MOV USER'S GROUP

PROGRESS REPORT
OF THE
VALIDATION COMMITTEE

Submitted: July, 1991

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PROGRESS REPORT ON VENDOR EQUIPMENT VALIDATION

Submitted to the MOV User's Group by the Validation Committee.

The undersigned represent the groups who prepared and reviewed this report.

MUG, Chairman 7/29/91

ABB Impell 7/29/91

INEL 7-29-91

ITI-MOVATS 7/29/91

Liberty Technologies 7/29/91

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UTL/KWU 7/29/91

Wyle Laboratories 7/29/91

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PROGRESS REPORT OF THE MUG VALIDATION COMMITTEE

1.0 Introduction

1.1 Background

The concept of a validation effort to be initiated by the MUG with the goal of verifying vendor accuracy claims was introduced at the MUG meeting in Orlando, Florida in January 1990. A working group consisting of MUG members was formed to research an acceptable approach for achieving the goal of validating/substantiating the stated accuracy claims for existing MOV diagnostic systems. This effort was endorsed by the NRC. The NRC also agreed to fund the validation effort through their ongoing research into MOV issues with the understanding that any reports would become public documents. The NRC provided the services of the Idaho National Engineering Laboratories (INEL) in the development of a standard to which vendor diagnostic equipment could be compared.

At the July, 1990 MUG meeting in Portland the Validation Committee convened for the first time. During this meeting, each major diagnostic equipment vendor provided a brief presentation on the method(s) used to measure given MOV parameters, the accuracy to which these parameters are measured and the methodology by which these stated accuracies were established. The Validation Committee also voted to develop a test plan by which claims of accuracy could be verified. At this MUG meeting, the general MUG membership approved the establishment of the VC and endorsed the development and implementation of a test program for accuracy claims validation.

An initial time frame to conduct and complete the testing by December 1990 was found to be unfeasible due to expressed concerns as to the fairness of the test standard at INEL and the test plan itself. The committee voted in October of 1990 during a conference call to delay the testing and review the concerns expressed by the vendors and committee members.

The January 1991 Validation Committee meeting in Juno Beach, Florida resulted in an agreement between the VC and the applicable vendors to rewrite the test plan in order to resolve the vendor concerns and to ensure the conduct of an objective test plan. Two additional vendors presented their claims at this meeting as a prerequisite for their participating in the testing. A new test schedule was established to conduct the testing in April and May of 1991 at

INEL Stroke Number -	INEL valve stroke corresponding to vendor stroke.
Torque switch setting -	self-explanatory
Desired Measurement -	The two values being recorded. T.S. Trip is the thrust at torque switch trip at a time identified by the vendor. Final is final thrust at a time identified by the vendor.
Vendor Read -	Vendor's thrust reading
INEL Read -	INEL's thrust reading
INEL Band -	The minimum is the INEL reading minus their error 145 lbf. The maximum is the INEL reading plus their error of 145 lbf.
Deviation from INEL -	The actual amount by which the vendor reading deviates from the INEL band. A negative sign indicates it deviates from the minimum INEL band.
Percent Deviation-	The deviation from INEL value divided by the closest INEL Band value.
Accum Level (inch)-	Accumulator level of the MOVLS
Accum Press (psig)-	Accumulator pressure of the MOVLS
Load Class -	Low, Medium or High stem loading conditions based on Accumulator level.

Note: The accumulator level in inches of water is an attempt to replicate the DP effect. Accumulator pressure is an attempt to replicate line pressure (pump output without flow). It is recognized that the two variables work in unison to produce a loading condition, however for the statistical summary only the accumulator level was used in identifying low, medium or high loading class.

Minor statistical computations have been performed on the data presented. The test plan called for 9 strokes of each individual transduce, with the strokes being divided into 3 at low loading rates, 3 at medium loading rates and 3 at high loading rates. In order to check for repeatability, 3 of each type transducer was tested. This produces a total of 27

the INEL facilities. A final working meeting was held in Richmond, Virginia in March, 1991 in which the final details of the test plan were worked out in cooperation with all the vendors, the INEL representative, the NRC and the Validation Committee.

1.2 Endorsement Statement

The MUG, the Validation Committee, the NRC and INEL do not endorse any particular diagnostic system. Further, the purpose of the validation testing program is not to directly or implicitly endorse or condemn any particular diagnostic system or methodology.

1.3 Statement on Final Report

A final report will be issued by the Validation Committee in the first quarter of 1992. It is intended at this time to have the report ready for distribution at the MUG Winter meeting. The final report will include graphical overlays of both the INEL and vendor data. The format of the data is intended to provide the reader with an easily understandable comparison between the actual vendor measurement accuracies and the stated accuracy claims. The format and content of the final report have yet to be decided upon and participating MUG utilities may request for consideration that particular relevant information be shown.

2.0 Discussion

2.1 Purpose and Goal of Progress Report

The purpose of this progress report is to present to the MUG members a brief summary, to date, of the completed activities related to the validation testing program. This includes:

1. The test plan,
2. A brief overview of individual vendor methodologies and statements of accuracy,
3. Specific data points from the data collected during the testing at INEL, and
4. A review of testing anomalies/difficulties encountered during the validation testing.

The goal of this report is to provide utilities with the same information currently available to the vendors. Note that each vendor only has information about their respective equipment.

2.2 Scope of Progress Report

This Progress Report is limited in it's scope to presenting only raw data for thrust measuring transducers at torque switch trip and final thrust. These values are presented as they were recorded on the data sheets by the vendor an INEL. Other data is outside the bounds of this progress report. Anomalies and test difficulties are presented as they were recorded in the comment section by the utility test coordinator. Vendor comments have been solicited and are presented in an unedited fashion.

2.3 Statement on Signal Conditioning Delays

It was recognized that signal conditioning delays could cause a difference between the time that a vendor would indicate torque switch trip and the time INEL would indicate torque switch trip. To avoid any possible problem, INEL provided a time reference signal which was simultaneously recorded by them and by the vendor. To insure analysis consistency, a policy was established that the vendor's recorded torque switch trip occurrence would be used as the point for thrust comparison.

> For example;
> If the vendor identified TST at 4.237 seconds, the thrust recorded by the vendor at that moment was compared to the INEL thrust reading at that same moment, regardless of when INEL identified the occurrence of TST.

The differences or potential differences in time discrepancy between the INEL and the vendor's equipment is a multi-variable effect. It is not within the scope of this report to determine the cause of the discrepancy but signal filtering, time base differences and/or sample rates are possible influences.

The final report will attempt to establish, through the use of graphical overlays, where such time differences exist and the significance of such differences.

2.4 Data Sheet Interpretation

The original data sheets have been converted into a Lotus Spread sheet format containing the following information:

Vendor Name and sensor type

Vendor Stroke Number - Identification of valve stroke from data sheet.

INEL Stroke Number -	INEL valve stroke corresponding to vendor stroke.
Torque switch setting -	self-explanatory
Desired Measurement -	The two values being recorded. T.S. Trip is the thrust at torque switch trip at a time identified by the vendor. Final is final thrust at a time identified by the vendor.
Vendor Read -	Vendor's thrust reading
INEL Read -	INEL's thrust reading
INEL Band -	The minimum is the INEL reading minus their error 145 lbf. The maximum is the INEL reading plus their error of 145 lbf.
Deviation from INEL -	The actual amount by which the vendor reading deviates from the INEL band. A negative sign indicates it deviates from the minimum INEL band.
Percent Deviation-	The deviation from INEL value divided by the closest INEL Band value.
Accum Level (inch)-	Accumulator level of the MOVLS
Accum Press (psig)-	Accumulator pressure of the MOVLS
Load Class -	Low, Medium or High stem loading conditions based on Accumulator level.

Note: The accumulator level in inches of water is an attempt to replicate the DP effect. Accumulator pressure is an attempt to replicate line pressure (pump output without flow). It is recognized that the two variables work in unison to produce a loading condition, however for the statistical summary only the accumulator level was used in identifying low, medium or high loading class.

Minor statistical computations have been performed on the data presented. The test plan called for 9 strokes of each individual transducer, with the strokes being divided into 3 at low loading rates, 3 at medium loading rates and 3 at high loading rates. In order to check for repeatability, 3 of each type transducer was tested. This produces a total of 27 strokes for each type transducer with 9 strokes at each loading rate. The following are the computations performed on the data presented in this report.

1. The average percent deviation for 27 strokes of each type of sensor has been calculated. The maximum and minimum percent deviation from the INEL standard is also presented for each type sensor.

2. The average percent deviation for the 9 strokes of each individual transducer has been calculated, with minimum and maximum percent deviation also presented.

3. The average percent deviation has been calculated for the 9 strokes at each loading condition. Maximum and minimum values are again identified for these 9 strokes.

2.5 Limitations on the Use of the Progress Report

Many factors influence the raw data that is transcribed in this report and until the signature overlays are produced, analyzed and presented in the final report, the Validation Committee strongly urges caution in using the presented data. Each vendor's data has been available to that vendor since the completion of his testing week and the Committee recommends that each utility discuss with their vendor or potential vendor any concerns that might arise through a review of this report. The Committee feels that it is imperative that utilities evaluate this report in light of their individual needs, the input of vendors and their own testing experience. Using the data presented as a basis for discussion will assist in furthering an individual utility's understanding of the final report when it is issued.

3.0 VENDOR INFORMATION

3.1 WYLE LABORATORIES

3.1.1 EQUIPMENT DESCRIPTION

The AVMODS test system measures thrust through a combination of the load reaction on the upper bearing housing of limitorque actuators using piezoelectric load washers and a strain gage mounted on the yoke of the valve. The strain gage is first zeroed in when no load is on the stem, then it is calibrated during the open to close stroke using the readings from the load washers under the bearing housing bolts. During operation, the load washer thrust is an actual reading and a preload as measured by the strain gage must be added to reflect the real stem thrust. The AVMODS system also measures motor current, stem position(string potentiometer), true power, power factor, spring pack displacement, and switch actuation.

3.1.2 DIFFICULTIES/ABNORMALITIES

During initial calibration traces, it was apparent that the AVMODS system was consistently 25-40% different than INEL readings. The readings were consistent and repeatable over various strokes. Since no useful purpose would be attained by continuing the test, Wyle was informed of the large error factor.

Numerous hours were spent troubleshooting the Wyle and INEL equipment. After verifying the accuracy of the INEL load cell and the Wyle load washers with the INEL Ingstrom machine, the upper bearing housing was removed to inspect condition of bearing. No visually apparent abnormalities were detected by Wyle, the Utility Host, or the Test Coordinator. The upper housing and bearing race were cleaned, the bearing was relubricated, and the assembly was reassembled. During subsequent strokes, Wyle appeared to be within their accuracy claim and the tests were completed.

Since the initial problem with the load washers and the upper bearing housing would have gone undetected without the presence of the INEL test stand, Wyle needs to address the root cause of this anomaly and determine steps to prevent recurrence.

8A

WYLE TEST DATA

S/N #1

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1706	1 & 2	1.25	T. S. TRIP	12413	13387	13242	13532	−829	6.3	9.5	25	L	LOAD
			FINAL	17627	17982	17837	18127	−210	1.2				WASHERS
1713	3 & 4	1.25	T. S. TRIP	11819	11462	11317	11607	212	1.8	9.5	75	L	LOAD
			FINAL	17517	16005	15860	16150	1367	8.5				WASHERS
1719	5 & 6	1.25	T. S. TRIP	11990	11486	11341	11631	359	3.1	9.5	125	L	LOAD
			FINAL	17439	15997	15852	16142	1297	8.0				WASHERS
1746	7 & 8	1.75	T. S. TRIP	16346	17834	17689	17979	−1343	7.6	5	50	M	LOAD
			FINAL	20550	21773	21628	21918	−1078	5.0				WASHERS
1750	9 & 10	1.75	T. S. TRIP	16770	16361	16216	16506	264	1.6	5	100	M	LOAD
			FINAL	18264	18286	18141	18431	0	0.0				WASHERS
1755	11 & 12	1.75	T. S. TRIP	17622	16671	16526	16816	806	4.8	5	170	M	LOAD
			FINAL	21343	20370	20225	20515	828	4.0				WASHERS
1809	13 & 14	2.25	T. S. TRIP	22133	21576	21431	21721	412	1.9	1.5	50	H	LOAD
			FINAL	25502	24897	24752	25042	460	1.8				WASHERS
1813	15 & 16	2.25	T. S. TRIP	24805	24173	24028	24318	487	2.0	1.5	100	H	LOAD
			FINAL	28629	27433	27288	27578	1051	3.8				WASHERS
1823	17 & 18	2.25	T. S. TRIP	24243	22384	22239	22529	1714	7.6	0.75	240	H	LOAD
			FINAL	24374	22526	22381	22671	1703	7.5				WASHERS

WYLE TEST DATA

S/N #2

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1922	1 & 2	2.25	T. S. TRIP	18925	19990	19845	20135	−920	4.6	0.75	170	H	LOAD
			FINAL	19111	19990	19845	20135	−734	3.7				WASHERS
1926	3 & 4	2.25	T. S. TRIP	21443	21049	20904	21194	249	1.2	0.75	100	H	LOAD
			FINAL	24797	24220	24075	24365	432	1.8				WASHERS
1930	5 & 6	2.25	T. S. TRIP	23505	21844	21699	21989	1516	6.9	0.75	50	H	LOAD
			FINAL	27079	25445	25300	25590	1489	5.8				WASHERS
1938	7 & 8	1.75	T. S. TRIP	15211	8076	7931	8221	6990	85.0	5	50	M	LOAD
			FINAL	19907	21370	21225	21515	−1318	6.2				WASHERS
1941	9 & 10	1.75	T. S. TRIP	18045	17480	17335	17625	420	2.4	5	100	M	LOAD
			FINAL	22220	18037	17892	18182	4038	22.2				WASHERS
1944	11	1.75	T. S. TRIP	18706	17530	17385	17675	1031	5.8	5	150	M	LOAD
			FINAL	22676	21309	21164	21454	1222	5.7				WASHERS
1959	12 & 13	1.25	T. S. TRIP	7770	10832	10687	10977	−2917	27.3	9.5	25	L	LOAD
			FINAL	13788	15790	15645	15935	−1857	11.9				WASHERS
2003	14 & 15	1.25	T. S. TRIP	9363	10390	10245	10535	−882	8.6	9.5	75	L	LOAD
			FINAL	15002	15078	14933	15223	0	0.0				WASHERS
2006	17 & 18	1.25	T. S. TRIP	8473	10813	10668	10958	−2195	20.6	9.5	50	L	LOAD
			FINAL	13893	15326	15181	15471	−1288	8.5				WASHERS

WYLE TEST DATA

S/N #3
OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1100	1 & 2	1.25	T. S. TRIP	9265	10442	10297	10587	−1032	10.0	9.5	50	L	LOAD
			FINAL	15389	15875	15730	16020	−341	2.2				WASHERS
1105	3 & 4	1.25	T. S. TRIP	9879	11472	11327	11617	−1448	12.8	9.5	25	L	LOAD
			FINAL	17912	*	−145	145	17767	12253.1				WASHERS
1111	5 & 6	1.25	T. S. TRIP	10809	10568	10423	10713	96	0.9	9.5	100	L	LOAD
			FINAL	16653	15822	15677	15967	686	4.3				WASHERS
1124	7 & 8	1.75	T. S. TRIP	16610	17608	17463	17753	−853	4.9	5	50	M	LOAD
			FINAL	21077	21532	21387	21677	−310	1.4				WASHERS
1128	9 & 10	1.75	T. S. TRIP	16895	16039	15894	16184	711	4.4	5	100	M	LOAD
			FINAL	21304	20114	19969	20259	1045	5.2				WASHERS
1132	11 & 12	1.75	T. S. TRIP	17515	15669	15524	15814	1701	10.8	5	150	M	LOAD
			FINAL	21661	19959	19814	20104	1557	7.7				WASHERS
1147	13 & 14	2.25	T. S. TRIP	18716	18052	17907	18197	519	2.9	1	50	H	LOAD
			FINAL	22100	21901	21756	22046	54	0.2				WASHERS
1151	15 & 16	2.25	T. S. TRIP	24220	22851	22706	22996	1224	5.3	1	100	H	LOAD
			FINAL	27741	26229	26084	26374	1367	5.2				WASHERS
1201	17 & 18	2.25	T. S. TRIP	16400	15850	15705	15995	405	2.5	0.75	150	H	LOAD
			FINAL	16545	15810	15665	15955	590	3.7				WASHERS

WYLE TEST DATA AVERAGES

DEVIATION (PERCENT)

LOAD WASHERS

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	26 STROKES	T. S. TRIP	0.9	27.3	6.5
	26 STROKES	FINAL	0.0	22.2	5.2
S/N #1	9 STROKES	T. S. TRIP	1.6	7.6	4.1
	9 STROKES	FINAL	0.0	8.5	4.4
S/N #2	8 STROKES	T. S. TRIP	1.2	27.3	9.7
	9 STROKES	FINAL	0.0	22.2	7.3
S/N #3	9 STROKES	T. S. TRIP	0.9	12.8	6.0
	8 STROKES	FINAL	0.2	7.7	3.7
LOW LOADING	9 STROKES	T. S. TRIP	0.9	27.3	10.2
	8 STROKES	FINAL	0.0	11.9	5.6
MED LOADING	8 STROKES	T. S. TRIP	1.6	10.8	5.3
	9 STROKES	FINAL	0.0	22.2	6.4
HIGH LOADING	9 STROKES	T. S. TRIP	1.2	7.6	3.9
	9 STROKES	FINAL	0.2	7.5	3.7

* DESIGNATES INCOMPLETE STROKE DATA. MARKED STROKES WERE NOT USED IN CALCULATIONS.

NOTE: VENDOR STROKE 1938 APPEARS TO BE INCORRECT. STROKE HAS BEEN ELIMINATED IN COMPUTING AVERAGES

WYLE TEST DATA

S/N #1

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1706	1 & 2	1.25	T. S. TRIP	12604	13387	13242	13532	−638	4.8	9.5	25	L	STRAIN
			FINAL	16143	14502	14357	14647	1496	10.2				GUAGE
1713	3 & 4	1.25	T. S. TRIP	10633	11462	11317	11607	−684	6.0	9.5	75	L	STRAIN
			FINAL	14256	16005	15860	16150	−1604	10.1				GUAGE
1719	5 & 6	1.25	T. S. TRIP	10414	11486	11341	11631	−927	8.2	9.5	125	L	STRAIN
			FINAL	13582	15997	15852	16142	−2270	14.3				GUAGE
1746	7 & 8	1.75	T. S. TRIP	16716	17834	17689	17979	−973	5.5	5	50	M	STRAIN
			FINAL	20473	21821	21676	21966	−1203	5.5				GUAGE
1750	9 & 10	1.75	T. S. TRIP	15789	16361	16216	16506	−427	2.6	5	100	M	STRAIN
			FINAL	17204	18286	18141	18431	−937	5.2				GUAGE
1755	11 & 12	1.75	T. S. TRIP	15418	16671	16526	16816	−1108	6.7	5	170	M	STRAIN
			FINAL	18552	20370	20225	20515	−1673	8.3				GUAGE
1809	13 & 14	2.25	T. S. TRIP	18900	21576	21431	21721	−2531	11.8	1.5	50	H	STRAIN
			FINAL	21500	24897	24752	25042	−3252	13.1				GUAGE
1813	15 & 16	2.25	T. S. TRIP	21265	24173	24028	24318	−2763	11.5	1.5	100	H	STRAIN
			FINAL	24332	27433	27288	27578	−2956	10.8				GUAGE
1823	17 & 18	2.25	T. S. TRIP	19311	22384	22239	22529	−2928	13.2	0.75	240	H	STRAIN
			FINAL	20490	22526	22381	22671	−1891	8.4				GUAGE

WYLE TEST DATA

S/N #2

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND		DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
						MIN	MAX						
1922	1 & 2	2.25	T. S. TRIP	16328	19990	19845	20135	−3517	17.7	0.75	170	H	STRAIN
			FINAL	16497	19990	19845	20135	−3348	16.9				GUAGE
1926	3 & 4	2.25	T. S. TRIP	19530	21049	20904	21194	−1374	6.6	0.75	100	H	STRAIN
			FINAL	22934	24220	24075	24365	−1141	4.7				GUAGE
1930	5 & 6	2.25	T. S. TRIP	20490	21844	21699	21989	−1209	5.6	0.75	50	H	STRAIN
			FINAL	23658	25445	25300	25590	−1642	6.5				GUAGE
1938	7 & 8	1.75	T. S. TRIP	14778	8076	7931	8221	6557	79.8	5	50	M	STRAIN
			FINAL	19816	21370	21225	21515	−1409	6.6				GUAGE
1941	9 & 10	1.75	T. S. TRIP	16446	17480	17335	17625	−889	5.1	5	100	M	STRAIN
			FINAL	20187	18037	17892	18182	2005	11.0				GUAGE
1944	11	1.75	T. S. TRIP	16783	17530	17385	17675	−602	3.5	5	150	M	STRAIN
			FINAL	19361	21309	21164	21454	−1803	8.5				GUAGE
1959	12 & 13	1.25	T. S. TRIP	10380	10832	10687	10977	−307	2.9	9.5	25	L	STRAIN
			FINAL	14188	15790	15645	15935	−1457	9.3				GUAGE
2003	14 & 15	1.25	T. S. TRIP	10565	10390	10245	10535	30	0.3	9.5	75	L	STRAIN
			FINAL	13278	15078	14933	15223	−1655	11.1				GUAGE
2006	17 & 18	1.25	T. S. TRIP	9976	10813	10668	10958	−692	6.5	9.5	50	L	STRAIN
			FINAL	14171	15326	15181	15471	−1010	6.7				GUAGE

WYLE TEST DATA

S/N #3

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1100	1 & 2	1.25	T. S. TRIP	10580	10442	10297	10587	0	0.0	9.5	50	L	STRAIN
			FINAL	14138	15875	15730	16020	-1592	10.1				GUAGE
1105	3 & 4	1.25	T. S. TRIP	11138	11472	11327	11617	-189	1.7	9.5	25	L	STRAIN
			FINAL	14341	*	-145	145	14196	9790.3				GUAGE
1111	5 & 6	1.25	T. S. TRIP	10380	10568	10423	10713	-43	0.4	9.5	100	L	STRAIN
			FINAL	15098	15822	15677	15967	-579	3.7				GUAGE
1124	7 & 8	1.75	T. S. TRIP	15587	17608	17463	17753	-1876	10.7	5	50	M	STRAIN
			FINAL	18890	21532	21387	21677	-2497	11.7				GUAGE
1128	9 & 10	1.75	T. S. TRIP	15705	16039	15894	16184	-189	1.2	5	100	M	STRAIN
			FINAL	16867	20114	19969	20259	-3102	15.5				GUAGE
1132	11 & 12	1.75	T. S. TRIP	14289	15669	15524	15814	-1235	8.0	5	150	M	STRAIN
			FINAL	16446	19959	19814	20104	-3368	17.0				GUAGE
1147	13 & 14	2.25	T. S. TRIP	15500	18052	17907	18197	-2407	13.4	1	50	H	STRAIN
			FINAL	17400	21901	21756	22046	-4356	20.0				GUAGE
1151	15 & 16	2.25	T. S. TRIP	19750	22851	22706	22996	-2956	13.0	1	100	H	STRAIN
			FINAL	21750	26229	26084	26374	-4334	16.6				GUAGE
1201	17 & 18	2.25	T. S. TRIP	13952	15850	15705	15995	-1753	11.2	0.75	150	H	STRAIN
			FINAL	14289	15810	15665	15955	-1376	8.8				GUAGE

WYLE TEST DATA AVERAGES

DEVIATION (PERCENT)

STRAIN GUAGE

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	27 STROKES	T. S. TRIP	0.0	79.8	9.5
	26 STROKES	FINAL	3.7	20.0	10.4
S/N #1	9 STROKES	T. S. TRIP	2.6	13.2	7.8
	9 STROKES	FINAL	5.2	14.3	9.6
S/N #2	9 STROKES	T. S. TRIP	0.3	79.8	14.2
	9 STROKES	FINAL	4.7	16.9	9.0
S/N #3	9 STROKES	T. S. TRIP	0.0	13.4	6.6
	8 STROKES	FINAL	3.7	20.0	12.9
LOW LOADING	9 STROKES	T. S. TRIP	0.0	8.2	3.4
	8 STROKES	FINAL	3.7	14.3	9.4
MED LOADING	9 STROKES	T. S. TRIP	1.2	79.8	13.7
	9 STROKES	FINAL	5.2	17.0	9.9
HIGH LOADING	9 STROKES	T. S. TRIP	5.6	17.7	11.6
	9 STROKES	FINAL	4.7	20.0	11.8

* DESIGNATES INCOMPLETE STROKE DATA. MARKED STROKES WERE NOT USED IN CALCULATIONS

H8

3.2 ABB IMPELL

3.2.1 EQUIPMENT DESCRIPTION

The OATIS MOV test system is designed around a portable Personal Computer (PC). Data is input by the user or collected by transducers and transferred to the PC through a signal conditioning unit known as the Back Pack. The PC is preconfigured with the OATIS MOV software package and a special Analog to Digital (A/D) acquisition card. The A/D card is located in a expansion chassis mounted at the rear of the PC. It gathers data with a twelve-bit resolution and stores the data in the PC's internal memory.

The OATIS MOV Back Pack consists of five separate signal conditioning cards, an output card, an output display device, and a triple output power supply. The signal conditioning cards are designed to isolate the incoming signal from its corresponding transducer and minimize the level of background noise generated by the surrounding environment. Each card contains a self test circuitry to verify operation.
The five cards are:

Card	Transducer	Parameter
LVDT	Linear displacement	Spring Pack Disp.
Strain Gauge	Compression Load Cell	Stem Thrust
Current	Current Probe	Motor Current
Limit Switch	Test Leads	Control Switch Trip
Torque Switch	Test Leads	Control Switch Trip

The Output card produces high level analog signals that are compatible with the A/D card in the PC and allows manual or automatic selection of stroke direction.

The Output Display indicates LVDT zero position adjustment, Load Cell calibration check, Current probe adjustment and power supply output.

Stem thrust is measured directly in the open direction into a load cell. Spring pack deflection is measured in the closed direction and used to correlate stem thrust. Thrust values measured equate to seat thrust (values greater than running load). Clamp-on AC/DC current probes measure motor current. Alligator clips attach to the limit and torque switches to monitor switch actuation

3.2.2 DIFFICULTIES/ABNORMALITIES

a. Testing for the first series of nine tests was performed with the Limit Switch Auto Control Switch being manually manipulated for the Open and Closed direction. The Limit Switch card sensitivity was adjusted and the next eighteen tests were conducted with the switch in auto.

b. Zero time reference for the OATIS testing was taken at the opening of limit switch contact number four. Due to the sensitivity problems encountered contact switch four was not able to be monitored during the first nine tests.

c. Current readings for the first nine tests were changed to zero for both the final open and close direction after the data was recorded.

d. After the first nine tests the INEL spring pack transducer was bumped from a zero setting. The data for the next eighteen tests must be zeroed to obtain the actual reading.

