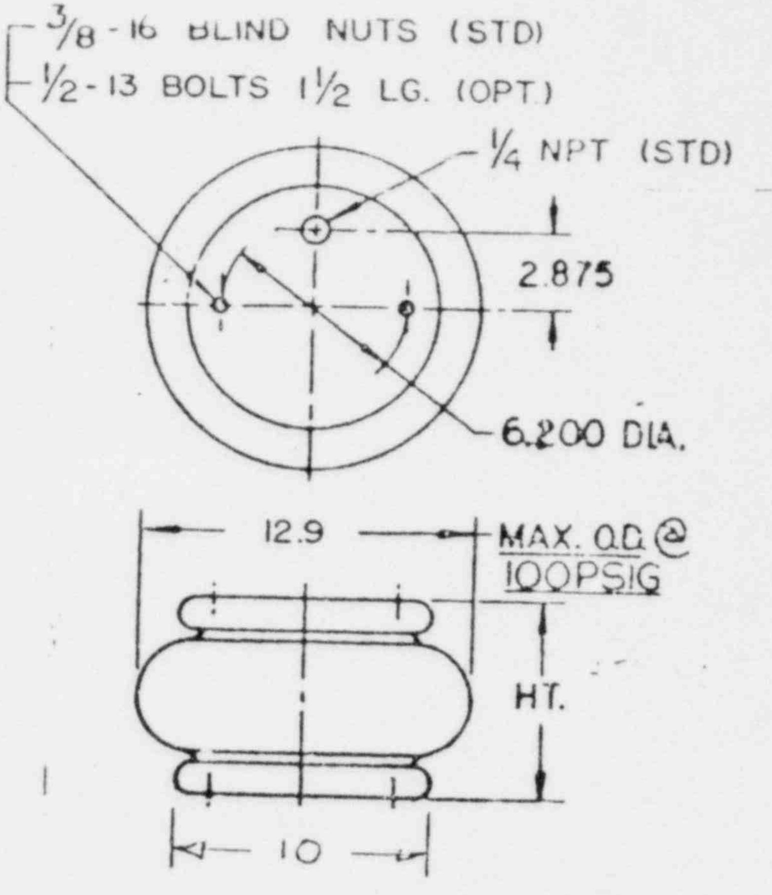
Pressure
12" x 3 Bellow
Lord P/N ASA-12C3-1-1



Pressure
14½" x 1 Bellow
Lord P/N ASA-14C1-1-1

RECOMMENDED DESIGN POSITION
STATIC PRESSURE 0 TO 100 PSI





FIRESTONE
"AIRIDE - AIRMOUNT"
#1 POSITION (@ ROCKY MOUNTAIN PLANT)

19B AIRMOUNT

APPENDIX C

WYLE MASS PROGRAM OUTLINE

PRØGRAM ØUTLINE

I. Start

II. Read in Constants

  A. Slope for load cell calibration equation

  B. Density (KG/m^3) from reference leg of differential pressure (DP)

III. Read in variables

  A. Time

  B. Load cell #1 (volts)

  C. Load cell #2 (volts)

  D. Load cell #3 (volts)

  E. Differential pressure (DP) cell #1 (in / $H_2Ø$)

  F. Temperature from vessel (K)

  G. DP cell #2 (in / $H_2Ø$)

  H. Average density

  I. Load cell #4 (volts) - if available -

IV. For first one hundred (100) samples

  A. Initialize variables to zero

  B. Sum values for load cell

  C. Sum values for DP cell #1

  D. Sum values for DP cell #2

V. Calculate density from temperature in vessel (IIIF) assuming saturated temperature.

VI. Calculate offsets using density from vessel temperature (V), density from reference leg of DP (IIB), and sum of the first 100 samples of either load cells (IVB) or DP cells (IVC).

  LØAD ØFFSET = 4133.55 - Average load cell for first 100 samples

  DP1 ØFFSET = 7.72668 - (density from reference leg / density from vessel temperature * 7.72668) - (Average of DP cell #1 for first 100 samples * 102 / density from vessel temperature).

DP2 OFFSET = 4.7244 - (density from reference leg / density from vessel temperature * 4.7244) - (Average of DP cell #2 for first 100 samples * 102. / density from vessel temperature).

VII. Convert both DP cells from KPa to meters / H_2O for each sample.

DP1 = density from reference leg / density from vessel temperature * 7.72668) - (original DP reading * 102. / density from vessel temperature) + DP1 OFFSET

DP2 = density from reference leg / density from vessel temperature * 4.7244) - (original DP2 reading * 102. / density from vessel temperature) + DP2 OFFSET

VIII. Calculate system weight from load cells

A. Sum all load cell readings for each sample.

B. Multiply the above sum by the slope for the load cell calibration equation (IIA).

C. Add above value to load offset.

IX. Initialize variables for vessel volumes and vessel heigths. (This is necessary because the internal shape of the vessel changes. See Figure 19 for drawing of vessel).

X. Initialize variables

A. For radius of vessel

B. For radius of hemisphere

XI. Convert DP cells from meters to centimeters

XII. Calculate volumes for each distinct shape of vessel (Figure 19).

A. If the reading for DP cell #1 is less than zero, the volume is set to zero.

B. If the reading for DP cell #1 is greater than zero, but less than 91.52, then the volume equals:

$\text{Pi} * (\text{reading} - 51.83)^2 * [\text{hemisphere radius} - ((\text{reading} - 51.83)/3)]$

C. If the reading for DP cell #1 is between 91.52 and 128.33, then the volume equals:

$\text{Pi} * \text{vessel radius}^2 * (\text{reading} - 91.52) + 204865.1125$

where 204865.1125 is the vessel volume constant

D. If the reading for DP cell #1 is between 128.33 and 637.61, then the volume equals:

(reading - 128.33) * 5476.3 + 204865.1125 + 319208.22

where 204865.1125 and 319208.22 are the vessel volume constants

E. If the reading for DP cell #1 is between 637.61 and 693.49, then the volume equals:

Pi * (reading - 637.61) * radius of vessel^2 + 204865.1125 + 319208.22 + 2815007.0

where 204865.1125, 319208.22, and 2815007.0 are the vessel volume constants

F. If the reading for DP cell #1 is between 693.49 and 733.1, then the volume equals:

- (Pi * (693.49 - reading)^2 * [hemisphere radius - (693.49 - reading/3)] + (2 * 204865.1125) + 319208.22 + 2815007.0 + 483755.215.

where 204865.1125, 319208.22, 2815007.0, and 483755.215 are the vessel volume constants

G. If the reading for DP cell #1 is between 733.1 and the top of the vessel, then the volume equals the sum total of the volume constants.