10A

OATIS (IMPELL) TEST DATA

S/N #1

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
A1	A1	1.25	T. S. TRIP	9890	13827	13682	13972	-3792	27.7	9.5	25	L	LVDT/
			FINAL	17570	16122	15977	16267	1303	8.0				LOAD CELL
A2	A2	1.25	T. S. TRIP	9820	11284	11139	11429	-1319	11.8	9.5	50	L	LVDT/
			FINAL	17750	15722	15577	15867	1883	11.9				LOAD CELL
A3	A3	1.25	T. S. TRIP	10130	15375	15230	15520	-5100	33.5	9.5	90	L	LVDT/
			FINAL	17570	15331	15186	15476	2094	13.5				LOAD CELL
A4	A4	1.75	T. S. TRIP	15150	16847	16702	16992	-1552	9.3	5	50	M	LVDT/
			FINAL	24130	20310	20165	20455	3675	18.0				LOAD CELL
A5	A5	1.75	T. S. TRIP	15760	13502	13357	13647	2113	15.5	5	100	M	LVDT/
			FINAL	24650	19744	19599	19889	4761	23.9				LOAD CELL
A6	A6	1.75	T. S. TRIP	15490	11914	11769	12059	3431	28.5	5	170	M	LVDT/
			FINAL	26390	11961	11816	12106	14284	118.0				LOAD CELL
A7	A7	2.25	T. S. TRIP	27510	20311	20166	20456	7054	34.5	0.75	50	H	LVDT/
			FINAL	39750	21154	21009	21299	18451	86.6				LOAD CELL
A8	A8	2.25	T. S. TRIP	28080	20317	20172	20462	7618	37.2	0.75	100	H	LVDT/
			FINAL	37350	21240	21095	21385	15965	74.7				LOAD CELL
A9	A9	2.25	T. S. TRIP	27950	22674	22529	22819	5131	22.5	0.625	190	H	LVDT/
			FINAL	28640	23087	22942	23232	5408	23.3				LOAD CELL

OATIS (IMPELL) TEST DATA

S/N #2

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
B1	B1	2.25	T. S. TRIP	25652	21935	21790	22080	3572	16.2	0.625	50	H	LVDT/
			FINAL	30030	28352	28207	28497	1533	5.4				LOAD CELL
B2	B2	2.25	T. S. TRIP	25922	22776	22631	22921	3001	13.1	0.625	100	H	LVDT/
			FINAL	30940	29141	28996	29286	1654	5.6				LOAD CELL
B3	B3	2.25	T. S. TRIP	26093	24241	24096	24386	1707	7.0	0.625	190	H	LVDT/
			FINAL	26510	23958	23813	24103	2407	10.0				LOAD CELL
B4	B4	1.75	T. S. TRIP	15250	12299	12154	12444	2806	22.5	5	50	M	LVDT/
			FINAL	22940	19435	19290	19580	3360	17.2				LOAD CELL
B5	B5	1.75	T. S. TRIP	15959	11919	11774	12064	3895	32.3	5	100	M	LVDT/
			FINAL	23010	19228	19083	19373	3637	18.8				LOAD CELL
B6	B6	1.75	T. S. TRIP	15347	12375	12230	12520	2827	22.6	5	170	M	LVDT/
			FINAL	23180	19453	19308	19598	3582	18.3				LOAD CELL
B7	B7	1.25	T. S. TRIP	9815	6151	6006	6296	3519	55.9	9.5	25	L	LVDT/
			FINAL	17720	14426	14281	14571	3149	21.6				LOAD CELL
B8	B8	1.25	T. S. TRIP	9815	5790	5645	5935	3880	65.4	9.5	50	L	LVDT/
			FINAL	17720	13871	13726	14016	3704	26.4				LOAD CELL
B9	B9	1.25	T. S. TRIP	9987	6801	6656	6946	3041	43.8	9.5	100	L	LVDT/
			FINAL	17720	14238	14093	14383	3337	23.2				LOAD CELL

OATIS (IMPELL) TEST DATA

S/N #3

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
C1	C1	1.25	T. S. TRIP	8934	5257	5112	5402	3532	65.4	9.5	25	L	LVDT/
			FINAL	14860	15229	15084	15374	-224	1.5				LOAD CELL
C2	C2	1.25	T. S. TRIP	9200	4625	4480	4770	4430	92.9	9.5	50	L	LVDT/
			FINAL	16110	14096	13951	14241	1869	13.1				LOAD CELL
C3	C3	1.25	T. S. TRIP	9200	7254	7109	7399	1801	24.3	9.5	100	L	LVDT/
			FINAL	16330	7278	7133	7423	8907	120.0				LOAD CELL
C4	C4	1.75	T. S. TRIP	14030	10302	10157	10447	3583	34.3	5	50	M	LVDT/
			FINAL	20590	18765	18620	18910	1680	8.9				LOAD CELL
C5	C5	1.75	T. S. TRIP	14030	10051	9906	10196	3834	37.6	5	100	M	LVDT/
			FINAL	20270	18690	18545	18835	1435	7.6				LOAD CELL
C6	C6	1.75	T. S. TRIP	13410	11797	11652	11942	1468	12.3	5	170	M	LVDT/
			FINAL	20680	19580	19435	19725	955	4.8				LOAD CELL
C7	C7	2	T. S. TRIP	17530	14582	14437	14727	2803	19.0	1	50	H	LVDT/
			FINAL	24110	22478	22333	22623	1487	6.6				LOAD CELL
C8	C8	2	T. S. TRIP	17920	14629	14484	14774	3146	21.3	1	100	H	LVDT/
			FINAL	24530	22861	22716	23006	1524	6.6				LOAD CELL
C9	C9	2	T. S. TRIP	18160	17693	17548	17838	322	1.8	1	170	H	LVDT/
			FINAL	18480	17216	17071	17361	1119	6.4				LOAD CELL

OATIS (IMPELL) TEST DATA AVERAGES

DEVIATION (PERCENT)

LVDT/ LOAD CELL

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	27 STROKES	T. S. TRIP	1.8	92.9	29.9
	27 STROKES	FINAL	1.5	120.0	25.9

S/N #1	9 STROKES	T. S. TRIP	9.3	37.2	24.5
	9 STROKES	FINAL	8.0	118.0	42.0
S/N #2	9 STROKES	T. S. TRIP	7.0	65.4	31.0
	9 STROKES	FINAL	5.4	26.4	16.3
S/N #3	9 STROKES	T. S. TRIP	1.8	92.9	34.3
	9 STROKES	FINAL	1.5	120.0	19.5

LOW LOADING	9 STROKES	T. S. TRIP	11.8	92.9	46.7
	9 STROKES	FINAL	1.5	120.0	26.6
MED LOADING	9 STROKES	T. S. TRIP	9.3	37.6	23.9
	9 STROKES	FINAL	4.8	118.0	26.2
HIGH LOADING	9 STROKES	T. S. TRIP	1.8	37.2	19.2
	9 STROKES	FINAL	5.4	86.6	25.0

100

3.3 LIBERTY TECHNOLOGIES

3.3.1 EQUIPMENT DESCRIPTION

The VOTES system consists of a yoke mounted strain sensor that correlates yoke strain to stem thrust. This sensor is calibrated against a NIST traceable diametral strain sensor temporarily applied to the valve stem while the valve is electrically seated. The diametral stem strain is converted to thrust by the software using the stem material properties and stem geometry.

3.3.2 DIFFICULTIES/ABNORMALITIES

TEST COMMENTS

Testing of the VOTES system was accomplished between April 29 and May 3, 1991. Revision 2.2 of the VOTES software was used for the entire test sequence. Only the VOTES Force Sensor was tested against the INEL standard for accuracy. The following VOTES sensors were monitored for informational purposes; Open Limit Switch for INEL zero time reference, Actuator Torque, Motor Current (1-phase, RMS), Torque Switch Trip, Motor Power and Motor Power Factor.

Four (4) VOTES Force Sensors were epoxied to the Motor Operated Valve Load Simulator (MOVLS) yoke. Two (2) on the inside of the yoke, one (1) on the outside of the yoke and one (1) on the vertical edge of the packing area access opening. Each Force Sensor was calibrated 4 times to ensure repeatability. All calibration runs met the VOTES 2.0 Manual acceptance criteria. Per the MUG Test Plan only three (3) Force Sensors were used during validation testing. During the calibration phase an anomaly was noted and acted upon by the vendor. See paragraph 3.3.D and below for a discussion of anomaly.

Each VOTES Force Sensor was stroked per the INEL/MUG test plan nine (9) times at various simulated loading conditions. Each stroke consisted of a combined open and close stroke. During the testing of VOTES Force Sensor #1 (INEL Strokes 1-9) a test anomaly was noted. See paragraph 3.3.D and below for a discussion of anomaly. After testing of VOTES Force Sensors #2 & #3 (INEL Strokes 10-18 and 19-27) INEL, Utility Representatives and Liberty agreed to perform additional strokes (INEL Strokes #28-34) of VOTES Force Sensor #1 to determine if the anomaly was due to the VOTES Force Sensor or something else. The anomaly could not be reproduced and INEL Stroke #34 was saved as a representative stroke of VOTES Force Sensor #1 without the anomaly present.

CALIBRATION ANOMALY

After approximately 75% of the calibration strokes, using the same C-clamp (Serial # A1007), Liberty was notified that the calibrator being used was consistently showing a final thrust value lower than the INEL output. Liberty suspected that the location of the calibrator (on the threaded portion of the stem just above where the threads stop) was the problem. Liberty's procedure calls for the calibrator to be located > 1 stem diameter away from any stem transition, on the threaded portion of the stem. This distance could not be achieved on the INEL MOVLS.

The calibrator was re-located to the center of the solid portion of the stem, but final thrust values were still consistently lower than INEL final thrust values.

Liberty then decided to use a different C-clamp calibrator (Serial # A1106). The final thrust values using this calibrator were consistently close to INEL final thrust values. All four (4) VOTES Force Sensors were then calibrated with the A1106 C-clamp.

Liberty committed to perform a Root Cause Analysis on the first C-clamp (A1007) and report their findings, for the C-clamp anomaly in the final test report. Post-test calibration of this C-clamp was within Liberty's calibration acceptance criteria.

On June 19, 1991 Liberty reported to the Utility Test Coordinator that they have determined that the cause of the calibrator anomaly was attributed to "a ground" in the C-clamp. Liberty is conducting additional testing to verify the problem and is planning to issue a Customer Service Bulletin to inform users of a method to detect the problem on field equipment. See paragraph 3.3.D for additional vendor comments.

TEST ANOMALY (4/30/91, SENSOR #1)

During initial analysis of Liberty and INEL data for the first VOTES Force Sensor tested (Serial # A6615, INEL Strokes 1-9) a parallel offset of approximately 1,000 lbs was noted between VOTES thrust traces and the INEL Load Cell whenever the MOVLS Motor was energized. Whenever the Motor was de-energized the offset would ramp down so the VOTES Force Sensor and INEL Load Cell were essentially equal. Testing of VOTES Sensor #1 was completed Tuesday afternoon on 4/30/91. The equipment was then disconnected and secured for the evening. See INEL overlay attached (W4: VOTES01.1CHAN32).

On Wednesday morning 5/1/91 VOTES test equipment was reconnected and testing of VOTES Sensors #2 & 3 was performed. The anomaly seen on 4/30/91 was not seen on the 5/1/91 data.

Upon completion of data collection and analysis for VOTES Force Sensors #2 & 3 a series of seven (7) test strokes (INEL Strokes 28-34) were performed (on 5/2/91) in an attempt to reproduce the test anomaly seen on VOTES Force Sensor # 1. The test strokes were monitored by 4 INEL Engineers, 3 Vendor representatives and 2 Utility representatives. The anomaly could not be reproduced nor fully explained by the group. The only conclusions at this time are:

1. When the MOVLS motor was started, during the testing of Sensor #1 on 4/30/91, a parallel offset of approximately 1,000 lbs was initiated between the VOTES and INEL thrust traces.

2. The offset began decreasing when the motor was de-energized and was essentially zero with the motor stopped.

3. The anomaly could not be induced by varying the orientation of the INEL Load Cell position.

4. The anomaly could not be induced by varying the type or placement of the motor current probes used by the vendor.

5. During calibration of VOTES Force Sensors on 4/30/91 the INEL motor speed sensor cable was accidently knocked off. It was reconnected just prior to INEL Stroke #1.

6. The vendor test equipment was disconnected, connected and adjusted between testing performed on 4/30/91 and 5/1/91.

7. The anomaly could not be reproduced during the 7 test strokes on 5/2/91. INEL agreed to process data from one (1) of these test strokes (INEL Stroke # 34) for a comparison of VOTES Force Sensor performance without the anomaly present. See INEL overlay attached (W6: VOTES.34.1CHAN32)

Notes: 51 out of 56 data points measured fell within Liberty's stated accuracy of ± 9.2%. The 5 data points which fell outside of this band were all recorded during the 4/30/91 test anomaly.

14A

LIBERTY TEST DATA

S/N #1 (A6615)
OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
2	1	1.25	T. S. TRIP	11251	9818	9673	9963	1288	12.9	9	25	L	FORCE
			FINAL	17921	17827	17682	17972	0	0.0				SENSOR
3	2	1.25	T. S. TRIP	11358	9780	9635	9925	1433	14.4	9	50	L	FORCE
			FINAL	17772	17136	16991	17281	491	2.8				SENSOR
4	3	1.25	T. S. TRIP	10258	8660	8515	8805	1453	16.5	9	100	L	FORCE
			FINAL	16387	15930	15785	16075	312	1.9				SENSOR
5	4	1.75	T. S. TRIP	19371	17476	17331	17621	1750	9.9	5	50	M	FORCE
			FINAL	24681	23655	23510	23800	881	3.7				SENSOR
6	5	1.75	T. S. TRIP	16449	14981	14836	15126	1323	8.7	5	100	M	FORCE
			FINAL	21894	21308	21163	21453	441	2.1				SENSOR
7	6	1.75	T. S. TRIP	14837	13138	12993	13283	1554	11.7	5	150	M	FORCE
			FINAL	20185	19564	19419	19709	476	2.4				SENSOR
8	7	2	T. S. TRIP	17256	16342	16197	16487	769	4.7	1	50	H	FORCE
			FINAL	17413	16339	16194	16484	929	5.6				SENSOR
9	8	2	T. S. TRIP	19324	18109	17964	18254	1070	5.9	1.5	50	H	FORCE
			FINAL	24160	23228	23083	23373	787	3.4				SENSOR
10	9	2	T. S. TRIP	19401	17960	17815	18105	1296	7.2	1.5	100	H	FORCE
			FINAL	24317	22317	22172	22462	1855	8.3				SENSOR

14B

LIBERTY TEST DATA

S/N #2 (A6618)

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1	10	2	T. S. TRIP	16961	16808	16663	16953	8	0.0	1.5	50	H	FORCE
			FINAL	21741	21799	21654	21944	0	0.0				SENSOR
2	11	2	T. S. TRIP	17556	17227	17082	17372	184	1.1	1.5	100	H	FORCE
			FINAL	22510	22762	22617	22907	−107	0.5				SENSOR
3	12	2	T. S. TRIP	13784	13884	13739	14029	0	0.0	1.5	170	H	FORCE
			FINAL	13784	13926	13781	14071	0	0.0				SENSOR
4	13	1.75	T. S. TRIP	16850	16639	16494	16784	66	0.4	5	50	M	FORCE
			FINAL	22565	22796	22651	22941	−86	0.4				SENSOR
5	14	1.75	T. S. TRIP	15234	15053	14908	15198	36	0.2	5	100	M	FORCE
			FINAL	20831	21125	20980	21270	−149	0.7				SENSOR
6	15	1.75	T. S. TRIP	13892	13427	13282	13572	320	2.4	5	150	M	FORCE
			FINAL	19541	19674	19529	19819	0	0.0				SENSOR
7	16	1.25	T. S. TRIP	9202	8800	8655	8945	257	2.9	9	25	L	FORCE
			FINAL	15630	15883	15738	16028	−108	0.7				SENSOR
8	17	1.25	T. S. TRIP	8576	8147	8002	8292	284	3.4	9	50	L	FORCE
			FINAL	15412	15686	15541	15831	−129	0.8				SENSOR
9	18	1.25	T. S. TRIP	8835	8094	7949	8239	596	7.2	9	100	L	FORCE
			FINAL	15571	15622	15477	15767	0	0.0				SENSOR

14C

LIBERTY TEST DATA

S/N #3 (A6622)
OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1	19	1.25	T. S. TRIP	9199	8747	8602	8892	307	3.5	9	25	L	FORCE
			FINAL	16196	16553	16408	16698	−212	1.3				SENSOR
2	20	1.25	T. S. TRIP	8601	8333	8188	8478	123	1.5	9	50	L	FORCE
			FINAL	14924	15450	15305	15595	−381	2.5				SENSOR
3	21	1.25	T. S. TRIP	8759	8322	8177	8467	292	3.4	9	100	L	FORCE
			FINAL	15564	15977	15832	16122	−268	1.7				SENSOR
4	22	1.75	T. S. TRIP	17080	16899	16754	17044	36	0.2	5	50	M	FORCE
			FINAL	22283	22628	22483	22773	−200	0.9				SENSOR
5	23	1.75	T. S. TRIP	14619	14459	14314	14604	15	0.1	5	100	M	FORCE
			FINAL	20295	20657	20512	20802	−217	1.1				SENSOR
6	24	1.75	T. S. TRIP	13709	13569	13424	13714	0	0.0	5	150	M	FORCE
			FINAL	19715	20080	19935	20225	−220	1.1				SENSOR
7	25	2	T. S. TRIP	17495	17366	17221	17511	0	0.0	1.5	50	H	FORCE
			FINAL	22576	22676	22531	22821	0	0.0				SENSOR
8	26	2	T. S. TRIP	16758	16428	16283	16573	185	1.1	1.5	100	H	FORCE
			FINAL	21855	21834	21689	21979	0	0.0				SENSOR
9	27	2	T. S. TRIP	14025	14385	14240	14530	−215	1.5	1.5	150	H	FORCE
			FINAL	14145	14385	14240	14530	−95	0.7				SENSOR

LIBERTY TEST DATA

S/N #1 (A6615)
OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
18	34	1.25	T. S. TRIP	8071	7936	7791	8081	0	0.0	9	25	L	FORCE
			FINAL	15331	15626	15481	15771	−150	1.0				SENSOR

THIS STROKE WAS RECORDED TO SHOW RESULTS WITHOUT THE OFFSET ANOMALY.

SEE DISCUSSION OF THE ANOMALY IN TEST COMMENTS

LIBERTY TEST DATA
AVERAGES

DEVIATION (PERCENT)

FORCE SENSOR

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	28 STROKES	T. S. TRIP	0.0	16.5	4.3
	28 STROKES	FINAL	0.0	8.3	1.6
S/N #1 (A6615)	10 STROKES	T. S. TRIP	0.0	16.5	9.2
	10 STROKES	FINAL	0.0	8.3	3.1
S/N #2 (A6618)	9 STROKES	T. S. TRIP	0.0	7.2	2.0
	9 STROKES	FINAL	0.0	0.8	0.3
S/N #3 (A6622)	9 STROKES	T. S. TRIP	0.0	3.5	1.2
	9 STROKES	FINAL	0.0	2.5	1.0
LOW LOADING	10 STROKES	T. S. TRIP	0.0	16.5	6.6
	10 STROKES	FINAL	0.0	2.8	1.3
MED LOADING	9 STROKES	T. S. TRIP	0.0	11.7	3.7
	9 STROKES	FINAL	0.0	3.7	1.4
HIGH LOADING	9 STROKES	T. S. TRIP	0.0	7.2	2.4
	9 STROKES	FINAL	0.0	8.3	2.0

3.4 Siemens/KWU/UTL

3.4.1 EQUIPMENT DESCRIPTION

The Siemens/KWU motor operated valve test system used in the INEL validation testing measured the parameters listed in Attachment 3.4 .

Measurements of stem torque and thrust used typical strain gages and experimental stress formulas for smooth columns. The gages are pre-bonded and wired to shim stock and installed on the stem as a complete unit including electrical connectors.

Motor current,voltage and power are measured by placing the signal conditioner in series with the current path between the supply voltage and the actuator motor. This requires removing the three motor leads to the motor. Current transformers in the signal conditioner sense the current with an RMS output. Voltage transducers sense the phase to phase voltage from 300 to 500 vac with RMS output. Power transducers measure true power with an RMS output.

Spring pack displacement is measured with an LVDT adapted to the spring pack. Torque or thrust correlation measurements may be made from the motor power vs torque (thrust) X-Y plots. These plots are stored in memory for each tested valve and the power trace can be rescaled using this correlation to indicate torque (thrust). Spring pack displacement can also be correlated to output torque.

3.4.2 DIFFICULTIES/ABNORMALITIES

KWU could not bring the torque measuring cell that would normally be used to calibrate the actuator output torque to either motor power or spring pack displacement. KWU calibrated the actuator using the INEL torque arm data to establish a torque correlation to SP displacement and motor power. However, this test information was not used to correlate torque but was later used to calculate approximate thrust values to check strain gage outputs.

From this early comparison of spring pack displacement and torque measurements, the strain gage values obtained were suspected of being too low. This situation was recognized by both KWU and the utility representatives. A comparison to the INEL load cell revealed ≈35% error. KWU participants were informed that the significant error existed; however, the magnitude of the error was not made known to them.

Following installation of 4 sets of strain gages, checking the accuracy of force calculations used and verifying equipment measuring circuits, KWU personnel could not resolve the suspect error. The test coordinator and utility host decided that a dynamic stroke should be taken to officially quantify the errors.

Data was taken for 18 tests. 9 were for strain gage set 3 and 9 for set 4. The error appeared to be evident on both torque and thrust channels.

KWU decided to accept the data "as is". The data would be recorded, compared and published. Subsequently; KWU would be given an opportunity to provide an explanation of the error in the post calibration data report. KWU would receive the test data sheets following the test.

KWU was aware that any future testing would not be sponsored by the MUG or INEL.

Data analysis for only one complete set of parameters was completed. Two sets of 9 strokes were taken but only the voltage parameter was analyzed on the first 9 strokes. The remaining 8 parameters were analyzed on the second set of 9 strokes. This was necessary because KWU had 8 channels available and was required to monitor a 9th parameter (ref time mark).

The 60hz noise on the INEL power channel was significant. Data analysis or comparison with this noise present may not provide any useful data to either the MUG or KWU.

KWU expressed concern with bearing friction causing torque loss on the strain gages of the torque arm. INEL personnel explained that lab testing had measured potential torque losses at less than 5 ft lbs at thrust values twice those expected during validation testing.

The INEL torque cell output had 60 hz noise present on the trace. This noise had a peak to peak value of 4 ft lb. Comparison of data with this noise unfiltered may not provide any useful data to either the MUG or KWU.

The KWU data acquisition equipment had a 4 msec. sample rate. The INEL equipment sample rate was 1 msec. This difference could affect the direct time-based comparison of KWU verses INEL data by no more than 4 msec.

The KWU strain gages were measured independently by the INEL system and verified to give more realistic thrust outputs than the KWU computer output. The conversion factor was independently calculated and the KWU factor was correct. KWU suspected that the conversion from 220v 50Hz to 110v 60Hz, wrong scaling, wrong gain control of the amplifier, software or transport damage adversely affected the equipment.

The transducers were reviewed for response times following testing. See Attachment 3.4 for uncertainty analysis and response times for INEL and vendor equipment.

The KWU accuracy claims summary sheet for thrust and torque was incorrectly interpreted as "percent of full scale" on the originally supplied data sheet. This value has since been changed to reflect "percent of reading" on the most current accuracy claims summary sheets included in this report. The INEL test data sheets and attached tables reflect the originally supplied accuracy information using "percent of full scale."

INEL ERROR BANDS				
CHANNEL	PARAMETER	RANGE	% ERROR FS	UNITS ERROR
CHAN 19	VOLTS (PH1 to 2)	± 0-575 v	.0898	± 0.516 v
CHAN 20	VOLTS (PH2 to 3)	± 0-575 v	.0950	± 0.546 v
CHAN 32	STEM FORCE	±0-40000 lbf	.3613	± 144.5lbf
CHAN 48	STEM TORQUE	±0-400ftlb	.1464	± .586ftlb
CHAN 49	STEM TORQUE	±0-400ftlb	.1456	± .582ftlb
CHAN 57	TIME REF	N/A	N/A	N/A
CHAN 64	STEM POSITION	0 - 10 in	.3176	±0.003176 in
CHAN 66	CST	N/A	N/A	N/A
CHAN 67	POWER (RMS 3PH)	0 - 40 kw	.2062	± 82.48 w (0.082kw)
CHAN 69	SP DISP	0 - 5 in	.1613	±0.008065 in
ADD FOR SET 2				
CHAN 16	CURRENT (RMS) (PH1)	0 - 20 A	.1410	± 0.0282 A
CHAN 34	CURRENT SINE (INSTAN)	0 - 400A	.2151	± 0.8604 A

- Response time of Power transducers is 250 msec to 90%

- Response time of Current transducers is 1 msec to 90%

- Response time of Voltage transducers is 400 msec

Values Used During INEL Testing

VENDOR ERROR BANDS			
PARAMETER	RANGE	% ERROR FS	UNITS ERROR
STEM FORCE (½BR)	0 - 141000 lbf	10.0	± 14100.0 lbf
STEM TORQUE (F BR)	0 - 1972 ftlb	10.0	± 197.2 ftlb
SP DISP	0 - .787 in	3.5	± .02755 in
CURRENT (RMS)	0 - 50 A	2.5	± 1.25 A
VOLTAGE (PH 1 to 3) (RMS)	300 - 500 vac	2.5	± 12.5 v
CST (RESOLUTION)	N/A	.004sec	N/A
THRUST CORRELATION	0 - 141000 lbf	13.0	± 18330.0 lbf
POWER (RMS)(3PH)	0 - 43.3 kw	2.7	± 1.161 kw

- Spring pack disp sign is opposite to INEL
- Response time of Power transducer is 50 msec to 90%
- Response time of Current transducer is 50 msec to 90%
- Response time of Voltage transducer is (unknown at time)

Revised Following INEL Testing (June 1991)

VENDOR ERROR BANDS				
PARAMETER	RANGE	% ERROR MV	UNITS ERROR	MV *
STEM FORCE (½BR)	0-141000 lbf	± 10.0	± 1200 lbf	12,000 lbf
STEM TORQUE (F BR)	0-1972 ftlb	± 10.0	± 19.0 ftlb	190 ftlb
SP DISP	0-.787 in	± 3.5	± .00525 in	0.15 inch
CURRENT (RMS)	0-50 A	± 2.5	± 0.362 A	14.5 amp
VOLTAGE (PH 1-3) (RMS)	300-500 vac	± 2.5	± 12.5 v	500 v
CST (RESOLUTION)	N/A	.004sec	N/A	N/A
THRUST CORRELATION	0-141000 lbf	± 10.4	± 1248 lbf	12,000 lbf
POWER (RMS)(3PH)	0-43.3 kw	± 2.7	± 0.0756 kw	2.8 kw

- Spring pack disp sign is opposite to INEL
- Response time of Power transducer is 50 msec to 99%
- Response time of Current transducer is 50 msec to 99%
- Response time of Voltage transducer is 50 msec to 99%

* MV means measured value. It represents the average value of all measured values of each variable during the tests.

Constants and Variables Table

Parameters used by KWU in calculations:

$E = 29 \times 10^6$ PSI
$A = 2.41$ in^2
Gage Factor = 1.98
Scale Factor (thrust) = 2mv/v / 141000 lbf
Scale Factor (torque) = 2mv/v / 1900 ftlb
Full Scale Strain ϵ (both gages) = 4000 μin/in or μm/m
No. of gages = 2 both in normal direction for thrust
No. of gages = 4 torque output gages.

20A

SIEMENS TEST DATA

S/N #1

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
2.1	10	2	T. S. TRIP	10534	16957	16812	17102	6568	39.1	1	50	H	THRUST/
			FINAL	13425	21635	21490	21780	−8065	37.5				TORQUE
2.2	11	2	T. S. TRIP	12393	19365	19220	19510	−6827	35.5	1	100	H	THRUST/
			FINAL	14940	24116	23971	24261	−9031	37.7				TORQUE
2.3	12	2	T. S. TRIP	10947	17676	17531	17821	−6584	37.6	1	180	H	THRUST/
			FINAL	10603	17077	16932	17222	−6329	37.4				TORQUE
2.4	13	1.75	T. S. TRIP	9634	15214	15069	15359	−5435	36.1	5	50	M	THRUST/
			FINAL	12117	19628	19483	19773	−7366	37.8				TORQUE
2.5	14	1.75	T. S. TRIP	9639	14861	14716	15006	−5077	34.5	5	100	M	THRUST/
			FINAL	12255	19886	19741	20031	−7486	37.9				TORQUE
2.6	15	1.75	T. S. TRIP	9432	14861	14716	15006	−5284	35.9	5	150	M	THRUST/
			FINAL	12461	20116	19971	20261	−7510	37.6				TORQUE
2.7	16	1.25	T. S. TRIP	6678	10014	9869	10159	−3191	32.3	9	25	L	THRUST/
			FINAL	10258	16820	16675	16965	−6417	38.5				TORQUE
2.8	17	1.25	T. S. TRIP	6885	10449	10304	10594	−3419	33.2	9	50	L	THRUST/
			FINAL	10327	16608	16463	16753	−6136	37.3				TORQUE
2.9	18	1.25	T. S. TRIP	6541	9627	9482	9772	−2941	31.0	9	100	L	THRUST/
			FINAL	10189	16556	16411	16701	−6222	37.9				TORQUE

NOTE: DATA IS INCORRECT DUE TO A HARDWARE PROBLEM. SEE COMMENT SECTION 4.4 FOR EXPLANATION.

SIEMENS TEST DATA AVERAGES

DEVIATION (PERCENT)

THRUST/ TORQUE

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	9 STROKES	T. S. TRIP	31.0	39.1	35.0
	9 STROKES	FINAL	37.3	38.5	37.7

S/N #1	9 STROKES	T. S. TRIP	31.0	39.1	35.0
	9 STROKES	FINAL	37.3	38.5	37.7
0	0 STROKES	T. S. TRIP	0.0	0.0	ERR
	0 STROKES	FINAL	0.0	0.0	ERR
0	0 STROKES	T. S. TRIP	0.0	0.0	ERR
	0 STROKES	FINAL	0.0	0.0	ERR

LOW LOADING	3 STROKES	T. S. TRIP	31.0	33.2	32.2
	3 STROKES	FINAL	37.3	38.5	37.9
MED LOADING	3 STROKES	T. S. TRIP	34.5	36.1	35.5
	3 STROKES	FINAL	37.6	37.9	37.8
HIGH LOADING	3 STROKES	T. S. TRIP	35.5	39.1	37.4
	3 STROKES	FINAL	37.4	37.7	37.5

NOTE: DATA IS INCORRECT DUE TO A HARDWARE PROBLEM. SEE COMMENT SECTION 4.4 FOR EXPLANATION.

3.5 ITI MOVATS TEST EQUIPMENT DESCRIPTION

3.5.1 OVERVIEW

ITI MOVATS tested five different types of stem thrust transducers as part of the equipment validation testing performed on the INEL MOVLS during the week of May 13, 1991. This section provides a description of these thrust transducers along with a description of abnormalities and difficulties encountered during the testing. Mr. Jon Sharpe was the test coordinator and Mr. Pat Conroy was the utility host for the ITI MOVATS equipment testing

3.5.2 EQUIPMENT DESCRIPTION

ITI MOVATS provides a wide variety of transducers to monitor the performance of motor-operated valves (MOV). These transducers can be used independently of one another, or in various combinations to enhance the user's diagnostic capabilities. The thrust measuring transducers that were used during the validation testing are described briefly as follows:

a. Correlation of Spring Pack Displacement to Stem Thrust

The basic methodology involves the correlation of spring pack displacement to stem thrust or actuator output torque. The MOV is electrically operated in the open direction into a load cell mounted above the actuator. Spring pack displacement and load cell output are monitored simultaneously, and the resulting calibration signature is then used to determine opening and closing stem thrust based on spring pack displacement.

Two different types of transducers were utilized during the validation testing to measure spring pack displacement. The first being a standard Thrust Measuring Device (TMD), which uses a Linear Variable Differential Transformer (LVDT) to measure spring pack displacement. The second transducer that was used was a Quick Mount TMD. The Quick Mount TMD is a magnetically mounted device that utilizes an optical encoder for measuring spring pack displacement. Both devices were used in conjunction with a standard 50K load cell.

In field applications, the TMD output is correlated to stem thrust under static conditions, i.e., zero differential and line pressure across the valve. The TMD output is then used to set the actuator torque switch for the required thrust output, again under static conditions. Under rate of loading conditions that differ from the static calibration conditions, TMD measured available stem thrust values may not represent the actual available thrust present. They would instead represent the stem thrust available under the static calibration conditions.

b. Stem Strain Ring (SSR)

The SSR is a strain-based axial force transducer that is mounted directly on the valve stem. It can be mounted either on stem threads or on the solid stem area. The output signal indicates stem thrust in both directions of valve travel.

The principle of operation is based on Hooke's Law, which defines a linear relationship between axial force and deformation within the elastic region of certain materials. The system functions in the same manner as a precision load cell, producing an output proportional to the measured strain.

There are currently two sizes of SSR available. Size A accommodates stem diameters from 0.75" to 1.5", and Size B accommodates stem diameters from 1.5" to 2.5". The Size B SSR was utilized during the validation testing.

c. Stem Load Sensor (SLS)

The SLS probe measures changes in the diametral strain of the valve stem. It is a capacitive proximity probe that mounts directly on either stem threads or on the solid area of the valve stem. When brought into close proximity of the valve stem surface, the SLS probe constitutes one plate of a parallel-plate capacitor. The other plate is the surface of the valve stem. The capacitance of this parallel-plate arrangement varies inversely with the length of the gap between the plates. The capacitive reactance varies directly with gap width. The SLS produces an output voltage that is proportional to the amount of force being applied to the valve stem in either tension or compression.

A complete set of SLS rings consists of 21 different size rings that will fit valve stem sizes from 0.5" to 4". The 1.75" SLS ring was utilized during the validation testing.

d. Torque Thrust Cell (TTC)

The TTC measures torque and thrust directly and simultaneously. It mounts between the valve yoke and actuator using two sets of bolts. The cell is constructed of two concentric load rings that attach to the adjacent components (valve yoke and actuator) in the load path. These rings are solid mechanical structures that are connected by radial bars of steel. All acting loads, (tensile, compressive, or torsional) act directly on the bars/webs. Deflection of the webs under acting loads is a direct indication of the torque and thrust. These deflections are then measured by bonded resistance gages.

3.5.3 DIFFICULTIES/ABNORMALITIES

As indicated in the overview, five different types of thrust-measuring transducers were tested on the INEL MOVLS. In order to optimize the collection of test data, the various types of transducers were installed on the MOVLS prior to valve stroking, so that data could be collected simultaneously.

For the standard TMD, Quick Mount TMD, TTC, and SSR, three different transducers of each type were tested at nine different torque switch settings/load conditions for a total of 27 valve strokes for each transducer type. To reduce the amount of time required for the collection of test data associated with these four different types of transducers, two MOVATS Series 3000 systems were used concurrently. One 3000 system monitored the standard TMD and TTC, and the other system was used to monitor the Quick Mount TMD and SSR. Configuration of the INEL MOVLS did not permit testing of the SSR on the threaded area of the valve stem. Thus, the data associated with the 27 valve strokes for the three different SSR's tested is entirely based on SSR installation on the solid area of the valve stem.

For the SLS, installation on the solid area of the valve stem was easily achievable, but due to space limitations, it was not possible to mount the SLS on the threaded area of the valve stem at the standard minimum distance of one valve stem major diameter from the solid/threaded boundary. Although this deviation was recognized, it was decided to test the SLS on both the solid and threaded areas of the valve stem. New design SLS rings with improved mounting characteristics were available for validation testing, however due to time constraints and validation testing guidelines, only the original design SLS probe was tested.

Whereas three different SLS transducers were available for testing, time did not permit nine strokes of each of these transducers on the solid area and nine strokes on the threaded area of the valve stem (i.e., a total of 54 valve strokes). As a result, only two different SLS rings were tested. Each transducer was tested at nine different torque switch settings/load conditions on the solid area and nine different torque switch settings/load conditions on the threaded area of the valve stem (i.e., a total of 18 valve strokes for each SLS transducer).

When the SLS transducers were mounted on the threaded stem area of the INEL MOVLS, they could only be positioned approximately one-quarter inch from the solid/threaded boundary. As indicated above, it is recognized that installation of the SLS in the solid to threaded transition area of the valve stem is considered abnormal. As such, this may have an adverse affect on the test data collected and test results reported for valve strokes taken with the SLS mounted on the threaded stem area.

The data collection sample rate for the four types of thrust-measuring transducers used with the two 3000 series systems was not able to be normalized to the same sample rate used by INEL. In order to minimize this difference, the stroke length of the INEL MOVLS was shortened to approximately one inch of stem travel. This resulted in a 4ms sample rate for the 3000 series systems compared with a 1ms sample rate for the INEL MOVLS. As discussed in Section 2.3, this difference can have an adverse affect on the accuracies associated with the test results.
The sample rate for the SLS transducers was normalized to the 1ms INEL MOVLS value.

The design of the INEL MOVLS test stand results in the valve stem always being under a compressive load. This characteristic posed somewhat of a difficulty during testing since zero load is typically required to exist and be defined prior to acquiring test data. It was therefore necessary to simulate a zero load on the MOVLS valve stem by performing a series of additional actions when preparing to acquire test data prior to each valve stroke.

Finally, the INEL test data for strokes 24 and 28 is not currently available due to INEL data processing difficulties. As such, these strokes have not been included in the test results provided in this progress report.

ITI–MOVATS TEST DATA

S/N #1

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1	1	1.25	T. S. TRIP	9406	10970	10825	11115	−1419	13.1	9.5	25	L	QUICK
			FINAL	13217	17974	17829	18119	−4612	25.9				MOUNT
2	2	1.25	T. S. TRIP	8758	8339	8194	8484	274	3.2	9.5	50	L	QUICK
			FINAL	13275	15445	15300	15590	−2025	13.2				MOUNT
3	3	1.25	T. S. TRIP	8922	6828	6683	6973	1949	28.0	9.5	100	L	QUICK
			FINAL	15021	13490	13345	13635	1386	10.2				MOUNT
4	4	1.75	T. S. TRIP	14218	14137	13992	14282	0	0.0	5	50	M	QUICK
			FINAL	18209	20322	20177	20467	−1968	9.8				MOUNT
5	5	1.75	T. S. TRIP	14161	11234	11089	11379	2782	24.4	5	100	M	QUICK
			FINAL	18677	16936	16791	17081	1596	9.3				MOUNT
6	6	1.75	T. S. TRIP	14419	10426	10281	10571	3848	36.4	5	150	M	QUICK
			FINAL	20485	16360	16215	16505	3980	24.1				MOUNT
7	7	2	T. S. TRIP	19742	14218	14073	14363	5379	37.5	1	50	H	QUICK
			FINAL	25196	18734	18589	18879	6317	33.5				MOUNT
8	8	2	T. S. TRIP	19860	16200	16055	16345	3515	21.5	1	100	H	QUICK
			FINAL	25022	20922	20777	21067	3955	18.8				MOUNT
9	9	2	T. S. TRIP	20792	14890	14745	15035	5757	38.3	1	180	H	QUICK
			FINAL	20977	14930	14785	15075	5902	39.2				MOUNT

ITI–MOVATS TEST DATA

S/N #2

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
10	10	2	T. S. TRIP	19851	13396	13251	13541	6310	46.6	2	50	H	QUICK
			FINAL	24620	18517	18372	18662	5958	31.9				MOUNT
11	11	2	T. S. TRIP	19426	15075	14930	15220	4206	27.6	2	100	H	QUICK
			FINAL	23800	20252	20107	20397	3403	16.7				MOUNT
12	12	2	T. S. TRIP	20335	16411	16266	16556	3779	22.8	2	200	H	QUICK
			FINAL	20451	16475	16330	16620	3831	23.1				MOUNT
13	13	1.75	T. S. TRIP	14468	13304	13159	13449	1019	7.6	5	50	M	QUICK
			FINAL	18757	19867	19722	20012	−965	4.9				MOUNT
14	14	1.75	T. S. TRIP	14279	10896	10751	11041	3238	29.3	5	100	M	QUICK
			FINAL	19004	17272	17127	17417	1587	9.1				MOUNT
15	15	1.75	T. S. TRIP	14405	10912	10767	11057	3348	30.3	5	150	M	QUICK
			FINAL	19187	16913	16768	17058	2129	12.5				MOUNT
16	16	1.25	T. S. TRIP	9509	9110	8965	9255	254	2.7	9	25	L	QUICK
			FINAL	13669	16638	16493	16783	−2824	17.1				MOUNT
17	17	1.25	T. S. TRIP	9218	8136	7991	8281	937	11.3	9	50	L	QUICK
			FINAL	13608	15750	15605	15895	−1997	12.8				MOUNT
18	18	1.25	T. S. TRIP	9103	6559	6414	6704	2399	35.8	9	100	L	QUICK
			FINAL	14631	13260	13115	13405	1126	8.4				MOUNT

ITI–MOVATS TEST DATA

S/N #3

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
19	19	1.25	T. S. TRIP	9302	8555	8410	8700	602	6.9	9	25	L	QUICK
			FINAL	13460	16328	16183	16473	−2723	16.8				MOUNT
20	20	1.25	T. S. TRIP	9545	7353	7208	7498	2047	27.3	9	50	L	QUICK
			FINAL	13776	14839	14694	14984	−918	6.2				MOUNT
21	21	1.25	T. S. TRIP	9606	6448	6303	6593	3013	45.7	9	100	L	QUICK
			FINAL	14650	12605	12460	12750	1900	14.9				MOUNT
22	22	1.75	T. S. TRIP	14461	12192	12047	12337	2124	17.2	5	50	M	QUICK
			FINAL	17946	18060	17915	18205	0	0.0				MOUNT
23	23	1.75	T. S. TRIP	14776	11087	10942	11232	3544	31.6	5	100	M	QUICK
			FINAL	18701	17285	17140	17430	1271	7.3				MOUNT
24	24	1.75	T. S. TRIP	14461	*	−145	145	14316	9873.1	5	150	M	QUICK
			FINAL	19343	*	−145	145	19198	13240.0				MOUNT
25	25	2	T. S. TRIP	17882	14259	14114	14404	3478	24.1	1	50	H	QUICK
			FINAL	22334	19587	19442	19732	2602	13.2				MOUNT
26	26	2	T. S. TRIP	18260	14551	14406	14696	3564	24.3	1	100	H	QUICK
			FINAL	22334	19336	19191	19481	2853	14.6				MOUNT
27	27	2	T. S. TRIP	18961	14937	14792	15082	3879	25.7	1	180	H	QUICK
			FINAL	18961	14937	14792	15082	3879	25.7				MOUNT

24D

ITI–MOVATS TEST DATA AVERAGES

DEVIATION (PERCENT)

QUICK MOUNT

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	26 STROKES	T. S. TRIP	0.0	46.6	23.8
	26 STROKES	FINAL	0.0	39.2	16.1
S/N #1	9 STROKES	T. S. TRIP	0.0	38.3	22.5
	9 STROKES	FINAL	9.3	39.2	20.4
S/N #2	9 STROKES	T. S. TRIP	2.7	46.6	23.8
	9 STROKES	FINAL	4.9	31.9	15.2
S/N #3	8 STROKES	T. S. TRIP	6.9	45.7	25.4
	8 STROKES	FINAL	0.0	25.7	12.4
LOW LOADING	9 STROKES	T. S. TRIP	2.7	45.7	19.3
	9 STROKES	FINAL	6.2	25.9	14.0
MED LOADING	8 STROKES	T. S. TRIP	0.0	36.4	22.1
	8 STROKES	FINAL	0.0	24.1	9.6
HIGH LOADING	9 STR	T. S. TRIP	21.5	46.6	29.8
	9 STROKES	FINAL	13.2	39.2	24.1

* DESIGNATES INCOMPLETE STROKE DATA. MARKED STROKES WERE NOT USED IN CALCULATIONS.

ITI–MOVATS TEST DATA

S/N #1

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1	1	1.25	T. S. TRIP	9485	10206	10061	10351	−576	5.7	9.5	25	L	TMD/LC
			FINAL	12684	17898	17753	18043	−5069	28.6				
2	2	1.25	T. S. TRIP	8477	8339	8194	8484	0	0.0	9.5	50	L	TMD/LC
			FINAL	12439	15927	15782	16072	−3343	21.2				
3	3	1.25	T. S. TRIP	9234	6557	6412	6702	2532	37.8	9.5	100	L	TMD/LC
			FINAL	14291	13490	13345	13635	656	4.8				
4	4	1.75	T. S. TRIP	13363	14517	14372	14662	−1009	7.0	5	50	M	TMD/LC
			FINAL	17194	20827	20682	20972	−3488	16.9				
5	5	1.75	T. S. TRIP	13443	11611	11466	11756	1687	14.4	5	100	M	TMD/LC
			FINAL	17679	17646	17501	17791	0	0.0				
6	6	1.75	T. S. TRIP	13967	10426	10281	10571	3396	32.1	5	150	M	TMD/LC
			FINAL	19428	16808	16663	16953	2475	14.6				
7	7	2	T. S. TRIP	18458	14473	14328	14618	3840	26.3	1	50	H	TMD/LC
			FINAL	24294	19459	19314	19604	4690	23.9				
8	8	2	T. S. TRIP	18729	16200	16055	16345	2384	14.6	1	100	H	TMD/LC
			FINAL	24107	21355	21210	21500	2607	12.1				
9	9	2	T. S. TRIP	19619	14871	14726	15016	4603	30.7	1	180	H	TMD/LC
			FINAL	19683	14907	14762	15052	4631	30.8				

ITI–MOVATS TEST DATA

S/N #2

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
10	10	2	T. S. TRIP	19431	13396	13251	13541	5890	43.5	2	50	H	TMD/LC
			FINAL	24119	18970	18825	19115	5004	26.2				
11	11	2	T. S. TRIP	19309	15453	15308	15598	3711	23.8	2	100	H	TMD/LC
			FINAL	23190	21166	21021	21311	1879	8.8				
12	12	2	T. S. TRIP	19715	16438	16293	16583	3132	18.9	2	200	H	TMD/LC
			FINAL	19837	16471	16326	16616	3221	19.4				
13	13	1.75	T. S. TRIP	14820	13718	13573	13863	957	6.9	5	50	M	TMD/LC
			FINAL	18480	20521	20376	20666	−1896	9.3				
14	14	1.75	T. S. TRIP	14016	10896	10751	11041	2975	26.9	5	100	M	TMD/LC
			FINAL	18689	17798	17653	17943	746	4.2				
15	15	1.75	T. S. TRIP	14223	11300	11155	11445	2778	24.3	5	150	M	TMD/LC
			FINAL	18689	17446	17301	17591	1098	6.2				
16	16	1.25	T. S. TRIP	9393	9505	9360	9650	0	0.0	9	25	L	TMD/LC
			FINAL	13404	17190	17045	17335	−3641	21.4				
17	17	1.25	T. S. TRIP	9529	8542	8397	8687	842	9.7	9	50	L	TMD/LC
			FINAL	13465	16108	15963	16253	−2498	15.6				
18	18	1.25	T. S. TRIP	8758	7001	6856	7146	1612	22.6	9	100	L	TMD/LC
			FINAL	14264	13868	13723	14013	251	1.8				

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ITI–MOVATS TEST DATA

S/N #3

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
19	19	1.25	T. S. TRIP	9500	8971	8826	9116	384	4.2	9	25	L	TMD/LC
			FINAL	13368	17261	17116	17406	−3748	21.9				
20	20	1.25	T. S. TRIP	9740	7772	7627	7917	1823	23.0	9	50	L	TMD/LC
			FINAL	13742	15562	15417	15707	−1675	10.9				
21	21	1.25	T. S. TRIP	9440	6559	6414	6704	2736	40.8	9	100	L	TMD/LC
			FINAL	14582	13719	13574	13864	718	5.2				
22	22	1.75	T. S. TRIP	14539	12600	12455	12745	1794	14.1	5	50	M	TMD/LC
			FINAL	17829	19189	19044	19334	−1215	6.4				
23	23	1.75	T. S. TRIP	14968	11870	11725	12015	2953	24.6	5	100	M	TMD/LC
			FINAL	18642	17799	17654	17944	698	3.9				
24	24	1.75	T. S. TRIP	14180	*	−145	145	14035	9679.3	5	150	M	TMD/LC
			FINAL	19407	*	−145	145	19262	13284.1				
25	25	2	T. S. TRIP	17704	14259	14114	14404	3300	22.9	1	50	H	TMD/LC
			FINAL	22447	19917	19772	20062	2385	11.9				
26	26	2	T. S. TRIP	18040	14551	14406	14696	3344	22.8	1	100	H	TMD/LC
			FINAL	22447	20317	20172	20462	1985	9.7				
27	27	2	T. S. TRIP	18446	14954	14809	15099	3347	22.2	1	180	H	TMD/LC
			FINAL	18485	15017	14872	15162	3323	21.9				

ITI–MOVATS TEST DATA AVERAGES

DEVIATION (PERCENT)

TMD/LC

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	26 STROKES	T. S. TRIP	0.0	43.5	20.0
	26 STROKES	FINAL	0.0	30.8	13.7
S/N #1	9 STROKES	T. S. TRIP	0.0	37.8	18.7
	9 STROKES	FINAL	0.0	30.8	17.0
S/N #2	9 STROKES	T. S. TRIP	0.0	43.5	19.6
	9 STROKES	FINAL	1.8	26.2	12.5
S/N #3	8 STROKES	T. S. TRIP	4.2	40.8	21.8
	8 STROKES	FINAL	3.9	21.9	11.5
LOW LOADING	9 STROKES	T. S. TRIP	0.0	40.8	16.0
	9 STROKES	FINAL	1.8	28.6	14.6
MED LOADING	8 STROKES	T. S. TRIP	6.9	32.1	18.8
	8 STROKES	FINAL	0.0	16.9	7.7
HIGH LOADING	9 STROKES	T. S. TRIP	14.6	43.5	25.1
	9 STROKES	FINAL	8.8	30.8	18.3

* DESIGNATES INCOMPLETE STROKE DAT[illegible]RKED STROKES WERE NO[illegible]D IN CALCULATIONS.

24H

ITI–MOVATS TEST DATA

S/N #1

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1	1	1.25	T. S. TRIP	10124	10970	10825	11115	−701	6.5	9.5	25	L	SSR
			FINAL	15623	17974	17829	18119	−2206	12.4				
2	2	1.25	T. S. TRIP	8482	8339	8194	8484	0	0.0	9.5	50	L	SSR
			FINAL	14536	15445	15300	15590	−764	5.0				
3	3	1.25	T. S. TRIP	3625	6828	6683	6973	−3058	45.8	9.5	100	L	SSR
			FINAL	9223	13490	13345	13635	−4122	30.9				
4	4	1.75	T. S. TRIP	12320	14137	13992	14282	−1672	11.9	5	50	M	SSR
			FINAL	17269	20322	20177	20467	−2908	14.4				
5	5	1.75	T. S. TRIP	10597	11234	11389	11379	−492	4.4	5	100	M	SSR
			FINAL	15380	16936	16791	17031	−1411	8.4				
6	6	1.75	T. S. TRIP	9994	10426	10281	10571	−287	2.8	5	150	M	SSR
			FINAL	14990	16360	16215	16505	−1225	7.6				
7	7	2	T. S. TRIP	12948	14218	14073	14363	−1125	8.0	1	50	H	SSR
			FINAL	16852	18734	18589	18879	−1737	9.3				
8	8	2	T. S. TRIP	14853	[illegible]	16055	16345	−1202	7.5	1	100	H	SSR
			FINAL	18781	20922	20777	21067	−1996	9.6				
9	9	2	T. S. TRIP	12756	14890	14745	15035	−1989	13.5	1	180	H	SSR
			FINAL	12756	14936	14791	15081	−2035	13.8				

H
J
N

ITI–MOVATS TEST DATA

S/N #2

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
10	10	2	T. S. TRIP	11329	13396	13251	13541	−1922	14.5	2	50	H	SSR
			FINAL	15857	18517	18372	18662	−2515	13.7				
11	11	2	T. S. TRIP	12708	15075	14930	15220	−2222	14.9	2	100	H	SSR
			FINAL	17526	20252	20107	20397	−2581	12.8				
12	12	2	T. S. TRIP	15001	16411	16266	16556	−1265	7.8	2	200	H	SSR
			FINAL	15188	16475	16330	16620	−1142	7.0				
13	13	1.75	T. S. TRIP	11329	13304	13159	13449	−1830	13.9	5	50	M	SSR
			FINAL	17312	19867	19722	20012	−2410	12.2				
14	14	1.75	T. S. TRIP	9486	10896	10751	11041	−1265	11.8	5	100	M	SSR
			FINAL	15076	17272	17127	17417	−2051	12.0				
15	15	1.75	T. S. TRIP	11206	10912	10767	11057	149	1.3	5	150	M	SSR
			FINAL	16104	16913	16768	17058	−664	4.0				
16	16	1.25	T. S. TRIP	9104	9110	8965	9255	0	0.0	9	25	L	SSR
			FINAL	15896	16638	16493	16783	−597	3.6				
17	17	1.25	T. S. TRIP	8358	8136	7991	8281	77	0.9	9	50	L	SSR
			FINAL	14984	15750	15605	15895	−621	4.0				
18	18	1.25	T. S. TRIP	6474	6559	6414	6704	0	0.0	9	100	L	SSR
			FINAL	12543	13260	13115	13405	−572	4.4				

ITI–MOVATS TEST DATA

S/N #3

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
19	19	1.25	T. S. TRIP	8830	8555	8410	8700	130	1.5	9	25	L	SSR
			FINAL	15784	16328	16183	16473	−399	2.5				
20	20	1.25	T. S. TRIP	7818	7353	7208	7498	320	4.3	9	50	L	SSR
			FINAL	14142	14839	14694	14984	−552	3.8				
21	21	1.25	T. S. TRIP	5935	6448	6303	6593	−368	5.8	9	100	L	SSR
			FINAL	11714	12605	12460	12750	−746	6.0				
22	22	1.75	T. S. TRIP	10358	12192	12047	12337	−1689	14.0	5	50	M	SSR
			FINAL	15600	18060	17915	18205	−2315	12.9				
23	23	1.75	T. S. TRIP	10236	11087	10942	11232	−706	6.5	5	100	M	SSR
			FINAL	15212	17285	17140	17430	−1928	11.2				
24	24	1.75	T. S. TRIP	11006	*	−145	145	10861	7490.3	5	150	M	SSR
			FINAL	16099	*	−145	145	15954	11002.8				
25	25	2	T. S. TRIP	14502	14259	14114	14404	98	0.7	1	50	H	SSR
			FINAL	18515	19587	19442	19732	−927	4.8				
26	26	2	T. S. TRIP	14751	14551	14406	14696	55	0.4	1	100	H	SSR
			FINAL	18892	19336	19191	19481	−299	1.6				
27	27	2	T. S. TRIP	13963	14937	14792	15082	−829	5.6	1	180	H	SSR
			FINAL	13963	14937	14792	15082	−829	5.6				

ITI–MOVATS TEST DATA AVERAGES

DEVIATION (PERCENT)

SSR

STROKE	DATA POINT	MIN	MAX	AVE % DEV
26 STROKES	T. S. TRIP	0.0	45.8	7.9
	FINAL	1.6	30.9	9.0

S/N #1	T. S. TRIP	0.0	45.8	11.2
9 STROKES	FINAL	5.0	30.9	12.4
S/N #2	T. S. TRIP	0.0	14.9	7.2
9 STROKES	FINAL	3.6	13.7	8.2
S/N #3	T. S. TRIP	0.4	14.0	4.8
8 STROKES	FINAL	1.6	12.9	6.0

LOW LOADING CONDITION	T. S. TRIP	0.0	45.8	7.2
9 STROKES	FINAL	2.5	30.9	8.0
MED LOADING CONDITION	T. S. TRIP	1.3	14.0	8.3
8 STROKES	FINAL	4.0	14.4	10.3
HIGH LOADING CONDITION	T. S. TRIP	0.4	14.9	8.1
9 STROKES	FINAL	1.6	13.8	8.7

* DESIGNATES INCOMPLETE STROKE DATA. MARKED STROKES WERE NOT USED IN CALCULATIONS.

ITI–MOVATS TEST DATA

S/N #1

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1	1	1.25	T. S. TRIP	11369	10206	10061	10351	1018	9.8	9.5	25	L	TORQUE/
			FINAL	17812	17898	17753	18043	0	0.0				THRUST
2	2	1.25	T. S. TRIP	9108	8339	8194	8484	624	7.4	9.5	50	L	TORQUE/
			FINAL	15788	15927	15782	16072	0	0.0				THRUST
3	3	1.25	T. S. TRIP	7489	6557	6412	6702	787	11.7	9.5	100	L	TORQUE/
			FINAL	13494	13490	13345	13635	0	0.0				THRUST
4	4	1.75	T. S. TRIP	15365	14517	14372	14662	703	4.8	5	50	M	TORQUE/
			FINAL	20560	20827	20682	20972	−122	0.6				THRUST
5	5	1.75	T. S. TRIP	12515	11611	11466	11756	759	6.5	5	100	M	TORQUE/
			FINAL	17609	17646	17501	17791	0	0.0				THRUST
6	6	1.75	T. S. TRIP	11224	10426	10281	10571	653	6.2	5	150	M	TORQUE/
			FINAL	16578	16808	16663	16953	−85	0.5				THRUST
7	7	2	T. S. TRIP	14809	14473	14328	14618	191	1.3	1	50	H	TORQUE/
			FINAL	19262	19459	19314	19604	−52	0.3				THRUST
8	8	2	T. S. TRIP	16665	16200	16055	16345	320	2.0	1	100	H	TORQUE/
			FINAL	21050	21355	21210	21500	−160	0.8				THRUST
9	9	2	T. S. TRIP	14725	14871	14726	15016	−1	0.0	1	180	H	TORQUE/
			FINAL	14758	14907	14762	15052	−4	0.0				THRUST

ITI–MOVATS TEST DATA

S/N #2

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
10	10	2	T. S. TRIP	14246	13396	13251	13541	705	5.2	2	50	H	TORQUE/ THRUST
			FINAL	18754	18970	18825	19115	−71	0.4				
11	11	2	T. S. TRIP	16289	15453	15308	15598	691	4.4	2	100	H	TORQUE/ THRUST
			FINAL	20966	21166	21021	21311	−55	0.3				
12	12	2	T. S. TRIP	16286	16438	16293	16583	−7	0.0	2	200	H	TORQUE/ THRUST
			FINAL	16320	16471	16326	16616	−6	0.0				
13	13	1.75	T. S. TRIP	14946	13718	13573	13863	1083	7.8	5	50	M	TORQUE/ THRUST
			FINAL	20368	20521	20376	20666	−8	0.0				
14	14	1.75	T. S. TRIP	11950	10896	10751	11041	909	8.2	5	100	M	TORQUE/ THRUST
			FINAL	17678	17798	17653	17943	0	0.0				
15	15	1.75	T. S. TRIP	12133	11300	11155	11445	688	6.0	5	150	M	TORQUE/ THRUST
			FINAL	17250	17446	17301	17591	−51	0.3				
16	16	1.25	T. S. TRIP	10371	9505	9360	9650	721	7.5	9	25	L	TORQUE/ THRUST
			FINAL	16979	17190	17045	17335	−66	0.4				
17	17	1.25	T. S. TRIP	9625	8542	8397	8687	938	10.8	9	50	L	TORQUE/ THRUST
			FINAL	15996	16108	15963	16253	0	0.0				
18	18	1.25	T. S. TRIP	7456	7001	6856	7146	310	4.3	9	100	L	TORQUE/ THRUST
			FINAL	13760	13868	13723	14013	0	0.0				

24N

ITI–MOVATS TEST DATA

S/N #3

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
19	19	1.25	T. S. TRIP	9901	8971	8826	9116	785	8.6	9	25	L	TORQUE/
			FINAL	17048	17261	17116	17406	−68	0.4				THRUST
20	20	1.25	T. S. TRIP	8882	7772	7627	7917	965	12.2	9	50	L	TORQUE/
			FINAL	15354	15562	15417	15707	−63	0.4				THRUST
21	21	1.25	T. S. TRIP	7046	6559	6414	6704	342	5.1	9	100	L	TORQUE/
			FINAL	13552	13719	13574	13864	−22	0.2				THRUST
22	22	1.75	T. S. TRIP	13663	12600	12455	12745	918	7.2	5	50	M	TORQUE/
			FINAL	18990	19189	19044	19334	−54	0.3				THRUST
23	23	1.75	T. S. TRIP	12675	11870	11725	12015	660	5.5	5	100	M	TORQUE/
			FINAL	17665	17799	17654	17944	0	0.0				THRUST
24	24	1.75	T. S. TRIP	11506	*	−145	145	11361	7835.2	5	150	M	TORQUE/
			FINAL	17270	*	−145	145	17125	11810.3				THRUST
25	25	2	T. S. TRIP	15091	14259	14114	14404	687	4.8	1	50	H	TORQUE/
			FINAL	19912	19917	19772	20062	0	0.0				THRUST
26	26	2	T. S. TRIP	15632	14551	14406	14696	936	6.4	1	100	H	TORQUE/
			FINAL	20081	20317	20172	20462	−91	0.5				THRUST
27	27	2	T. S. TRIP	14783	14954	14809	15099	−26	0.2	1	180	H	TORQUE/
			FINAL	14850	15017	14872	15162	−22	0.1				THRUST

ITI–MOVATS TEST DATA AVERAGES

DEVIATION (PERCENT)

TORQUE/ THRUST

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	26 STROKES	T. S. TRIP	0.0	12.2	5.9
	26 STROKES	FINAL	0.0	0.8	0.2
S/N #1	9 STROKES	T. S. TRIP	0.0	11.7	5.5
	9 STROKES	FINAL	0.0	0.8	0.2
S/N #2	9 STROKES	T. S. TRIP	0.0	10.8	6.0
	9 STROKES	FINAL	0.0	0.4	0.2
S/N #3	8 STROKES	T. S. TRIP	0.2	12.2	6.2
	8 STROKES	FINAL	0.0	0.5	0.2
LOW LOADING	9 STROKES	T. S. TRIP	4.3	12.2	8.6
	9 STROKES	FINAL	0.0	0.4	0.2
MED LOADING	8 STROKES	T. S. TRIP	4.8	8.2	6.5
	8 STROKES	FINAL	0.0	0.6	0.2
HIGH LOADING	9 STROKES	T. S. TRIP	0.0	6.4	2.7
	9 STROKES	FINAL	0.0	0.8	0.3

* DESIGNATES INCOMPLETE STROKE DATA. MARKED STROKES WERE NOT USED IN CALCULATIONS.