(2 * 204865.1125) + 319208.22 + 2815007.0 + 483755.215

XIII. Compute system weight using volume obtained from DP cells (cubic centimeters), average density (Kg) and density from vessel temperature (Kg).

Sysmass* = (Vol[illegible] 1 million * density from vessel temperature)
+ (0.[illegible]028 * average density)

* if DP cell reading (cm) $\geq$ 750, then Sysmass = Sysmass + 73.21

XIV. Compute mass flow from load cells and from DP cells

A. Read in number of terms (NTERMS) and values of coefficients for positive direction to be used in the digital filter.

B. Set the middle coefficient equal to zero and the negative coefficients equal to the negative of the corresponding coefficient in the positive direction.

example: for 3 terms with values of .1, .2, and .3, the coefficients would be -.3, -.2, -.1, 0.0, .1, .2, .3

C. For the first 100 samples, fill the mass flow array with the mass of those samples. (This is done because the software used cannot go backward in time and the filter used needs both past and future times.)

D. Calculate the mass flow of the system, using either the load cells or DP cells, by summing, from 1 to (NTERMS + 1), the mass times the corresponding coefficient.

   1) Present time sample corresponds to the zero coefficient.

   2) Past (NTERMS) time samples correspond to the coefficients of negative direction and future (NTERMS) samples to coefficients of the positive direction.

      (NOTE: The oldest time sample must correspond to the coefficient of the most negative direction).

E. Multiply the value obtained in the previous summation by the number of samples per second to get the mass flow from the load cells when using the load cell mass and the mass flow from the DP cells when using DP cell mass. **