24Q

ITI–MOVATS TEST DATA (VITALS SMOOTH)

S/N #1 STD–40–5432–9013

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
1	1	1.25	T. S. TRIP	11028	11487	11342	11632	–314	2.8	9.5	25	L	VITALS
			FINAL	17757	18113	17968	18258	–211	1.2				SLS
2	2	1.25	T. S. TRIP	8678	9360	9215	9505	–537	5.8	9.5	50	L	VITALS
			FINAL	15514	16039	15894	16184	–380	2.4				SLS
3	3	1.25	T. S. TRIP	6622	7217	7072	7362	–450	6.4	9.5	100	L	VITALS
			FINAL	13190	13710	13565	13855	–375	2.8				SLS
4	4	1.75	T. S. TRIP	15247	15712	15567	15857	–320	2.1	5	50	M	VITALS
			FINAL	20454	20878	20733	21023	–279	1.3				SLS
5	5	1.75	T. S. TRIP	12256	12766	12621	12911	–365	2.9	5	100	M	VITALS
			FINAL	17410	17882	17737	18027	–327	1.8				SLS
6	6	1.75	T. S. TRIP	11268	11570	11425	11715	–157	1.4	5	150	M	VITALS
			FINAL	16582	16810	16665	16955	–83	0.5				SLS
7	7	2	T. S. TRIP	14392	14898	14753	15043	–361	2.4	1	50	H	VITALS
			FINAL	19199	19512	19367	19657	–168	0.9				SLS
8	8	2	T. S. TRIP	16288	16794	16649	16939	–361	2.2	1	100	H	VITALS
			FINAL	21041	21360	21215	21505	–174	0.8				SLS
9	9	2	T. S. TRIP	14446	14907	14762	15052	–316	2.1	1	180	H	VITALS
			FINAL	14446	14925	14780	15070	–334	2.3				SLS

ITI–MOVATS TEST DATA (VITALS SMOOTH)

S/N #2 STD–40–5433–9013

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
10	10	2	T. S. TRIP	13418	14285	14140	14430	–722	5.1	2	50	H	VITALS
			FINAL	18358	18940	18795	19085	–437	2.3				SLS
11	11	2	T. S. TRIP	15835	16650	16505	16795	–670	4.1	2	100	H	VITALS
			FINAL	20961	21160	21015	21305	–54	0.3				SLS
12	12	2	T. S. TRIP	15674	16431	16286	16576	–612	3.8	2	200	H	VITALS
			FINAL	15794	16303	16158	16448	–364	2.3				SLS
13	13	1.75	T. S. TRIP	13952	14836	14691	14981	–739	5.0	5	50	M	VITALS
			FINAL	20000	20581	20436	20726	–436	2.1				SLS
14	14	1.75	T. S. TRIP	11816	12588	12443	12733	–627	5.0	5	100	M	VITALS
			FINAL	17637	17855	17710	18000	–73	0.4				SLS
15	15	1.75	T. S. TRIP	11402	12416	12271	12561	–869	7.1	5	150	M	VITALS
			FINAL	16809	17418	17273	17563	–464	2.7				SLS
16	16	1.25	T. S. TRIP	10094	10892	10747	11037	–653	6.1	9	25	L	VITALS
			FINAL	16636	17177	17032	17322	–396	2.3				SLS
17	17	1.25	T. S. TRIP	8839	9490	9345	9635	–506	5.4	9	50	L	VITALS
			FINAL	15861	16172	16027	16317	–166	1.0				SLS
18	18	1.25	T. S. TRIP	6515	7589	7444	7734	–929	12.5	9	100	L	VITALS
			FINAL	13164	13879	13734	14024	–570	4.2				SLS

ITI–MOVATS TEST DATA (VITALS SMOOTH) AVERAGES

DEVIATION (PERCENT)

VITALS SLS

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	18 STROKES	T. S. TRIP	1.4	12.5	4.6
	18 STROKES	FINAL	0.3	4.2	1.8

S/N #1	9 STROKES	T. S. TRIP	1.4	6.4	3.1
STD–40–5432–9013	9 STROKES	FINAL	0.5	2.8	1.6
S/N #2	9 STROKES	T. S. TRIP	3.8	12.5	6.0
STD–40–5433–9013	9 STROKES	FINAL	0.3	4.2	2.0
	0 STROKES	T. S. TRIP	0.0	0.0	ERR
	0 STROKES	FINAL	0.0	0.0	ERR

LOW LOADING	6 STROKES	T. S. TRIP	2.8	12.5	6.5
	6 STROKES	FINAL	1.0	4.2	2.3
MED LOADING	6 STROKES	T. S. TRIP	1.4	7.1	3.9
	6 STROKES	FINAL	0.4	2.7	1.5
HIGH LOADING	6 STROKES	T. S. TRIP	2.1	5.1	3.3
	6 STROKES	FINAL	0.3	2.3	1.5

24T

ITI–MOVATS TEST DATA (VITALS THREADED)

S/N #1 STD–40–5432–9013
OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
19	19	1.25	T. S. TRIP	9186	10456	10311	10601	–1125	10.9	9	25	L	VITALS
			FINAL	15503	17227	17082	17372	–1579	9.2				SLS
20	20	1.25	T. S. TRIP	7622	8827	8682	8972	–1060	12.2	9	50	L	VITALS
			FINAL	13853	15544	15399	15689	–1546	10.0				SLS
21	21	1.25	T. S. TRIP	6514	7212	7067	7357	–553	7.8	9	100	L	VITALS
			FINAL	12301	13660	13515	13805	–1214	9.0				SLS
22	22	1.75	T. S. TRIP	12006	13784	13639	13929	–1633	12.0	5	50	M	VITALS
			FINAL	17141	19203	19058	19348	–1917	10.1				SLS
23	23	1.75	T. S. TRIP	10602	12538	12393	12683	–1791	14.5	5	100	M	VITALS
			FINAL	15626	17830	17685	17975	–2059	11.6				SLS
24	24	1.75	T. S. TRIP	10393	*	–145	145	10248	7067.6	5	150	M	VITALS
			FINAL	15367	*	–145	145	15222	10497.9				SLS
25	25	2	T. S. TRIP	13348	15361	15216	15506	–1868	12.3	1	50	H	VITALS
			FINAL	18101	20130	19985	20275	–1884	9.4				SLS
26	26	2	T. S. TRIP	13249	15719	15574	15864	–2325	14.9	1	100	H	VITALS
			FINAL	17756	20289	20144	20434	–2388	11.9				SLS
27	27	2	T. S. TRIP	12757	14973	14828	15118	–2071	14.0	1	180	H	VITALS
			FINAL	12806	14992	14847	15137	–2041	13.7				SLS

ITI–MOVATS TEST DATA (VITALS THREADED)

S/N #2 STD–40–5433–9013
OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
28	28	2	T. S. TRIP	10688	*	−145	145	10543	7271.0	1	50	H	VITALS
			FINAL	14493	*	−145	145	14348	9895.2				SLS
29	29	2	T. S. TRIP	11008	14473	14328	14618	−3320	23.2	1	100	H	VITALS
			FINAL	15257	19184	19039	19329	−3782	19.9				SLS
30	30	2	T. S. TRIP	12006	15634	15489	15779	−3483	22.5	1	170	H	VITALS
			FINAL	16303	20392	20247	20537	−3944	19.5				SLS
31	31	1.75	T. S. TRIP	10553	13893	13748	14038	−3195	23.2	5	50	M	VITALS
			FINAL	15380	19251	19106	19396	−3726	19.5				SLS
32	32	1.75	T. S. TRIP	9100	12314	12169	12459	−3069	25.2	5	100	M	VITALS
			FINAL	13693	17471	17326	17616	−3633	21.0				SLS
33	33	1.75	T. S. TRIP	8459	11612	11467	11757	−3008	26.2	5	150	M	VITALS
			FINAL	13299	17047	16902	17192	−3603	21.3				SLS
34	34	1.25	T. S. TRIP	4248	5846	5701	5991	−1453	25.5	9	25	L	VITALS
			FINAL	10208	12929	12784	13074	−2576	20.2				SLS
35	35	1.25	T. S. TRIP	4445	6096	5951	6241	−1506	25.3	9	50	L	VITALS
			FINAL	10405	13080	12935	13225	−2530	19.6				SLS
36	36	1.25	T. S. TRIP	4642	6321	6176	6466	−1534	24.8	9	70	L	VITALS
			FINAL	10688	13315	13170	13460	−2482	18.8				SLS

ITI–MOVATS TEST DATA (VITALS THREADED) AVERAGES

DEVIATION (PERCENT)

VITALS SLS

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	16 STROKES	T. S. TRIP	7.8	26.2	18.4
	16 STROKES	FINAL	9.0	21.3	15.3
S/N #1	8 STROKES	T. S. TRIP	7.8	14.9	12.3
STD–40–5432–9013	8 STROKES	FINAL	9.0	13.7	10.6
S/N #2	8 STROKES	T. S. TRIP	22.5	26.2	24.5
STD–40–5433–9013	8 STROKES	FINAL	18.8	21.3	20.0
	0 STROKES	T. S. TRIP	0.0	0.0	ERR
	0 STROKES	FINAL	0.0	0.0	ERR
LOW LOADING	6 STROKES	T. S. TRIP	7.8	25.5	17.8
	6 STROKES	FINAL	9.0	20.2	14.5
MED LOADING	5 STROKES	T. S. TRIP	12.0	26.2	20.2
	5 STROKES	FINAL	10.1	21.3	16.7
HIGH LOADING	5 STROKES	T. S. TRIP	12.3	23.2	17.4
	5 STROKES	FINAL	9.4	19.9	14.9

* DESIGNATES INCOMPLETE STROKE DATA. MARKED STROKES WERE NOT USED IN CALCULATIONS.

3.6 TELEDYNE

3.6.1 EQUIPMENT DESCRIPTION

Teledyne Engineering Services (TES) measures valve stem thrust or torque using bonded resistance strain gages mounted directly to the valve stem. Stem loads are measured by either field installed strain gages or a calibrated "Smartstem" traceable to NIST. The Smartstem is installed in the valve in lieu of the manufacturer's standard stem.

The thrust and torque gages are applied in diametrically opposed panes and connected in a full wheatstone bridge configuration.

The TES TOTEM is a portable data acquisition system capable of operating in three modes: drop-off, remote or direct. The drop-off mode was used during the INEL testing. The TOTEM is completely self-contained including power.

Data from up to seven sensors can be connected to the TOTEM. If more channels are required, multiple TOTEMs are used. The seven primary inputs are sampled at 1000sps using 16-bit A-D which provided fixed and gain-ranged outputs. After digitization, the data is processed by a Digital Signal Processor (DSP) which provides anti-alias filtering.

The TES TESTEM is an IBM-PC compatible 386 computer using an MOV data analysis application developed as a signal analysis spreadsheet. The data monitored by the TOTEM is transferred to the TESTEM for analysis, display and reporting.

3.6.2 DIFFICULTIES/ABNORMALITIES

It was originally intended to test three SMARTSTEMs, three sets of strain gauges on the smooth portion of the stem, and three sets of strain gauges on the threaded portion of the stem. This would have required eighty-one test strokes. The full twenty-seven strokes for the SMARTSTEM were completed.

At that point it became obvious that it would not be possible to complete fifty-four strokes within the test period. It was determined by mutual consent of Teledyne, INEL and the Test Coordinator that only six strokes for each of two sets of gauges on the smooth portion of the stem and six strokes for each of two sets of gauges on the threaded portion of the stem would be run.

The six strokes for the two sets of gauges on the smooth portion of the stem were completed. The Teledyne system was setup to run the test strokes for the two sets of gauges on the threaded portion of the stem. A calibration and checkout stroke was run. It was obvious to Teledyne that the results were not as expected. Teledyne stated that the problem could be corrected by applying a different scaling factor. However, since this was not covered in an existing Teledyne procedure, it was not allowed. Teledyne elected to withdraw the strain gauges on the threaded portion of the stem from the validation program.

26A

TELEDYNE TEST DATA

S/N #1

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
2 & 3	1	1.25	T. S. TRIP	6745.6	6259	6114	6404	341.6	5.3	9	25	L	SMART
			FINAL	12500	12253	12108	12398	102	0.8				STEM
4 & 5	2	1.25	T. S. TRIP	7658.8	7111	6966	7256	402.8	5.6	9	50	L	SMART
			FINAL	12952	12691	12546	12836	116	0.9				STEM
6 & 7	3	1.25	T. S. TRIP	7401.3	6845	6700	6990	411.3	5.9	9	100	L	SMART
			FINAL	13359	13065	12920	13210	149	1.1				STEM
8 & 9	4	1.75	T. S. TRIP	14057	13236	13091	13381	676	5.1	5	50	M	SMART
			FINAL	19336	18990	18845	19135	201	1.1				STEM
10 & 11	5	1.75	T. S. TRIP	14174	13097	12952	13242	932	7.0	5	100	M	SMART
			FINAL	18856	18456	18311	18601	255	1.4				STEM
12 & 13	6	1.75	T. S. TRIP	1424	13279	13134	13424	−11710	89.2	5	150	M	SMART
			FINAL	18321	17915	17770	18060	261	1.4				STEM
14 & 15	7	2	T. S. TRIP	18258	17462	17317	17607	651	3.7	1	50	H	SMART
			FINAL	21722	21283	21138	21428	294	1.4				STEM
16 & 17	8	2	T. S. TRIP	18147	17033	16888	17178	969	5.6	1	100	H	SMART
			FINAL	21509	21011	20866	21156	353	1.7				STEM
18 & 19	9	2	T. S. TRIP	15422	15011	14866	15156	266	1.8	1	180	H	SMART
			FINAL	15425	14989	14844	15134	291	1.9				STEM

TELEDYNE TEST DATA

S/N #2

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
3 & 4	10	2	T. S. TRIP	20701	20144	19999	20289	412	2.0	1	50	H	SMART
			FINAL	23511	23706	23561	23851	−50	0.2				STEM
5 & 6	11	2	T. S. TRIP	19740	19490	19345	19635	105	0.5	1	100	H	SMART
			FINAL	23100	23378	23233	23523	−133	0.6				STEM
7 & 8	12	2	T. S. TRIP	18767	18987	18842	19132	−75	0.4	1	220	H	SMART
			FINAL	18773	18989	18844	19134	−71	0.4				STEM
9 & 10	13	1.75	T. S. TRIP	14912	14349	14204	14494	418	2.9	5	50	M	SMART
			FINAL	19051	19193	19048	19338	0	0.0				STEM
11 & 12	14	1.75	T. S. TRIP	15251	14751	14606	14896	355	2.4	5	100	M	SMART
			FINAL	18599	18703	18558	18848	0	0.0				STEM
13 & 14	15	1.75	T. S. TRIP	14843	14307	14162	14452	391	2.7	5	150	M	SMART
			FINAL	19042	19208	19063	19353	−21	0.1				STEM
15 & 16	16	1.25	T. S. TRIP	9560	5818	5673	5963	3597	60.3	9	25	L	SMART
			FINAL	14002	14198	14053	14343	−51	0.4				STEM
17 & 18	17	1.25	T. S. TRIP	8892	8605	8460	8750	142	1.6	9	50	L	SMART
			FINAL	14005	14162	14017	14307	−12	0.1				STEM
19 & 20	18	1.25	T. S. TRIP	8086.5	7020	6875	7165	921.5	12.9	9	100	L	SMART
			FINAL	14385	14354	14209	14499	0	0.0				STEM

26C

TELEDYNE TEST DATA

S/N #3

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
24 & 25	19	1.25	T. S. TRIP	9311.4	9055	8910	9200	111.4	1.2	9	25	L	SMART
			FINAL	14389	14442	14297	14587	0	0.0				STEM
26 & 27	20	1.25	T. S. TRIP	9010.2	8469	8324	8614	396.2	4.6	9	50	L	SMART
			FINAL	14294	14329	14184	14474	0	0.0				STEM
28 & 29	21	1.25	T. S. TRIP	8905.9	8619	8474	8764	141.9	1.6	9	100	L	SMART
			FINAL	14150	14232	14087	14377	0	0.0				STEM
30 & 31	22	1.75	T. S. TRIP	14067	13493	13348	13638	429	3.1	5	50	M	SMART
			FINAL	18548	18595	18450	18740	0	0.0				STEM
32 & 33	23	1.75	T. S. TRIP	14097	13748	13603	13893	204	1.5	5	100	M	SMART
			FINAL	18181	18277	18132	18422	0	0.0				STEM
34 & 35	24	1.75	T. S. TRIP	14636	14106	13961	14251	385	2.7	5	100	M	SMART
			FINAL	18515	18585	18440	18730	0	0.0				STEM
36 & 37	25	2	T. S. TRIP	18307	17707	17562	17852	455	2.5	1	50	H	SMART
			FINAL	22037	22088	21943	22233	0	0.0				STEM
38 & 39	26	2	T. S. TRIP	17597	16678	16533	16823	774	4.6	1	100	H	SMART
			FINAL	21673	21657	21512	21802	0	0.0				STEM
40 & 41	27	2	T. S. TRIP	15820	15861	15716	16006	0	0.0	1	190	H	SMART
			FINAL	15850	15914	15769	16059	0	0.0				STEM

TELEDYNE TEST DATA AVERAGES

DEVIATION (PERCENT)

SMART STEM

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	27 STROKES	T. S. TRIP	0.0	89.2	8.8
	27 STROKES	FINAL	0.0	1.9	0.5

S/N #1	9 STROKES	T. S. TRIP	1.8	89.2	14.3
	9 STROKES	FINAL	0.8	1.9	1.3
S/N #2	9 STROKES	T. S. TRIP	0.4	60.3	9.5
	9 STROKES	FINAL	0.0	0.6	0.2
S/N #3	9 STROKES	T. S. TRIP	0.0	4.6	2.4
	9 STROKES	FINAL	0.0	0.0	0.0

LOW LOADING	9 STROKES	T. S. TRIP	1.2	60.3	11.0
	9 STROKES	FINAL	0.0	1.1	0.4
MED LOADING	9 STROKES	T. S. TRIP	1.5	89.2	12.9
	9 STROKES	FINAL	0.0	1.4	0.4
HIGH LOADING	9 STROKES	T. S. TRIP	0.0	5.6	2.4
	9 STROKES	FINAL	0.0	1.9	0.7

TELEDYNE TEST DATA

STRAIN GUAGE S/N #1 (SMOOTH)

OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
3 & 4	28	2	T. S. TRIP	14742	15594	15449	15739	−707	4.6	1	50	H	STRAIN
			FINAL	19252	21119	20974	21264	−1722	8.2				GUAGE
5 & 6	29	2	T. S. TRIP	14583	16023	15878	16168	−1295	8.2	1	180	H	STRAIN
			FINAL	14591	16088	15943	16233	−1352	8.5				GUAGE
7 & 8	30	1.75	T. S. TRIP	13245	14041	13896	14186	−651	4.7	5	50	M	STRAIN
			FINAL	17485	19284	19139	19429	−1654	8.6				GUAGE
9 & 10	31	1.75	T. S. TRIP	12190	12938	12793	13083	−603	4.7	5	50	M	STRAIN
			FINAL	16318	18015	17870	18160	−1552	8.7				GUAGE
11 & 12	32	1.25	T. S. TRIP	7603.8	7973	7828	8118	−224.2	2.9	9	25	L	STRAIN
			FINAL	12982	14295	14150	14440	−1168	8.3				GUAGE
13 & 14	33	1.25	T. S. TRIP	7066.4	7419	7274	7564	−207.6	2.9	9	100	L	STRAIN
			FINAL	12986	14348	14203	14493	−1217	8.6				GUAGE
			T. S. TRIP			−145	145	0	0.0				
			FINAL			−145	145	0	0.0				
			T. S. TRIP			−145	145	0	0.0				
			FINAL			−145	145	0	0.0				
			T. S. TRIP			−145	145	0	0.0				
			FINAL			−145	145	0	0.0				

26F

TELEDYNE TEST DATA

STRAIN GUAGE S/N #2 (SMOOTH)
OPEN TO CLOSE STROKE

VENDOR STROKE NUMBER	INEL STROKE NUMBER	TORQUE SWITCH SETTING	DESIRED MEASUREMENT	VENDOR READ	INEL READ	INEL BAND MIN	INEL BAND MAX	DEVIATION FROM INEL	PERCENT DEVIATION	ACCUM LEVEL (INCH)	ACCUM PRESS (PSIG)	LOAD CLASS	SENSOR TYPE
17 & 18	34	1.25	T. S. TRIP	8220.9	8521	8376	8666	−155.1	1.9	9	25	L	STRAIN
			FINAL	14431	15695	15550	15840	−1119	7.2				GUAGE
19 & 20	35	1.25	T. S. TRIP	7504.3	7664	7519	7809	−14.7	0.2	9	100	L	STRAIN
			FINAL	13615	14709	14564	14854	−949	6.5				GUAGE
21 & 22	36	1.75	T. S. TRIP	13333	13890	13745	14035	−412	3.0	5	50	M	STRAIN
			FINAL	17831	19287	19142	19432	−1311	6.8				GUAGE
23 & 24	37	1.75	T. S. TRIP	12536	13135	12990	13280	−454	3.5	5	100	M	STRAIN
			FINAL	17242	18614	18469	18759	−1227	6.6				GUAGE
25 & 26	38	2	T. S. TRIP	15709	16449	16304	16594	−595	3.6	1	50	H	STRAIN
			FINAL	20283	21877	21732	22022	−1449	6.7				GUAGE
27 & 28	39	2	T. S. TRIP	16370	17726	17581	17871	−1211	6.9	1	100	H	STRAIN
			FINAL	16362	17752	17607	17897	−1245	7.1				GUAGE
			T. S. TRIP			−145	145	0	0.0				
			FINAL			−145	145	0	0.0				
			T. S. TRIP			−145	145	0	0.0				
			FINAL			−145	145	0	0.0				
			T. S. TRIP			−145	145	0	0.0				
			FINAL			−145	145	0	0.0				

TELEDYNE TEST DATA AVERAGES

DEVIATION (PERCENT)

STRAIN GUAGE

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	12 STROKES	T. S. TRIP	0.2	8.2	3.9
	12 STROKES	FINAL	6.5	8.7	7.6
STRAIN GAUGE S/N #2	6 STROKES	T. S. TRIP	2.9	8.2	4.6
	6 STROKES	FINAL	8.2	8.7	8.5
STRAIN GAUGE S/N #2	6 STROKES	T. S. TRIP	0.0	6.9	3.2
	6 STROKES	FINAL	0.0	7.2	6.8
	0 STROKES	T. S. TRIP	0.0	0.0	ERR
	0 STROKES	FINAL	0.0	0.0	ERR
LOW LOADING	4 STROKES	T. S. TRIP	0.2	2.9	1.9
	4 STROKES	FINAL	6.5	8.6	7.6
MED LOADING	4 STROKES	T. S. TRIP	3.0	4.7	4.0
	4 STROKES	FINAL	6.6	8.7	7.7
HIGH LOADING	4 STROKES	T. S. TRIP	3.6	8.2	5.8
	4 STROKES	FINAL	6.7	8.5	7.6

4.0 VENDOR COMMENTS

4.1 WYLE LABORATORIES

Following a review of the MOV Users Group Equipment Validation Progress Report on the tests performed at Idaho National Engineering Laboratory (INEL), Wyle wishes to state the following:

4.1.1 Stem Thrust Measurements

It should be noted that WYLE's procedures are being modified to add a visual check of the actuator upper bearing assembly prior to installation of the piezoelectric load washers, and WYLE assumes that routine bearing maintenance and lubrication will be performed by qualified personnel as required. A properly operating upper bearing assembly is important for normal MOV operability as well as AVMODS acquisition of stem thrust data.

As indicated in the Progress Report, the initial readings acquired by WYLE at the upper bearing assembly of the SMB-0 Limitorque actuator truly indicated an approximate 30% loss of stem thrust. This finding supports a high probability that an upper bearing assembly problem existed before, during and after the validation tests. The significance of the upper bearing problem should be investigated because it may make suspect:

a. Previous results attributed to this actuator since it is our understanding that it had been used in previous tests at WYLE and KWU. The fact that is may have had an additional problem, which had gone undetected, suggest the possibility that previous anomalous behavior may not have been attributed to all of the right sources of errors and thus, the impact of this bearing problem should be investigated, and

b. Limitorque's "refurbishment" activity, since it is our understanding that it had been refurbished prior to the validation effort.

After discovering the anomalous stem thrust readings, the following were performed:

- The INEL and WYLE transducers were independently and collectively checked and proven to be accurate.

- The upper bearing assembly was disassembled, lubricated, and re-assembled.

- The upper bearing bolt torque, as required by the WYLE procedure, was checked after every three strokes which found that half the bolts required retorquing while the other half were over-torqued. This condition was discovered after each three stroke cycle.

The results of this evaluation clearly indicated that the upper bearing assembly was moving instead of remaining fixed and that the bearing assembly was cocking from the horizontal position. This implied that too much play existed between the upper flange and the bearing race and between the bore of the actuator and the OD of the upper bearing race. Therefore, WYLE concluded that the upper bearing assembly or the bearing cap housing of the SMB-O used by INEL during the test was defective.

It is important to note that this upper bearing assembly defect would not have been detected without the use of WYLE's AVMODS System.

4.1.2 Data Results

WYLE suspects that the following data results are either erroneous, incomplete or inaccurate:

1. Series #2, File 7: The INEL load reading at Torque Switch Trip is erroneous as the Final Load readings for both INEL and WYLE are well within expected results. WYLE reexamined the data and confirmed its value to within 500 pounds of the original reading.

2. Series #2, Files 9,12,17: WYLE believes that the INEL Torque Switch Trip values recorded in Files 12 and 17, and the INEL Final Load value recorded in File 9, should be reconfirmed to clear up the discrepancies between the INEL and WYLE recorded values. One possible explanation for these discrepancies is that each of these strokes was recorded late in the evening after a thoroughly exhausting day of testing by both Validation Committee and WYLE personnel. WYLE reexamined its data and confirmed that its values are within 500 pounds of its original readings, and that all but one of WYLE's twenty-seven (27) Final Load values are well within WYLE's stated accuracy claims.

3. Series #3, File 3: The Final Load value for this stroke was not recorded by INEL and the reading should either be provided or the results be discarded.

4.1.3 Strain Gage Measurement Table

The data from the strain gage recorded during the Open-to-Closed stroke was not intended to be used for stem thrust measurement. This strain gage data should only be used for stem thrust measurement during the Closed-to-Open stroke.

4.2 ABB IMPELL

ABB Impell Corporation has reviewed the MOV Users Group (MUG) Subcommittee on Test Equipment and Method Validation report "Progress Report on Equipment Validation". ABB Impell Corporation is currently performing a detailed evaluation of the data available from the testing of OATIS at INEL. In comparing the Preliminary Report with the detailed evaluation, two items have been identified which require consideration.

4.2.1 ITEM 1 - TIME DEVIATIONS

The statement on Signal Conditioning Delays provided in the Progress Report does identify the possibility that variations of time exist and may result in differences between vendor and INEL thrust values. It also specifies that the evaluation of the impact on vendor to INEL comparisons is beyond the scope of the preliminary report. During the detailed evaluation, it has been determined that a discrepancy in time does exist between INEL and OATIS. The impact of the time discrepancy is quite significant and was evaluated along with additional methods of comparison for applicability to test data.

Although there may be additional means of performing comparisons of the data as determined by the INEL standard and OATIS diagnostic equipment, the two most logical appear to be time referenced and event referenced.

<u>INEL Time Referenced Method</u>

The use of point to point comparison at an instant in time removes the inaccuracy associated with transducer output interpretation (signature analysis). If the comparative time computations between standard and test were negligible, then this method would provide highly accurate comparisons of thrust. Deviation in the time calculations, which may affect displayed time between the standard and test, will have proportional effects on the thrust comparisons. As a result any thrust comparisons made in a time reference based method will include error induced by deviations in time from the standard. While this time discrepancy may be of importance during any comparisons or evaluations of time, its impact on thrust determination may be negligible and only induced by the method of comparison.

<u>Signature Event Referenced Method</u>

The use of event comparisons removes the inaccuracy induced by inconsistent time computations. It does induce error associated with event evaluations. As technicians are responsible for the evaluation of transducer waveforms, and the waveforms can vary during similar event occurrence, an inaccuracy associated with misinterpretation or

inconsistent interpretation is induced. This inaccuracy is variable but can be minimized through consistent and defined interpretation techniques.

Method Comparison

While both of the comparison methods are valid and have merit, one must be chosen for continued use during evaluation of data. The time referenced method may incorporate error which is unrelated to thrust and cannot be controlled. The event method introduces error which may be variable and based on subjective evaluation. If the time references and presentations are compatible, then a time referenced method would yield the more accurate and consistent results. An evaluation of the time reference compatibility was performed to determine applicability of the INEL method.

Time Comparison Between INEL Standard and OATIS

The method of comparison utilized by the MOV Users group, Test Equipment and Method Validation Committee, Test Plan 91-1 is based on time. Comparisons are made and evaluated through system time comparisons of event (Torque Switch Trip, Final Load) activities. To review the accuracy of this thrust comparison, an evaluation of variance between INEL monitored Torque Switch Trip times and OATIS Torque Switch Trip times, as normalized to the INEL time reference, was performed.

Evaluation of the compared data leads to the following conclusions:

- The times deviated by a mean value of 0.049 seconds with a standard deviation of .058 seconds.
- In 85.2% of the test cases the OATIS normalized torque switch trip times were larger than the INEL torque switch trip times.

While the time evaluation performed indicates that there is some deviation between OATIS and the INEL standard; it was inconclusive whether this is the result of overall discrepancies or deviations of the OATIS torque switch or limit switch indication values. If the discrepancy is due to misrepresentation of switch trip time or a time shift between transducer representations, then the resulting error would greatly impact the accuracy of thrust reported at switch trip. However, if the discrepancy is an overall variance between OATIS and the standard, and all OATIS transducer responses are represented on a consistent time scale, then the impact will be isolated to time referenced comparisons. All representations by OATIS will not be affected and only the representation of time may be in question.

To determine the cause of this apparent time discrepancy it was necessary to evaluate additional data which can provide isolation of time deviations. If the representation of switch indication were invalid, then it should be expected that comparisons of relative spring pack displacement at torque switch trip would be discrepant. It was determined that the variations measured between INEL spring pack displacement at INEL torque switch trip and OATIS spring pack displacement at OATIS torque switch trip are all within reputed equipment accuracies. The lack of variation in measured displacement may not be representative of switch indication accuracy, however, either;

- the INEL standard and OATIS are equal in time variance,
- the OATIS measurement of spring pack displacement is out of tolerance and the time variance makes it appear acceptable, <u>or</u>
- the variation lies in the computational deviations of time. To further investigate the cause of time variance, a comparison of overall stroke times was performed.

The result of stroke time comparisons indicate that stroke time deviation averaged .072 seconds and the time discrepancies are not limited to switch trip indication but are present throughout data display.

<u>Conclusions On Method Analysis</u>

From this evaluation, the time discrepancy bounds the entire signature region. As this is the case the more appropriate method of thrust comparison would be signature event analysis. While the use of an event base method will correctly ignore overall time discrepancies, and reflect any misrepresentations in switch trip indication, it will induce error associated with data interpretation. The impact of this error can be minimized through consistent analysis techniques and definitions.

4.2.2 ITEM 2 - GENERIC APPLICABILITY

While the results of this test should be considered as valuable and informative, they should not be considered as the basis for the establishment of revised tolerance The MUG validation has been designed for deter ing the conformance/nonconformance of results to a specific test and not to establish equipment tolerances for all ranges and applications. A small population sample (one set of MOVLS specifications) and a limited number of cycles at any specific test condition impose finite limitations on evaluation of this data.

In addition to the Items noted, ABB Impell and OATIS users are continuing with detailed data evaluation to determine the most applicable analysis and applications of the INEL testing. The results of this analysis will be reconciled with MOV programs of OATIS users upon completion of data evaluation. ABB Impell does note that the limited data sample provides analysis restrictions in the areas of rate of loading and stem factor repeatability. Review of the wealth of data as collected by INEL throughout equipment validation, may prove insightful and provide the industry with a better understanding of these phenomena. The review of this data could be initiated by release of all the INEL MOVLS obtained data to public domain.

4.3 LIBERTY TECHNOLOGIES - VOTES

4.3.1 LIBERTY TECHNOLOGIES' COMMENTS

CALIBRATION ANOMALY

Upon return, C-Clamp Calibrator A1007 which exhibited the anomaly was found to have a short to ground in its connector. A C-Clamp with this defect can function properly on an ungrounded Quick Cal fixture, yet exhibit different results on a grounded valve. A1007 is an old C-Clamp, the seventh one made. It is utilized by Engineering and has been subjected to many changes over several years. It was of course calibrated prior to the INEL Test, but it was not checked for grounds. By contrast, the replacement Calibrator A1106 was the 106th C-Clamp made, and since it was a production unit, it was subjected to stringent production quality controls. Liberty does not expect any of its field calibrators to exhibit any grounding problems, however a customer service bulletin is being prepared advising users about the possibility of grounds and how to check for them.

TEST ANOMALY

The parallel offset problem which showed up on 4/30/91 while the motor was turning had never before been seen by ourselves or by any VOTES user. The fact that the problem was gone on 5/1/91 and could not be reproduced made it impossible to track down. Post-test recollection about the damaged motor speed sensor at INEL made it a potential suspect. However, a subsequent recent temporary episode of the same anomaly on the same system now makes it appear to be an intermittent problem specific to that system. Liberty will try to make the anomaly reappear on this system, and will attempt to pinpoint its cause if and when it does reappear. The committee and all VOTES users will be made aware of the results, and of any generic implications. In the meantime, it should be stressed that this is not a blind anomaly, that is, if one were to have the anomaly, one would be aware of it. This is because the apparent force offset starts to appear right at motor start, in the lost motion region, even with little or no initial torque. Since this is not physically possible, it is clearly an anomaly. Also note that the retest of Sensor 1 on 5/2/91 (INEL Test #34) proves that the anomaly was not a problem with Sensor 1, but simply a matter of its occurrence during the testing of Sensor 1. Despite the fact that the inclusion of the anomaly data does not degrade the overall accuracy averages very much (± 4.3% at TST; ± 1.6% at final thrust), readers are urged to concentrate on INEL Stroke #'s 10 through 27, and 34 as more indicative of true VOTES performance.

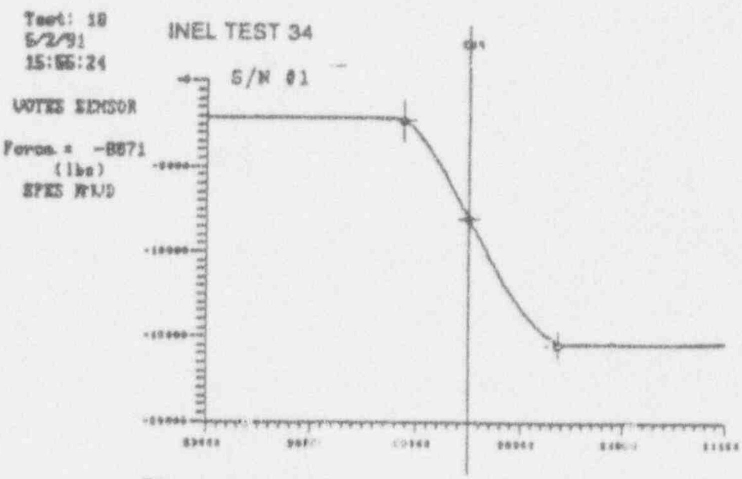
NON-ANOMALOUS DATA

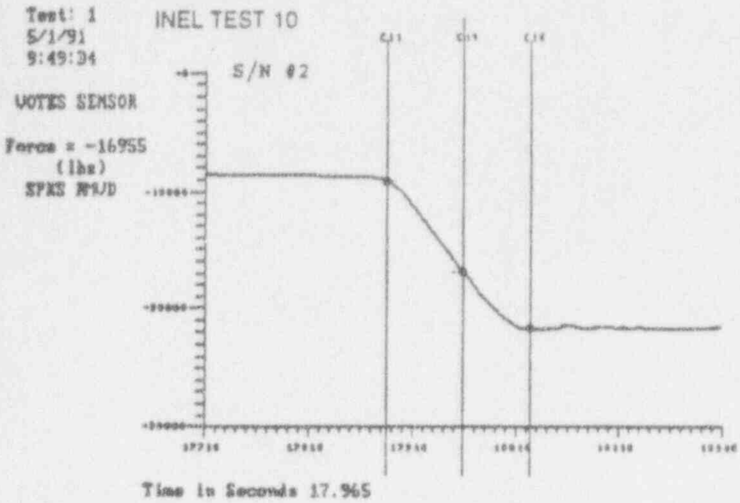
The (19) non-anomalous strokes have been expanded to a half second about the torque switch trip region. These are standard VOTES force traces, with circles indicating the corresponding INEL readings at wedging, at torque switch trip and at final thrust. INEL Test #34, the retest of Sensor 1, is shown below. The other (18) strokes are shown on the following three pages. Wedging was not one of the required measurement points, however, it was one of the additional points selected by Liberty, and under the rules, INEL provided their corresponding reading. Wedging is not indicated for INEL Test #'s 12 and 27 since it did not occur in these strokes.

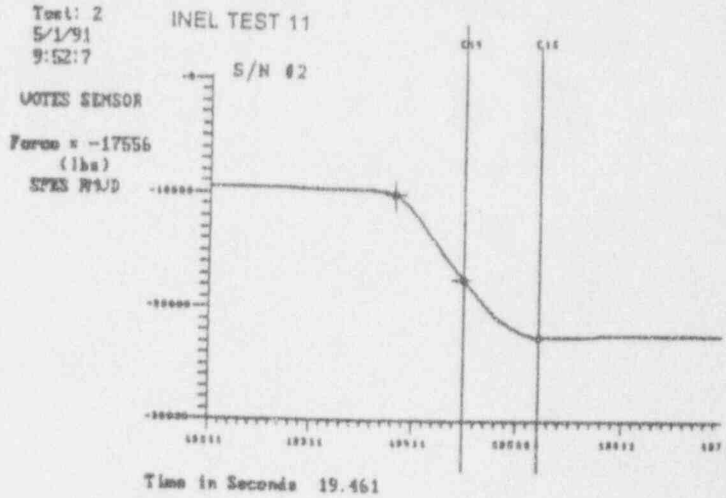
Cursors marked C14 are the torque switch trip points. In all cases, the corresponding force value is indicated at the left of the plot. The one exception is INEL Test #24 where C14 was mismarked 4 msec early. The actual torque switch trip point is marked CST and its value is indicated at the left. The INEL comparison however is at C14. Other indicated marks that may appear on some traces are C11, start of wedging; C15, motor current cutoff; and C16, maximum thrust value.

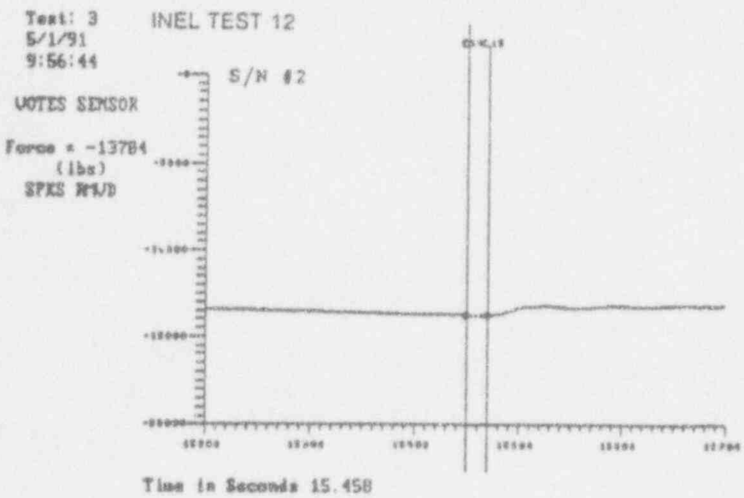
Note from the date and time indications, the rapidity with which tests can be run, typically less than three minutes between tests. Also note the SPKS RMVD marker indicating that the spike removal capability of software version 2.2 was utilized.

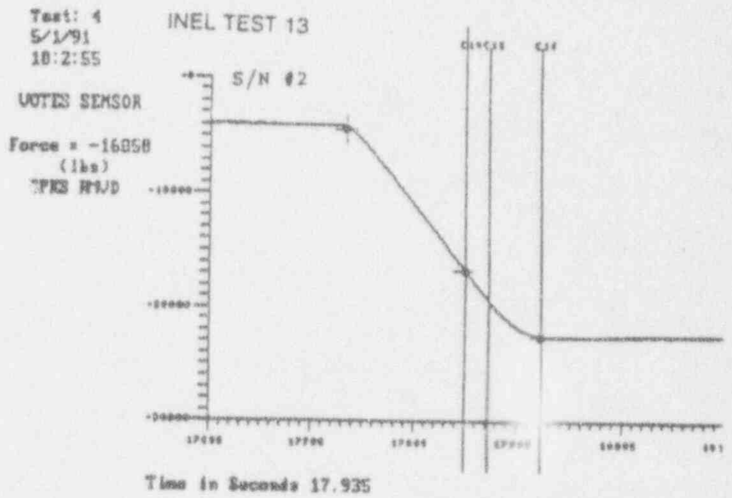
Finally, from Test #'s 13 and 14, and Test #'s 22 and 23, rate of loading comparisons at the same torque switch setting can be made. Test 14 would be indicative of a higher ΔP condition than test 13, and test 23 a higher ΔP condition than test 22. Note how VOTES correctly indicates the reduced thrust at torque switch trip in both cases.

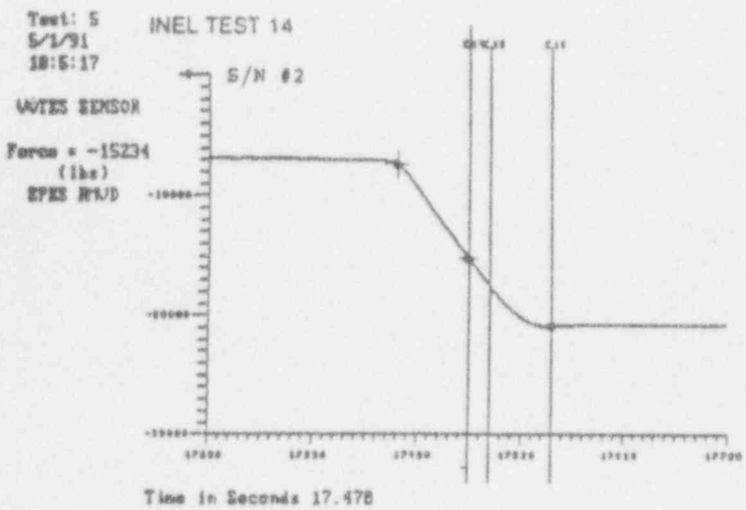


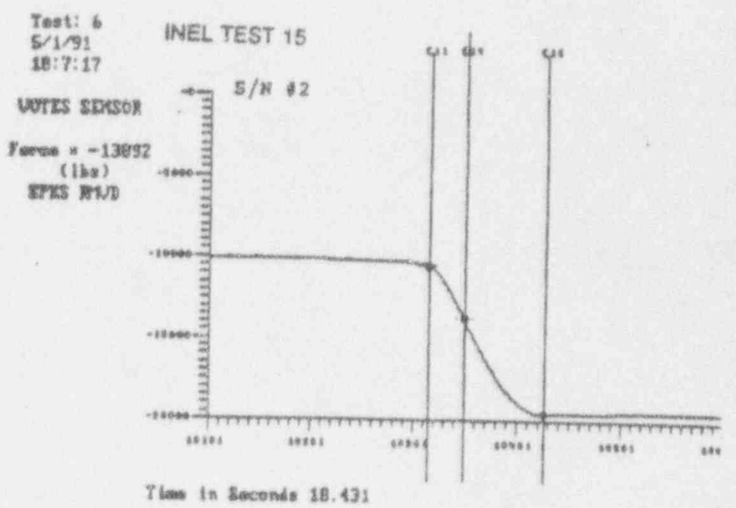

Test: 1
5/1/91
9:49:34
INEL TEST 10
S/N #2
VOTES SENSOR
Force = -16955
(lbs)
SPKS R1/D
Time in Seconds 17.965

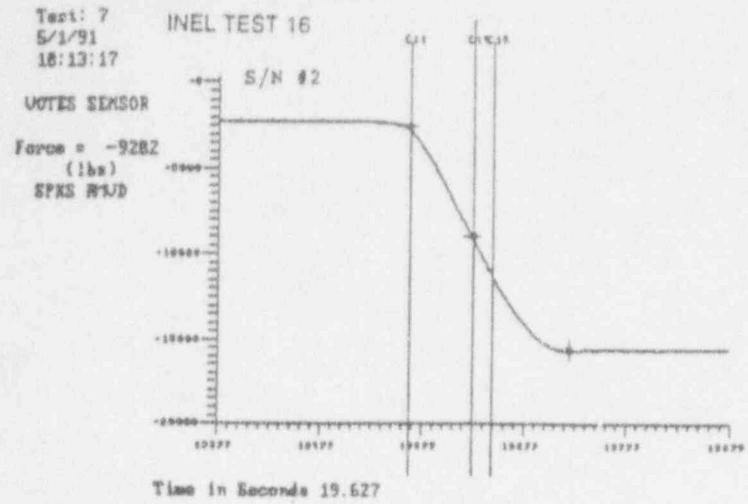

Test: 2
5/1/91
9:52:7
INEL TEST 11
S/N #2
VOTES SENSOR
Force = -17556
(lbs)
SPKS R1/D
Time in Seconds 19.461

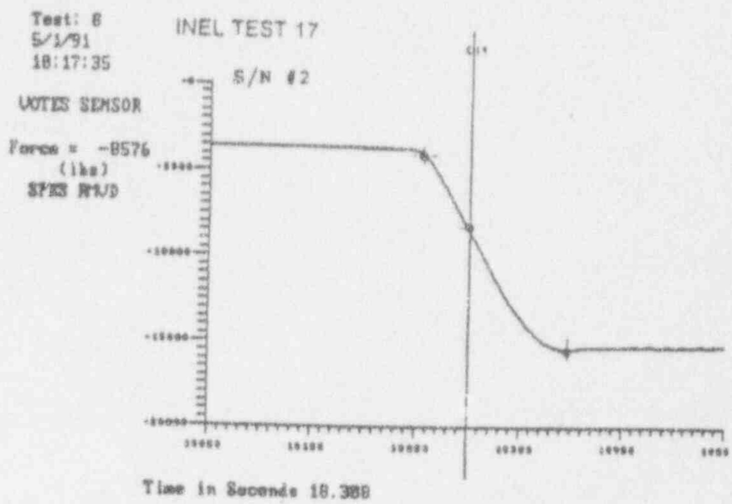

Test: 3
5/1/91
9:56:44
INEL TEST 12
S/N #2
VOTES SENSOR
Force = -13784
(lbs)
SPKS R1/D
Time in Seconds 15.458

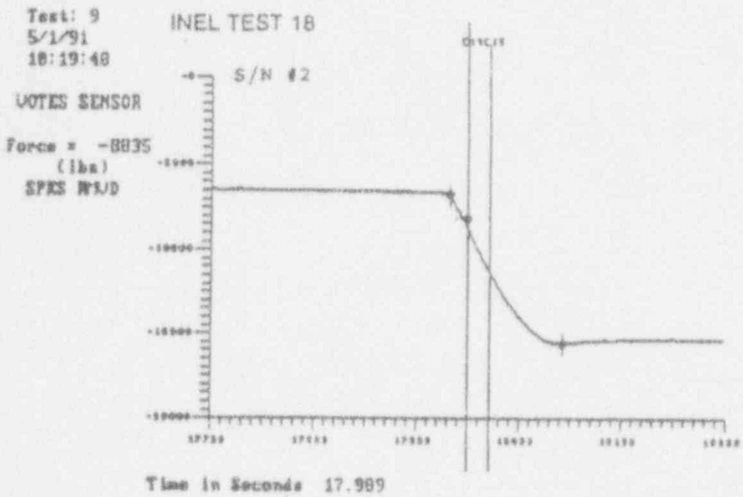

Test: 4
5/1/91
10:2:55
INEL TEST 13
S/N #2
VOTES SENSOR
Force = -16058
(lbs)
SPKS R1/D
Time in Seconds 17.935

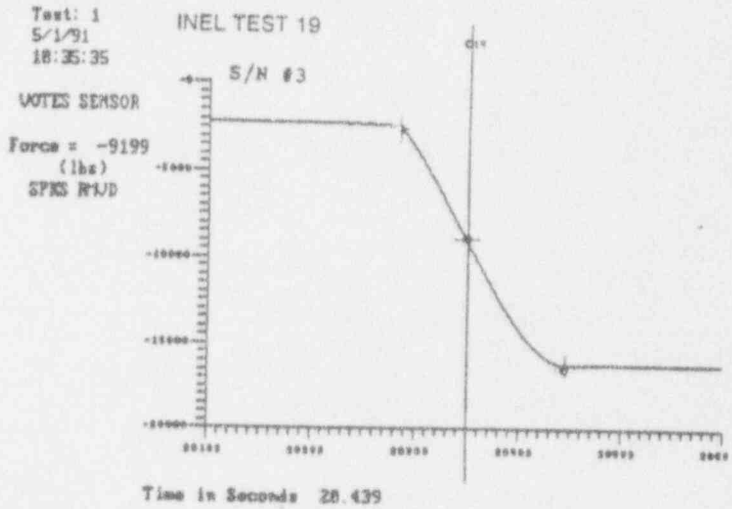

Test: 5
5/1/91
10:5:17
INEL TEST 14
S/N #2
VOTES SENSOR
Force = -15234
(lbs)
SPKS R1/D
Time in Seconds 17.478

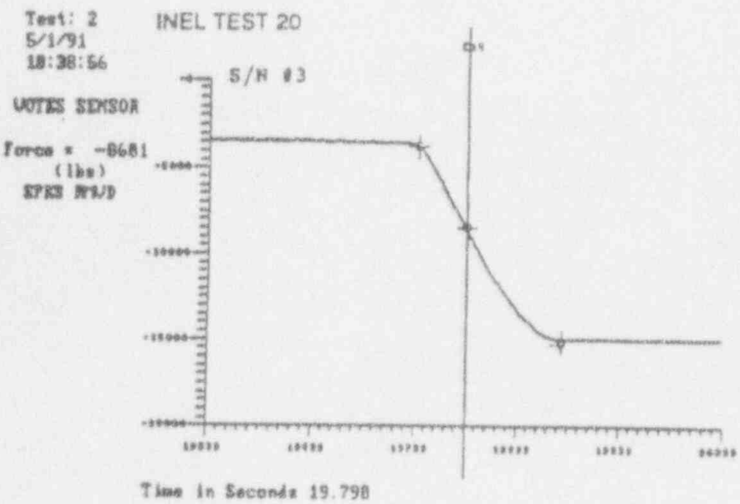

Test: 6
5/1/91
10:7:17
INEL TEST 15
S/N #2
VOTES SENSOR
Force = -13892
(lbs)
SPKS R1/D
Time in Seconds 18.431

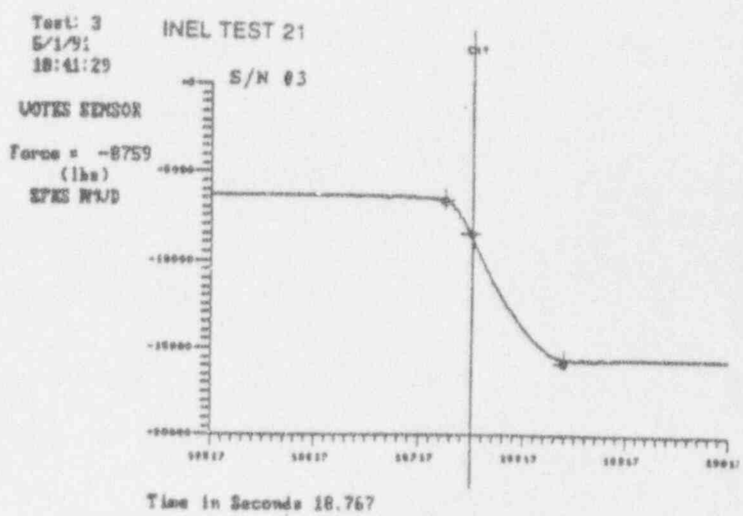

Test: 7
5/1/91
18:13:17
INEL TEST 16
S/N #2
VOTES SENSOR
Force = -9282
(lbs)
SPKS R1/D
Time in Seconds 19.627


Test: 8
5/1/91
18:17:35
INEL TEST 17
S/N #2
VOTES SENSOR
Force = -8576
(lbs)
SPKS R1/D
Time in Seconds 18.388


Test: 9
5/1/91
18:19:48
INEL TEST 18
S/N #2
VOTES SENSOR
Force = -8835
(lbs)
SPKS R1/D
Time in Seconds 17.989


Test: 1
5/1/91
18:35:35
INEL TEST 19
S/N #3
VOTES SENSOR
Force = -9199
(lbs)
SPKS R1/D
Time in Seconds 20.439


Test: 2
5/1/91
18:38:56
INEL TEST 20
S/N #3
VOTES SENSOR
Force = -8681
(lbs)
SPKS R1/D
Time in Seconds 19.798

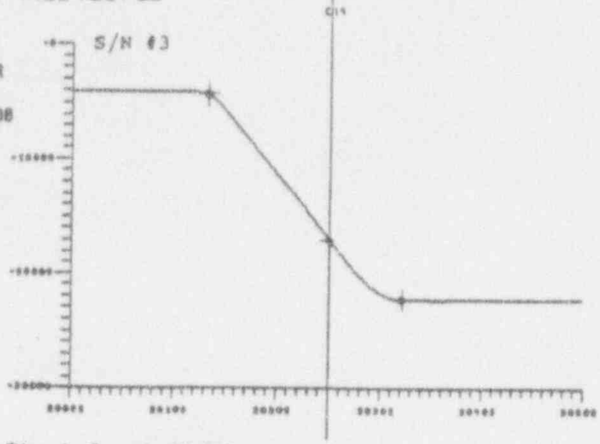

Test: 3
5/1/91
18:41:29
INEL TEST 21
S/N #3
VOTES SENSOR
Force = -8759
(lbs)
SPKS R1/D
Time in Seconds 18.767

Test: 4
5/1/91
10:50:28

INEL TEST 22

VOTES SENSOR

Force = -17888
(lbs)
SPKS R1/D



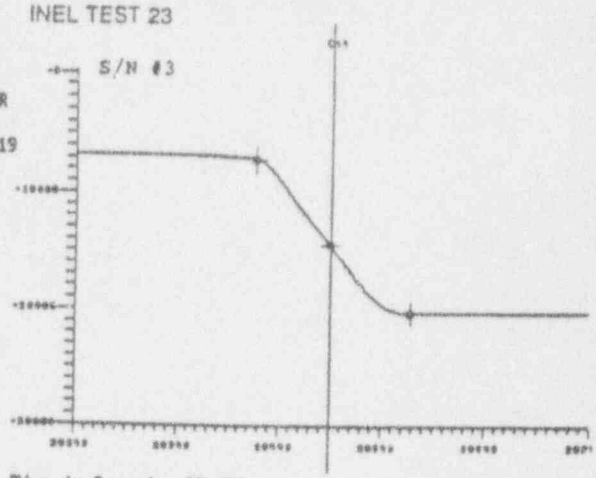
Time in Seconds 28.252

Test: 5
5/1/91
10:52:52

INEL TEST 23

VOTES SENSOR

Force = -14619
(lbs)
SPKS R1/D



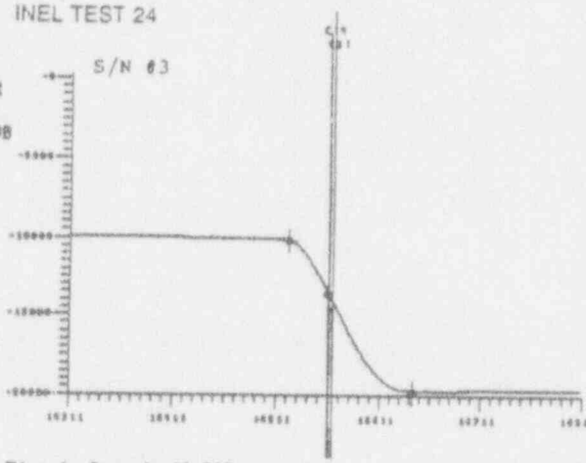
Time in Seconds 28.499

Test: 6
5/1/91
10:54:55

INEL TEST 24

VOTES SENSOR

Force = -14198
(lbs)
SPKS R1/D



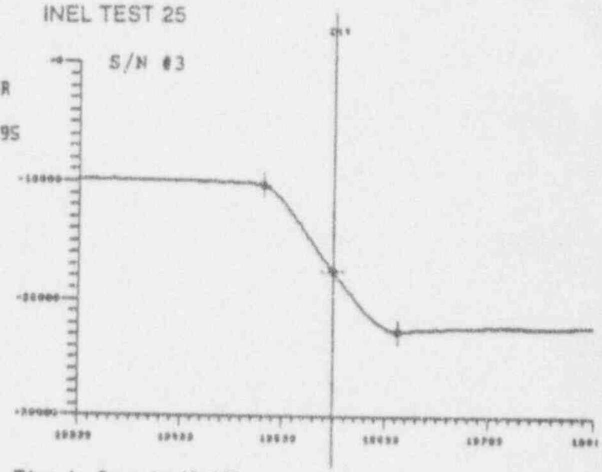
Time in Seconds 16.565

Test: 7
5/1/91
11:6:3

INEL TEST 25

VOTES SENSOR

Force = -17495
(lbs)
SPKS R1/D



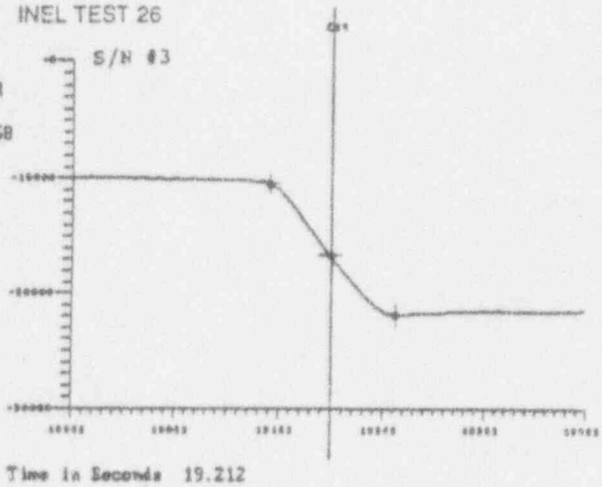
T'me in Seconds 19.648

Test: 8
5/1/91
11:8:29

INEL TEST 26

VOTES SENSOR

Force = -16758
(lbs)
SPKS R1/D



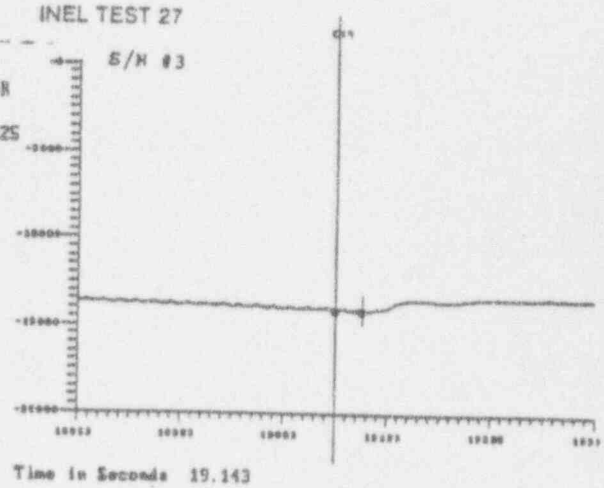
Time in Seconds 19.212

Test: 9
5/1/91
11:14:35

INEL TEST 27

VOTES SENSOR

Force = -14825
(lbs)
SPKS R1/D



Time in Seconds 19.143

4.4 SIEMENS/UTL/KWU

4.4.1 General

After the equipment had been returned to Germany functional tests and postcalibrations were performed. No deviations in the calibration data or device failures were detected in both measuring chains for stem thrust and torque.