XV. Compute the root mean square (RMS) difference

   A. Of load cell mass and DP cell mass for all samples

   B. Of mass flow from the load cells and the mass flow from the DP cells for all samples.

XVI. Output values

   A. Time

   B. System weight from load cells in kilograms

   C. Mass flow from load cells in kilograms / second

   D. System weight from DP cells in kilograms

   E. Mass flow from DP cells in kilograms / second

   F. RMS difference of load cell weight versus DP cell weight

   G. RMS difference of mass flow from load cells versus mass flow from DP cells.

XVII. Stop

** The value for the mass flows at this point have been shifted forward in time, due to the software used. Upon completion, the mass flows need to be shifted back in time by NTERMS/samples per seconds.

```
TRMLC,P3,T400,STMFB.
ACCOUNT,6710,542151C02,TAU.
ATTACH,OLDPL,LOFTPL,ID=LFT,ST=MFA.
FILE,OLDPL,RT=S.
UPDATE,Q,W,K.
REWIND,COMPILE.
FTN,I,R=3,S=SYSTEXT,S=PFMTEXT,PL=250000.
FTN,R=3.
ATTACH,LIB1,CCPLIB,ID=LFT,ST=MFA.
REQUEST,ABS,*PF.
SEGLOAD,I=COMPILE.
LDSET,PRESET=ZERO.
LDSET,LIB=LIB1.
LOAD,LGO.
NOGO.
CATALOG,ABS,WCOPERA,ID=GRR,RP=999,MR=1.
*ID CUFL
*DEFINE MFA
*D COPERA$.56
*COMPILE COPERA
*COMPILE CCPDIRC
C $$$$$$$$$$  $$      $$  $$      $$   $$$$$$$$    $$$$$$$$       $$
C $$$$$$$$$$  $$      $$  $$$     $$  $$$$$$$$$$  $$$$$$$$$$     $$$$
C $$          $$      $$  $$ $    $$  $$      $$  $$      $$    $ $$
C $$          $$      $$  $$ $$   $$  $$          $$               $$
C $$$$$$      $$      $$  $$  $$  $$  $$          $$$$$$$$$        $$
C $$$$$$      $$      $$  $$  $$  $$  $$          $$$$$$$$$$       $$
C $$          $$      $$  $$   $$ $$  $$          $$      $$       $$
C $$          $$      $$  $$    $ $$  $$      $   $$      $$       $$
C $$          $$$$$$$$$$  $$     $$$  $$$$$$$$$$  $$$$$$$$$$  $$$$$$$$$$
C $$           $$$$$$$$   $$      $$   $$$$$$$$    $$$$$$$$   $$$$$$$$$$
      SUBROUTINE FUNC61   (X,N,C,NOVAR,A,S,FRMKNT,SAMPLE,NCHOT,XNAME)
      INTEGER FRMKNT
      REAL MOFF
      DIMENSION X(25),C(25),SAMPLE(25),S(25),A(7628),OPTIONS(66)
C---
C *****************************************************************
      DATA OPTIONS
     1/   "
     2
     3
     4        THIS FUNCTION COMPUTES THE WYLE TRANSIENT SYSTEM
     5        WEIGHT AND MASS FLOW FROM THE LOAD CELL VOLTAGE
     6        OUTPUT AND THE 300 INCH DELTA P.
     7
     8
     9      "/,SUBNAME /8H         /
C---
      NCHOT=7
      NCONST=4  $      NXNAME=9
      IF(FRMKNT.EQ.1) CALL INFOUT(C,NCONST,XNAME,NXNAME,SUBNAME,OPTIONS)
C---
C 345678     1 2345678 2 2345678 3 2345678 4 2345678 5 2345678 6 2345678
C ******************************************************************
C---
C---                         CONSTANTS                              UNITS
C---     C( )
C---       1   .....   UNUSED
C---       2   .....   SLOPE FOR LOAD CELL CAL EQUATION
C---       3   .....   DENSITY (KG/M**3) REFERENCE LEG OF DP
C---       4   .....   FLAG FOR LOAD CELL COMPUTATION  1= DC
C---       5   .....   FLAG FOR DP CELL COMPUTATION  1= DO
C---       6   .....   UNUSED
C---       7   .....   UNUSED
```

```
C---        8  .....
C---                                   VARIABLES                              UNITS
C---     X( )
C---        1  .....  TIME  SECONDS
C---        2  .....  LOAD CELL # 1  VOLTS OUTPUT
C---        3  .....  LOAD CELL # 2  VOLTS OUTPUT
C---        4  .....  LOAD CELL # 3  VOLTS OUTPUT
C---        5  .....  300 INCH DP CELL  INCHES WATER OUTPUT
C---        6  .....  TEMPERATURE  TF-V-1
C---        7  .....  UNUSED
C---        8  .....  DP-V-1
C---        9  .....  AVERAGE DENSITY OR DE-1-B OR DE-2-B
C---                                   OUTPUT                                 UNITS
C  SAMPLE( )
C---        1  .....  TIME  SECONDS
C---        2  .....  SYSTEM WEIGHT KILOGRAMS FROM LOAD CELLS
C---        3  .....  SYSTEM WEIGHT DIFFERENTIAL FROM LOAD CELLS
C---        4  .....  SYSTEM WEIGHT KILOGRAMS FROM DP CELL
C---        5  .....  SYSTEM WEIGHT KILOGRAMS DIFFERENTIAL FROM DP
C---        6  .....  RMS DIFFERENCE LOAD CELL VS DP CELL WEIGHT
C---        7  .....  RMS DIFFERENCE LOAD CELL VS DP CELL DIF. WEIGHT