Adjustment or operating faults during the measuring procedure are also excluded for both measurement chains according to the documentation supplied by the DAW/DEA memory.

4.4.2 Stem Torque Measurement

Preliminary examinations and an analysis of the INEL simulation equipment indicate good reasons for the fact that this equipment is not suited for correct and accurate torque measurements. This can be proved by the following considerations:

The comparison of the INEL with S/KWU measuring values indicates good conformity throughout the total measuring range from 0 to approx. 220 ft.lbf. (S/KWU's values are approx. 5% lower). However, this conformity applies only to the stroke range until touch-down of the hydraulic piston, called "wedging" (see Fig. 1)

After touch-down of the hydraulic piston (TST + Final) the course of the torque measurement indicates an unsteadiness in spite of steady increase of the stem thrust. The TST and final measuring values are approximately 30% lower than the wedging values. Obviously, a partial reduction of the torque supplied at the hydraulic part was submitted after touch-down of the hydraulic piston so that the total torque value could not be measured on the torque arm (see Fig. 2). This fact also implies that the thrust bearing transfers stem torques. The fact that the cut stem and the hydraulic cylinder are not guided very well - opposite to a real valve stem - generates single-sided loads on the bearing causing certain heavy functioning and enables the torque transfer.

The S/KWU measurements always include the total torque. They do not indicate any unsteadiness and, therefore, they are more realistic.

During testing KWU expressed a concern with bearing friction causing torque loss on the strain gauges of the torque arm. INEL personnel explained that lab testing had measured potential torque losses at less than 5 ft-lbs at thrust values twice those expected during validation testing. This torque loss of 5 ft-lbs was the required torque to overcome the static friction of the bearing and does not necessarily represent dynamic conditions experienced during valve/load simulator closing.

4.1.3 Stem Thrust Measurement

At first, we assumed that the deviations in thrust measurement are also based on similar problems. But further evaluation and a comparison of all pre-operational measurement results with the official measurement results showed that the failure is caused by our own instrumentation.

The detected deviations of the thrust measurements by INEL and S/KWU can only be related to a temporarily occurred failure in the measuring chain from the strain gauge to the input plug of the DC-amplifier in our DAW. An intensive check of all parts of this measuring chain showed that with high probability this failure is caused by a defect in the isolation of one cable lead of the strain gauge extension cable. This defect was found inside one of two plugs.

Due to a small twisting of the cable lead wire (strain gauge excitation voltage) and the cable screen a short circuit may occur. The reduction of the strain gauge excitation voltage and of the related sensitivity in the thrust measuring chain measured under laboratory conditions was at the same level as the deviations determined between INEL's and KWU's values measured.

Sporadically occurring effects are confirmed by the commissioning measurements performed by S/KWU the day before. The thrust measurement values showed approximately the same values as INEL's later measurements.

Theoretical considerations and calculations performed by Mr. Kradepohl of the valve engineering department, V453, confirm the correctness of KWU's torque measuring results and that the results of the S/KWU stem force measurements show too low values.

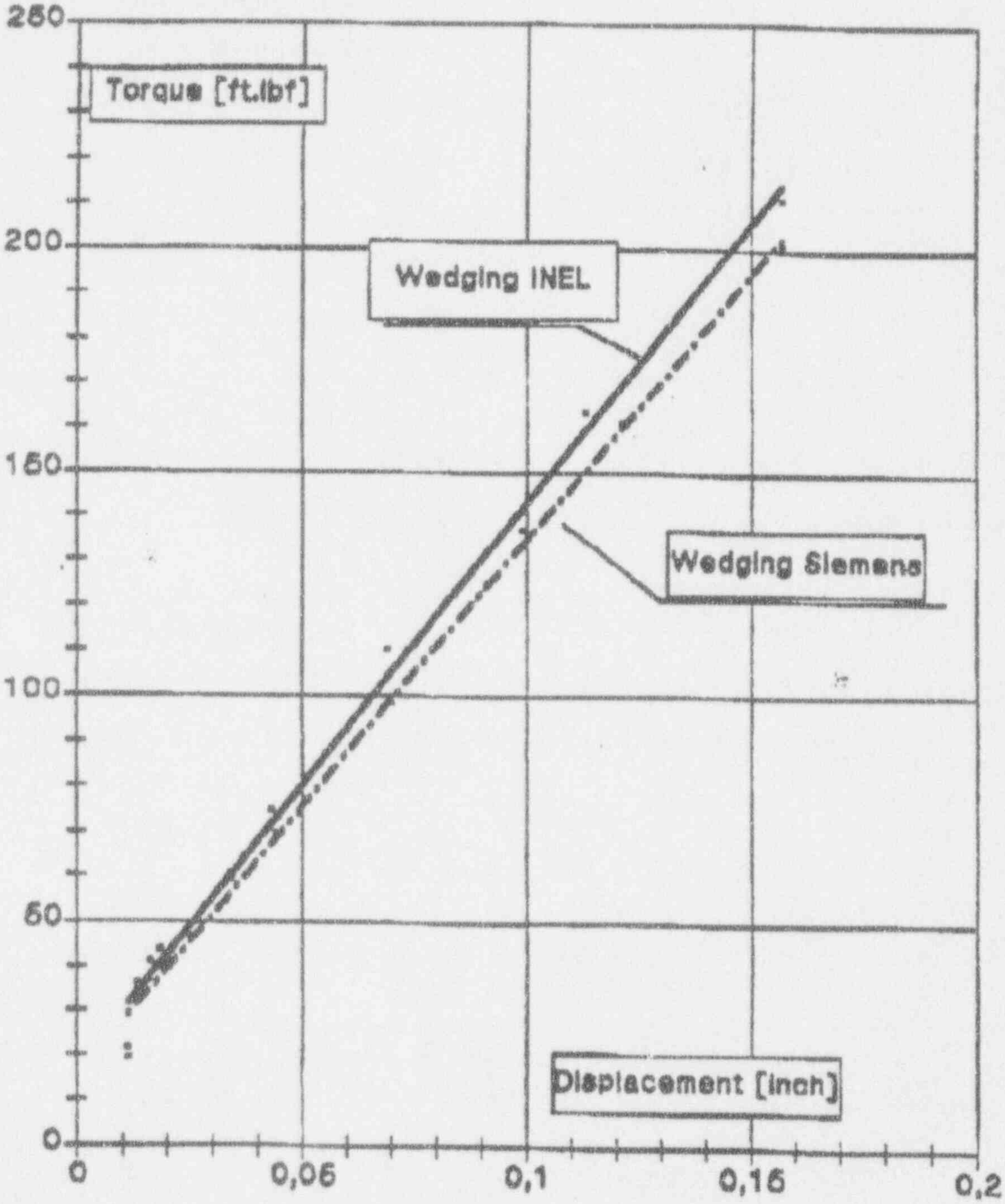
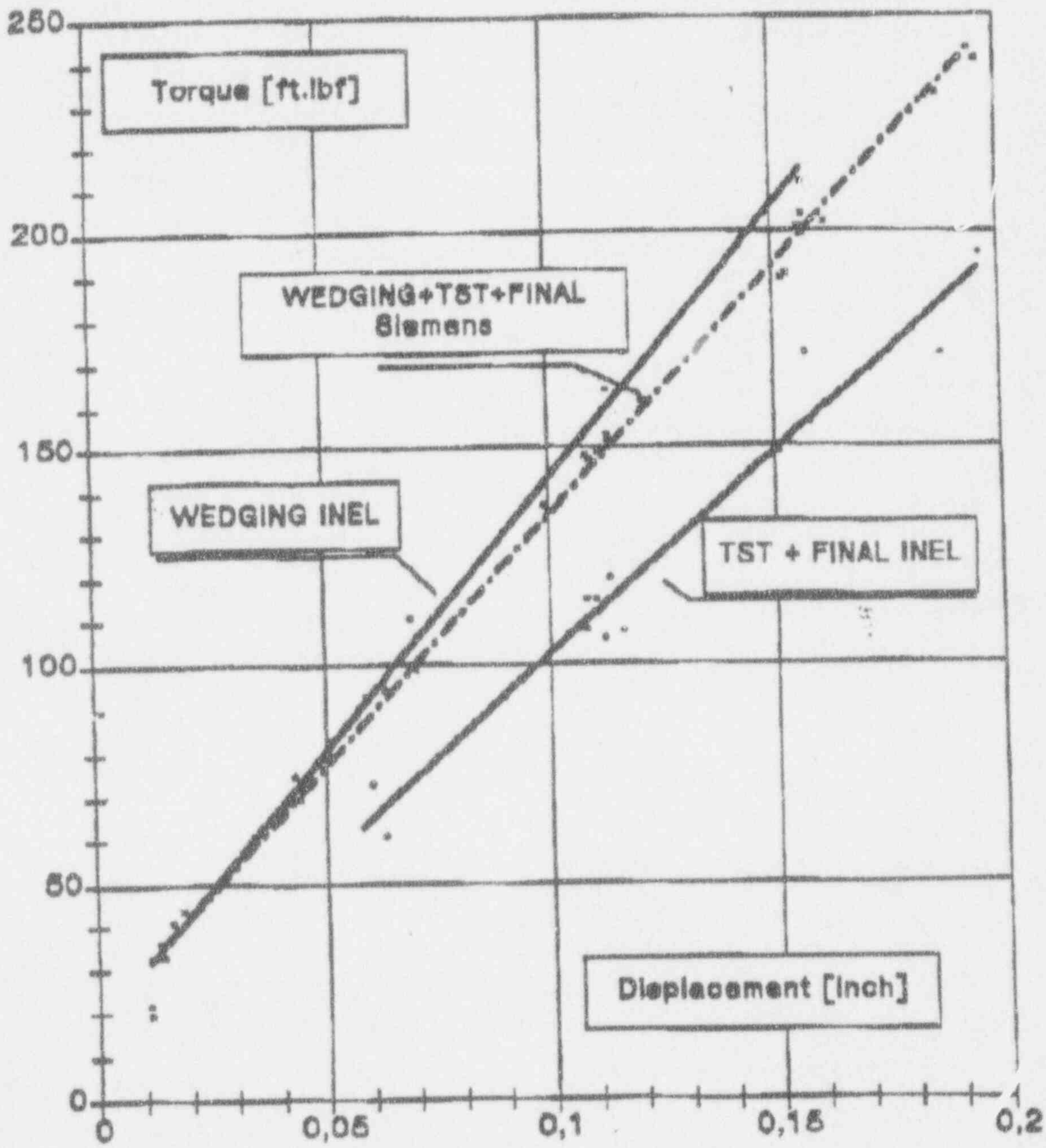

Torque [ft.lbf]
Wedging INEL
Wedging Siemens
Displacement [inch]
250
200
150
100
50
0
0
0,05
0,1
0,15
0,2

Fig. 1

36A



Torque [ft.lbf]
WEDGING+TST+FINAL
Siemens
WEDGING INEL
TST + FINAL INEL
Displacement [inch]
250
200
150
100
50
0
0
0,05
0,1
0,15
0,2

Fig. 2

36B

4.5 ITI MOVATS COMMENTS

4.5.1 GENERAL

The INEL testing has resulted in a large volume of data showing performance of ITI MOVATS transducers compared to INEL standards. The data analyzed to date has identified several areas that require investigation. The areas that relate to the information presented in Section 3.5 of this report are discussed in the following sections.

The comments provided are preliminary in nature since they are based on a limited review. Substantial effort is continuing to thoroughly review all of the data. It is expected that additional comments will be provided and/or the comments provided in this report will be modified when the data analysis is complete.

4.5.2 RATE OF LOADING/STEM FACTOR

Rate of loading/loading condition and stroke-to-stroke stem factor changes both had an effect on TMD thrust measurements during the testing. The following paragraphs discuss our observations in each of these areas.

The test results showed very large changes in actuator performance with no torque switch adjustment. On the first stroke with the torque switch set at 1.25, thrust at torque switch trip was 10970 pounds as measured by the INEL load cell. On the third stroke with the torque switch unchanged, the INEL load cell measured 6828 pounds at torque switch trip. During these three tests, the accumulator level was constant at 9.5 inches (the highest used) and the pressure was varied from 25 psi to 100 psi. This set of tests showed the largest change; however, several other sets showed variation in the 20% range.

The fact that the largest change in actuator performance occurred when accumulator level was constant and pressure was varied reemphasizes the note in Section II.D which indicates that pressure and level work together to change the loading condition. As a result, caution should be exercised in evaluating the tables which show results separated by level only. It may be possible with overlays to classify loading by curve shape to get a more realistic view of the effects of load condition.

In addition to variations due to loading condition, on several occasions, there appeared to be significant changes in stem factor from stroke to stroke with no changes in test parameters. During some of the INEL load verification strokes simulating a high loading condition, the torque switch tripped prior to completing the stroke. The stem was then unloaded and stroked enough times to "relubricate" the stem and stem nut threads. While some stem factor degradation can be expected over time, large changes from stroke to stroke are not typical. The changes appear to be caused by the fact that the stem was always in compression regardless of direction of stem travel. This does not allow the stem or stem nut to shift sides and relubricate the thread faces when direction is changed.

A somewhat similar situation was encountered during load rate testing performed at ITI MOVATS in 1988. A valve was repeatedly stroked open into a load cell and thrust at torque switch trip degraded from approximately 26,000 pounds to 21,000 pounds in 20 strokes with no changes in operating parameters. Investigation determined that this was caused by a very short stroke in the closing direction which did not allow the threads to relubricate as they would during normal valve operation. In this case, the 2 1/4 inch stem was stroked less than two inches in the closing direction before being stroked open into the load cell. When the stem was moved several inches, stroke-to-stroke variations were less than 3%.

Another factor which may have contributed to large stem factor changes is the lubricant used. Never-Seez compounds are at the bottom of the performance list according to the information coming out of the EPRI sponsored lubrication study. In particular, they have been found to result in large variations in friction factor.

During normal in-plant testing, valve packing load is present in both directions of stem travel and is generally the same. As a result, the TMD is only used to measure thrust above packing load. At INEL, however, there was no packing load in the opening direction when the TMD was calibrated, but there was a simulated packing load in the closing direction. It is not clear what effect this difference had on the data acquired or analysis of the data.

All of these issues make it difficult to assess the TMD measurement of thrust at INEL. Changes in stem factor between the calibration stroke and the test strokes cause corresponding changes in TMD thrust measurement. In addition, rate of loading testing performed at ITI MOVATS has shown up to 26% variations in thrust at torque switch trip. None of the TMD measurement variations seen during INEL testing are outside what could be expected for the conditions encountered. The test results point clearly to the need to complete the stem factor and rate of loading portions of the separate effects testing planned by EPRI.

4.5.3 TIME BASED PROBLEMS

The first timing problem encountered was that the 3000 system had to be used at a 4mS sample rate. The system is capable of collecting 4 seconds of data at 1mS. The open then closed strokes used at INEL were longer than this. During field testing, ITI MOVATS acquires a separate thrust verification signature for each direction to ensure that a 1mS sample rate can be used. Unfortunately, it was not deemed possible to perform separate opening and closing strokes without substantially impacting the schedule so a slower sampling rate was chosen.

The 4mS sample rate results in a potential for ±5mS deviation between INEL's and ITI MOVATS' time measurement of torque switch trip. To minimize the impact of this difference, the thrust comparisons were made using ITI MOVATS' measurement of time to torque switch trip and picking the corresponding point from the INEL thrust trace. Using this approach, there is still a potential for ITI MOVATS thrust to be selected up to 4mS later in real time than INEL. This difference occurs when the 3000 System samples just prior to the 2V start signal and INEL samples immediately after it occurs.

During investigation of timing differences, a problem was identified in the 3000 System software that can cause a 4 to 8mS error between ITI MOVATS and INEL timing. An inconsistency in several routines handling data input causes 4mS of data to be skipped every 3.174 seconds. When the data is skipped, the next sampled point occupies the position of the missing data in time, resulting in data compression. Compression of the data occurs on all of the channels at the same point in time so, for normal field testing, it does not affect thrust measurements unless it occurs right at the point where the torque switch trips. However, it is difficult to compare transient response data to another system using a different time base.

4.5.4 TORQUE/THRUST CELL

The most obvious effect of timing problems is on the torque/thrust cell measurements of thrust at torque switch trip. The data sheets show less than 1% deviation at total thrust and our analysis of running load numbers shows similar performance. However, the thrust at torque switch trip varied by 5.9% on the average with a maximum deviation of 12% from INEL measurements. Overlays of the data clearly show these differences are due to timing and not torque/thrust cell performance.

4.5.5 SSR

SSR performance was reasonable except for one stroke in which thrust at torque switch trip varied by 45.8%. The cause is being investigated, but no obvious problems with the test have been identified. Just prior to the INEL testing a report was completed which showed the need for an additional ±400 pounds to be included in the SSR accuracy, particularly at the low ends. The change was not made in time to modify the accuracy statements previously submitted to the validation committee.

A review of the data indicates the SSR thrust measurements are consistently low. This appears to be a trend in SSR performance on the solid portion of the stem. If future testing confirms this trend, the equation for calculating thrust from stem elongation will be modified to reduce the deviations.

4.5.6 SLS

As indicated in Section 3.5, the SLS rings were installed on the threaded part of the stem in close proximity to the threaded/solid boundary. In this transition region, it is expected that stem diameter changes would be smaller than they would at locations further up the threaded part of the stem. While the magnitude of the variations caused by mounting in this area cannot be determined, it is noteworthy that all of the SLS measurements on the threaded part of the stem were lower than the INEL measurements. Even with this problem, all of the SLS measurements were within the stated accuracy of the equipment.

A new design which reduces SLS errors due to torque was available, but was disallowed from testing due to time constraints. If an opportunity arises, it may be tested in the future.

4.6 TELEDYNE

The TES strain gage based transducers and test equipment performed at or above the claimed accuracies. The pre-test and post-test calibrations (NIST traceable) of the Smartstems verified the claimed accuracy of 0.5% FS. For field applied strain gages, the accuracy proved better than claimed.

TES believes for their preliminary results, the thrust load deviations at torque switch trip are more indicative of the ability to match the INEL timing of TST, and not of the ability to accurately measure the thrust parameter. However, having reviewed the preliminary data, we stand firm behind our claims.

There were three results with unusually high deviations. TES investigated these points and determined that data extraction errors had occurred. These errors are described in detail in the following comment section. Based on the correction the Averages table should be corrected to match the one presented in the following comment section.

Additional comments outlined below expand upon the above statements plus provide our insight as to problems associated with the testing. This information will be helpful for those wishing to study the signal analysis results in greater detail.

4.6.1 <u>Comments on Progress Report/Validation</u>

1. MUG is requested to provide copy of GSU QA audit report of INEL to vendors for review. Also data reduction and analysis procedures should be provided along with design and software control procedures.

2. The validation performed at INEL was end-to-end. The accuracy claimed for the field applied Strain Gages is the end-to-end claim. The accuracy claimed for the Smartstem is for the transducer only since it is normally purchased as a standard transducer and it can be used with other monitoring equipment. The Smartstem is calibrated NIST traceable to ±0.5% full scale. The accuracy for the Smartstem end-to-end using TESTEM/TOTEM is ±1.2% full scale or ±2.5% of reading. (These values are determined by combining the statistical system error with the transducer error).

3. INEL Standard Accuracy and Signal Oscillation - TES performed validation testing at INEL in January, 1991, independent of the MUG effort. At that time, the data

provided by INEL contained a 60 hz "oscillation". When deviations are calculated from the INEL standard, this oscillation amplifies the differences between the two data signals, particularly at lower load levels.

We had expected that INEL would have been able to correct this problem by the MUG and NRC sponsored validation tests. Again in reviewing preliminary data, the INEL signal contains this oscillation component. We are assuming that the INEL error band has taken this oscillation into account.

4. Signal Conditioning Delay - The MUG/INEL policy on signal condition delay compounds the problems associated with accurate thrust measurement. Using this policy, the test program preliminary results for thrust at torque switch trip became an exercise in torque switch trip timing accuracy rather than the determination of the ability of equipment to measure valve stem thrust. This policy requires a review in terms of the test purpose.

5. TES planned to validate gages applied to the threaded portion of the stem. This method requires that the threads be filled with an epoxy and the gages applied to the filled area using patented techniques. Due to an omission of the necessary methods in the TES procedures, the threaded gages were withdrawn from the test.

   It is TES' intention to conduct a series of validation tests on the threaded-filled stems on our in-house test equipment. TES has a fully developed test facility capable of the full range of loadings required for measuring thrust and torque. This test will be performed under TES QA program meeting 10 CFR 50 Appendix B with NIST traceable metrology. A complete validation report will be available to TES's clients.

6. There were three tests with unusually high deviations. TES investigated each of these in order to verify the values reported.

1) Smartstem #1, Stroke 6 was reported as:

VENDOR	INEL	DEVIATION	PERCENT DEVIATION
1412	13279	-11710	89.2

In reviewing the data taken during the test it was determined that the TES' value was shifted one decimal point. The table should read:

VENDOR	INEL	DEVIATION	% DEVIATION
14240	13279	816	6.1%

2) Smartstem #2, Stroke 16 was reported as:

VENDOR	INEL	DEVIATION	% DEVIATION
9560	5818	3597	60.3%

The INEL data was received at TES on 7/10/91. In reviewing this data it was determined that INEL chose a point that was 5.004 seconds after the open limit switch reference rather than the 5.040 seconds that was listed on the data sheet. The table should read:

VENDOR	INEL	DEVIATION	% DEVIATION
9560	9373	42	0.4%

3) Smartstem #2, Stroke 18 was reported as:

VENDOR	INEL	DEVIATION	% DEVIATION
8086.5	7020	921.5	12.9%

In reviewing the INEL data it was determined that INEL chose a point that was 5.073 seconds after the open limit switch reference rather than the 5.080 listed on the data sheet. The table should read:

VENDOR	INEL	DEVIATION	% DEVIATION
8086.5	7691	250.5	3.2%

As a result of these changes, TES has revised the values for the summary table. The summary table should read as follows:

DATA USED	STROKES	DATA POINT	MIN	MAX	AVE % DEV
ALL STROKES	27 STROKES	T.S.TRIP	0.0	7.0	3.1
	27 STROKES	FINAL	0.0	1.9	0.5

S/N #1	9 STROKES	T.S.TRIP	1.8	7.0	5.1
	9 STROKES	FINAL	0.8	1.9	1.3
S/N #2	9 STROKES	T.S.TRIP	0.4	3.2	1.8
	9 STROKES	FINAL	0.0	0.6	0.2
S/N #3	9 STROKES	T.S.TRIP	0.0	4.6	2.4
	9 STROKES	FINAL	0.0	0.0	0.0

LOW LOADING	9 STROKES	T.S.TRIP	0.4	5.9	3.3
	9 STROKES	FINAL	0.0	1.1	0.4
MED LOADING	9 STROKES	T.S.TRIP	1.5	3.3	3.7
	9 STROKES	FINAL	0.0	1.4	0.4
HIGH LOADING	9 STROKES	T.S.TRIP	0.0	5.6	2.4
	9 STROKES	FINAL	0.0	1.9	0.7

7. TES' initial sampling rates for the Smartstems were 200 s/s for open limit switch and 1000 s/s for thrust. In the area of TST the load is changing at approximately 100 lbs/ms. TES' accuracy claim for the Smartstem is +/- 0.5% full scale (transducer only). With a calibrated full scale load of 30,000 lbs the acceptable error is 150 lbs. A shift of 2 milliseconds can put TES outside its claim. With the sample rate at 200 s/s on open limit switch, time differences of 3 ms between INEL and TES can occur. It should be noted that on the second day of testing, the sample rate of the open limit switch was changed to 1000 sample/second for field applied gages. This

change resulted in a marked improvement in accuracy of the loads at T.S.Trip.

8. The % deviation results given in this report are actual differences or percentage of reading deviations. The accuracy claim for the TES Smartstem is given in % of full scale. To determine the percent deviation based on full scale, the "Deviation from INEL" value must be divided by the full scale load. The Smartstems tested at INEL had a full scale thrust load of 30,000 lbs.

9. Primary Reports and Methods - The accuracy of a particular transducer and system in measuring stem thrust can better be determined from the examination of full stroke traces of the vendor versus the INEL standard. The preliminary results and methods applied in this report are not representative of the requirements normally applied to the sensor and measurement industry. We welcome the distribution of preliminary results, and we agree with the statements from Section 2.5 emphasizing the need for caution in interpreting the results as presented in this Progress Report. We look forward to a conclusive and comprehensive final report.

5.0 INEL COMMENTS

The INEL's role in the MUG validation was one of service. We did not make policy or enforce it. All vendors chose to test at our facility and they accepted the risks knowingly. Policy and outcome remarks should be reserved for MUG.

Many comments concern event timing and measured values. Timing is critical when evaluating measurements at some event during the stroke such as torque switch trip. Measurement channels with signal processing time delays or transducer response time variations may overestimate the torque and/or force available. With timing delays, measured values of force and torque include momentum effects that may not respond the same at higher loadings. The real question is how accurately a vendor can determine event timing with respect to his system's time response. Small errors in the timing scale itself are trivial, as long as the sequential spacing and the relationship of the event to time is maintained.

Several vendors questioned the INEL stem torque measurements. The INEL typically looks at the torque balance across the operator. The spring pack force multiplied by the effective moment arm length gives the input torque. The difference between this and the measured stem torque is equal to the losses in the operator and the losses not accounted for in the calibrations (e.g. MOVLS lower thrust bearing). Figure 1 shows the INEL torque spring pack force measurement for a typical MOVLS closure stroke. Figure 2 shows the INEL stem torque measurement for the same stroke. By dividing the stem torque measurement by the spring pack force measurement we can determine the apparent moment arm length. Figure 3 compares this apparent moment arm length with the theoretical length obtained from Limitorque. The two curves lie on top of one another indicating no significant losses between input and output torque. Figure 4 shows the difference between input torque (measured spring pack force times moment arm length) and output torque (INEL stem torque measurement). This data shows that essentially there is no error due to losses in the operator or lower thrust bearing. This relationship remains constant from the lowest to the highest MOVLS loadings, convincing us that the MOVLS stem torque measurement methodology is sound.

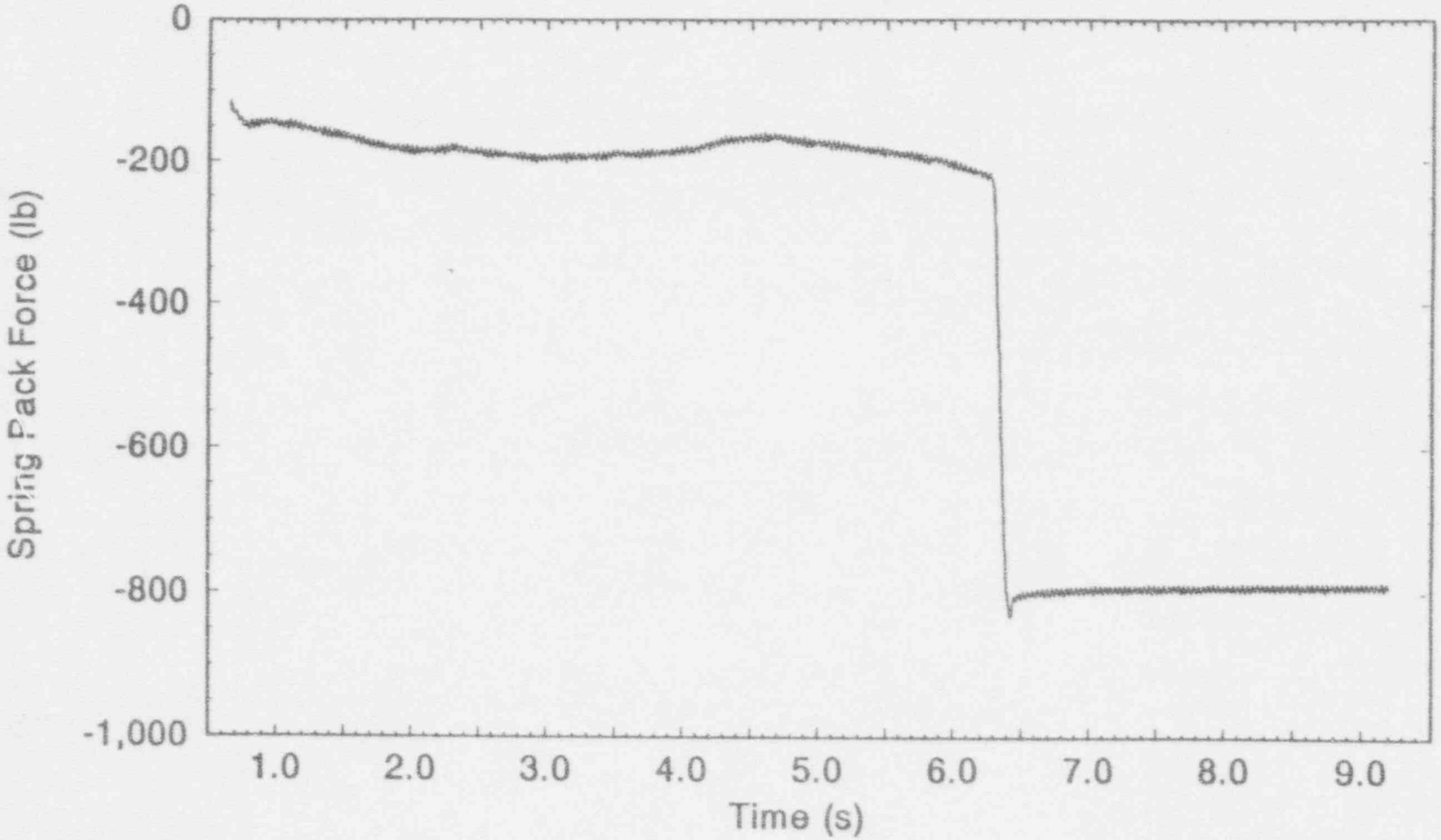


Figure 1. Torque spring pack force

M371 kgd-0791-01

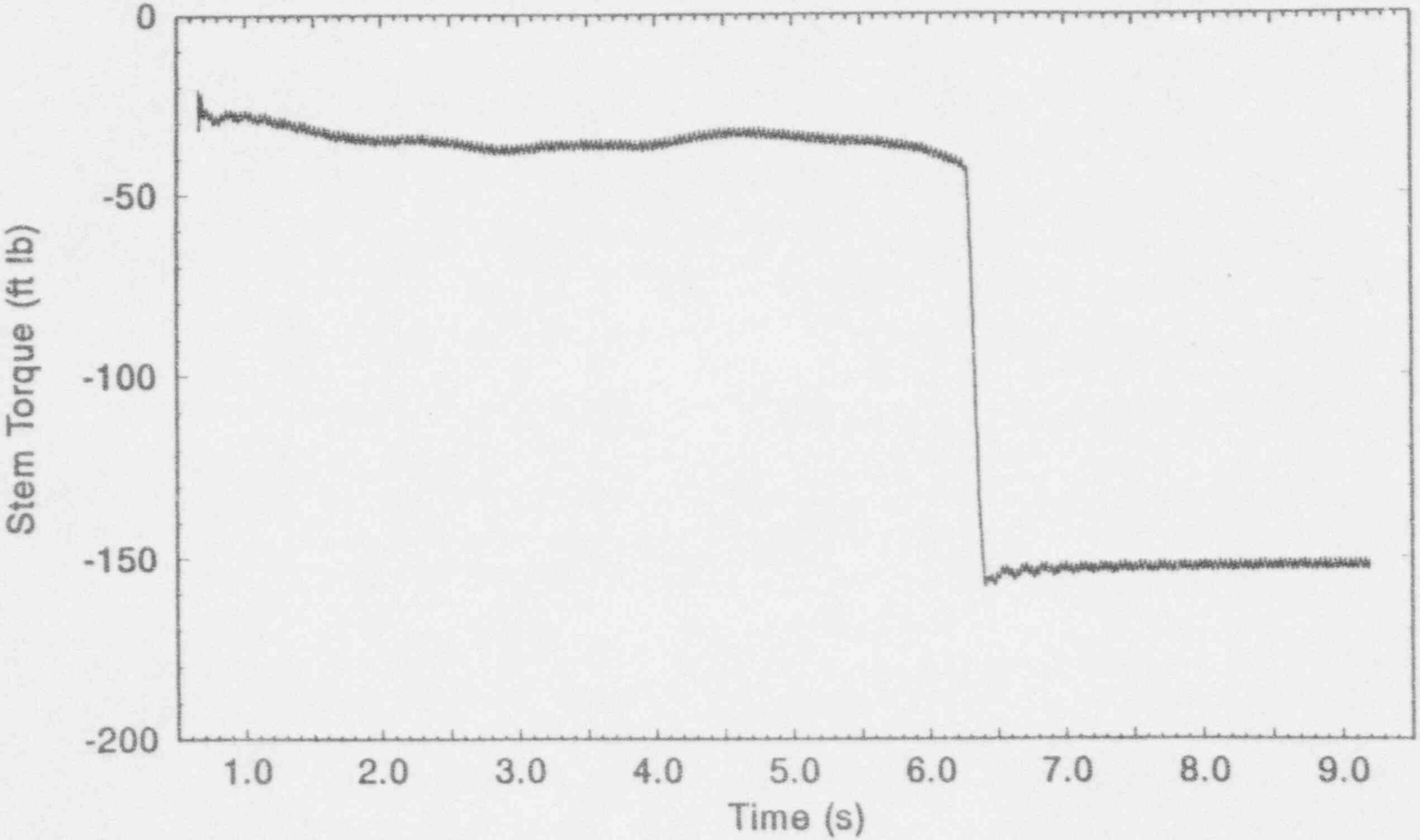


Figure 2. Stem torque

M371 kgd-0791-02

46B

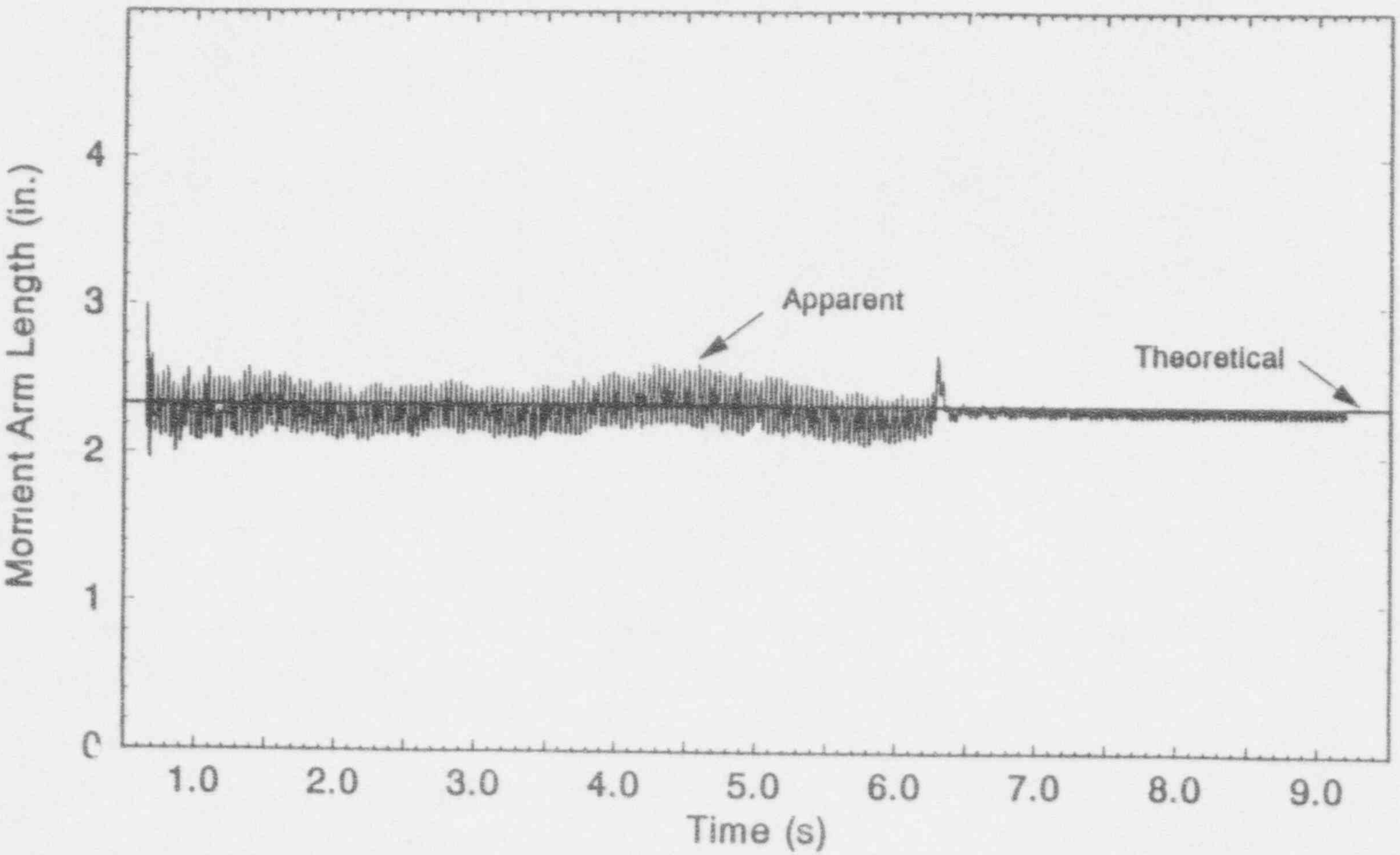


Figure 3. Apparent vs theoretical moment arm length

M371 kgd-0791-03

46 C

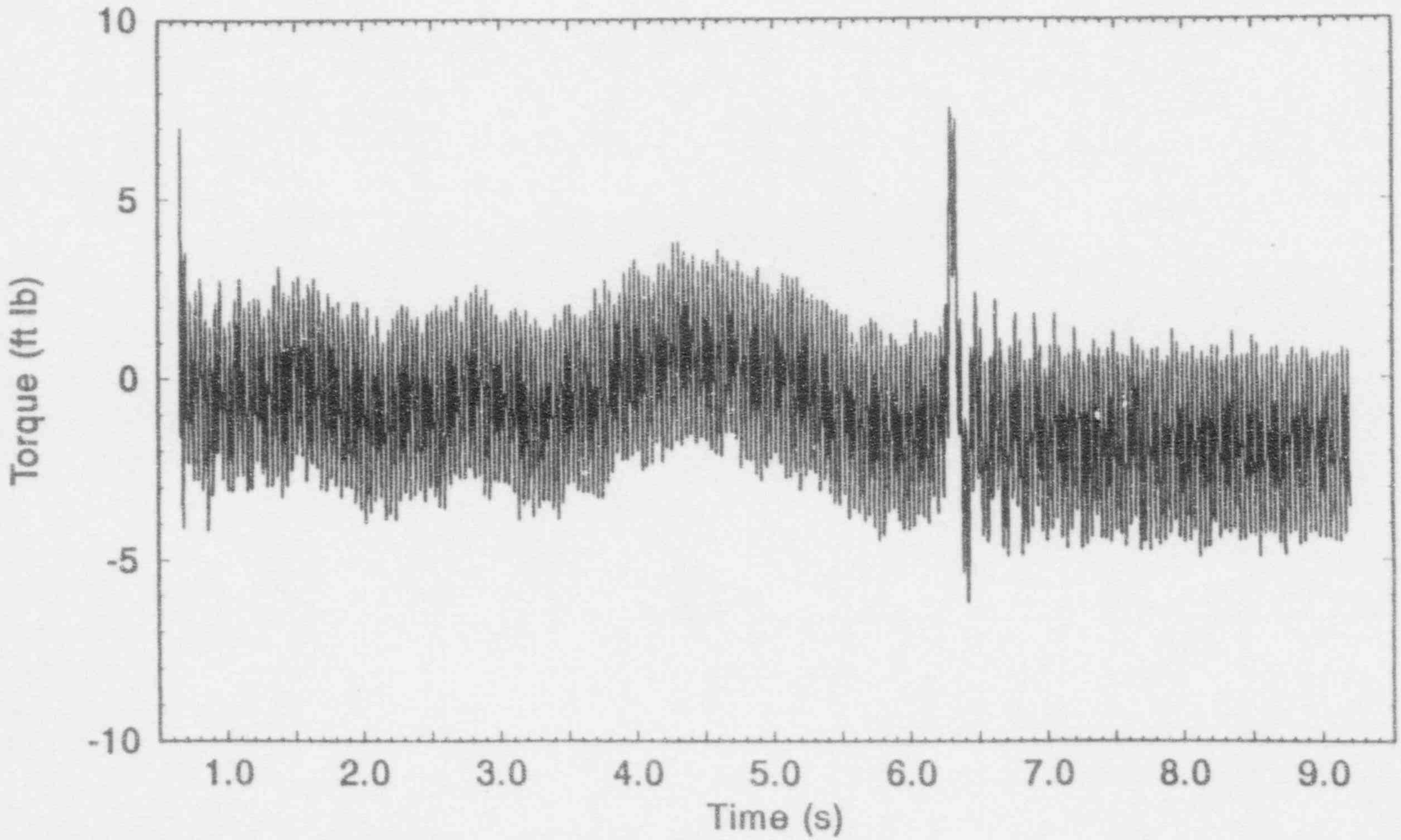


Figure 4. Input vs output torque error

M371 kgd-0791-04

MOV USER'S GROUP
TEST EQUIPMENT AND METHOD VALIDATION COMMITTEE
TEST PLAN 91-1

Measurement of significant operating parameters of MOVs with non-rotating rising stems in Limitorque actuators

REVISION 0
APRIL 3, 1991

APPROVED BY THE MUG STEERING CMTE:

Norm Dingman Chairman	Date
John Sharpe Vice Chairman	Date
Mark Pittman	Date
Robert Elfstrom	Date
William Ross	Date
Bill Black TEMV Chairman	Date

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MOV USER'S GROUP
TEST EQUIPMENT AND METHODS VALIDATION COMMITTEE
TEST PLAN 91-1

1.0 PURPOSE

1.1 The purpose of this testing is to verify vendor specified accuracies of Motor Operated Valve (MOV) diagnostic systems in measuring specific quantitative parameters.

2.0 SCOPE OF TESTING

2.1 The MOVs which are the subject of this test program have non-rotating rising stem Limitorque actuators. The parameters which are the primary focus of this test program are those which relate the mechanical loading provided by the motor to the mechanical loading developed in the valve stem and the capability of diagnostic systems to accurately measure such parameters.

2.2 A variety of ways are available for measuring these parameters. Attachment B provides a list of the parameters which may be included in this test program.

2.3 The test program will be conducted under laboratory conditions.

2.4 The laboratory testing and analysis will be conducted at Idaho National Engineering Laboratory (INEL) in Idaho Falls, Idaho.

2.5 Testing will be conducted on the INEL MOV Load Simulator. Attachment A provides a description of the test stand. Testing will involve 27 test strokes for each <u>type</u> transducer. Three of each type thrust or torque transducer will be used where available. Each of these three transducers will be tested at each of 3 torque switch settings and 3 loading conditions.

2.6 This test program does not explicitly include the diagnostic system's or the test equipment supplier's ability to identify maintenance deficiencies in the actuator. The tests are intended to provide quantitative comparisons of measurements of the specified parameters.

2.7 All transducers will be tested on the MOV Load Simulator, however, the test combination sequence may not be the same (Attachment C lists the various combinations).

2.8 A Test system may not measure all the parameters listed in the test plan data sheet (Attachment B). In the event that a particular stated parameter is not applicable to the test equipment being evaluated it shall be indicated as not tested, (N/A) on the data sheet.

2.9 Test equipment measurements will be compared to common standards, supplied by INEL.

3.0 QUALITY ASSURANCE

3.1 All work performed by the test equipment suppliers and INEL shall be done in accordance with their quality assurance plans, including 10CFR50 Appendix B, for activities related to the nuclear industry. Part 21 applies only to the calibration.

4.0 STANDARD and CALIBRATION REQUIREMENTS

4.1 The STANDARDs against which each diagnostic system's measurements will be compared are the responsibility of INEL. All STANDARD equipment shall have calibration traceable to the NIST, and shall have an accuracy at least 4 times greater than the equipment being compared when practical. An end to end accuracy band for each STANDARD shall be established, the true value will reside within this accuracy band and it is against this band that the stated accuracy of each diagnostic system will be compared.

4.2 INEL shall document to the MUG prior to the start and at the completion of the test the calibration of the STANDARDs. This documentation will be incorporated into the test report to substantiate the validity of the test data collected by INEL during the test program.

4.3 The equipment suppliers shall document prior to the start and at the completion of the test, the calibration of their equipment. This documentation will be incorporated into the test report to substantiate the validity of the test data collected by equipment suppliers during the test program.

4.4 The equipment vendors shall deliver copies of all pertinent equipment calibration certifications to the utility host prior to the start of testing. These documents will be made available to all interested parties after testing is completed.

4.5 Submittal of post-test calibration certification by the equipment suppliers shall be a prerequisite to their review of the INEL test data.

4.6 Kalsi Engineering acting as a third party independent reviewer, will review prior to the start of testing, INEL's calibration documentation. Kalsi will advise the MUG Chairman of any calibration discrepancies.

4.7 INEL will perform a calibration check after the completion of each vendor's scheduled testing. The purpose of this calibration check is to ensure that the INEL true value band remains consistent for each successive vendor.

5.0 TEST and ANALYSIS CONDUCT

5.1 In order to ensure fairness in the test, the following code of conduct has been developed.

5.2 Each equipment supplier shall have in attendance during the testing the minimum number of participants necessary to successfully conduct their portion of the test program. Adherence to this request will reduce the possibility of confusion during the testing. INEL requests that no more than 2 foreign nationals per equipment supplier be allowed to attend the validation testing due to the burden of obtaining a security clearance for admittance to the INEL facilities.

5.3 Equipment suppliers will not be allowed to view the INEL computer screen or outputs during testing.

5.4 During the test sequence, conversation between the INEL engineer and the equipment supplier shall be limited to the extent necessary to allow each party to independently collect test data from the MOV Load Simulator. Conversation will be monitored by the Test Coordinator.

5.5 The Test Coordinator will direct all testing. Any deviations to the testing procedure will be noted by the Test Coordinator on the test comment sheets which are part of attachment B. These will become part of the permanent test record.

5.6 The test stand will be fully stroked (approximately 2") when possible. Therefore, transducers that will not allow for full stroking of the stand will require a modification to the test sequence. All modifications to the test sequence (including partial strokes) will be noted on the Test Plan Data Sheets under comments (attachment B).

5.7 The testing is limited to the following sequence: a test stroke, partial analysis of the stroke by the equipment supplier if deemed necessary by the equipment supplier, next stroke, ... The INEL engineers will not be required to analyze data taken between strokes.

5.8 See attachment D for calendar of test schedule.

5.9 During the test sequence if the equipment supplier's equipment fails or malfunctions the equipment supplier may stop the test sequence and reschedule. If the failure necessitates replacement, adjustment, correction, or recalibration of the suppliers equipment, this will only be permitted if the <u>entire</u> test sequence can be restarted and completed within the scheduled date. Any failure of the INEL equipment will allow for a recalibration of the equipment suppliers equipment and a retest within the remaining test period. In the event of an INEL equipment failure, every effort will be made by INEL to complete the testing within the effected vendor's allotted time frame.

5.10 Minor non-intent changes to the test procedure may be made with the concurrence of the Test Coordinator and will be noted on the comment sheets.

5.11 The equipment suppliers' partial data analysis as described in section 7.0 of this test plan will be submitted, on the attached data sheet (Attachment B) to the Test Coordinator at the end of each thrust or torque transducer test cycle.

5.12 After an initial analysis (as a minimum the time reference point, torque switch trip and total thrust will be marked), copies of the actual signatures acquired during the test sequence will be supplied to the Test Coordinator. This will be accomplished by the equipment supplier giving the Test Coordinator electronic copies (disk) of the test signatures upon completion of the test sequence or by allowing INEL to collect the signatures during the test sequence. Note that each stroke must be clearly identified for accurate comparison. The electronic copies need to be supplied to the Test Coordinator prior to the equipment vendor leaving the test site.

IMPORTANT: THE EQUIPMENT SUPPLIER MUST ENSURE THAT INEL IS CAPABLE OF READING HIS ELECTRONIC DATA.

6.0 RELEASE AND WAIVER OF LIABILITY

6.1 Participation by an equipment supplier, utility host, or INEL employee or other individual or corporation shall be understood to mean that the represented organization is satisfied with this test plan and its implementation methods for comparing equipment supplier measurements to the INEL standards, methods used by the Utility host and INEL to control, evaluate, and report the test results,and to the extent that such test plan, implementation methods used to control, evaluate and report the test results are carried out in accordance with and in full compliance with the guidelines and procedures set forth herein, the represented organization will hold harmless each other, their employees, INEL, DOE, NRC, and other participating equipment suppliers who freely choose to use this test plan, from any liability incurred by such represented organization arising from or resulting out of this test plan, implementation methods, and methods to control, evaluate, and report the test results.

7.0 TEST PROCEDURE (MOVLS)

7.1 INEL shall install their equipment on the MOVLS per their generic procedure. Each step of the installation procedure will be verified by the Test coordinator. Deviations to the procedure will be noted, initialled and dated by INEL on the procedure in black ink. The actuator will be stroked, the transducers checked for operability and the integrity of the MOVLS i.e., bolt tightness and adequate lubrication, will be verified. The INEL engineer will also ensure that a zero mechanical load on the stem is achieved at some point during each stroke of the test sequence.

7.2 The INEL engineer will supply the equipment supplier with a time reference input. The equipment supplier will be required to input this reference into their equipment and record this input during all data collection strokes of the test actuator.

7.3 The equipment supplier shall install and, if required calibrate their equipment on the MOVLS per their standard procedure as supplied with their equipment. (Multiple strokes may be used during the calibration) Each step of the installation procedure and/or calibration will be verified by the utility host. Deviations to the procedure will be noted, initialled and dated by the utility host on the procedure in black ink. The actuator will be stroked and the transducers checked for operability. Modifications to the vendor's installation or additional calibrations will not be allowed for the remainder of section 7 (except as allowed by section 5.9).

NOTE: If the equipment supplier's transducer requires an extended curing period, such as experienced with stem mounted strain gauges or yoke mounted sensors, the equipment supplier may install their transducer(s) the day prior to the test sequence. (This test will involve the removal and installation of three transducers.) Installation of the transducers will be monitored by the utility host and fully documented, in accordance with the suppliers procedures.

NOTE: Calibration shall be performed with a torque switch setting not less than the maximum torque switch setting used in the loading combination testing sequence.

7.4 The INEL engineer will adjust one or more of the following parameters on the actuator: Torque switch setting, Load condition, (The magnitude and combinations of the adjustments will be documented prior to each test stroke). In order to ensure that each parameter has been correctly adjusted, the INEL engineer will be required to stroke the actuator a minimum of one time after making adjustments. Additional strokes may be required. The equipment supplier will not take data during the INEL set-up strokes.

NOTE: During step 7.4 of the testing only the stated parameters can be changed.

7.4.1 The actuator will be stroked closed and open during which time both INEL and the equipment supplier will electronically measure the applicable parameters using their standard procedures which are normally supplied with their equipment.

7.4.2 Repeat steps 7.4 and 7.4.1 for a total of nine stroke cycles.

7.4.3 Upon completion of the data acquisition strokes, a short review of the data shall be made by the Test Coordinator with the equipment supplier, only to ensure that complete signatures have been obtained. At this time the equipment supplier will perform a data analysis which as a minimum will mark the time reference point, torque switch trip and total thrust for each of the previous nine strokes. These points will be recorded on the data sheet by the Test Coordinator, other points referenced on the data sheet may be recorded if desired by the equipment supplier.

NOTE: If additional data sheets are required, copies of blank data sheets may be made. The Equipment Supplier, Test Coordinator and Utility Host will sign each data sheet as a verification that the recorded values on the data sheet correspond to the identified points on the traces.

7.4.4 When this review and recording of data is complete, another of the same type transducer will be tested by repeating the applicable portions of steps 7.3 through 7.4.3 inclusive, until a total of 3 of the same type transducers have been tested.

8.0 ANALYSIS PROCEDURE

8.1 The INEL engineer and the equipment supplier representative will retrieve on their analysis computers the data sets acquired for each stroke performed under section 7, including calibration strokes if applicable.

8.2 The equipment supplier representative will verify that the data point values from their data set, which as a minimum include the time reference point, torque switch trip and total thrust, are marked correctly on the electronic copy (disk) which is to be turned over to the Test Coordinator.

Note: For those equipment suppliers that allowed INEL to record their data during testing, comparison of their data and the INEL data on the INEL computer can be completed inside the scope of this test plan.

Note: The Test Coordinator will ensure that all data points marked by the equipment supplier will also be recorded by INEL.

8.3 The data analysis is complete. Thank you for your participation. The Test Coordinator shall retain all original data sheets and verified copies of the processed electronic data. Equipment suppliers and INEL shall be provided with copies of the data sheets.

9.0 POST TEST REQUIREMENTS

9.1 Each equipment supplier and INEL are required to submit post-test calibration certifications for each device used in the program. Submittal of the post test calibration certification by the equipment suppliers shall be required within 15 working days from the completion of their testing. Submittal of the post-test calibration certification by INEL, is required as soon as possible after completion of the entire test program not to exceed 45 days. Post-test calibration certification should be mailed to KALSI Engineering. If it is determined from the post-calibration certification that either the INEL or vendor equipment was out of calibration during the testing, an attempt will be made to reconcile these differences. Kalsi Engineering will be utilized as necessary to resolve any such differences. The data and written analysis will remain in the Public Record.

9.2 Analysis of the data will be conducted within the following guidelines:

Each type of thrust transducer tested will be analyzed individually.

All data from each recorded stroke of a thrust transducer will be presented. This will be accomplished by overlaying the vendor trace with error band on top of the INEL trace with error band. The vendor error band will be computed from the INEL true value (error) band.

Copies of all data sheets will be processed and used in conjunction with the stroke signatures as a basis for the analysis.

A discussion section of the final report will be written by the MUG members who analyze the results from each vendor. This section of the report will include as a minimum an evaluation of such items as transducer repeatability, vendor accuracy, and equipment response over the entire valve stroke.

A vendor discussion section will be included in the final report. The vendor will use this section to comment on the analysis of their equipment written by participating MUG members.

9.3 The final test data, resulting from this test plan and test effort, will go into the public domain at the same time it is made available to the MUG membership.

ATTACHMENT A

Limitorque Motor Operator

Model	SMB-0-25
Motor Speed	1750 RPM
Motor Power	3 phase, 480 volt
Overall Gear Ratio	34.96
Spring Pack	0501-184

Valve Stem

Material	SS 410 (hardened) ASTM-A479
Diameter	1 3/4 in.
Pitch and Lead	1/4

Torque Arm

Material	Carbon Steel A-36
Length	23 3/4 in.
Width	2 in.
Thickness	3/4 in.

Valve Yoke

Material	Carbon Steel WCB ASTM-A216

Bolts, Studs, and Nuts

Upper yoke to yoke attachment bolts	ASTM-A574 alloy steel
Yoke to bonnet attachment bolts	ASTM-A574 alloy steel
Yoke to operator attachment studs	Grade B7 ASTM-A193
Nuts	Grade 2H ASTM-A194

TEST PLAN DATA SHEET

VARIATIONS IN TEST STAND CHARACTERISTICS

TEST ID	TORQUE SWITCH SETTING	LOADING CONDITION
1	L	L
2	L	L
3	L	L
4	L	M
5	L	M
6	L	M
7	L	H
8	L	H
9	L	H
10	M	L
11	M	L
12	M	L
13	M	M
14	M	M
15	M	M
16	M	H
17	M	H
18	M	H
19	H	L
20	H	L
21	H	L
22	H	M
23	H	M
24	H	M
25	H	H
26	H	H
27	H	H

H = HIGH LEVEL
M = MEDIUM LEVEL
L = LOW LEVEL

These conditions will be varied randomly throughout the stroke sequences. The actual conditions at each stroke will be recorded by INEL.

ATTACHMENT D

Equipment Supplier	Date	Test Coordinator/Utility Host
Wyle Labs	4/15/91	Mark Pittman/Ron Robinson
Impell	4/22/91	Jim Salmon/Al Gort
Liberty	4/29/91	George Smith/Hank Pozzuoli
KWU	5/6/91	Tim Cline/Bob Elfstrom
ITI-Movats	5/13/91	John Sharpe/Pat Conroy
Teledyne	5/20/91	PGE/Norm Dingman

All vendor accuracy statements will be submitted prior to testing.

The Utility Host and Test Coordinator responsibilities are interchangeable within this test procedure.