C  ******************************************************************************
C---
C---  REMARKS:    THIS PROGRAM CALCULATES THE MASS AND TIME DERIVATIVE OF
C---              THE WYLE SYSTEM GIVEN THE OUTPUT OF THE INDIVIDUAL LOAD
C---              CELLS AND THE OUTPUT FROM THE DIFFERENTIAL PRESSURE
C---              CELL DP-V-2 (300 INCH).  THE RMS DIFFERENCE BETWEEN
C---              THE LOAD CELL COMPUTATION AND DP CELL COMPUTATION
C---              IS ALSO COMPUTED AND OUTPUT.
C---
C---  *************************************************************************
C---
C---                      PROGRAM COMMENCES HERE
C---
C---    INITALIZE VARIABLES FOR SUMMATION
C---
      IF (FRMKNT .EQ. 1) SUM3 = 0.0
      IF (FRMKNT .EQ. 1) SUM4 = 0.0
      IF (FRMKNT .EQ. 1) SUM5 = 0.0
C---
C---   FOR FIRST 100 SAMPLES OF DATA, INITALIZE VARIABLES TO 0.0
C---
      IF (FRMKNT-100) 20,30,30
   20 CONTINUE
      LCLMASS = 0.
      SAMPLE(1) = 0.
      SAMPLE(2) = 0.
      SAMPLE(3) = 0.
      SAMPLE(4) = 0.
      SAMPLE(5) = 0.
      SAMPLE(6) = 0.
      CDMASS = 0.
C---
C---     SUM VALUES FOR DP CELL #2
C---
      SUM3 = SUM3 + X(5)
C---
C---     SUM VALUES FOR DP CELL #1
C---
      SUM5 = SUM5 + X(8)
C---
C---     SUM VALUES FOR LOAD CELL
C---
     SUM4 = SUM4 + (C(2) * (X(2) + X(3) + X(4)))
C---
C---    CALCULATE DENSITY FROM TEMPERATURE IN VESSEL
C---
     X(6) = (X(6) * (9./5.)) -459.67
     DEN = -.00056004 + (X(6) * 1.15893E-4) +
    +       ( X(6) * X(6) * (-2.57209E-7)) +
    +          (X(6) * X(6) * X(6) * 2.18697E-10)
     DEN = (1./DEN) * 16.018
C---
      GO TO 400
C---
```

```
   30   CONTINUE
      X(6) = (X(6) * (9./5.)) -459.67
      DEN = -.00056004 + (X(6) * 1.15893E-4) +
     +        ( X(6) * X(6) * (-2.57209E-7)) +
     +        (X(6) * X(6) * X(6) * 2.18697E-10)
      DEN = (1./DEN) * 16.018
C---
C---    CALCULATE OFFSETS USING DENSITY FROM VESSEL TEMP.,
C---      DENSITY FROM REFERENCE LEG OF DP, AND FROM THE SUM
C---      OF THE FIRST 100 SAMPLES OF EITHER LOAD OR DP CELLS.
C---
      IF (FRMKNT .NE  100) GOTO 35
C---
C---    OFFSET FOR DP #2
C---
      OFFSET = 7.72668-((C(3)/DEN*7.72668) - (SUM3/99.*102./DEN))
C---
C---    OFFSET FOR DP #1
C---
      OFFV1 = 4.7244 -((C(3)/DEN*4.7244) - (SUM5/99.*102./DEN))
C---
C---    OFFSET FOR LOAD CELL
C---
      MOFF = -(SUM4/99.) + 4133.55
   35 CONTINUE
C---
C---   ADJUST DP INPUT FROM KPA TO M/H2O FOR EACH SAMPLE
C---
C---       DP #2
      X(5) = (C(3)/DEN*7.72668) - (X(5) * 102./DEN) + OFFSET
C---       DP #1
      X(8) =(C(3)/DEN*4.7244) - (X(8) *102./DEN) + OFFV1
C---
C---    CHECK FOR FLAG TO COMPUTE LOAD CELL WEIGHT
C---
       IF (C(4)) 50,50,40
C---
C---    COMPUTE SYSTEM WEIGHT FROM LOAD CELLS
C---
   40 CONTINUE
      SUM = X(2) + X(3) + X(4)
      WEIGHT = (C(2)*SUM) + MOFF
C---
C---    CHECK FOR DP CELL WEIGHT
C---
   50 CONTINUE
      IF (C(5)) 60,60,70
C---
C---    COMPUTE SYSTEM WEIGHT FORM DP CELLS
C---
C---    VESSEL VOLUME CONSTANTS (IN CENTIMENTERS) AND
C---      HEIGHT CONSTANTS (IN CUBIC CENTIMETERS)
C---
C---    INITALIZE VESSEL HEIGHT AT WHICH SYSTEM INTERNAL SHAPE
C---      CHANGES
C---
   70 CONTINUE
      H1 = 91.52
       H2 = 128.33
       H5 = 637.61
       H6 = 693.49
       H7 = 733.10
C---
C---     INITALIZE VESSEL VOLUME CONSTANTS FOR EACH DISTINCT SHAPE
       V1 = 204865.1125
       V2 = 319208.22
       V3 = 2815007.0
       V6 = 483755.215
C---     INITALIZE CONSTANTS FOR VESSEL AND PIPE RADIUSES
       RVES = 52.53162
       RHEMI = 54.61
C---
C---    DEFINE PI
C---
      PI = 3.14159
```

```
C---
C---     ASSUME DP CELL IN METERS OF WATER AND CONVERT TO
C---        CENTIMETERS
C---
C---     DP #1
      HFLV1 = X(8) * 100.
C---     DP #2
      HFLUID = X(5) * 100.
C---
C---     CALCULATE VOLUME FOR EACH HEIGHT, DEPENDING ON THE
C---        DISTINCT SHAPE OF THE VESSEL AT THAT HEIGHT
C---
      IF (HFLUID .GT. 0.) GO TO 90
      SYSVOL = 0.
      GO TO 200
C---
   90 IF (HFLUID .GT. H1) GOTO 100
      SYSVOL = PI*(HFLUID-51.83)**2.*(RHEMI-(HFLUID-51.83)/3.)
         GOTO 180
C---
  100  IF (HFLUID .GT. H2) GOTO 110
         SYSVOL = PI   RVES**2. * (HFLUID - H1) + V1
       GOTO 180
C---
  110 IF (HFLUID .G  . H5) GOTO 140
         SYSVOL = 5[illegible]76.3 * (HFLUID- H2)
         SYSVOL = SYSVOL + V1 + V2
         GOTO 180
C---
  140 IF (HFLUID .GT. H6) GOTO 150
         SYSVOL = (HFLUID - H5) * PI * RVES**2 + V1 + V2 + V3
         GOTO 180
C---
  150 IF (HFLUID .GT. H7) GOTO 160
      SYSVOL = -(PI * (H7-HFLUID)**2 * (RHEMI-(H7-HFLUID)/3))
         SYSVOL = SYSVOL + 2.*V1 + V2 + V3 + V6
         GOTO 180
C---
  160 CONTINUE
      SYSVOL = V1 + V2 + V3 + V6 + V1
  180 CONTINUE
      IF (HFLV1 .LE. H2 ) GOTO 200
      IF (HFLV1 .GE. 472.44) GOTO 181
      SYSVOL = SYSVOL + (HFLV1 -H2)* 2470.2
      GOTO 200
C---
  181 CONTINUE
  181 SYSVOL = SYSVOL + 937062.7
C---
C---     COMPUTE SYSTEM MASS GIVEN SYSTEM VOLUME IN CC AND
C---        DENSITY IN KG/MS**2
C---
  200 SYSMASS = SYSVOL/1000000. * DEN + 0.449028 * X(9)
      IF (HFLUID .GE. 750.) SYSMASS = SYSMASS + 73.21
C---
C---      CHECK TO SEE IF BOTH DP AND LOAD CELL USED,
C---        IF TRUE COMPUTE DIFFERENTIAL OF BOTH
C---
   60 IF ( C(4)*C(5) .LE. 0.) GOTO 300
C---
C---     COMPUTE DIFFERENTIAL OF BOTH
C---
      CALL DIFF2 (WEIGHT,SYSMASS,D1,D2,FRMKNT)
C---
C---     COMPUTATION OF RMS DIFFERENCE LOAD CELL VS DP CELL MASS
C---
       DMASS = (WEIGHT-SYSMASS)**2. + DDMASS
      SAMPLE(5) = SQRT (DMASS/FLOAT(FRMKNT))
       DDMASS = DMASS
C---
C---      COMPUTATION OF RMS DIFFERENCE OF DIFFERENCES
C---
       DDMASS = (D1-D2)**2. + DDDMASS
      SAMPLE(6) = SQRT (DDMASS/FLOAT(FRMKNT))
       DDDMASS = DDMASS
```

```
C---
C---        OUTPUT OF COMPUTED PARAMETERS LOAD CELL AND DP CALCULATED
C---
      SAMPLE(1) = WEIGHT
      SAMPLE(2) = D1
      SAMPLE(3) = SYSMASS
      SAMPLE(4) = D2
      GOTO 400
  300 IF (C(4) .EQ. 0.) GOTO 500
C---
C---        OUTPUT OF COMPUTED PARAMETERS LOAD CELL ONLY CALCULATED
C---
      ZERO = 0.0
      CALL DIFF2 (WEIGHT,ZERO,D1,D2,FRMKNT)
C---
      SAMPLE(1) = WEIGHT
      SAMPLE(2) = D1
      SAMPLE(3) = 0.
      SAMPLE(4) = 0.
      SAMPLE(5) = 0.
      SAMPLE(6) = 0.
      GOTO 400
C---
C---        OUTPUT OF COMPUTED PARAMETERS DP CELL ONLY CALCULATED
C---
  500 CALL DIFF2(ZERO,SYSMASS,D1,D2,FRMKNT)
C---
      SAMPLE(1) = 0.
      SAMPLE(2) = 0.
      SAMPLE(3) = SYSMASS
      SAMPLE(4) = D2
      SAMPLE(5) = 0.
      SAMPLE(6) = 0.
  400 CONTINUE
      RETURN
      END
C******
C******
      SUBROUTINE DIFF2 (V1,V2,D1,D2,NFRAME)
      DIMENSION ALOAD(500),ADP(500),COEFF1(250),COEFF2(250)
C---        V1 = VARIABLE USED TO COMPUTE LOAD CELL DERIVATIVE
C---        V2 = VARIABLE USED TO COMPUTE DP DERIVATIVE
C---        D1 = DERIVATIVE OF LOAD CELL
C---        D2 = DERIVATIVE OF DP
C---    NFRAME = PRESENT FRAME COUNT
C---    NTERMS = NUMBER OF SETS OF TERMS IN FILTER
C---             (READ IN FROM CARDS)
C--- DIFF2 ASSUMES THAT FRAME COUNT IS EQUALS 100 FOR FIRST
C---       DERIVATIVE TO BE COMPUTED.
C---
C--- READ IN DATA INPUT AND INITALIZE VARIABLES.
C---
C---
      D1 = 0.0    $    D2 = 0.0
      IF (NFRAME .LT. 100)  RETURN
      IF (NFRAME .GT. 100)  GO TO 15
      READ (5,*) NTERMS
      READ(5,*) SAMPLES
C----
C---- INITALIZE VARIABLES
C----     NUM = POSITION OF FIRST COEFF. IN POSITIVE DIRECTION
C----     NTWO = POSITION OF LAST COEFF. IN POSITIVE DIRECTION
C----     NVAL = POSITION OF MIDDLE COEFF. W/ VALUE = 0.0
C----
      NUM = NTERMS + 2    $     NTWO = NTERMS * 2  + 1
      NVAL = NTERMS + 1
C----
      READ (5,*) (COEFF1(I),I = NUM,NTWO)
      READ (5,*) (COEFF2(I),I = NUM,NTWO)
C----
C---- SET MIDDLE COEFFICIENT VALUE
C----
      COEFF1(NVAL) = 0.0
      COEFF2(NVAL) = 0.0
C----
```

```
C---- SET NEGATIVE DIRECTION COEFFICIENTS
C----
      DO 5 I = 1,NTERMS
      IF (I .EQ. 1) J = NTWO - I + 1
      IF (I .NE. 1) J = J - 1
      COEFF1(I) = - COEFF1(J)
      COEFF2(I) = - COEFF2(J)
    5 CONTINUE
C----
C----  FILL ALOAD AND ADP W/ 100 FRAME VALUE FOR INITALIZATION
C----
      DO 10 I = 1,NTWO
      ALOAD(I) = V1
      ADP (I) =V2
   10 CONTINUE
      IB = 1
      RETURN
   15 CONTINUE
      DO 20   L=1,NTWO
      D1 = D1 + (ALOAD(IB) * COEFF1(L))
      D2 = D2 + (ADP(IB) * COEFF2(L))
      IB = IB + 1
      IF (IB .GT. NTWO) IB = 1
   20 CONTINUE
      D1 = D1 * SAMPLES
      D2 = D2 * SAMPLES
      ALOAD(IB) = V1
      ADP (IB) = V2
      IB = IB + 1
      IF (IB .GT. NTWO) IB = 1
      RETURN
      END
```

APPENDIX D

LOAD CELL FILL CALIBRATION PROCEDURE

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP
WESTERN OPERATIONS, EL SEGUNDO FACILITY

TEST PROCEDURE NO. 3958

DATE: 30 May 1979

12 - Page Procedure

EG&G I

TRANSIENT FLOW CALIBRATION SYSTEM

WEIGHING ACCURACY TEST

APPROVED BY:
FOR:

APPROVED BY:
FOR:

APPROVED BY:
FOR:

APPROVED BY: L Housteau
WYLE LABORATORIES
FOR:

APPROVED BY: L M Broderick
WYLE LABORATORIES
FOR:

PREPARED BY: H Wheelock
WYLE LABORATORIES

REVISIONS

REV. NO.	DATE	PAGES AFFECTED	BY	APP'L.	DESCRIPTION OF CHANGES
A	6/20/79	4, 5, 6		LH	Additional information
B	7/2/79	8		LH	Error reference 9000 lbs

CONTENTS

1.0 PURPOSE

The purpose of this document is to present the procedures to be followed in performing the Weighing Accuracy Test.

2.0 REFERENCES

2.1 Wyle Laboratories Test Procedure No. 3936, dated 24 January 1979.

2.2 ASME Research Committee on Fluid Meters, Sixth Edition, dated 1971.

2.3 Dick Munns Company Flowmeter Calibration Certificate, Wyle Laboratories Turbine Meter #31064, dated 24 April 1979.

3.0 REQUIREMENTS

3.1 Perform the Weighing Accuracy Test required by Reference 2.1.

3.2 To demonstrate the calibration accuracy of the weighing system, ambient water will be metered into the test vessel. The total weight of the water metered into the test vessel will be compared with the differential weight indicated by the load cell system.

4.0 TEST CONDITIONS AND TEST EQUIPMENT

4.1 Ambient Conditions

Unless otherwise specified herein, all tests required by the specification shall be performed at an atmospheric pressure of 28.5 +2/-4.5 inches of mercury absolute, a temperature of 73 ± 18 F, and a relative humidity of 50 ± 30 per cent.

4.2 Instrumentation and Equipment

4.2.1 Measuring and test equipment utilized in the performance of this contract have been calibrated by the Wyle Laboratories Standards Laboratory, or a commercial facility utilizing reference standards (or interim standards) whose calibration has been certified as being traceable to the National Bureau of Standards. All reference standards utilized in the above calibration system are supported by certificates, reports or data sheets attesting to the date, accuracy and conditions under which the results furnished were obtained. All subordinate standards and measuring and test equipment are supported by like data when such information is essential to achieve the accuracy control required by the subject contract.

4.2.2 Wyle Laboratories attests that the commercial sources providing calibration services on the above referenced equipment, other than the National Bureau of Standards, are in fact capable of performing the required services to the satisfaction of the Wyle Laboratories Quality Control Department. Certificates and reports of all calibrations performed are retained in the Wyle Laboratories Quality Control files and are available for inspection upon request by authorized customer representatives.

4.2.3 Actual test equipment used in the performance of this test program will be listed on the appropriate test data sheets. (See sample, page 12).

4.3 Test Equipment

Item	Manufacturer	Model	Description	
Flowmeter	Foxboro	FL-16-SB	10-40 GPM	
Frequency Meter	Fluke	1941A	1-100K Hz	
Digital Totalizer	Fluke	1941A	1-100K Hz	
Load Cell Indicator	Interface	7500	6-150K Lbs.	
Digital Thermometer	Fluke	2100A	-320 to 750°F	
Load Cell	Interface	1221-J2	S/N 12291 12292 12293	A

5.0 PROCEDURE

5.1 The test system will be plumbed and instrumented as shown in Figure 1. The installation of the reference flowmeter will duplicate the system plumbing used during the calibration, Reference 2.3, as shown in Figure 2.

5.2 Initial System Preparation

a) Activate the water supply transfer pumps and flood the system.

b) Continue to flood and drain the system until the water and air temperatures (T_W and T_A) have stabilized and the general performance of the frequency meter and totalizer has been verified.

5.3 Data Point Acquisition

a) Record the load cell indicator initial weight reading on the data sheet, Figure 3.

b) Zero the digital totalizer.

c) Open the solenoid valve to begin the filling process.

d) During the filling process, maintain a constant filling rate and enter the flowmeter frequency, water temperature, air temperature and barometric pressure on the data sheet. A

e) Continue to fill the test tank until at least 3000 pounds of water has been added to the system.

f) Terminate the filling process by closing the solenoid valve.

g) Record the load cell indicator final weight and the totalized flowmeter count on the data sheet.

h) Using the equation from Figure 4, compute ΔW_F, then % ΔW.

i) Repeat steps (a) through (h) three times. The measured water into the system during the last increment must be sufficient to fill the horizontal test spool. A

j) Drain the test tank and repeat steps (a) through (i) two more times, generating a total of 9 data points. A

6.0 SUPPLEMENTAL INFORMATION

A plot of the Foxboro flowmeter calibration is shown in Figure 5 and the reference water density in Figure 6.

FIGURE 1

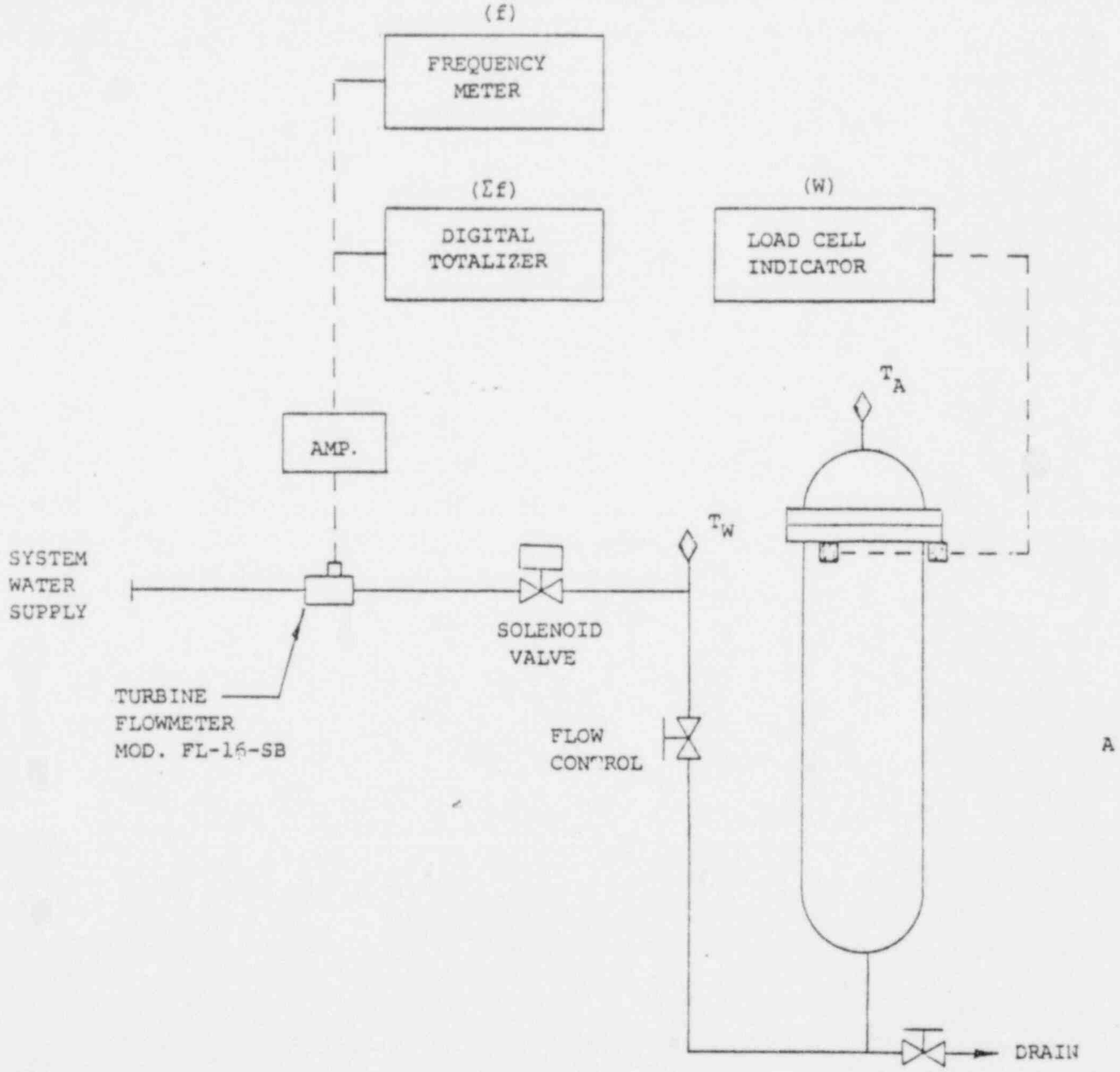
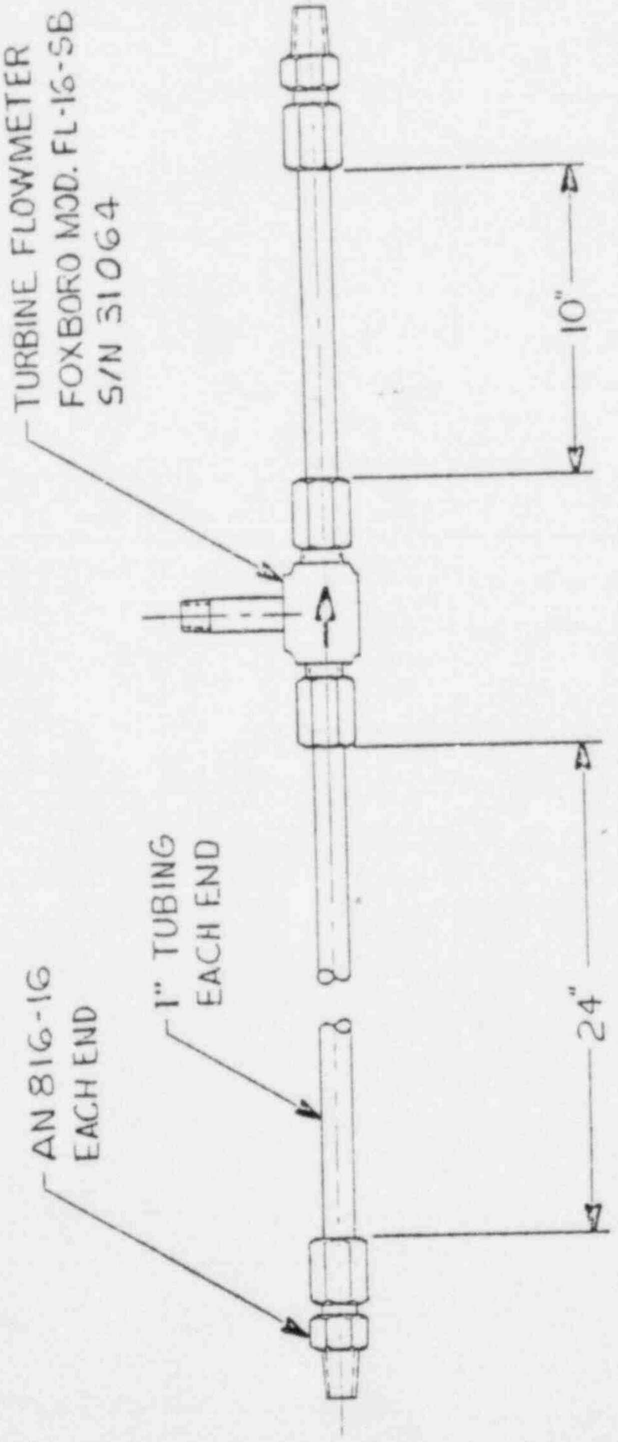

(f)
FREQUENCY METER
(Σf)
DIGITAL TOTALIZER
(W)
LOAD CELL INDICATOR
AMP.
T_A
T_W
SYSTEM WATER SUPPLY
SOLENOID VALVE
TURBINE FLOWMETER MOD. FL-16-SB
FLOW CONTROL
A
DRAIN

FIGURE 2


TURBINE FLOWMETER
FOXBORO MOD. FL-16-SB
S/N 31064
10"
1" TUBING
EACH END
AN 816-16
EACH END
24"

WYLE LABORATORIES

DATA SHEET

CUSTOMER ______________________
Test Title: ______________________
Specimen ______________________ Job No. ______________________
______________________ S/N ______________________
Part No. ______________________ Date ______________________

RUN NO.	LOAD CELL READING			FLOWMETER			TANK AIR TEMP. (T_A)	BAR. PRESS. (P_B)	METERED WT.	
	INIT. WT.	FINAL WT.	ΔW_L	FREQ. (f)	TOTAL COUNT (Σf)	TEMP. (T_W)			ΔW_F	%ΔW
	$\% \Delta W = 100 \frac{\Delta W_L - \Delta W_F}{9000}$									

(B)

Q. C. Form Approval

SHEET ____ OF ____

FIGURE 4

$$\Delta W_F = \frac{(\Sigma f)\ (\gamma_W - \gamma_A)}{7.481\ (K)}$$

$K = A + B\ (f) + C\ (f)^2$ CYCLE/GAL

$\gamma_W = D + E\ (T_W) + F\ (T_W)^2$ LB/FT^3

$\gamma_A = \dfrac{144\ P_B}{53.35\ (T_A + 460)}$ LB/FT^3

f	CYCLE/SEC
T_W	°F
T_A	°F
P_B	PSIA

A	5.40069 E 2
B	-4.03109 E-2
C	6.00409 E-5
D	6.23205 E 1
E	6.76993 E-3
F	-9.98624 E-5

FIGURE 5

FLOWMETER CALIBRATION

DICK MUNNS CO. 4-24-79

METER NO. 31064

FOXBORO MODEL FL-16-SB

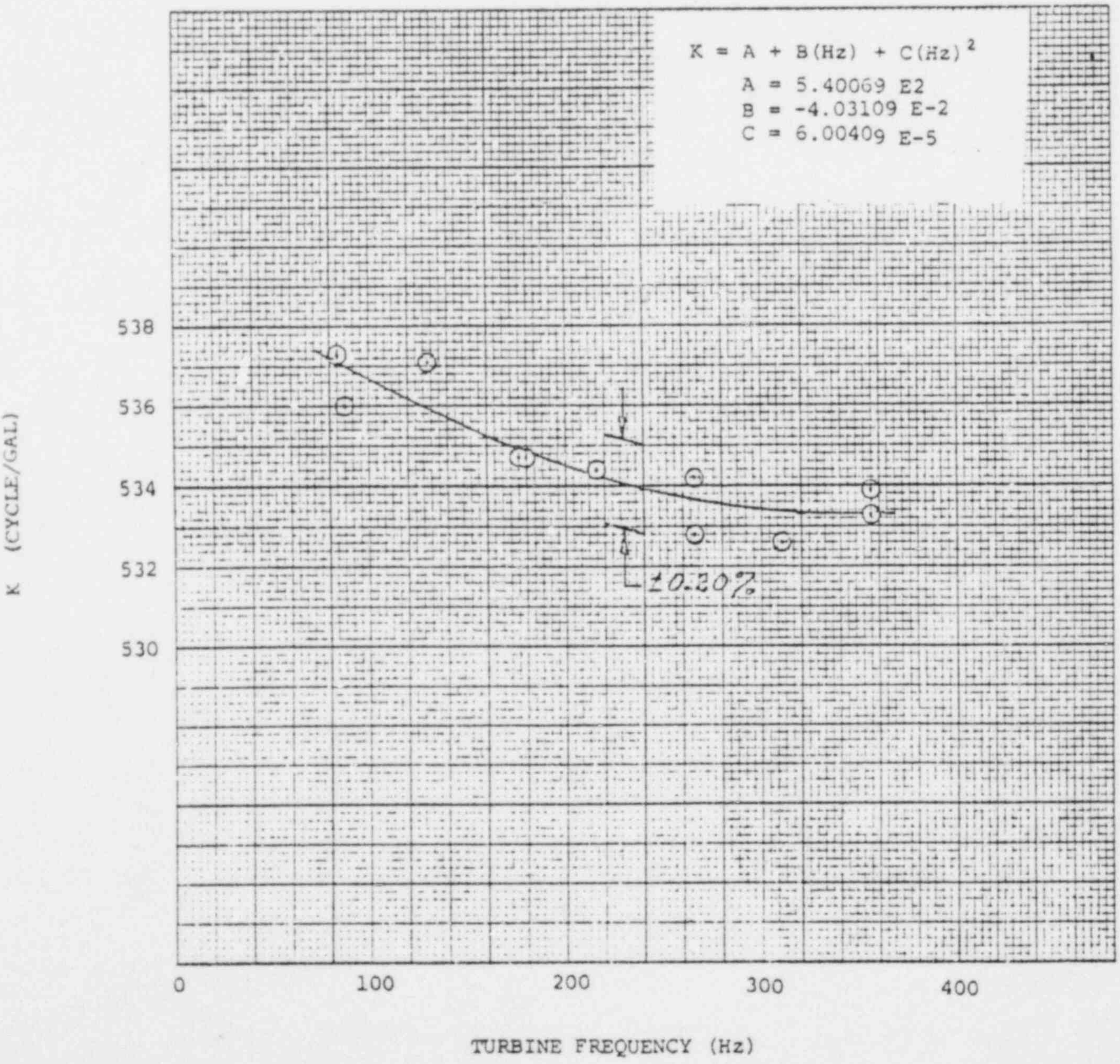
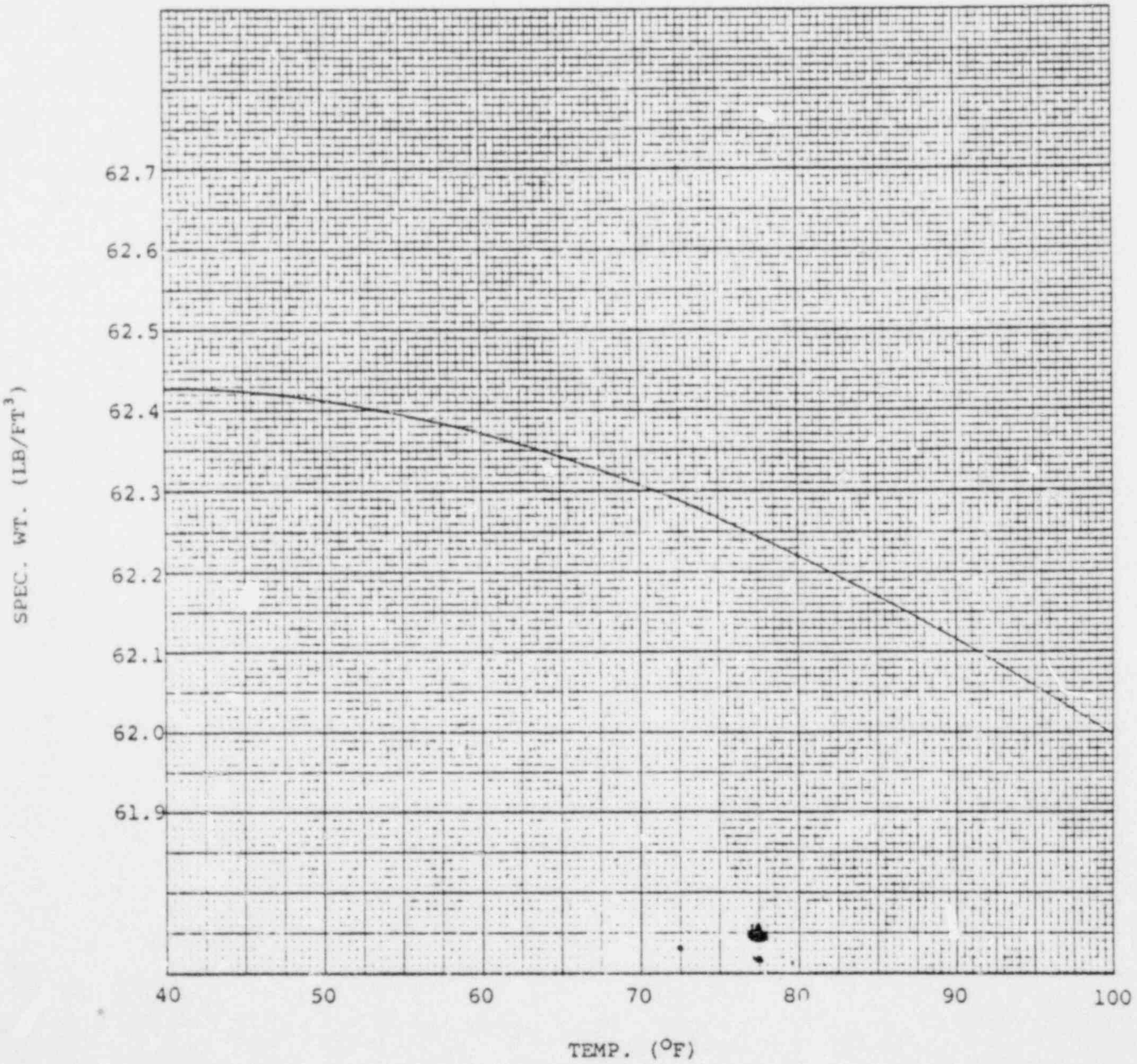


FIGURE 6

SPECIFIC WEIGHT OF WATER

REF: Fluid Meters, ASME, Sixth Edition, 1971



SPECIMEN ______________________

CUSTOMER ______________________

PART NO. ______________________

S/N ______________________

JOB NO. ____________

DATE ____________

TEST BY ____________

WITNESS ____________

WYLE LABORATORIES

TEST: ______________________

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION		ACCY.
					LAST	DUE	

W 614 C Q.C. Approval

SHEET OF