Summary of Vendor Claims for Measurement Accuracy

(Note: The values listed on this sheet have not been validated by the MUG)

Preparer: James Polidora **Date of origination:** 2/18/91 REV 5 4-91 TLC
Test Equipment Vendor / System: ITI Movats/VITALS
Description of test method: Stem force is measured with a Stem Load Sensor (strain sensor). This device measures poisson strain in the stem. This strain is converted to read out in pounds force thrust. Motor current, motor power, stem position, and switch actuations are also monitored. The signals are acquired by a modular signal conditioning unit and portable computer.

Present Accuracy Specifications:

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
Thrust Sensor A SLS (Solid)	±	±	±	±(10.0 %rdg+ 2.0% FS)	1,2
Thrust Sensor B SLS (Threads)	±	±	±	± (14.3 %rdg+ 3.2% FS)	3,4,5
Torque	±	±	±	± %	
Stem Position	±	±	±	± 0.5 %FS	
Motor Current (AC)		±	±	Greater of ±2.5% of RDG or 0.15A	
Motor Voltage	±	±	±	± 2.0% RDG above 100 vrms	
Motor Power(KW)	±	±	±	Greater of ±3.0% RDG or 100w	
Time Base	±	±	±	± 500 μsec/min	
Data Sample	-	-	-	1500 s/s/c (8 chan)	
Motor Power(W)	±	±	±	Greater of ±3.0% of RDG or 25W	

Notes:

1: Accuracies are measured "end-to-end" (full loop accuracies).
2: "Total" accuracy specification includes the "units" (ie. %FS, %RDG, etc.).
3: Data sample rate units are "samples/sec/max channels"

Definitions:

Accuracy - A measure of the degree by which the actual output of a device approximates the output of an ideal device nominally performing the same function.
Repeatability - The closeness of agreement among repeated measurements of the output for the same value of input made under the same operating conditions over a period of time.
Drift - Gradual accuracy deviation in a given time period unrelated to input or environment.
Field Variables - Conditions which may affect equipment accuracy and are not accounted for in the accuracy statements above (ie. spring pack loading rate, non-standard stem threads, actuator mounting position, improper bolt torque, etc).

FV Notes:

1: The SLS accuracy does not include errors from time delays between the reference load measurement and the SLS sensor due to different filtering, nor does it include errors from EMI noise spikes. The SLS accuracy may vary with non-standard stem threads.
2:

Other Notes:

A: The SLS full scale value is typically ±30K lbs.

Additional Data Sheet Space

Preparer: James Palidora Date of origination: 2/18/91
Test Equipment Vendor / System: ITI MOVATS / VITALS

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	

FV Notes:

3:

4:

5:

6:

7:

Other Notes:

C:

D:

E:

Summary of Vendor Claims for Measurement Accuracy

(Note: The values listed on this sheet have not been validated by the MUG)

Preparer: Roger Carr **Date of origination:** 2/21/91 REV 5-9-91 TLC
Test Equipment Vendor / System: ITI MOVATS / 3000 Series

Description of test method: Thrust sensor A involves calibration of spring pack displacement to stem thrust (torque for ¼ turn actuators) in either the open or close direction using a variety of direct thrust measuring transducers. This method determines thrust above actuator running load. Thrust sensors B and C clamp on the stem and measure axial strain which is converted to thrust by calculation. Thrust sensor D mounts between the yoke and actuator measuring torque and thrust directly.

Present Accuracy Specifications:

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
Various Load Cells Thrust Sensr A	±	±	±	± see attached tables	1,2,3
SST Thrust Sensr B	±	±	±	± see attached tables	
SSR Thrust Sensr C				± see attached tables	
Thrust/Torque Cell D	±	±	±	± see attached tables	
Stem Position	±	±	±	± %	
Motor Current	±	±	±	±6.5 % RNG AC ±6.0 % RNG DC	
Motor Voltage	±	±	±	± %	
Motor Power	±	±	±	±(3.0% rdg+ 25 watts)	
Time Base	±	±	±	-7500 to -20000 µsec/min	
Data Sample	-	-	-	10-1000 s/s/c	
	±	±	±	±	

Notes:

1: Accuracies are measured "end-to-end" (full loop accuracies).
2: "Total" accuracy specification includes the "units" (ie. %FR, %RDG, etc.).
3: Data sample rate units are "samples/sec/max channels"

Definitions:

Accuracy - A measure of the degree by which the actual output of a device approximates the output of an ideal device nominally performing the same function.
Repeatability - The closeness of agreement among repeated measurements of the output for the same value of input made under the same operating conditions over a period of time.
Drift - Gradual accuracy deviation in a given time period unrelated to input or environment.
Field Variables - Conditions which may affect equipment accuracy and are not accounted for in the accuracy statements above (ie. spring pack loading rate, non-standard stem threads, actuator mounting position, improper bolt torque, etc).

FV Notes:

1: Variation in loading rate between the calibration trace and subsequent strokes affect the relationship between stem force and spring pack development.
2: Actuator maintenance problems such as degraded drive sleeve bearings, loose yoke to actuator bolts, spring pack grease, inconsistent stem lubrication, etc. affect the relationship between opening and closing thrust.
3: Changes in stem running load between the calibration trace and subsequent strokes affect the accuracy of TMD determined thrust when running load is less than spring pack preload.
4:

Additional Data Sheet Space

Preparer: Roger Carr Date of origination: 2/21/91
Test Equipment Vendor / System: ITI MOVATS / 3000 Series

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	

FV Notes:

5:

6:

7:

8:

9:

Other Notes:

A:

B:

C:

OVERALL SYSTEM ACCURACY

Overall system accuracy in percent of reading for .e noted thrust range based on use of the following components:

a. MOVATS® Series 2151 or 3000 Valve Analysis Systems

b. TMD or TST

c. 50K or 200K load cell

d. Limitorque's® Torque Switch Repeatability

"A"

Thrust (lbs)	Overall Set-up Accuracy (±%)
2000 - 2999	15.9
3000 - 3999	13.6
4000 - 4999	12.4
5000 - 5999	8.3
6000 - 6999	7.8
7000 - 7999	7.6
8000 - 13999	7.3
14000 - 23999	6.7
24000 - 44999	6.4
45000 - 69999	6.2
70000 - 139,999	7.9
140,000 - 199,999	6.3
200,000 - +	6.1

Overall system accuracy when listed component is used in lieu of item c, load cells:

"B" SST

Thrust (lbs)	Overall Set-up Accuracy (±%)
2,000 - 4,400	11.5
4,401 - +	7.6

"C" SSR

Thrust (lbs)	Overall Set-up Accuracy (±%)
2,000 - 4,400	14.4
4,401 - +	11.5

"A" **Screw-In Load Cells**

Thrust (lbs)	Overall Set-up Accuracy (±%)
2000 - 2999	17.4
3000 - 3999	14.4
4000 - 4999	13.1
5000 - 5999	8.9
6000 - 6999	8.3
7000 - 7999	7.9
8000 - 13,999	7.6
14,000 - 23,999	6.8
24,000 - 44,999	6.5
45,000 - 69,999	6.3
70,000 - +	6.2

"A" **BART™ System Unit**

	HBC Output Torque (ft-lbs)	Overall Set-up Accuracy (±%)
HOBC	42 - 82	12.0
	83 - 124	11.1
	125 - 208	10.9
	209 - 417	10.8
	418 - 455	10.7
H1BC	117 - 145	15.9
	146 - 175	14.4
	176 - 233	13.5
	234 - 408	12.5
	409 - 583	11.5
	584 - 1300	11.1
H2BC	134 - 167	15.8
	168 - 200	14.4
	201 - 267	13.5
	268 - 467	12.5
	468 - 667	11.5
	668 - 1167	11.1
	1168 - 2176	6.6
	2177 - 2200	6.3

"A"

H3BC	430 - 539	15.9
	540 - 649	14.4
	650 - 759	13.5
	760 - 859	12.9
	860 - 1079	12.6
	1080 - 1299	8.3
	1300 - 2099	7.8
	2100 - 5650	7.0

"D"

Torque Thrust Cells Thrust	Overall Set-up Accuracy (±%) SMB-000	SMB-00	SMB-0
2000 - 2999	11.23	12.40	15.13
3000 - 3999	10.86	11.46	13.00
4000 - 4999	10.72	11.10	12.00
5000 - 5999	6.20	6.62	7.62
6000 - 6999	6.11	6.44	7.20
7000 - 7999	6.06	6.32	7.00
8000 - 13,999	6.00	6.20	6.73
14,000 - 23,999	---	6.00	6.30
24,000 - 40,000	---	---	6.00

"D"

Torque Thrust Cells (Without TMD/TST) Torque (ft.lbs)	Overall Set-up Accuracy (±%) SMB-000	SMB-00	SMB-0
15 - 29	13.4	19.3	42.2
30 - 44	11.5	13.7	23.8
45 - 59	11.0	12.2	18.1
60 - 74	6.5	7.8	12.9
75 - 89	6.3	7.3	11.2
90 - 104	6.2	6.9	10.1
105 - 119	6.1	6.7	9.3
120 - 199	6.1	6.6	8.7
200 - 399	5.9	6.2	7.3
400 - 749	---	6.0	6.4
750 - 1200	---	---	6.0

OVERALL SYSTEM ACCURACY

Overall system accuracy in percent of reading for the noted thrust range based on use of the following components:

a. MOVATS® Series 2151 or 3000 Valve Analysis Systems

b. TMD or TST

c. 50K or 200K load cell

d. Limitorque's® Torque Switch Repeatability

"A"

Thrust (lbs)	Overall Set-up Accuracy (±%)
2000 - 2999	15.9
3000 - 3999	13.6
4000 - 4999	12.4
5000 - 5999	8.3
6000 - 6999	7.8
7000 - 7999	7.6
8000 - 13999	7.3
14000 - 23999	6.7
24000 - 44999	6.4
45000 - 69999	6.2
70000 - 139,999	7.9
140,000 - 199,999	6.3
200,000 - +	6.1

Overall system accuracy when listed component is used in lieu of item c, load cells:

"B" SST

Thrust (lbs)	Overall Set-up Accuracy (±%)
2,000 - 4,400	11.5
4,401 - +	7.6

"C" SSR

Thrust (lbs)	Overall Set-up Accuracy (±%)
2,000 - 4,400	14.4
4,401 - +	11.5

"A" Screw-In Load Cells

Thrust (lbs)	Overall Set-up Accuracy (±%)
2000 - 2999	17.4
3000 - 3999	14.4
4000 - 4999	13.1
5000 - 5999	8.9
6000 - 6999	8.3
7000 - 7999	7.9
8000 - 13,999	7.6
14,000 - 23,999	6.8
24,000 - 44,999	6.5
45,000 - 69,999	6.3
70,000 - +	6.2

"A" BART™ System Unit

	HBC Output Torque (ft-lbs)	Overall Set-up Accuracy (±%)
HOBC	42 - 82	12.0
	83 - 124	11.1
	125 - 208	10.9
	209 - 417	10.8
	418 - 455	10.7
H1BC	117 - 145	15.9
	146 - 175	14.4
	176 - 233	13.5
	234 - 408	12.5
	409 - 583	11.5
	584 - 1300	11.1
H2BC	134 - 167	15.8
	168 - 200	14.4
	201 - 267	13.5
	268 - 467	12.5
	468 - 667	11.5
	668 - 1167	11.1
	1168 - 2176	6.6
	2177 - 2200	6.3

"A" H3BC

"A" H3BC	430 - 539	15.9
	540 - 649	14.4
	650 - 759	13.5
	760 - 859	12.9
	860 - 1079	12.6
	1080 - 1299	8.3
	1300 - 2099	7.8
	2100 - 5650	7.0

"D" Torque Thrust Cells

Thrust	Overall Set-up Accuracy (±%) SMB-000	SMB-00	SMB-0
2000 - 2999	11.23	12.40	15.13
3000 - 3999	10.86	11.46	13.00
4000 - 4999	10.72	11.10	12.00
5000 - 5999	6.20	6.62	7.62
6000 - 6999	6.11	6.44	7.20
7000 - 7999	6.06	6.32	7.00
8000 - 13,999	6.00	6.20	6.73
14,000 - 23,999	---	6.00	6.30
24,000 - 40,000	---	---	6.00

"D" Torque Thrust Cells (Without TMD/TST)

Torque (ft.lbs)	Overall Set-up Accuracy (±%) SMB-000	SMB-00	SMB-0
15 - 29	13.4	19.3	42.2
30 - 44	11.5	13.7	23.8
45 - 59	11.0	12.2	18.1
60 - 74	6.5	7.8	12.9
75 - 89	6.3	7.3	11.2
90 - 104	6.2	6.9	10.1
105 - 119	6.1	6.7	9.3
120 - 199	6.1	6.6	8.7
200 - 399	5.9	6.2	7.3
400 - 749	---	6.0	6.4
750 - 1200	---	---	6.0

Summary of Vendor Claims for Measurement Accuracy

(Note: The values listed on this sheet have not been validated by the MUG)

Preparer: Bill Schauki **Date of origination:** 3-11-91 REV 7-1-91 TLC
Test Equipment Vendor / System: Universal Testing Labs / KWU / Siemens / E343 System DAW

Description of test method: Stem thrust and torque measured with strain gages. Three phase active power is also measured. A computer is used to control the data acquisition and a custom signal conditioning unit prepares the data.

Present Accuracy Specifications:

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
Thrust Sensr A	± 8%	± 2%	± 1%	±10 % MV	E
Thrust Sensr B	±	±	±	±10.4% % MV	1,E
Torque	± 8%	± 2%	± 1%	±10 % MV	E
Stem Position	±	±	±	± %	
Motor Current	± 2%	± 0.5%	± 0.5%	±2.5% MV	B
Motor Voltage	± 2%	± 0.5%	± 0.5%	±2.5% MV	B
Motor Power	± 2%	± 0.8%	± 0.5%	±2.7% MV	1,B
Time Base	±	±	±	±4000 μsec/min	2,C
Data Sample	-	-	-	256 s/s/c	D
LVDT	± 3.0%	±0.3%	± 0.3%	±3.5% MV	

Notes:

1: Accuracies are measured "end-to-end" (full loop accuracies).
2: "Total" accuracy specification includes the "units" (ie. %FS, %RDG, etc.).
3: Data sample rate units are "samples/sec/max channels"

Definitions:

Accuracy - A measure of the degree by which the actual output of a device approximates the output of an ideal device nominally performing the same function.
Repeatability - The closeness of agreement among repeated measurements of the output for the same value of input made under the same operating conditions over a period of time.
Drift - Gradual accuracy deviation in a given time period unrelated to input or environment.
Field Variables - Conditions which may affect equipment accuracy and are not accounted for in the accuracy statements above (ie. spring pack loading rate, non-standard stem threads, actuator mounting position, improper bolt torque, etc).

FV Notes:

1: Active power measurement can be correlated to stem thrust within the stated accuracy.
2: Limit switch, torque switch and bypass switch accuracies are ± 4 msec.
3:

Other Notes:

A: MV means error related to measured value. The average value of all measured maximum values of each variable during the tests.
B: Response time is 50 msec to 99%
C: 4000 μsec (exact value is 3910 μsec) chan 1 to chan 1, 100 μsec chan 1 to chan 2
D: Maximum channel number is 8. Each channel has 256 samples/sec.
E: The value of this accuracy depends on the normal error of Young's Modulus (E). If E error is less than 1%, the accuracy can be changed to ±6% MV

Additional Data Sheet Space

Preparer: Bill Schauki **Date of origination:** 3-11-91

Test Equipment Vendor / System: Universal Testing Labs / KWU / Siemens / E343 System DAW

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	

FV Notes:

4: _____

5: _____

9: _____

10: _____

11: _____

Other Notes:

F: _____

G: _____

H: _____

Summary of Vendor Claims for Measurement Accuracy

(Note: The values listed on this sheet have not been validated by the MUG)

Preparer: David E. Thrall **Date of origination:** 3/12/91 REV 4-25-91 TLC

Test Equipment Vendor / System: Teledyne Engineering Services / TOTEM and TESTEM

Description of test method: TOTEM is a battery powered drop-off data acquisition system. TESTEM is a battery powered test analysis system. Thrust is measured by either a field installed strain gage on the stem or a pre-calibrated stem may be installed in the valve. A computer is used to setup the data acquisition parameters for the test in the signal conditioning unit. The data can be taken with or without the computer attached to TOTEM. The data is transferred to the computer after the test. Up to 7 inputs may be monitored.

Present Accuracy Specifications:

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
Smart Stem. Thrust & Torque Sensr A	±0.5%	±0.1%	±	±0.5 % FS	
Strain Gages. Thrust Sensr B	±5.0%	±0.2%	±	±5.0 % FS	A,1
Strain Gages. Torque Sensr B	±5.0%	±0.2%	±	±5.0 % FS	A,1
Stem Position	±.03 inches	±	±	±0.1 % FS	
Motor Current	±	±	±	±5 % RDG ±2 A	
Motor Voltage	±	±	±	± %	
Motor Power	±	±	±	± %	
Time Base	±	±	±	±30 µsec/min	B
Data Sample	-	-	-	1000 s/s/c	C
	±	±	±	±	

Notes:

1: Accuracies are measured "end-to-end" (full loop accuracies).
2: "Total" accuracy specification includes the "units" (ie. %FS, %RDG, etc.).
3: Data sample rate units are "samples/sec/max channels"

Definitions:

Accuracy - A measure of the degree by which the actual output of a device approximates the output of an ideal device nominally performing the same function.
Repeatability - The closeness of agreement among repeated measurements of the output for the same value of input made under the same operating conditions over a period of time.
Drift - Gradual accuracy deviation in a given time period unrelated to input or environment.
Field Variables - Conditions which may affect equipment accuracy and are not accounted for in the accuracy statements above (ie. spring pack loading rate, non-standard stem threads, actuator mounting position, improper bolt torque, etc).

FV Notes:

1: In-situ gage application variables: stem diameter measurement, E, µ, gage factor accuracy and gage alignment deviation.
2:
3:
4:

Other Notes:

A: ±5.0 % FS or ±10% RDG from 15% to 100% of FS
B: Can be compensated for time drift.
C: Up to 7 channels.

Additional Data Sheet Space

Preparer: David E. Thrall **Date of origination:** 3/12/91

Test Equipment Vendor / System: Teledyne Engineering Services / TESTEM and TOTEM

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	

FV Notes:

5: ___

6: ___

7: ___

8: ___

9: ___

Other Notes:

D: ___

E: ___

F: ___

Summary of Vendor Claims for Measurement Accuracy

(Note: The values listed on this sheet have not been validated by the MUG)

Preparer: Eddy Sayed **Date of origination:** 2/19/91
Test Equipment Vendor / System: ABB Impell Corporation / OATIS III

Description of test method: Stem thrust is measured directly in the open direction into load cell. Spring pack deflection is measured in the closed direction and used to correlate thrust. Thrust values measured equate to seat thrust (values greater than running load). Clamp-on AC/DC current probes measure motor current. Alligator clips attach to limit and torque switches to monitor switch actuation.

Present Accuracy Specifications:

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
Thrust Sensr A	±	±	±	SEE ATTACHED	1,2,3,4
Thrust Sensr B	±	±	±	± %	
Torque	±	±	±	± %	
Stem Position	±	±	±	± %	
Motor Current	±	±	±	SEE ATTACHED	5,C
Motor Voltage	±	±	±	± %	
Motor Power	±	±	±	± %	
Time Base	±	±	±	± 0.0 μsec/min	B
Data Sample	-	-	-	1000 s/s/c	
Spring Pack Deflection	±	±	±	±0.01 inch	

Notes:

1: Accuracies are measured "end-to-end" (full loop accuracies).
2: "Total" accuracy specification includes the "units" (ie. %FS, %RDG, etc.).
3: Data sample rate units are "samples/sec/max channels"

Definitions:

Accuracy - A measure of the degree by which the actual output of a device approximates the output of an ideal device nominally performing the same function.
Repeatability - The closeness of agreement among repeated measurements of the output for the same value of input made under the same operating conditions over a period of time.
Drift - Gradual accuracy deviation in a given time period unrelated to input or environment.
Field Variables - Conditions which may affect equipment accuracy and are not accounted for in the accuracy statements above (ie. spring pack loading rate, non-standard stem threads, actuator mounting position, improper bolt torque, etc).

FV Notes:

1: Spring pack conditions: fatigue, gap, loading rate, grease, preload.
2: Stem / stem nut conditions: lubrication, non-standard threads, gap, packing load, stem speed.
3: Actuator conditions: mounting position, gear/bearing wear, lubrication, running load, bolt torque, torque thrust conversion.
4: General conditions: environment, line pressure during calibration, open calibration / close thrust correlation.
5: Motor conditions: voltage, frequency.

Other Notes:

A: Repeatability and drift variables fall within the stated total accuracy value.
B: Negligible error.
C: Current values represent the value selected on the signal conditioning unit. The range on the current probe remains set at 200 amp for any motor current value from 0-200 amp. Accuracy values are based upon manufactures claims for a range setting of 200 amps. Based on calibration results, the actual accuracy values are reduced to approximately the accuracy value at the 200 amp range throughout the entire range. (i.e. Simpson = 4.13% from 0-200 amp, Fluke = 2.24% from 0-200 amp)

Additional Data Sheet Space

Preparer: Eddy Sayed **Date of origination:** 2/19/91
Test Equipment Vendor / System: ABB Impell Corporation / OATIS III

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
Thrust Range					
4000 lbs	±	±	±	±16.8 % RNG	
8000 lbs	±	±	±	±9.4 % RNG	
14000 lbs	±	±	±	±10.1 % RNG	
24000 lbs	±	±	±	±8.2 % RNG	
45000 lbs	±	±	±	±6.4 % RNG	
70000 lbs	±	±	±	±8.1 % RNG	
140000 lbs	±	±	±	±6.4 % RNG	
200000 lbs	±	±	±	±6.2 % RNG	
Simpson Current range					
10	±	±	±	±80 % RNG	
20	±	±	±	±40 % RNG	
50	±	±	±	±16.4 % RNG	
100	±	±	±	±8.06 % RNG	
200	±	±	±	±4.13 % RNG	
Fluke Current range					
10	±	±	±	±40 % RNG	
20	±	±	±	±20 % RNG	
50	±	±	±	±8.06 % RNG	
100	±	±	±	±4.12 % RNG	
200	±	±	±	±2.24 % RNG	

FV Notes:

6: ________

7: ________

8: ________

9: ________

10: ________

Other Notes:

D: ________

E: ________

F: ________

Summary of Vendor Claims for Measurement Accuracy

(Note: The values listed on this sheet have not been validated by the MUG)

Preparer: Robert L. Leon **Date of origination:** 2/20/91 REV 6-2-91 TLC

Test Equipment Vendor / System: Liberty Technology / VOTES ver 2.2

Description of test method: Yoke mounted strain sensor to sense thrust. This sensor is calibrated against a traceable diametral strain sensor temporarily applied tho the stem while the valve is seated using the motor. The diametral stem strain is converted to thrust by the software using the stem material properties and stem geometry.

Present Accuracy Specifications:

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
Thrust Sensr A	±	±	±	±9.2% RDG	1,9,A
Thrust Sensr B	±	±	±	±9.2% RDG	1,9,B
Torque	±	±	±	±10.0% RDG	2,9,11,C
Stem Position	±	±	±	± %	
Motor Current	±	±	±	±6.0% RDG	3,D
Motor Voltage	±	±	±	± %	
Motor Power	±	±	±	±20.0% RDG	3,4,5,6,E
Time Base	±	±	±	±6000 μsec/min	
Data Sample	-	-	-	1000 s/s/c	7
Motor PF (Phase)	±	±	±	±10°	3,4,5,8,F

Notes:

1: Accuracies are measured "end-to-end" (full loop accuracies).
2: "Total" accuracy specification includes the "units" (ie. %FS, %RDG, etc.).
3: Data sample rate units are "samples/sec/max channels"

Definitions:

Accuracy - A measure of the degree by which the actual output of a device approximates the output of an ideal device nominally performing the same function.

Repeatability - The closeness of agreement among repeated measurements of the output for the same value of input made under the same operating conditions over a period of time.

Drift - Gradual accuracy deviation in a given time period unrelated to input or environment.

Field Variables - Conditions which may affect equipment accuracy and are not accounted for in the accuracy statements above (ie. spring pack loading rate, non-standard stem threads, actuator mounting position, improper bolt torque, etc).

FV Notes:

1: Requires the user to know the stem material (E/ν) within ±3.5%.
2: Requires the user to know worm gear pitch radius. (Just actuator size for Limitorque actuators)
3: Measurement made on one phase; assumes balanced phases.
4: Requires use of AC/DC motor current probe.
5: Assumes PF in lost motion area to be within .13 and .44.
6: Requires the user to know motor line voltage.
7: 1000 samples/sec on each channel regardless of the number of channels selected.
8: Transients shorter than 30 milliseconds could exibit degraded amplitude accuracy.
9: Trace should be rezeroed after acquisition.
10:

Other Notes:

A: VOTES sensor bonded to the yoke, calibrated with c-clamp calibrator on the stem. (curve fit cal)
B: VOTES sensor bonded to the yoke, calibrated with u-clamp calibrator on the stem. (curve fit cal)
C: VTC sensor requires removal of the SP cartridge cap and locking ring; affected by preload. (NOT / SP)
D: AC or AC/DC probe or Quicktest cable sensor.
E: AC/DC probe only or Quicktest cable sensor (nickel core)

Additional Data Sheet Space

Preparer: Robert L. Leon **Date of origin** [illegible] **on:** 2/20/91
Test Equipment Vendor / System: Liberty Technology / VOTES ver 2.2

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
Low Freq Accelerometer	±	±	±	± 3db	12,13,G
H.F. Acceler envelope	±	±	±	± 3db	14,G
Total [illegible]	±	±	±	± 3db	15,G
Switch t[illegible]	±	±	±	± 1 msec	16,H
Worm displacement	±	±	±	± 3 mils	9,17,I
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	

FV Notes:

11: Does not read opening torques.
12: Detects flow initiation and cutoff.
13: Detects gear train frequencies and gear and spring pack defects.
14: Detects metal to metal impacts and rubs.
15: Detects tooth mesh frequecies greater than 300 hertz.
16: Detects limit and torque switch openings and closings.
17: This spec applies for actuator sizes up to and including SMB-2; use ±6 mils for SMB-3 and SMB-4.

Other Notes:

F: AC/DC probe only or Quicktest cable sensor.
G: On[illegible] piezoelectric accelerometer temporarily mounted to the actuator housing.
H: [illegible] and AC/DC probes are provided.
I: Part of VTC DC to DC LVDT.

Summary of Vendor Claims for Measurement Accuracy

(Note: The values listed on this sheet have not been validated by the MUG)

Preparer: Claude L. Thibault **Date of origination:** 2/28/91 REV 7-1-91 TLC
Test Equipment Vendor / System: Wyle Labs/AVMODS

Description of test method: Thrust is measured through a combination of the load reaction on the upper bearing housing of Limitorque actuators using piezoelectric load washers and a strain gage mounted on the stem or yoke. The strain gage is calibrated during the stroke using readings from the load washers. The strain gages are used to detect any preload on the upper bearing. The output of the charge amplifier is processed by an A to D converter and stored on computer disk media. Motor current, stem position, stem nut RPM, True power, power factor, switch actuation and spring pack displacement are also measured and recorded.

Present Accuracy Specifications:

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
Thrust Senor A Loadwasher and Strain Gage Combination	± 3% FSO	± 10%	± 0.5% FS	± 14.0 % FSO	A,C,1,2
Thrust Sensr B	±	±	±	± %	
Torque	±	±	±	± %	
Stem Position	±0.12% 0-15" 0-31"	±0.1% 0-15" 0-31"	±	±0.15% 0-15" 0-31"	
Motor Current	±2% FSO 0-20A 0-200A	±0.01	±	±2.01% FSO 0-20A & 0-200A	
Motor Voltage	±	±	±	±0.201 %FSO	
Motor Power	±	±	±	±0.8 % FSO -10° to +60°C	
Time Base	±	±	±	±15 μsec/min	
Data Sample	-	-	-	100 to 200 s/s/c	B
Power Factor	±	±	±	±0.01% of FSO	

Notes:

1: Accuracies are measured "end-to-end" (full loop accuracies).
2: "Total" accuracy specification includes the "units" (ie. %FS, %RDG, etc.).
3: Data sample rate units are "samples/sec/max channels"

Definitions:

Accuracy - A measure of the degree by which the actual output of a device approximates the output of an ideal device nominally performing the same function.
Repeatability - The closeness of agreement among repeated measurements of the output for the same value of input made under the same operating conditions over a period of time.
Drift - Gradual accuracy deviation in a given time period unrelated to input or environment.
Field Variables - Conditions which may affect equipment accuracy and are not accounted for in the accuracy statements above (ie. spring pack loading rate, non-standard stem threads, actuator mounting position, improper bolt torque, etc).

FV Notes:

1: Measures force in closing direction, and in the OPENING DIRECTION
2: Housing cover bolt torque critical.

Other Notes:

A: Depending on actuator size, different loadwashers are used: 0-8000, 0-14000, 0-20000, 0-45000, 0-90000 lbf
B: Depends on sweep time and number of channels.
C: Test system is currently designed to test Limitorque SMB-000 through SMB-5.

Additional Data Sheet Space

Preparer: Claude L. Thibault Date of origination: 2/28/91
Test Equipment Vendor / System: Wyle Labs / AVMODS

Parameter	Accuracy	Repeatability	Drift	Total	Field Variables (FV)
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
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	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	
	±	±	±	± %	

FV Notes:

3:

4:

5:

6:

7:

Other Notes:

D:

E:

F: