UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

Cent al - File

October 20, 1993

MEMORANDUM FOR: James A. Norberg, Chief
Mechanical Engineering Branch
Division of Engineering

THRU: George Johnson, Section Chief
Pumps and Valves Section
Mechanical Engineering Branch
Division of Engineering

FROM: Thomas G. Scarbrough
Pumps and Valves Section
Mechanical Engineering Branch
Division of Engineering

SUBJECT: MINUTES OF PUBLIC MEETING TO DISCUSS EPRI MOV PERFORMANCE PREDICTION PROGRAM

On October 6 and 7, 1993, the NRC staff held a public meeting with the Nuclear Management and Resources Council (NUMARC) and the Electric Power Research Institute to discuss the EPRI Motor-Operated Valve (MOV) Performance Prediction Program. Enclosure 1 is a list of the meeting participants.

Nuclear power plant licensees initiated the EPRI program in an effort to allow static tests of MOVs to be used to predict their performance under dynamic conditions. EPRI has obtained a significant amount of data from its MOV tests and is analyzing the data to develop its MOV Performance Prediction Methodology. The test data reveal that valve vendors underpredicted the thrust required to operate many types and sizes of gate valves. The valve vendors also underpredicted the thrust required to operate some globe valves. Butterfly valve torque requirements are still being evaluated. Enclosure 2 contains the slides presented by EPRI during the meeting.

Many licensees will be relying on the EPRI MOV test data through either the EPRI methodology or as prototype data to demonstrate that MOVs are capable of performing their design-basis capability function. Also, licensees might identify immediate problems with particular MOVs based on the EPRI test data. The staff emphasized that EPRI will need to ensure that the application of the test data and methodology is clearly understood. For example:

Licensees typically use a "valve factor" while the EPRI data is based on the EPRI "valve coefficient of friction" equation.

EPRI uses a mean seat diameter in its gate valve calculations to determine valve friction coefficient and some licensees might use other diameters.

The preliminary EPRI test data tables do not include diagnostic equipment error. EPRI stated that its methodology will include its own diagnostic equipment error. Licensees will need to include margin for their own diagnostic equipment.

EPRI will not recommend assumptions for actuator torque capability different from manufacturer guidelines. However, one licensee has referenced an EPRI report for a low stem friction coefficient that might not be appropriate for its MOVs and plant conditions.

If a licensee uses disk area for globe valves, EPRI test data indicate that a 1.1 valve factor might not always be adequate to predict the thrust requirement.

EPRI has found that the flow isolation point is difficult to determine based on thrust traces. EPRI found that pressures can converge in tests before flow isolation.

Dynamic thrust traces that look like static traces might indicate low differential pressure across the valve.

EPRI plans to complete its MOV Performance Prediction Program in April 1994. The staff has indicated to EPRI that it will review EPRI's test reports in advance of EPRI's submittal of its topical report on the program. However, the release of EPRI's test reports has been delayed. As a result, the staff will require time following April 1994 to complete its review. During the October 6-7 meeting, EPRI stated that the test data will be available on November 1. The staff will develop a list of the highest priority data and Gerry Weidenhamer of RES will contact EPRI on that date.

EPRI and Borg-Warner (BW) are continuing to evaluate high valve friction revealed by a BW valve during EPRI testing. The issue was first identified a year ago and the 10 CFR Part 21 notice has not been finalized. BW stated that it is currently recommending a 0.45 valve factor to its customers. BW plans to complete the Part 21 notice and to issue a customer bulletin by the end of 1993. During the meeting, the staff expressed concern about other damaged valves and high valve friction with little action taken by valve manufacturers to address these issues in response to Part 21.

During the October 6-7 meeting, the staff requested that John Holser of EPRI confirm that a draft information notice on the EPRI MOV testing did not contain proprietary information. Upon his review, John Hosler stated that the draft information notice did not contain any proprietary information. He then requested that EPRI be allowed an opportunity to provide comments on the draft information notice to ensure its technical accuracy and completeness. Because of time constraints, the comments of the meeting participants could not be provided during the meeting. Therefore, the staff stated that any comments promptly forwarded following the meeting would be considered. Enclosure 3 is the draft information notice discussed during the meeting.

The staff and EPRI discussed MOV issues raised by the staff in previous correspondence. Enclosure 4 is a letter dated September 16, 1993, that provides the EPRI response to staff questions and comments. Based on the discussions at the meeting, the staff categorized the items listed in the September 16 letter as (a) no further response necessary - items 5, 6, 9, 10, 14, 15, 22, 23, and 25-28; (b) continuing issue - items 1-4, 7, 12, 13, and 19; and (c) further response necessary - items 8, 11, 16-18, 20, 21 and 24.

Among the significant remaining issues are:

(a) ensuring that licensees understand the EPRI data and methodology;

(b) the EPRI methodology may allow damage and predict thrust;

(c) EPRI might allow stroke count to be considered in reducing thrust requirements below the pre-conditioning plateau;

(d) some EPRI-test valves did not receive complete preconditioning;

(e) ensuring EPRI's stem orientation data is consistent with industry experience;

(f) EPRI does not have any vertical pipe test data;

(g) the potential for open direction load sensitive behavior;

(h) peer review considerations (valve vendor involvement);

(i) applicability of methodology to particular valves installed in plants;

(j) reliability of handwheel method to estimate rate-of-loading (ROL) effect and ability to address potentially higher stem friction coefficient at initial wedging;

(k) location of pressure measurement for stem rejection load, and

(l) consideration of limit-seat valves

The staff will continue to meet with NUMARC and EPRI to discuss the EPRI MOV Performance Prediction Program.

At the request of NUMARC and EPRI representatives, the staff agreed that the results from the latest MOV research, sponsored by the NRC Office of Nuclear Regulatory Research (RES), would be presented by the Idaho National Engineering Laboratory (INEL) immediately following the completion of the meeting agenda. Two areas of MOV research currently being studied by INEL and presented at the meeting are (a) the effects of temperature and reduced voltage on motor operator performance, and (b) the effects of loadings on stem friction magnitude. Enclosure 5 contains the viewgraphs presented by INEL. However, it is important to state that the results of the temperature and reduced voltage effects on operator performance are preliminary and should not be used either for NRC regulatory applications or by licensees.

If you have any questions on the EPRI MOV Performance Prediction Program, I will be glad to discuss them with you.

/s/

Thomas G. Scarbrough
Pumps and Valves Section
Mechanical Engineering Branch
Division of Engineering

Enclosures: As stated

cc (with enclosures): C. Callaway, NUMARC

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ENCLOSURE 1

PARTICIPANTS AT PUBLIC MEETING TO DISCUSS THE EPRI MOV PERFORMANCE PREDICTION PROGRAM (October 6-7, 1993)

NAME	ORGANIZATION
J. Norberg	NRC/NRR
T. Scarbrough	NRC/NRR
A. Hanson	NRC/NRR
G. Weidenhamer	NRC/RES
C. Hsu	NRC/AEOD
P. K. Eapen	NRC/RI
J. O. Schiffgens	NRC/NRR/SPSB
C. Callaway	NUMARC
J. Hosler	EPRI
K. Wolfe	EPRI
P. Damerell	MPR
M. Albers	MPR
T. Walker	MPR
M. Kalsi	Kalsi Engineering
M. Eidson	Southern Nuclear
F. Martsen	NYPA
N. Estep	Duke Power Company
J. Lomm	Commonwealth Edison
R. Woehl	PG&E
D. Wright	Anchor/Darling
D. Koo	BW/IP
T. Matty	Westinghouse
B. Harry	Crane
R. Steele	INEL
B. Gallogly	General Physics (also representing SCE)

ENCLOSURE 2

EPRI MOV
Performance Prediction Program

OVERVIEW & STATUS

EPRI/TAG/NUMARC/NRC Meeting

Rockville, Maryland

October 6-7, 1993

JOHN F. HOSLER

MOV PROGRAM STATUS SUMMARY

- Program Products delivered to date
  - In-Situ MOV Testing Guide
  - Evaluation of NRC/INEL Gate Valve Flow Isolation Test Results
  - MOV General Information Database
  - MOV Design Margin Improvement Guide
  - Butterfly Valve Application Guide
  - Stem/Stem Nut Lubrication Report

MOV PROGRAM STATUS SUMMARY

- Engineering level models developed for Predictive methods -- Validation in progress
- CFD Analysis complete -- report under EPRI review
- Separate Effects Testing
  - Friction Testing Complete--Report in Publication
  - Operator Dynamics Testing 90% complete
  - Valve Design Effects Testing 90% complete

MOV PROGRAM STATUS SUMMARY

- Flow Loop Testing
  - All Wyle/Siemens testing complete (current scope) except for 1 test sequence.
  - Cold Water Pumped Flow Loop Test Report in Publication
  - Draft reports to EPRI by October 31, 1993 for:
    - Huntsville Interm. Pressure Flow Loop Testing
    - Norco Flow Loop Testing
    - Karlstein Flow Loop Testing
- Butterfly Valve Flow Loop Test Program complete -- Draft report October 31.

Summary of All MOV Test Data to be used for Methodology Validation/Assessment

	No. Valves	No. Test Seq.
EPRI Wyle/Siemens Flow Loop Testing	34	64
Duke F/L Testing at Utah State	2	8
EPRI Kalsi Butterfly Valve F/L Testing	10	37
EPRI In Situ Testing (Fully Enhanced)	35	35
	81	144
EPRI In Situ Tests w/o full enhancement	9	9
	90	153
INEL/NRC Blowdown Test Program	9	12
	99	165

TABLE 3
FLOW LOOP TEST MATRIX
34 VALVES/64 TEST SEQUENCES

No.	Valve Type	Manufacturer	Size (inch)	ANSI Class/ Material	Limitorque Actuator SMB-Type (Note 4)	Ambient Water 15 FPS (Note 6) MAX DP	Ambient Water 50 FPS (Note 5) MAX DP	450°F Water 15 FPS (Note 1) MAX DP	500°F Water Blowdown (Note 2) MAX DP	Sat. Steam 200 FPS MAX DP	Sat. Steam Blowdown (Note 2) MAX DP	Alternate Configuration Testing Notes
1	FWG	Anchor Darling	3	300 cs	00	740 (HI)						
2	FWG	Anchor Darling	6	150 ss	000	250 (HP)						
3	FWG	Anchor Darling	6	900 cs	0	1800 (N)	(N)1800	(N) 1200	(N) 1200			
4	FWG	Anchor Darling	10	300 cs	0	740 (HI)						
5	FWG	Anchor Darling	10	900 cs	2-150	1800 (S)						B,C, F
6	FWG	Anchor Darling	18	300 cs	2	500 (S)						
7	FWG	Borg-Warner	3	1500 cs	00	2500 (N)	(N) 2500					
8	FWG	Borg-Warner	6	150 cs	Rotork	250 (HP)						
9	FWG	Borg-Warner	6	1500 cs	1	1800 (N)			(N) 1200			
10	FWG	Borg-Warner	12	300 cs	1-25	500 (HI)						
13	FWG	New Velan	2-1/2	1500 ss	000	2500 (N)	(N) 2500		(N) 2500			
14	FWG	Crane	6	900 cs	0	1800 (N)	(N) 1800		(N) 1200			
15	FWG	Walworth/Aloyco	4	150 ss	Rotork	250 (HP)						
16	FWG	Anchor Darling	3	900 cs	00	1800 (N)						
17	FWG	Pacific	10	150 cs	000	250 (HP)						
18	FWG	Pacific	4	150 cs	Rotork	250 (HP)						
21	FWG	Rockwell	2-1/2	900 cs	000-5	1800 (N)						
23	FWG	Velan	6	150 cs	000	250 (HP)	(HP) 250					
24	FWG	Velan	6	900 cs	0	1800 (N)	(N) 1800	(N) 1200	(N) 1200	(S) 1200	(S) 1200	
25	FWG	Velan	10	300 cs	0	500 (HI)						
26	FWG	Velan	10	900 cs	2	1800 (HI)					(S) 1200	
29	FWG	Walworth	6	150 cs	Rotork	250 (HP)						
30	FWG	Walworth	6	900 cs	0	1800 (N)			(N) 1200			
31	FWG	Walworth	12	150 cs	Rotork	250 (HI)						
34	FWG	Westinghouse	3	1500 ss	00	2500/750 (N)						G
41	PDG	Anchor/Darling	6	900 cs	0	1800 (N)			(N) 1200		(S) 1200	
43	SWG	Edwards	10	900 cs	2	1800 (HI)					(S) 1200	
44	Globe	Borg - Warner	6	900 cs	2	1800 (N)	(N) 1800					
48	Globe	Rockwell/Edwards	2	1500 ss	00	2500 (N)	(N) 2500		(N) 2500			
49	Globe	Velan	2-1/2	1500 ss	00	2500 (N)						
50	Globe	Anchor Darling	10	300 cs	2	500 (HI)						D
54	BFly	Pratt 1400 Sym	6	150 cs	000 -HOBC	150 (HP)						
55	BFly	Pratt 1200 Single O/S	6	150 cs	000 -HOBC	150 (HP)						D
XX	FWG	Powell	14	600 cs		500 (HI)						

HP= Wyle Huntsville Pumped Flow Loop Test Facility
HI= Wyle Huntsville Intermediate Pressure Test Facility
N= Wyle Norco High Pressure Test Facility
S= Siemens/KWU High Pressure Test Facility

EPRI BUTTERFLY VALVE FLOW LOOP TESTS

Kalsi Engineering Test Program (10 Valves, 37 Sequences)
(Each Test Sequence includes Flow and DP Parametrics)

NO.	DISK SHAPE AND ORIENTATION	ASPECT RATIO	NO ELBOW	ELBOW CONFIGURATION TESTS								
				HYDRODYN. TORQUE INCR			HYDRODYN.TORQUE DECR			HYDRODYN. TORQUE NEGL		
			20D	0D	3D	7D	0D	3D	7D	0D	3D	7D
1	SYMMETRIC	0.15	X									
2	SYMMETRIC	0.25	X	X	X	X	X	X	X	X	X	X
3	NONSYM.,SHAFT UPSTR.	0.15	X									
4	NONSYM.,SHAFT UPSTR.	0.25	X	X	X	X	X	X	X	X	X	X
5	NONSYM.,SHAFT UPSTR.	0.35	X									
6	NONSYM., SHAFT DOWNSTR.	0.15	X									
7	NONSYM., SHAFT DOWNSTR.	0.25	X	X	X	X	X	X	X	X	X	X
8	NONSYM., SHAFT DOWNSTR.	0.35	X									
9	NONSYM., 42"SCALE MODEL, SHFT UPSTR	0.17	X									
10	NONSYM., 42"SCALE MODEL, SHFT DWNSTR	0.17	X									

ADDITIONAL LARGE BUTTERFLY DATA
UTAH STATE

MFG.	SIZE	TYPE	TEST DP	FLOW	FLOW DIRECTION		ELBOW CONFIGURATION			
					FORWARI	REVERSE	0	90	180	270
POSI-SEAL	10	BF-SO	48	4,500		X	NA	NA	NA	NA
POSI-SEAL	10	BF-SO	48	4,500	X		NA	NA	NA	NA
POSI-SEAL	10	BF-SO	48	4,500	X		X			
POSI-SEAL	10	BF-SO	48	4,500	X			X		
POSI-SEAL	10	BF-SO	48	4,500	X				X	
POSI-SEAL	10	BF-SO	48	4,500	X					X
POSI-SEAL	42	BF-SO	14	55,000		X	NA	NA	NA	NA
POSI-SEAL	42	BF-SO	14	55,000	X		NA	NA	NA	NA

NOTE: ADDITIONAL SEATING/UNSEATING SEQUENCES FOR BOTH VALVES AT 75 PSI (42") AND 97PSI (10")

ENHANCED IN-SITU TEST MATRIX

9/22/93 14:24

35 MOVS

(GATES: 17, BF: 10, GLOBES: 8)

NUMBER	FAMILY	TAG	MFG	TYPE	SIZE	ANSI	TEST DP	TEST FLOW	MEDIUM	INSPECT
				TU ELECTRIC (COMANCHE PEAK)						
1	G6	HV2494	BW	FWG	4	900	1592	700	WATER	PH
2	G12	HV4709	BW	FWG	4	1500	2205	195	WATER	PH
3	G53	HV4776	BW	FWG	16	300	246	8,896	WATER	PH/HAND
4	G53	HV4777	BW	FWG	16	300	246	7,600	WATER	PH/HAND
5	G32	8000A	WESTIN	FWG	3	1525	2485	210,000	STEAM	PH
6	G32	8000B	WESTIN	FWG	3	1525	2485	210,000	STEAM	PH
7	G16	8804A	WESTIN	FWG	8	316	244	1,800	WATER	PH
8	BF16	HV4286	FISHER	BF-SO	24		85	15,000	WATER	NA
9	BF9	HV4572	FISHER	BF-S	18		83	7,600	WATER	NA
10	GL50	FV4772	FISHER	GLOBE	4		281	750	WATER	NA
				NORTHERN STATES POWER (MONTICELLO)						
11	G36	MO-2014	A/D	FWG	16	600	335	16,000	WATER	HAND
12	G36	MO-2015	A/D	FWG	16	600	335	16,000	WATER	HAND
13	GL13	MO-2012	A/D	GLOBE	16	600	335	16,000	WATER	NA
				PACIFIC, GAS & ELECTRIC (DIABLO CANYON)						
14	G11	FCV-37	VELAN	FWG	4	600	910	40,000	STEAM	HAND
15	BF16	FCV-495	FISHER	BF-S	24		90	8 fps	WATER	NA
16	BF16	FCV-430	FISHER	BF-S	30		30	9 fps	WATER	NA
				ARIZONA PUBLIC SERVICE (PALO VERDE)						
17	BF4	NC-401	PRATT	BF-SO	10	150	120	3,815	WATER	NA
				WASHINGTON PUBLIC POWER S S (WNP-2)						
18	G40	SW-V-12B	VELAN	FWG	18	300	150	10,000	WATER	HAND
				ILLINOIS POWER CO (CLINTON)						
19	G15	1SX173B	A/D	FWG	10	150	140	[illegible] fps,VE[illegible]	WATER	HAND
				SOUTHERN NUCLEAR (FARLEY)						
20	G37	Q2E11MOV	C-V	FWG (SS)	10	300	200	3,000	WATER	HAND
21	G37	Q2E11MOV	C-V	FWG (SS)	10	300	200	3,000	WATER	HAND
22	G8	Q2E21MOV	VELAN	FWG (SS)	3		2700	200	WATER	HAND
23	G8	Q2E21MOV	VELAN	FWG (SS)	3		2700	200	WATER	HAND
24	BF	Q2P16V545	PRATT	BF-SO	30		30	10000	WATER	NA
25	BF	Q2P16V508	PRATT	BF-SO	42		100	18000	WATER	NA
26	BF	Q2P16V507	PRATT	BF-SO	60		60	18000	WATER	NA
				YANKEE ATOMIC (VERMONT YANKEE)						
27	GL11	V14-26A	WALWC	GLOBE	8	300	312		WATER	HAND
28	GL11	V14-26B	WALWC	GLOBE	8	300	312		WATER	HAND
				PHILIDELPHIA ELECTRIC CO. (LIMMERICK & PEACH BOTTOM)						
29	GL38	M03-10-34B	WALWC	GLOBE	18	300	360	12,500	WATER	NA
30	GL38	M03-10-34B	WALWC	GLOBE	18	300	360	12,500	WATER	NA
31	BF14	HV-12-32-A	BIF	BF-SO	30	150	100	16-21K	WATER	NA
32	BF14	HV-12-32-B	BIF	BF-SO	30	150	100	16-21K	WATER	NA
				TVA (WATTS BAR)						
33	G41	3-33A	WALWC	FWG	16	600	500	1,500	WATER	HAND
				CONSOLIDATED EDISON CO (INDIAN POINT 2)						
34	GL1	856A	VELAN	GLOBE	2		1500	440	WATER	NA
35	GL1	856B	VELAN	GLOBE	2		1500	440	WATER	NA

OTHER IN-SITU TEST MATRIX

9/22/93 14:23

9 MOVs

(GATES: 7, BF: 2, GLOBES:0)

NUMBER	FAMILY	TAG	MFG	TYPE	SIZE	ANSI	TEST DP	TEST FLOW	MEDIUM	INSPECT	TST. DATE
				TU ELECTRIC (COMANCHE PEAK)							
1	G24	8801A	WESTING	FWG	4	1525	2690	700	WATER	NONE	COMPLETE
2	G21	8812B	WESTING	FWG	14	316	436	4,900	WATER	NONE	COMPLETE
3	G18	8840	WESTING	FWG	10	1525	1241	2,700	WATER	NONE	COMPLETE
				PACIFIC, GAS & ELECTRIC (DIABLO CANYON)							
4	G2	FCV-95	A/D	PDG	4	600	910	40,000	STEAM	HAND(NG	COMPLETE
				ARIZONA PUBLIC SERVICE (PALO VERDE)							
5	BF2	SP-49A	PRATT	BF-S	24	150	51	17,600	WATER	NA	COMPLETE
6	BF3	SP-49B	PRATT	BF-S	18	150	51	17,600	WATER	NA	COMPLETE
				SOUTHERN CALIFORNIA EDISON (SAN ONOFRE)							
7		2HV9306	WKM	PDG	4	900			WATER	NA	Jun-89
8		2HV6366	WKM	PDG	10	150			WATER	NA	Jun-89
9		2HV9337	WKM	PDG	16	1500			WATER	NA	Jun-89

ADDITIONAL MOV TEST DATA

9 MOVs

INEL GATE VALVE

No.	Type	Manufacturer	Size	ANSI	Mat'l	Actuator	Ambient Water 15 fps Max DP	Ambient Water 50 fps Max DP	450 degF Water 15 fps Max DP	500 degF Water Blowdn Max DP	Sat. Steam 200 fps Max DP	Sat. Steam Blowdn Max DP
1	FWG	A/D	6	900		SMB-0-25				1300/900		
2	FWG	VELAN	6	900		SMB-0-25				1500/1000		1210
3	FWG	WALWORTH	6	600		SMB-0-25				1200		
4	FWG	A/D	10	900		SMB-1-60						720
5	FWG	POWELL	10	900		SMB-1-60						1020
6	FWG	VELAN	10	600		SMB-1-60						1300

INEL BUTTERFLY PURGE

No.	Type	Manufacturer	Size	ANSI	Mat'l	Actuator	Ambient WATER 15 fps Max DP	Ambient Water 50 fps Max DP	450 degF Water 15 fps Max DP	AMBIENT GAS Blowdn Max DP	Sat. Steam 200 fps Max DP	Sat. Steam Blowdn Max DP
1	BF/SO	ALLIS-CHMRS	8	150						60		
2	BF/SO	PRATT	8	150						60		
3	BF/SO	PRATT	24	150						60		

Table 1

EPRI MOV PERFORMANCE PREDICTION PROGRAM PRODUCTS

Product	Estimated Publication Date
Application Guide for MOV's in Nuclear Power Plants (NMAC Product)*	Complete
Review of INEL Gate Valve Test Program	Complete
In Situ Test Guide*	Complete
MOV Margin Improvement Guide*	Complete
MOV General Information Database*	Complete
Butterfly Application Guide (NMAC Product)*	Complete
Stem Nut Lubricant Test Report	Complete
Huntsville Low Pressure Flow Loop Test*	October 1993
Methodology Input Specification Draft	October 1993
Friction Test Report	October 1993
Preliminary Static Test Method for Disc μ	October 1993
Preliminary Static Test Method for ROL	October 1993
Computational Fluid Dynamics Analysis Report	October 1993
Butterfly Valve Subscale Test Report	November 1993
Globe Valve Model Report*	November 1993
Operator Test Report	November 1993
System Model Report	November 1993
Gate Valve Design Effects Report	November 1993
MOV PPP Topical Report *(Draft Sections to be issued as completed.)*	November 1993 to March 1994
In Situ Test Report (Phase 1)*	December 1993
Siemens/KWU Flow Loop Test Report*	December 1993
Norco Flow Loop Test Report*	December 1993
Huntsville Int. Pressure Flow Loop Test*	December 1993
Butterfly Valve Model Report*	January 1994
Operator Effects Methodology Report*	January 1994
Gate Valve Model Report	February 1994
In Situ Test Report (Phase 2)*	April 1994
Empirically Based Methods Reports*	April 1994
Integrated Methodology Assessment Report	April 1994
Integrated Methodology PC Code*	April 1994
PC Code Users Manual*	April 1994
Model Implementation Guide*	April 1994

* Products which can be directly applied by Utilities in assessing MOV performance capability.

154G/JFH/jp

KEY RESULTS FROM Wyle/Siemens FLOW LOOP TESTING

- Objectives/scope
- Gate Valve Preconditioning Approach/Philosophy
- Key results

SCOPE

OBJECTIVES

1. Obtain test and inspection data (both valve and operator) for most populous valve designs over a range of size, pressure, ΔP, and flow conditions to validate the MOV performance prediction methodology.

2. Directly measure valve performance over a range of parameters (e.g., flow rate, media, temperature ΔP, etc.) which bound typical design basis conditions

SCOPE

TEST PROGRAM

- Testing is complete on 34 valves in 64 sequences at 4 Wyle/Siemens flow loop facilities to support the EPRI Performance Prediction Methodology Program. Two sequences remain to be performed.
  - — 28 flex or solid wedge or parallel disc gate valves ranging in size from 2-1/2 to 18 inch and 150 to 1500 lb. class
  - — 4 globe valves ranging in size from 2-1/2 to 10 inch and 300 to 1500 lb class
  - — 2 butterfly valves; 6", 150 lb. class

SCOPE

FLOW LOOP FACILITIES (Wyle & Siemens)

1. Low pressure, cold water pumped flow at Wyle Laboratories, Huntsville, Alabama. 6" valves @ 250 psi.
2. Intermediate pressure, cold water blowdown (simulating pumped flow) at Wyle Laboratories, Huntsville, Alabama. 12" valves @ 500 psi, 10" @ 740 psi.
3. High pressure, cold water and hot water blowdown (simulating pumped flow) and hot water and steam blowdown at Wyle Laboratories, Norco, California. 6" valves @ 1800 psi, 3" @ 2500 psi.
4. High pressure, cold water blowdown (simulating pumped flow) and steam blowdown at Siemens/KWU, Karlstein, Germany. 10" @ 1800 psi, 18" @ 500 psi.

SCOPE

TEST CONFIGURATIONS

- Pump flow - simulates opening or closing against the head of an upstream centrifugal pump with some specified downstream resistance
  - Accomplished in each facility by holding test valve upstream pressure nearly constant and providing a throttle in series to limit flow
- Blowdown - valve is opened or closed against a storage vessel of hot water or stream whose pressure remain essentially constant and whose piping has low flow resistance

DATA CHANNELS

Stem thrust

Stem torque

Stem position

Valve upstream pressure

Valve downstream pressure

Valve differential pressure

Valve bonnet pressure

Valve under disc pressure

Valve downstream total pressure

Flow rate

Spring pack displacement

Spring pack force

Switch timing (5)

Motor speed

Motor voltage (3 phases)

Motor current (3 phases)

Motor power

Motor power factor

Valve temperature

Fluid temperature

GATE VALVE PRECONDITIONING APPROACH/PHILOSOPHY

- Preconditioning of Flow Loop Gate Valves
  - Objective
    - Precondition (age) test valves prior to test to eliminate stroke effect (reach "plateau" level)
    - Flow loop parametrics would be unaffected by stroke effect
    - Determine relationship between contact stress and number of strokes required to reach plateau
  - Approach
    - Short stroke (~ 10%) open/close MOV in test loop with DP and very low cold water flow until apparent μ reaches "plateau" level
    - DP to be based on max test DP or DP resulting in a contact stress of 20 ksi on seats, whichever is less

PRINCIPAL FINDINGS

Butterfly Valves

- Butterfly valve torques bounded by vendor predictions

Globe Valves

- Under incompressible flow 15 fps conditions, globe valve factors ranged from 1.0 to 2.1 (standard industry equations recommend valve factors in 1.0 - 1.1 range)
- Under incompressible flow 50 fps conditions, a globe valve factor of 1.37 was observed.
- Under hot water blowdown (2 phase) conditions, a globe valve factor of 1.87 was observed

PRINCIPAL FINDINGS

GLOBE VALVES (Con't)

- Increased thrust requirements for globe valves under incompressible flow conditions can be reconciled by the appropriate choice of disc vs guide area
- Increased thrust requirements under 2 phase conditions attributed to side loading on globe valve plug due to circumferential pressure variations
  - Methods to account for this affect are in development

PRINCIPAL FINDINGS

Gate Valves

- Number of strokes to achieve a plateau in apparent disc coefficient of friction during preconditioning varied from 100 to 900 (Initial μ values in 0.1 - 0.3 range)
- Maximum apparent disc μ's during cold water pumped flow testing (after preconditioning) were generally between 0.3 and 0.6, with the exception of four valves tested (μ's ranged from 0.66 to 1.93)

  (Industry practice had been to assume a μ of 0.3)

PRINCIPAL FINDINGS

- Disc sliding μ tends to decrease with higher ΔP (higher seat bearing stress) -- supports use of linear extrapolation of reduced DP data -- particularly for non-blowdown applications
- Hot water (450°F, 15 FPS) testing after cold water preconditioning and testing, decreased apparent disc μ to the range of 0.34 to 0.41, with an average of 0.38
- No significant damage observed under 15 fps flow conditions

PRINCIPAL FINDINGS

- Hot water (530°F) blowdown apparent disc μ's ranged between 0.35 and 0.80 -- some valves sustained significant guide and/or seat damage
- Steam blowdown disc μ's ranged between 0.25 to 0.64 -- some valves sustained significant guide and/or seat damage
- No measurable effect on apparent disc μ (gate valves) due to upstream elbow orientation or stem orientation

Key Results from In Situ Test Program

EPRI MOV Performance Prediction Program
Meeting at NRC

October 6, 1993

Status

- In Situ Test Matrix Expanded as Shown Earlier During Meeting
- 18 Test Data Packages Received
- 8 Test Data Reports Issued to EPRI

ENHANCED IN-SITU TEST MATRIX

9/22/93 14:24

35 MOVS

(GATES: 17, BF: 10, GLOBES: 8)

NUMBER	FAMILY	TAG	MFG	TYPE	SIZE	ANSI	TEST DP	TEST FLOW	MEDIUM	INSPECT	Data Received	Test Report Issued
				TU ELECTRIC (COMANCHE PEAK)								
1	G6	HV2494	BW	FWG	4	900	1592	700	WATER	PH	✓	✓
2	G12	HV4709	BW	FWG	4	1500	2205	195	WATER	PH	✓	
3	G53	HV4776	BW	FWG	16	300	246	8,893	WATER	PH/HAND	✓	✓
4	G53	HV4777	BW	FWG	16	300	246	7,600	WATER	PH/HAND	✓	✓
5	G32	8000A	WESTIN	FWG	3	1525	2485	210,000	STEAM	PH	✓	
6	G32	8000B	WESTIN	FWG	3	1525	2485	210,000	STEAM	PH	✓	
7	G16	8804A	WESTIN	FWG	8	316	244	1,800	WATER	PH	✓	
8	BF16	HV4286	FISHER	BF-SO	24		85	15,000	WATER	NA	✓	✓
9	BF9	HV4572	FISHER	BF-S	18		83	7,600	WATER	NA	✓	✓
10	GL50	FV4772	FISHER	GLOBE	4		281	750	WATER	NA	✓	✓
				NORTHERN STATES POWER (MONTICELLO)								
11	G36	MO-2014	A/D	FWG	16	600	335	16,000	WATER	HAND	✓	
12	G36	MO-2015	A/D	FWG	16	600	335	16,000	WATER	HAND	✓	
13	GL13	MO-2012	A/D	GLOBE	16	600	335	16,000	WATER	NA	✓	
				PACIFIC, GAS & ELECTRIC (DIABLO CANYON)								
14	G11	FCV-37	VELAN	FWG	4	600	910	40,000	STEAM	HAND	✓	✓
15	BF16	FCV-495	FISHER	BF-S	24		90	8 fps	WATER	NA		
16	BF16	FCV-430	FISHER	BF-S	30		30	9 fps	WATER	NA		
				ARIZONA PUBLIC SERVICE (PALO VERDE)								
17	BF4	NC-401	PRATT	BF-SO	10	150	120	3,815	WATER	NA		
				WASHINGTON PUBLIC POWER S S (WNP-2)								
18	G40	SW-V-12B	VELAN	FWG	18	300	150	10,000	WATER	HAND		
				ILLINOIS POWER CO (CLINTON)								
19	G15	1SX173B	A/D	FWG	10	150	140	0 fps, VERT	WATER	HAND		
				SOUTHERN NUCLEAR (FARLEY)								
20	G37	Q2E11MOV	C-V	FWG (SS)	10	300	200	3,000	WATER	HAND		
21	G37	Q2E11MOV	C-V	FWG (SS)	10	300	200	3,000	WATER	HAND		
22	G8	Q2E21MOV	VELAN	FWG (SS)	3		2700	200	WATER	HAND		
23	G8	Q2E21MOV	VELAN	FWG (SS)	3		2700	200	WATER	HAND		
24	BF	Q2P16V545	PRATT	BF-SO	30		30	10000	WATER	NA		
25	BF	Q2P16V508	PRATT	BF-SO	42		100	18000	WATER	NA		
26	BF	Q2P16V507	PRATT	BF-SO	60		60	18000	WATER	NA		
				YANKEE ATOMIC (VERMONT YANKEE)								
27	GL11	V14-26A	WALWO	GLOBE	8	300	312		WATER	HAND		
28	GL11	V14-26B	WALWO	GLOBE	8	300	312		WATER	HAND		
				PHILIDELPHIA ELECTRIC CO. (LIMMERICK & PEACH BOTTOM)								
29	GL38	M03-10-34B	WALWO	GLOBE	18	300	360	12,500	WATER	NA		
30	GL38	M03-10-34B	WALWO	GLOBE	18	300	360	12,500	WATER	NA		
31	BF14	HV-12-32-A	BIF	BF-SO	30	150	100	16-21K	WATER	NA		
32	BF14	HV-12-32-B	BIF	BF-SO	30	150	100	16-21K	WATER	NA		
				TVA (WATTS BAR)								
33	G41	3-33A	WALWO	FWG	16	600	500	1,500	WATER	HAND		
				CONSOLIDATED EDISON CO (INDIAN POINT 2)								
34	GL1	856A	VELAN	GLOBE	2		1500	440	WATER	NA		
35	GL1	856B	VELAN	GLOBE	2		1500	440	WATER	NA		

OTHER IN-SITU TEST MATRIX

9/22/93 14:23

9 MOVs

(GATES: 7, BF: 2, GLOBES:0)

NUMBER	FAMILY	TAG	MFG	TYPE	SIZE	ANSI	TEST DP	TEST FLOW	MEDIUM	INSPECT	TST. DATE	Data Received	Test Report Issued
				TU ELECTRIC (COMANCHE PEAK)									
1	G24	8801A	WESTING	FWG	4	1525	2690	700	WATER	NONE	COMPLETE	✓	
2	G21	8812B	WESTING	FWG	14	316	436	4,900	WATER	NONE	COMPLETE	✓	
3	G18	8840	WESTING.	FWG	10	1525	1241	2,700	WATER	NONE	COMPLETE	✓	
				PACIFIC, GAS & ELECTRIC (DIABLO CANYON)									
4	G2	FCV-95	A/D	PDG	4	600	910	40,000	STEAM	HAND(NG	COMPLETE	✓	✓
				ARIZONA PUBLIC SERVICE (PALO VERDE)									
5	BF2	SP-49A	PRATT	BF-S	24	150	51	17,600	WATER	NA	COMPLETE		
6	BF3	SP-49B	PRATT	BF-S	18	150	51	17,600	WATER	NA	COMPLETE		
				SOUTHERN CALIFORNIA EDISON (SAN ONOFRE)									
7		2HV9306	WKM	PDG	4	900			WATER	NA	Jun-89		
8		2HV6366	WKM	PDG	10	150			WATER	NA	Jun-89		
9		2HV9337	WKM	PDG	16	1500			WATER	NA	Jun-89		

Data Procurement Process

Define Acceptable Approach and Product

- Meet With Utility -- review test program, approach for specific valves, procedures, QA, etc. against In Situ Test Guide
- QA Plan For Data Procurement
- Data Procurement Specification
- Interaction with Utility

Data Procurement Process (continued)

Valve Test Data Package (Prepared by Utility)

- Verification of Package Contents
- Technical Review
- Resolution and Documentation of Discrepancies

Evaluation and Documentation

- Limited Data Evaluation
- Data Report

Key In Situ Test Results

PRELIMINARY

diagnostic error not included

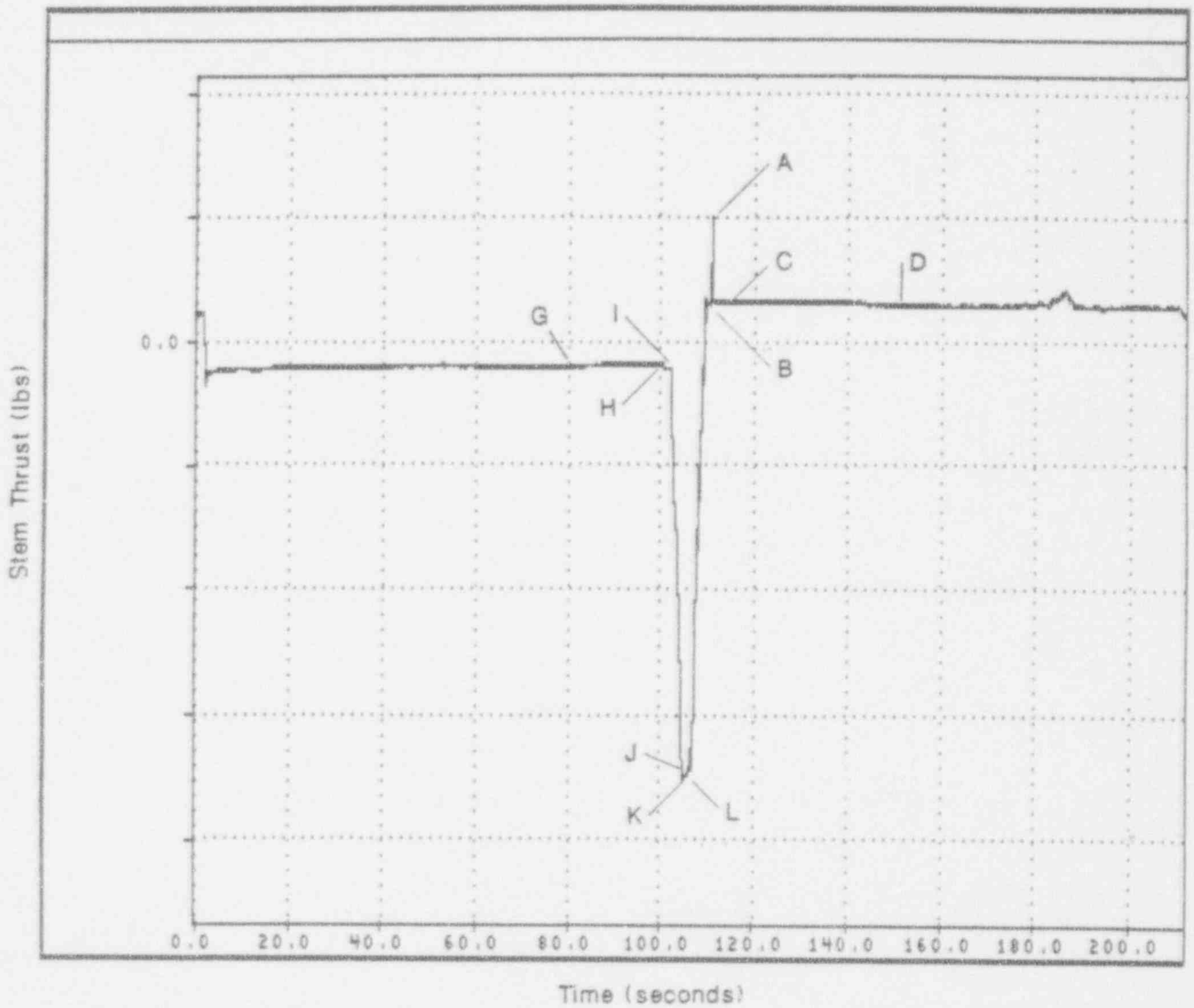
Valve Number	Manufacturer, Size and Type	Maximum Differential Pressure	Flow Velocity	Fluid Temperature	Maximum Apparent Disk Friction Coef.		Maximum Apparent Stem Friction Coef.		Stem Thrust at Torque Switch Trip	
					Open	Close	Open	Close	Static	Dynamic
1	Borg Warner 4-inch FWG	1620 psid	17 ft/sec (water)	Ambient	0.305	0.304 * (0.555)	0.135	0.105	24,605 lbs	20,376 lbs
3	Borg Warner 16-inch FWG	300 psid	13 ft/sec (water)	86 °F	0.332	0.373	0.161	0.113	36,622 lbs	34,114 lbs
4	Borg Warner 16-inch FWG	300 psid	12 ft/sec (water)	86 °F	0.371	0.355	0.166	0.134	35,039 lbs	35,281 lbs
8	Fisher 24-inch BFLY-SO	120 psid	12 ft/sec (water)	56 °F	- - -	- - -	- - -	- - -	Limit Seated	Limit Seated
9	Fisher 18-inch BFLY-SYM	140 psid	10 ft/sec (water)	Ambient	- - -	- - -	- - -	- - -	Limit Seated	Limit Seated
10	Fisher 4-inch Globe	275 psid	40 ft/sec (water)	Ambient	- - -	- - -	0.116	0.127	4,919 lbs	4,802 lbs
17	Velan 4-inch FWG	900 psid	30 ft/sec (steam)	535 °F	0.394	0.338 * (0.512)	0.167	0.122	9,810 lbs	10,020 lbs
18	Anchor/Darling 4-inch PDG	965 psid	60 ft/sec (steam)	540 °F	0.196 **	0.353	- - -	- - -	13,410 lbs	Limit Seated

(Handwritten margin notes: valves 1–10 "Comanche Peak"; valves 17–18 "Diablo Canyon")

* These valves showed brief thrust increases just before wedging. The first value of apparent disk friction coefficient is just prior to the increase. The second value in parenthesis is at initial wedging.

** Data indicate a possible zero shift during opening stroke which would increase apparent disk friction coefficient to about 0.30.

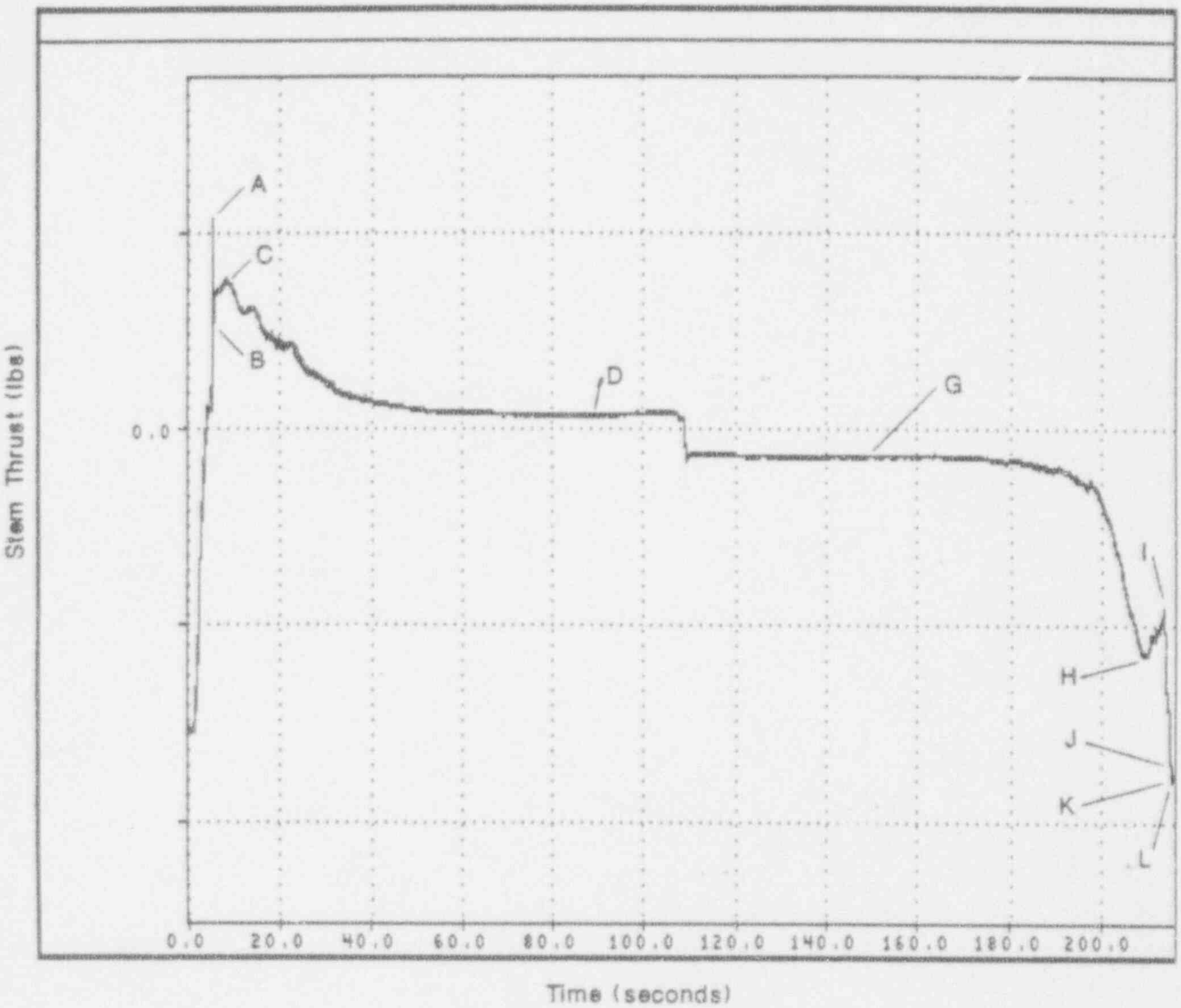
PRELIMINARY



Stem Thrust for Static Closure and Opening

Borg Warner 16" Gate Valve No. 2-HV-4777

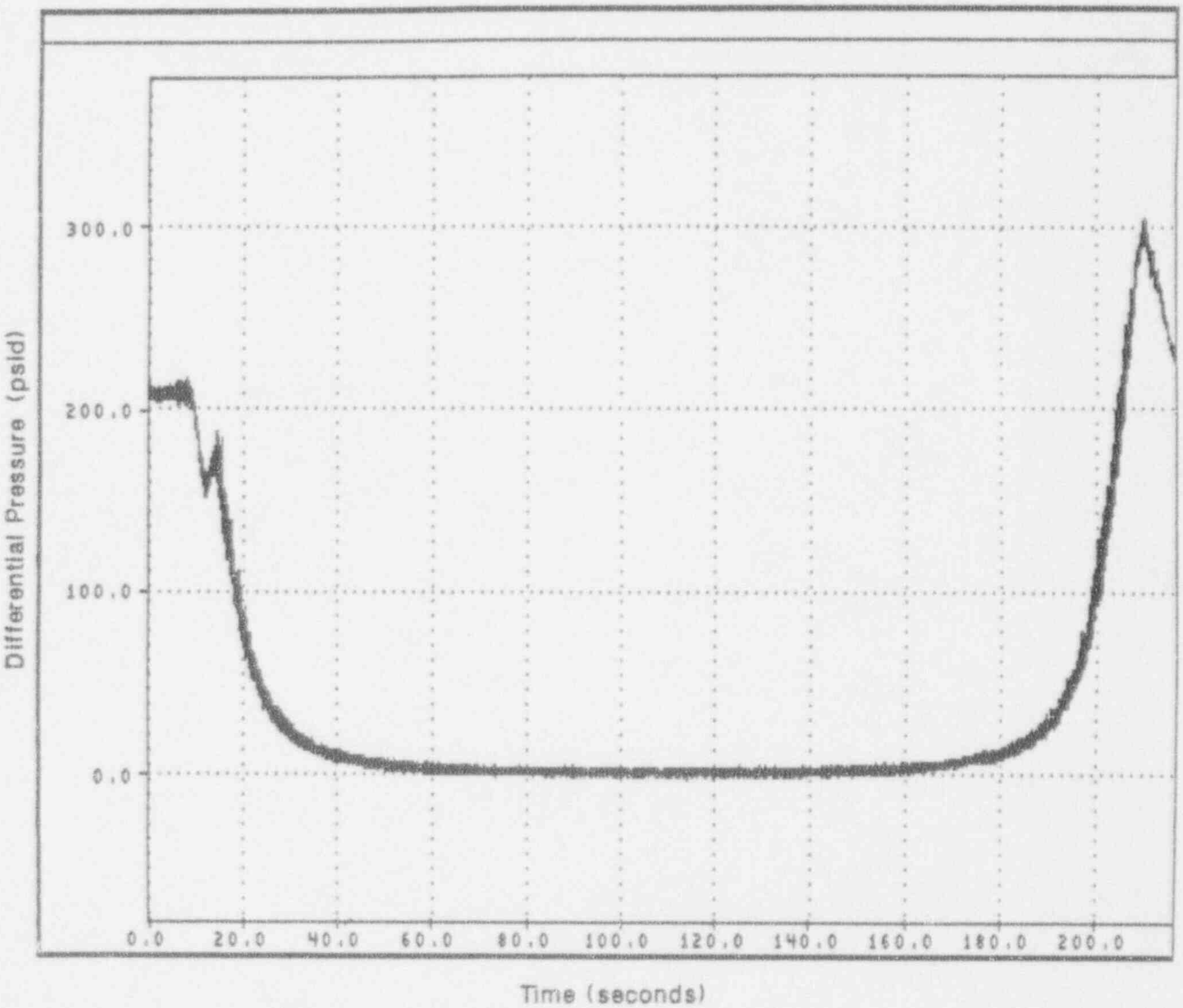
PRELIMINARY



Stem Thrust for DP Opening and Closure

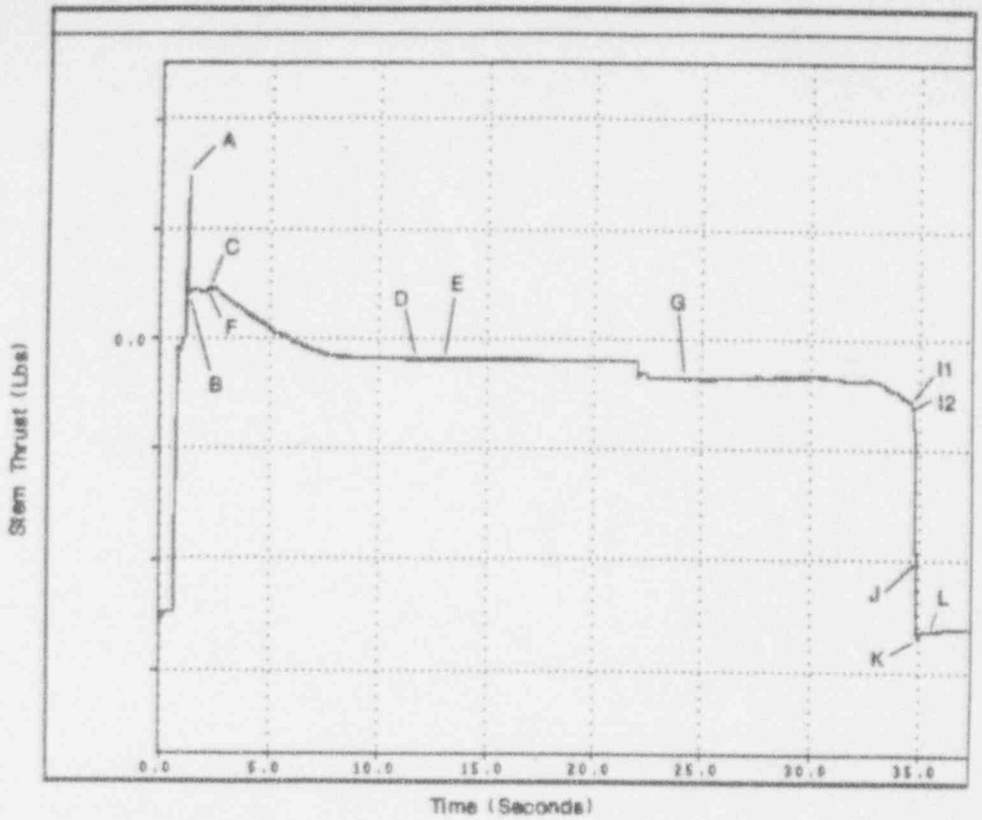
Borg Warner 16" Gate Valve No. 2-HV-4777

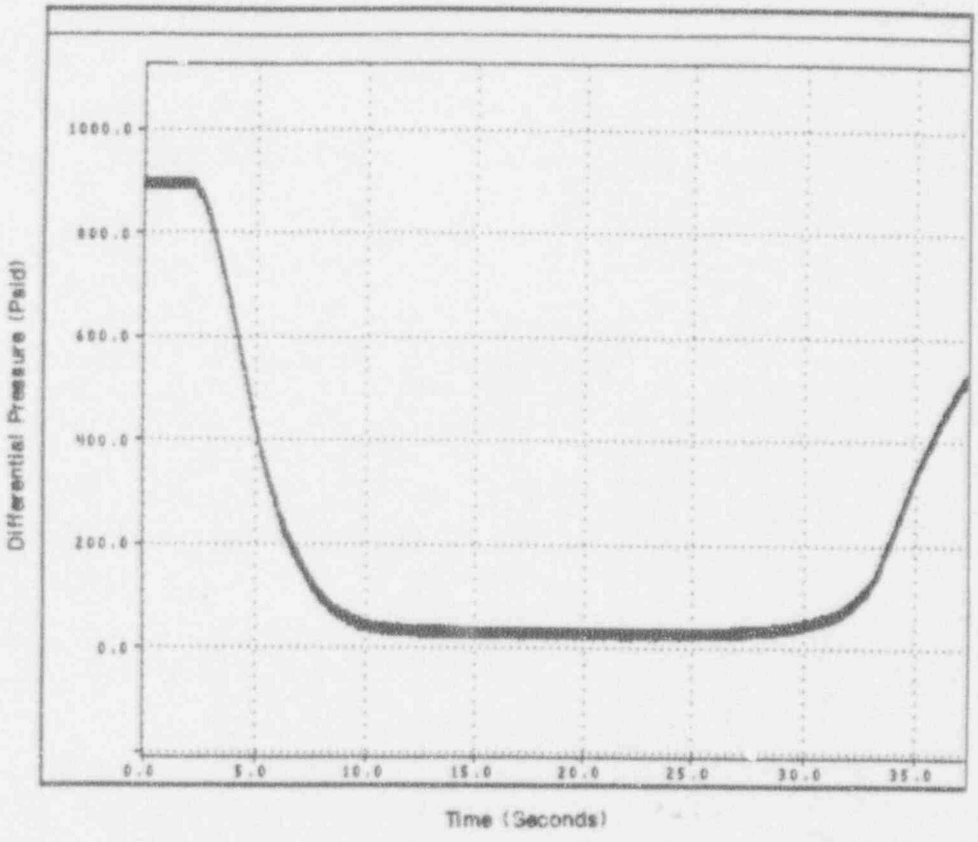
PRELIMINARY



Differential Pressure

Borg Warner 16" Gate Valve No. 2-HV-4777



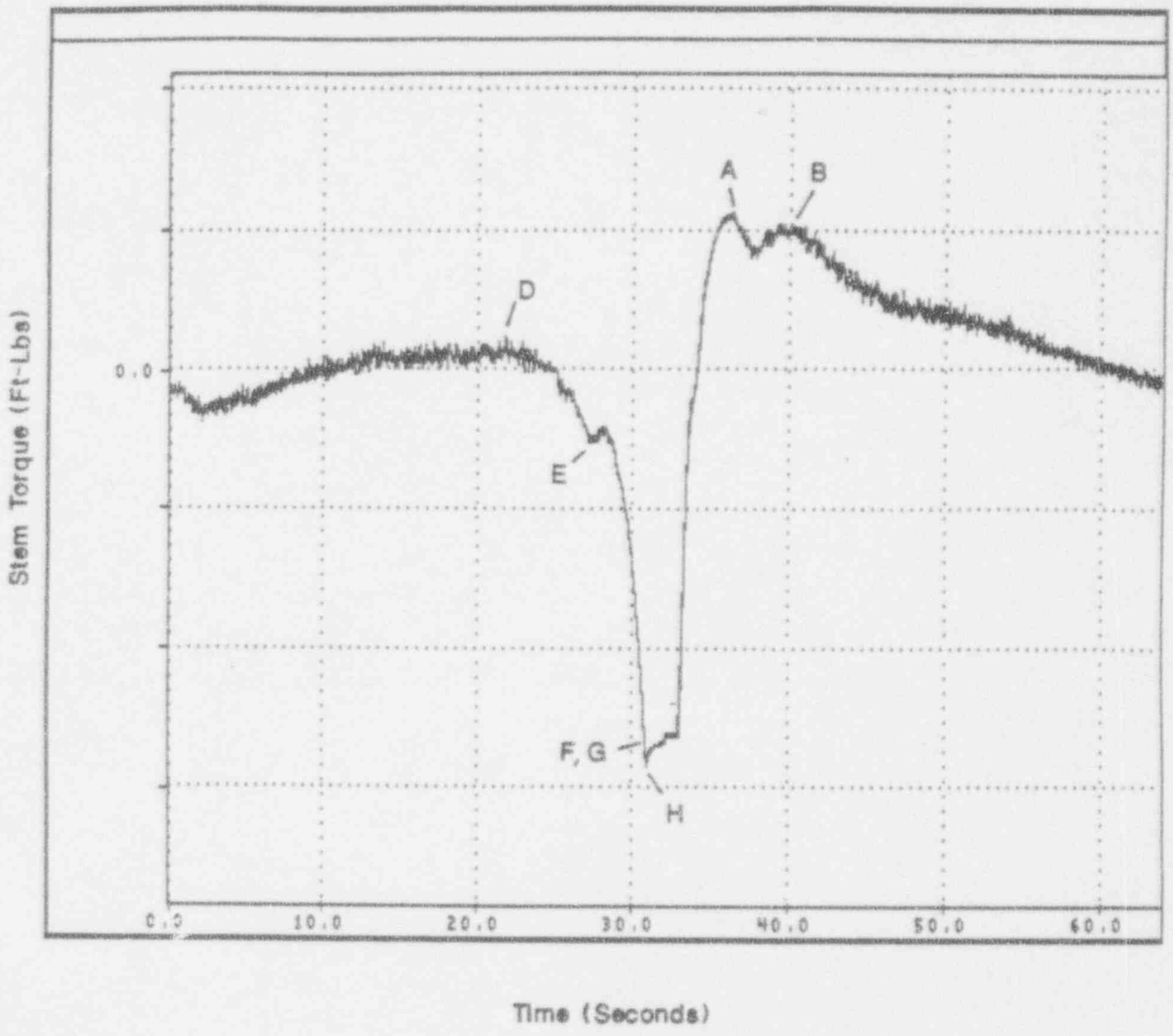


PRELIMINARY

Stem Thrust and Differential Pressure for DP Closure and Opening

Velan 4" Gate Valve No. 2-FCV-37

PRELIMINARY

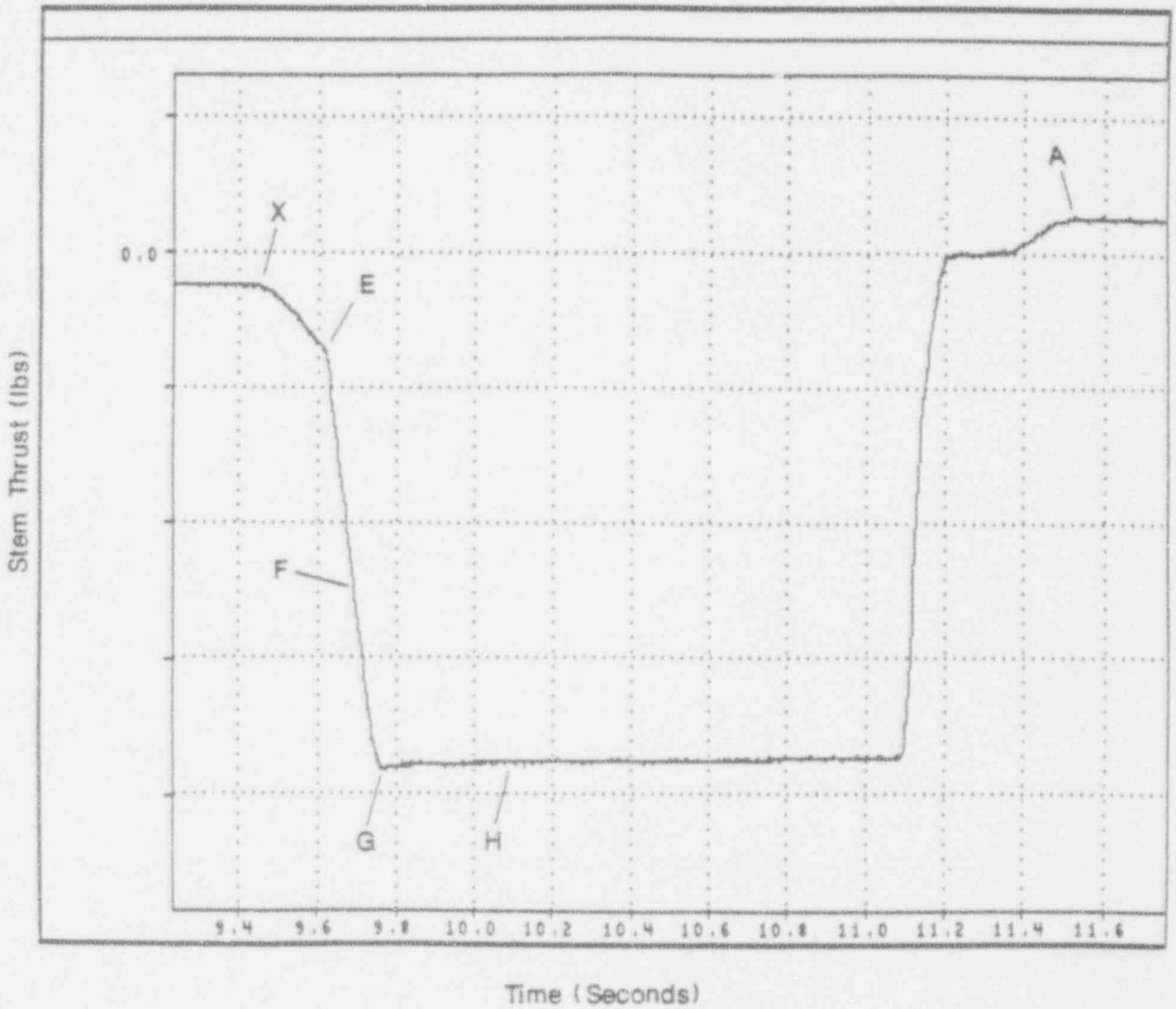


Stem Torque for DP Closure and Opening

Fisher 18" Butterfly Valve No. 2-HV-4572

symmetric

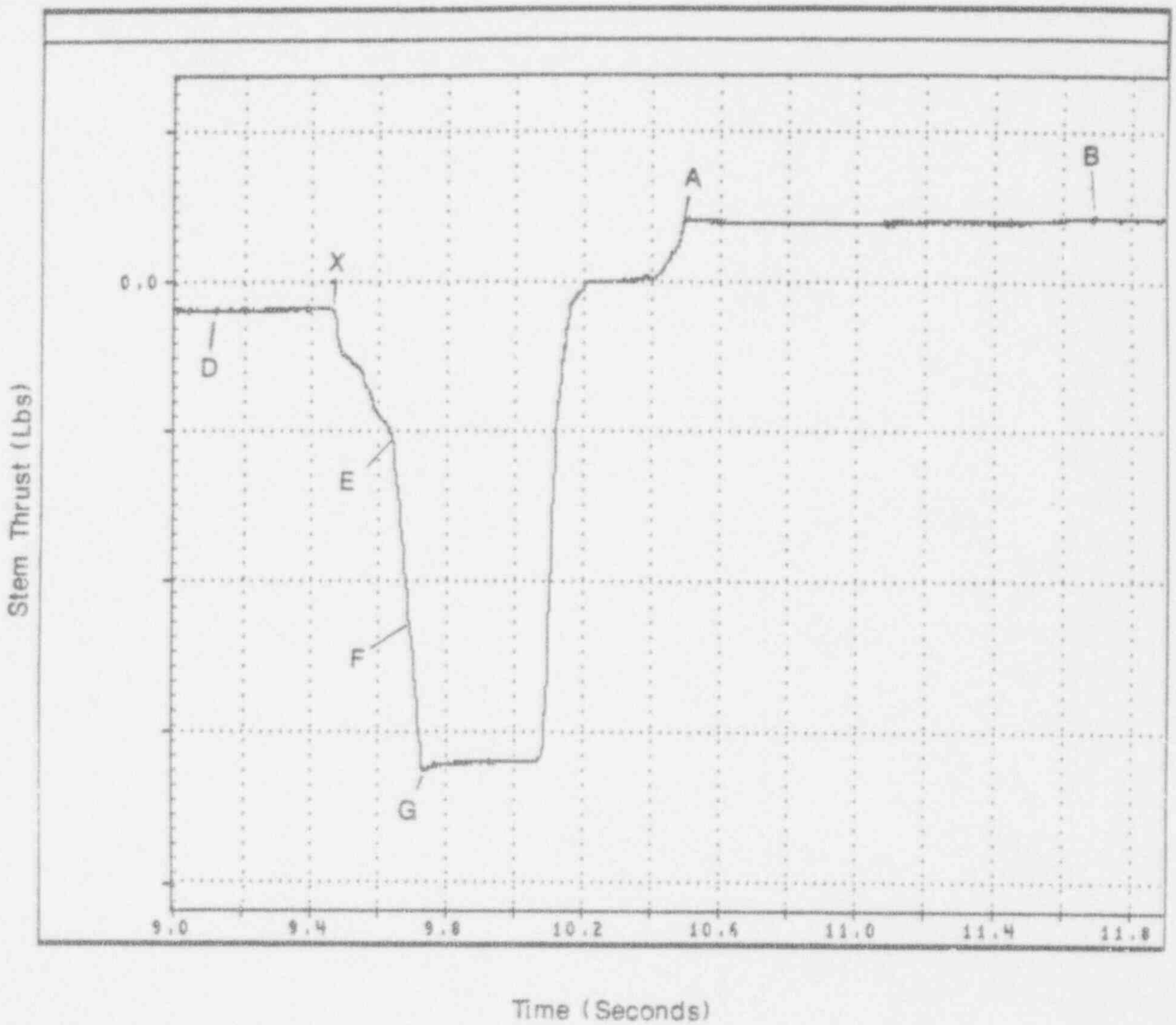
PRELIMINARY



Stem Thrust for Static Closure and Opening

Fisher 4" Globe Valve No. 2-FV-4772-2

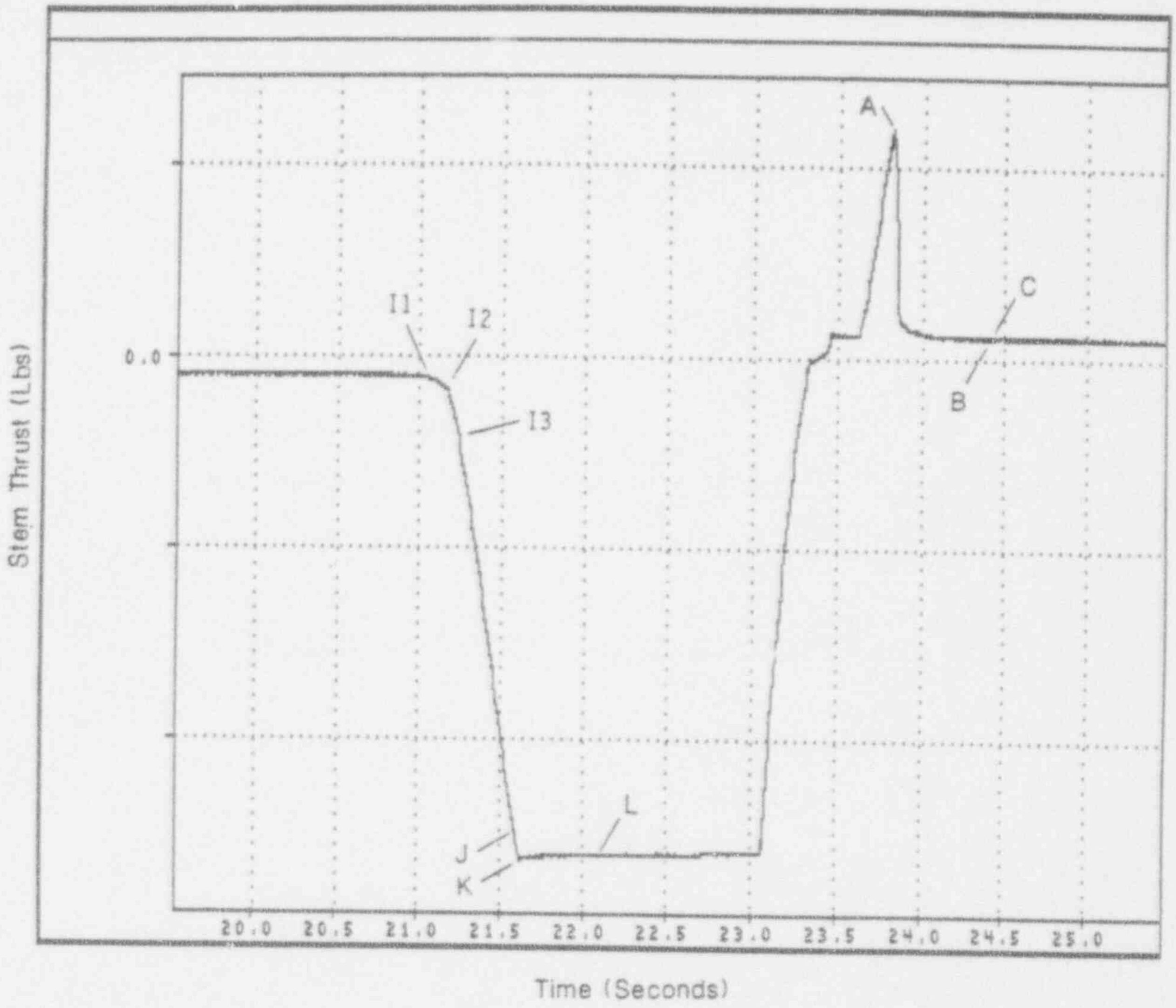
PRELIMINARY



Stem Thrust for DP Closure and Opening

Fisher 4" Globe Valve No. 2-FV-4772-2

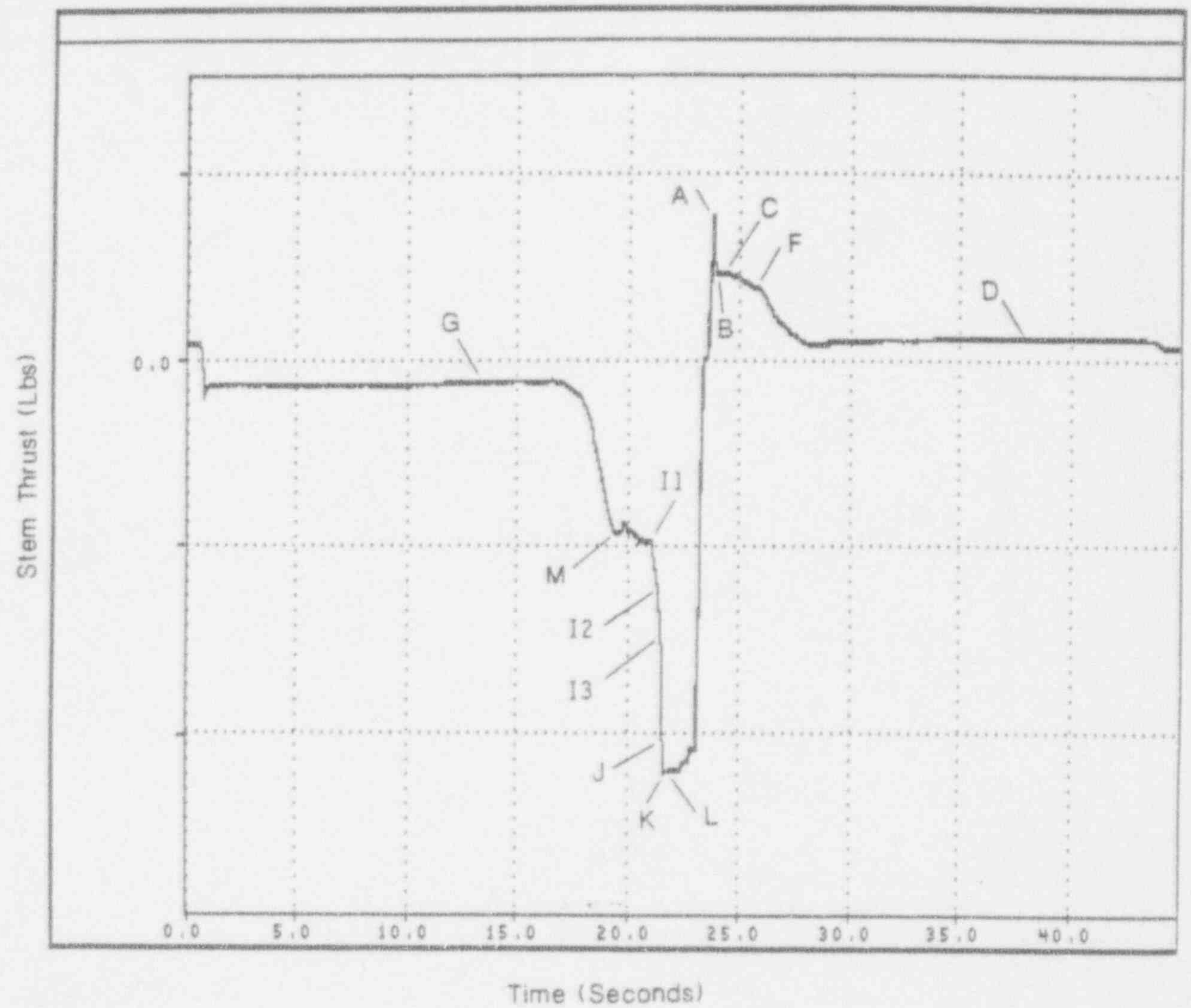
PRELIMINARY



Stem Thrust for Static Closure and Opening

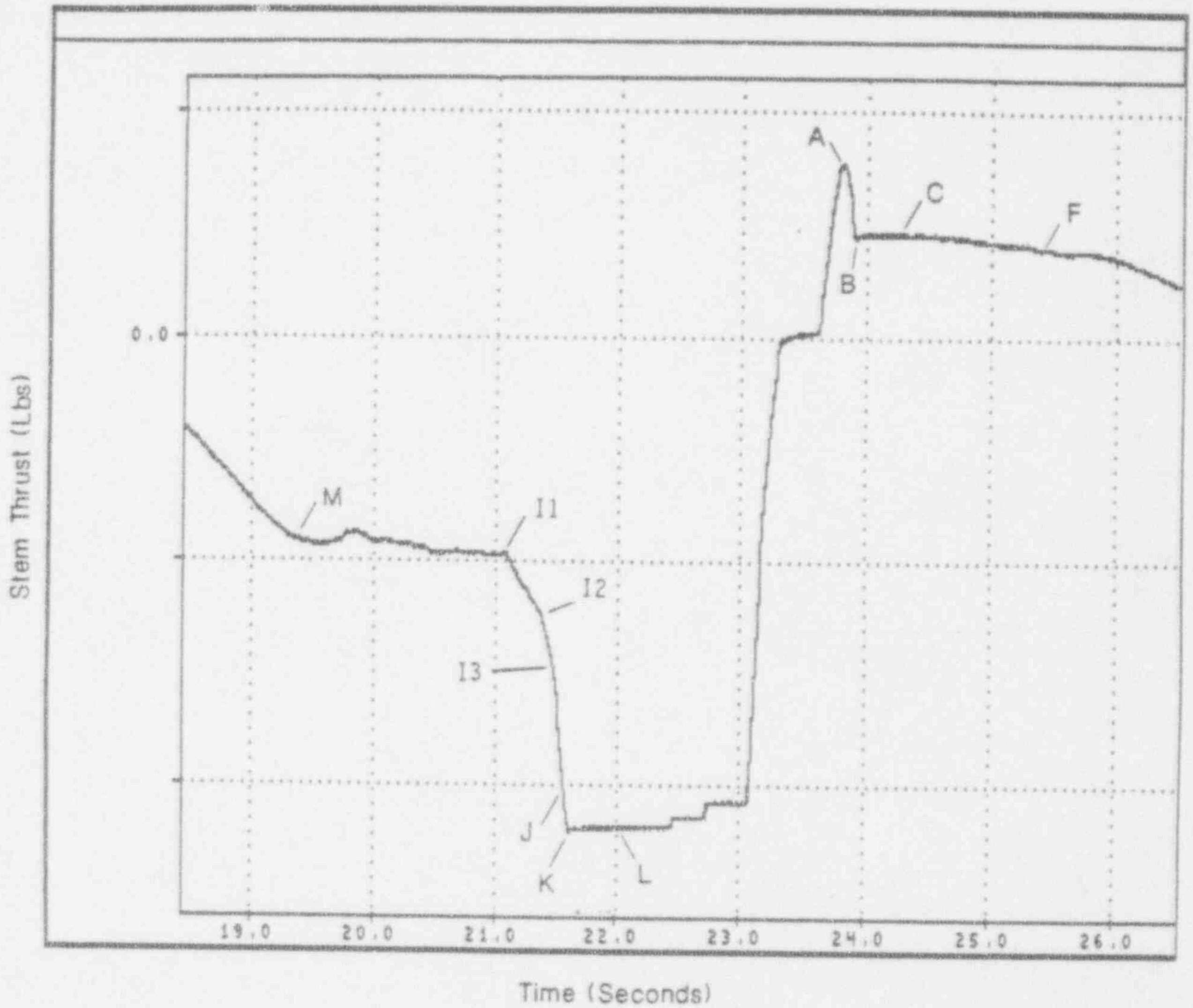
Borg Warner 4" Gate Valve No. 2-HV-2494A

PRELIMINARY



Stem Thrust for DP Closure and Opening

Borg Warner 4" Gate Valve No. 2-HV-2494A



Stem Thrust for DP Closure and Opening

Borg Warner 4" Gate Valve No. 2-HV-2494A

Borg-Warner Gate Valve Evaluation

Status

EPRI MOV Performance Prediction Program
Meeting with NRC

October 6, 1993

MPR Associates

Background

- First Borg-Warner Gate Valve tested by EPRI had high apparent disk-to-seat friction coefficient (max 0.9).

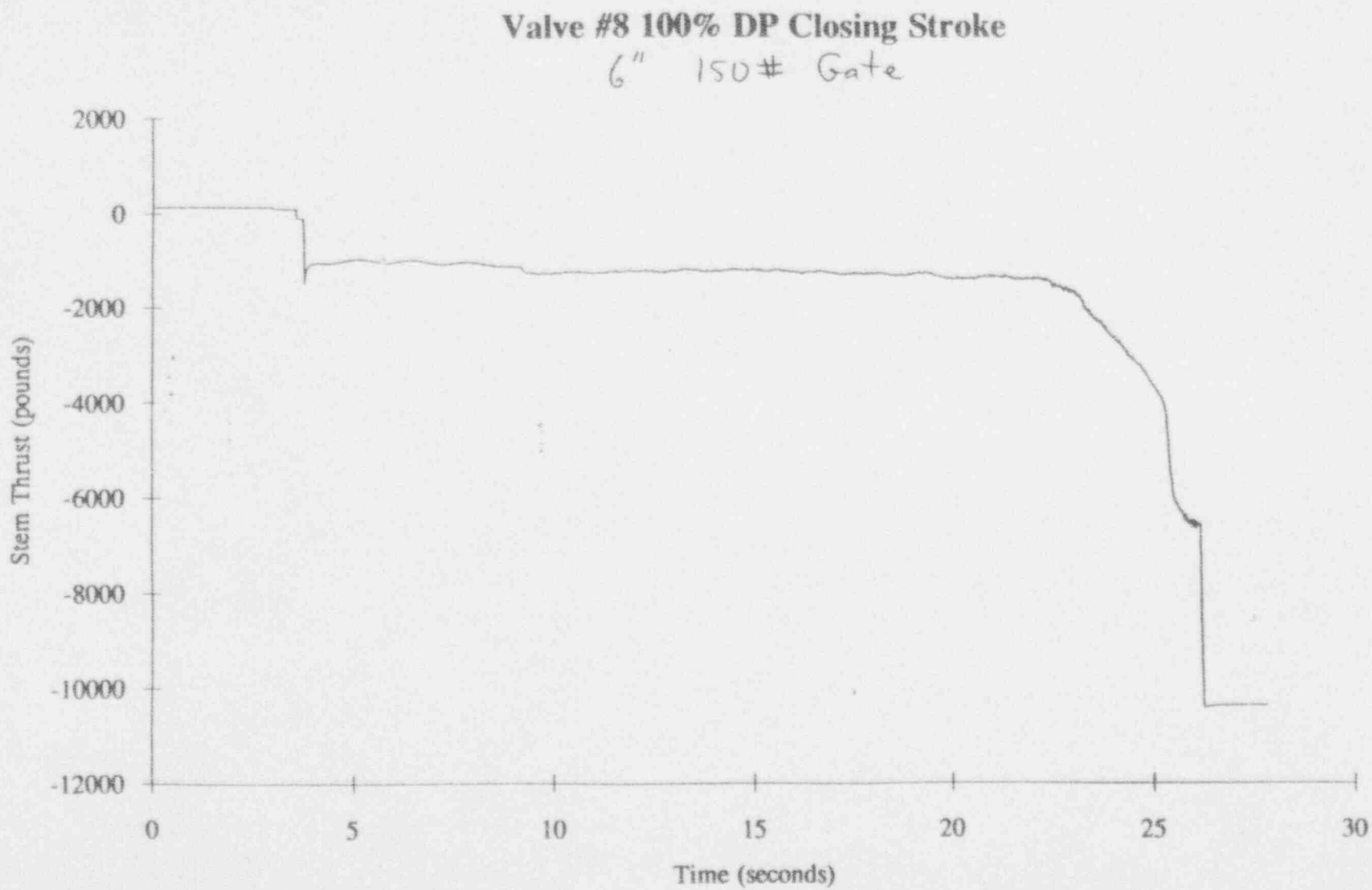
- Detailed post-test inspection identified potential root cause

  - Eccentric stem
  - T-slot perpendicular to flow
  - Torque transmittal into disk

Background (Cont'd)

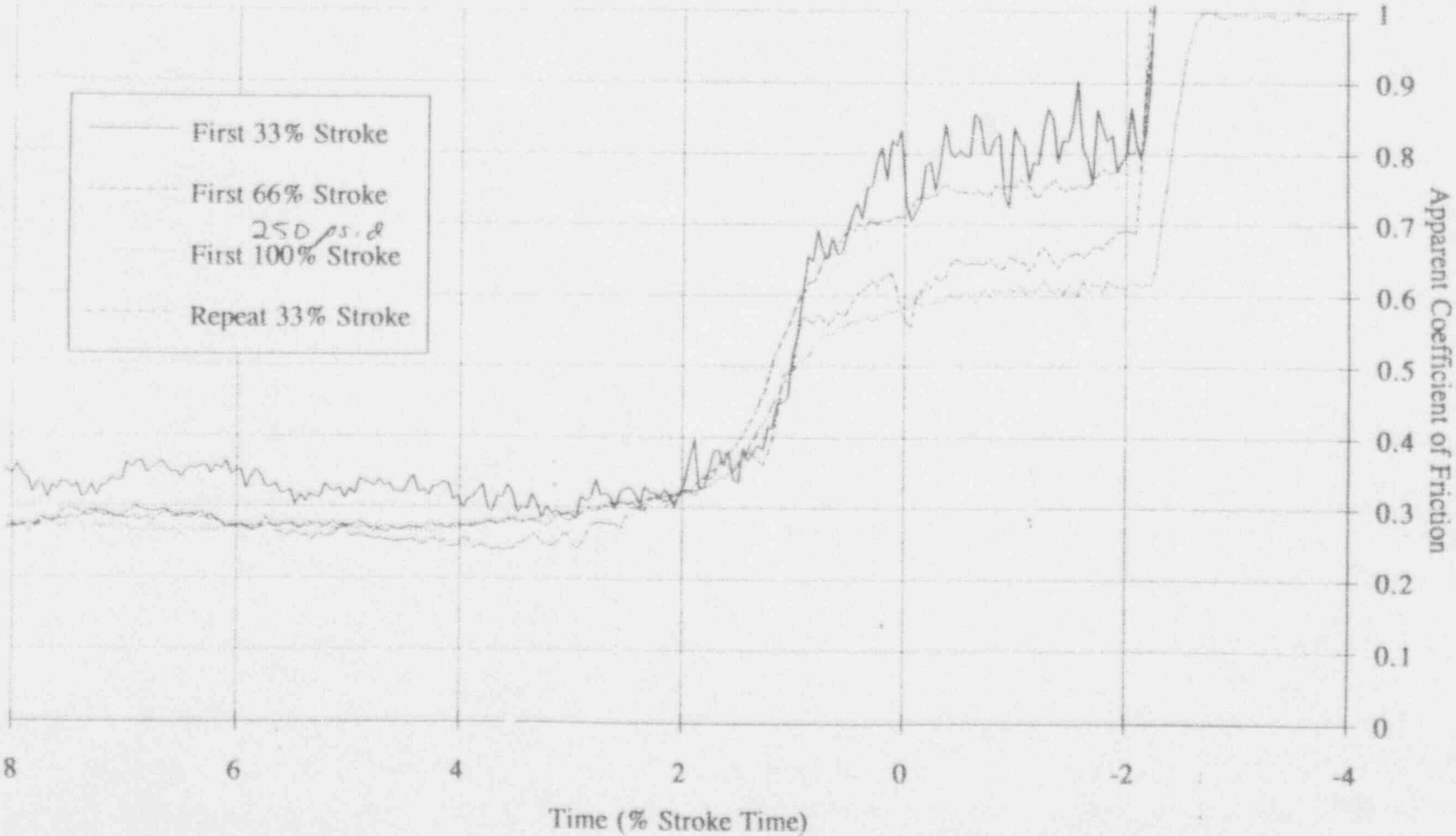
- Action Plan defined to determine root cause and approach for B-W Valves
- Test data for other B-W Valves now obtained

PRELIMINARY



PRELIMINARY

Borg-Warner Valve #8 Friction Data



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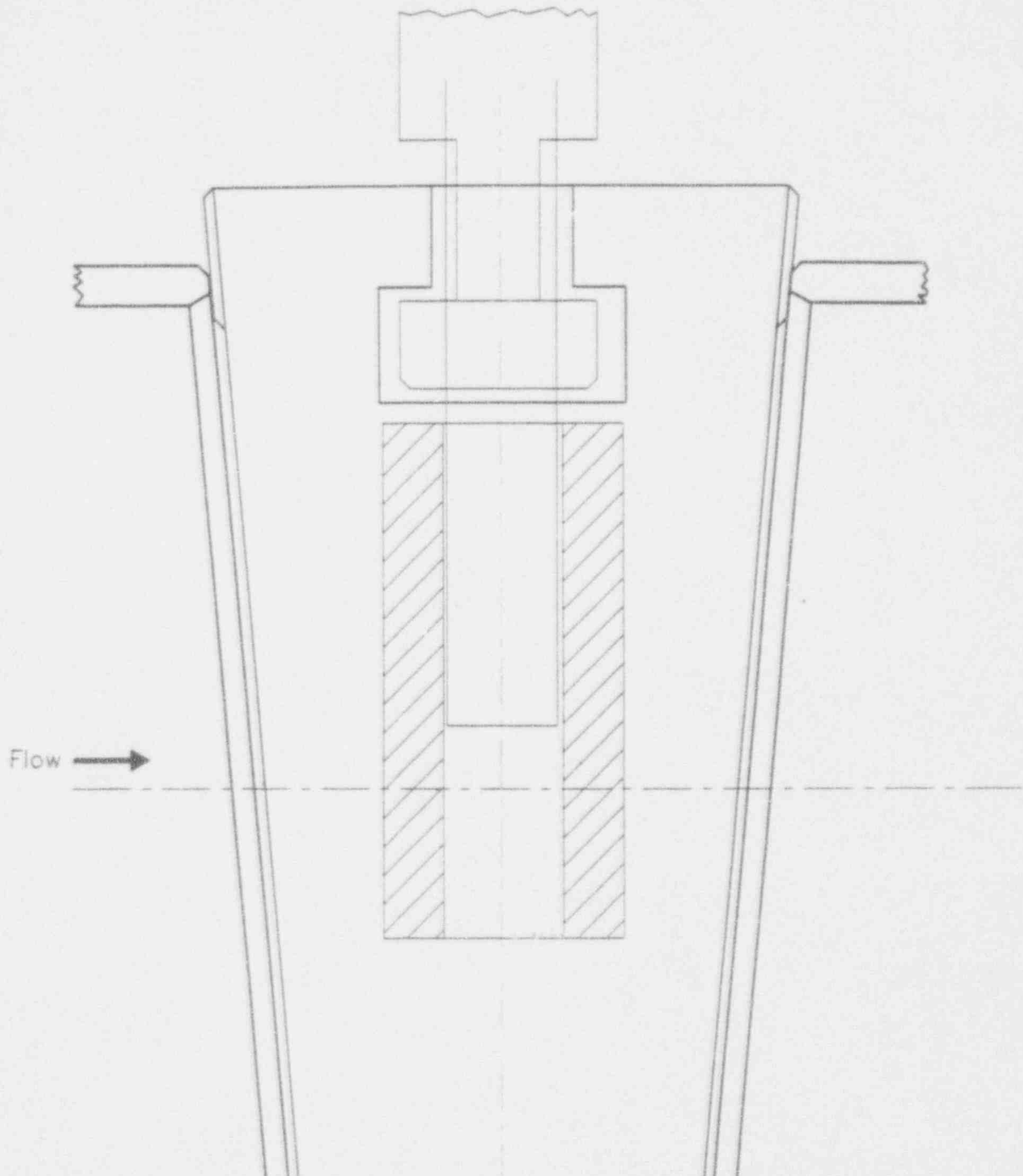
BWIP_11.XLC

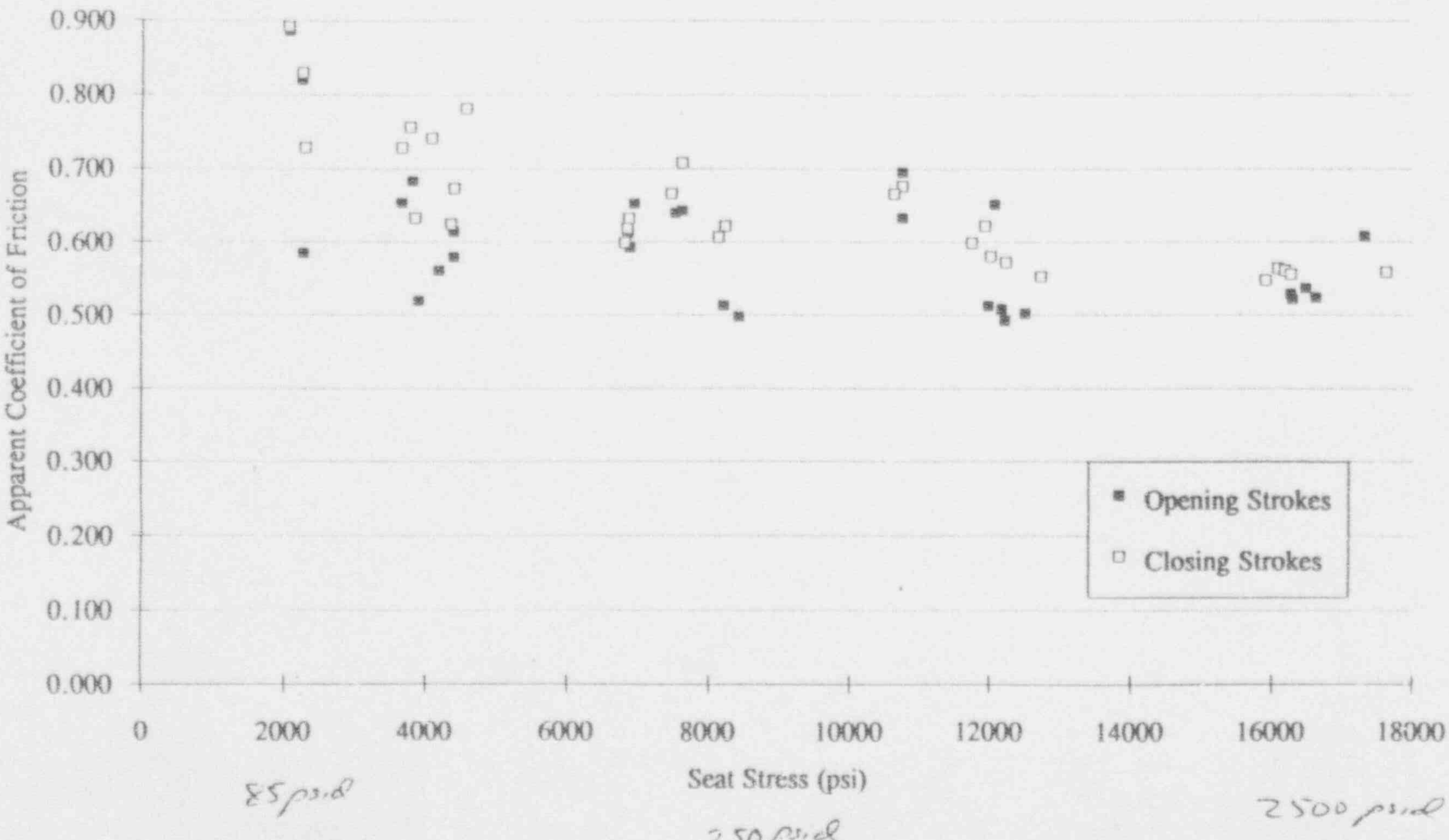

Flow

Borg-Warner Valve Tests

- Four Borg-Warner Gate Valves tested in EPRI flow loops
  - Carbon steel valves
  - Apparent friction coefficients generally about 0.6
  - Maximum value of 0.9 (valve 8 at 85 psi)
  - Unusual features observed in thrust traces

PRELIMINARY

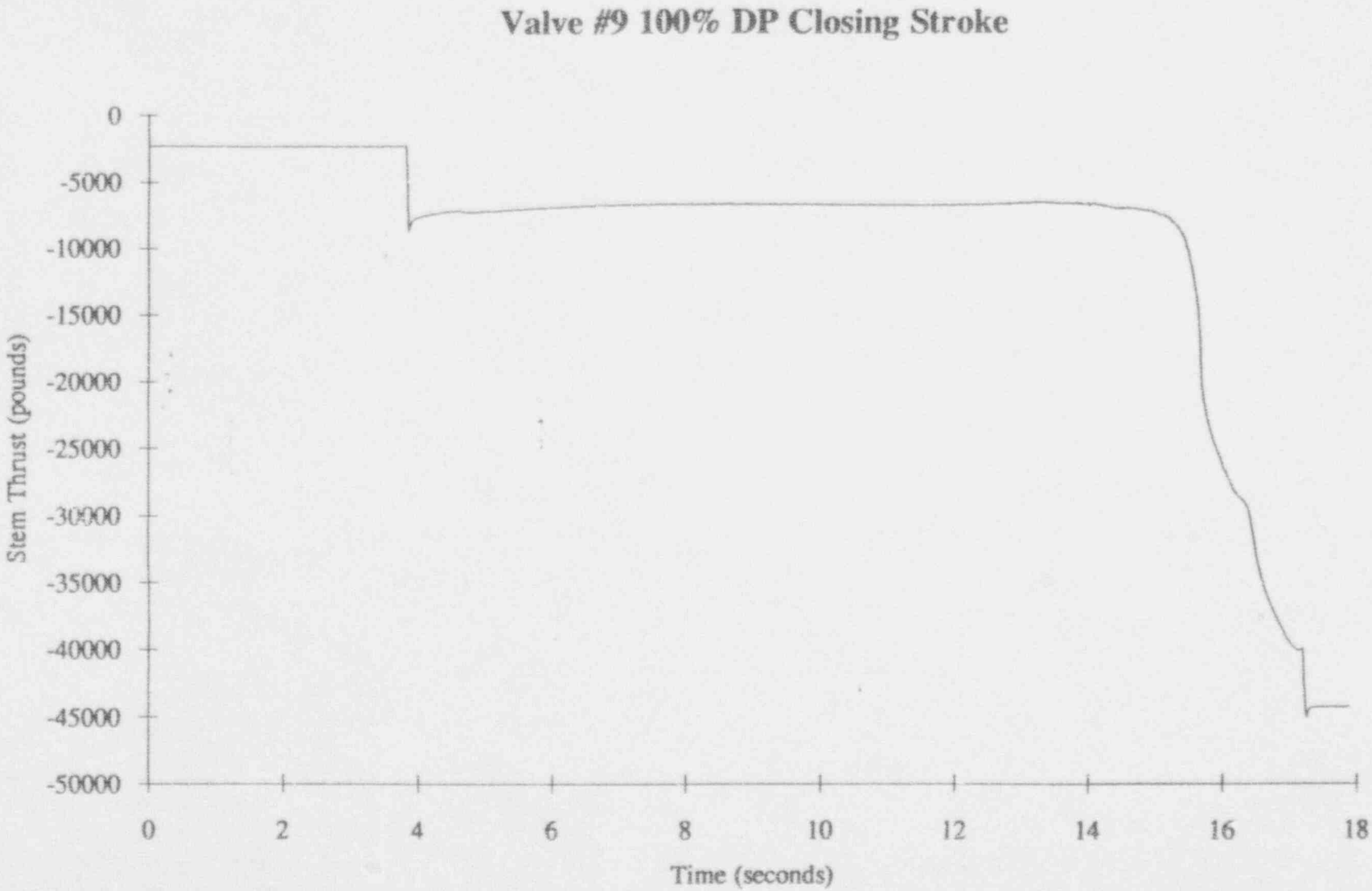
Borg-Warner Gate Valve Friction
(EPRI Valves 7, 8, 9 and 10)



9/22/93 8:25 AM

BWIP_10.XLC

PRELIMINARY



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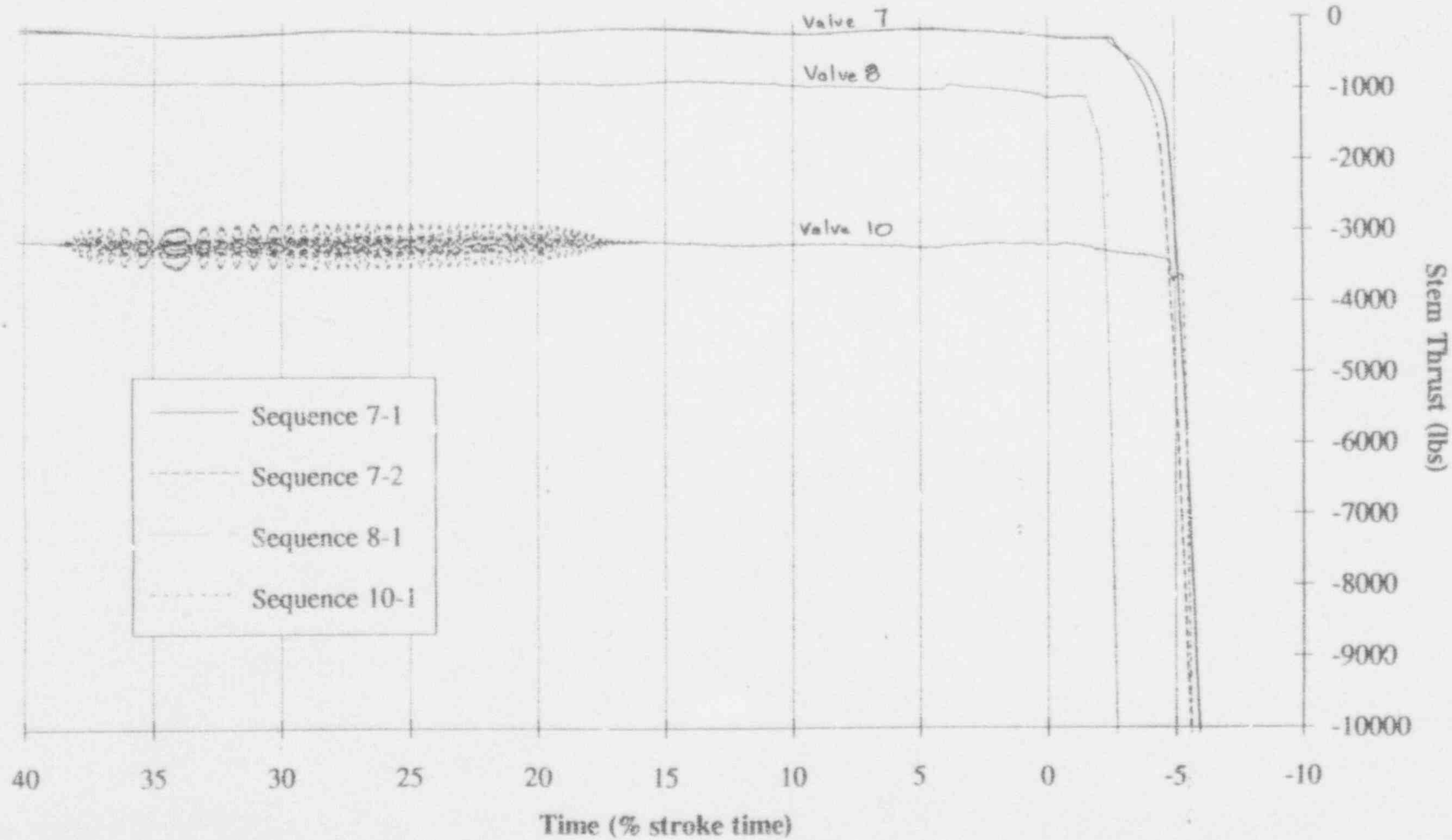
BWIP_19.XLC

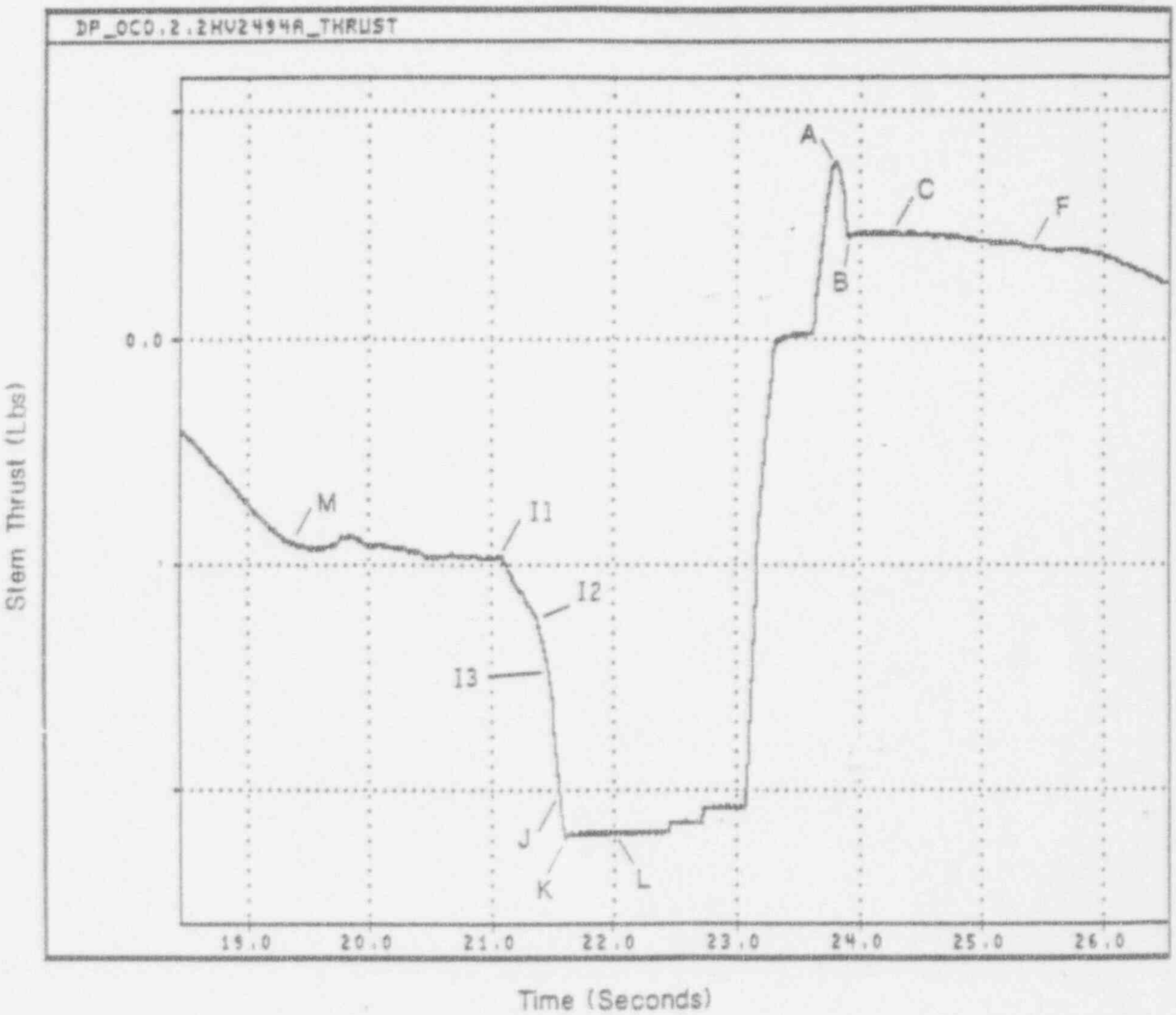
PRELIMINARY

Borg-Warner Valve Thrust Comparison - Static Closures



Borg-Warner Valve Tests (Cont'd)

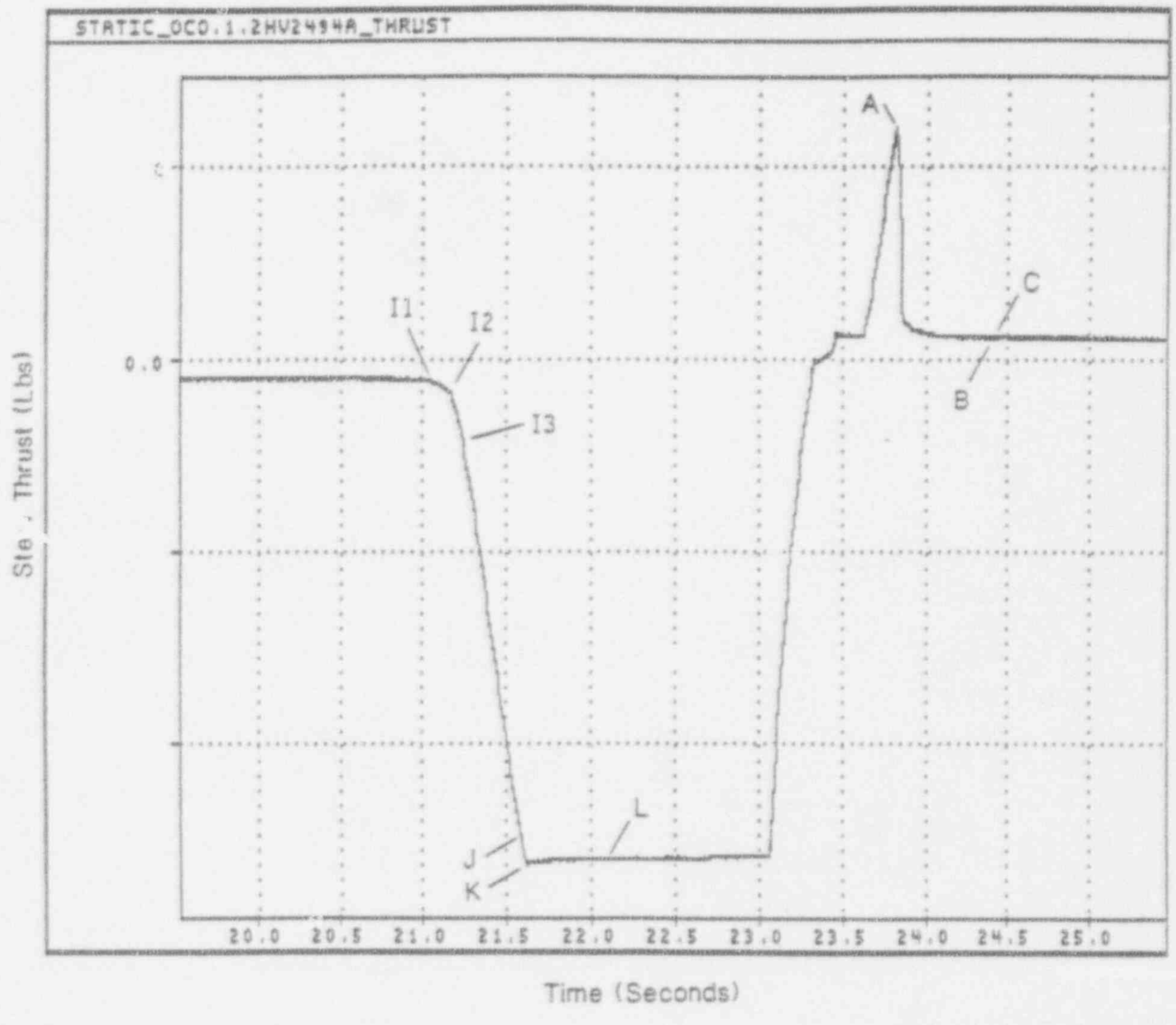
- One Borg-Warner Gate Valve tested in BW/IP flow loop
  - Nominally identical to EPRI Valve #8
  - Apparent friction coefficient of 0.42 (at 400 psi)
- Three Borg-Warner Gate Valves tested at Comanche Peak
  - Stainless steel disks
  - Apparent friction coefficients 0.3 to 0.4 for 2 valves
  - Third valve had a thrust increase just before wedging--maximum value of 0.55 at initial wedging



F-140-86-130
9/3/93

Figure 4-21. Valve Tag No. 2-HV-2494A Dynamic Test Open-to-Closed-to-Open, Stem Thrust, Enlargement of Disk Seating/Unseating Portion

PRELIMINARY



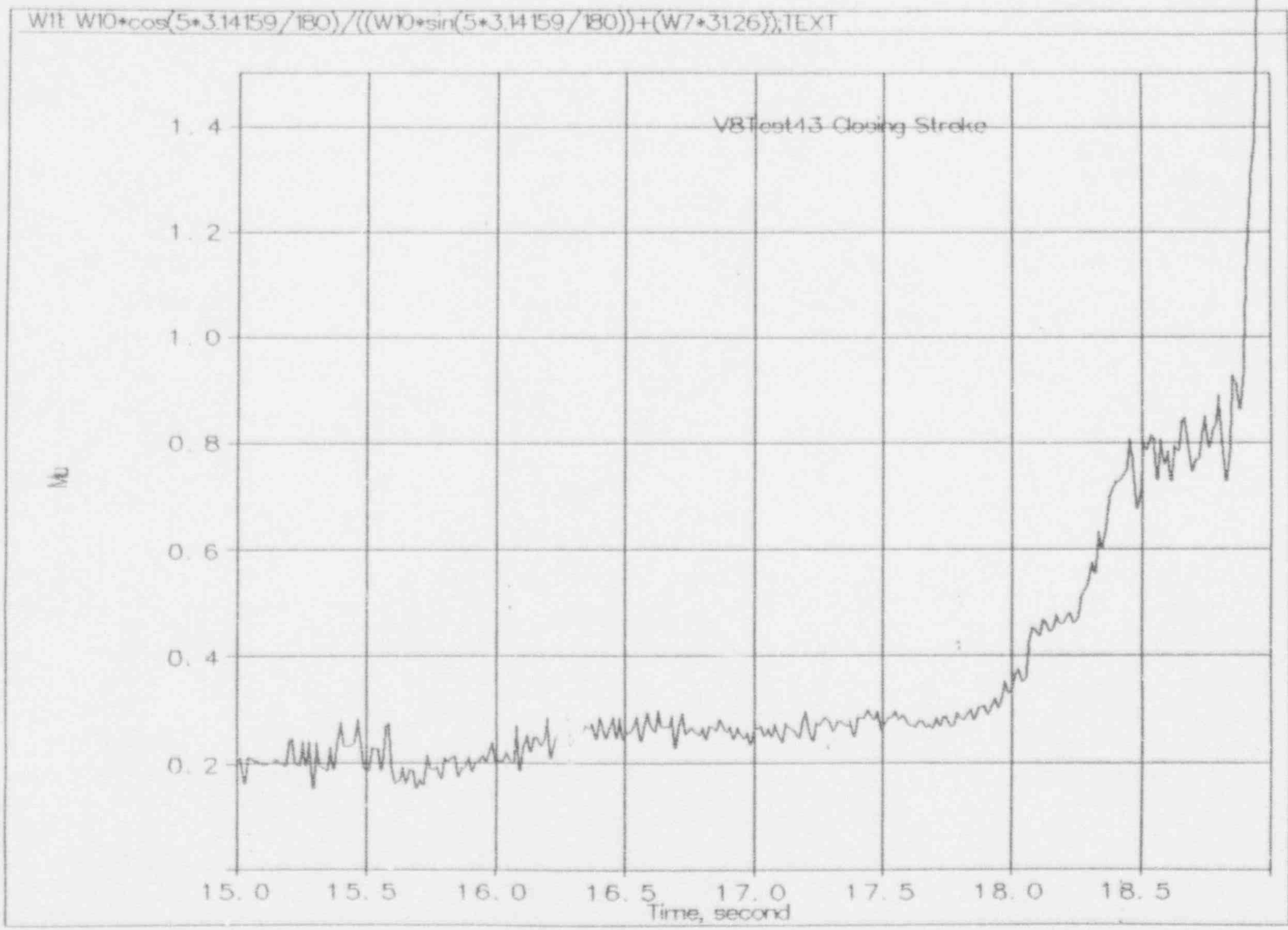
F-140-66-118
9/3/93

Figure 4-9. Valve Tag No. 2-HV-2494A Static Test Open-to-Closed-to-Open, Stem Thrust, Enlargement of Disk Seating/Unseating Portion

Additional Valve #8 Testing

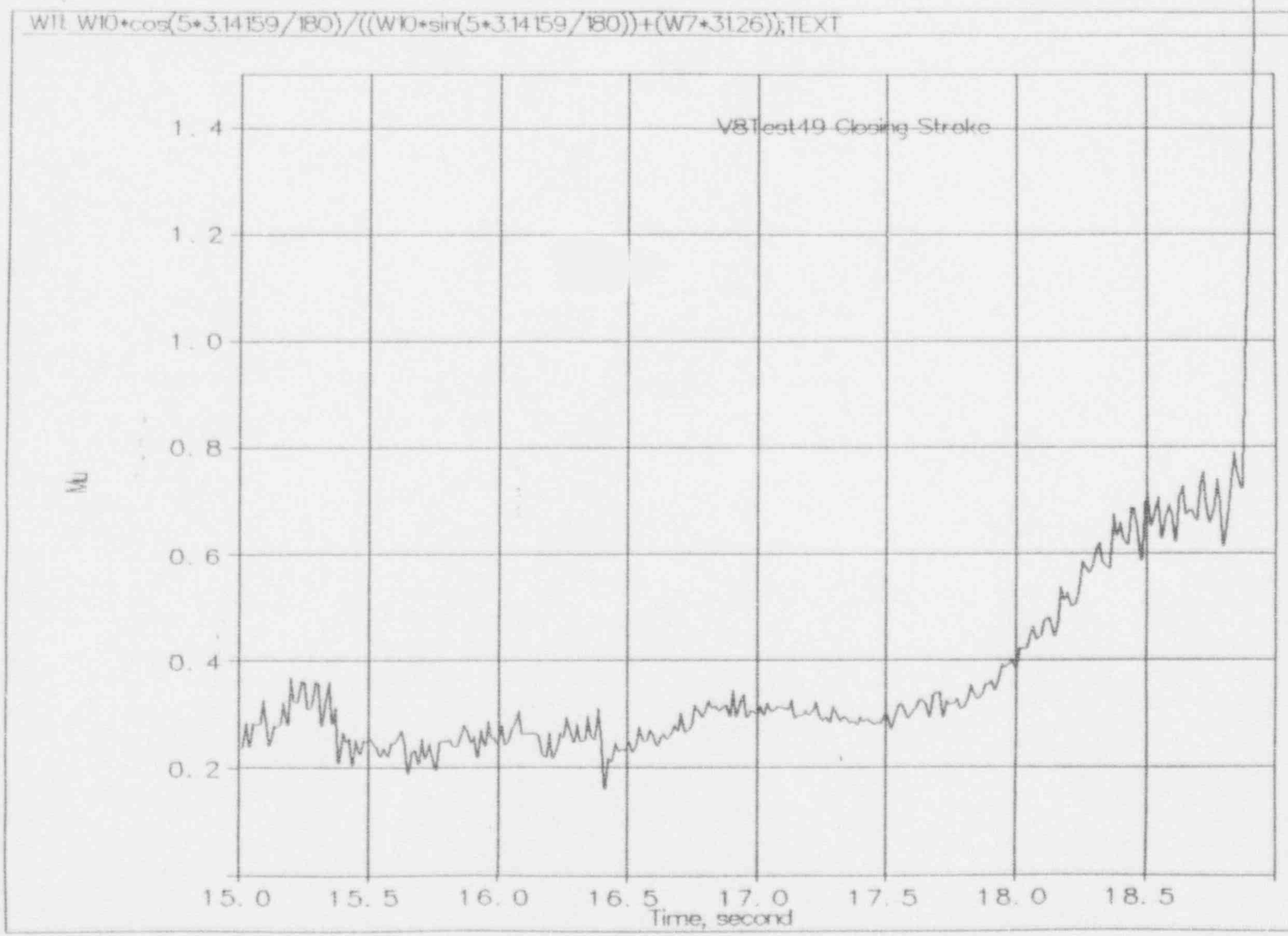
- Testing at KEI with 90 psi at 15 fps (water)
- Results - apparent friction coefficient
  - Without torque arm ~ 0.8
  - With torque arm ~ 0.7
  - Thrust change occurs during transition from guide to seat
- Conclusion
  - Effect of torque increases apparent friction

PRELIMINARY



8

PRELIMINARY

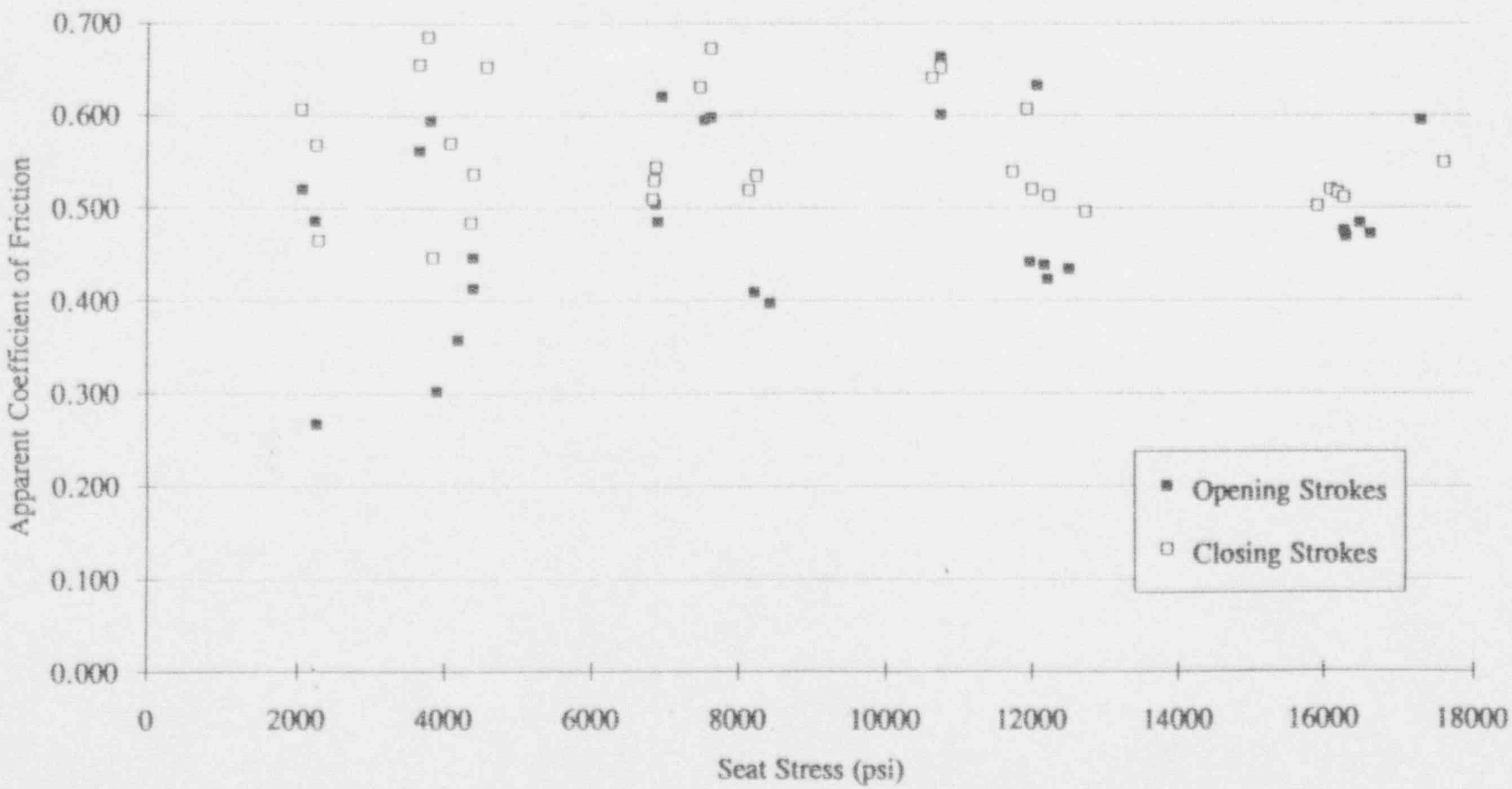


Future Work

- Conduct additional tests with Valve #8 at KEI loop -disk slot machined to change transition point and to unambiguously identify disk-to-seat sliding
- Develop and validate an approach for addressing B-W in-plant valves using the PPM computer program
  - Account for torque effect
- Revise action plan activities to include additional valve testing rather than valve design effects testing

PRELIMINARY

Borg-Warner Gate Valve Friction With Corrected Packing Loads (EPRI Valves 7, 8, 9 and 10)



Globe Valve Performance Evaluation Status

EPRI MOV Performance Prediction Program
Meeting at NRC Office
October 6, 1993

Overview

Objective

Develop an engineering method and software module to determine globe valve stem thrust under DP conditions.

Assumption

Behavior beyond traditional approaches does not occur.

Status

- Model and software developed
- Comparisons to data performed (5 valves)
- Reports in preparation

Conclusions

Incompressible Flow

- Method is an accurate predictor of stem force.

- Unbalanced disk valves—necessary to identify "controlling area" for DP force (seat area or guide area). Guidelines based on valve configuration have been prepared.

- Balanced disk valves—side load correlation may not be precisely applicable to all designs. Resolve by:

  - Demonstrating significant margin, or
  - DP test of valve type

Conclusions
(Continued)

Flashing Water Blowdown

- Method does not predict high stem force observed in the single flashing water blowdown test (Valve 48).
- Valve inspection indicates disk side loading.
- Adjustments to the method to cover this condition are being studied.

Summary of Method Features

Stem Thrust Contributors

• Weight	Negligible when DP (psi) > 70*Size (inches).
• Stem Rejection	Based on pressure over disk.
• Packing	User input, negligible for rotating stems.
• Torque Reaction	Only for nonrotating stems.

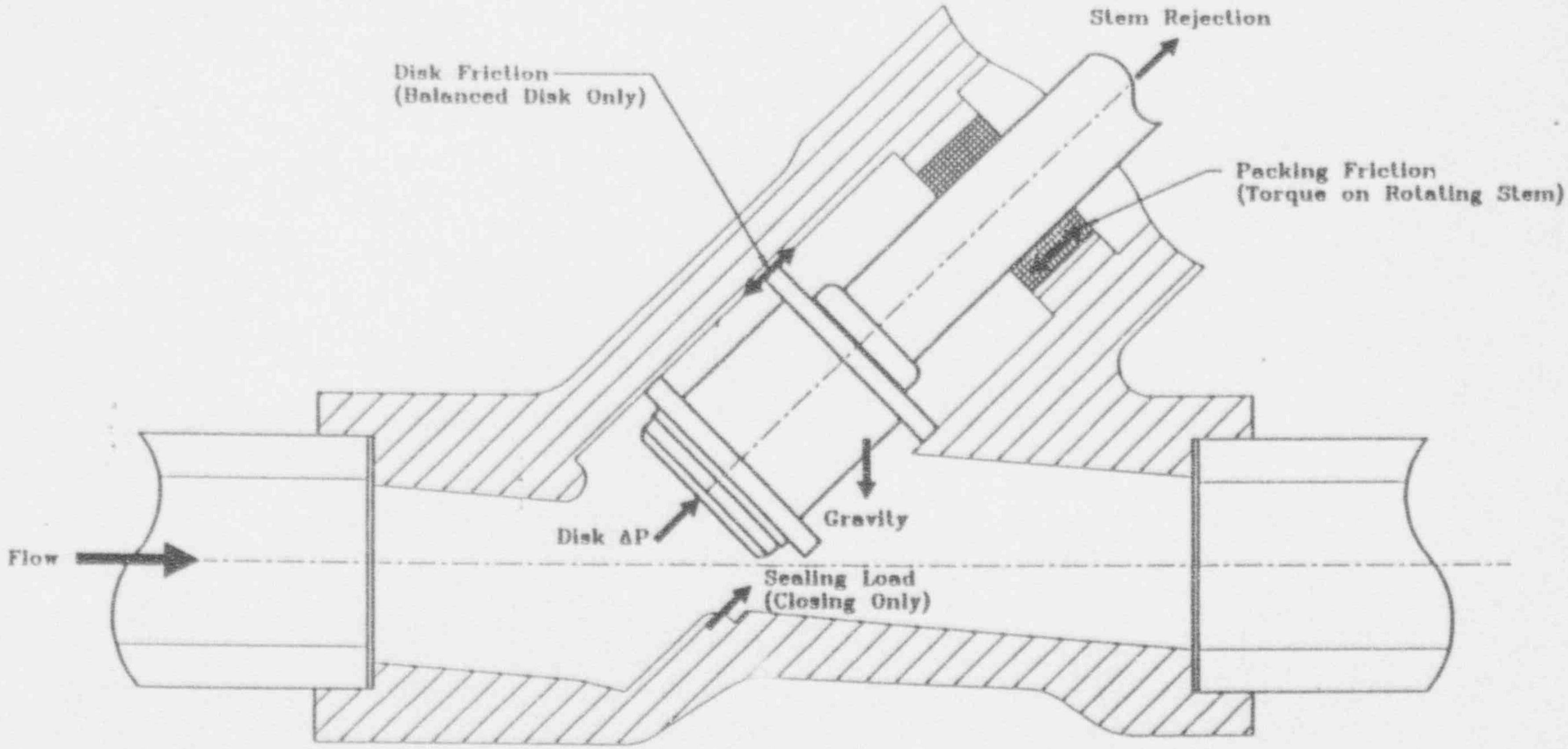
Summary of Method Features
(Continued)

Stem Thrust Contributors (Cont'd)

- DP Force:

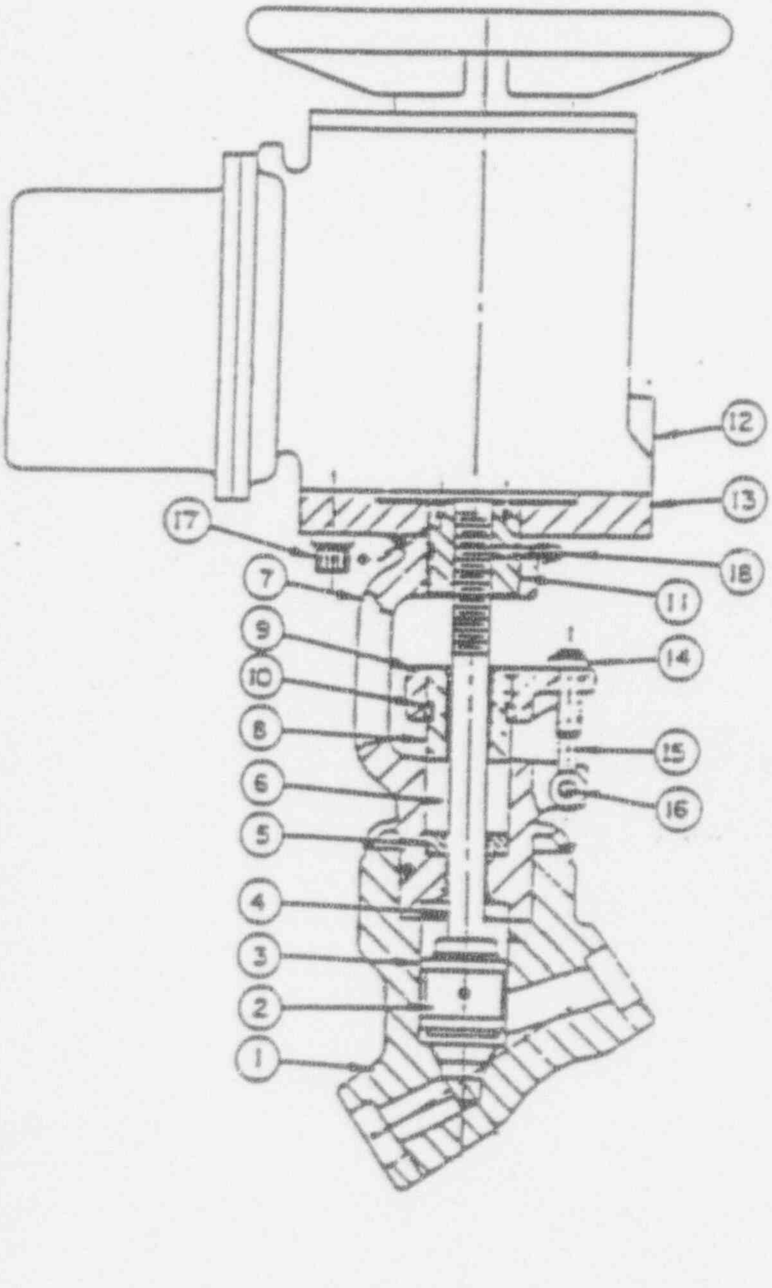
- Unbalanced disk	Based on user identification of seat area or guide area
- Balanced disk	Based on side load correlation and friction coefficient of 0.5

Guideline for Determining Area of Unbalanced Disks



Globe Valve Stem Force Components

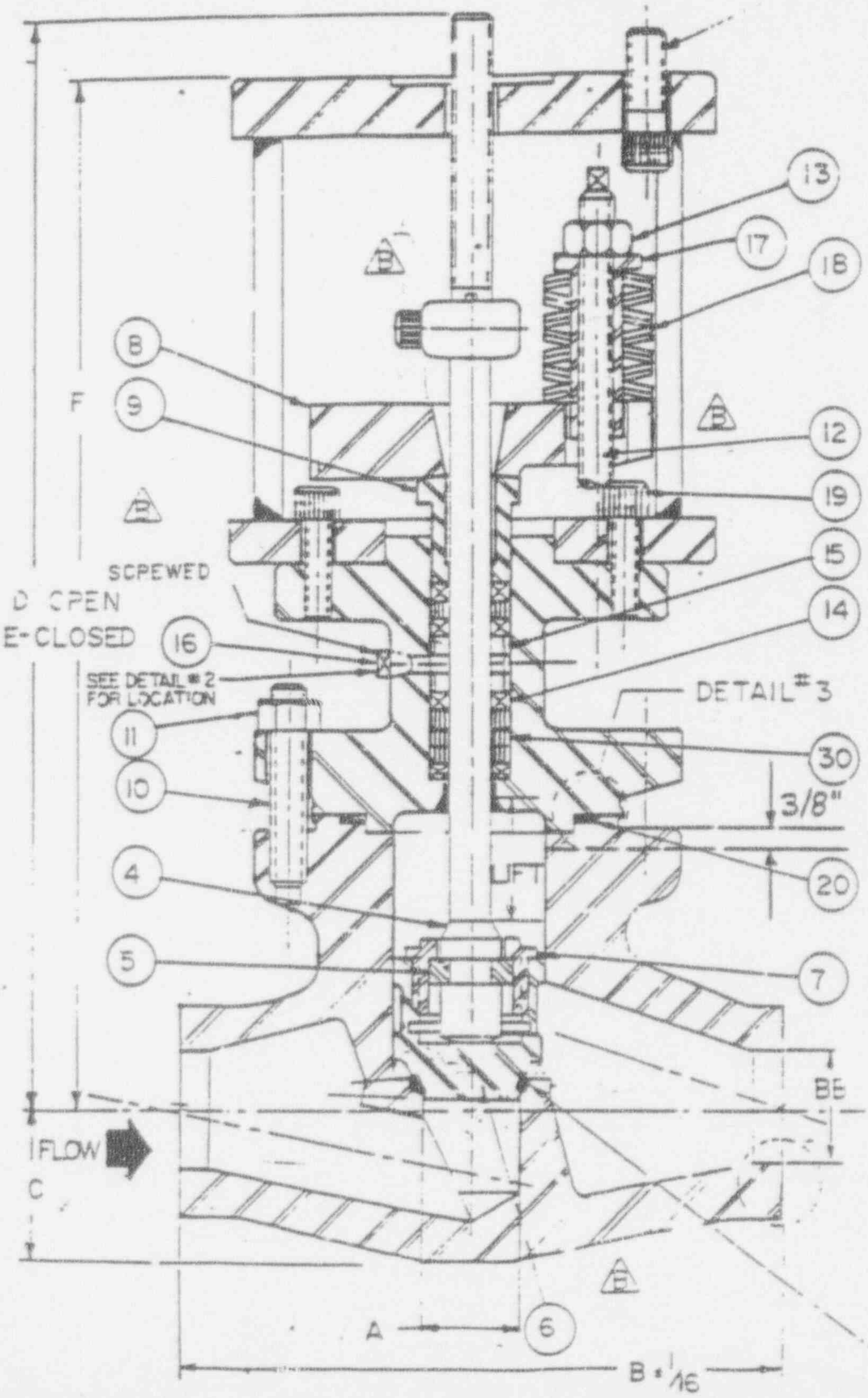
ROCKWELL - EDWARDS
2" - 1500 LB.
GLOBE VALVE



1 Body
2 Stem Assembly
3 Disc
4 Stem
5 Junk Ring
6 Packing Rings
7 Bonnet
8 Gland
9 Gland Flange
10 Split Ring
11 Yoke Bushing
12 Limitorque Actuator
13 Motor Flange
14 Eyebolt Nuts
15 Eyebolts
16 Eyebolt Pins
17 Capscrew
18 Grease Fitting

VELAN 2 1/2"

BOLTED BONNET GLOBE VALVE



Method/Data Comparisons

Valve No.	Manufacturer	Size	Stem	Disk	DP (psi)	Flow (fps)	Direction
Ambient							
44	B-W	6	NR	Unbal.	1800	15, 50	Under
48	Edward	2	R	Unbal.	2500	15, 50	Under
49	Velan	2-1/2	NR	Unbal.	2500	15	Under
50	A/D	10	NR	Unbal.	500	15	Under, Over
2-FV-4772-2	Fisher	4	NR	Bal.	275	~40	Under
635°F Water							
48	Edward	2	R	Unbal.	2500	B/D	Under

Note: For stem, NR = nonrotating, R = rotating.

Summary of Comparisons — Incompressible Flow

Valves 49 and 50 — Seat Area Controlled

- Good, bounding agreement if seat area used.
- Excellent agreement if measured sealing diameter used.

Valves 44 and 48 — Guide Area Controlled

- Bounding prediction if guide area used. Percent bounding depends on flow rate.
- Nonconservative prediction if seat area used.

Summary of Comparisons — Incompressible Flow (Continued)

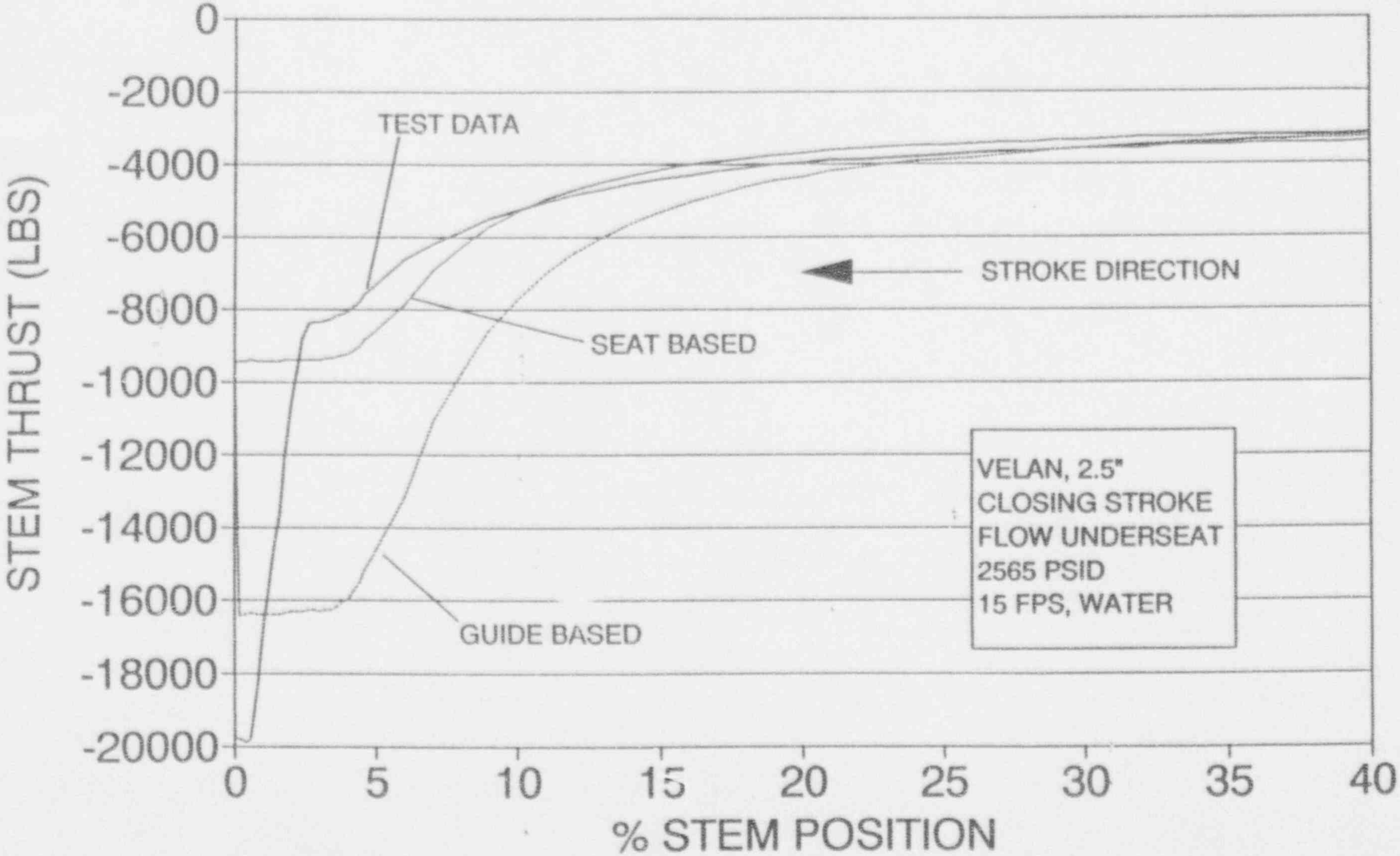
Valve 2-FV-4772-2 — Balanced Disk

- Slightly nonconservative prediction
- DP thrust small and margin large for this valve.

VALVE 49, STROKE 172

SMOOTHED DATA

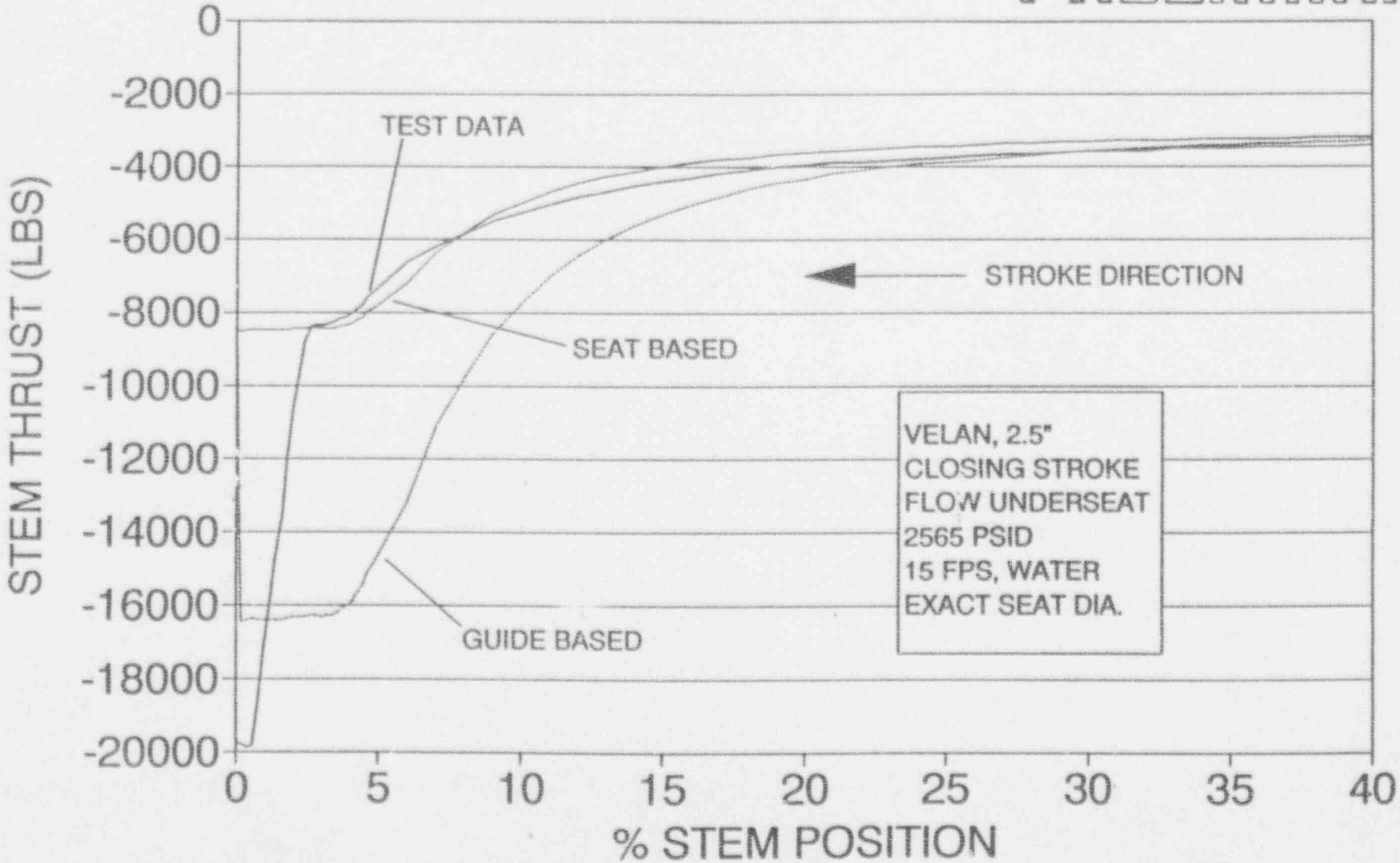
PRELIMINARY



VALVE 49, STROKE 172

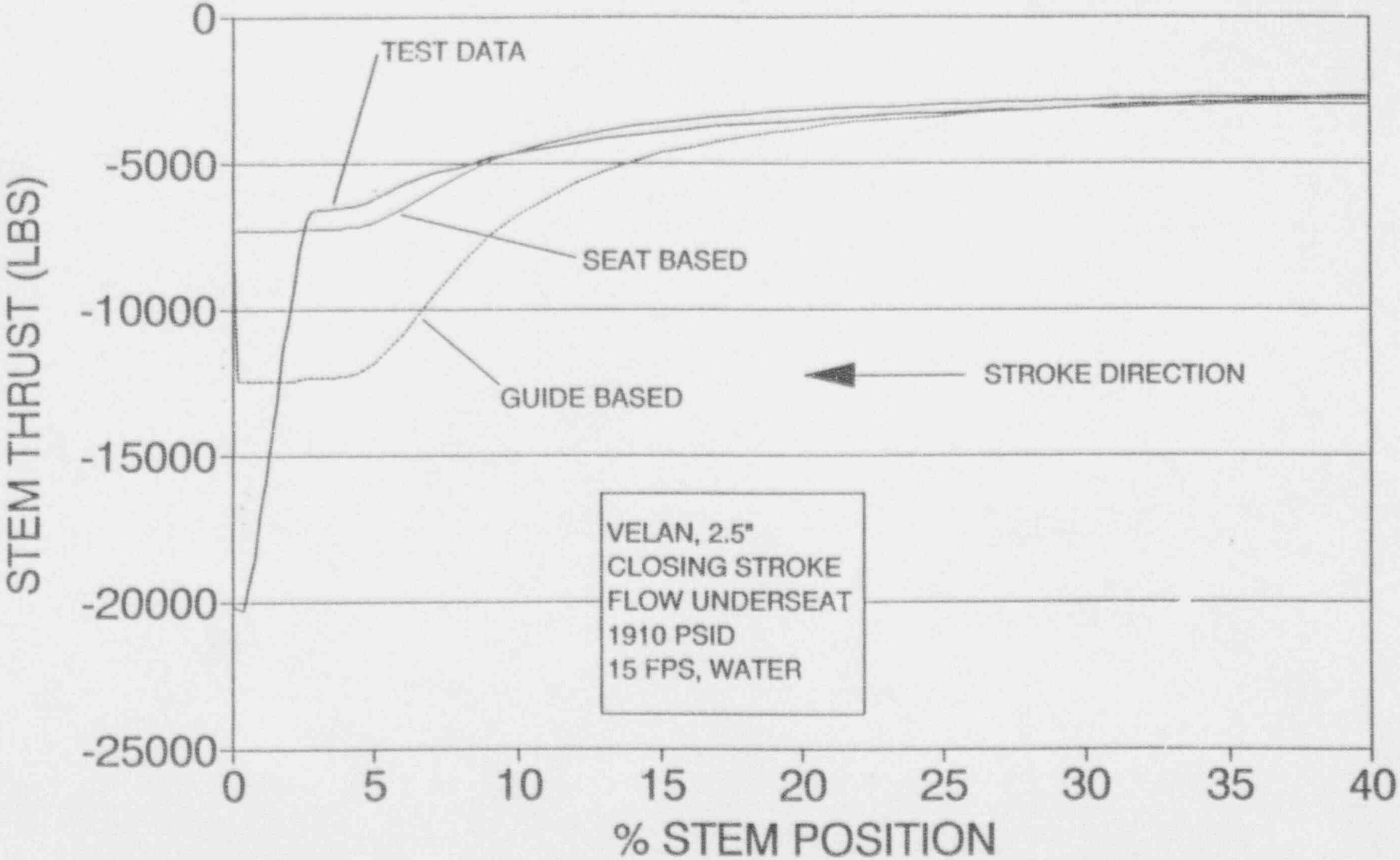
SMOOTHED DATA

PRELIMINARY



VALVE 49, STROKE 170

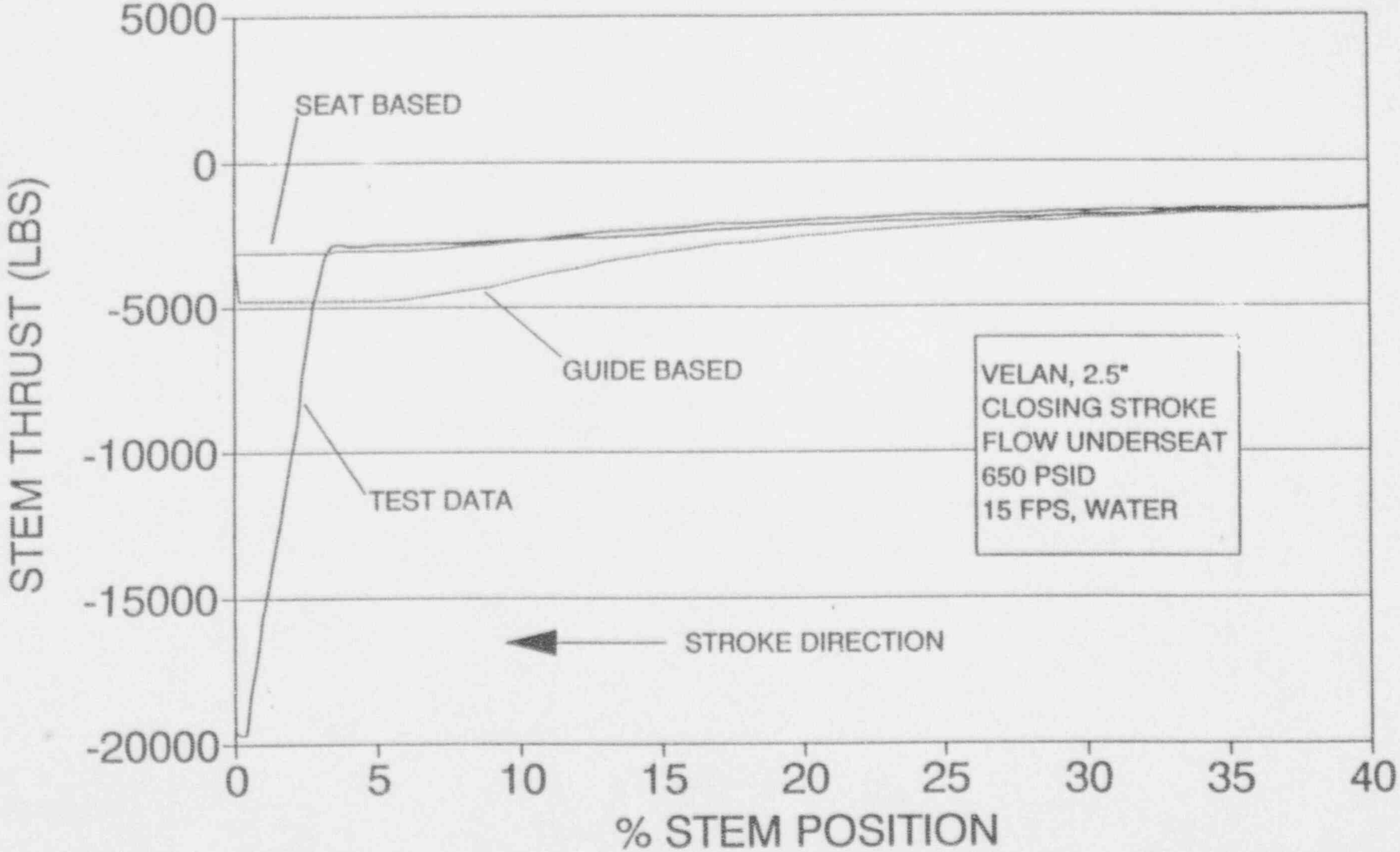
SMOOTHED DATA PRELIMINARY



VALVE 49, STROKE 164

SMOOTHED DATA

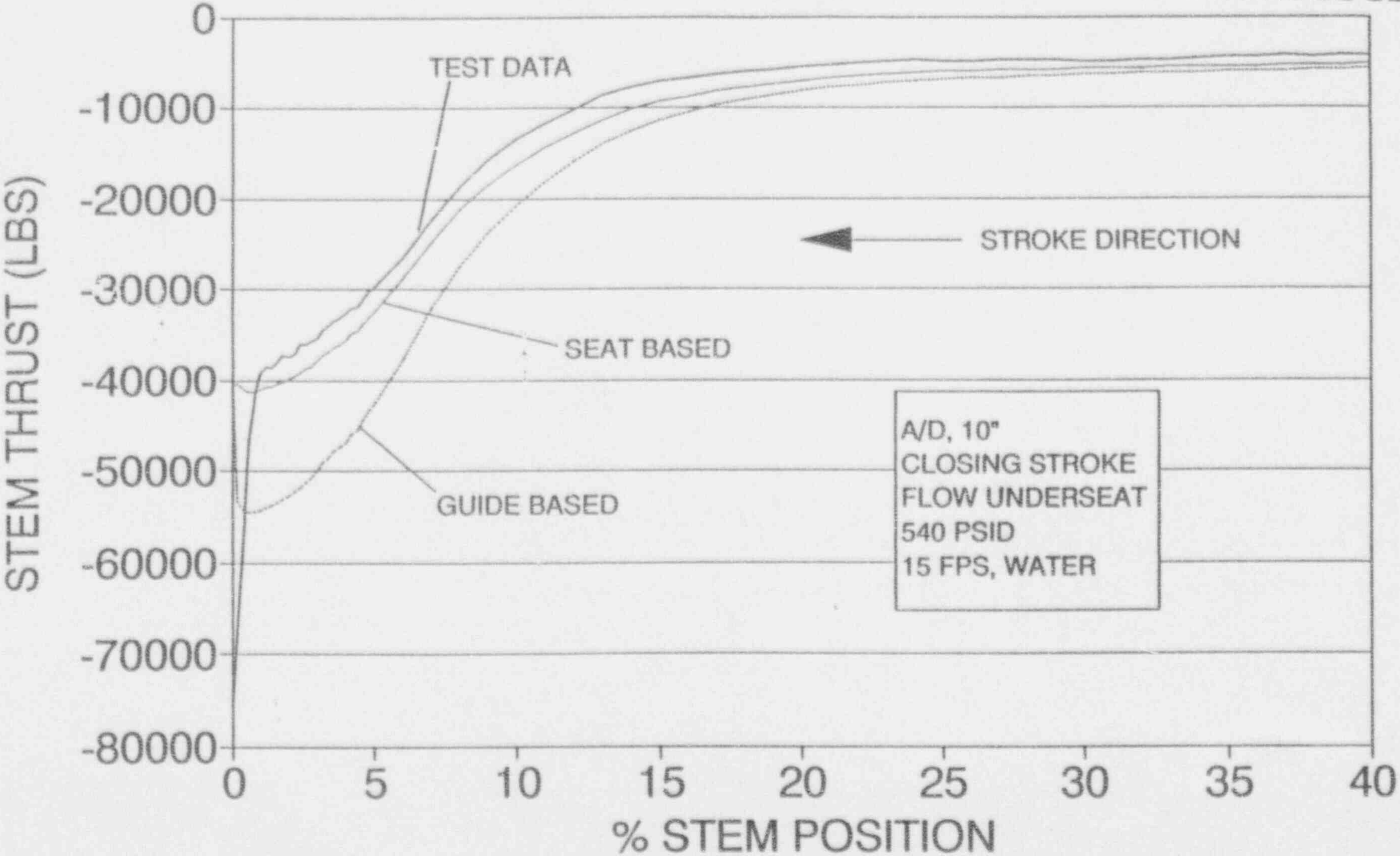
PRELIMINARY



VALVE 50, STROKE 262

FLOW UNDERSEAT

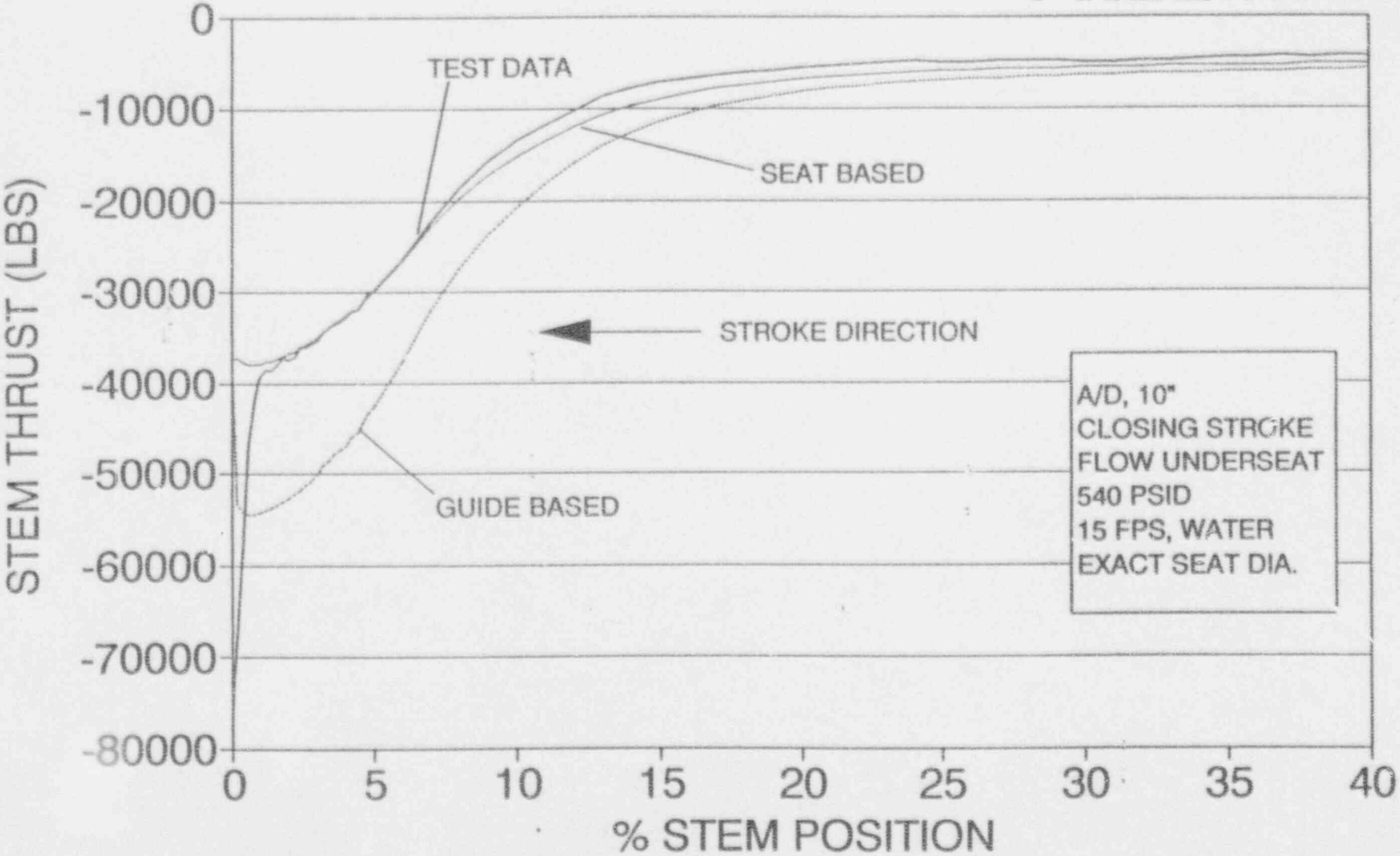
PRELIMINARY

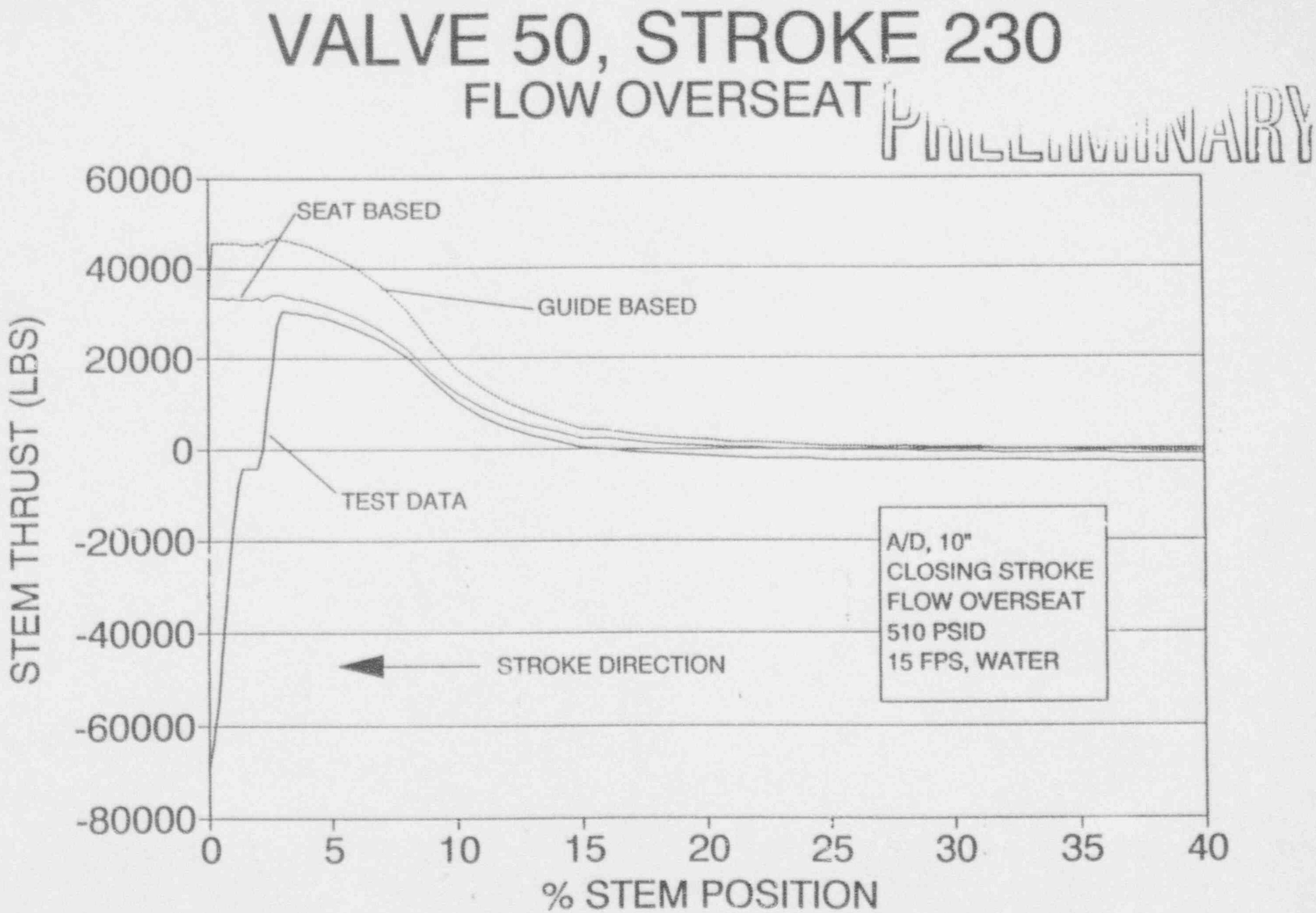


VALVE 50, STROKE 262

FLOW UNDERSEAT

PRELIMINARY



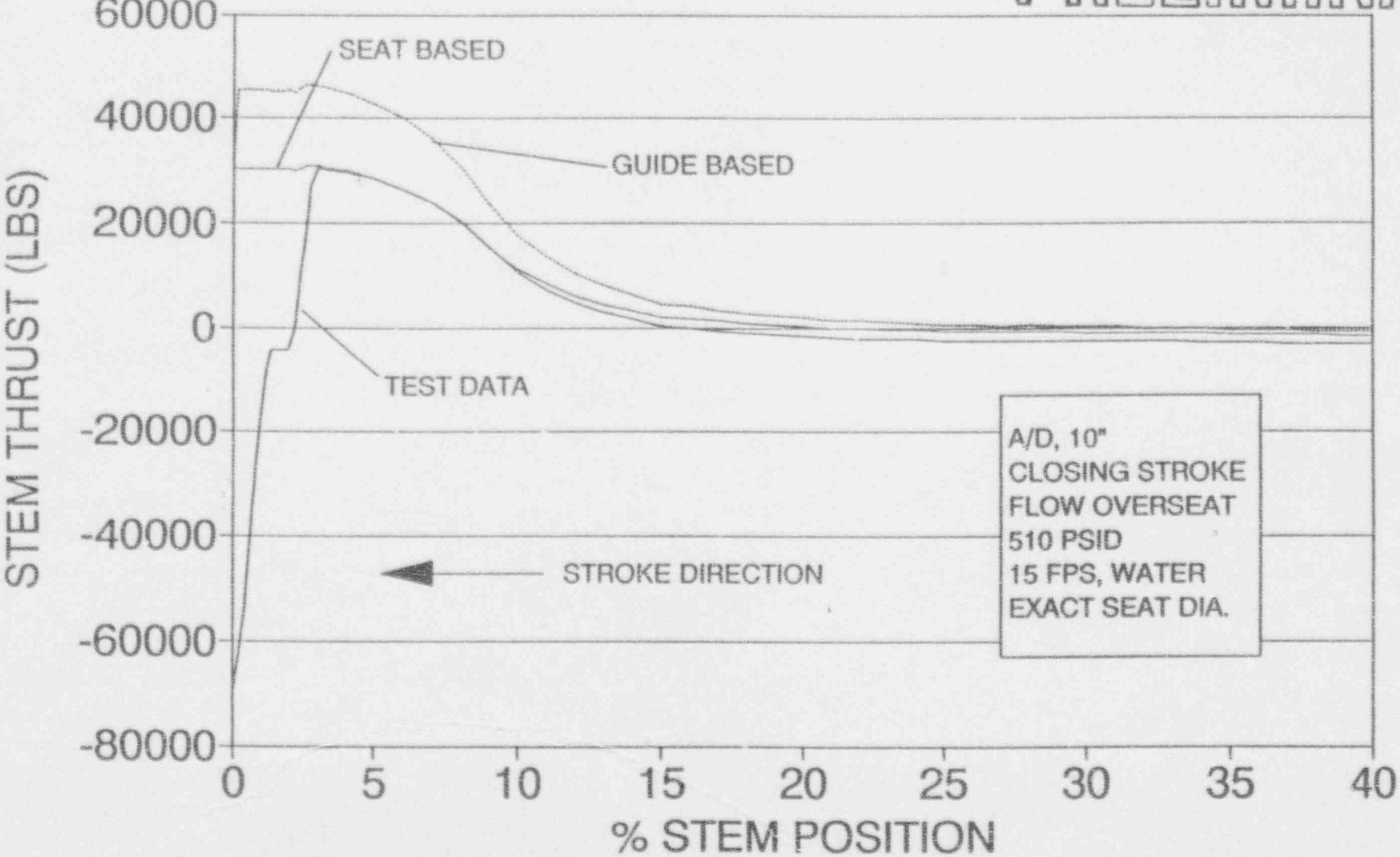


VALVE 50, STROKE 230
FLOW OVERSEAT
PRELIMINARY
60000
40000
20000
0
-20000
-40000
-60000
-80000
STEM THRUST (LBS)
SEAT BASED
GUIDE BASED
TEST DATA
STROKE DIRECTION
A/D, 10"
CLOSING STROKE
FLOW OVERSEAT
510 PSID
15 FPS, WATER
0
5
10
15
20
25
30
35
40
% STEM POSITION

VALVE 50, STROKE 230

FLOW OVERSEAT

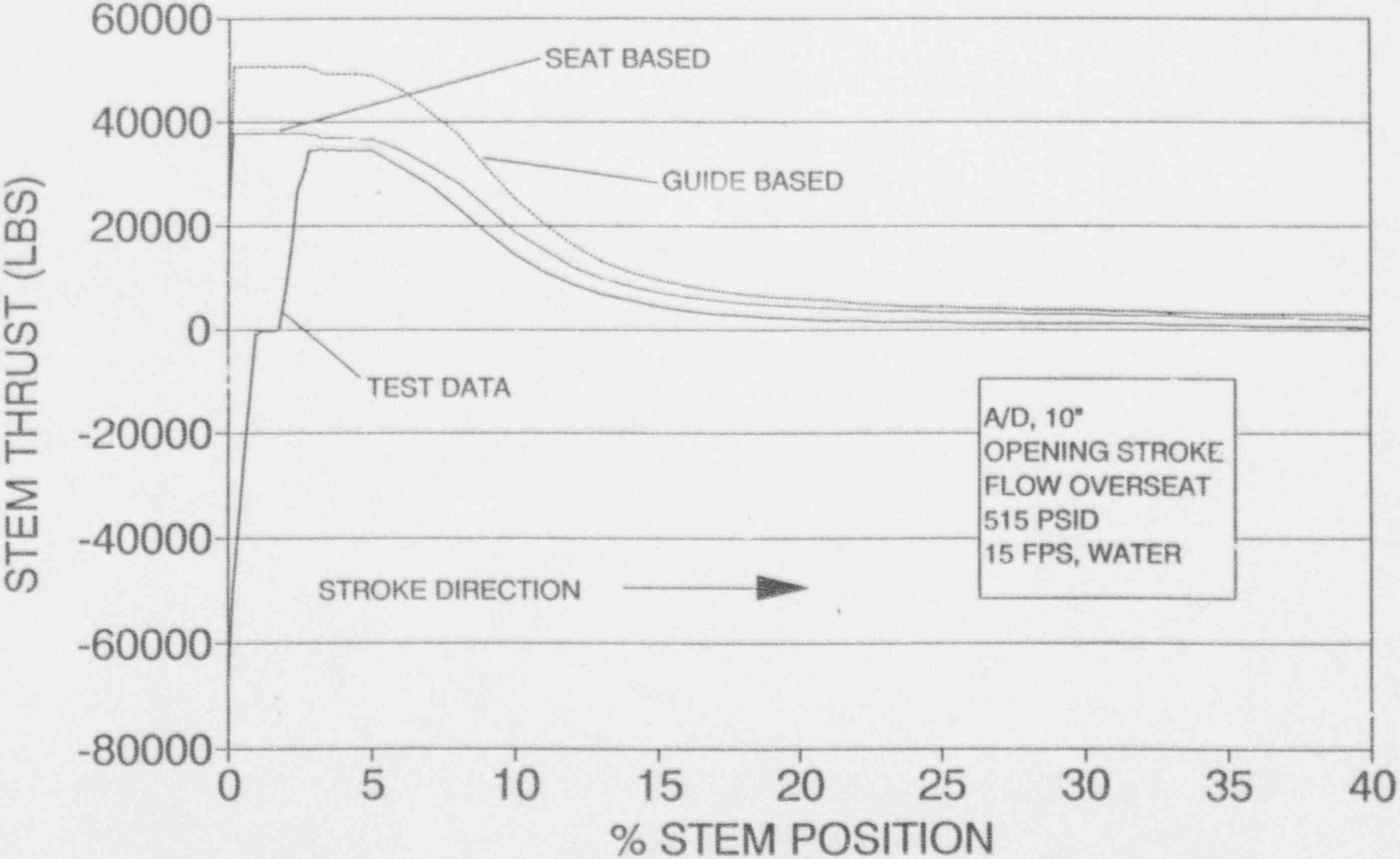
PRELIMINARY

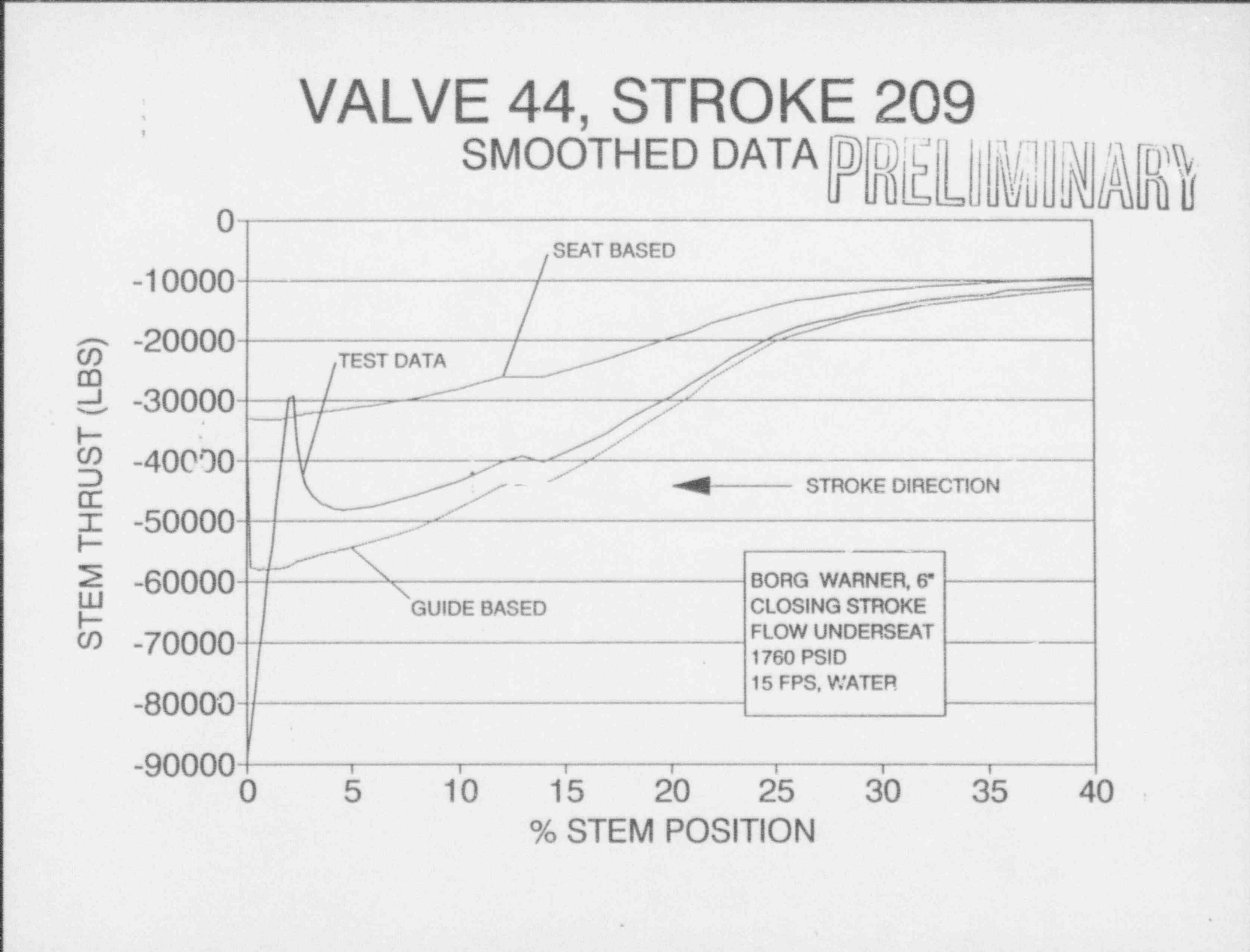


VALVE 50, STROKE 231

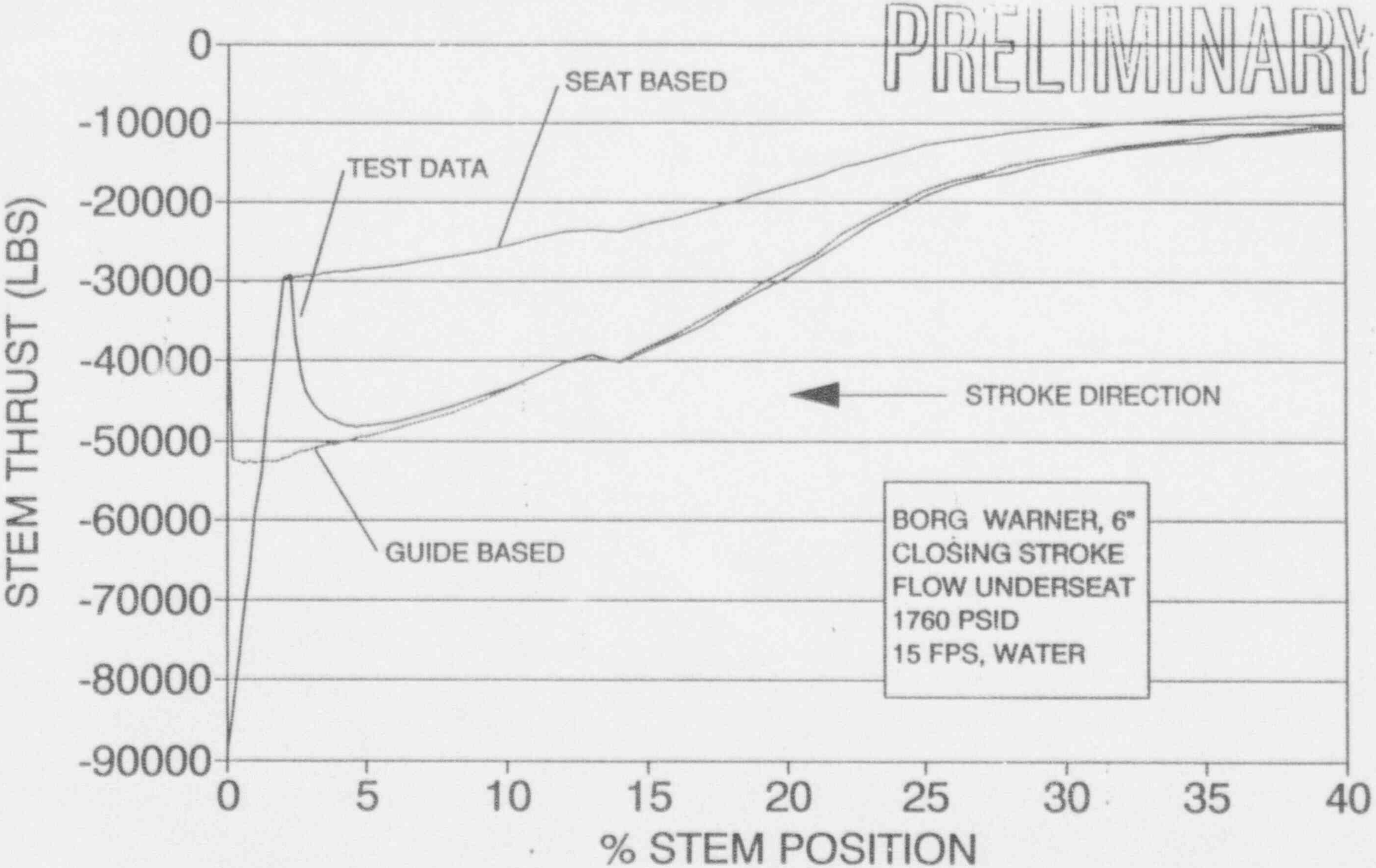
FLOW OVERSEAT

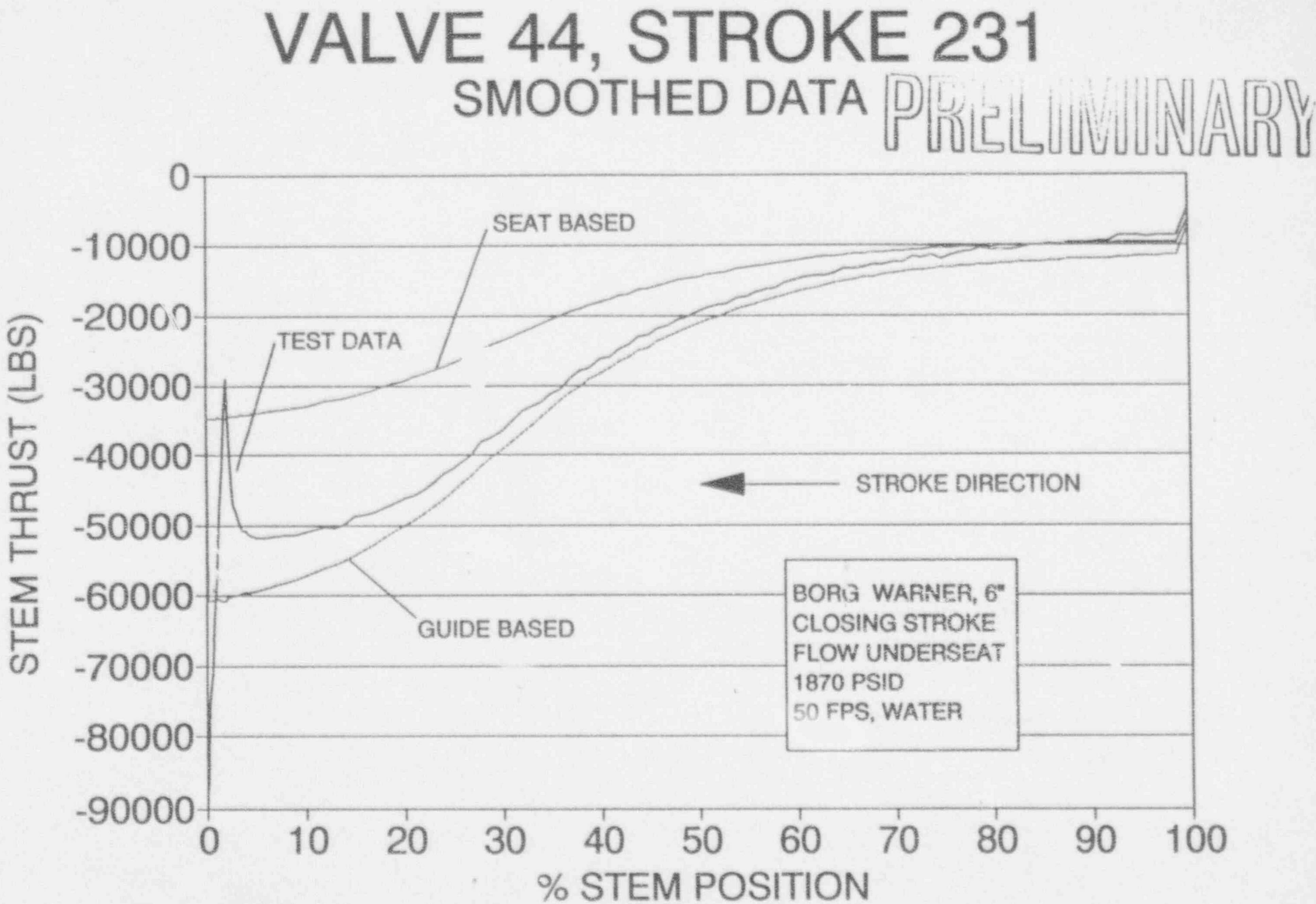
PRELIMINARY




VALVE 44, STROKE 209
SMOOTHED DATA
PRELIMINARY
STEM THRUST (LBS)
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
SEAT BASED
TEST DATA
GUIDE BASED
STROKE DIRECTION
BORG WARNER, 6"
CLOSING STROKE
FLOW UNDERSEAT
1760 PSID
15 FPS, WATER
0
5
10
15
20
25
30
35
40
% STEM POSITION

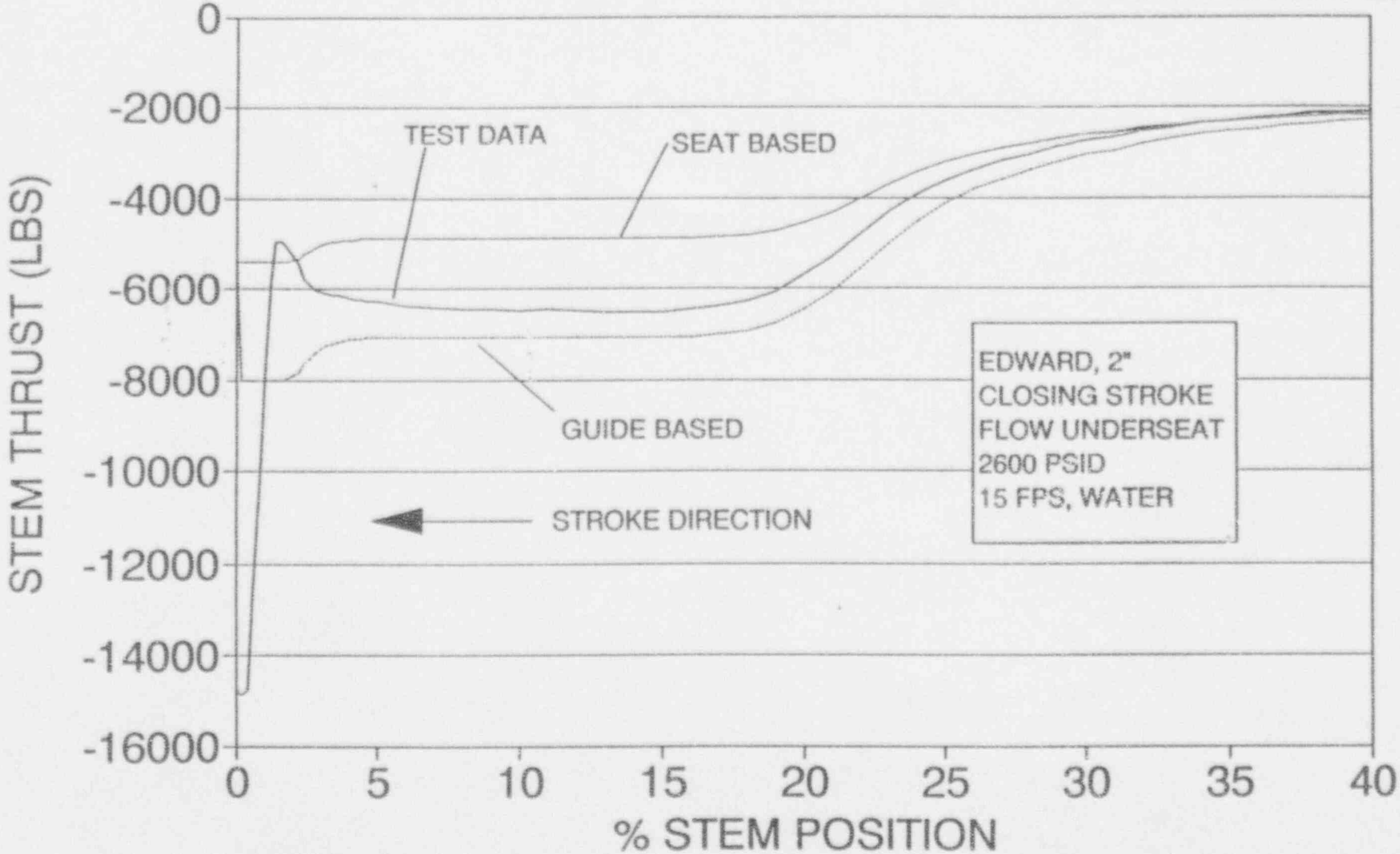
VALVE 44, STROKE 209
SMOOTHED DATA - TRF MINIMIZED




VALVE 44, STROKE 231
SMOOTHED DATA
PRELIMINARY
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
STEM THRUST (LBS)
SEAT BASED
TEST DATA
GUIDE BASED
STROKE DIRECTION
BORG WARNER, 6"
CLOSING STROKE
FLOW UNDERSEAT
1870 PSID
50 FPS, WATER
0
10
20
30
40
50
60
70
80
90
100
% STEM POSITION

VALVE 48, STROKE 084

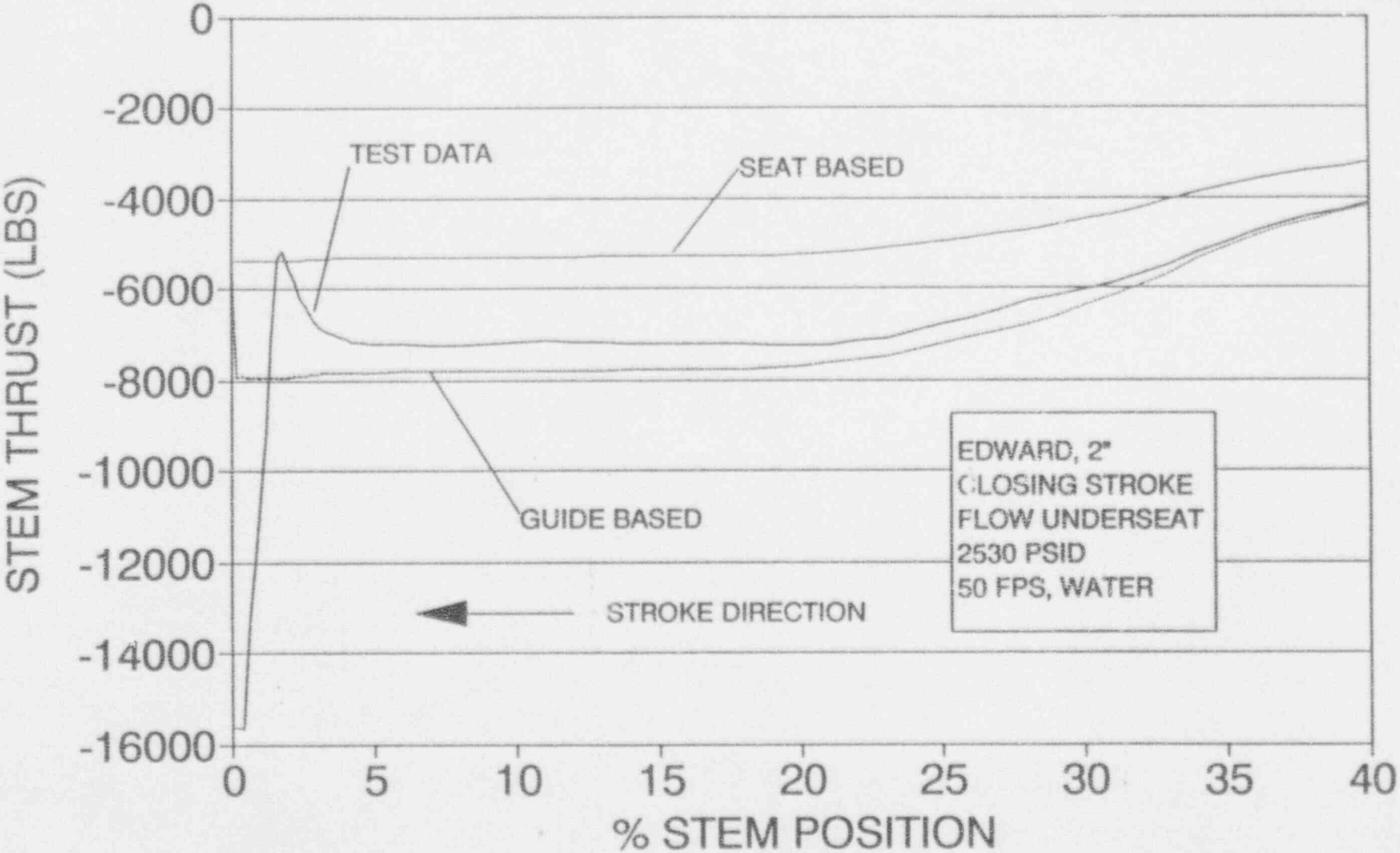
SMOOTHED DATA PRELIMINARY



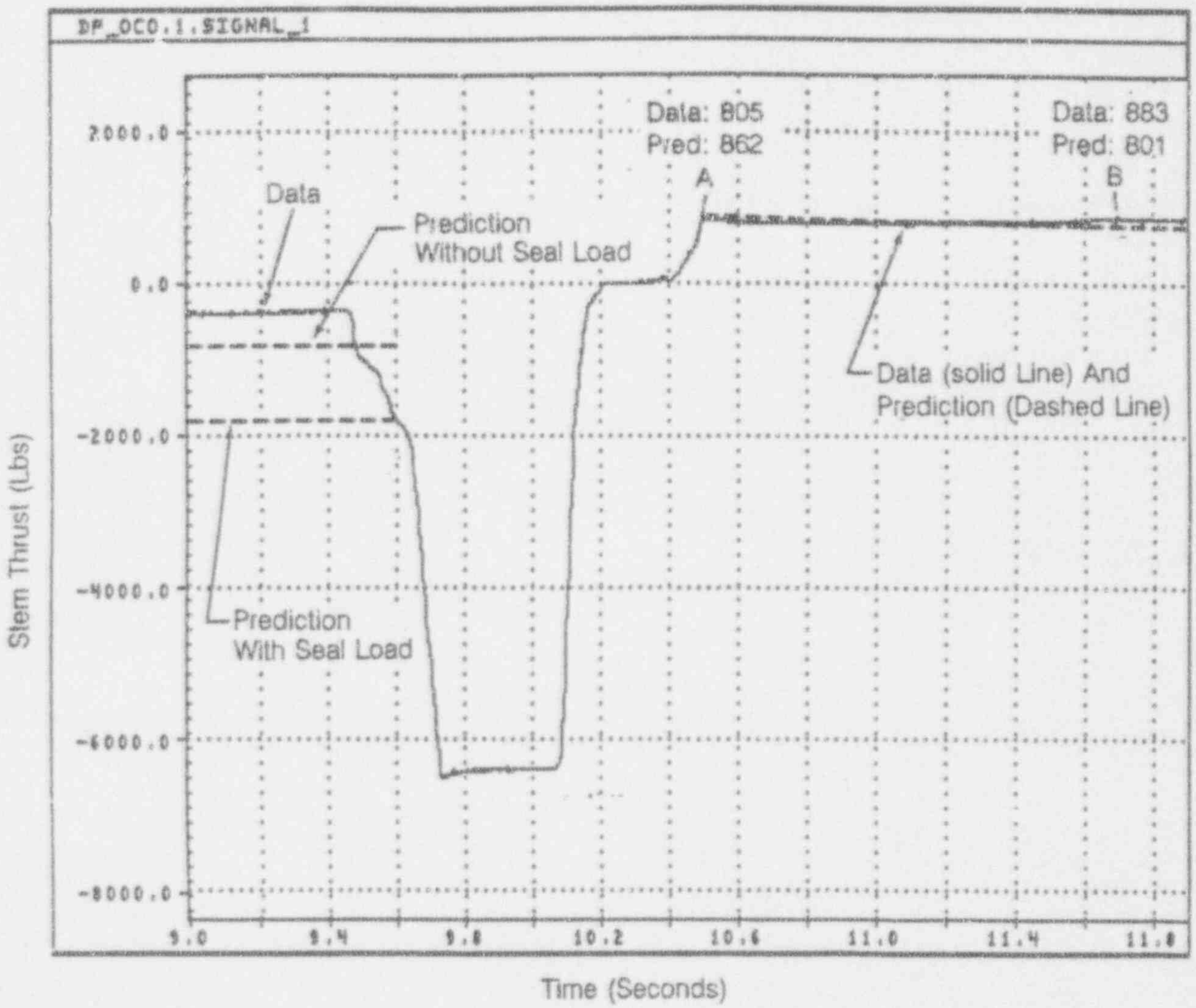
VALVE 48, STROKE 107

SMOOTHED DATA

PRELIMINARY



PRELIMINARY



Measured And Calculated Thrust For DP Closure And Opening
Valve 2-FV-4772-2 Fisher 4" Globe Valve

F-140-82-14
10/4/93

Summary of Comparison — Flashing Water Blowdown

- Stem thrust exceeds prediction at 50% to 80% stroke
  - Valve bore damage indicates high disk side load
  - Vendor tests indicated low disk side load
  - Possible influence of foreign material
- Stem torque increased during last half of stroke
  - Torque switch tripped at ~65% stroke and did not untrip when thrust reduced
  - Stem damage indicates contact at gland follower

PRELIMINARY

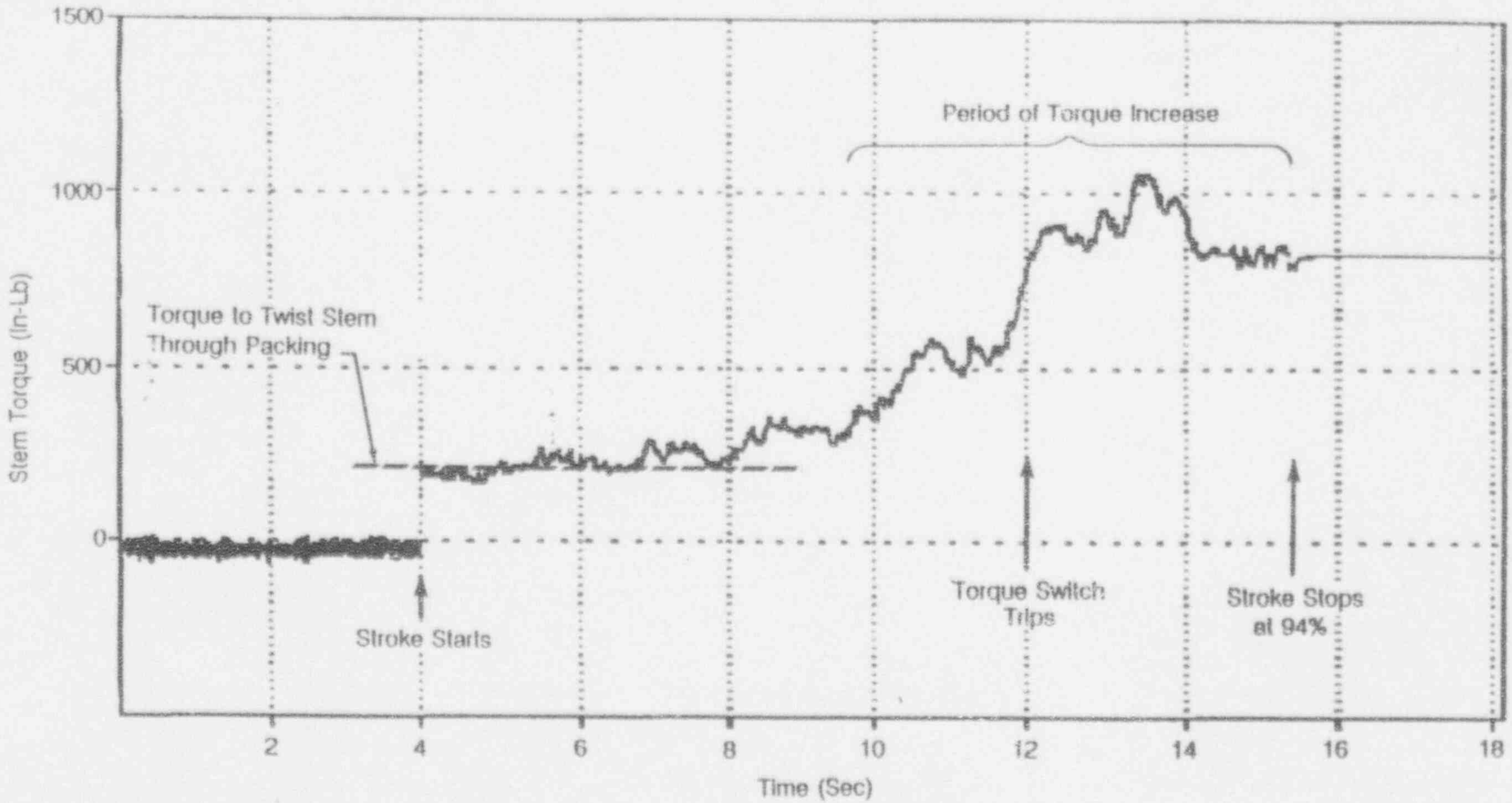


Figure 2. Valve 48 Stem Torque Time History (Measured Between Threaded Region and Packing) for Closure Against 2500 psi Blowdown

F-140-82-10
8/16/93

PRELIMINARY

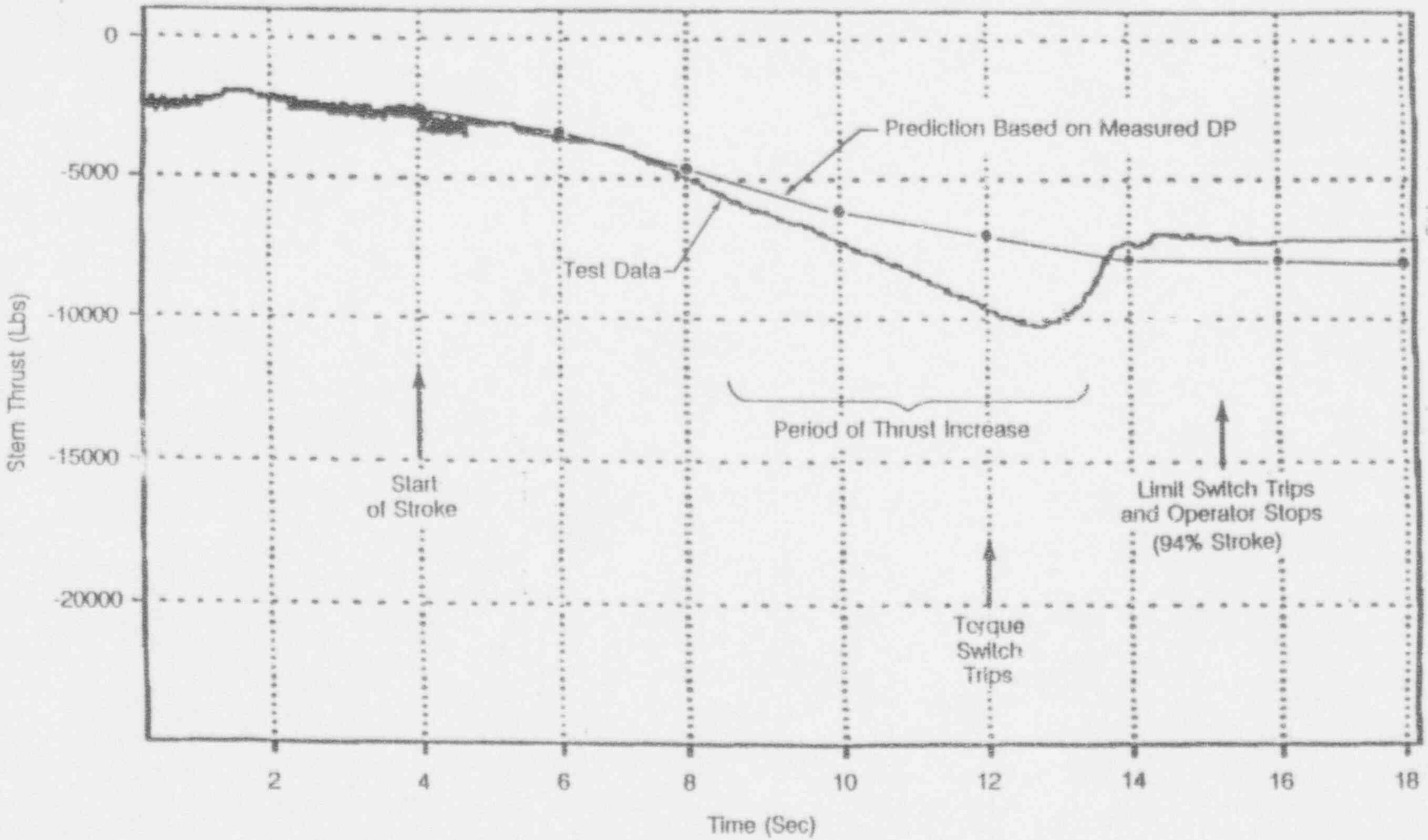


Figure 1. Valve 48 Stem Thrust Time History for Closure Against 2500 psi Blowdown

Determination of Disk-to-Seat Sliding Friction Coefficient from In Situ Testing

EPRI MOV Performance Prediction Program
Meeting with NRC
October 6, 1993

Background
(Continued)

- Gate valve tests (flow loop, in situ, etc.) indicate a wide range of disk-to-seat μ can occur at low temperature. Possible ways to account for specific valve conditions (e.g., stroke history) are being investigated.

Disk-to-Seat Friction Coefficient--Prediction by Method

- Friction Coefficient = f (temperature, contact stress).
- In some cases, method will provide significantly conservative value.
- Largest potential conservatism is at low temperature, particularly at low contact stress. This is where user input methods are likely to be most beneficial.

Disk-to-Seat Friction Coefficient--User Input

- Based on test of specific gate valve
  - DP test with flow (open or close)
  - Hydropump DP (open only)
  - Wedging/unwedging static test

General Guidance for Tests to Develop User Specified Friction Coefficient

- Perform test with design basis fluid in pipes (prob. water).

  Basis--Fluid variation difficult to account for.

- Perform test at T $\leq$ design basis T
  DP $\leq$ design basis DP

  Basis--Friction coefficient decreases with increasing temperature and contact stress.

General Guidance for Tests to Develop User Specified Friction Coefficient (Continued)

- For DP tests, measurement of stem thrust and DP required.

  Basis--Stem thrust and DP are needed to calculate friction coefficient.

- Measurement or knowledge of upstream pressure required.

  Basis--Data evaluation requires upstream pressure.

DP Test with Flow

- Time history measurement of DP required for closure stroke.

  Basis--DP under flow conditions changes rapidly at closure and can undershoot or overshoot "steady" DP.

DP Test with Flow
(Continued)

- Time history measurement of DP probably not required for opening stroke, but might be in some cases.

  Basis--DP is typically steady prior to flow initiation.

  Exceptions:
  1. Systems with multiple valve actuation can show DP changes around flow initiation.
  2. High flow systems may show thrust increases after flow initiation.

Test with Hydropump DP Conditions

- Open stroke only.
- Upstream pressure and DP need to be held steady until flow initiation.
- "Single-point" measurement of upstream pressure and DP required.

Evaluation of DP Tests (Hydropump and Flow)

- Identify portion of test with disk-to-seat sliding
  - Initial part of open stroke after cracking
  - Final part of closure stroke before wedging
- Determine DP thrust component (properly correct for running and stem rejection load).

Evaluation of DP Tests (Hydropump and Flow) (Continued)

- Determine μ from EPRI/NMAC Application Guide equation

  Inputs: DP
  Area based on mean seating diameter (A)
  Disk wedge half-angle (Θ)
  Measured DP thrust (F_{DP})

$$\mu = F_{DP} \cos \Theta / (DP * A \pm F_{DP} \sin \Theta)$$

  "–" for opening
  "+" for closing

- Evaluate uncertainty in μ based on measurement accuracies.

Guidance for Static Wedging/Unwedging Test

- No or minimal line pressurization (specific criteria to be developed).
- Close and re-open valve with minimal delay.
- No pressure or DP perturbations between closing and re-opening.
- Procedures for evaluation being developed.

Implementation of User-Input Disk-to-Seat Friction Coefficient

- Determine user-input μ based on test results and uncertainty (bounding).
- Perform methodology analysis of valve under "tested" condition with user-input μ
  - Confirm predicted thrust shows favorable, bounding agreement with measured result
  - Confirm predicted thrust shows behavior limited by disk-to-seat sliding in region where test data used

Implementation of User-Input Disk-to-Seat Friction Coefficient (Continued)

- Perform methodology analysis of valve under design basis conditions with same user-input μ
  - Effects of flow loading, disk contact modes, and potential material damage covered by calculations.

BUTTERFLY VALVE MODEL STATUS

EPRI Project RP3433-31

Contractor

KALSI ENGINEERING, INC.

EPRI MOV Performance Prediction Program Review

NRC Offices

Rockville, Maryland
October 6 - 7, 1993

Objective

Provide validated butterfly valve methodology to cover the following range of applicability:

- AWWA and ANSI high performance designs
- Sizes up to 72 inches
- Symmetric, single offset, and double offset disks
- Compressible (air, steam) and incompressible (water) flow
- Interference type and pressure energized seats
- Solid bronze bearings, or stainless steel bearings with Teflon lining
- Upstream elbows

Model Validation

Various features of the EPRI butterfly model are being validated by test data from

- Wyle Laboratories
- Kalsi Engineering, Inc.
- Duke Power/USU Water Research Lab
- NRC/INEL containment purge valve test program
- Utilities: Enhanced in situ testing

(See validation matrix for details)

Table 1
Validation Matrix for Butterfly Valve Performance Prediction Methodology (6/30/93) under EPRI RP3433-16 / MPR RP 140-91

	Item	Valve Description	Disk Design	Media	Source	No. of Valves	ΔP, psi	Max Q, gpm	Max V ft/sec	Test Description: Seating/Unseating	Flow: w/o Elbow	Flow: w/Elbow
	1	6" model, t/d = 0.15	S	Water	KEI	1	88	2,700	30	No	Yes	No
	2	6" model, t/d = 0.25	S	Water	KEI	1	88	2,700	30	No	Yes	Yes
	3	6" model, t/d = 0.15	SO	Water	KEI	1	88	2,700	30	No	Yes	No
	4	6" model, t/d = 0.25	SO	Water	KEI	1	[illegible]	2,700	30	No	Yes	Yes
	5	6" model, t/d = 0.35	SO	Water	KEI	1	88	2,700	30	No	Yes	No
	6	6" model of 42" Posi-Seal	SO	Water	KEI	1	88	2,700	30	No	Yes	No
	7	6" Henry Pratt (EPRI #54)	S	Water	Wyle	1	50, 100, 150	1,500	15	Yes	Yes	No
	8	6" Henry Pratt (EPRI #55)	SO	Water	Wyle	1	50, 100, 150	1,500	15	Yes	Yes	No
	9	42" Posi-Seal	SO	Water	Duke/USU	1	8	46,000	11	Yes	Yes	No
	10	10" Posi-Seal (blind)	SO	Water	Duke/USU	1	100	4,700	19	Yes	Yes	Yes
	11	18" Fisher (blind)	SO	Water	TU	1	130	8,000	11	Yes	Yes	No
	12	24" Fisher	SO	Water	TU	1	?	0	0	Yes	No	No
	13	24" Fisher	SO	Water	TU	1	85	15,000	12	No	No	Yes
	14	10" Henry Pratt	SO	Water	APS	1	120	3,815	16	Yes	No	Yes
(1)	15	18" Henry Pratt	S	Water	APS	1	51	16,300	23	Yes	No	Yes
(1)	16	24" Henry Pratt	S	Water	APS	1	51	16,300	13	Yes	Yes	No
(2)	17	24" Posi-Seal	SO	Water	CECo	1	?	?	?	Yes	?	?
(2)	18	8" Posi-Seal	SO	Water	TVA	1	?	?	?	Yes	?	?
(2)	19	12" Posi-Seal	SO	Water	TVA	1	?	?	?	Yes	?	?
(3)	20	8" Allis Chalmers	SO	Nitrogen	INEL	1	5 → 60	N/A		Yes*	Yes	Yes
(3)	21	8" Henry Pratt	SO	Nitrogen	INEL	1	5 → 60	N/A		Yes*	Yes	Yes
(3)	23	24" Henry Pratt	SO	Nitrogen	INEL	1	5 → 60	N/A		Yes*	Yes	Yes
		Total Number of Valves				22						

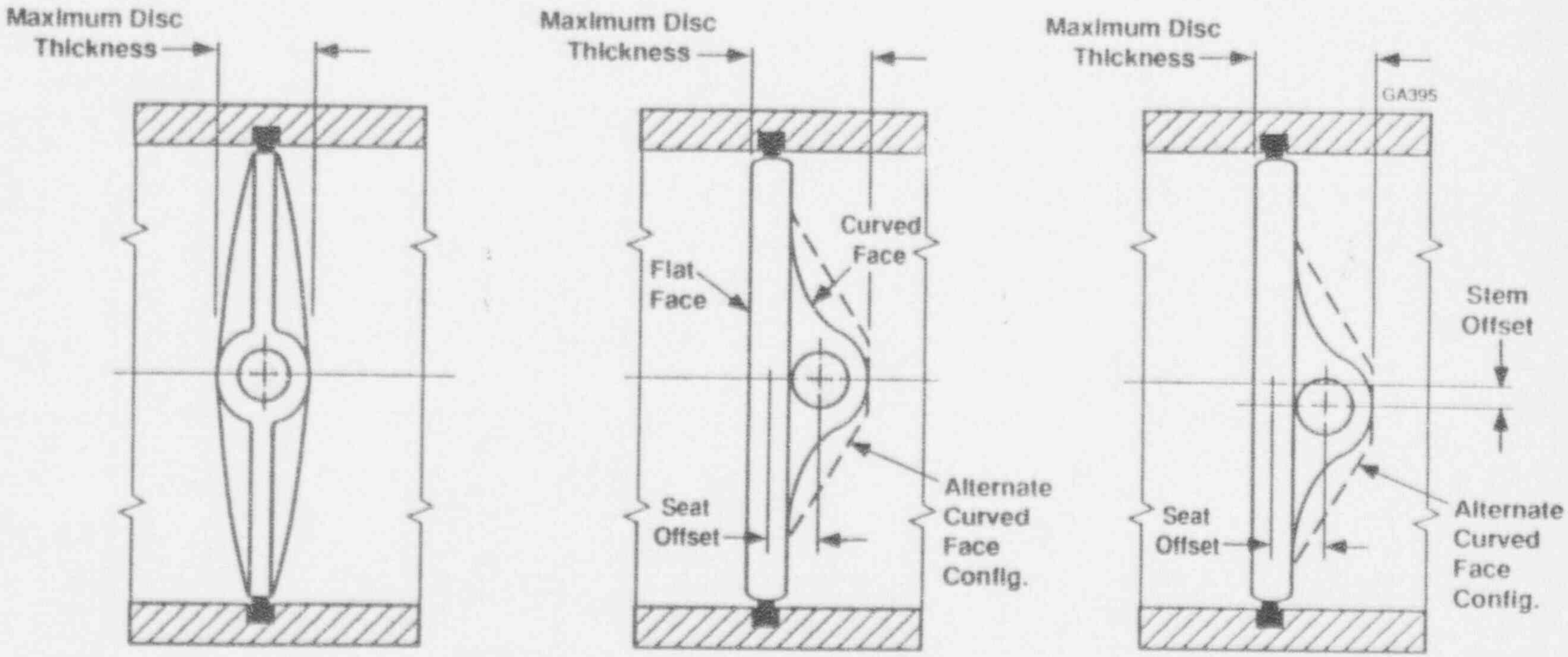
Notes:
1 These valves are operated in tandem and have no ΔP or Q data at intermediate disk positions. Data may be acceptable for assessment of BFM and SFM. Substitute valves with ΔP data are being sought.
2 Substitute valves are being sought because data availability may not meet the program schedule.
3 Unpublished data to be obtained from INEL.

Key Technical Areas

- Effect of disk shape and disk aspect ratio on hydrodynamic torque
- Validation data for scaling
- Effect of upstream elbow orientation, proximity, and disk direction of rotation on dynamic torque
- Approach to address seat and bearing degradation

Approach

- Performed industry survey to identify disk shapes and aspect ratios to be tested
- Designed and fabricated butterfly valve test specimens
- Performed matrix of 37 tests to cover disk shape variations and upstream elbow effects
- Recommended an approach to identify seat and bearing degradation by in situ testing

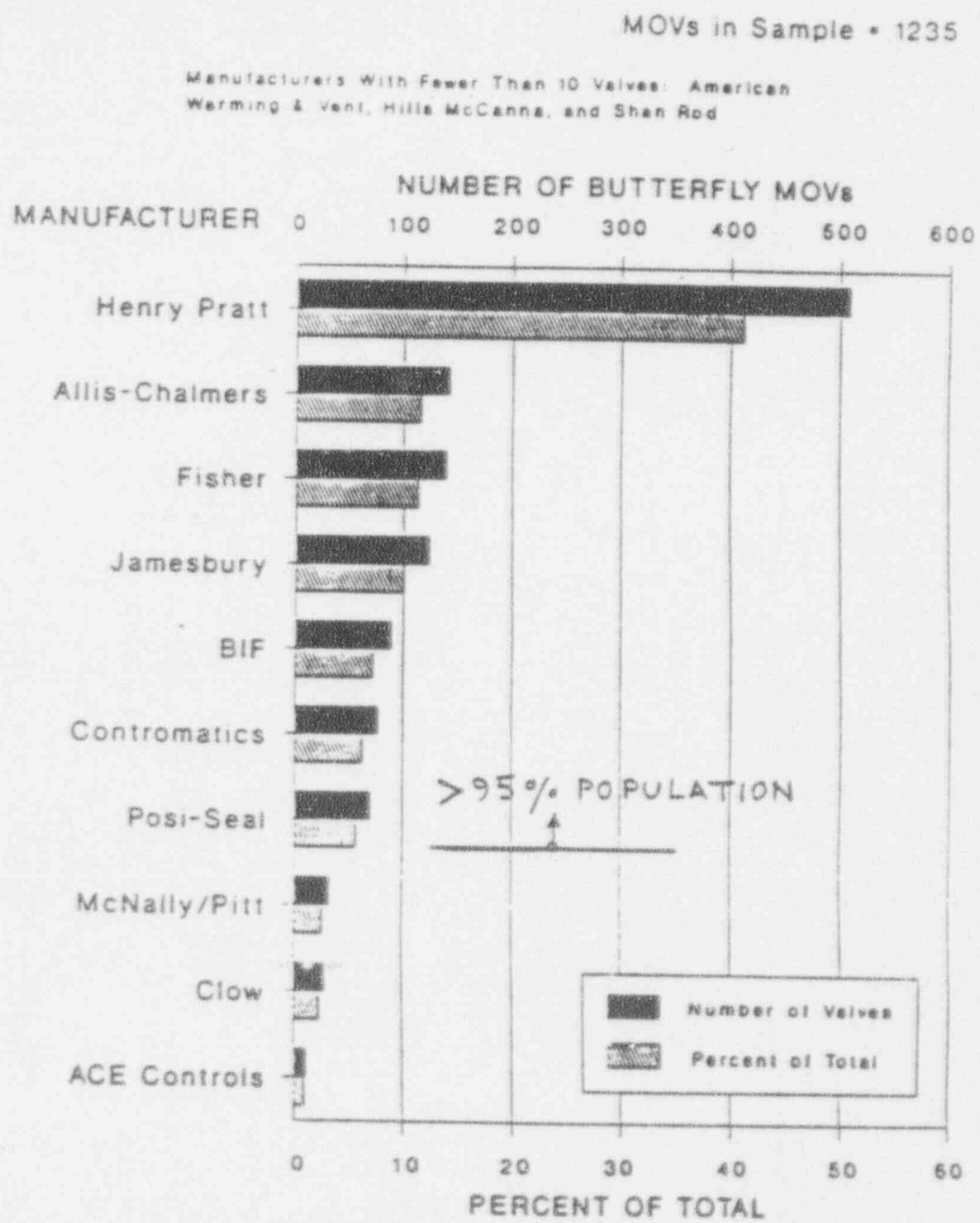


(a) Symmetric Disc Design

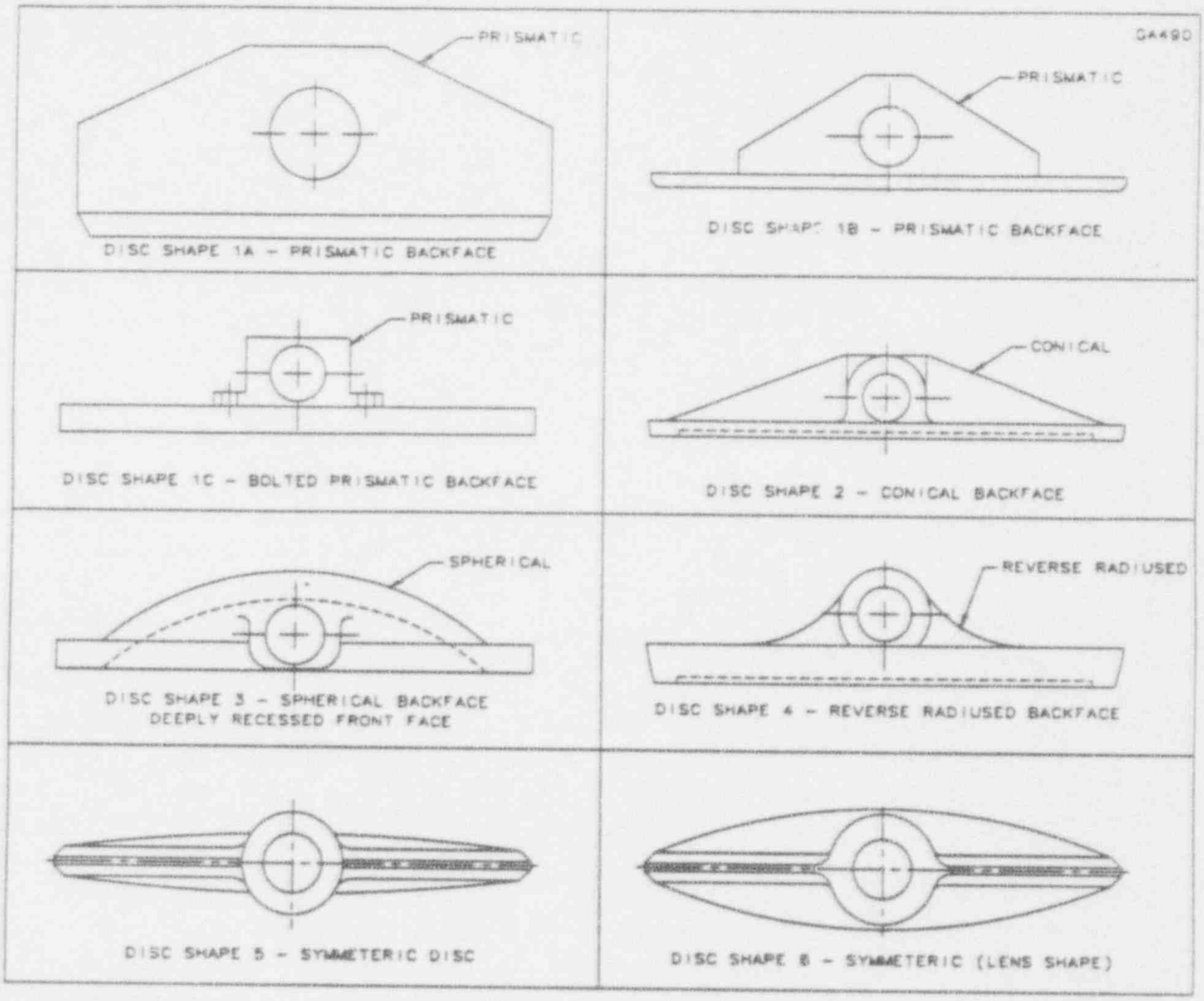
(b) Single Offset Design

(c) Double Offset Design

Key Features of Symmetric, Single Offset, and Double Offset Butterfly Disk Designs



Motor Operated Butterfly Valves
Breakdown By Manufacturer



Disk Shape Variations

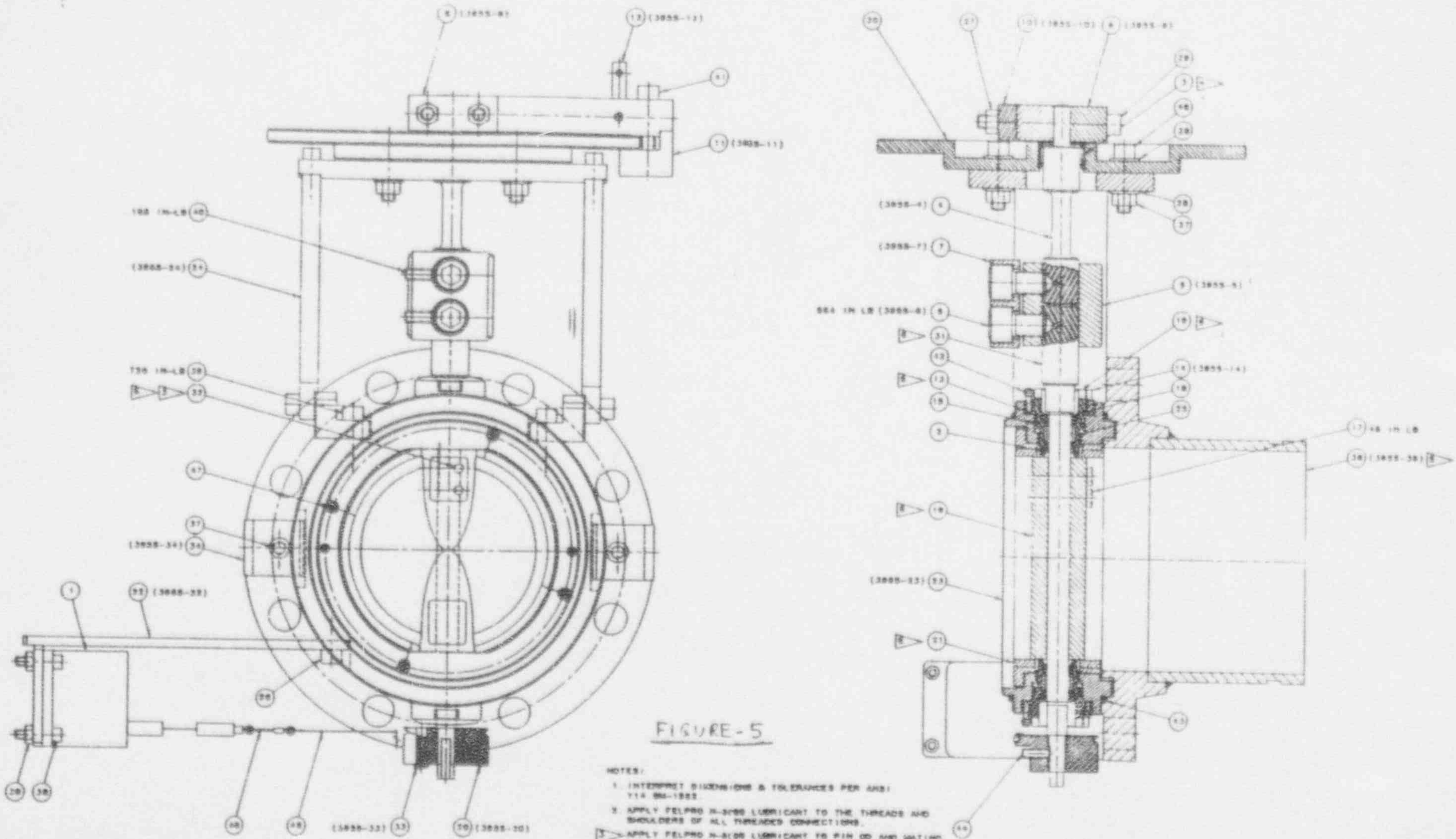


FIGURE-5

NOTES:

1. INTERPRET DIMENSIONS & TOLERANCES PER ANSI Y14.5M-1982.
2. APPLY FELPRO N-5000 LUBRICANT TO THE THREADS AND SHOULDERS OF ALL THREADED CONNECTIONS.
3. APPLY FELPRO N-5000 LUBRICANT TO PIN OD AND MATING SURFACES OF DISC AND SHAFT. APPLY 1500 LBS TO INSERT PIN INTO DISC. SUPPORT ASSEMBLY WITH CRADLE PN 3855-38 AND BASEPLATE PN 3855-37 DURING PIN INSERTION. CUT PIN FLUSH WITH DISC AND JAM NUT AFTER ASSEMBLY.
4. USE BEARING INSTALLATION TOOL PN 3855-48 WHEN INSTALLING ITEM 3 INTO ITEM 30.
5. TWO OF ITEM 36 ARE USED BUT ONLY 1 IS SHOWN.
6. SIX DIFFERENT BUTTERFLY VALVE TEST FIXTURE ASSEMBLIES CAN BE ACHIEVED BY SUBSTITUTION OF ITEMS 13, 18, 19, 21, 31 AND 32 AS DOCUMENTED IN THE ARRANGEMENT TABLE. ARRANGEMENT NUMBER 2 IS ILLUSTRATED.

6 ARRANGEMENT TABLE

VALVE ASSEMBLY NUMBER	DISK SHAPE	ASPECT RATIO	ITEM 19 DISK PN	ITEM 21 BODY LINER PN	ITEM 31 STEM PN	ITEM 18 BEARING HOUSING PN	ITEM 13 BEARING ABUTMENT PN	ITEM 32 PIN PN	ASSEMBLE USING CRADLE PN
1	SYMMETRIC	.15	3855-17	3855-21	3855-74	3855-18	3855-13	3855-80	3855-40
2 (SHOWN)	SYMMETRIC	.35	3855-18	3855-31	3855-74	3855-18	3855-13	3855-32	3855-38
3	NON-SYMMETRIC	.15	3855-81	3855-86	3855-74	3855-83	3855-84	3855-80	3855-15
4	NON-SYMMETRIC	.35	3855-59	3855-87	3855-74	3855-18	3855-13	3855-32	3855-15
5	NON-SYMMETRIC	.35	3855-57	3855-85	3855-74	3855-18	3855-13	3855-88	3855-15
6	NON-SYMMETRIC 1/3 SCALE DOWN	.17	3855-71	3855-72	3855-76	3855-83	3855-84	3855-89	3855-15

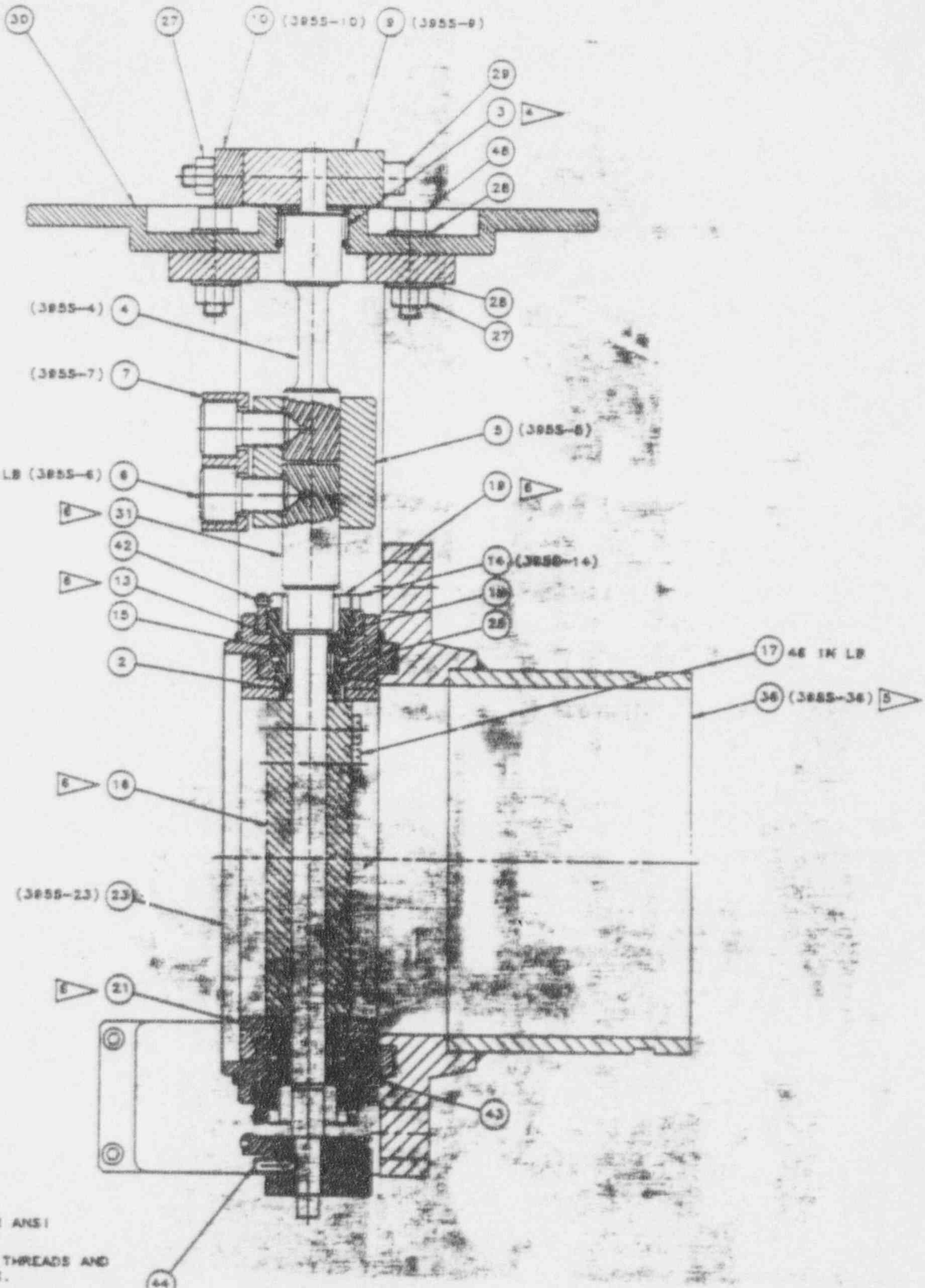
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± DECIMALS ± ANGLES ±

APPROVALS	DATE
DRAWN DIETLE	5-28-83
CHECKED	
ISSUED	

KALSI ENGINEERING INC
DESIGN & ANALYSIS CONSULTANTS

BUTTERFLY VALVE
TEST FIXTURE

SIZE D | DWG NO 3955 | SCALE 1:1 | SHEET 1 OF 4



35-11)

5

NS & TOLERANCES PER ANSI

D LUBRICANT TO THE THREADS AND
HREADED CONNECTIONS.

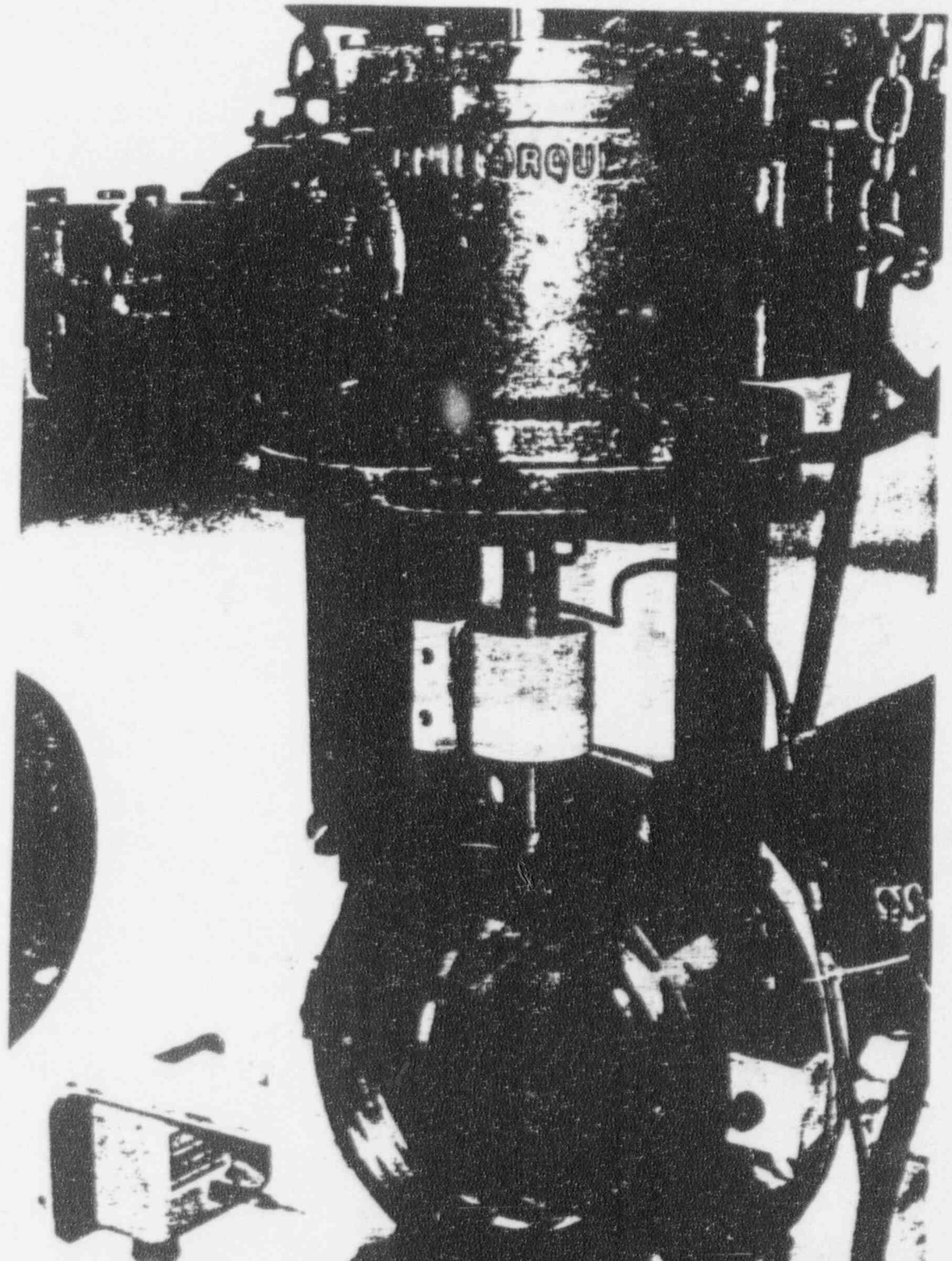
D LUBRICANT TO PIN OD AND MATING
ND SHAFT. APPLY 1560 LBS TO INSERT
PORT ASSEMBLY WITH CRADLE PN 3955-38
955-37 DURING PIN INSERTION.
DISC AND JAM NUT AFTER ASSEMBLY.

LATION TOOL PN 3955-46 WHEN
INTO ITEM 30.

USED BUT ONLY 1 IS SHOWN.

ERFLY VALVE TEST FIXTURE ASSEMBLIES CAN
STITUTION OF ITEMS 13, 16, 19, 21, 31
ED IN THE ARRANGEMENT TABLE. ARRANGEMENT
RATED.

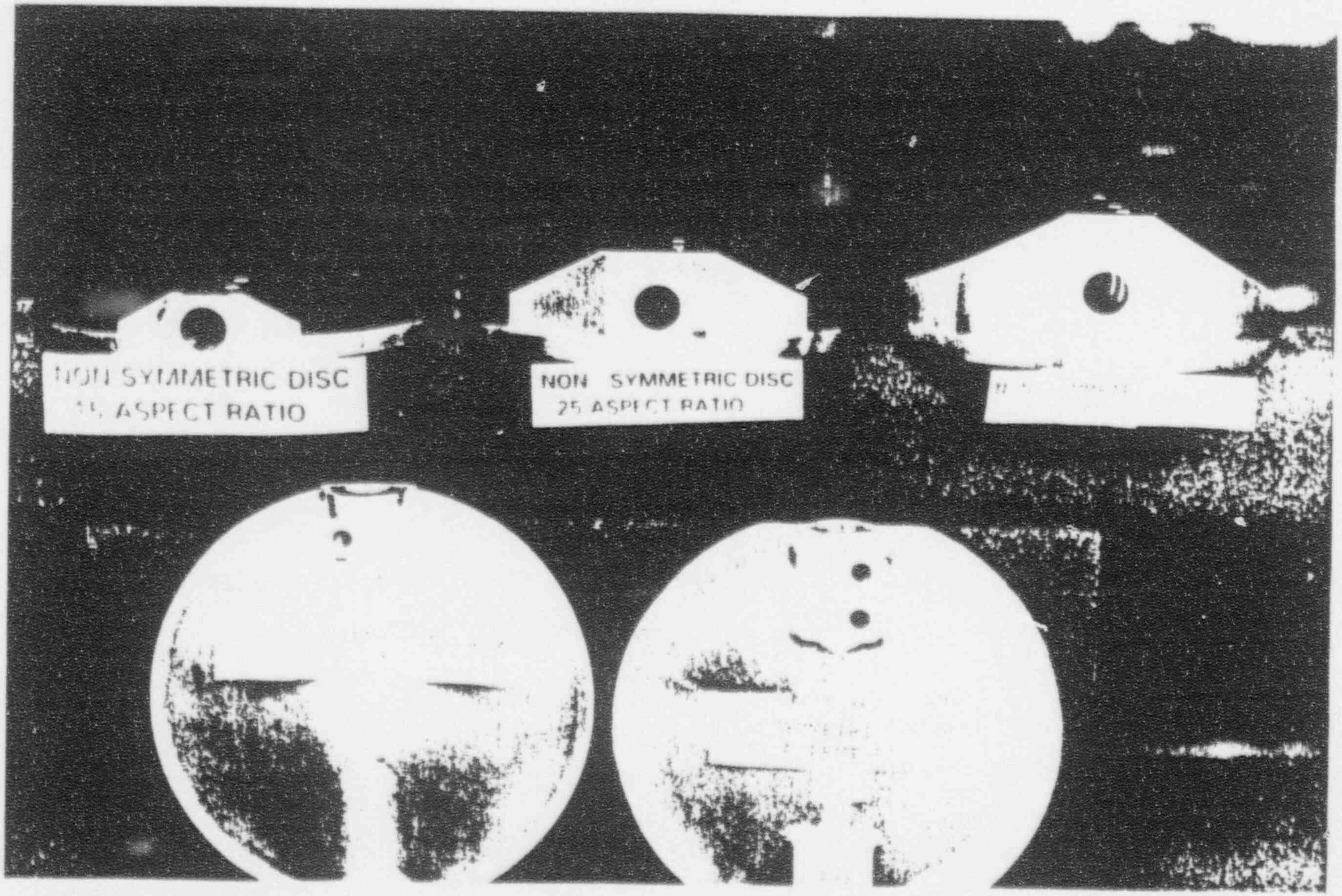
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ± 1°	APPROVALS	DATE	KALSI ENGINEERING INC. DESIGN & ANALYSIS CONSULTANTS
MATERIAL:	DRAWN: DIETLE	5-26-83	BUTTERFLY VALVE TEST FIXTURE
	CHECKED:		
FINISH:	ISSUED:		SIZE D · DWG. NO. 3955 · REV.
DO NOT SCALE DRAWING			SCALE: 3:4 · SHEET 1 OF 4

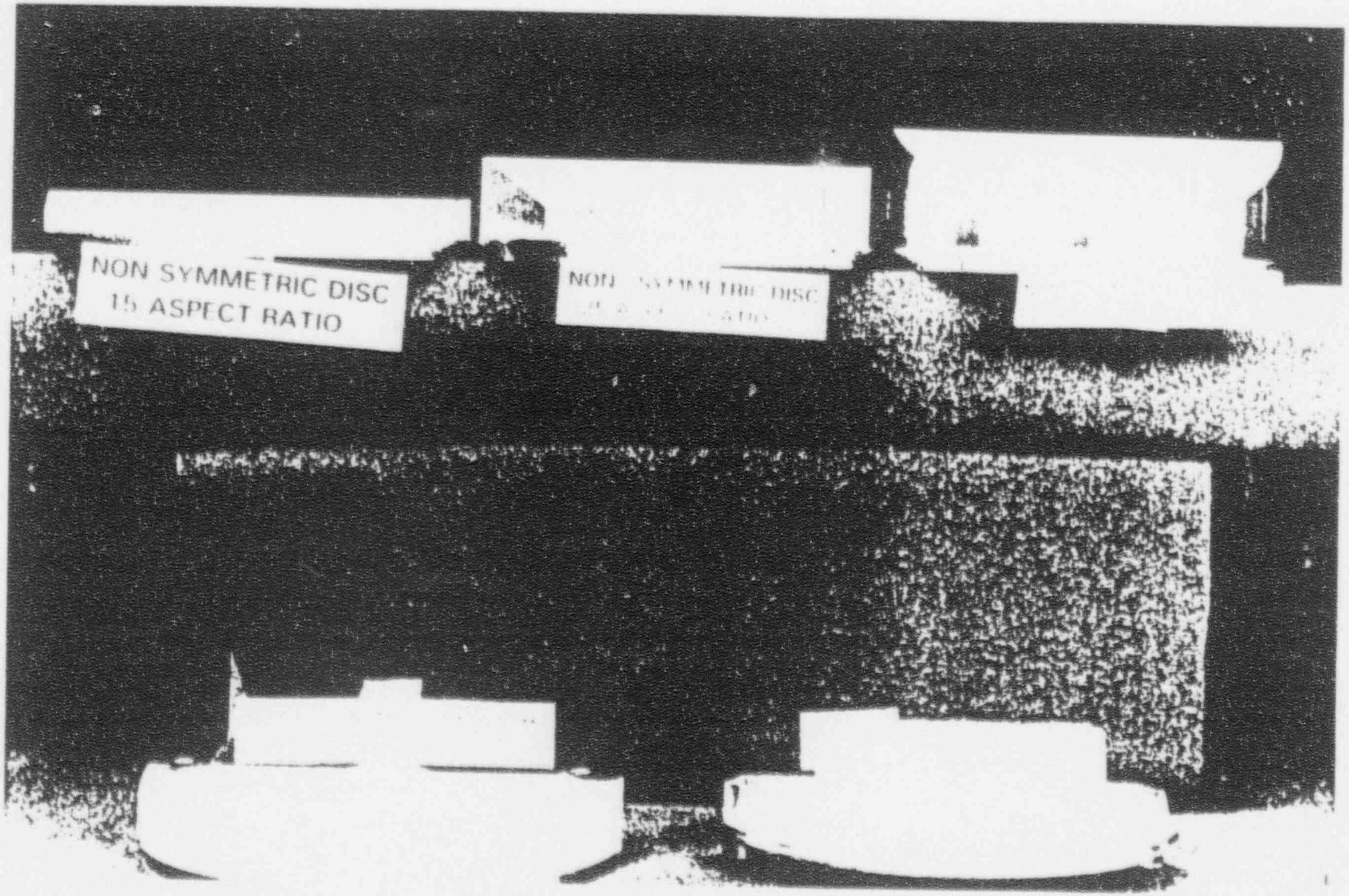


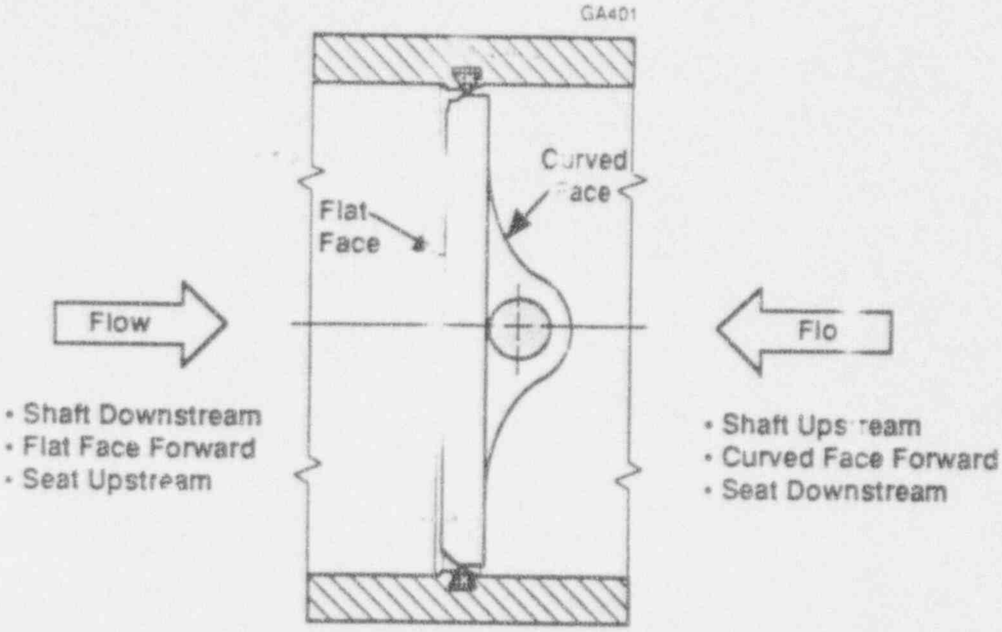
Disk Shape	*Aspect Ratio*	*Number of Valves*
Nonsymmetric, prismatic back face	**0.15, 0.25, 0.35***	**3**
Symmetric	**0.15, 0.25***	**2**
Nonsymmetric, conical back face (scaled model of 42" Posi-Seal)	**0.17**	**1**
Total number of disk geometries tested		**6**

* **KEI data supplemented by .47 aspect ratio data for nonsymmetric and .31 aspect ratio data for symmetric disk valves tested at Wyle Laboratories**

Matrix of Butterfly Valve Geometries Tested at KEI


NON SYMMETRIC DISC
ASPECT RATIO
NON SYMMETRIC DISC
25 ASPECT RATIO


NON SYMMETRIC DISC
15 ASPECT RATIO

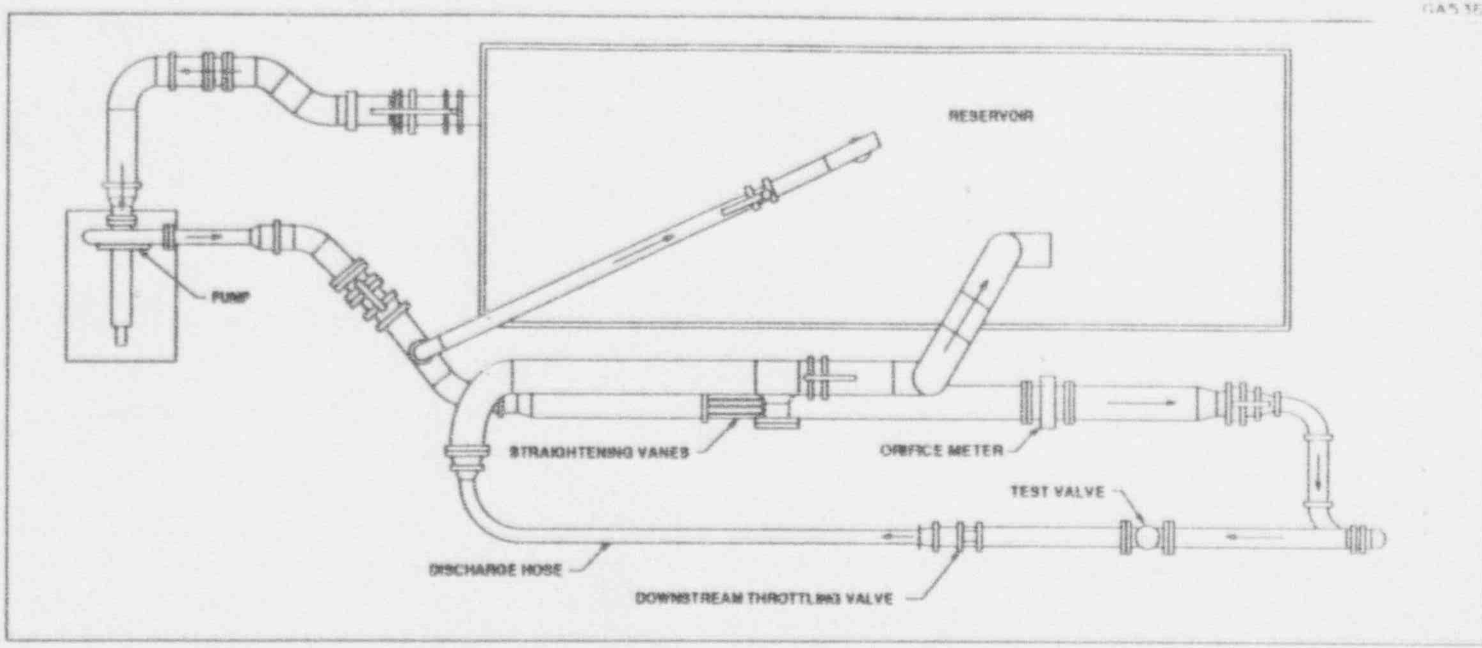


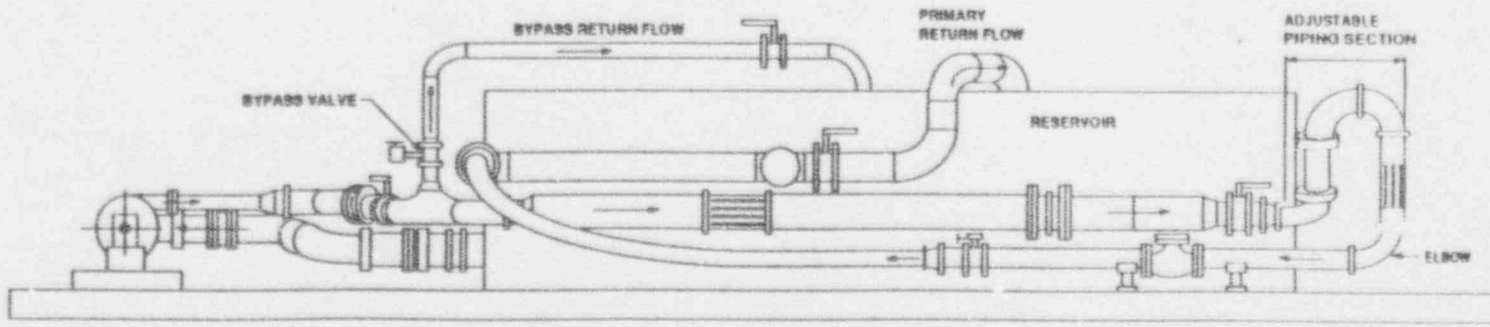
Commonly Used Terminology to Identify Flow Direction

Test Group	Disk Shape and Orientation	Aspect Ratio	Elbow Config	Elbow Proximity	Flow Range
1	Symmetric	0.15 0.25	N/A	> 20D	30, 60, 90 psi ΔP /15 fps 90 psi ΔP/30 fps
2	Nonsymmetric: shaft upstream	0.15 0.25 0.35	N/A	>20D	"
3	Nonsymmetric: shaft downstream	0.15 0.25 0.35	N/A	> 20D	"
4	42' scale model shaft upstream	0.17	N/A	> 20D	"
5	42' scale model shaft downstream	0.17	N/A	> 20D	"

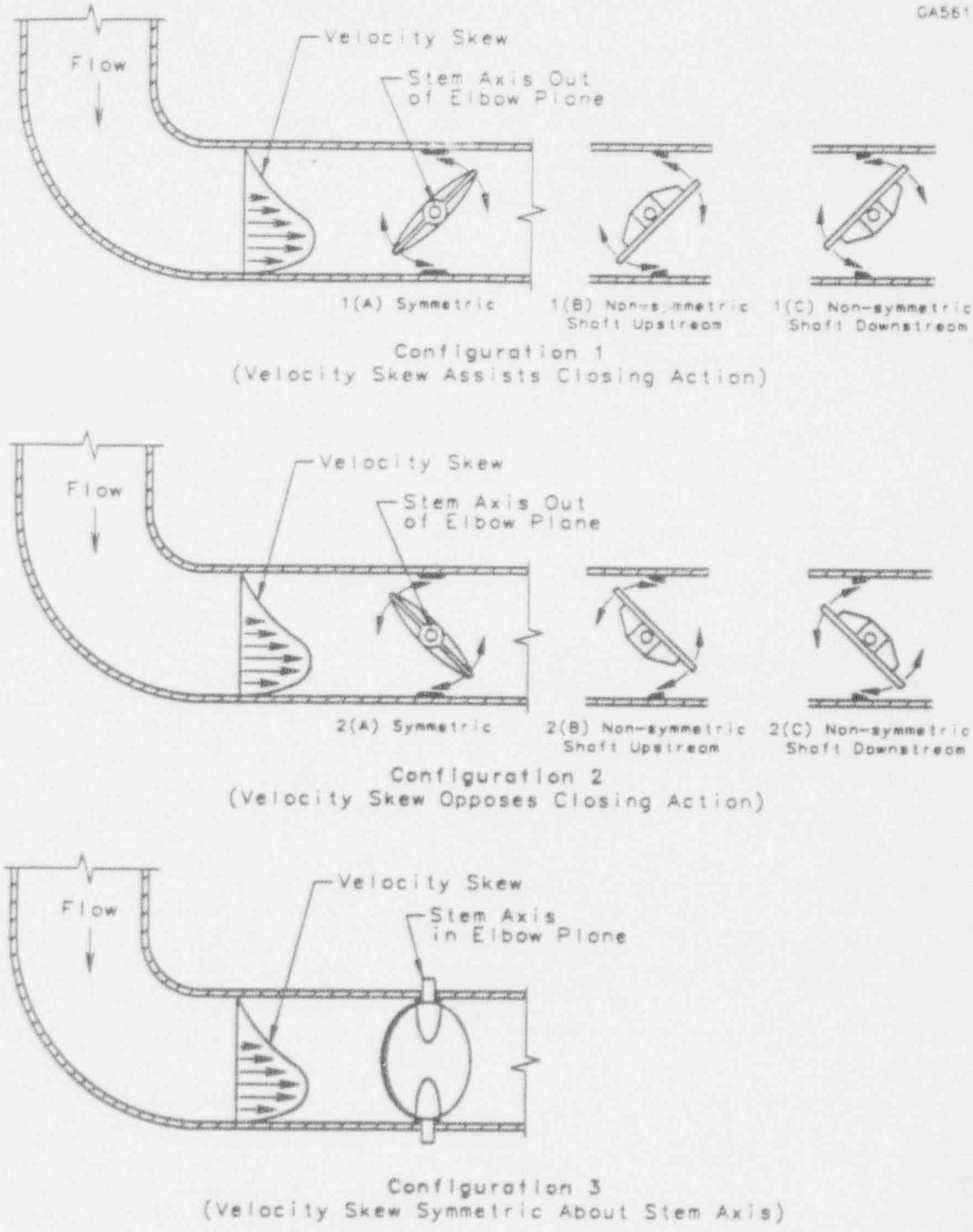
Disk Shape Variations and Scale Model Verification Test Matrix

EPRI Butterfly Valve Model/Testing





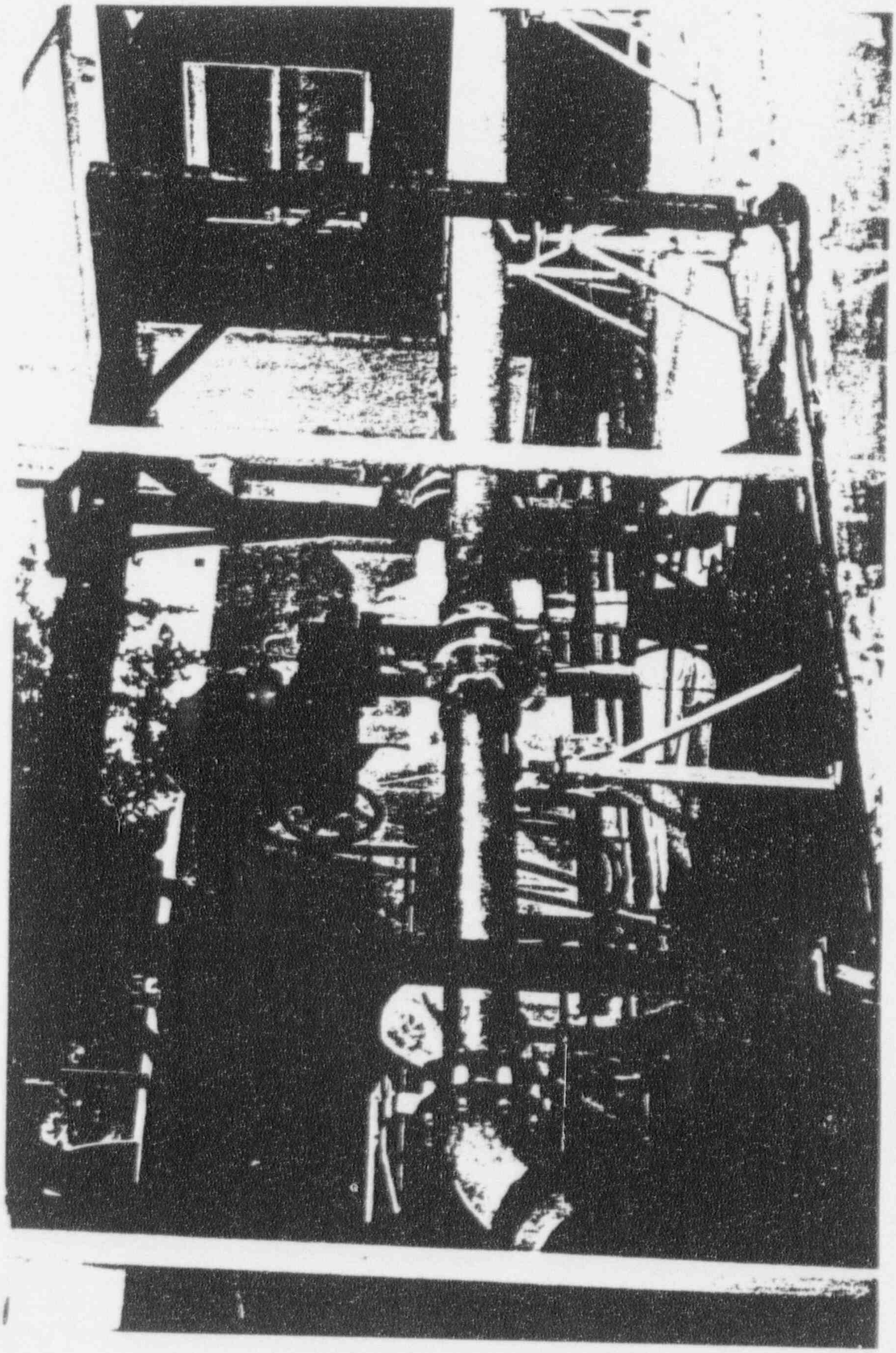
Kalsi Engineering Flow Test Facility

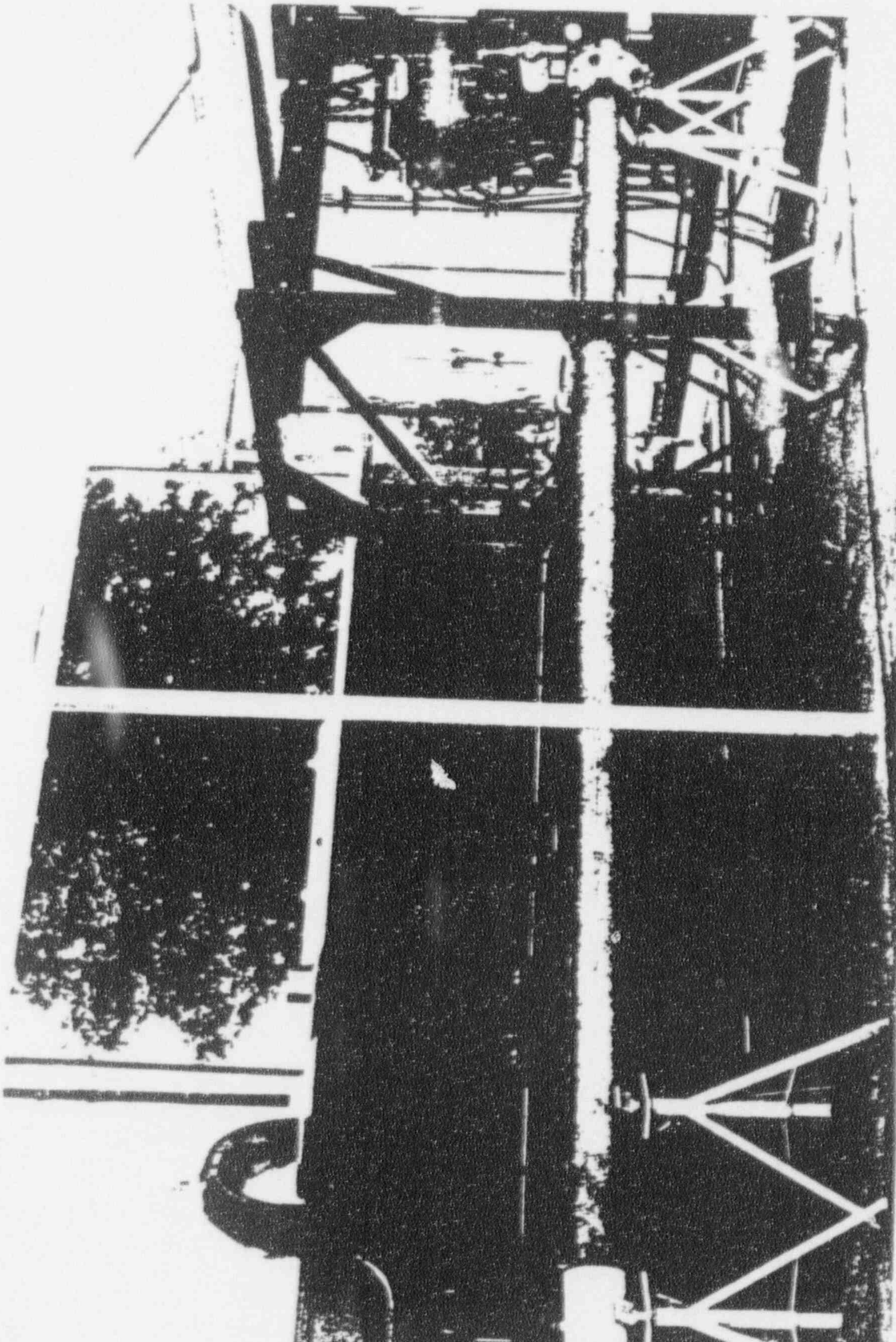


Upstream Elbow Configurations to Identify Stem Orientation and Disk Opening Direction

Test Group	Disk Shape and Orientation	Aspect Ratio	Elbow Config	Elbow Prox	Flow Range
6	Symmetric	0.25	Configuration 1	0D 3D 7D	30, 60, 90 psi/15 fps 90 psi/30 fps
7	"	0.25	Configuration 2	0D 3D 7D	"
8	"	0.25	Configuration 3	0D 3D 7D	"
9	Nonsymmetric shaft upstream	0.25	Configuration 1	0D 3D 7D	"
10	"	0.25	Configuration 2	0D 3D 7D	"
11	"	0.25	Configuration 3	0D 3D 7D	"
12	Nonsymmetric shaft downstream	0.25	Configuration 1	0D 3D 7D	"
13	"	0.25	Configuration 2	0D 3D 7D	"
14	"	0.25	Configuration 3	0D 3D 7D	"

Upstream Elbow Test Matrix





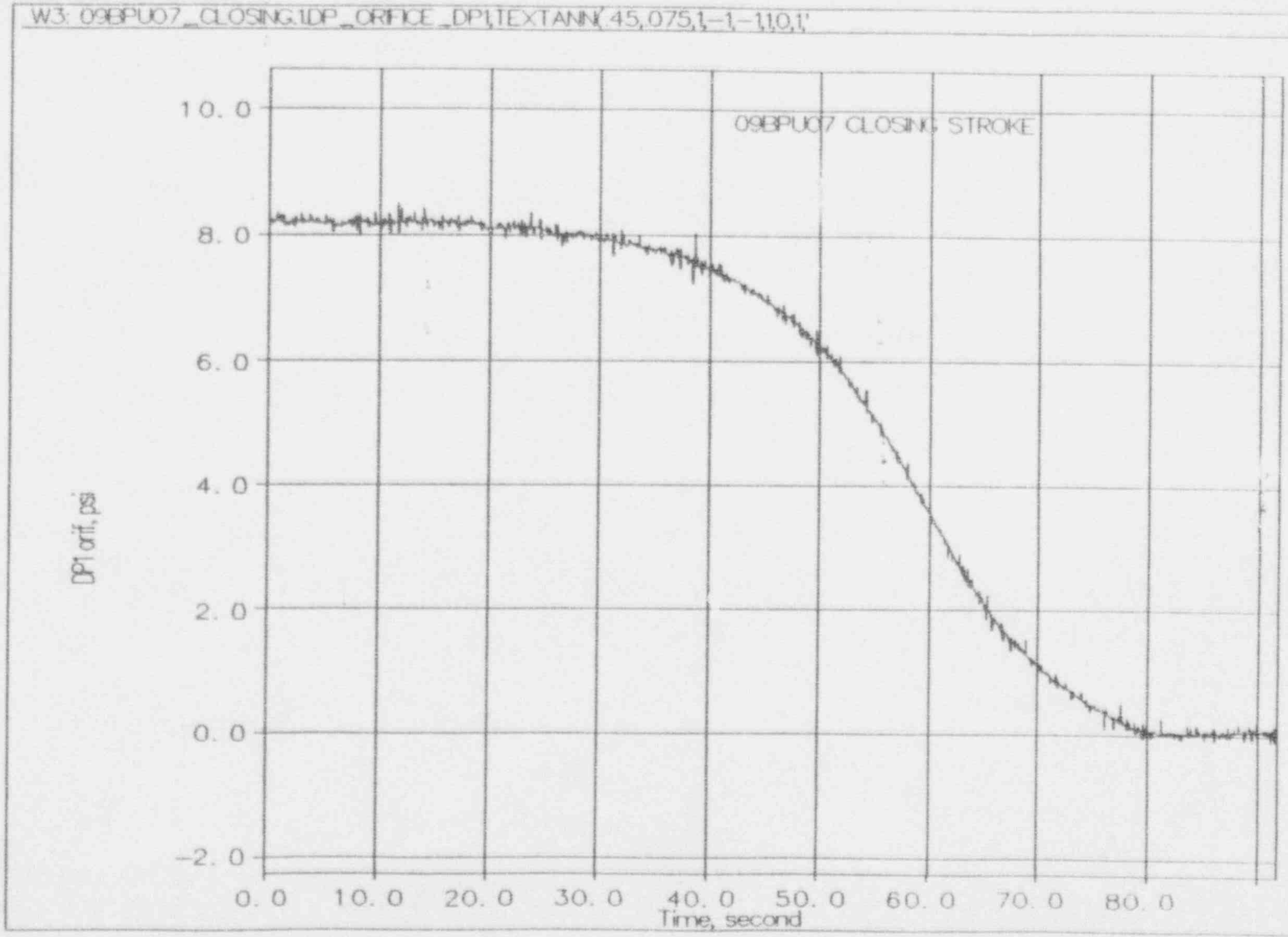
KEI Flow Loop Testing Status

- Testing completed
- Data reduction completed

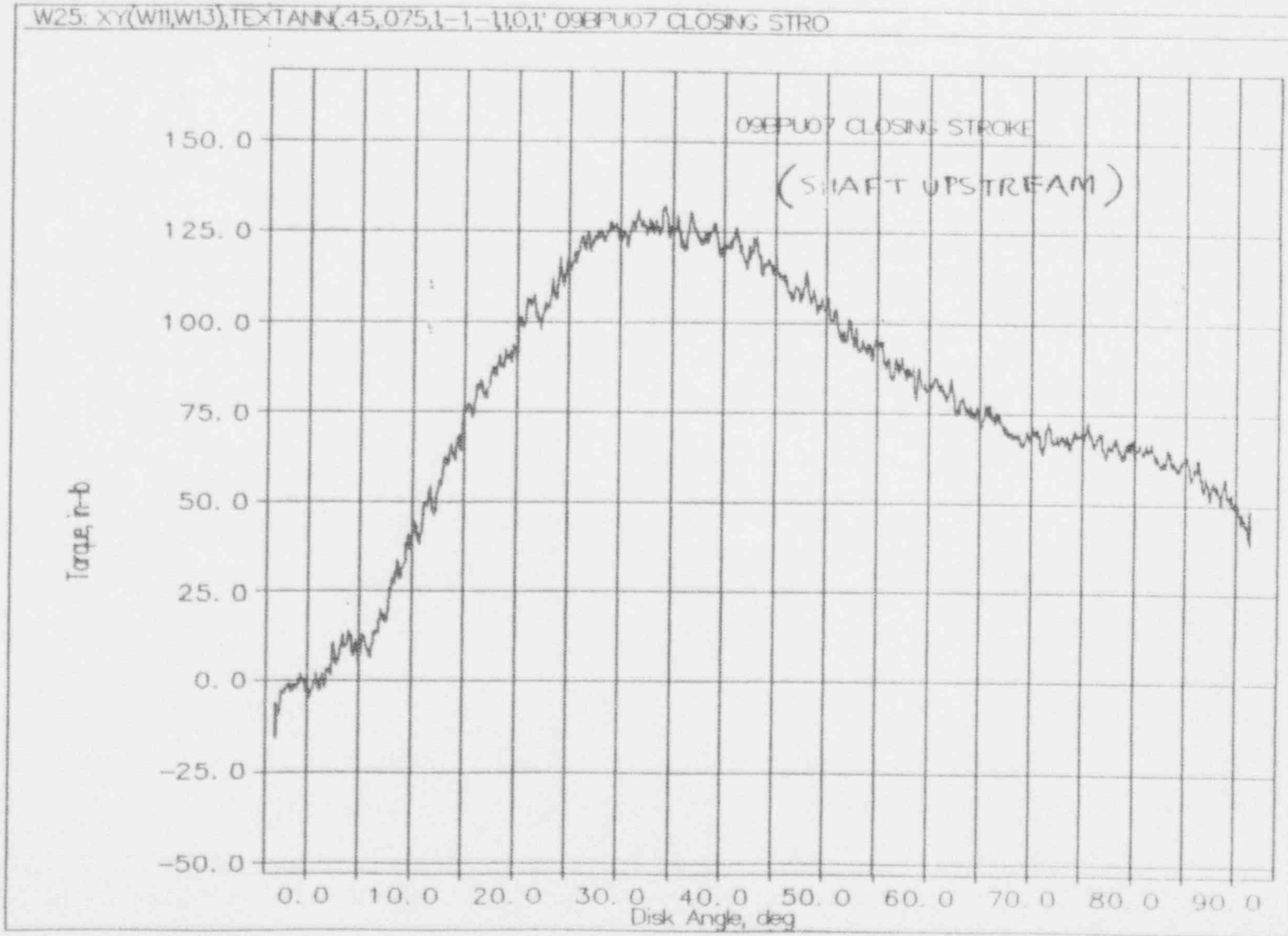
Highlights of Typical Results

- Valve size : 6"
- Disk shape : Nonsymmetric w/conical backface
- ΔP/flow velocity : 30, 60, 90 psi/15 fps
  90 psi/30 fps
- Test configuration : Baseline (no elbows)
- Flow direction: : Shaft upstream
  Shaft downstream

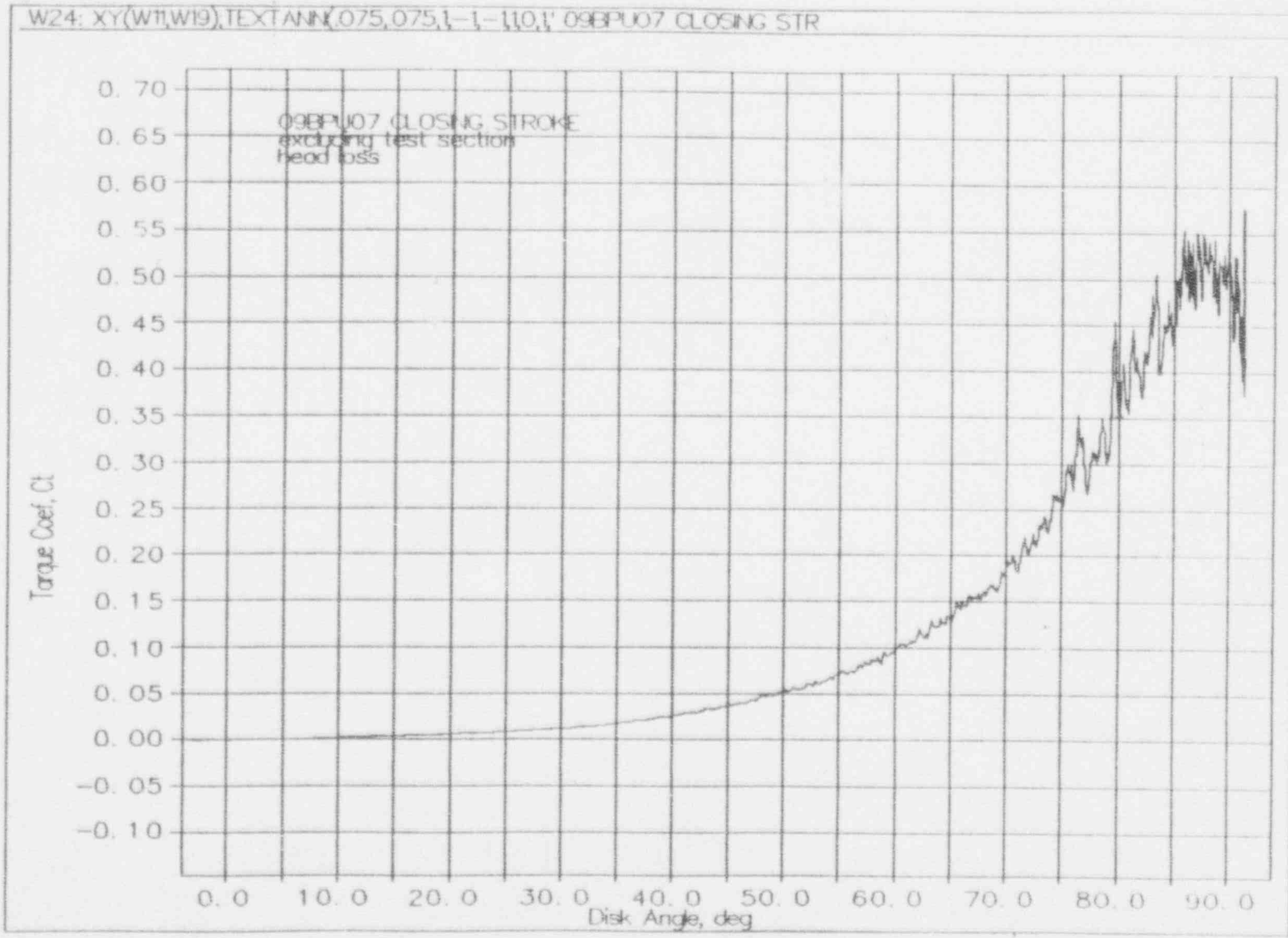

W1: 09BPU07_CLOSING.1DISK_ANGLE;TEXTANN(.45,.075,1,-1,-1,1,0,1,' 09BP
09BPU07 CLOSING STROKE
Disk Angle, deg
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Time, second


W3: 09BPU07_CLOSING.1DP_ORFICE_DP1,TEXTANN('.45,.075,1,-1,-1,1,0,1,'
09BPU07 CLOSING STROKE
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
DP1 orif, psi
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Time, second

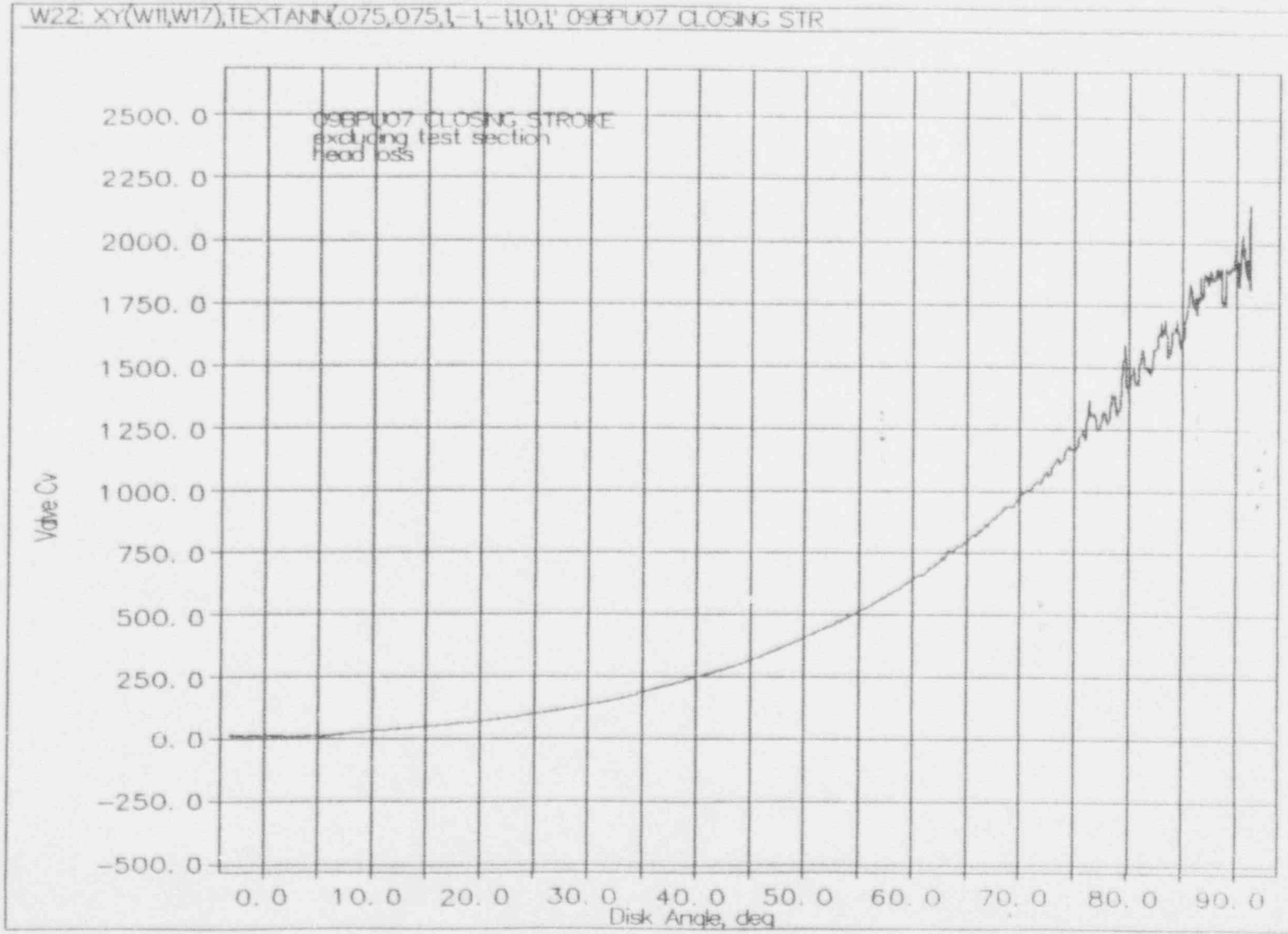

W2t XY(W11,W15),TEXTANN(.45,075,1,-1,-1,1,0,1,' 09BPU07 CLOSING STRO
09BPU07 CLOSING STROKE
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
DP Valve, psi
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
Disk Angle, deg

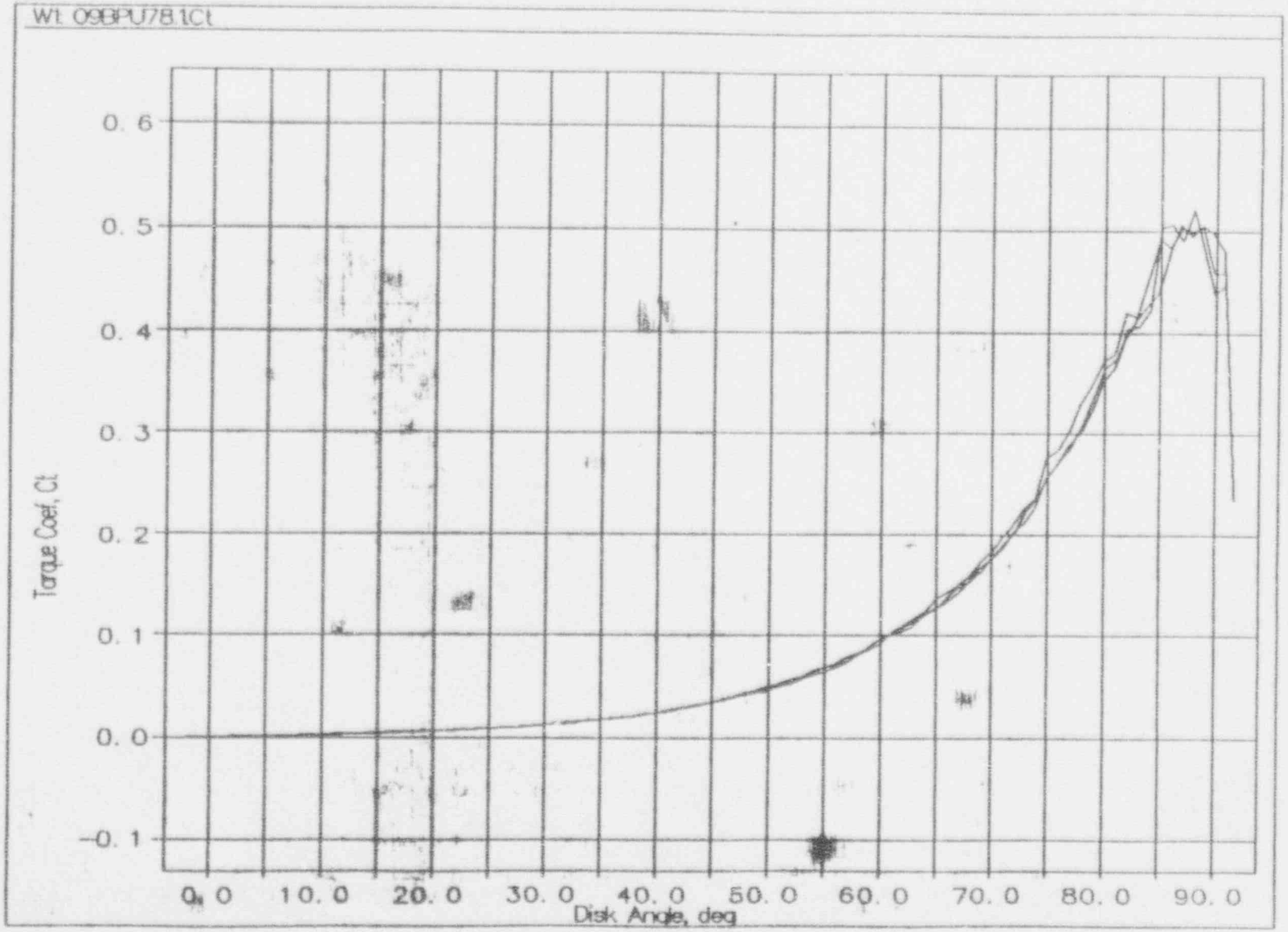

W25: XY(W11,W13),TEXTANN(.45,075,1,-1,-1,1,0,1,' 09BPU07 CLOSING STRO
09BPU07 CLOSING STROKE
(SHAFT UPSTREAM)
Torque, in-lb
150.0
125.0
100.0
75.0
50.0
25.0
0.0
-25.0
-50.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
Disk Angle, deg

$$T = C_t \cdot D^3 \cdot \Delta P_v \quad \Rightarrow \quad C_t = \frac{T}{D^3 \cdot \Delta P_v}$$



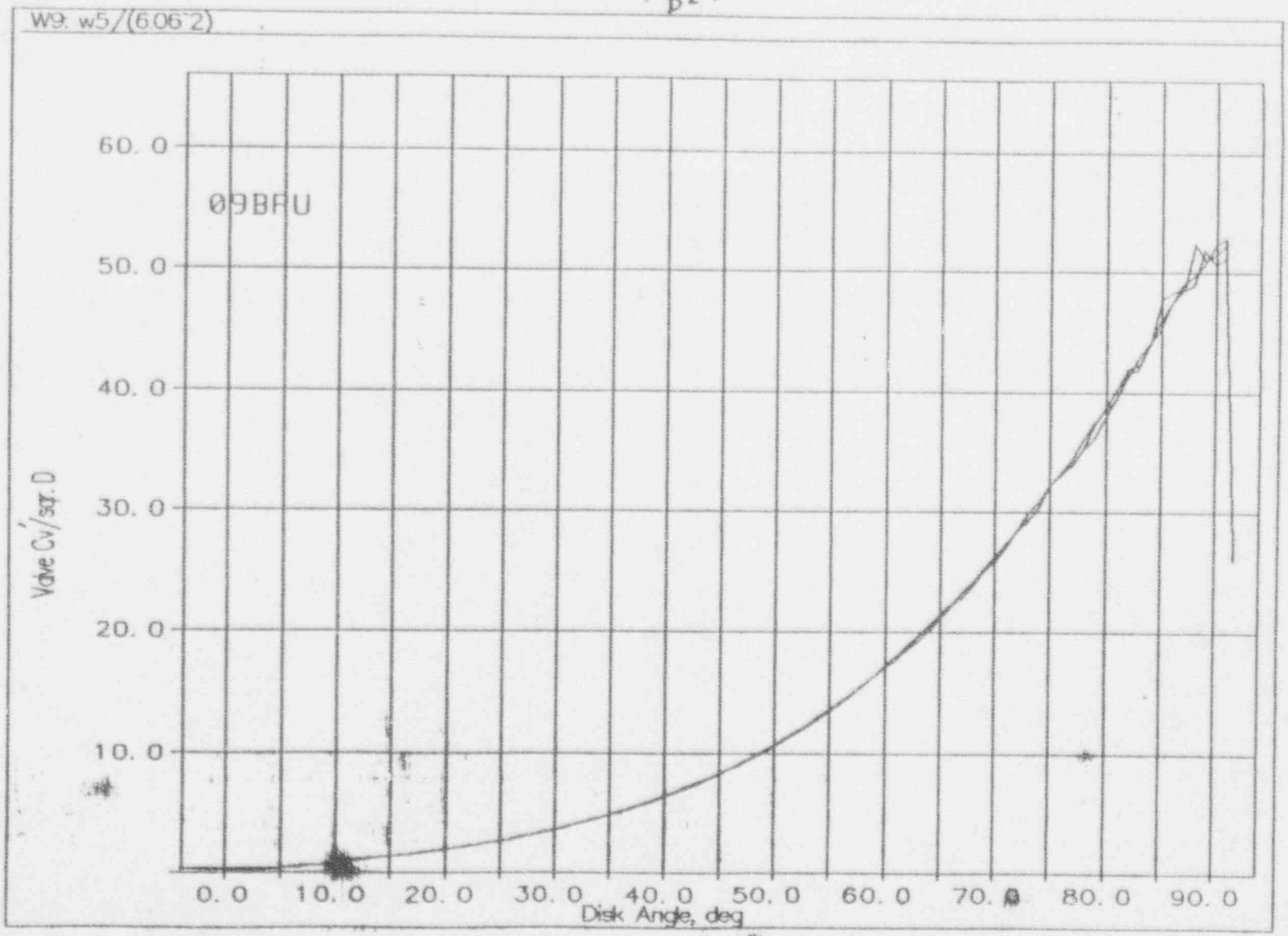
$$Q = C_v \sqrt{\Delta P_v \cdot \frac{62.4}{\rho}} \Rightarrow C_v = \frac{Q}{\sqrt{\Delta P_v \cdot 62.4/\rho}}$$

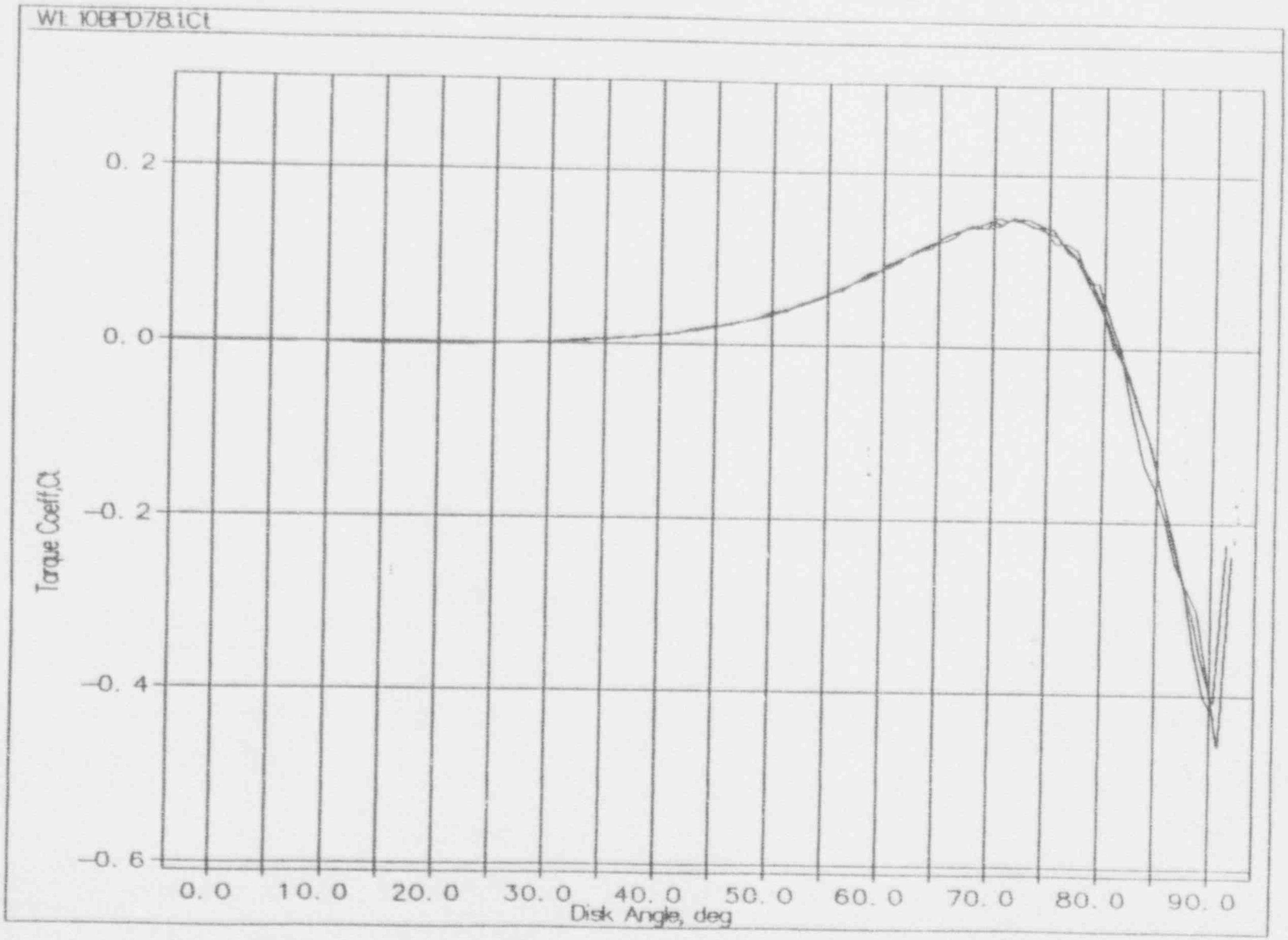




COMPARISON OF NONDIMENSIONAL TORQUE COEFFICIENTS FROM THREE DIFFERENT ΔP/FLOW TESTS

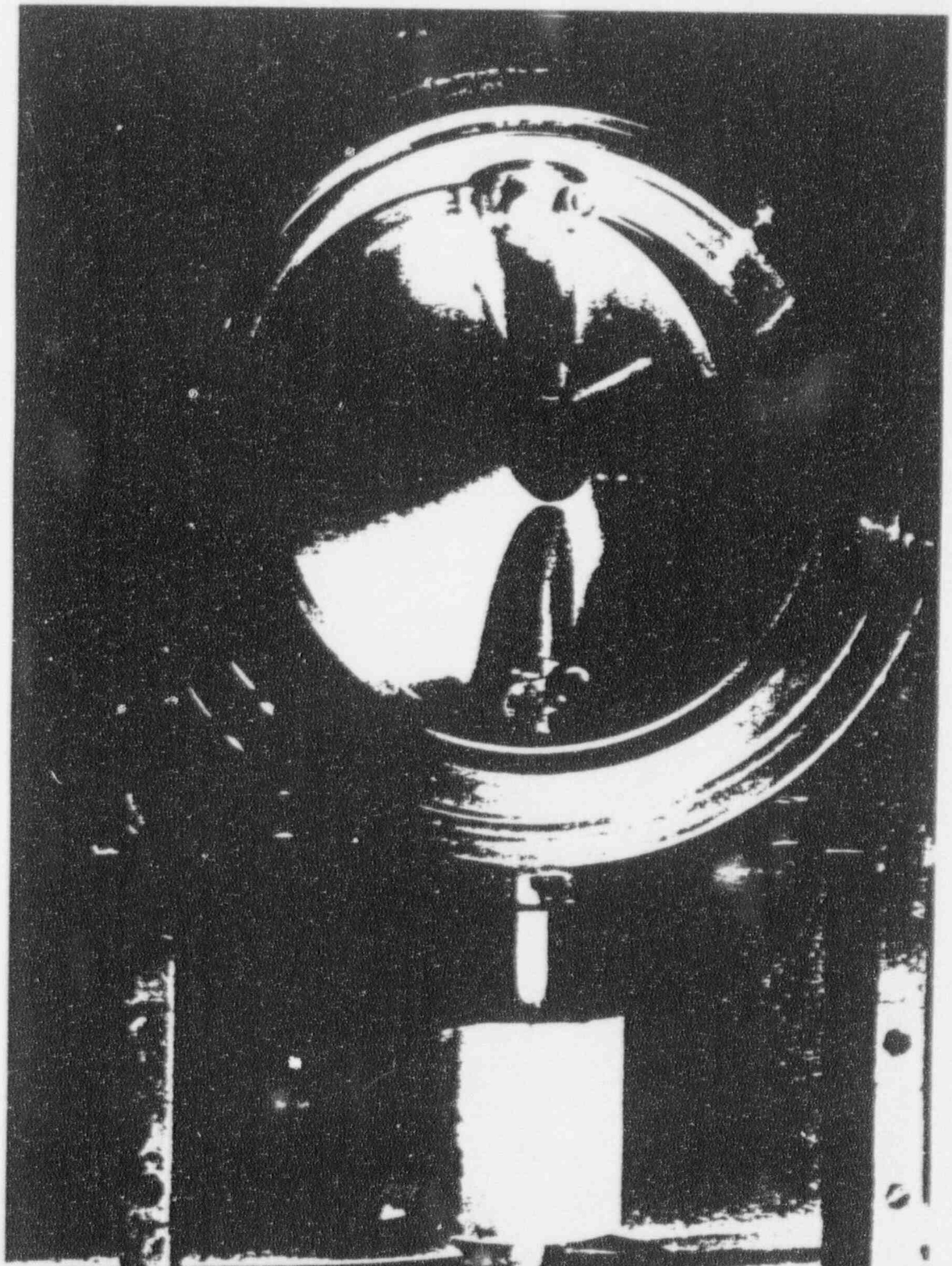
$C_v' = \left(\frac{C_v}{D^2}\right)$

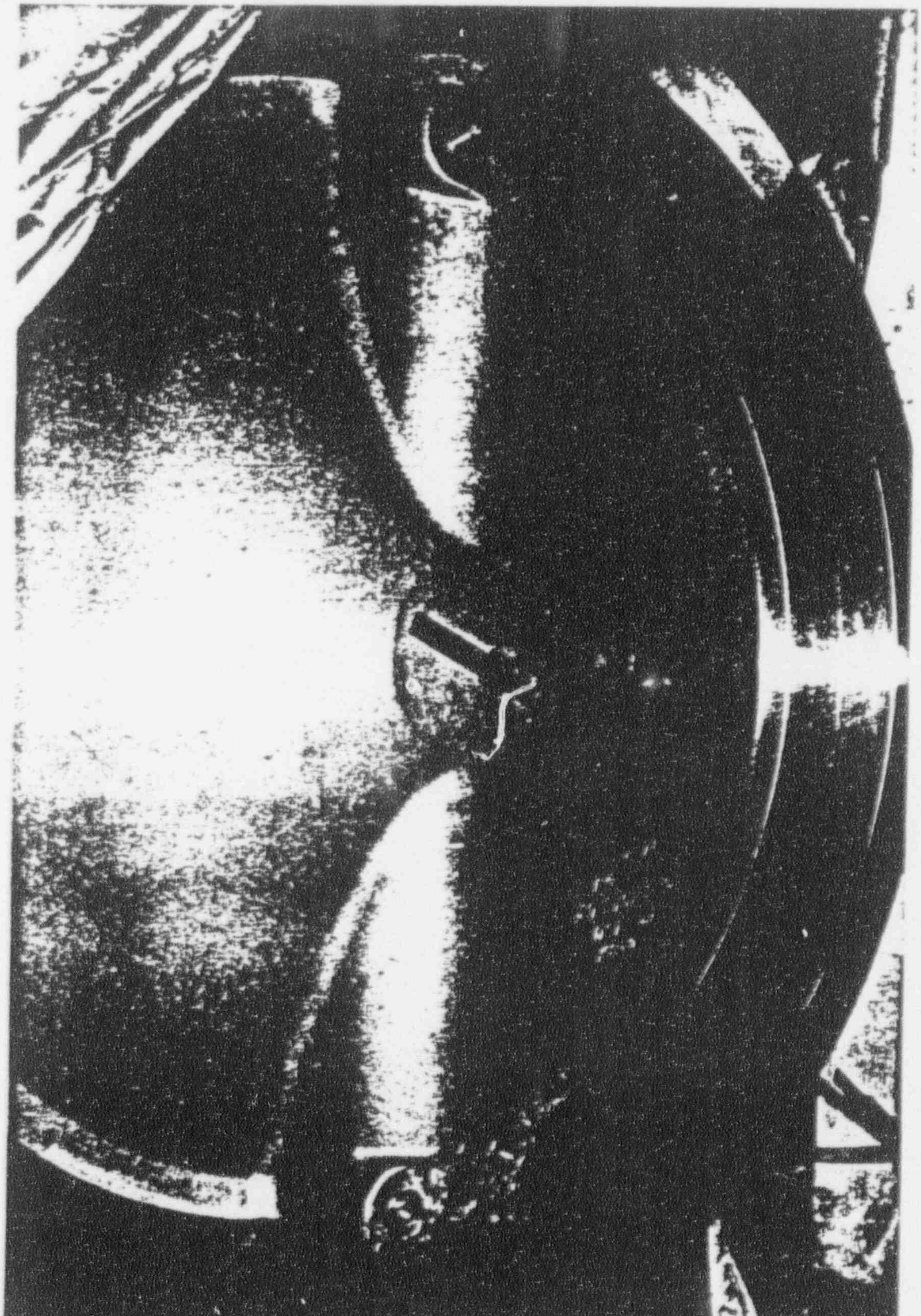


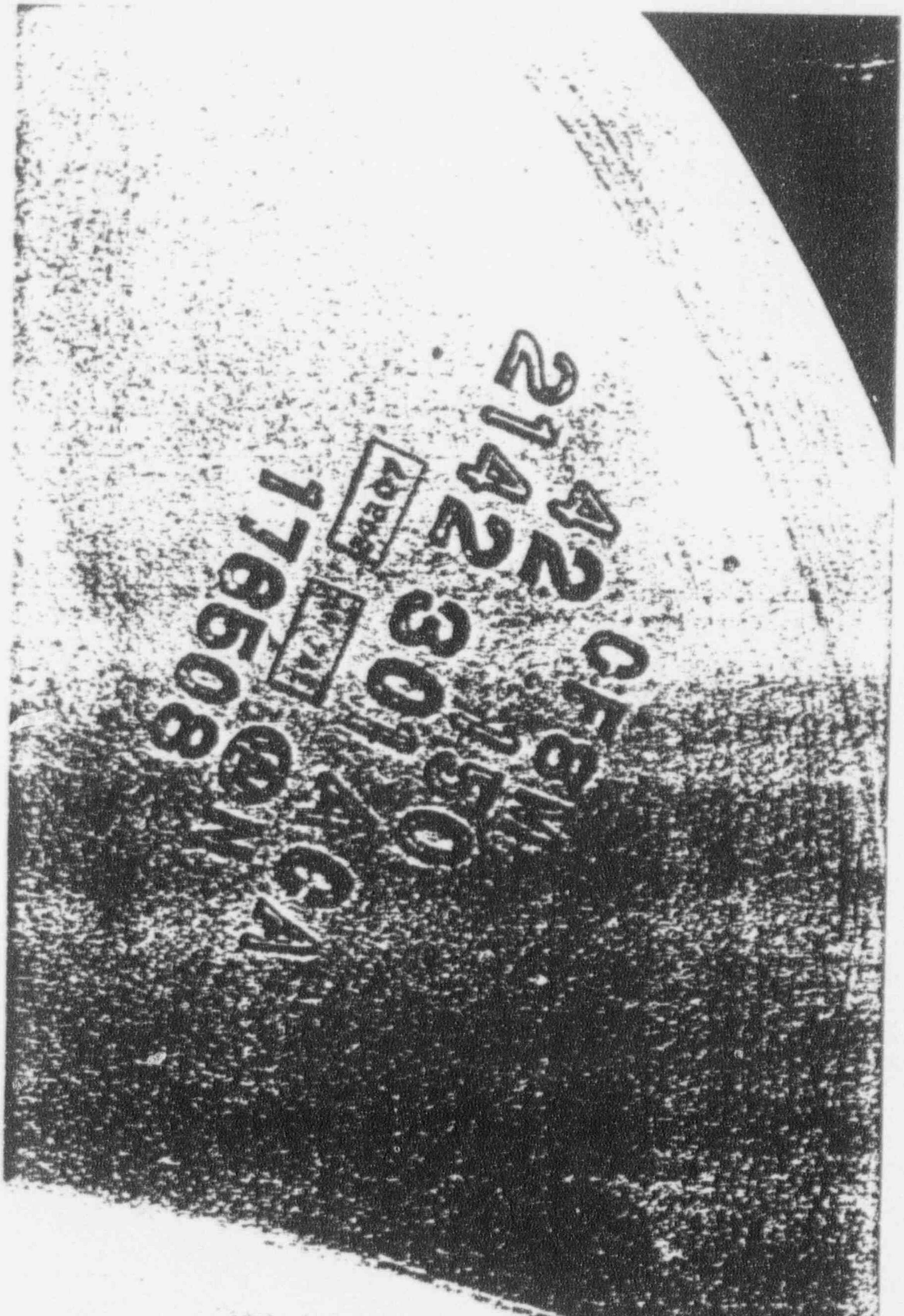

WI: 10BPD78.1Ct
Torque Coeff,Ct
0.2
0.0
-0.2
-0.4
-0.6
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
Disk Angle, deg

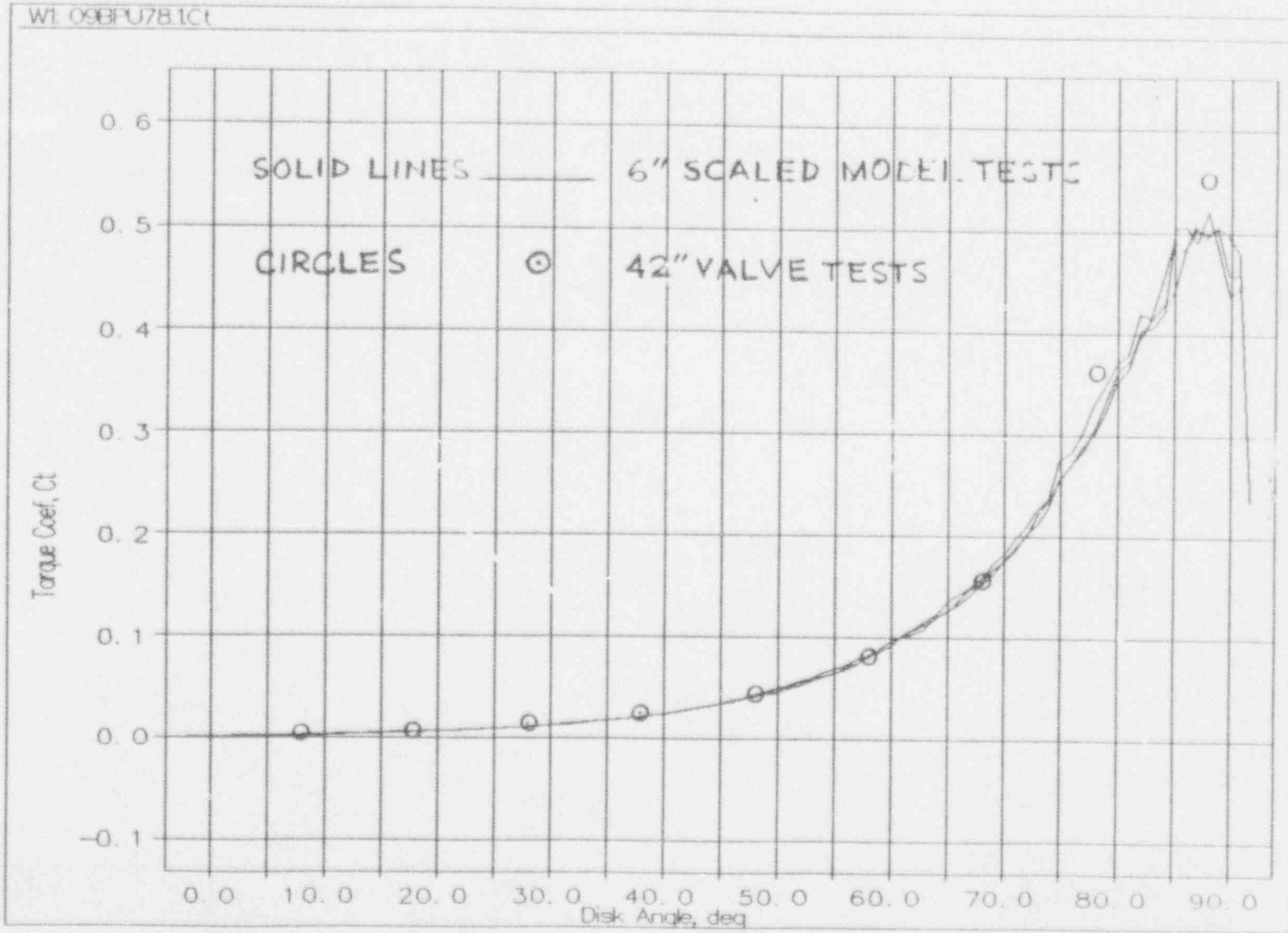
Conclusion 1:

From ΔP and flow velocity variations used in the test matrix, torque coefficients and flow coefficients have been validated to be nondimensional.

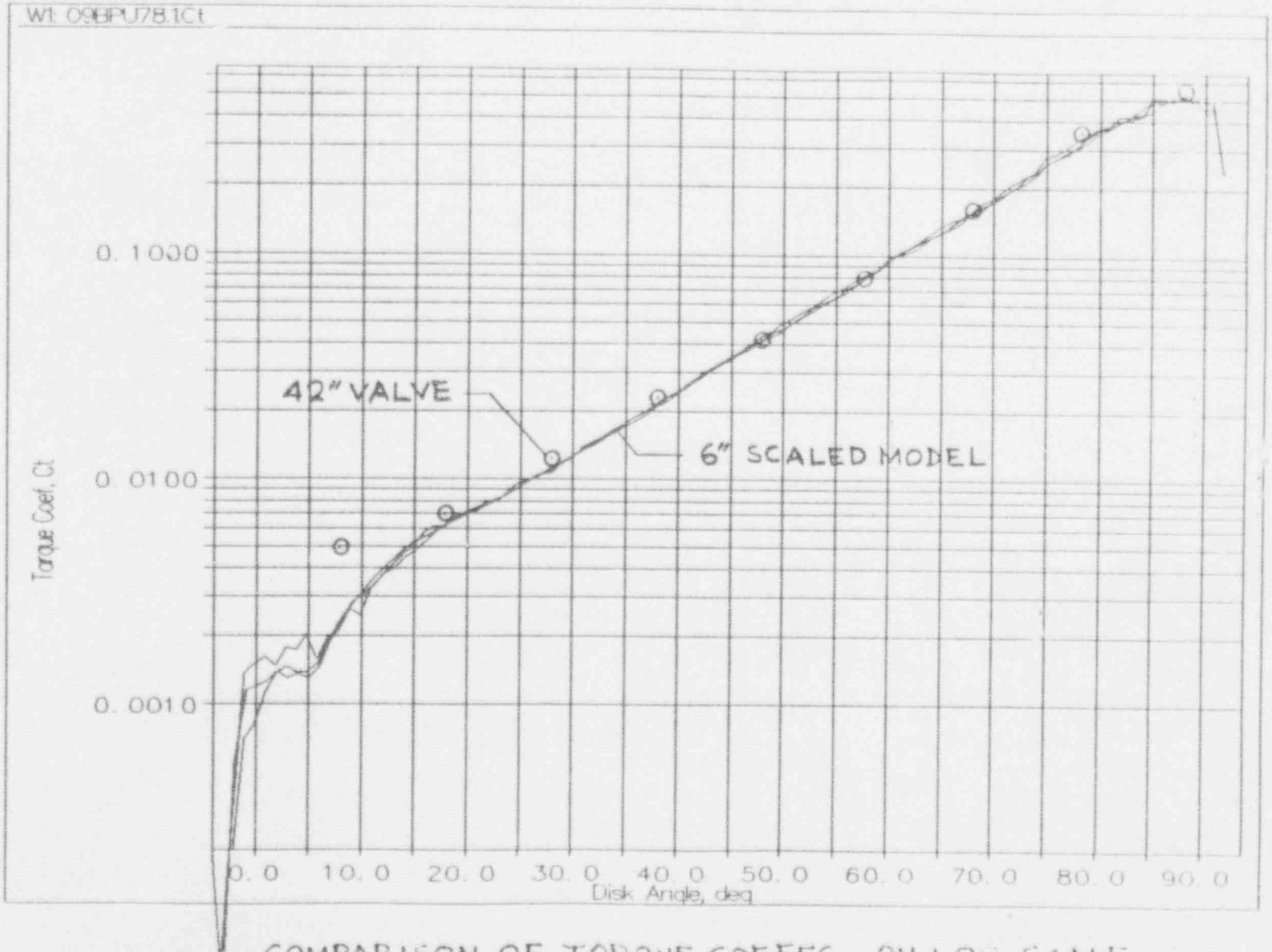






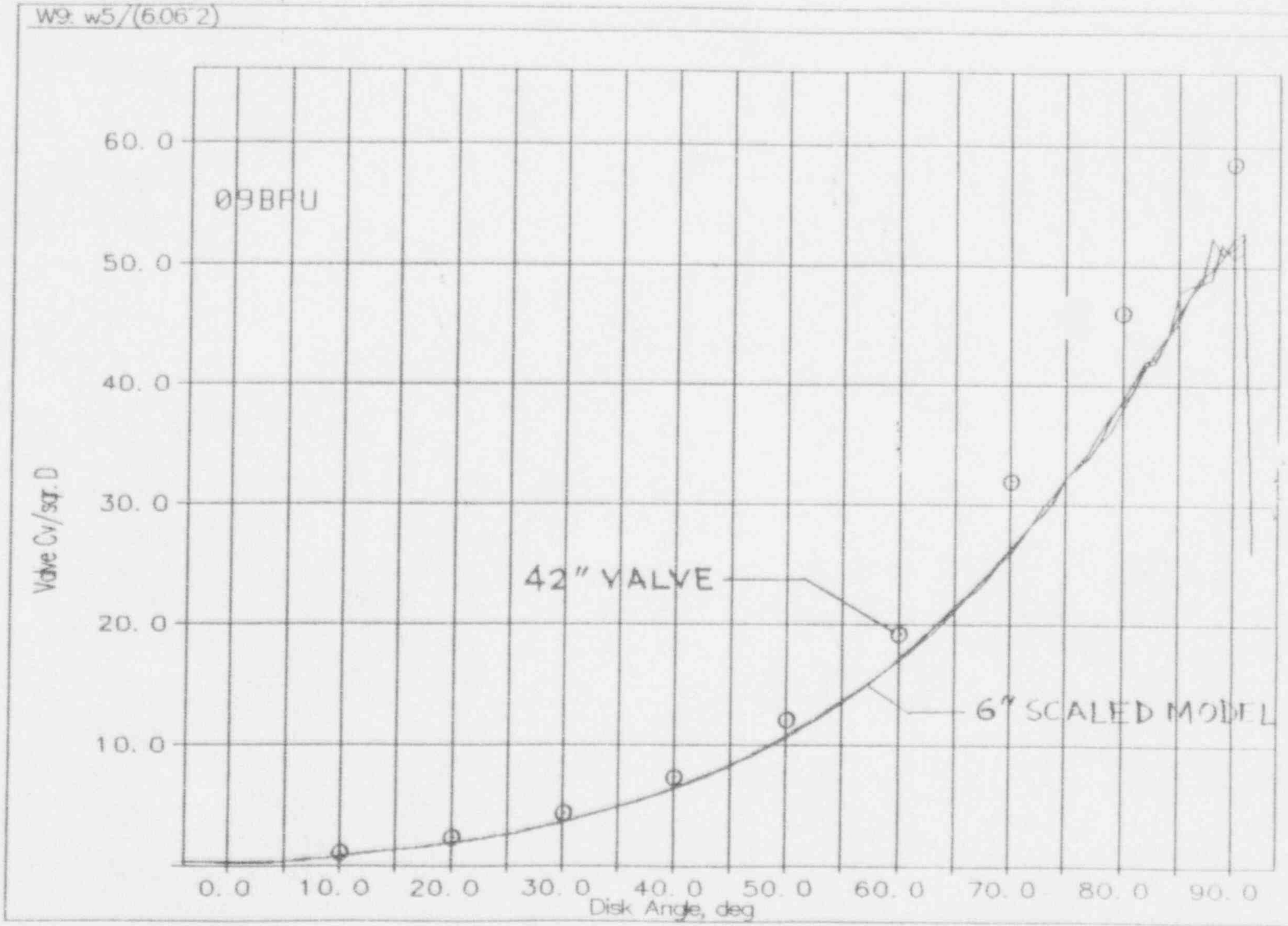


COMPARISON OF NONDIMENSIONAL TORQUE COEFFS.
SHAFT UPSTREAM



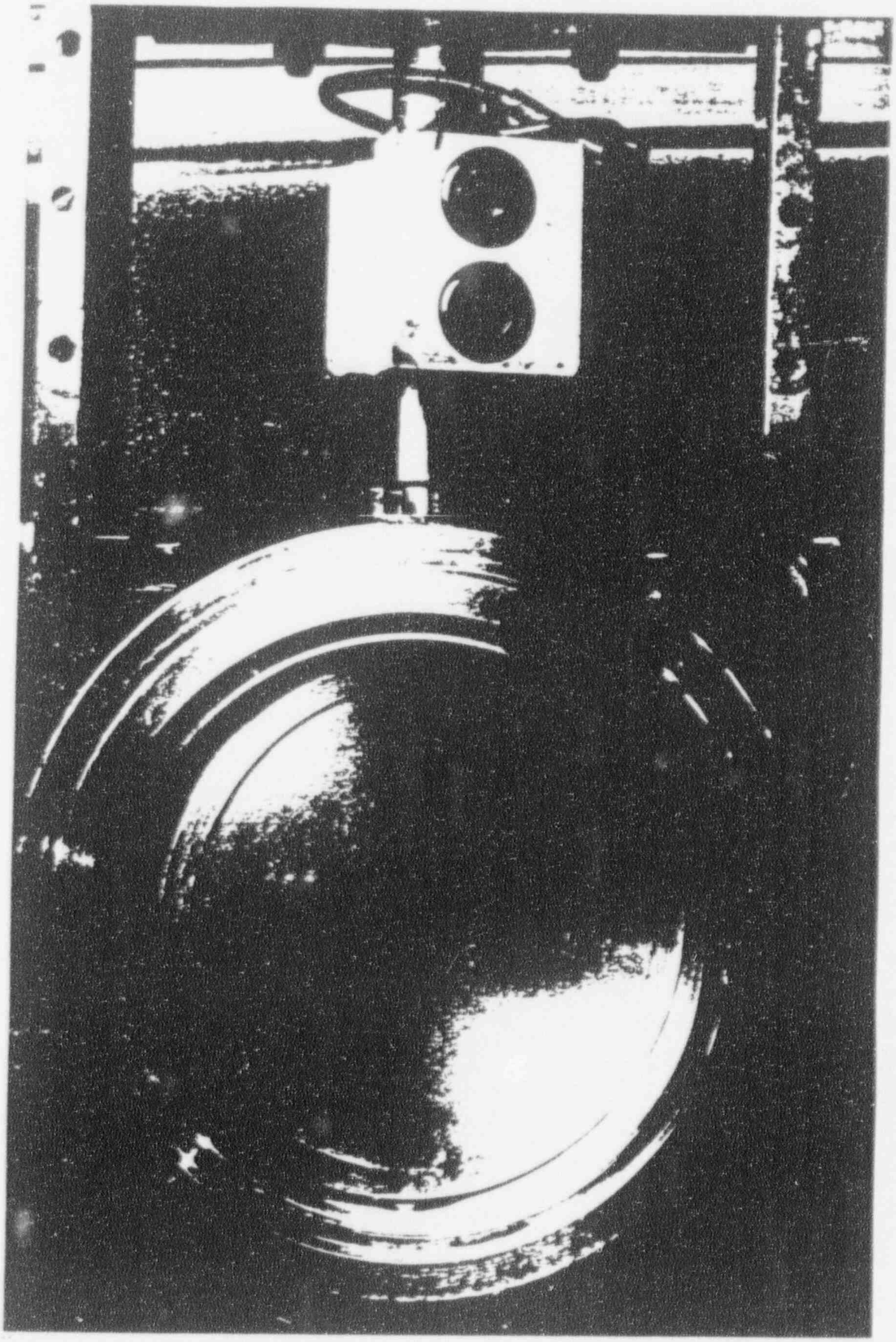
COMPARISON OF TORQUE COEFFS. ON LOG SCALE

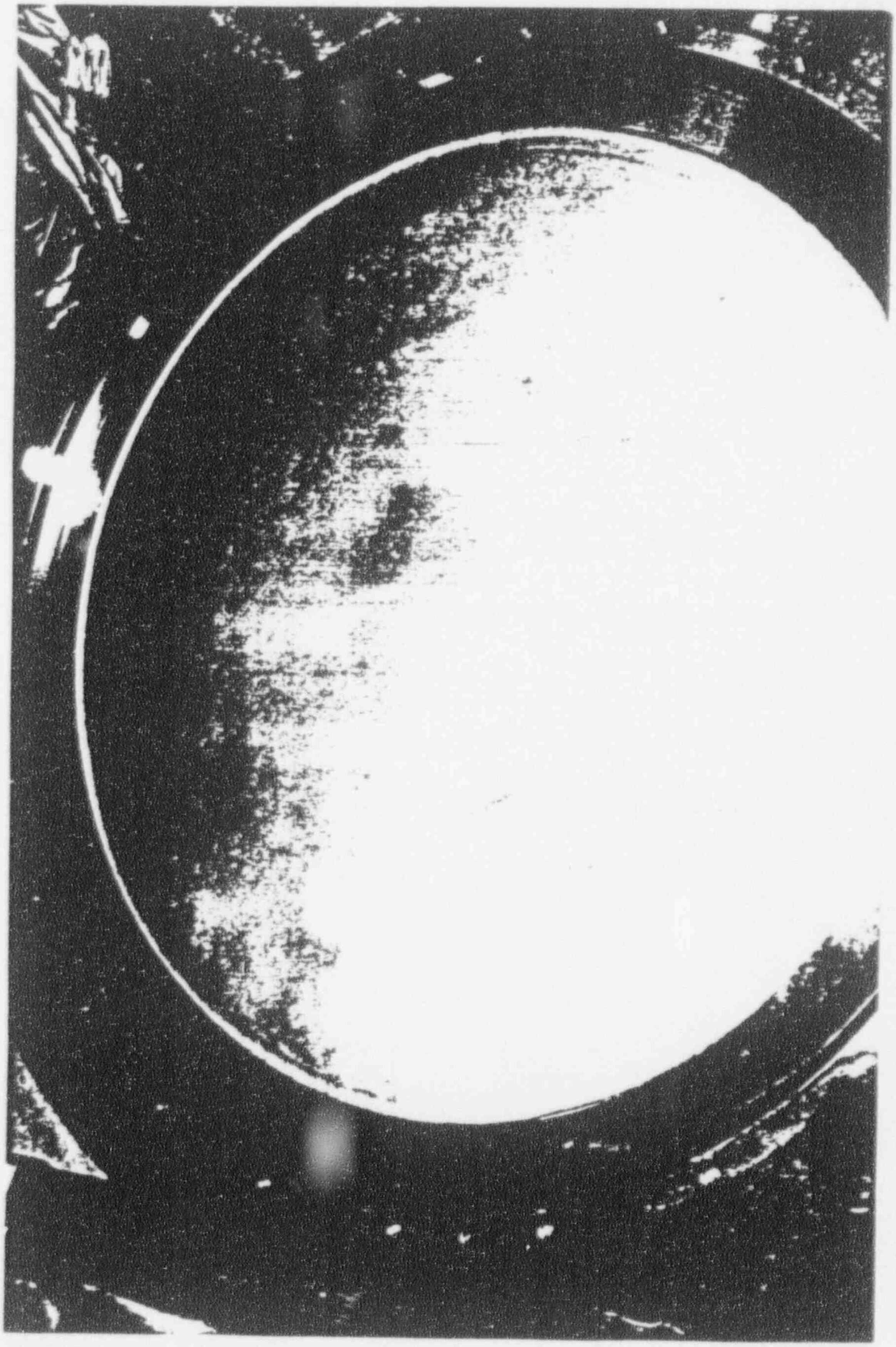
SHAFT UPSTREAM

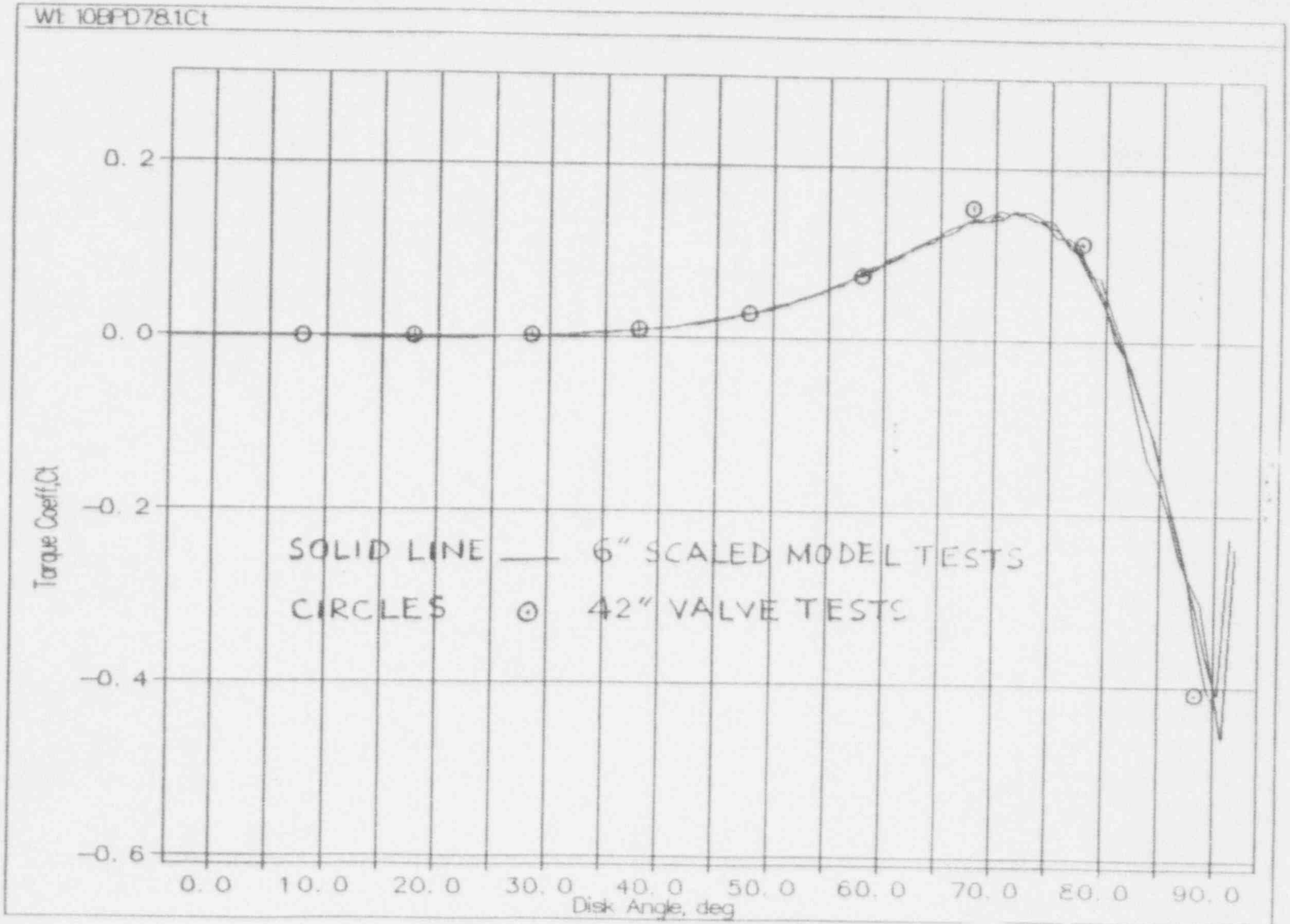


COMPARISON OF FLOW COEFFICIENTS, C_v/D^2

SHAFT UPSTREAM







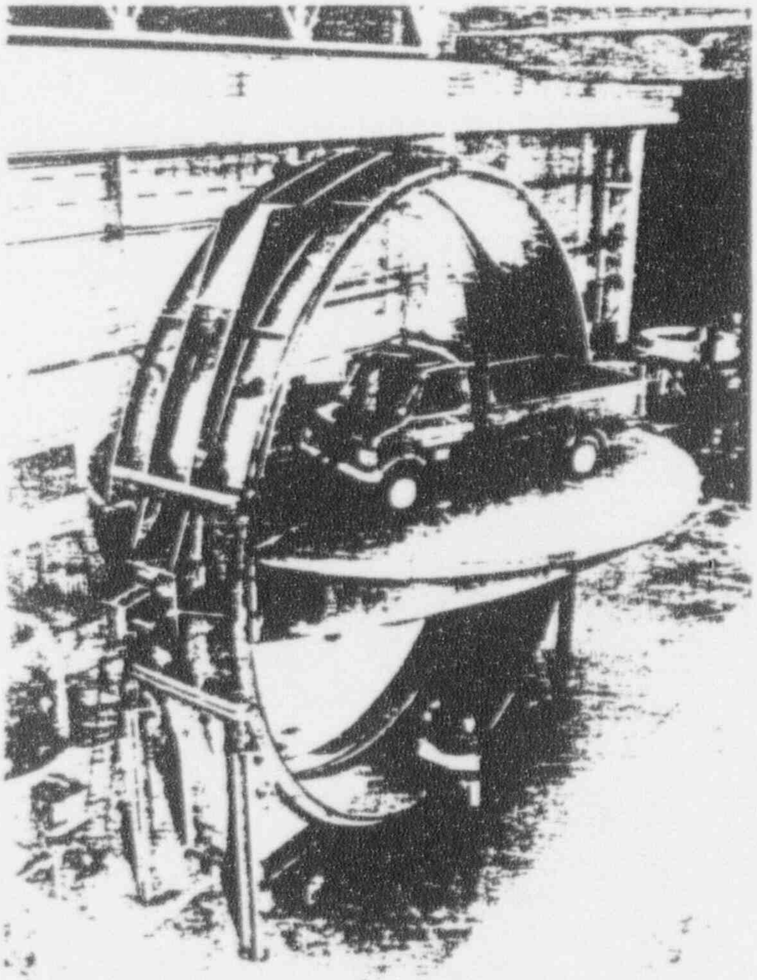
COMPARISON OF NONDIMENSIONAL TORQUE COEFFS.

SHAFT DOWNSTREAM

April 1980 RR 1602

TORQUE INDUCED BY COMPRESSIBLE FLOW THROUGH A BUTTERFLY VALVE WITH AN ASYMMETRIC DISC DESIGN

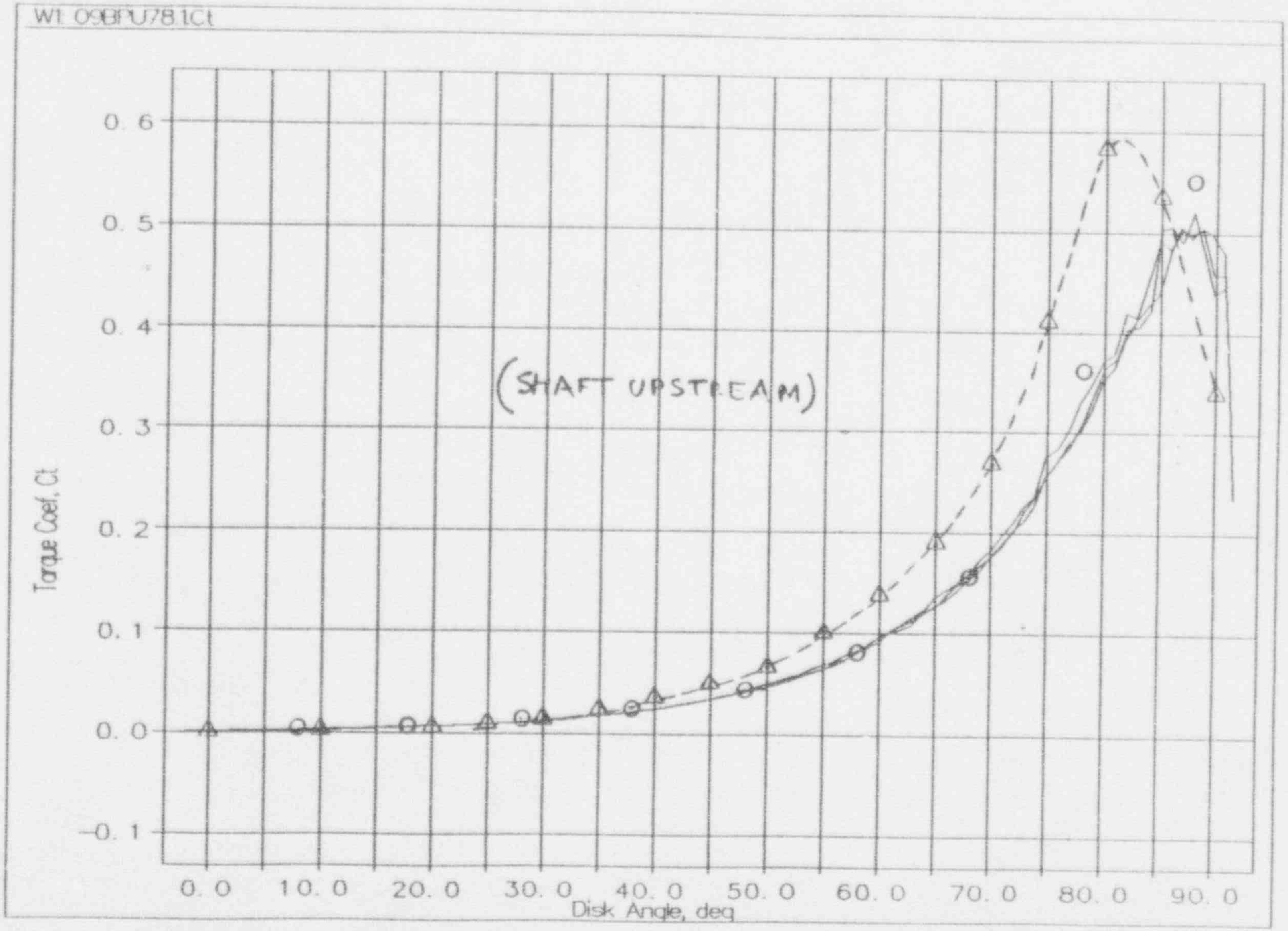
R. S. Silvester



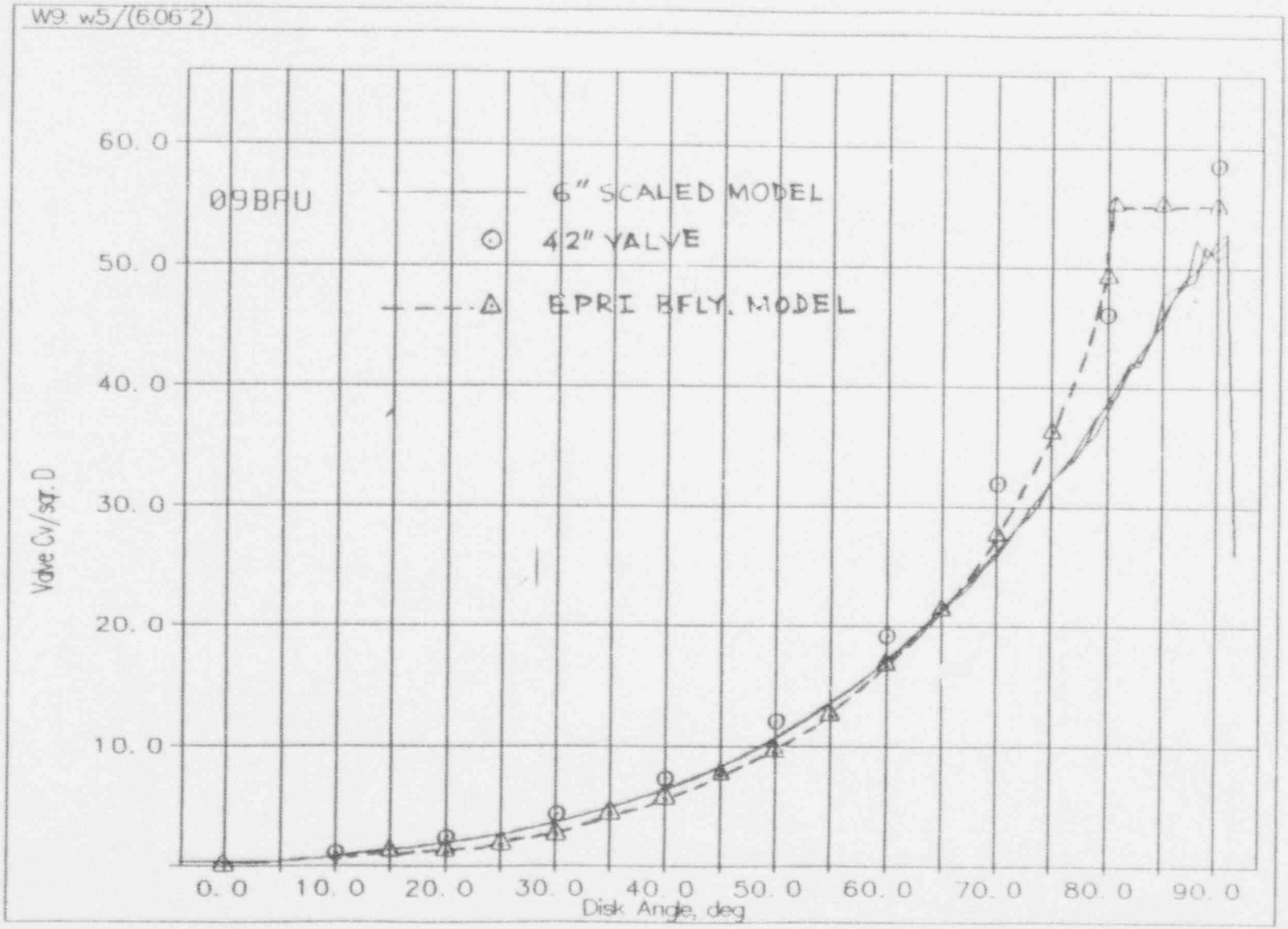
bhra fluid engineering

Conclusion 2:

EPRI butterfly PPM model and nondimensional coefficients have been validated for predicting performance of large valves from small scale model tests.



COMPARISON OF TORQUE COEFFS. FROM TESTS AGAINST
EPRI BUTTERFLY MODEL



COMPARISON OF FLOW COEFFS. FROM TESTS AGAINST EPRI BUTTERFLY MODEL

Conclusion 3:

EPRI butterfly valve model bounds test results.

Butterfly PPM Status

- Butterfly model documentation complete
- V&V plan complete
- BFM software complete
- V&V against incompressible media flow loop test data in progress
- V&V against available in situ test data planned in October 1993
- V&V against NRC/INEL compressible flow data planned in November 1993
- Final design review package scheduled for December 1993

Enclosure 3

DRAFT

NRC INFORMATION NOTICE 93-XX: STATUS OF MOTOR-OPERATED VALVE PERFORMANCE PREDICTION PROGRAM BY THE ELECTRIC POWER RESEARCH INSTITUTE

Addressees

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose

This information notice is intended to alert addressees to preliminary results of motor-operated valve (MOV) tests conducted by the Electric Power Research Institute (EPRI). It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, related to thrust requirements for MOV operation. However, suggestions contained in this information notice do not constitute NRC requirements; therefore, no specific action or written response is required.

Background

On June 28, 1989, the NRC issued Generic Letter (GL) 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance," to request that nuclear power plant licensees and construction permit holders verify the design-basis capability of their safety-related MOVs. In GL 89-10, the NRC staff requested that licensees and permit holders test each MOV within the scope of the generic letter under design-basis differential pressure and flow conditions, where practicable. The recommended schedule in GL 89-10 would have licensees and permit holders verify MOV design-basis capability by June 28, 1994, or three refueling outages after December 28, 1989 (whichever is later).

In response to GL 89-10, NUMARC coordinated an effort by the nuclear industry for a research program at EPRI to develop a methodology to predict the performance of MOVs under design-basis conditions. The EPRI program includes detailed analyses and testing of MOVs at test facilities and nuclear power plants. If successful, the EPRI MOV Performance Prediction Methodology will allow licensees to demonstrate the design-basis capability of MOVs from tests conducted under less severe conditions. In August 1993, EPRI provided a status of its MOV Performance Prediction Program to the NRC staff.

Description of Circumstances

In performing its MOV Performance Prediction Program, EPRI has tested 35 gate, globe and butterfly valves in 63 sequences at its test loop facilities as of August 1993. EPRI planned to perform a small number of additional tests at its test loop facility in Huntsville, Alabama. EPRI plans to obtain test data for an additional 30 valves to be tested in nuclear power plants. EPRI has contracted Kalsi Engineering to test a butterfly valve with multiple disc designs.

EPRI indicated that its tests demonstrated "valve friction coefficients" (based on mean seat diameter) for gate valves as follows: 0.3 to 0.6 for cold water pumped flow, with values of 0.75 and 0.9 for two valves; 0.34 to 0.41 for hot water pumped flow; 0.35 to 0.80 for hot water blowdown; and 0.25 to 0.64 for steam blowdown. Most valve vendors used a "valve factor" of 0.3 for flexible wedge gate valves and 0.2 for parallel disc gate valves in sizing motor operators. Therefore, the EPRI test results indicate that the thrust required to operate gate valves could be significantly greater than the thrust predicted by the valve vendors. The EPRI testing confirms the limited testing program conducted by the Idaho National Engineering Laboratory (INEL) for the NRC Office of Nuclear Regulatory Research in 1989. EPRI reported that valve friction tends to decrease for particular valves with increasing differential pressure, which lends support for linear extrapolation of differential pressure test results.

EPRI reported that several gate valves were damaged during testing. The damaged valves included a six-inch Anchor Darling gate valve; two six-inch Borg-Warner gate valves; a twelve-inch Borg-Warner gate valve; a six-inch Crane gate valve; a two and one-half inch Edward gate valve; a six-inch Velan gate valve; a ten-inch Velan gate valve; a six-inch Walworth gate valve; and a ten-inch Edward gate valve. One large Anchor Darling gate valve was damaged when the valve disc was forced through the seating area such that leakage occurred above the disc.

EPRI stated that its testing showed the thrust required to operate globe valves was generally consistent with the valve factor used by valve manufacturers. However, some of the test results revealed valve factors greater than the 1.1 typically used by globe valve vendors. Also, a two-inch Edward globe valve tested under blowdown conditions demonstrated a valve factor of 1.87 with damage on the valve internals.

EPRI stated that its testing revealed torque requirements to operate butterfly valves from one manufacturer (Pratt) to be bounded by the torque predictions. However, butterfly valves at several nuclear power plants (for example, Catawba, Palo Verde, and Salem) have demonstrated torque requirements that exceed vendor predictions.

EPRI stated that it determines the point of flow isolation based on a hydrostatic test to establish the stem position when flow begins to occur during an opening stroke. EPRI adjusts the stem position for closing to account for the stem-to-disc connection gap. EPRI uses the greatest thrust requirement to overcome differential pressure up to this stem position to determine the valve friction coefficient. EPRI assumes the highest differential pressure observed during the test regardless of the stem position where the greatest thrust requirement occurs. This results in a lower valve friction coefficient than would be determined if the actual differential pressure at the point of greatest thrust was used in determining the valve friction coefficient. Also, the EPRI test results revealed that it is not possible to determine accurately a point of flow isolation prior to disk wedging based on the thrust diagnostic trace.

EPRI stated that it had not observed differences in thrust requirements for valve operation between valves installed in horizontal pipes with the stem either vertical or horizontal. This finding differs from operating experience in nuclear power plants.

EPRI plans to submit a topical report for NRC review in April 1994. EPRI intends to submit test reports in advance of the topical report to allow the staff to raise questions with EPRI early in the review process. This early review is essential for the NRC staff to complete the review of the EPRI topical report during the Spring of 1994. However, EPRI has been delayed in completing its test reports.

Related Generic Communications

The NRC has issued other generic communications on MOV testing, such as NRC Information Notice 90-40.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below.

Brian K. Grimes, Director
Division of Operating Reactor Support
Office of Nuclear Reactor Regulation

Technical Contact: Thomas G. Scarbrough, NRR
(301) 504-2794

Enclosure T

NUCLEAR MANAGEMENT AND RESOURCES COUNCIL

1776 Eye Street, N.W. • Suite 300 • Washington, DC 20006-3706
(202) 872-1280

September 16, 1993

Mr. Thomas G. Scarbrough
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852

Dear Mr. Scarbrough:

This letter transmits the EPRI TAG responses to the staff questions concerning the EPRI MOV Performance Prediction Program. We expect to further discuss our responses during the October 6 and 7, 1993 meeting.

If you have any questions, please give me a call.

Sincerely,

R. Clive Callaway

R. Clive Callaway
Senior Project Manager
Operations, Management and Support
Services Division

RCC:sp
Enclosure

c: Dr. G. Weidenhamer, NRC/RES
Mr. Bob Steel, INEL

Updated EPRI/TAG Responses to the NRC Staff Status Comments on the EPRI MOV PPP
(September, 1993)

Following are EPRI updated responses to NRC's October, 1992 comments on the EPRI MOV Performance Prediction Program, as well as responses to six additional NRC comments received in December, 1992. For NRC comments 1-22 the following information is given: the October 1992 NRC Comment; the November 1992 EPRI Response; the NRC Status as presented by NRC in a December, 1992 Memorandum from Sullivan to Norberg; and an updated EPRI Response to the NRC's Status evaluation. NRC Comments 23-28 are new comments originally made in the December memorandum and, consequently, do not have an associated interim response.

As a result of the testing and analytical work completed to date, the EPRI methodology has evolved from a purely analytical tool to a more performance-based approach. The revised methodology will allow use of data from the installed MOV as input to analytical predictions resulting in a significant increase in prediction accuracy and a minimization of excess conservatism. This change in philosophy is reflected throughout the following updated responses.

1. **NRC Oct. 92 COMMENT:**

   EPRI should release the results of its motor-operated valve (MOV) tests on a regular basis for use by licensees in their Generic Letter (GL) 89-10 programs in sizing and setting MOVs for which design basis testing is not practicable. EPRI will need to provide the basis for valve or stem friction coefficients determined from the test results. This information should include valve disk position used to select the thrust required to close the valve such that the design requirements of the MOV are satisfied. At the October 1992 meeting, EPRI and NUMARC stated that guidance would be developed for use of preliminary EPRI test data by licensees.

   EPRI Nov. 92 RESPONSE:

   Table 1 provides a listing of all Program products along with their estimated publication dates. Note that test data from MOV testing will be provided as testing is completed in each specific test loop. The MOV test data will be summarized on forms (see Figures 1 and 2). The time, thrust, torque, DP, apparent disc and stem coefficients of friction will be provided for selected points during the valve stroke. These include (for a closure) the point when maximum thrust occurred prior to initial wedging, at initial wedging and at flow isolation. Data at similar points will be provided for opening strokes.

Table 1

EPRI MOV PERFORMANCE PREDICTION PROGRAM PRODUCTS

Product	Estimated Publication Date
Application Guide for MOV's in Nuclear Power Plants (NMAC Product)*	Complete
Review of INEL Gate Valve Test Program	Complete
In Situ Test Guide*	Complete
MOV Margin Improvement Guide*	Complete
MOV General Information Database*	Complete
Butterfly Application Guide (NMAC Product)*	Complete
Stem Nut Lubricant Test Report	Under TAG Review - Aug. '93
Gate Valve Dimensional Specification*	August 1993
Huntsville Low Pressure Flow Loop Test*	Under TAG Review - Sept. 93
Methodology Input Specification Draft	October 1993
Preliminary Static Test Method for Disc μ	October 1993
Preliminary Static Test Method for ROL	October 1993
Operator Test Report	October 1993
Butterfly Valve Subscale Test Report	October 1993
Globe Valve Model Report*	October 1993
Computational Fluid Dynamics Analysis Report	November 1993
Friction Test Report	November 1993
System Model Report	November 1993
Gate Valve Design Effects Report	November 1993
MOV PPP Topical Report *(Draft Sections to be issued as completed.)*	November 1993 to March 1994
In Situ Test Report*	December 1993
Siemens/KWU Flow Loop Test Report*	December 1993
Norco Flow Loop Test Report*	December 1993
Huntsville Int. Pressure Flow Loop Test*	December 1993
Butterfly Valve Model Report*	January 1994
Operator Effects Methodology Report*	January 1994
Gate Valve Model Report	February 1994
Empirically Based Methods Reports*	April 1994
Integrated Methodology Assessment Report	April 1994
Integrated Methodology PC Code*	April 1994
PC Code Users Manual*	April 1994
Model Implementation Guide*	April 1994

* Products which can be directly applied by Utilities in assessing MOV performance capability.

FIGURE 1

EPRI Gate Valve Test Analysis Data Sheet

Valve # ____________ Test Date ____________ Test Time ____________

Test # ________________________ Stroke Direction ____________________

Test Description ____

Valve Mean Seat Diameter ____________________ in.

Data File ____________________________ Data Set ____________________

Motor Current Start Time* ______________

Motor Current Stop Time* ______________

Contactor Dropout Time* ______________

Packing Load at Running ______________ lb.

Closed to Open								
	Time (sec)	Thrust (lb.)	Torque (ft-lb)	SPDISP (in.)	Mean Upstream Press (psig)	Mean DP PSID	App Disk µ	App Stem µ
A. At cracking*					----	----	----	
B. Just after cracking								
C. Max after cracking								
D. Running (No DP)							----	
E. Limit SW Trip		----	----	----	----	----	----	----
F. At Flow Initiation**								

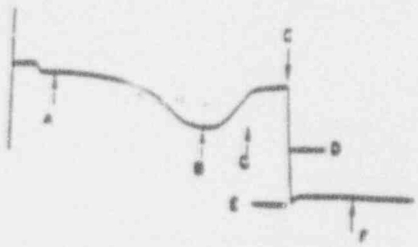
Open to Closed								
	Time (sec)	Thrust (lb.)	Torque (ft-lb)	SPDISP (in.)	Mean Upstream Press (psig)	Mean DP PSID	App Disk µ	App Stem µ
A. Running (No DP)							----	
B. Max prior to initial wedging								
C. At initial wedging								
D. TS Trip*					----	----	----	
E. Max after wedging					----	----	----	
F. Final					----	----	----	
G. At flow isolation**								

MJS050

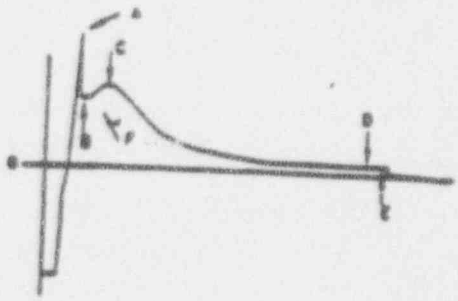
* *Values to nearest .001 second, all other values to nearest .01 second.*

** *Determined by flowrate measurement.*

FIGURE 2
Flow Loop Data Analysis Definitions



$$T = T_A - P_A A_s + P_c A_s + \mu \Delta P_c A_o / (\cos\theta - \mu \sin\theta)$$



$$T = T_D + P_D A_s - P_B A_s + \mu \Delta P_B A_o / (\cos\theta + \mu \sin\theta)$$

Opening Stroke

T = Stem Thrust, lb.
P = Upstream pressure, psi
A_s = Stem area, in.^{2}
A_o = Disk mean seat area, in.^{2}

ΔP = Different pressure, psi
μ = Disk coefficient of friction
θ = Half disk angle

Stem μ = (24FS cos α - d cos α tan a)/(24FS tan a + d)

FS = Torque/thrust, ft.
d = Stem OD - P/2, in.
p = Pitch, in.

α = Half thread angle
a = Thread lead angle
Stem μ = Stem coefficient of friction

It is important to note that the "apparent disk coefficient of friction" calculated by Wyle and reported on the summary forms is not to be confused with the actual coefficient of friction and is not a parameter which will be used in development or assessment of the Methodology. The apparent coefficient of friction calculation is based on solving the NMAC equation for disc coefficient of friction (See Figure 2).

The apparent disc coefficients of friction calculated from the flow loop data are not intended to represent true friction coefficients. The purpose of calculating an "apparent" disc μ in presenting the results of the flow loop gate valve tests is only to provide a straight forward basis for comparing measured thrusts at various points in the valve stroke to the single thrust prediction from the NMAC equation. In order for this comparison to be meaningful, the NMAC equation must be applied as it would for design basis purposes, i.e., the DP used is the full (valve closed) DP, the area of the disc is calculated using the mean seat diameter and the stem rejection load is calculated by multiplying the design basis upstream pressure (P_{up}) by the stem cross-sectional area (A_s).

All necessary information will be provided to the Program participants for their use in assessing performance of in plant MOVs of the same designs as those tested.

Obviously, when evaluations of flow loop test data are made which will be used to validate the MOV Methodology, they will properly account for the actual conditions (DP, area, etc.) occurring at intermediate stroke positions.

NRC Dec. 92 STATUS:

At the December 3, 1992, meeting, EPRI stated that it would produce the reports for Huntsville low pressure loop tests, Huntsville high pressure loop tests, Norco loop tests, and Siemens/KWU loop tests as promptly as resources would allow. EPRI does not plan to release data sheets for individual tests before completion of the test report for those series of tests. For example, EPRI will not release any data sheets for low pressure tests at Huntsville until the Huntsville low pressure loop test report is completed. Because EPRI does not plan to finalize each test report until many months after completion of all the tests at the specific test loop, the staff believes that licensees could obtain useful information on a more timely basis from individual test data sheets that are considered by EPRI to be complete. EPRI stated that it would release specific test data in advance of the finalized test report upon request of an individual licensee. This response is not completely acceptable since other licensees may also benefit from this information. The staff will continue to discuss with EPRI the schedule for the release of important test information.

EPRI Sept. 93 UPDATED RESPONSE:

The reason for delaying the release of final test data until the test loop reports are complete is that full quality assurance is not applied until that time. However, preliminary data is being made available to all licensees participating in the program. Data on apparent disk coefficient of friction and measured stem factor are published in quarterly progress reports and are presented at the EPRI Update Meetings which are held in conjunction with MUG Meetings. Note that Table 1 has been updated to reflect the current estimated completion dates for Program products. Note that some slippage in dates has occurred and that the dates shown incorporate all review and publication activities (prior completion dates did not include publication time). Actions have been taken to minimize review cycle times.

2. NRC Oct. 92 COMMENT:

EPRI should notify licensees, as quickly as feasible, if it finds that certain types or sizes of MOVs do not behave predictably and must be excluded from the EPRI program.

EPRI Nov. 92 RESPONSE:

If, during the course of the Program, it is determined that conservative prediction of the performance of a specific valve design, in combination with specific operating conditions, will not be possible, EPRI will notify participating utilities that the methodology will not be applicable in such cases.

NRC Dec. 92 STATUS:

In the letter dated November 30, 1992, EPRI commits to notify participating utilities if it finds that the methodology will not be applicable to any particular valves. NUMARC had agreed in an earlier meeting to distribute certain information to non-participating utilities. The staff will discuss this in more detail at subsequent meetings.

EPRI Sept. 93 UPDATED RESPONSE:

In April, 1993 Status Report sent to all program participants, EPRI provided a preliminary listing of the valve-types for which the methodology would be applicable. That list is reproduced here as Table 2. The applicability has not changed since that time. If, in the future, changes do occur, participating utilities will be notified in a similar manner.

Table 2

PRELIMINARY ASSESSMENT OF EPRI MOV PROGRAM COVERAGE OF INDUSTRY VALVE DESIGNS

Covered by Computer Methodology:

A/D Flex and solid wedge gates
Crane Flex and solid wedge gates
Pacific Flex and solid wedge gates
Powell Flex and solid wedge gates
Velan Flex and solid wedge gates (with torque arm)
Walworth Flex and solid wedge gates

Other flex and solid wedge designs with similar internal configurations as those listed above.

All Butterfly Valve designs, except Clow and C&S (Triple offset discs') and flow through discs (Triton by Pratt).

All Globe valve designs, except valves with stem guided or large balanced discs.

Covered by Prototype Testing/Application Guidance:

Westinghouse flexwedge gates
Edward Equiwedge gates
A/D Double Disk gates
Aloyco split wedge gates
WKM Parallel slide gates
Velan flexwedge gates without torque arms.
Borg-Warner flex wedge gates.

3. **NRC Oct. 92 COMMENT:**

EPRI has stated that it does not plan to develop criteria by which a licensee can verify that the performance prediction model is applicable to each specific MOV installed in the licensee's nuclear plant. EPRI stated that it assumes that the model is applicable to any MOV if the model predicts that the MOV will exhibit predictable behavior. The staff considers the absence of such criteria to be a potential weakness in the implementation of the EPRI model.

EPRI Nov. 92 RESPONSE:

As discussed in the October, 1992 meeting, an evaluation of the applicability of the methodology to each specific MOV will be performed by the user as part of the implementation of the methodology. The applicability will be evaluated in several areas including system features, valve design features, and operator features. The range of applicability of the methodology (i.e., the criteria for evaluating whether the methodology is applicable to a particular MOV) will be determined based on the assumptions used in the models and the range of data used to support the models. EPRI will develop specific criteria in each area for use in applicability evaluations.

Once the method is shown to be applicable, it can be used to conservatively predict thrust/torque requirements for globe and butterfly valves.

For gate valves, after applicability is established, the method can be used to determine whether or not damage which exceeds the threshold for unpredictability would be expected to occur at design basis conditions. If such damage is predicted, the model cannot be used to accurately predict required thrust and other approaches (i.e., reanalysis using measured internal dimensions, in situ testing or valve replacement) will need to be considered. If the method predicts that the damage threshold will not be exceeded, it can be used to conservatively predict required thrust at design basis conditions.

NRC Dec. 92 STATUS:

At the December 3 meeting, EPRI asserted that its testing program will identify all required parameters without the need for performance-based criteria. EPRI stated that, because many MOVs can be tested only under static conditions, the licensee may have only physical parameters to determine the applicability of the methodology to a particular MOV. The staff noted that there have been cases where valves that appear to be physically identical demonstrated significantly different thrust requirements to operate. The staff stated that, if the EPRI methodology predicts a low thrust requirement for a particular valve, then licensees might find instances where the methodology underpredicts thrust requirements. In such instances, the staff and licensees will question the validity of the EPRI methodology. EPRI stated that it would provide its acceptability criteria at the next meeting.

EPRI Sept. 93 UPDATED RESPONSE:

Recent results from modeling and test efforts have indicated that model conservatism may be reduced if the methodology includes some performance based inputs. For example, the Friction Separate Effects Program has shown that coefficients of sliding friction in cold water can, under some conditions, approach numbers as high as 0.7. However, it is well known that much lower values are commonly measured in-situ. In order that users of the EPRI methodology not be burdened with unrealistically high coefficients for all cold water valves, performance based methods are being developed for determining the disc sliding friction coefficient in-situ. Such methods include reduced DP testing, hydropump opening against DP and potentially, static testing to determine the ratio of wedging to unwedging thrust.

Similarly, a performance based method is being developed to account for rate-of-loading effects.

4. **NRC Oct. 92 COMMENT:**

The EPRI friction test program includes the development of a model to replicate the surface-to-surface contact conditions wear patterns that have been observed on valve internal parts resulting from MOV tests. EPRI will need to ensure that the model can account for orientation and lubrication. EPRI will also need to consider whether surface conditions of the valve internal parts (such as corrosion) can affect friction; particularly when MOVs will be installed in nuclear plant system environments detrimental to specific valve materials.

EPRI Nov. 92 RESPONSE:

The friction tests at Battelle include studies of several different contact orientations which could be expected to occur in a gate valve. For example, the investigations include flat-to-flat configurations such as occur in guides and seats, edge-to-flat configurations such as occur in guides (when the disk is tipped), and edge-to-edge configurations such as occur in guides and seats (when the disk is tipped). The friction tests are carried out in demineralized water or steam which are expected to be free of oil/greases or other potential contaminants, which could potentially act as lubricants.

In general, gate valves installed in safety related systems have stellited disc and body seats. Stellite is not significantly susceptible to corrosion (oxidation rates are extremely low) and its performance would not be expected to degrade due to corrosion phenomena. In fact, the possible build up of an oxide layer on the surface of the stellite would be expected to reduce friction by providing a lubrication layer.

All EPRI flow loop testing is performed on valves which have been thoroughly cleaned (to remove any potential grease/oil/dirt) and then "preconditioned" to remove any oxide layer on the stellite surface. As a result, the apparent friction coefficients which are obtained during stellite to stellite sliding are expected to be conservative relative to in plant MOVs.

The effect of corrosion on carbon steel components is more complicated. Mild corrosion (i.e., the development of a thin surface oxide) typically reduces the coefficient of friction's by eliminating base metal contact. In isolated cases, severe corrosion could potentially alter internal clearances in a gate valve so as to affect the amount of disk tipping which can occur. This could conceivably be handled by artificially increasing the manufacturers tolerance on certain dimensions. However, this is not within the current scope of the program.

See "NRC ec. 92 STATUS" after no. 6.

5. **NRC Oct. 92 COMMENT:**

The focus of the EPRI program is on the initial qualification of the MOVs installed in nuclear power plants. EPRI will also need to address the effects of aging or degradation over the interval between preventive maintenance (such as cumulative corrosion of parts and reduction of actuator/stem lubrication).

EPRI Nov. 92 RESPONSE:

Development and implementation of MOV preventative maintenance and periodic testing programs are the responsibility of each utility and are not within the scope of the EPRI Program.

See "NRC Dec. 92 STATUS" after no. 6.

6. **NRC Oct. 92 COMMENT:**

Long term aging can affect MOV performance. Ten explicit examples of these aging mechanisms are identified as common MOV degradation conditions and are contained in the list of 33 items included as Attachment A to GL 89-10. These examples are numbered 9, 10, 11, 12, 13, 14, 16, 20, 22 and 23. The recommendations in GL 89-10 for the periodic verification of MOV capability are intended to address these types of aging concerns. EPRI will need to develop appropriate methodologies to model and/or monitor (detect and trend) these effects such that licensees can satisfy their commitments to GL 89-10. The staff does not have adequate information to determine whether EPRI's plan to study aging through the testing of a few older MOVs installed in nuclear plants will provide sufficient information to address all of the staff's concerns.

EPRI Nov. 92 RESPONSE:

All of the examples of "aging" mechanisms cited in comment 6 refer to items external to the valve itself and can be addressed through utility preventative and predictive maintenance programs. Assessment of the aging mechanisms is outside of the scope of the EPRI methodology development program.

NRC Dec. 92 STATUS OF NRC STAFF COMMENTS 4, 5 AND 6

In the November 30 letter, EPRI states than an evaluation of aging mechanisms is outside the scope of its MOV performance methodology development program. EPRI also states that the development and implementation of MOV preventative maintenance and periodic testing programs are the responsibility of each licensee and are not within the scope of the EPRI program. At the December 3 meeting, the staff noted that the EPRI program will provide information on the thrust requirement to operate valves only for an initial test and not include aging effects. Consequently, the EPRI program might not assist licensees in meeting their commitments to periodically verify the design-basis capability of safety-related MOVs in response to Generic Letter 89-10. At the December 3 meeting, EPRI stated that its use of in-situ test data as part of the validation of its methodology may help indicate whether aging effects are significant. EPRI stated that it was cleaning and degreasing internal valve parts before reassembly and that it was stroking valves many times in an effort to remove the oxide layer from the disk and guides before obtaining thrust requirements. EPRI has indicated that the increase in thrust requirements can be significant from this pre-conditioning. The staff considers the increase in thrust requirements with stroking to emphasize the need to periodically verify the design-basis capability of MOVs. Although the staff acknowledged the problem with including aging effects specifically in the current EPRI MOV Performance Prediction Program, the staff encouraged EPRI to begin now to consider and identify important aging parameters. This encouragement was offered because of the planned in-situ MOV tests to be performed at selected plants. These in-situ tests present an opportunity to start developing a database upon which aging effects can be detected and quantified. EPRI stated that its in-situ test guide provides information on the collection of data for evaluation of aging effects. The staff will review the guide and provide comments to EPRI. The staff also has aging programs in progress and will be discussing this issue with NUMARC and EPRI in the future.

In Question 4, the staff states that the EPRI friction test program includes the development of a model to replicate the surface-to-surface contact conditions wear patterns that have been observed on valve internal parts resulting from MOV tests. EPRI will need to ensure that the model can account for orientation and lubrication. EPRI's answer to Questions 4, 5 and 6 pertains to the evaluation of aging mechanisms. This portion of Question 4 remains open and will be discussed with EPRI at the next meeting.

EPRI Sept. 93 UPDATED RESPONSE to NRC STAFF COMMENTS 4, 5 AND 6:

Aging: Resolved -- the EPRI program will not address aging effects directly.

Friction (effects of orientation and lubrication):

The Friction Separate Effects Test program will establish coefficients of friction and damage criteria for different contact orientations which can occur in a valve. Examples of these orientations are the flat-on-flat contact which occurs during normal sliding and the edge-on-edge contact which can occur when a tipped disk initially contacts the valve body seat.

Potential degradation in stem lubricants can be evaluated by static testing conducted as part of each utility's periodic test program.

7. **NRC Oct. 92 COMMENT:**

EPRI has stated that its actuator tests will use the Torque Thrust Cell (TTC) developed by ITI-MOVATS for diagnostic data. EPRI also has stated that thrust and torque measurements will be obtained during the MOV differential pressure and flow tests using Smart Stems developed by Teledyne. EPRI will need to ensure that the accuracy's of the TTC and Smart Stems are validated for the actual thrust and torque ranges required to open and close the valve. This effort will need to include resolution of any accuracy issues raised by the testing of the TTC and Smart Stems by the MOV Users Group.

EPRI Nov. 92 RESPONSE:

The Torque Thrust cells and Smart Stems used in the EPRI Program are all fully calibrated over the full range of expected opening/closing thrust and torque both prior to and following test completion. The Final Reports for the Actuator and MOV tests will provide analyses of TTC and Smart Stem accuracies in sufficient detail to establish data error bands.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that the Torque Thrust Cells and Smart Stems used in its program are calibrated over the full range of thrust and torque requirements. EPRI states that its reports will provide analyses of the TTC and Smart Stem accuracies. The staff considers EPRI's response acceptable. The staff has recently learned of a concern about the accuracy of the TTC at the Turkey Point nuclear plant. EPRI should ensure that the concern is resolved before relying on the TTC data in its reports.

EPRI Sept. 93 UPDATED RESPONSE:

EPRI is aware of the FP&L issues. These issues are not relevant to the EPRI testing because all Operator Separate Effects testing is conducted with a single TTC installation configuration i.e., we do not conduct tests with and without the TTC installed and all tests are conducted with full stem nut engagement.

8. **NRC Oct. 92 COMMENT:**

In studying load sensitive behavior (i.e., rate of loading affects), EPRI should determine if the reduction in actuator output resulting from this phenomenon is important for both opening and closing the valve.

EPRI Nov. 92 RESPONSE:

Load sensitive behavior (i.e., rate of loading) may occur in the opening as well as closing directions. EPRI concurs that the final methodology and the procedure for its implementation will have to address the issue of possible rate of loading effects on valve opening and that the operator margin is adequate to accommodate such effects should they exist.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that it would evaluate load sensitive behavior in both the valve opening and closing directions. The staff considers EPRI's response acceptable.

EPRI Sept. 93 UPDATED RESPONSE:

The detailed approach for addressing potential rate-of-loading effects in the opening direction is currently being finalized. This approach will be presented at the October 6-7, 1993 meeting with NRC.

9. NRC Oct. 92 COMMENT:

EPRI has stated that preliminary testing indicates a small reduction in torque delivered by the actuator under loaded conditions as compared to unloaded conditions. EPRI should continue to evaluate this phenomenon to determine its potential effect on the capability of MOVs to perform their safety functions under design-basis conditions.

EPRI Nov. 92 RESPONSE:

To date, torque variations observed at Battelle and Wyle have been small and may be statistically insignificant. However, the Program will fully assess any potential torque output losses under loaded conditions and will incorporate the results of this assessment into the final methodology.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that its test results to date have indicated minimal torque variations. EPRI states that it would assess torque variations in its program. The staff considers EPRI's response acceptable.

EPRI Sept. 93 UPDATED RESPONSE:

EPRI response accepted, no update.

10. NRC Oct. 92 COMMENT:

EPRI should provide a detailed description of its method for simulating pump flow to the staff as soon as possible. The staff will review this method of simulating pump flow and will provide EPRI with any concerns regarding this method.

EPRI Nov. 92 RESPONSE:

Most safety-related MOV's are installed in pumped flow systems. The flow velocity, through these systems generally are less than 15 feet per second. Closure of an MOV under such conditions will result in a build-up in significant DP across the valve only near the very end of the stroke. Accurate simulation of this DP build-up in the EPRI test program is important to ensure that the loading time history on the valve disc is representative of the loading which would occur on such a valve in a plant pumped flow system.

For purposes of the EPRI Program, "pumped flow" is defined as a system where flow through the MOV is limited when the MOV is fully open by a pump or other system components to a nominal flow velocity in the range 10 to 15 feet per second. This range of flow velocities is typical of pumped flow systems in nuclear plants. It is to be distinguished from "blowdown flow" where the pressure upstream of the MOV is essentially constant and flow is limited only by the closing of the MOV and by the piping resistance which may be low.

Pump flow characteristic curves for a large number of plant systems were reviewed. In general, the head vs. flow curves were found to be quadratic. Based on the assumption of a quadratic pump curve, the relationship between flow rate and valve DP during a stroke is quadratic and is given by (Ref. Attachment 1):

$$\frac{\Delta P_v}{\Delta P_{v_{max}}} = \left(1 - \frac{Q^2}{Q_{max}^2}\right)$$

where:

ΔP_v = valve pressure drop at stroke position "x"
$\Delta P_{v_{max}}$ = valve DP closed (= pump shut-off head)
Q = flow rate at stroke position "x"
Q_{max} = flow rate with valve fully open

This is the basis of the specification used in establishing conditions for flow loop testing. This condition can be obtained or approximated in a number of ways in a flow loop. For example, the pressure upstream of the valve could be maintained constant during the MOV stroke with a control valve while the full-open flow rate is restricted by an orifice in the system. This would produce the desired pumped-flow DP behavior across the MOV.

At the Wyle Norco facility, the fluid source is a very large pressure vessel whose pressure remains very nearly constant by regulating the tank ullage pressure using high capacity nitrogen regulators during a MOV stroke. Downstream of the MOV is a restricting orifice which restricts the flow when the MOV is open to the desired flow rate (e.g., 15 fps). This test method produces the desired DP behavior across the MOV.

At the Huntsville pumped flow loop, a slightly different approach was taken. There, a number of pumps are operated in parallel at a cumulative flow rate much higher than required to flow through the MOV at the nominal full-open flow rate (e.g., 15 fps). A significant fraction of the flow is bypassed around the MOV. By manually adjusting valves upstream and downstream of the MOV and in the bypass line, it is possible to establish a conditions such that the nominal full-open flow rate is achieved with the MOV fully open and the desired shut-off head is achieved with the MOV closed. The pressure at the inlet to the valve remains very nearly constant throughout the stroke and the pumped flow DP behavior is very nearly approximated.

In practice, a tolerance of approximately 5 percent is added to the theoretical curve and the result is used to evaluate the loop performance on each test. Figure 3 is a plot from the Huntsville Loop which shows that the test data approximates a quadratic and falls within the tolerance band.

It should be noted that achieving an accurate reproduction of the ideal pumped flow DP vs Flow curve is not critical to validating the Methodology. The Methodology will calculate required thrust for any arbitrary variation of DP with stroke position (including constant or varying upstream pressure). What is more important is that tests conducted provide a range of fluid loads on the valve disc to allow a comprehensive model validation. For example, in low velocity pumped flow the disk is loaded only near the fully closed position. Higher velocity pumped flow loads the disk earlier in the stroke and blowdown loads the disk even earlier. The techniques used at Wyle to simulate pumped flow systems provide this variation and, as a bonus, quite accurately reproduce pumped flow system characteristics.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI provides a description of its method for simulating pump flow. The staff considers EPRI's response acceptable, but noted at the December 3 meeting that EPRI should ensure that the flow rates are appropriate for MOVs installed in nuclear plants.

EPRI Sept. 93 UPDATED RESPONSE:

The EPRI justification for the approach taken to simulate pumped flow was accepted.

As to the actual velocities which were simulated, 15 fps appears to bound the majority of the applications (design velocities for most piping systems are on the order of 10 to 15 fps). 50 fps bounds all pumped flow applications.

11. **NRC Oct. 92 COMMENT:**

At a May 1992 meeting, EPRI presented its matrix and schedule for testing 60 MOVs in test facilities or at nuclear plants, under various differential pressure, temperature, and flow conditions to validate its model. At the October 1992 meeting, EPRI stated that those tests may be used to refine the methodology. The staff does not consider tests used to refine the methodology appropriate for use in validating the methodology. EPRI will need to select additional MOVs to be tested to validate the methodology.

EPRI Nov. 92 RESPONSE:

The valve and operator models will be based on first principles. The separate effects test data will be used to refine the models and to obtain required empirical data. During model development, the flow loop and in situ test data (including NRC/INEL data) will be studied and reviewed to ensure that all significant physical phenomena which appear to be occurring are addressed by the models e.g., guide bending was observed during testing and the calculation of guide bending will be included in the methodology.

The flow loop and in situ test data will not be used to define empirical constants within the model, and the models will not be empirical correlations of MOV test data.

Once it is determined that all significant phenomena are addressed by first principles modeling and all empirical constants have been derived from the separate effects testing, the methodology will be used to make predictions of the flow loop and in situ test results. In addition to these comprehensive model-to-data comparisons, the methodology will be used to make "blind" predictions for selected tests. The tests selected for "blind" prediction will fully exercise the model over a wide range of valve design and test condition variations.

If there is inadequate agreement between model predictions and data, considerations of model refinement may need to be evaluated at that stage. Quantitative use of data, if needed, would need to be thoroughly evaluated and justified; the intent would be to utilize the best available information.

NRC Dec. 92 STATUS:

At the December 3 meeting, EPRI stated that the valve and operator models in its program would be based on first principles of engineering. EPRI stated that it was using separate effects testing to refine the models and would use the loop and in-situ test data to validate the models. EPRI stated that, in certain instances, it might need to use loop or in-situ data to refine the models, but would notify the NRC staff in those instances. The staff believes that EPRI should attempt to use test data to validate the realistic model to ensure its first principles analysis is appropriate. The staff does not have a philosophical problem with EPRI using limited aspects of its loop and in-situ data for model refinement. However, the staff considers the acceptability of the use of loop and in-situ test data for model refinement will depend on the specific circumstances.

EPRI Sept. 93 UPDATED RESPONSE:

EPRI response accepted, no update.

12. **NRC Oct. 92 COMMENT:**

At the October 1992 meeting, EPRI indicated that it is planning to test fewer MOVs at test facilities than stated in May 1992. EPRI plans to test more MOVs at nuclear plants to maintain the total of 60 MOVs tested. The staff is concerned that testing MOVs at nuclear plants will limit the range of test conditions and reduce the amount of test data obtained. The staff also is concerned about the small amount of testing under steam and high pressure/temperature conditions. In this regard, EPRI identified some of these tests as "Option 3" which might not be conducted. The reduction in the test database appears to result in the EPRI program covering smaller population of MOVs. The staff is concerned that some licensees will have many MOVs outside the scope of the EPRI program and that completion of their GL 89-10 programs might be delayed.

EPRI Nov. 92 RESPONSE:

No reduction has been made to the range of MOV designs to be covered by the MOV Flow Loop or in situ test Programs. Specifically, 4 butterfly valves have been deleted from the flow loop test program, but 6 butterfly valves have been added to the in situ test program. In addition, a new butterfly valve test project has been added to the Program. This project will test scale model (6 inch) butterfly valves in a separate test loop. These tests will focus on confirmation of scaling laws and assessment of upstream piping configuration effects on butterfly valve performance.

Although in situ testing generally results in data only at a single DP, it does provide real world MOV performance information. The current split of 34 MOV's in flow loops and 26 MOV's in situ is believed to represent a good balance between parametric and real world data for methodology validation.

No change has been made to the number of steam flow tests planned. However, tests which exactly replicate tests already performed by INEL have been moved to the end of the test sequence. Since data already exist for such valves under such conditions, these tests are considered lower priority. These tests or other tests which may be desired based on review of earlier test results will be completed contingent on funding availability.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that no reduction has been made to the range of MOV designs to be covered by the testing program. EPRI acknowledges that in-situ testing generally limits the testing to only a single differential pressure condition as opposed to the range of differential pressure conditions possible during loop testing. EPRI also states in the letter that it was not planning to change the number of steam flow tests. However, EPRI also states that these tests will be completed contingent on funding availability. At the December 3 meeting, EPRI stated that those tests will be performed. The staff is concerned about the limitations in the scope of applicability of the EPRI methodology with the reduction in the range of differential pressure test conditions from in-situ testing and the potential omission of the steam flow tests. In response to these concerns, EPRI committed to provide the staff with a comparison of the scope of its testing program with the population of valves installed in safety-related applications in nuclear plants. The staff will review that comparison and will discuss this concern with EPRI at future meetings.

EPRI will not be testing each type and size of MOV currently installed in nuclear plants. Even though EPRI might not test a particular type and size of MOV, EPRI stated at the December 3 meeting that licensees would be allowed to apply the EPRI methodology to that MOV unless specific information disqualifies that MOV from application of the methodology. EPRI is relying on licensees to identify valves that do not perform as predicted by the EPRI methodology. Therefore, licensees will need to record test data and dimensional information in a manner that can be compared to the EPRI methodology. At the December 3 meeting, NUMARC stated that it is working with the industry in an effort to develop a test database for sharing information between licensees. The staff will continue to discuss with NUMARC the need for an industry-wide test database.

See "EPRI Sept. 93 UPDATED RESPONSE" after no. 13.

13. **NRC Oct. 92 COMMENT:**

The staff noted in the matrix of valves to be tested by EPRI that only one parallel disk gate valve would be tested at a test facility and that the valve is a new design. EPRI stated that it would test one parallel disk gate valve at a nuclear plant. The staff noted that the test matrix included only a small number of butterfly valves and one over-the-plug globe valve. Further, the test matrix included one new design of split-wedge gate valve. EPRI may need to test additional valves to complete the validation for valve types that are minimally tested.

EPRI Nov. 92 RESPONSE:

The philosophy for determining the MOV designs to be tested is to test the full range of design features which will need to be addressed by the models. Specifically, for gate valves, the model will predict the performance of solid/flexible wedge valves. These are by far the most predominant gate valve designs and the designs considered most susceptible to performance variation due to vendor specific design differences. The test matrix includes substantial flexible/solid wedge gate valve design and test condition variations.

A second category of gate valves, i.e., unique designs with small representation in the overall MOV population, are being covered by testing to provide data under design basis conditions which can be used directly by utilities to assess expected performance for the same valve designs. Current plans call for addressing the parallel disc gate valve design in this manner. Because these are specific unique designs each manufactured by only a single vendor, the limited number of such tests planned are believed to be adequate to assess their performance.

Our testing coverage for butterfly valves is discussed in the response to Comment 12.

Current methods for the prediction of globe valve performance are expected to be adequate based on industry experience. The current limited set of globe valve tests planned is considered adequate to confirm the adequacy of current prediction methods. If, based on test data obtained in the Program, or new industry experience this is shown not to be the case, additional globe valve testing will be considered.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that its model will predict the performance of solid/flexible wedge gate valves. EPRI states in the letter that its data from testing other gate valves (such as parallel disk gate valves) will be used by licensees directly. At the December 3 meeting, EPRI stated that the two parallel disk gate valves to be tested are designs currently used in nuclear plants. In the November 30 letter, EPRI states that globe valve testing is being conducted to verify current performance prediction methods. At the December 3 meeting, EPRI stated that it will conduct sufficient testing on butterfly valves to include those valves in its methodology. The staff remains concerned about the scope of applicability of the EPRI methodology. Many licensees have installed or are considering installation of parallel disk gate valves. Testing performed in Europe has revealed that the performance of parallel disk gate valves is similar to flexible wedge gate valves. This information casts doubt on assertions by valve vendors for many years that parallel disk gate valves have significantly lower thrust requirements than flexible wedge gate valves.

At the May 1992 meeting, EPRI requested data from NRC-supported butterfly valve tests completed in the mid-1980s. The NRC Office of Nuclear Regulatory Research subsequently agreed to provide the data to EPRI and instructed the Idaho National Engineering Laboratory (INEL) to coordinate the effort. At the December 3 meeting, INEL provided a status of this effort. INEL stated that progress has been made and that the data are being assembled in the agreed format.

EPRI Sept. 93 UPDATED RESPONSE TO NRC COMMENTS 12 AND 13:

As mentioned in the initial comment and response, there has been a reduction in the amount of test data at parametric DP conditions. However, it is important to recognize that there is a substantial amount of parametric DP data from the flow loop tests. Specifically, each of the 34 flow loop valves was tested at multiple DPs under one or more types of flow conditions. Particularly when coupled with the friction and valve design effects test results (which were done at parametric load levels) these data represent by far the most thorough and exhaustive study of the effect of DP loading level ever conducted. It is concluded that the existing mix of flow loop and in situ data will provide adequate information in this regard.

The potential reduction in steam testing has been re-evaluated based on the results of INEL testing, friction separate effects testing and initial EPRI flow loop blowdown testing. Specifically, it has been found in separate effects and valve testing that there is no significant difference in sliding friction behavior between steam and water environments at the same temperature. Accordingly, a reduction in EPRI flow loop steam testing to the point where this conclusion is simply being confirmed was deemed to be in order. The final flow loop test matrix (Table 3) includes 1200 psi steam blowdown testing of two 6"" and two 10" valves as well as nominal flow (200 fps) steam testing of one 6" valve. In addition, the in situ test matrix (Table 4) includes the testing of two 3" valves under steam blowdown conditions and two 4" valves under nominal flow (40,000 lbs/hr) steam conditions. Beyond these data which are being obtained during the EPRI test Program, the methodology will be assessed via comparing model predictions of thrust requirements and damage level to steam blowdown data obtained for one 6" and three 10" valves during the NRC/INEL test Program (Table 5). This approach is considered sufficient to validate the performance methodology for steam conditions.

The scope of the EPRI testing program in relationship to the overall population of valves has been evaluated in two ways:

- First, the applicability criteria of the methodologies has been worked out in detail, and the features of the valves known to be in service at the plants has been compared to these criteria. The result is that the methodologies are expected to cover:

  - about 90% of gate valves (about 1/2 with the computer code and 1/2 with empirically based methods)
  - essentially all globe valves
  - about 95% of butterfly valves.

  The key area where coverage is lacking for gate valves is non-stellite valves. For butterfly valves, certain low population design types are not covered.

- Second, the flow loop and in situ test matrices were compared to the more than 3,000 89-10 gate valves currently documented in the EPRI General Information Database. This valve population as been evaluated in terms of NSSS and A/E design types and is considered to be reasonably representative of the industry gate valve population as a whole. The gate valves in the database were "grouped" according to manufacturer, size and pressure class. The resultant groups were arranged according to their strength of representation in the population, and a check was made to determine which groups were covered by a test valve. The results are shown on the attached Table 6. This comparison indicates that the most prevalent valve groups are well-represented in the test Program.

With regard to parallel disk gate valves, the principal one in use in U.S. nuclear power plants is the Anchor/Darling double disk gate valve. We estimate that slightly over 5% of all safety related gate valves are Anchor/Darling double disk valves, and that all other parallel disk valves (such as Target Rock, Atwood & Morrill, etc.) are a very small percentage (much less than 1%). In the EPRI program, test data are being obtained from two Anchor/Darling double disk gate valves. This representation in the test group (2 of 47 gate valves or 4.3%) is similar to the overall representation of this valve type in the gate valve population. Further, one of the two valves is being tested at a wide range of flow conditions including pumped water, water blowdown and steam blowdown conditions. These valves are fabricated of similar materials as solid and flexible wedge gate valves, so that the friction information generated from other parts of the program is expected to be applicable to double disk gate valves.

14. **NRC Oct. 92 COMMENT:**

Licensees will be using the EPRI methodology as part of their GL 89-10 programs to demonstrate that MOVs for which design-basis testing is not practicable are capable of performing their design-basis functions. EPRI will need to ensure that all design-basis parameters (such as fluid temperature and flow, ambient temperature effects on the motor output and cable voltage losses, seismic/dynamic effects, and degraded voltage) consistent with the recommendations of GL 89-10 and its supplements are incorporated into the EPRI methodology.

TABLE 3
FLOW LOOP TEST MATRIX
34 VALVES/64 TEST SEQUENCES

No.	Valve Type	Manufacturer	Size (Inch)	ANSI Class/ Material	Limitorque Actuator SMB- Type (Note 4)	Ambient Water 15 FPS (Note 6) MAX DP	Ambient Water 50 FPS (Note 5) MAX DP	450°F Water 15 FPS (Note 1) MAX DP	500°F Water Blowdown (Note 2) MAX DP	Sat. Steam 200 FPS MAX DP	Sat. Steam Blowdown (Note 2) MAX DP	Alternate Configuration Testing Notes
1	FWG	Anchor Darling	3	300 cs	00	740 (HI)						
2	FWG	Anchor Darling	6	150 ss	000	250 (HP)						
3	FWG	Anchor Darling	6	900 cs	0	1800 (N)	(N)1800	(N) 1200	(N) 1200			
4	FWG	Anchor Darling	10	300 cs	0	740 (HI)						B,C, F
5	FWG	Anchor Darling	10	900 cs	2-150	1800 (S)						
6	FWG	Anchor Darling	18	300 cs	2	500 (S)						
7	FWG	Borg-Warner	3	1500 cs	00	2500 (N)	(N) 2500					
8	FWG	Borg-Warner	6	150 cs	Rotork	250 (HP)						
9	FWG	Borg-Warner	6	1500 cs	1	1800 (N)			(N) 1200			
10	FWG	Borg-Warner	12	300 cs	1-25	500 (HI)						
13	FWG	New Velan	2-1/2	1500 ss	000	2500 (N)	(N) 2500		(N) 2500			
14	FWG	Crane	6	900 cs	0	1800 (N)	(N) 1800		(N) 1200			
15	FWG	Walworth/Aloyco	4	150 ss	Rotork	250 (HP)						
16	FWG	Anchor Darling	3	900 cs	00	1800 (N)						
17	FWG	Pacific	10	150 cs	000	250 (HP)						
18	FWG	Pacific	4	150 cs	Rotork	250 (HP)						
21	FWG	Rockwell	2-1/2	900 cs	000-5	1800 (N)						
23	FWG	Velan	6	150 cs	000	250 (HP)	(HP) 250					
24	FWG	Velan	6	900 cs	0	1800 (N)	(N) 1800	(N) 1200	(N) 1200	(S) 1200	(S) 1200	
25	FWG	Velan	10	300 cs	0	500 (HI)						
26	FWG	Velan	10	900 cs	2	1800 (HI)					(S) 1200	
29	FWG	Walworth	6	150 cs	Rotork	250 (HP)						
30	FWG	Walworth	6	900 cs	0	1800 (N)			(N) 1200			
31	FWG	Walworth	12	150 cs	Rotork	250 (HI)						
34	FWG	Westinghouse	3	1500 ss	00	2500/750 (N)						G
41	PDG	Anchor/Darling	6	900 cs	0	1800 (N)			(N) 1200		(S) 1200	
43	SWG	Edwards	10	900 cs	2	1800 (HI)					(S) 1200	
44	Globe	Borg - Warner	6	900 cs	2	1800 (N)	(N) 1800					
48	Globe	Rockwell/Edwards	2	1500 ss	00	2500 (N)	(N) 2500		(N) 2500			
49	Globe	Velan	2-1/2	1500 ss	00	2500 (N)						
50	Globe	Anchor Darling	10	300 cs	2	500 (HI)						D
54	BFly	Pratt 1400 Sym	6	150 cs	000 -HOBC	150 (HP)						
55	BFly	Pratt 1200 Single O/S	6	150 cs	000 -HOBC	150 (HP)						D
XX	FWG	Powell	14	600 cs		500 (HI)						

HP= Wyle Huntsville Pumped Flow Loop Test Facility

HI= Wyle Huntsville Intermediate Pressure Test Facility

N= Wyle Norco High Pressure Test Facility

S= Siemens/KWU High Pressure Test Facility

126G/JFH/jp

NOTES FOR TABLE 3

Alternate Configuration Testing: In addition to test sequences shown on the matrix, selected valves will be tested w[illegible] ambient water 15 FPS for the following conditions:

A. These MOV's will be tested to confirm preconditioning methods up to 5 test sequences per valve).

B. These MOV's will be tested with an upstream elbow parallel to stem (flow from above) at zero diameter (i.e., immediately upstream of the mating flange).

C. These MOV's will be tested with the stem in a horizontal orientation with the pipe run horizontal (with straight inlet configuration).

D. These MOV's will be tested with the flow direction reversed (from that used in the nominal test).

E. These MOV's will be tested with the an elbow perpendicular to stem and parallel to stem at zero diameters upstream, and with an elbow perpendicular to stem at 3 diameters and 5 diameters upstream.

F. These MOV's will be tested with an elbow perpendicular to the stem at zero diameter upstream.

G. Test to 750 psid (closures) and to 2500 psid (openings).

Notes:

1. Upstream and downstream pressures for the 450°F water (non-blowdown tests) shall be high enough to prevent flashing downstream of the test MOV.

2. Refer to Task 2 description for a discussion of required blowdown capacity.

3. The maximum DP specified for each MOV in this table is the DP across the test MOV when it is fully closed. The maximum flow (corresponding to the specified velocity) occurs when the test MOV is fully open.

4 The actuator sizes shown are preliminary and will vary based on undervoltage specified at time of purchase. It is expected that a limited number (approximately 5) SB and SBD type actuators will be substituted for SMB actuators. It is expected that a limited number (approximately 5) of Rotorque actuators will be substituted for SMB actuators.

5. 30-35 FPS for butterfly valves.

6. 12-13 FPS for 18" butterfly valve.

TABLE 4

IN-SITU TEST MATRIX

28 MOVs (GATES: 19, BF: 7, GLOBES: 2)

25 Enhanced In Situ MOVs
3 Enhanced In Situ MOVs w/o inspections

8/3/93 13:27

NUMBER	FAMILY	TAG	SYSTEM	MFG	TYPE	SIZE	ANSI	TEST DP	TEST FLOW	MEDIUM	INSPECT	TST. DATE	DATA PCKG	TEST RPT.
				TU ELECTRIC (COMANCHE PEAK)										
1	G6	HV2494	AF	BW	FWG	4	900	1592	700	WATER	PH	COMPLETE	Aug-93	Sep-93
2	G12	HV4709	CC	BW	FWG	4	1500	2205	195	WATER	PH	COMPLETE	Aug-93	Sep-93
3	G53	HV4776	CT	BW	FWG	16	300	246	8,896	WATER	PH/HAND	COMPLETE	RECEIVED	COMPLETE
4	G53	HV4777	CT	BW	FWG	16	300	246	7,600	WATER	PH/HAND	COMPLETE	RECEIVED	COMPLETE
5	G32	8000A	RC	WESTING.	FWG	3	1525	2485	210,000	STEAM	PH	COMPLETE	Aug-93	Sep-93
6	G32	8000B	RC	WESTING.	FWG	3	1525	2485	210,000	STEAM	PH	COMPLETE	Aug-93	Sep-93
7	G16	8804A	SI	WESTING.	FWG	8	316	244	1,800	WATER	PH	COMPLETE	Aug-93	Sep-93
8	BF16	HV4286	SW	FISHER	BF-SO	24		85	15,000	WATER	PH	COMPLETE	Aug-93	Sep-93
9	BF9	HV4572	CC	FISHER	BF-S	18		83	7,600	WATER	NA	COMPLETE	RECEIVED	Jul-93
10	GL50	FV4772	CT	FISHER	GLOBE	4		281	750	WATER	NA	COMPLETE	RECEIVED	Jul-93
11	G24	8801A	SI	WESTING.	FWG	4	1525	2690	700	WATER	NA	COMPLETE	RECEIVED	Jul-93
12	G21	8812B	SI	WESTING.	FWG	14	316	436	4,900	WATER	NONE	COMPLETE	Aug-93	Sep-93
13	G18	8840	SI	WESTING.	FWG	10	1525	1241	2,700	WATER	NONE	COMPLETE	Aug-93	Sep-93
				NORTHERN STATES POWER (MONTICELLO)										
14	G36	MO-2014	LPCI	A/D	FWG	16	600	335	16,000	WATER	HAND	COMPLETE	6-Aug-93	Aug-93
15	G36	MO-2015	LPCI	A/D	FWG	16	600	335	16,000	WATER	HAND	COMPLETE	6-Aug-93	Aug-93
16	GL13	MO-2012	RHR	A/D	GLOBE	16	600	335	16,000	WATER	NA	COMPLETE	6-Aug-93	
				PACIFIC, GAS & ELECTRIC (DIABLO CANYON)										
17	G11	FCV-37	AFW	VELAN	FWG	4	600	910	40,000	STEAM	HAND	COMPLETE	RECEIVED	Jul-93
18	G2	FCV-95	AFW	A/D	PDG	4	600	910	40,000	STEAM	HAND(NQ)	COMPLETE	RECEIVED	Jul-93
				DUKE POWER/FISHER (UTAH STATE)										
19	BF25			POSI-SEAL	BF-SO	10		35	4,500	WATER	NA	COMPLETE	Jul-93	Aug-93
20	BF38			POSI-SEAL	BF-SO	42		50	4,500	WATER	NA	COMPLETE	Jul-93	Aug-93
				ARIZONA PUBLIC SERVICE (PALO VERDE)										
21	BF4	HC-401		PRATT	BF-SO	10	150	120	3,815	WATER	NA	COMPLETE	15-Jul-93	Aug-93
22	BF2	SP-49A		PRATT	BF-S	24	150	51	17,600	WATER	NA	COMPLETE	15-Jul-93	Aug-93
23	BF3	SP-49B		PRATT	BF-S	18	150	51	17,600	WATER	NA	COMPLETE	15-Jul-93	Aug-93
				WASHINGTON PUBLIC POWER S S (WNP-2)										
24	G40	SW-V-12B	SW	VELAN	FWG	18	300	150	10,000	WATER	HAND	COMPLETE	Jul-93	Aug-93
				SOUTHERN CALIFORNIA EDISON (SAN ONOFRE)										
25		2HV9306	HPSI	WKM	PDG	4	900			WATER	NA	Jul-93	Aug-93	Sep-93
26		2HV6366	CCW	WKM	PDG	10	150			WATER	NA	Jul-93	Aug-93	Sep-93
27		2HV9337	SDCS	WKM	PDG	16	1500			WATER	NA	Jul-93	Aug-93	Sep-93
				ILLINOIS POWER CO. (CLINTON)										
28	G15	15X173B	SDSW	A/D	FWG	10	150	140	30 fps VERT	WATER	HAND	Sep-93	Oct-93	Oct-93

TABLE 5

				ADDITIONAL MOV TEST DATA								
					9 MOVs							
				INEL GATE VALVE								
No.	Type	Manufacturer	Size	ANSI	Mat'l	Actuator	Ambient Water 15 fps Max DP	Ambient Water 50 fps Max DP	450 degF Water 15 fps Max DP	500 degF Water Blowdn Max DP	Sat. Steam 200 fps Max DP	Sat. Steam Blowdn Max DP
1	FWG	A/D	6	900		SMB-0-25				1300/900		
2	FWG	VELAN	6	900		SMB-0-25				1500/1000		1210
3	FWG	WALWORTH	6	600		SMB-0-25				1200		
4	FWG	A/D	10	900		SMB-1-60						720
5	FWG	POWELL	10	900		SMB-1-60						1020
6	FWG	VELAN	10	600		SMB-1-60						1300
				INEL BUTTERFLY PURGE								
No.	Type	Manufacturer	Size	ANSI	Mat'l	Actuator	Ambient WATER 15 fps Max DP	Ambient Water 50 fps Max DP	450 degF Water 15 fps Max DP	AMBIENT GAS Blowdn Max DP	Sat. Steam 200 fps Max DP	Sat. Steam Blowdn Max DP
1	BF/SO	ALLIS-CHMRS	8	150						60		
2	BF/SO	PRATT	8	150						60		
3	BF/SO	PRATT	24	150						60		

TABLE 6

MOV POPULATION STUDY
GATE Valve Sample, Size/Class Groupings
3155 Valves in Study
10-08-1991 18:34:07

Family	Valve Manufacturer	Valve Size (inches)	ANSI Class	# Valves	Cumulative % of Valves	In F.L. Matrix?	In I.S. Matrix?	Other?	Remarks
1	ANCHOR AND A/D	4 - 8	≤ 300	124	3.930	Y			25 PDG
2	ANCHOR AND A/D	4 - 8	600-1500	120	7.733	Y	Y	INEL	54 PDG
3	WALWORTH AND W-G	16 - 22	≤ 300	116	11.41				
4	BORG-WARNER	4 - 8	≤ 300	114	15.02	Y			
5	WALWORTH AND W-G	4 - 8	≤ 300	104	18.32	Y			
6	BORG-WARNER	≤ 3	600-1500	102	21.55	Y			
7	VELAN	4 - 8	≤ 300	97	24.62	Y			3 PDG
8	VELAN	≤ 3	600-1500	97	27.70	Y			
9	POWELL	4 - 8	≤ 300	95	30.71				
10	WALWORTH AND W-G	4 - 8	600-1500	88	33.50	Y		INEL	
11	VELAN	4 - 8	600-1500	87	36.25	Y	Y	INEL	2 PDG
12	BORG-WARNER	4 - 8	600-1500	82	38.85	Y	Y		
13	WALWORTH AND W-G	10 - 14	≤ 300	80	41.39	Y			
14	ANCHOR AND A/D	10 - 14	600-1500	76	43.80	Y		INEL	13 PDG
15	ANCHOR AND A/D	10 - 14	≤ 300	75	46.18	Y			16 PDG
16	WESTINGHOUSE	4 - 8	≤ 300	69	48.36		Y		
17	ALOYCO,A-W,W-A,C-A	4 - 8	≤ 300	67	50.49	Y			4 PDG
18	WESTINGHOUSE	10 - 14	600-1500	62	52.45		Y		
19	POWELL	10 - 14	≤ 300	57	54.26				
20	CRANE	4 - 8	600-1500	56	56.03	Y			
21	WESTINGHOUSE	10 - 14	≤ 300	53	57.71		Y		
22	ANCHOR AND A/D	≤ 3	600-1500	52	59.36	Y			33 PDG
23	PACIFIC	4 - 8	≤ 300	50	60.95	Y			
24	WESTINGHOUSE	4 - 8	600-1500	49	62.50		Y		
25	VELAN	≤ 3	≤ 300	48	64.02				
26	ANCHOR AND A/D	16 - 22	≤ 300	47	65.51	Y			6 PDG
27	WALWORTH AND W-G	10 - 14	600-1500	46	66.97				
28	ALOYCO,A-W,W-A,C-A	10 - 14	≤ 300	45	68.39				8 PDG
29	BORG-WARNER	≤ 3	≤ 300	45	69.82				
30	VELAN	10 - 14	≤ 300	44	71.22	Y			
31	VELAN	10 - 14	600-1500	44	72.61	Y		INEL	
32	WESTINGHOUSE	≤ 3	600-1500	39	73.85	Y	Y		
33	CRANE	4 - 8	≤ 300	38	75.05				
34	ANCHOR AND A/D	≤ 3	≤ 300	37	76.22	Y			14 PDG
35	POWELL	4 - 8	600-1500	36	77.36				
36	ANCHOR AND A/D	16 - 22	600-1500	33	78.61		Y		1 PDG
37	COPES-VULCAN	10 - 14	≤ 300	31	79.39				2 PDG
38	POWELL	16 - 22	≤ 300	30	80.34				
39	CRANE	10 - 14	600-1500	27	81.20				
40	VELAN	16 - 22	≤ 300	27	82.06		Y		
41	WALWORTH AND W-G	16 - 22	600-1500	26	82.88		Y		
42	COPES-VULCAN	10 - 14	600-1500	24	83.64				2 PDG
43	ROCKWELL AND EDW	≤ 3	600-1500	24	84.40	Y			
44	COPES-VULCAN	4 - 8	≤ 300	24	85.16				
45	CRANE	10 - 14	≤ 300	22	85.86				
46	POWELL	10 - 14	600-1500	21	86.52	Y		INEL	
47	WESTINGHOUSE	≤ 3	≤ 300	20	87.16				
48	PACIFIC	10 - 14	600-1500	18	87.73				
49	WALWORTH AND W-G	≤ 3	≤ 300	17	88.27				
50	WALWORTH AND W-G	≤ 3	600-1500	15	88.74				
51	BORG-WARNER	10 - 14	600-1500	14	89.19				
52	WALWORTH AND W-G	≥ 24	≤ 300	14	89.63				
53	BORG-WARNER	10 - 14	≤ 300	13	90.04	Y			
54	POWELL	≤ 3	≤ 300	13	90.45				
55	BORG-WARNER	16 - 22	≤ 300	13	90.87		Y		
56	WESTINGHOUSE	≥ 24	600-1500	12	91.25				
57	ROCKWELL AND EDW	≤ 3	≤ 300	11	91.60				
58	VELAN	≥ 24	600-1500	11	91.94				
59	PACIFIC	10 - 14	≤ 300	10	92.26	Y			
60	CHAPMAN-CRANE	≥ 24	600-1500	10	92.58				
61	POWELL	≥ 24	≤ 300	9	92.86				
62	ALOYCO,A-W,W-A,C-A	4 - 8	600-1500	9	93.15				
63	VELAN	16 - 22	600-1500	9	93.43				
64	VELAN	≥ 24	≤ 300	8	93.69				
65	COPES-VULCAN	≤ 3	≤ 300	8	93.94				
66	ANCHOR AND A/D	≥ 24	600-1500	8	94.19				1 PDG
67	CRANE	16 - 22	≤ 300	8	94.45				
68	CRANE	≥ 24	600-1500	8	94.70				
69	ANCHOR AND A/D	≥ 24	≤ 300	7	94.92				1 PDG
70	CRANE	16 - 22	600-1500	7	95.15				

EPRI Nov. 92 RESPONSE:

The EPRI methodology will predict MOV performance considering fluid temperature, flow and system characteristics as well as valve design variations.

In addition, the methodology will have the capability of predicting MOV performance under reduced voltage conditions. Assessment of specific cable losses, seismic/dynamic effects as well as ambient temperature effects on operator performance are the responsibility of the utilities and outside the scope of the EPRI methodology.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that its methodology will predict MOV performance considering fluid temperature, flow, system characteristics, and degraded voltage. EPRI states that an assessment of cable losses, seismic/dynamic and ambient temperature effects are the responsibility of licensees and are outside the scope of the EPRI methodology. The staff would like information on whether the EPRI methodology will accept plant input for those items considered to be outside the scope of the methodology to assist in evaluating MOV capability.

EPRI Sept. 93 UPDATED RESPONSE:

Evaluation of cable loss effects is part of an overall evaluation to be performed by each utility to determine the design degraded voltage at the MOV. The design degraded voltage at the MOV is used as input to the EPRI/NMAC MOV Application guide methodology for determining operator output torque capability.

Definition of seismic effects on valve and actuator structural capability and/or performance is beyond the scope of the EPRI MOV Performance Prediction Program. Consideration of such affects is the responsibility of each utility.

Definition of possible temperature effects on motor-actuator performance is the responsibility of the actuator manufacturer. The EPRI Program is not conducting research in this area. Utilities will rely on the actuator manufacturer to provide guidance in accounting for temperature effects on operator performance. Once these effects are appropriately accounted for, the resulting operator output capability can be used in combination with the EPRI methodology to assess MOV performance.

15. **NRC Oct. 92 COMMENT:**

EPRI will need to demonstrate that the methodology provides for sufficient thrust to ensure that valve closure is adequate to maintain leakage control in accordance with applicable regulatory or safety analyses requirements.

EPRI Nov. 92 RESPONSE:

The EPRI methodology will predict the thrust required to reach initial wedging for gate valves, hard seat contact for globe valves and the fully closed position for butterfly valves. Use of the EPRI methodology is not intended to replace leak testing currently being conducted by utilities to meet regulatory requirements.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that its methodology will predict thrust requirements for achieving initial wedging for gate valves, hard seat contact for globe valves, and fully closed positions for butterfly valves. EPRI states that its methodology is not intended to replace leak testing to meet regulatory requirements. The staff considers EPRI's response on the objective of its program and the limitation regarding leakage to be acceptable.

EPRI Sept. 93 UPDATED RESPONSE:

EPRI response accepted, no update.

16. **NRC Oct. 92 COMMENT:**

As discussed in the cover letter to these comments, EPRI has stated that the intent of its program is to allow the licensee to extrapolate the performance of its MOVs from static conditions to design-basis differential pressure and flow conditions. The staff believes that the wide range of MOV performance seen to date will mandate a large bounding margin being incorporated into the methodology to allow licensees to use the methodology to demonstrate that an MOV is capable of operating under design-basis conditions. Therefore, EPRI should consider developing means to allow a reduction of this mandatory margin through the use of pressurized static test data or intermediate differential pressure/flow test data for specific MOVs.

EPRI Nov. 92 RESPONSE:

The EPRI Methodology does not extrapolate results from static testing to design basis conditions. The methodology will calculate the thrust which must be achieved in a static test in order to ensure that the proper thrust is available under design basis conditions (including consideration of effects such as rate of loading). The static test is performed to confirm that the required static thrust is actually achieved.

It is difficult to predict the magnitude of the conservatism which will result from use of the EPRI Methodology at this particular point in the Program. That will only be done with confidence once the Models have been fully validated and assessed against test data.

It is expected that the results from a reduced differential pressure test could be used in conjunction with the EPRI methodology to obtain a more accurate prediction of MOV performance at design basis conditions. Procedures for utilizing such data are under development.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI asserts that its methodology does not extrapolate but rather will calculate the thrust that must be achieved during a static test to have confidence that the MOV will operate under design-basis conditions. EPRI states that, at this time, it cannot predict the amount of conservatism that will be needed. However, EPRI states that a reduced differential pressure test could be used in conjunction with its methodology to obtain a more accurate prediction of MOV performance at design-basis conditions. EPRI states that procedures for utilizing partial differential pressure test data are under development. The staff is concerned that the mandatory margin in using the EPRI methodology when testing only under static conditions may be severe. In regard to this staff concern, EPRI stated at the December 3 meeting that it would respond to staff questions on EPRI's plans for providing the required margin. The staff questions are as follows:

(a) How will EPRI assess degraded voltage capability if the methodology provides only a required thrust?

(b) How will the EPRI testing demonstrate the predictability of the stem friction coefficient from static to dynamic conditions?

(c) For each MOV for which the EPRI methodology is to be applied, will the EPRI methodology include the comparison of stem friction coefficient determined from the static test of the MOV in question to the assumption for stem friction coefficient in the MOV sizing and setting calculations?

(d) How will EPRI demonstrate that its measurement of stem friction coefficient after the disk has seated under static conditions (with reduced stem velocity) is representative of the stem friction coefficient at the point of initial wedging (or higher thrust-required positions caused by flow) under dynamic conditions (with normal stem velocity)? Initial INEL testing has indicated that the stem friction coefficient may be much lower at the point selected by EPRI for measurement compared to the stem friction coefficient when the disk is closing against flow. If an MOV failed to close during a dynamic test because of load sensitive behavior, the stem would be traveling at normal velocity (immediately before failure) with a higher stem friction coefficient than at EPRI's measurement point for stem friction coefficient with the reduced stem velocity.

(e) Has EPRI determined the cause of high stem friction coefficients that have been seen in some MOVs tested under static conditions in plants and how such instances will be addressed in developing the EPRI methodology?

(f) How does EPRI plan to address the large differences in stem friction coefficient observed in various stem and stem nut combinations?

(g) How will the EPRI methodology address the determination of stem friction coefficients for MOVs that are not designed to hard seat and what criteria will be used to assess the capability of the MOV?

(h) Will the conversion of static test results to dynamic conditions also account for the type of stem grease being used, the stem nut speed, the overall actuator ratio, the column stiffness of the operator, and other characteristics of the unit?

EPRI Sept. 93 UPDATED RESPONSE:

(a) The EPRI method for determination of operator output torque capability under degraded voltage conditions is to apply standard methods as documented in the EPRI/NMAC MOV Application Guide. The actual determination of the design degraded voltage at the actuator is the responsibility of each utility.

(b) Data from initial testing at Battelle indicates that if a "static test" is performed very slowly, for example by closing the valve with the handwheel, the thrust at torque switch trip will be representative of that obtained under DP conditions. That is, the stem coefficient of friction in a slow static closure approximates that in a DP closure. Additional testing to validate this hypothesis is underway. If the method is proved to be valid, a similar in-situ test will likely be incorporated into the implementation of the EPRI Methodology.

(c) The methodology as currently conceived does not rely on determination of coefficient of friction from a static test. Consequently, no analysis of such data is planned. Variations in stem μ due to potential ROL effects will be accounted for as described in (b) above.

(d) EPRI agrees that the coefficient of friction which exists under transient conditions of a static test may be different than that which exists during a DP test. Recent test data have indicated that a slow closure of the valve (e.g. by using the handwheel) results in a loading history sufficiently like a DP history that rate-of-loading effects are accurately assessed. Additional test data is being generated to validate this assumption.

(e) It is recognized that a variation in stem μ has been observed in field testing. The current methodology approach will determine the effect of the actual stem coefficient of friction on thrust output by test as opposed to using an analytical method. As a result, in situ MOV to MOV variations in stem μ will be accounted for properly.

(f) The EPRI Lubrication testing will provide the basis for selection of lubricants that exhibit minimal change in friction characteristics over a large number of strokes. Further, in situ "handwheel" closure testing to set the torque switch will account for any stem/stem-nut mismatch.

(g) The approach for determining operator output capability for valves which cannot be hard seated is currently being finalized and will be discussed during the October 6-7, 1993 meeting with NRC.

(h) The handwheel test, which is used to account for the difference between static and dynamic conditions will be done using the actual MOV under evaluation. As such, overall ratio, stiffness and grease type will be MOV specific. The handwheel test will produce a stem/stem nut load profile (and resulting stem μ history) to simulate design basis-DP conditions (i.e. no extrapolation from static to dynamic conditions is required).

17. **NRC Oct. 92 COMMENT:**

EPRI has stated that it defines predictability of an MOV in terms of actual performance during its testing program, rather than internal damage to valve surfaces. EPRI will need to ensure that cumulative damage will not cause an MOV to become unpredictable and that leakage limits are not exceeded under differential pressure conditions with such cumulative damage.

EPRI Nov. 92 RESPONSE:

At this time, EPRI has not clearly defined the exact circumstances under which the methodology would be incapable of predicting required thrust for a specific gate valve/flow condition combination. The Friction Separate Effects Program and the Gate Valve Design Effects Program will provide the data to make such a definition possible. Both programs investigate to some degree the cumulative effects of high contact stresses on surface damage and effective friction coefficient.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that, at this time, it has not clearly defined the exact circumstances under which its methodology would be incapable of predicting thrust requirements for a specific valve and flow condition. The staff will review the EPRI criteria when developed.

EPRI Sept. 93 UPDATED RESPONSE:

Testing conducted in our friction and valve design effects test rigs indicates that for certain material combinations, contact orientations and stress levels, moderate levels of damage can be sustained while maintaining stable and predictable tractional performance. The final methodology will probably allow valid thrust predictions for some valve/loading condition combinations even when some (currently undefined) level of valve damage is predicted to occur.

18. **NRC Oct. 92 COMMENT:**

EPRI has stated that its methodology will predict thrust requirements throughout the valve stroke for each MOV. In verifying the design-basis capability of a safety-related MOV, each licensee must demonstrate that the motor actuator can deliver sufficient torque without motor stall when opening or closing the valve. The conversion of torque to thrust in an MOV is dependent on the stem friction coefficient which does not remain constant throughout the valve stroke. EPRI should develop its methodology to provide both thrust and torque requirements throughout the valve stroke to assist licensees in demonstrating the design-basis capability of safety-related MOVs.

EPRI Nov. 92 RESPONSE:

The EPRI Methodology will calculate the torque and the thrust required to operate a valve over its entire stroke. In order to do so, it must properly account for variations in stem factor which may occur during the stroke. Such variations have been seen to various degrees in flow loop test data and in the Operator Separate Effects Test Program being conducted by Battelle.

The source of these variations is not obvious at the present time. However, the test program which Battelle is executing has the objective of understanding and quantifying the phenomena. Once understood, the results will be incorporated into the MOV Methodology in such a way as to ensure that the effect of such variations on the torque and thrust predictions made by the Methodology are appropriately addressed.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that its methodology will calculate torque and thrust required to operate a valve over its entire stroke. EPRI stated that its testing program has the objective of understanding and quantifying the variations in stem friction coefficient over the entire stroke to ensure that its methodology adequately predicts torque and thrust. The staff will review EPRI's consideration of stem friction coefficient variations when completed.

EPRI Sept. 93 UPDATED RESPONSE:

Recent testing at Battelle has led to an improved understanding of what may cause changes in the stem factor. Such changes have been referred to as "rate of loading" effects or as "load sensitive behavior."

Rate of loading effects appear to result from transient reduction in the COF which can occur when the stem is loaded rapidly (e.g., during a static electric valve closure); as such, it can result in an increase in the thrust achieved at torque switch trip on static tests relative to that which may occur in a dynamic tests. It is hypothesized that the transient reduction in stem coefficient of friction is due to the fact that as the valve disc wedges, there is insufficient time (generally less than 100 ms) to squeeze the stem lubricant from between the threads. During this short time span, sufficient grease remains between the threads and does not allow full metal to metal contact. The lubrication mode is mixed, i.e., a combination of hydrodynamic and boundary lubrication and the resulting stem COF can be quite low (~.05). During a stroke with a sufficiently long "time at load" (i.e., >> 100 ms) all the grease that is going to be squeezed out has been squeezed out resulting in a thin film of lubricant and more complete metal to metal contact (boundary lubrication). This lubrication mode generally results in more nominal stem COFs (~0.1 - 0.15).

Separate effects testing indicates that the thicker the grease, the more difficult it is to squeeze it out during a static electric closure (i.e., <100 ms) and therefore more likely that significant ROL effects will be present. This is consistent with our observation from flow loop testing that degraded (thickened) stem lubricant can result in more severe ROL effects.

Battelle is developing a procedure for adjusting the torque switch by means of a manual handwheel closure stroke (or strokes: the exact procedure is still being tested). During this slow manual closure, it has been shown that the COF which occurs at torque switch trip is representative of that which would exist in a DP stroke. Consequently, if this procedure is used, the relation between torque and thrust during valve set-up will be representative of that in the design basis condition. The load sensitive behavior of the COF is appropriately considered because the actual design basis load is achieved on the manual closure. Using such an approach, rate of loading effects will not need to be addressed separately because they are only a factor if the torque switch is set up using a static stroke in which the load increases very rapidly. This manual closure stroke will likely be a part of the EPRI methodology.

19. **NRC Oct. 92 COMMENT:**

Some licensees might not be able to obtain precise values for the parameters to be input into the EPRI methodology. Therefore, licensees may want to estimate certain parameters with best available information. EPRI should perform a sensitivity study of the model and identify the input parameters which have the greatest impact on the model's results. EPRI should then provide guidance to licensees on parameters that can be estimated and those that must be known precisely.

EPRI Nov. 92 RESPONSE:

The Gate Valve Performance Prediction Methodology will require that the user provide basic valve dimensional information as input. Typical dimensions required include such things as guide length, mean seat diameter and clearance between the disk guides and the body rails.

While the list of required dimensions is, at present, quite extensive, EPRI has held discussions with the valve vendors and they have agreed that they are able to provide both nominal values and tolerances for all dimensions. Further, EPRI has developed a specification which will be used by the utilities to procure from the valve vendors, all required information.

The Methodology will be implemented in such a way that the dimensions and range of tolerances from the vendor will be combined in development of needed input values to produce a conservative prediction. A sensitivity analysis is being performed in order to determine what combination of dimensions results in a conservative result. In addition, the results of this sensitivity study will show which parameters most strongly affect valve performance.

If a user wishes to reduce the amount of conservatism in the Methodology for an analysis conducted using nominal dimensions, he has several options, one of which is to obtain actual dimensions for a specific valve and use that data as input to the model. The results of the sensitivity analysis will provide guidance to the utility in determining how accurately such measurements should be made and which dimensions are most critical.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that its methodology will include conservatism to account for the manufacturing tolerances of valve dimensions. EPRI states that licensees will have the option of obtaining actual dimensions to reduce the amount of conservatism. The staff will review EPRI's determination of the amount of required conservatism when completed.

EPRI Sept. 93 UPDATED RESPONSE:

Agreed -- still under evaluation.

20. NRC Oct. 92 COMMENT:

EPRI has agreed to allow the staff to observe its MOV tests on a periodic basis and to review test data. The staff may request EPRI to provide test setup and performance information as well as raw data from selected tests.

EPRI Nov. 92 RESPONSE:

The NRC staff is welcome to observe MOV testing.

EPRI has agreed to provide test setup and performance information as well as raw data (i.e. plots of test results as well as engineering unit data in digital format) from selected tests. This data will be available when the test report for each test loop is complete. At that time, as-tested facility configuration information will have been assembled into a presentable form and test data will have been certified.

The first report which covers tests conducted in the Huntsville pumped flow loop is scheduled for distribution to Program participants in March, 1993.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI states that detailed test data will be available when the test reports are finalized. At the December 3 meeting, EPRI provided information on the planned testing for the spring of 1993 which the staff might decide to observe. The staff will discuss with EPRI the need for specific test data and its plans for observing tests.

EPRI Sept. 93 UPDATED RESPONSE:

An NRC contractor visited the Siemens/KWU flow loop test facility in July. Data will be made available to NRC as soon as test reports are complete. The Wyle Huntsville Low Pressure Pumped Flow Loop Test Report is scheduled for publication in September, 1993.

21. **NRC Oct. 92 COMMENT:**

The staff noted a concern with EPRI's selection of a pressure measurement location in determining stem rejection load. The staff referred EPRI to Figure 33 of NUREG/CR-5720 for a comparison of pressure measured at three different locations. EPRI agreed to review the issue and resolve the concern.

EPRI Nov. 92 RESPONSE:

The staff concern is assumed to relate to c ur use of valve upstream pressure for calculating stem rejection loads when determining apparent disc coefficients of friction.

The apparent disc coefficient of friction calculated from the flow loop data are not intended to represent true friction coefficients. The purpose of calculating an "apparent" disc μ in presenting the results of the flow loop gate valve tests is only to provide a straight forward basis for comparing measured thrusts at various points in the valve stroke to the single thrust prediction from the NMAC equation. In order for this comparison to be meaningful, the NMAC equation must be applied as it would be for design purposes, i.e., the stem rejection load is computed by multiplying the design basis upstream pressure (P_{up}) by the stem cross-sectional area (A_s).

It is recognized that under various flow conditions and stroke positions the product of $P_{up} \times A_s$ may not accurately predict the true stem rejection force. In the implementation of the methodology, an appropriate pressure will be used to ensure a conservative result.

NRC Dec. 92 STATUS:

At the December 3 meeting, EPRI stated that it would use upstream pressure for determining stem rejection load if the error resulting from the use of pressure measurements at this location is not significant. The staff will evaluate EPRI's determination of stem rejection load during its review of the EPRI methodology.

EPRI Sept. 93 UPDATED RESPONSE:

EPRI will provide the basis for its determination of stem rejection load when data evaluation is complete and is ready for NRC review.

22. **NRC Oct. 92 COMMENT:**

The staff is aware of three areas of significant disagreement that remain between EPRI and INEL with respect to the NRC-sponsored MOV tests (including results) performed by INEL. In summary, these areas are (1) the difference in the predictions of required thrust by the Limitorque, EPRI and INEL equations, (2) the selection of the point of flow isolation during valve closure, and (3) the behavior of INEL Valve 2 during flow tests. With respect to the EPRI MOV Performance Prediction Program, the staff believes that these areas of disagreement need to be resolved only to the extent that the disagreement might affect the staff's determination of the reliability of the EPRI MOV Performance Prediction Methodology. For example, the selection of the point of flow isolation might be used to predict the amount of thrust necessary to close a valve. Although this point might be adequate for the particular valve tested, it might not predict the thrust required to isolate flow for another valve because of concerns such as the difficulty in precisely determining this point from test data and the difference in internal clearances between similar valves.

EPRI Nov. 92 RESPONSE:

EPRI agrees that these areas of disagreement need to be resolved only to the extent that such disagreement might affect the staff's determination of the reliability of the EPRI MOV Performance Prediction Program.

The first area of disagreement, potential differences in Limitorque, NMAC and INEL thrust equations, is not relevant to the EPRI methodology and no further discussion should be necessary.

The second area of disagreement, selection of the point of flow isolation, is not relevant to the EPRI methodology since the point of flow isolation will not be predicted by the model.

The third area of disagreement, potential causes for behavior of INEL valve 2, may become relevant based on the results of our separate effects and modeling activities. Further discussion of this issue should be deferred pending completion of these activities.

NRC Dec. 92 STATUS:

In the November 30 letter, EPRI agrees that these areas of disagreement need only be resolved with respect to the reliability of the EPRI MOV Performance Prediction Program. EPRI states that the area of disagreement on the differences in the various thrust equations is not relevant to the EPRI methodology. EPRI states that the area of disagreement on the point of flow isolation is not relevant to the EPRI methodology because the methodology will not predict the point of flow isolation. EPRI states that the area of disagreement on the behavior of INEL valve 2 might become relevant based on separate effects tests and modeling. If this area of disagreement does become relevant, EPRI states it will discuss this issue with the staff. The staff considers EPRI's response acceptable unless future information causes these areas of disagreement to become relevant.

EPRI Sept. 93 UPDATED RESPONSE:

Response accepted by NRC, no update.

NEW COMMENTS

23. NRC Dec. 92 COMMENT:

At the December 3 meeting, EPRI stated that it would perform a small amount of actuator testing in determining output capability. However, EPRI stated that it would be using the Limitorque standard equation with some adjustments. The staff would like to know the extent to which the EPRI program will provide reliable information on the output capability of Limitorque actuators in comparison to the standard Limitorque equation.

EPRI Sept. 93 RESPONSE:

The EPRI program does not have as an objective the evaluation of ultimate operator torque capability and there are no plans to produce a modification to the manufacturer's specifications. In order for the flow loop testing to provide useful data on ultimate output capability, the operators would have to be significantly challenged. This is not likely since, in general, the operators were sized very conservatively for use in the flow loop.

24. NRC Dec. 92 COMMENT:

The staff does not understand the extent to which MOVs controlled by the use of limit switches (for example, most butterfly valves, many parallel disk gate valves, and rotating rising stem valves) will be addressed by the EPRI program. This is important because of the significant number of MOVs that are presently controlled by limit switches or might be controlled by limit switches in the future.

EPRI Sept. 93 RESPONSE:

The approach for addressing limit seated valves is currently being finalized and will be presented at the October 6-7, 1993 meeting with NRC.

25. NRC Dec. 92 COMMENT:

EPRI should develop a program to provide for continuing updating of its methodology to incorporate new information or to correct deficiencies in the methodology found through future MOV tests.

EPRI Sept. 93 RESPONSE:

The EPRI Methodology will be formally distributed to participating utilities by Power Computing Corporation (PCC). Under the terms of the PCC distribution contract, Part 21 requirements are provided from the developing contractor to the receiving utility. In addition, PCC will receive reports of any field problems which may develop and will promptly notify all users of required corrective action, if any.

EPRI will maintain cognizance of industry MOV issues/results and will take appropriate action if industry test results indicate an inadequacy in the methodology.

26. **NRC Dec. 92 COMMENT:**

In the November 30 letter, EPRI includes Figure 1, "Gate Valve Test Analysis Data Sheet," identifying specific information to be recorded from each MOV test. The staff indicated that some of the abbreviations are not clear. Because these data sheets may be used by valve engineers in setting up similar MOVs, it is important that the data be clearly defined. NUMARC agreed to follow-up on this staff concern.

EPRI Sept. 93 RESPONSE:

The definition of the data recorded in Figure 1 of the November 30 letter is defined in Figure 2 of that letter. Both Figures 1 and 2 are reproduced earlier in this transmittal. If the staff has further questions, EPRI will provide further clarification.

27. **NRC Dec. 92 COMMENT:**

Will EPRI evaluate any load sensitive behavior in the performance of motor-operated butterfly valves?

EPRI Sept. 93 RESPONSE:

Rate-of-loading does not affect the performance of butterfly valves because the torque transfer does not involve a stem to stem nut interface which has been identified as the source of rate-of-loading effects.

28. **NRC Dec. 92 COMMENT:**

The EPRI methodology will be applicable to any MOV that can pass the design similarity analysis. Design features not currently being addressed could present problems, such as encountered with the Borg-Warner test valve. How will EPRI account for future design similarity analysis problems?

EPRI Sept. 93 RESPONSE:

See response to no. 25.

124G/JFH/jp

Idaho
National
Engineering
Laboratory

NRC-EPRI-TAG Presentation

INEL MOV Research Update

Researchers
R. Steele
K. G. DeWall
J. C. Watkins

USNRC Technical Monitor
Dr. G. H. Weidenhamer

Presentation to
NRC-EPRI-TAG Valve Review Group
October 7, 1993
Rockville, MD

Enclosure 5

INEL MOV Research Update
October 1993

- The Idaho National Engineering Laboratory (INEL) is performing research related to motor-operated valves (MOVs) to assist the NRC in its implementation of Generic Letter 89-10 "Safety-Related Motor-Operated Valve Testing and Surveillance."

- Research focuses on motor-operated valve margins and how they are affected by valve loadings

Research results have suggested questions on the following topics:

- MOV electric motor testing
- Consistently inconsistent stem factor

Electric Motor Testing

Note:
All data contained in this section are preliminary and are presented for information only. We are still working on our test methods to ensure we have correctly separated the loads.

DRAFT

Correct MOV sizing depends on several calculations, including the electric motor capability with consideration given to degraded voltage and elevated temperature.

DRAFT

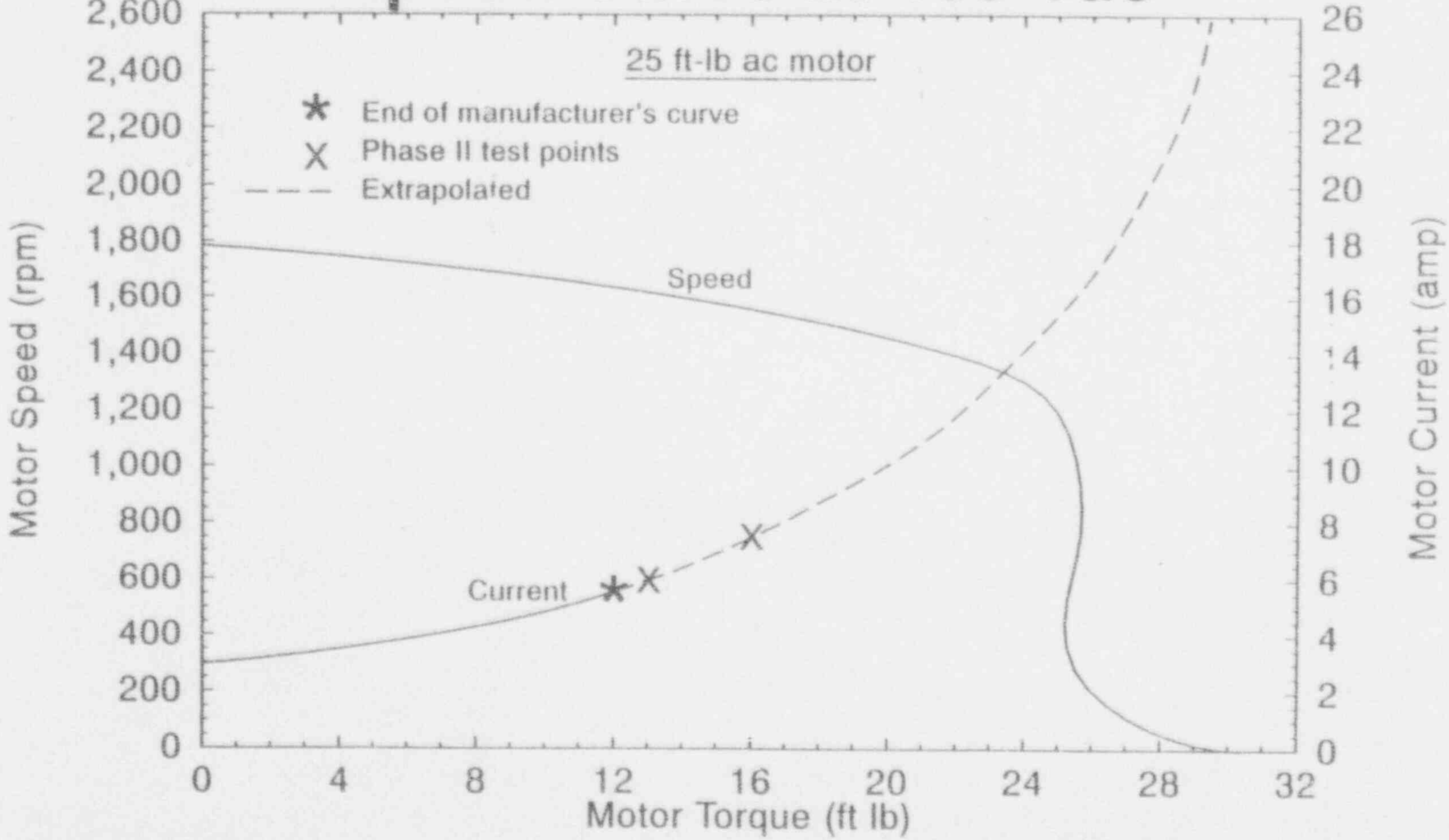
Most Limitorque ac motors (built for nuclear applications by the Reliance Electric Company) are furnished with performance curves.

- Curves indicate estimates of loaded performance from the normal running load through stall

- Curves do not include degraded voltage or elevated-temperature performance, which must also be estimated

DRAFT

Manufacturer's 25 ft-lb Motor Torque Speed Curve at 460 Vac



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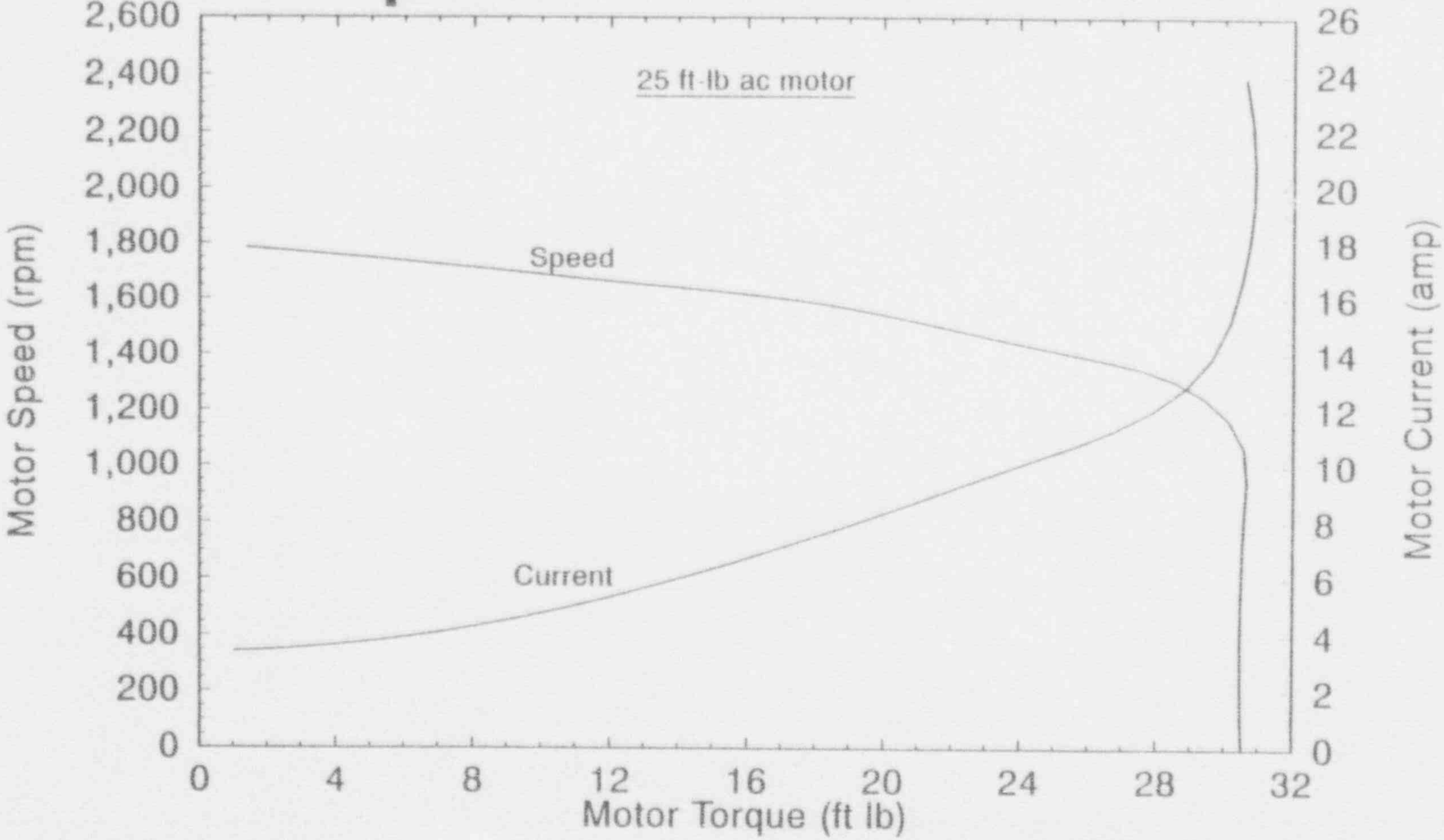
Actual 25 ft-lb Motor Torque Speed Curve at 460 Vac



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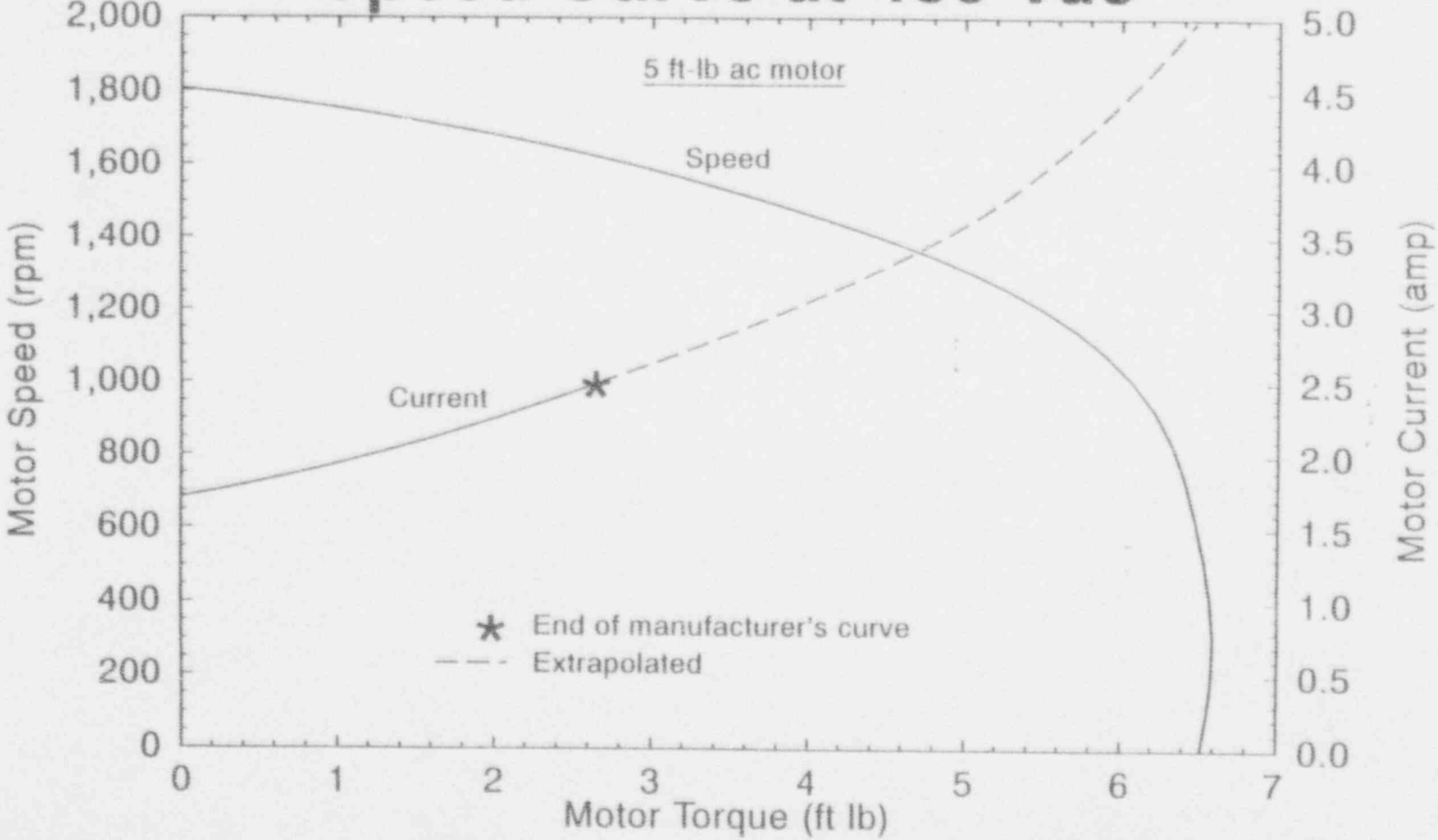
DRAFT

Manufacturer's 5 ft-lb Motor Torque Speed Curve at 460 Vac



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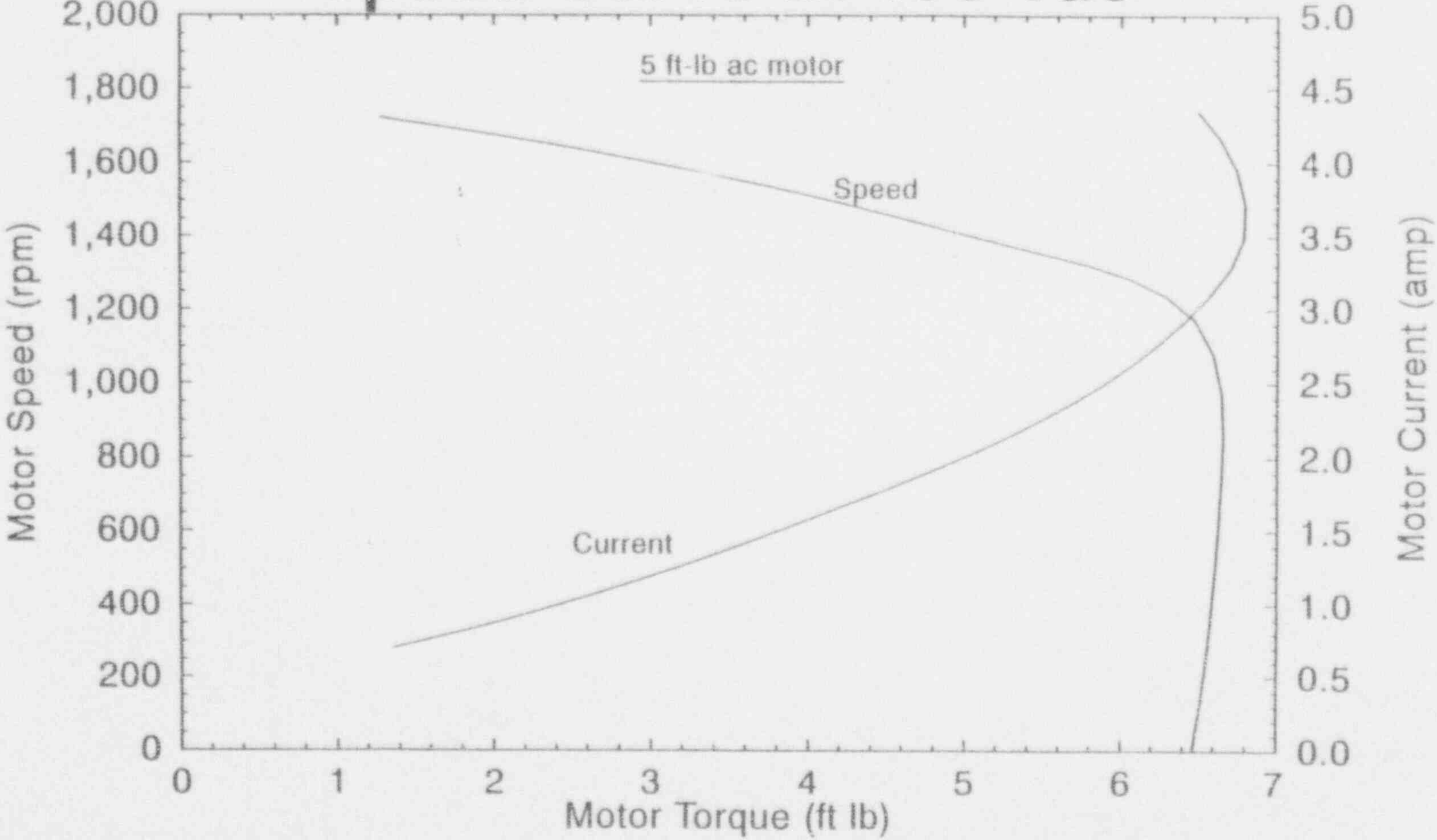
Actual 5 ft-lb Motor Torque Speed Curve at 460 Vac



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DRAFT

Research questions reveal some answers and the need for more data.

How much of the motor's capability can you count on?
Limitorque SEL (sizing guide) recommends using a stall efficiency of 0.55 to determine the stall torque. This value appears to be conservative and appropriate for overload purposes.

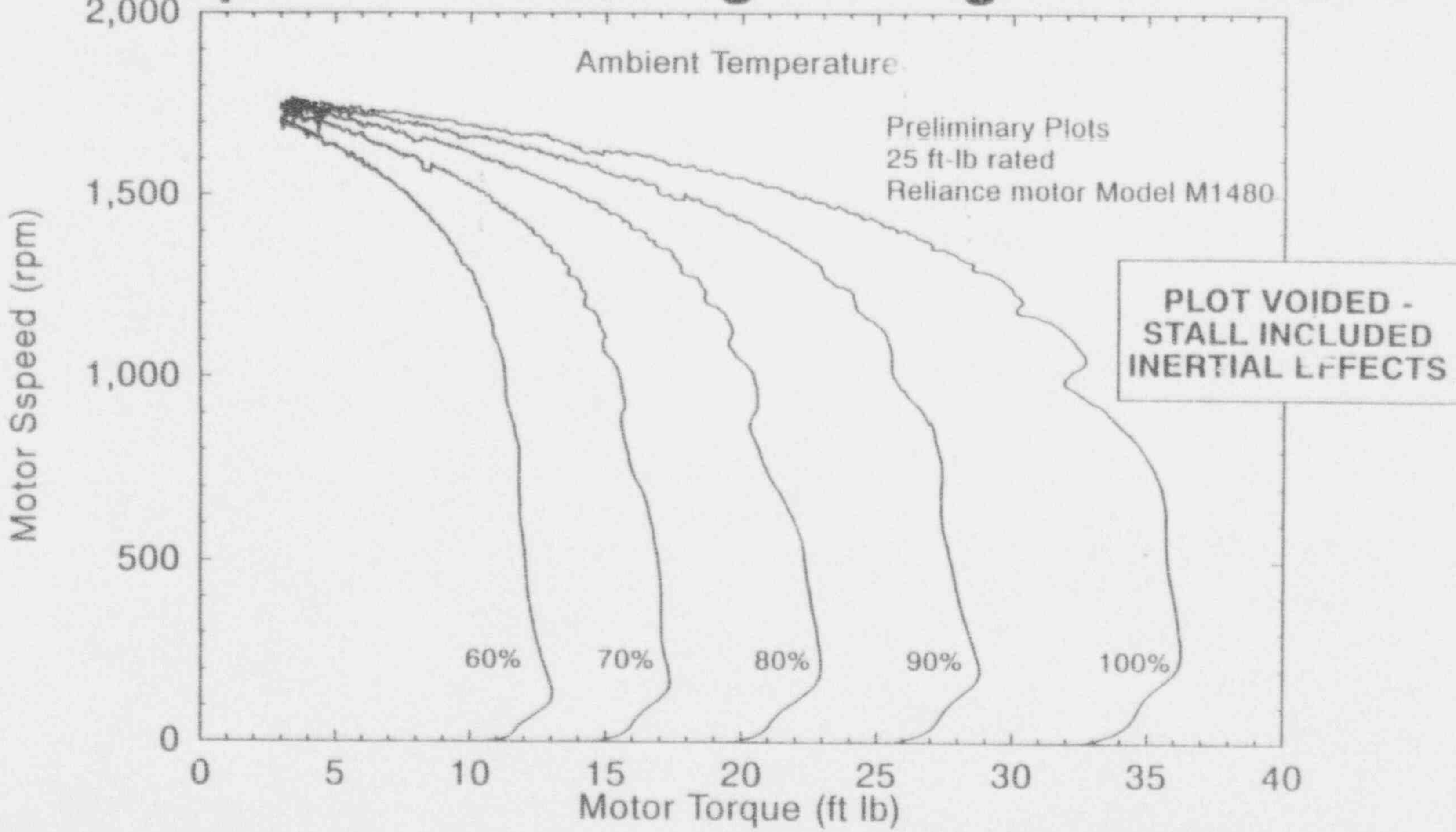
But how much of the stall torque can be used to overcome design basis?
Pull-out efficiency is 0.4.

Is that the best number for calculating how much the motor can actually deliver before it stalls?
The industry is unsure about which value should be used. Further, the motor manufacturer states that the motor may vary as much as 20% from its rated output value.

How can a motor be evaluated for its variance from the rated performance and how are these numbers influenced by degraded voltages and ambient temperature?

DRAFT

Comparing Voltage Effects on Motor Speed and Torque from Running Through Stall Loads



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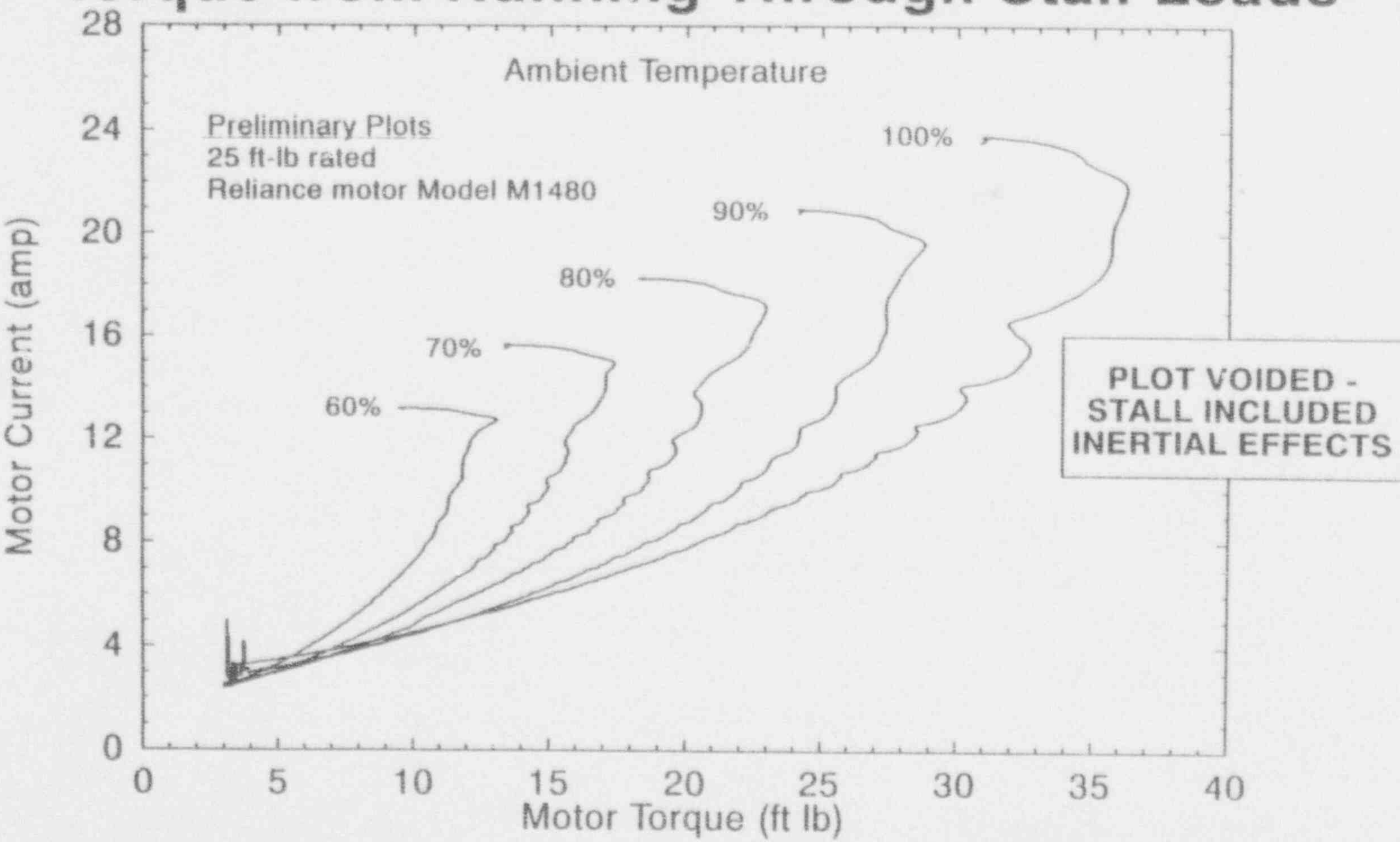
Comparing Voltage Effects on Motor Current and Torque from Running Through Stall Loads



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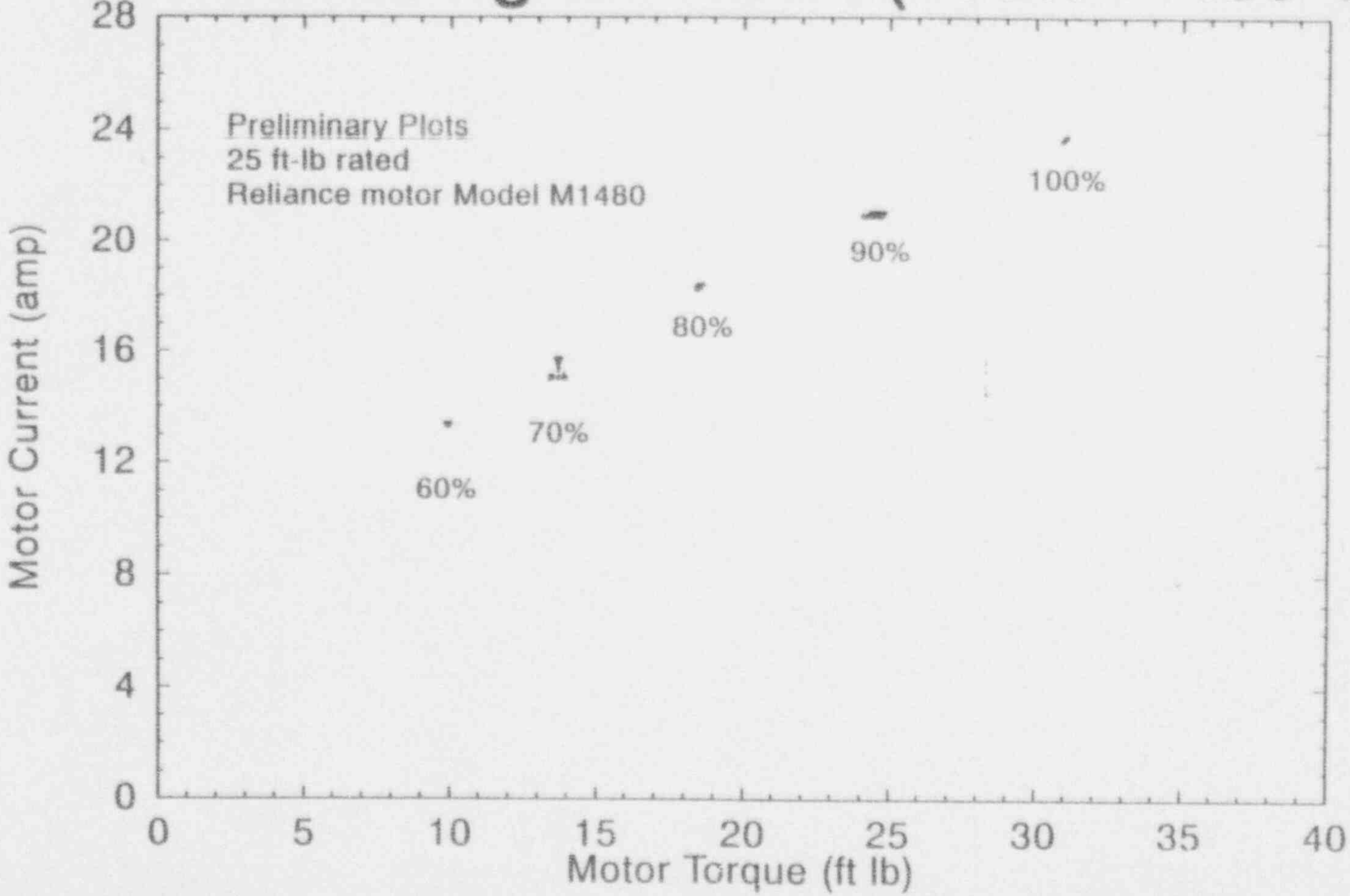
Comparing Voltage Effects on Locked Rotor Starting Currents (100% = 460 Vac)



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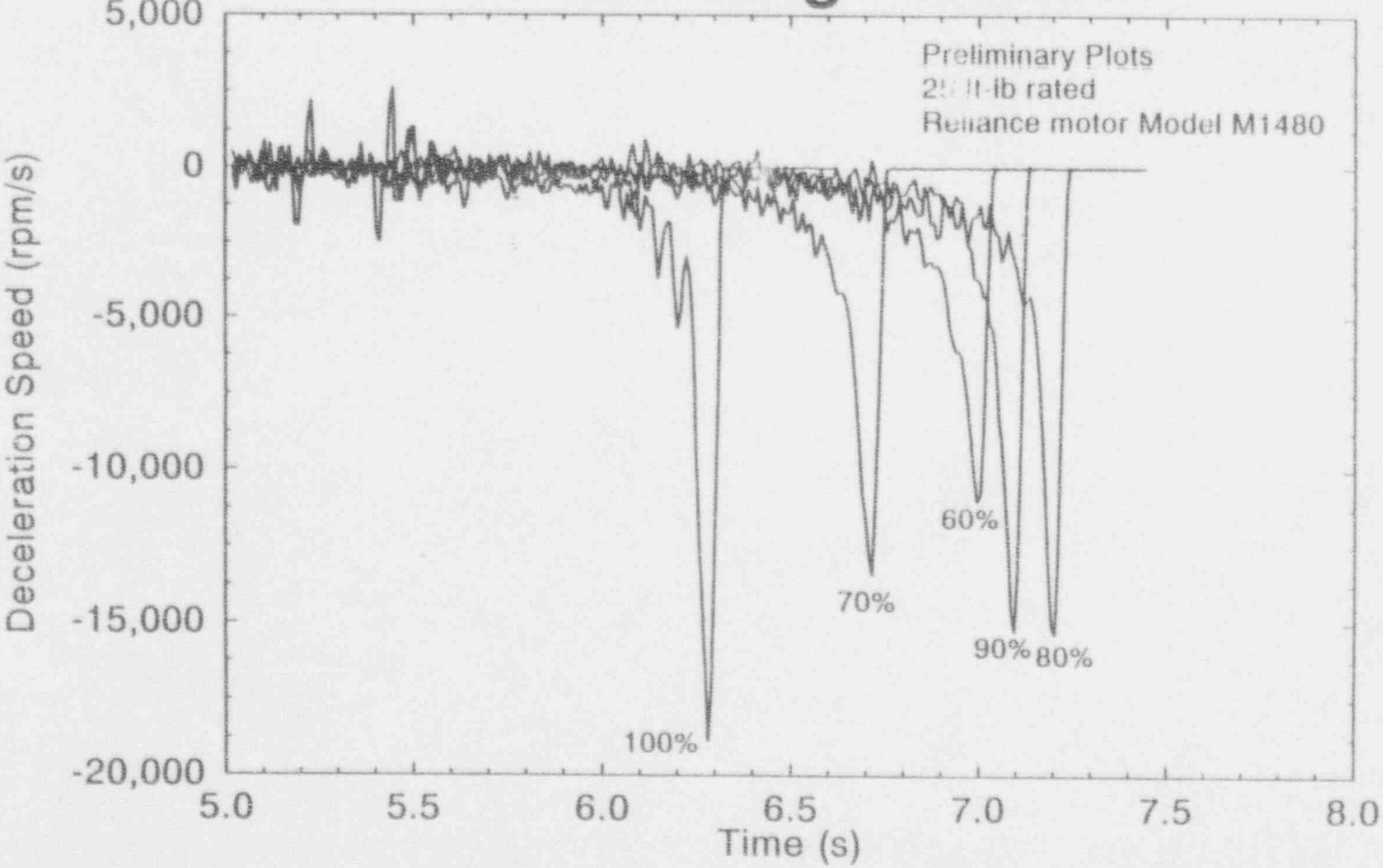
Maximum deceleration appears to be voltage related.



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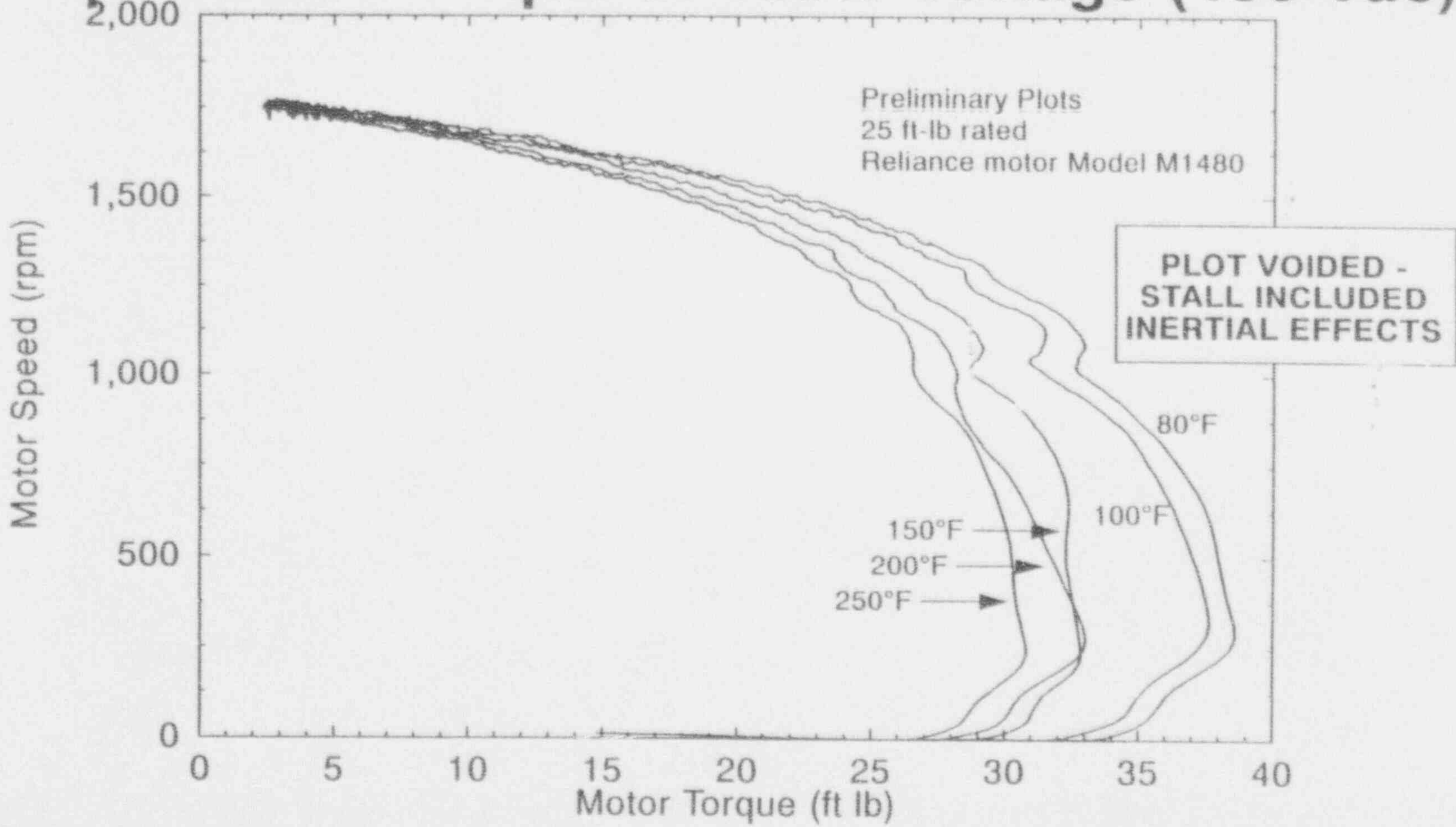
Comparing Temperature Effects on Motor Speed and Torque at 100% Voltage (460 Vac)



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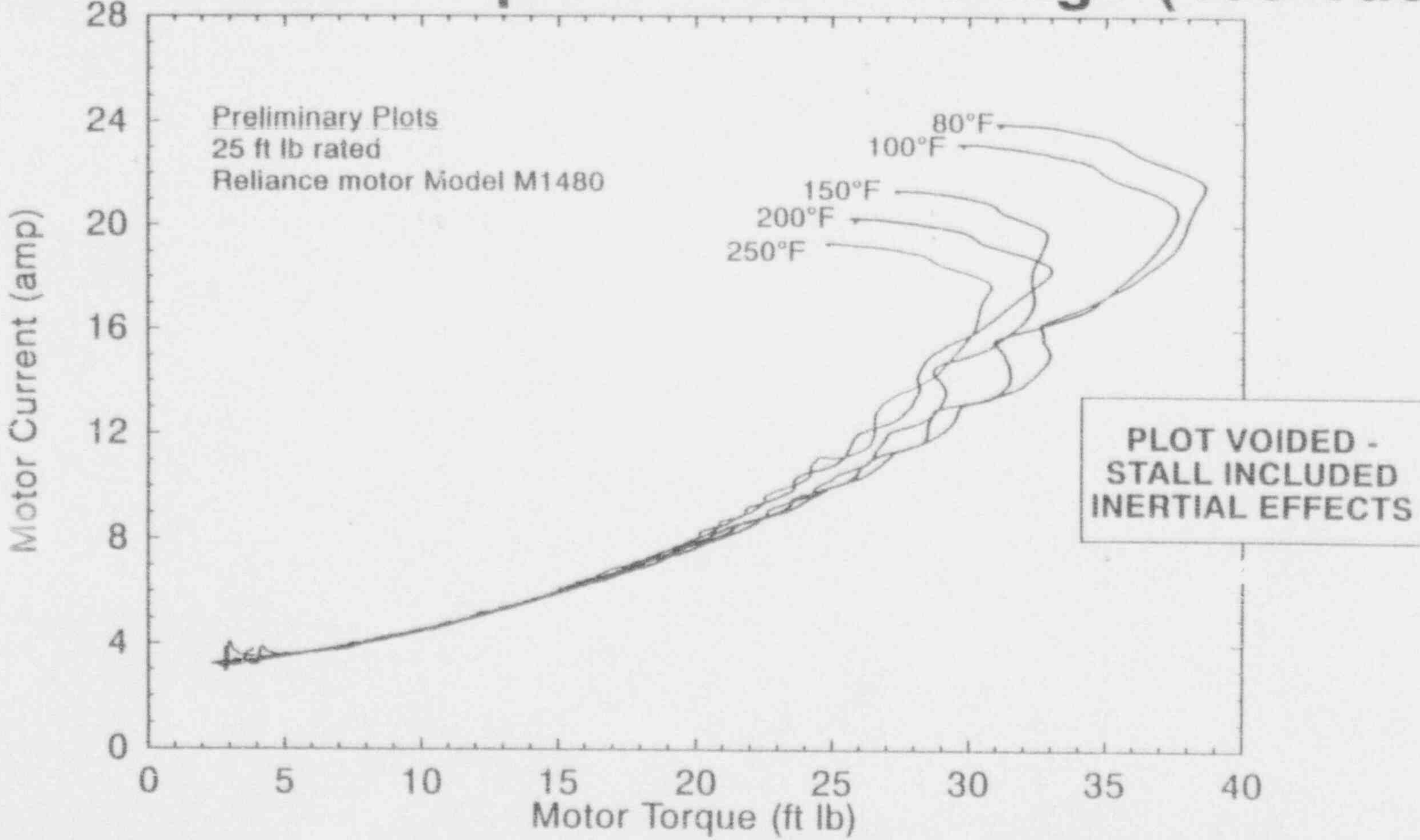
Comparing Temperature Effects on Motor Current and Torque at 100% Voltage (460 Vac)



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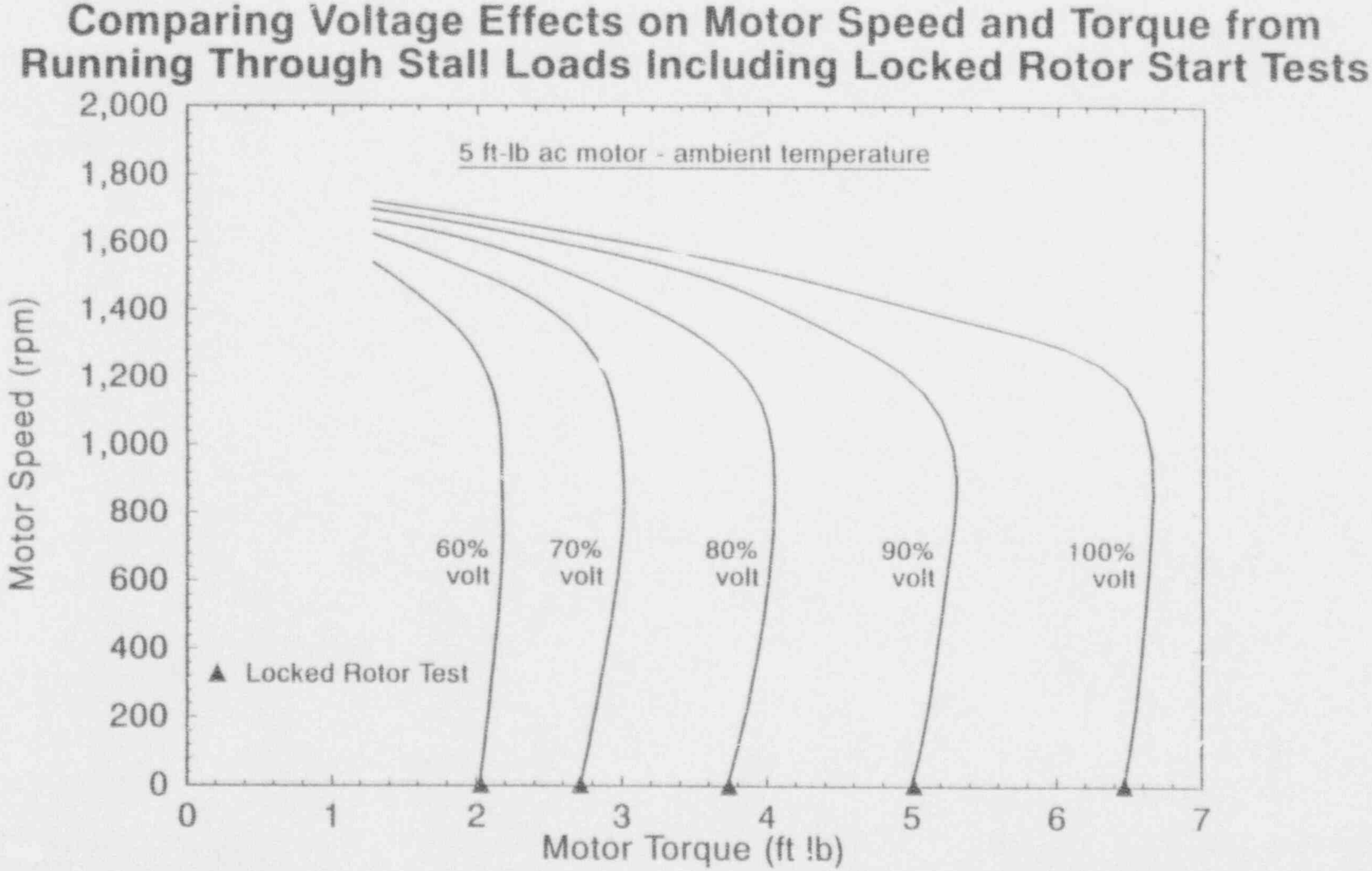

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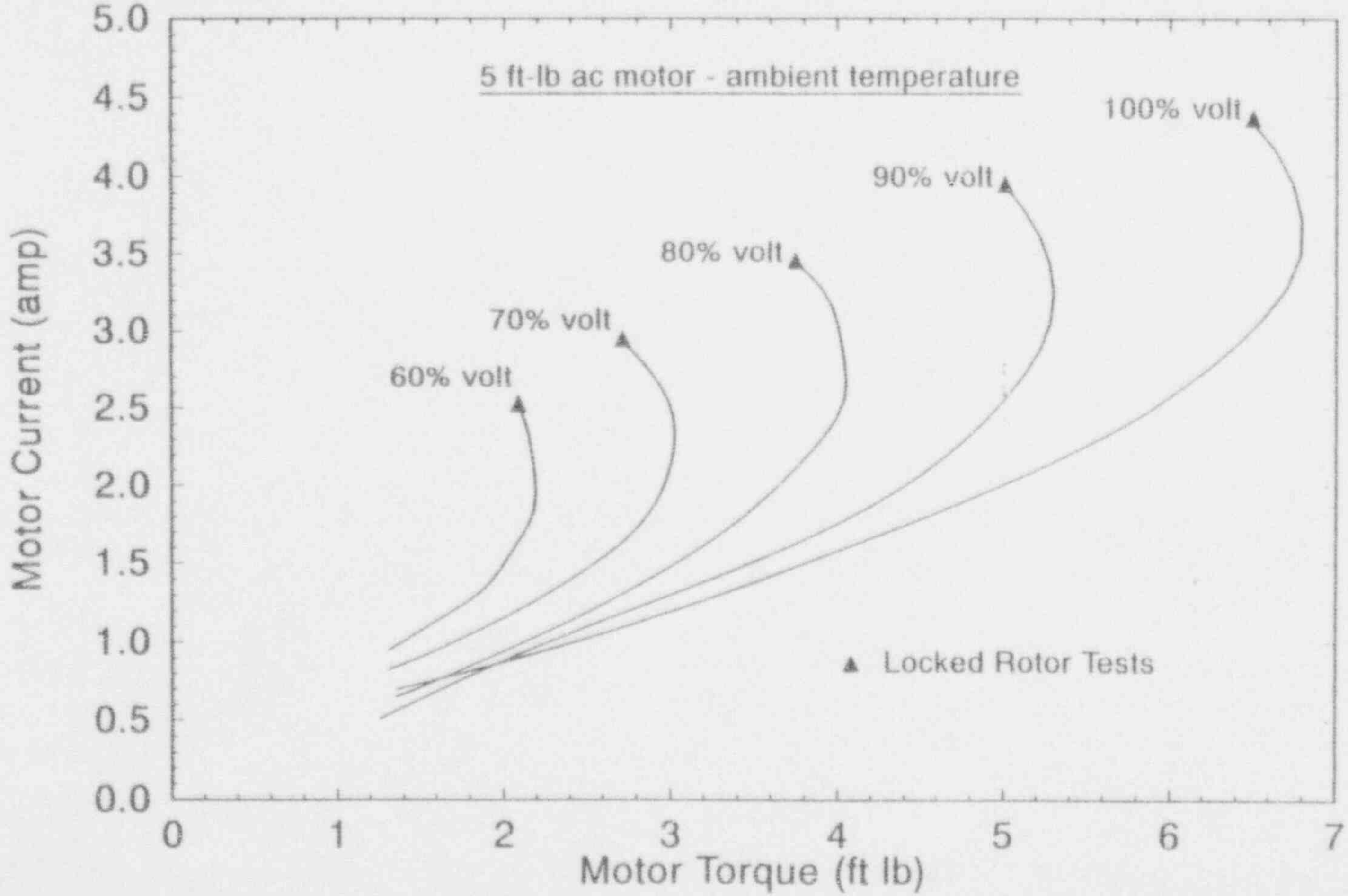
DRAFT

Comparing Voltage Effects on Motor Current and Torque from Running Through Stall Loads Including Locked Rotor Start Tests



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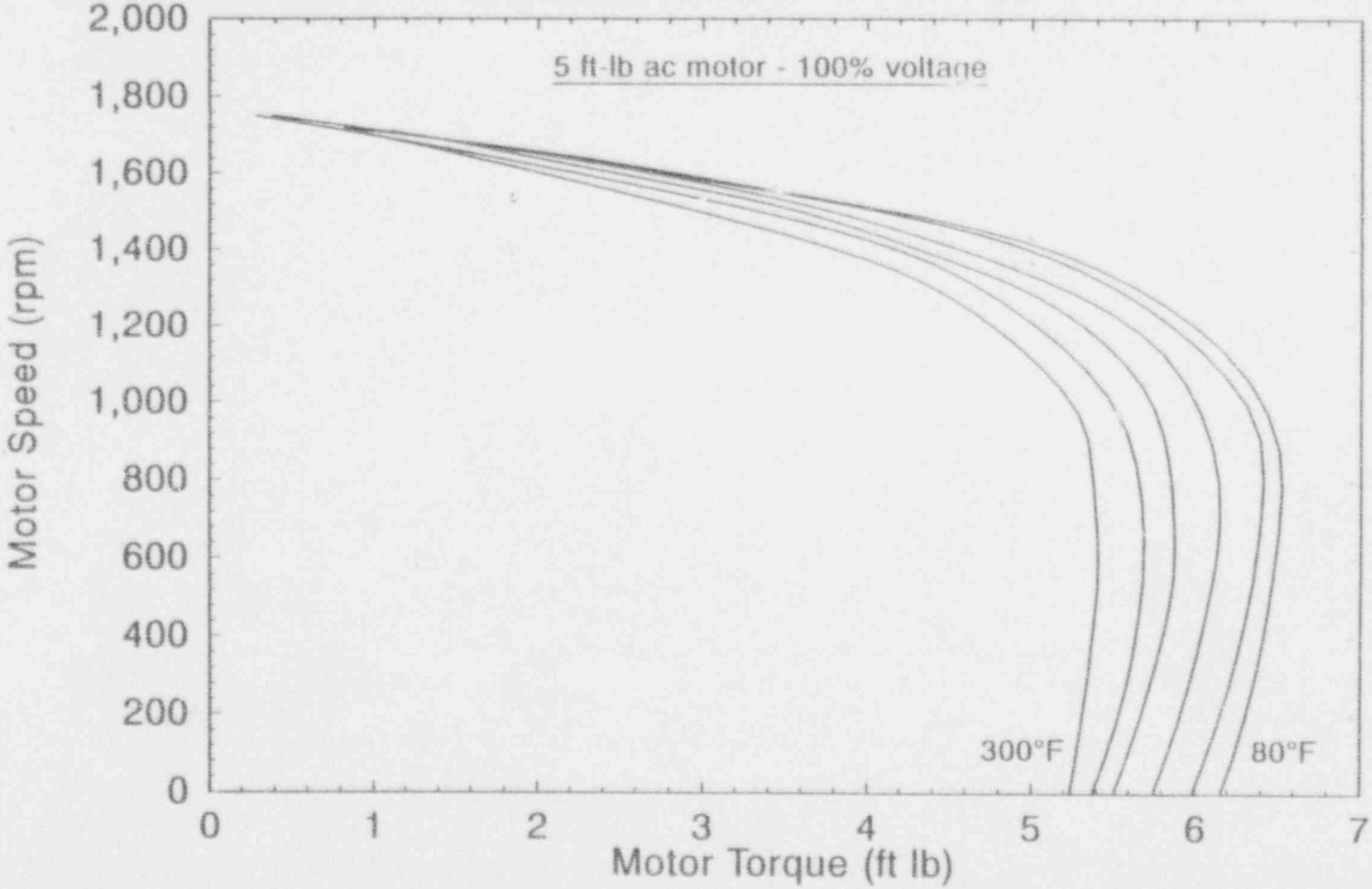
DRAFT

Comparing Elevated Temperature Effects on Motor Torque and Speed from Running Loads Through Stall at 460 Vac



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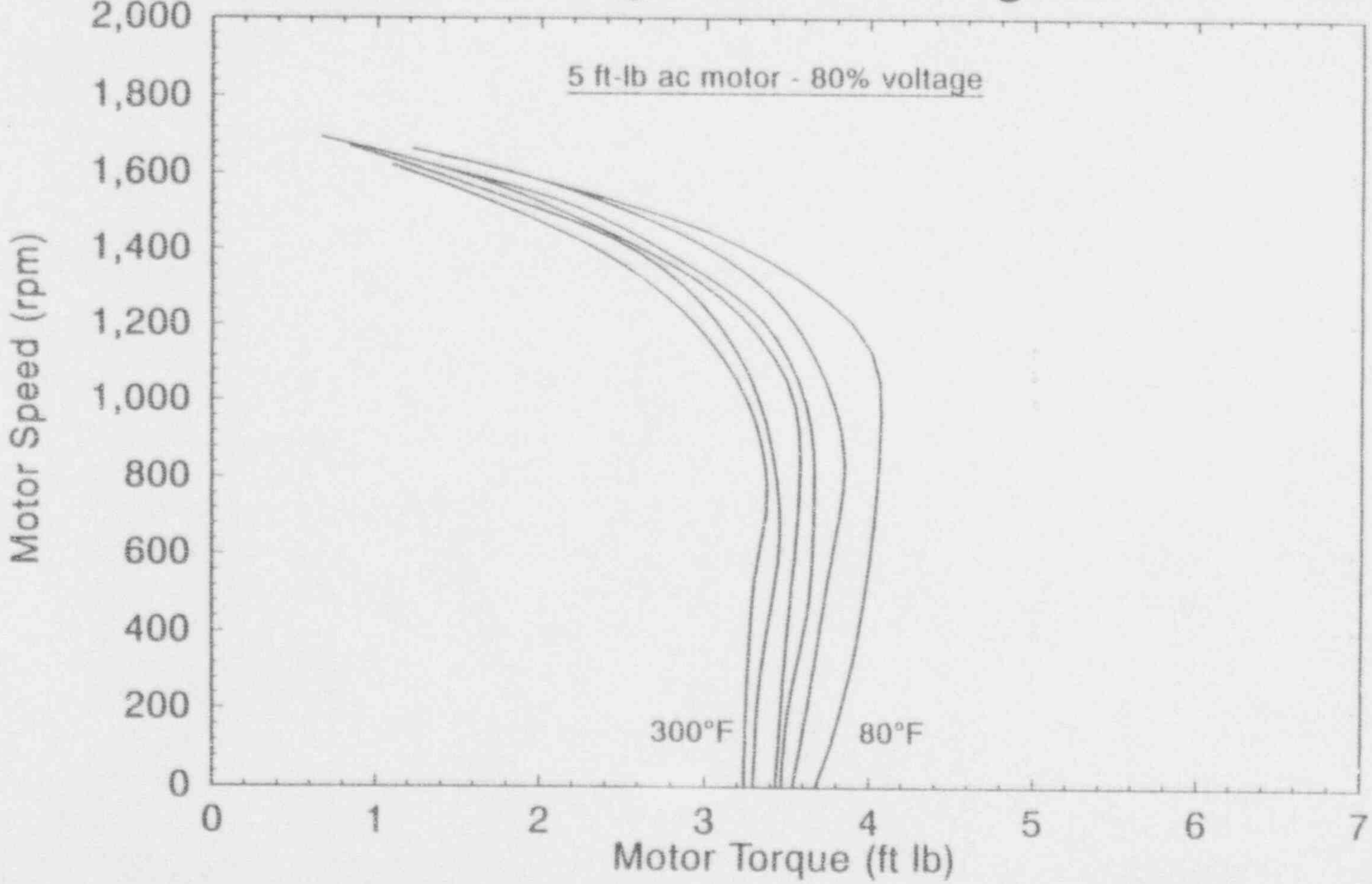
DRAFT

Comparing Elevated Temperature Effects on Motor Torque and Speed from Running Loads Through Stall at 368 Vac



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DRAFT

Conclusions for Electric Motor Testing

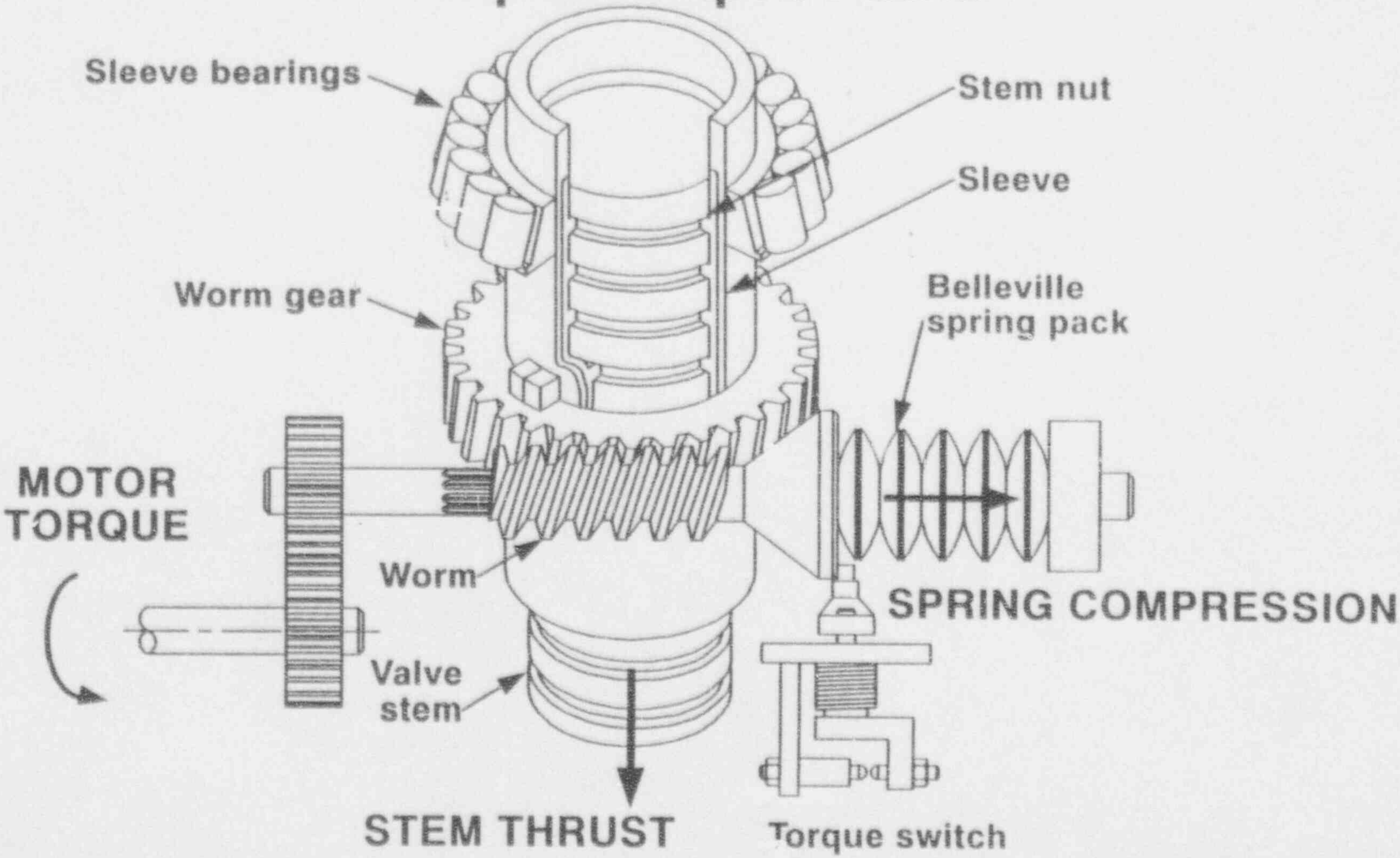
- A locked rotor starting test may be valuable to determine the stall torque value.
  - Motor capability must be based on the knee of the motor torque speed curve
  - Performance reductions for ambient temperature and reduced voltage must be made from the knee of the motor torque speed curve
  - A motor performance test will reduce the conservatism that must be added to account for manufacturing tolerances

Stem Factor

Stem factor is operator torque divided by stem thrust, which can be analyzed with industry's power screw equations for ACME threads.

- For a given stem/stem-nut combination, the only variable is the coefficient of friction
- The coefficient of friction is load dependent and causes load-sensitive behavior (rate of loading)
- The unique performance of each stem/stem-nut combination can also be influenced by the lubricant

Key Components of Motor Operator and Input-Output Paths



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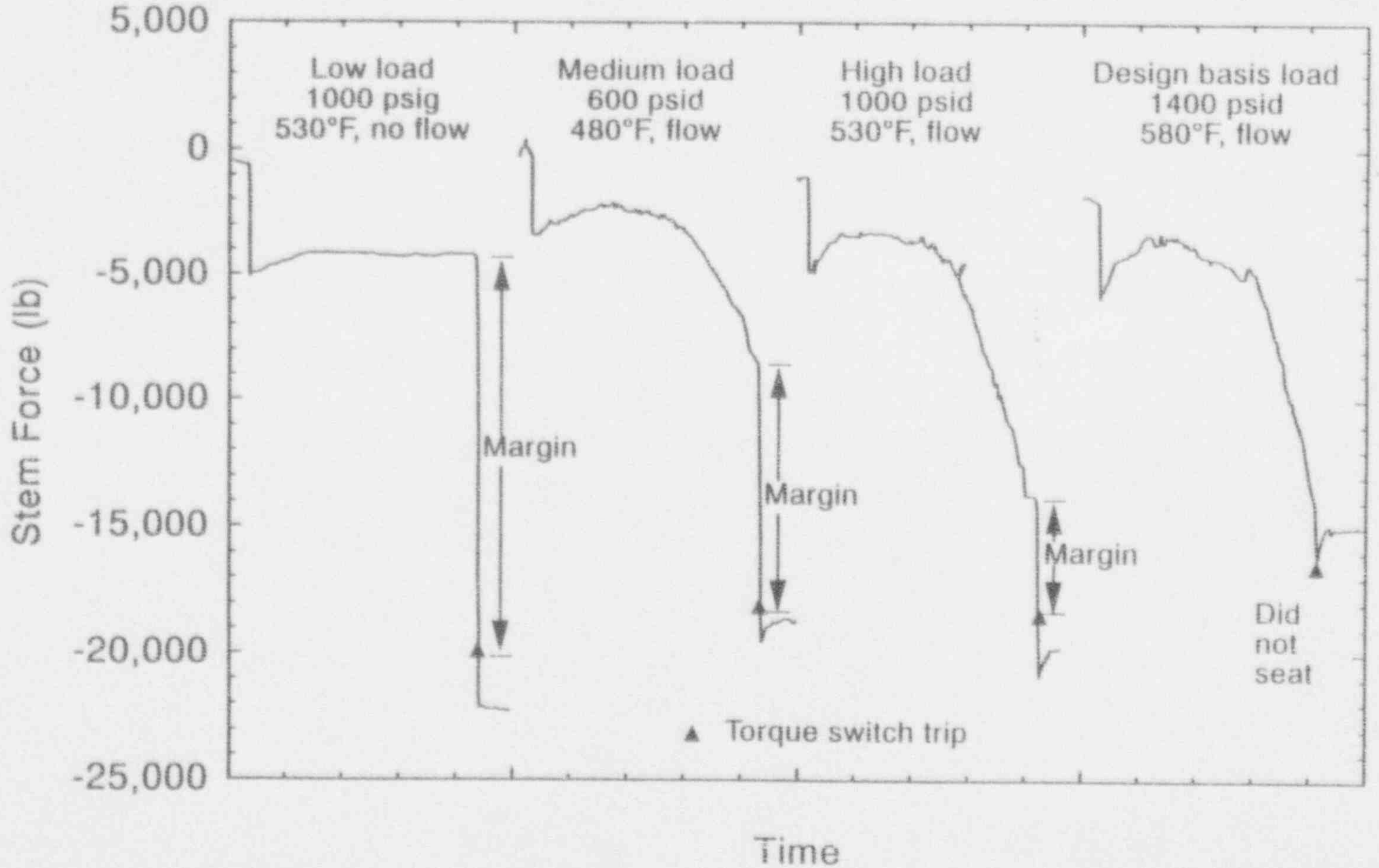
Flow Loop Results

6-inch RWCU valve tests: the stem thrust produced at torque switch trip was lower in tests with higher flow and pressure loads.



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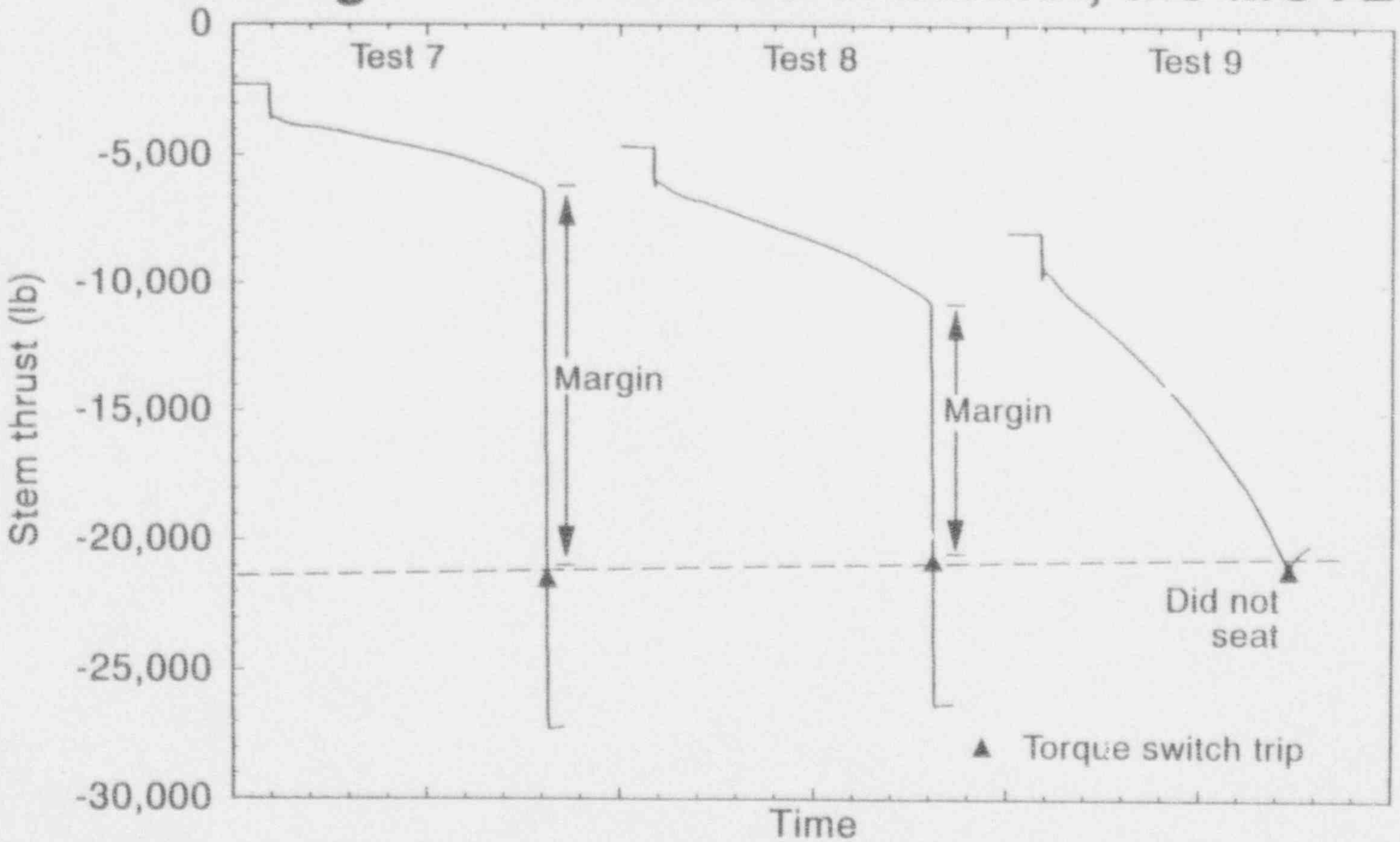
We have also observed load-sensitive behavior in testing on a valve load simulator, the MOVLS.



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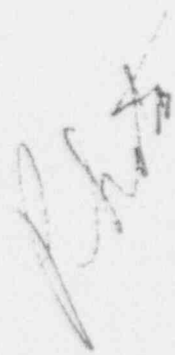
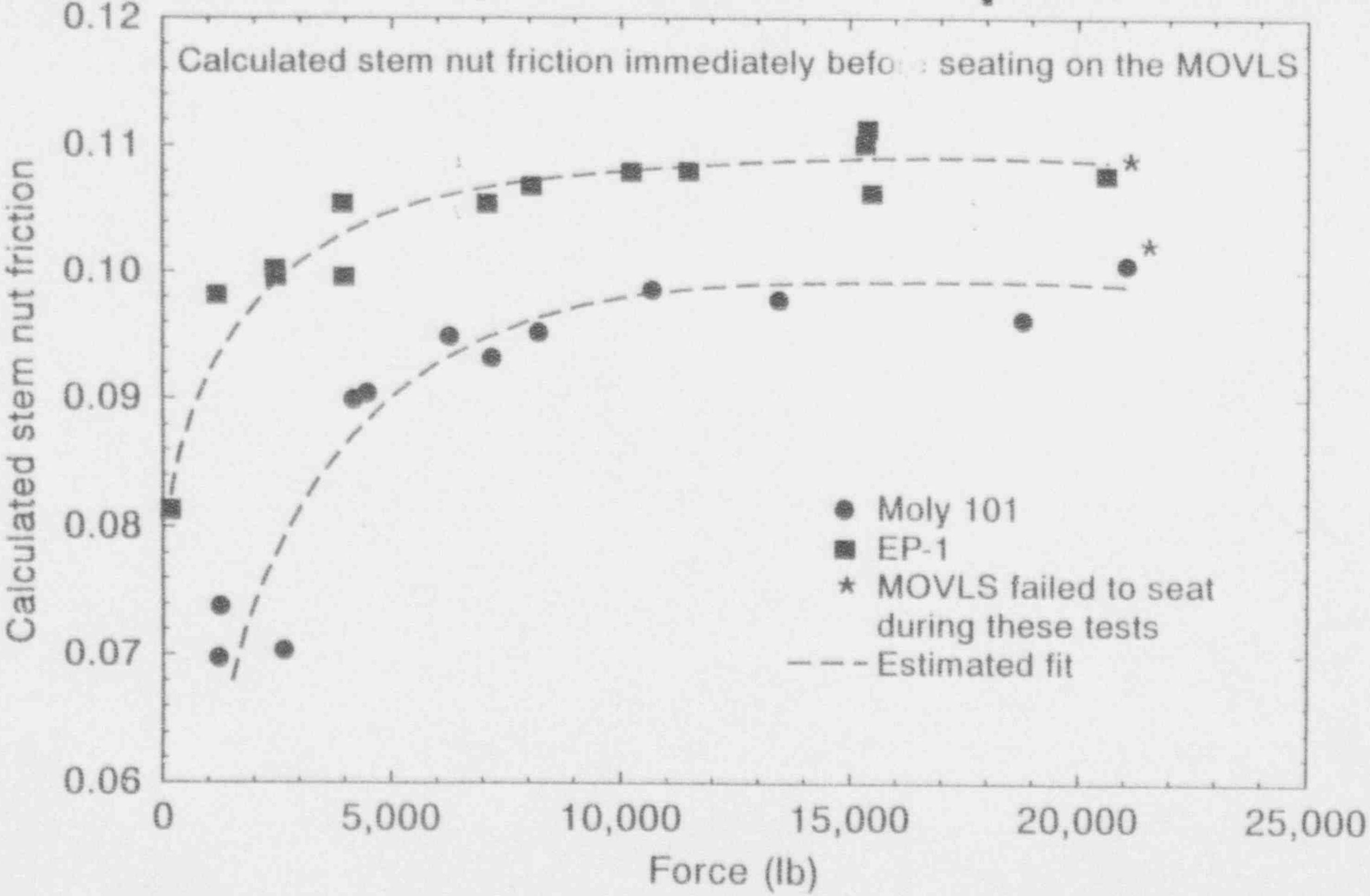
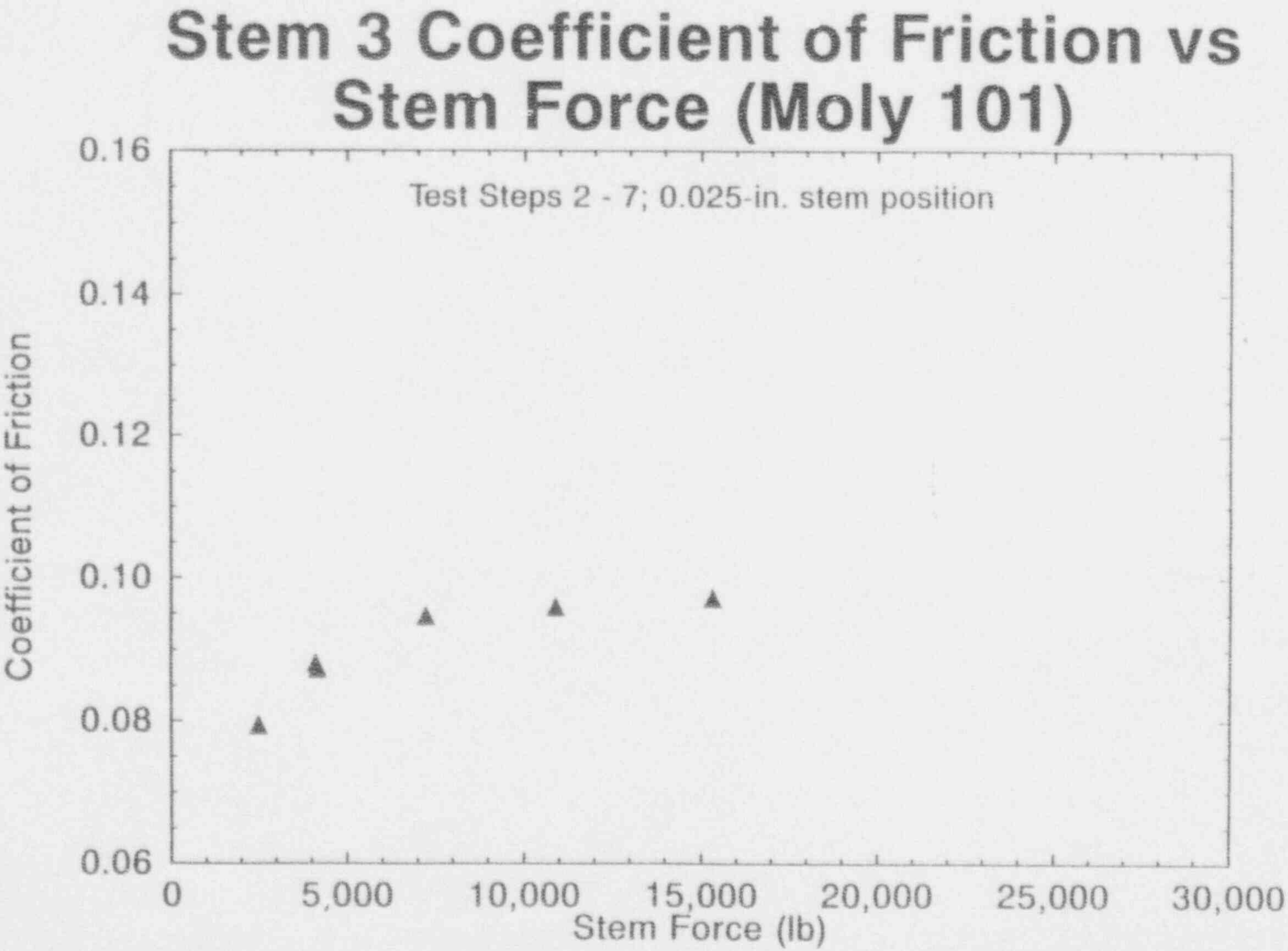


Although choice of lubricant influences the absolute values, stem load response is similar.

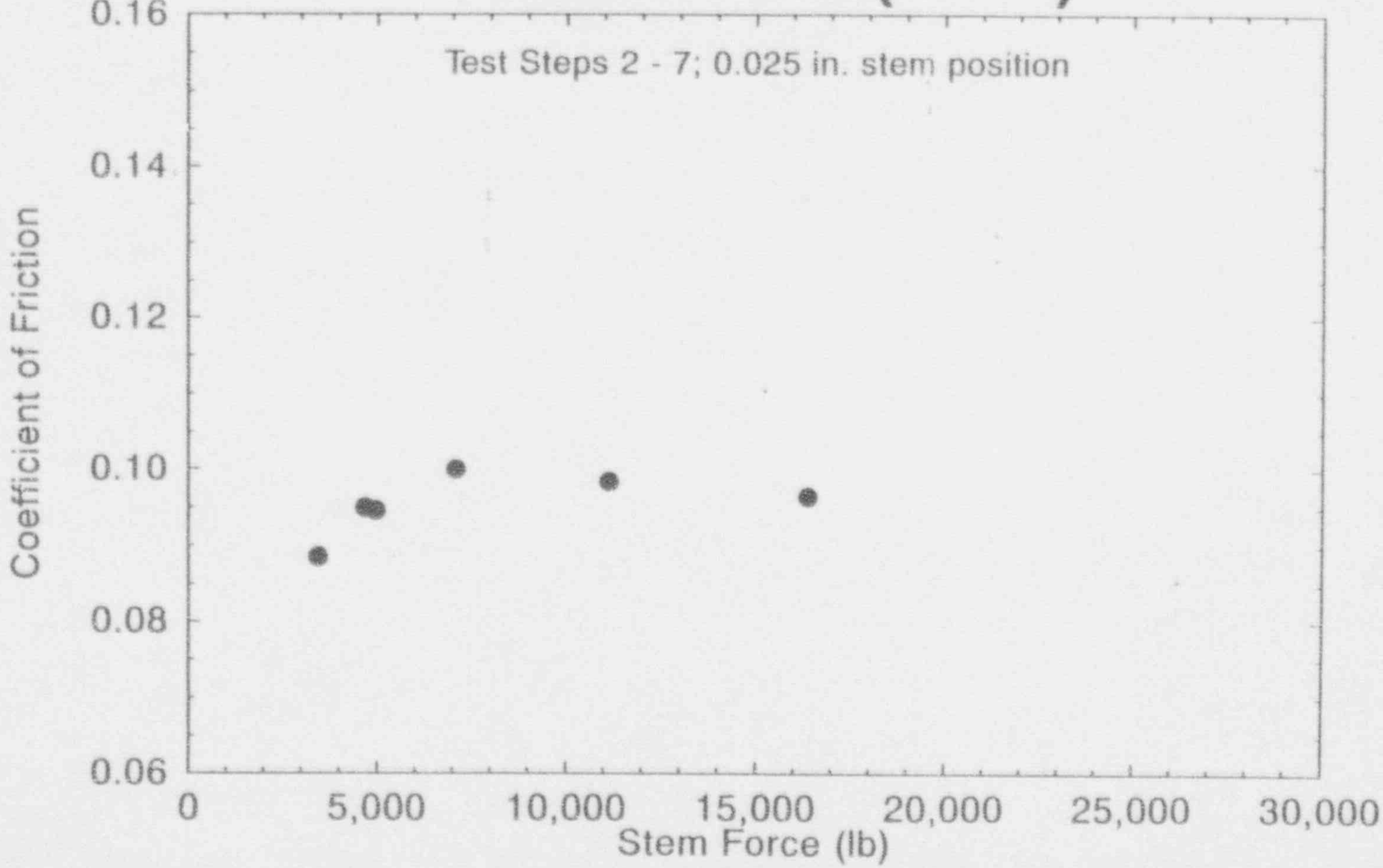


M884 rs 0593 11



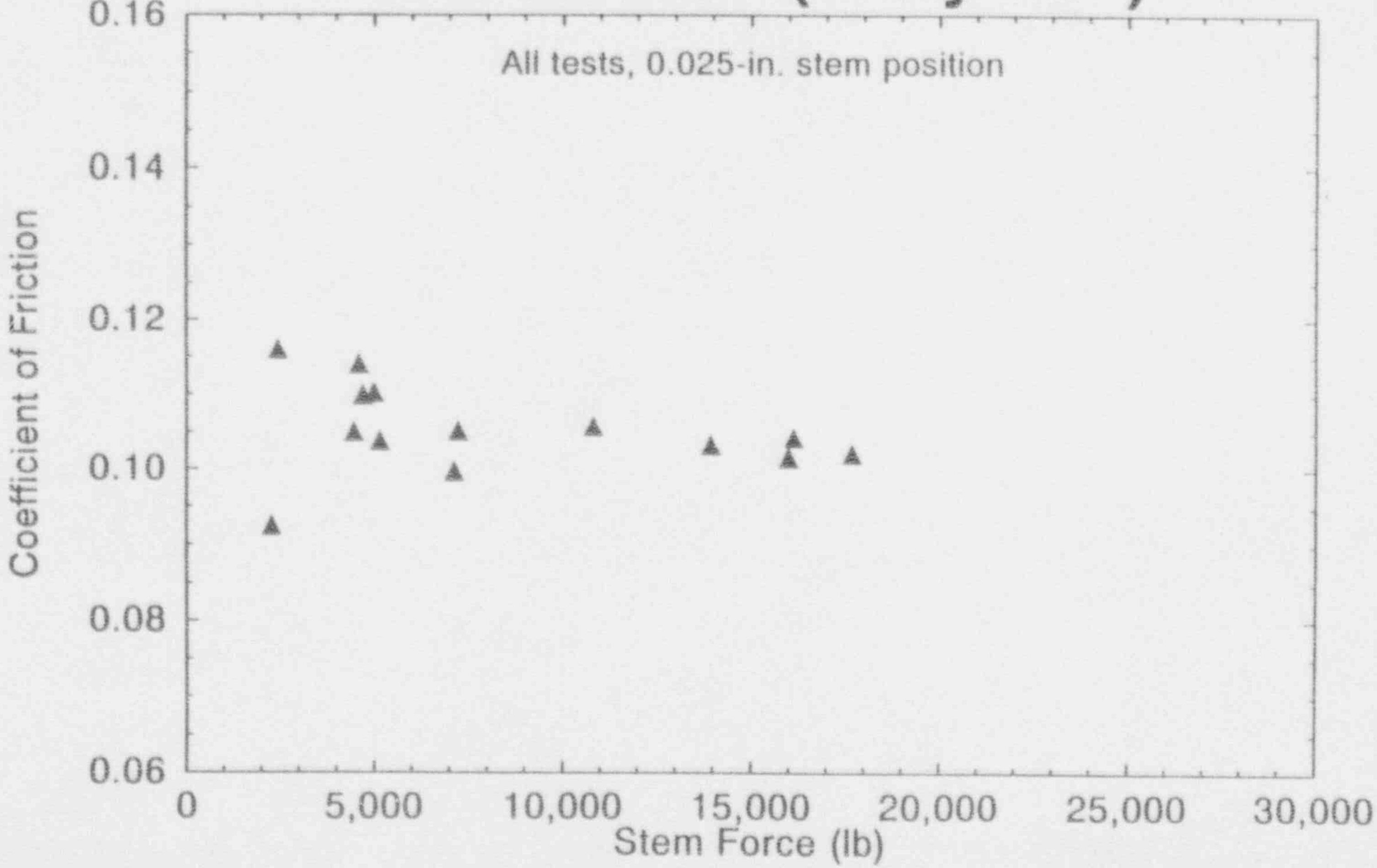
M821 rs 0693 08b

Stem 3 Coefficient of Friction vs Stem Force (EP-1)



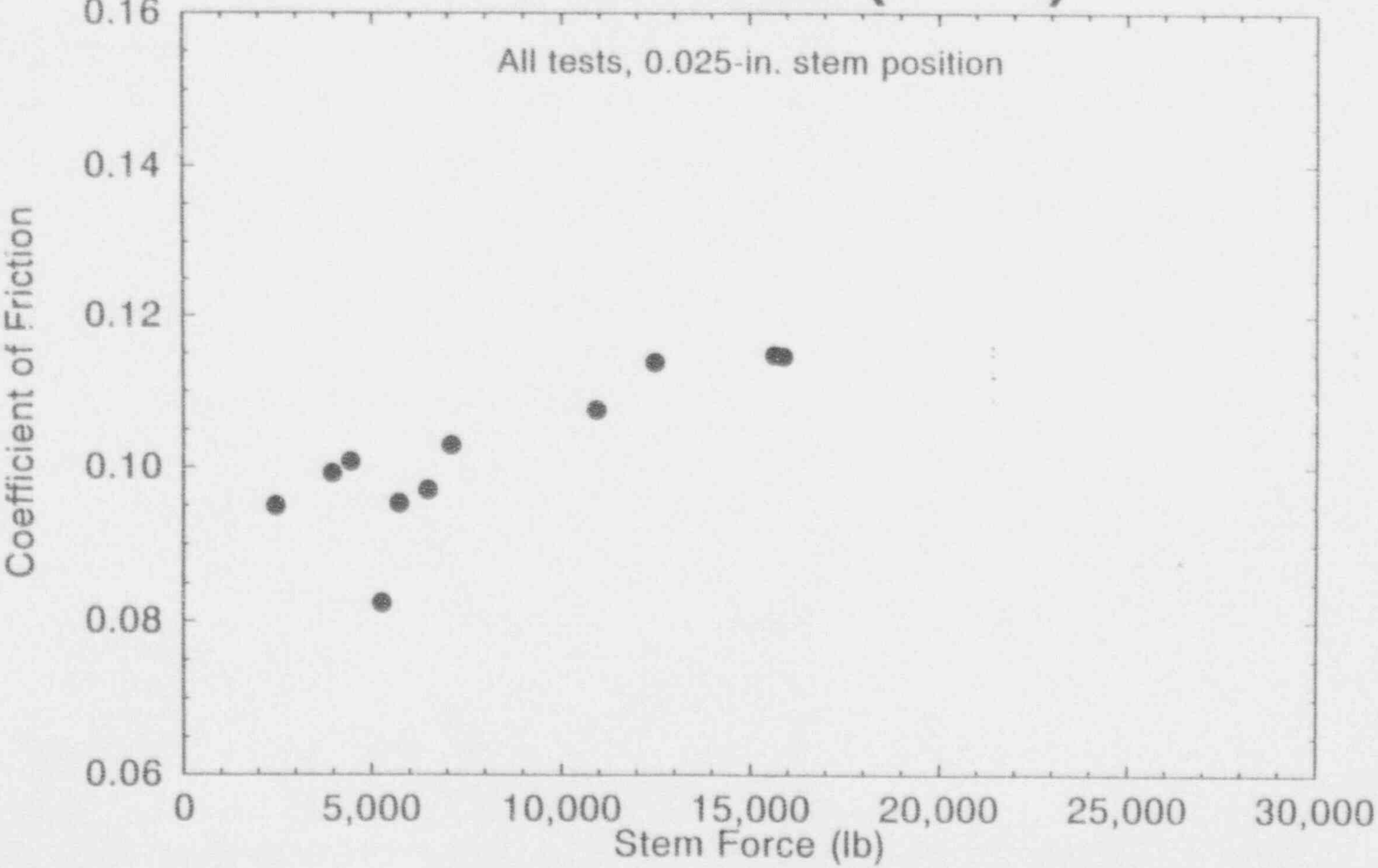
M921 rs-0693-08a

Stem 1 Coefficient of Friction vs Stem Force (Moly 101)



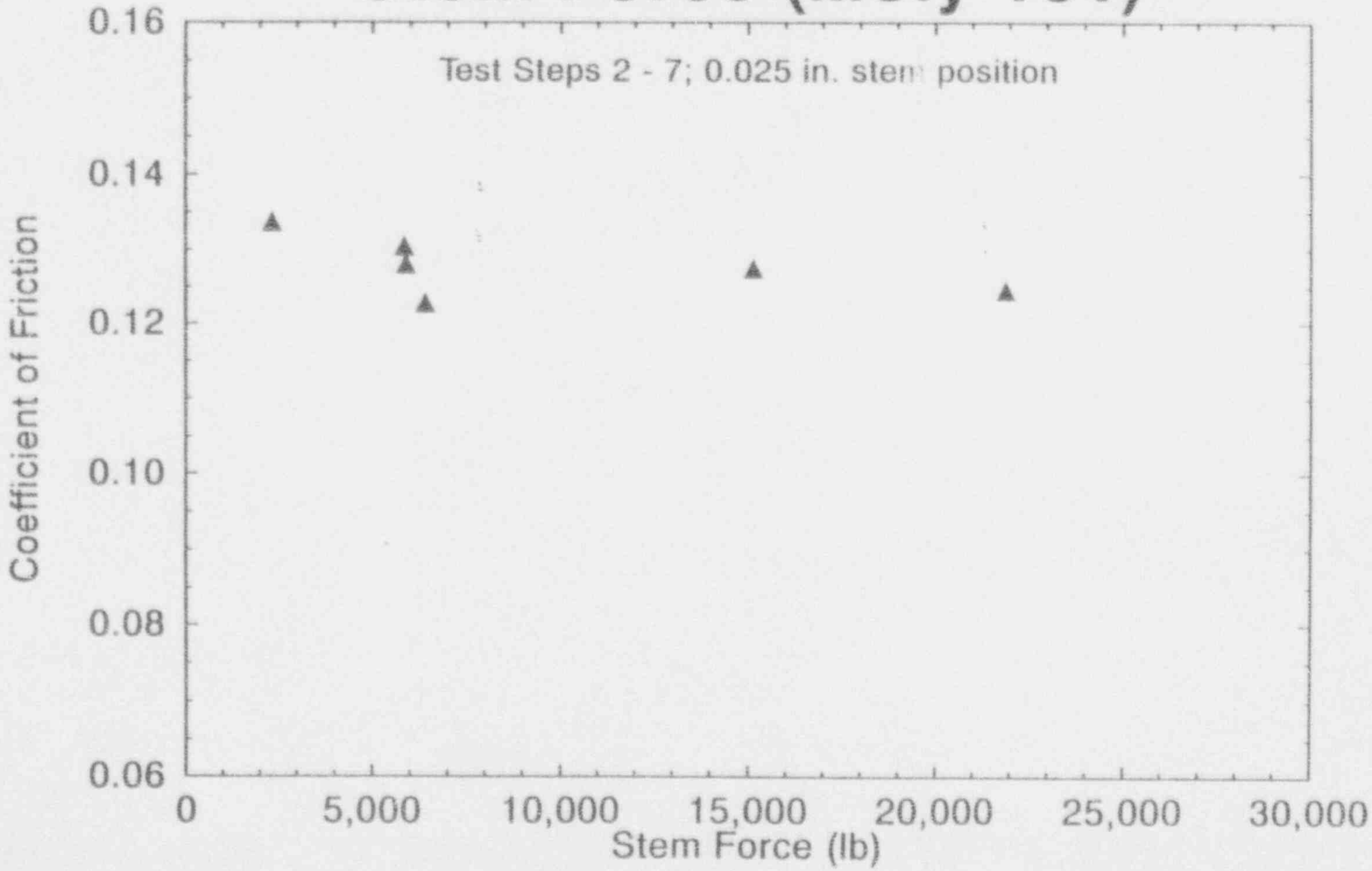
M921 rs 0693 06b

Stem 1 Coefficient of Friction vs Stem Force (EP-1)

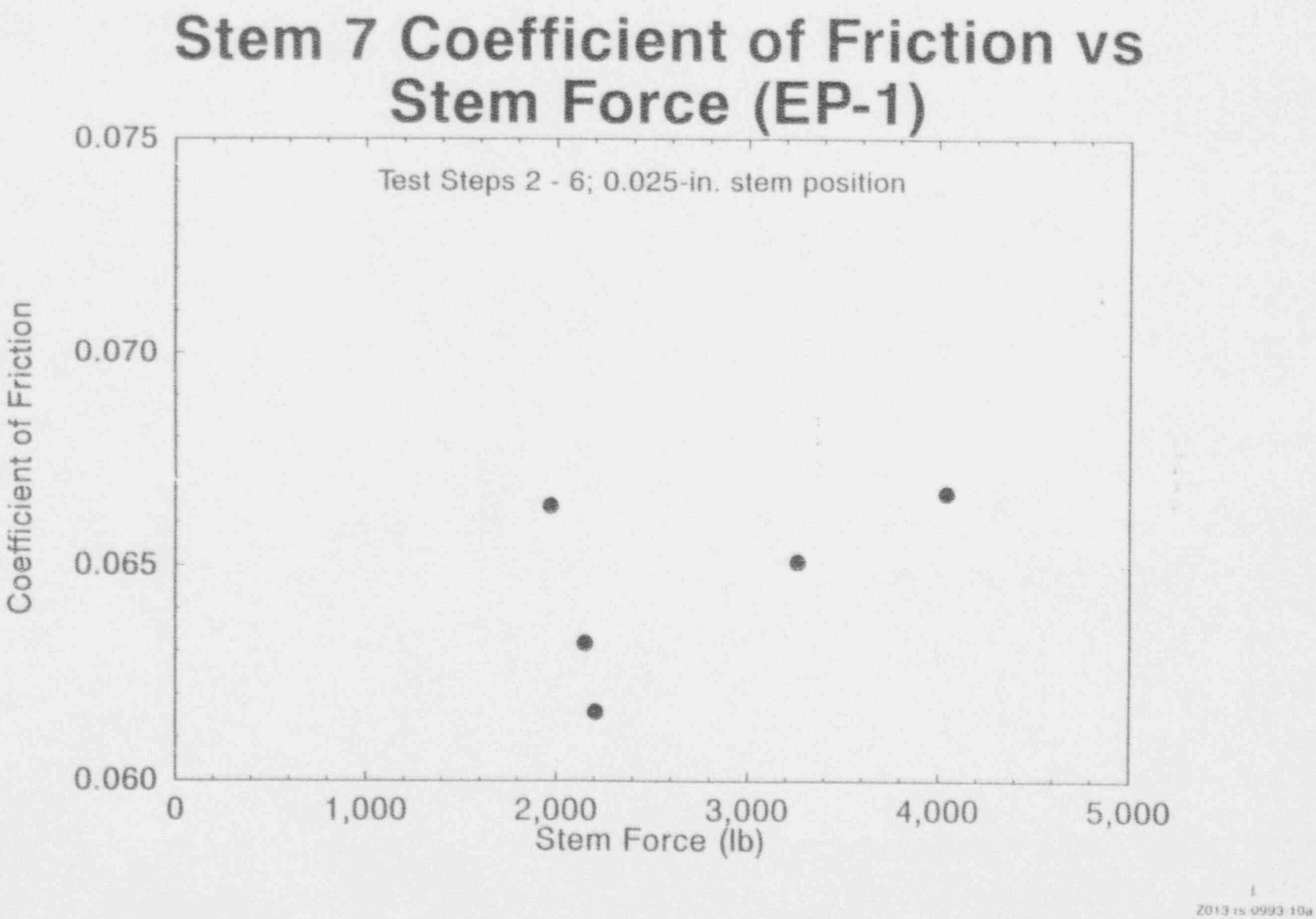


M921 rs 0693 06a

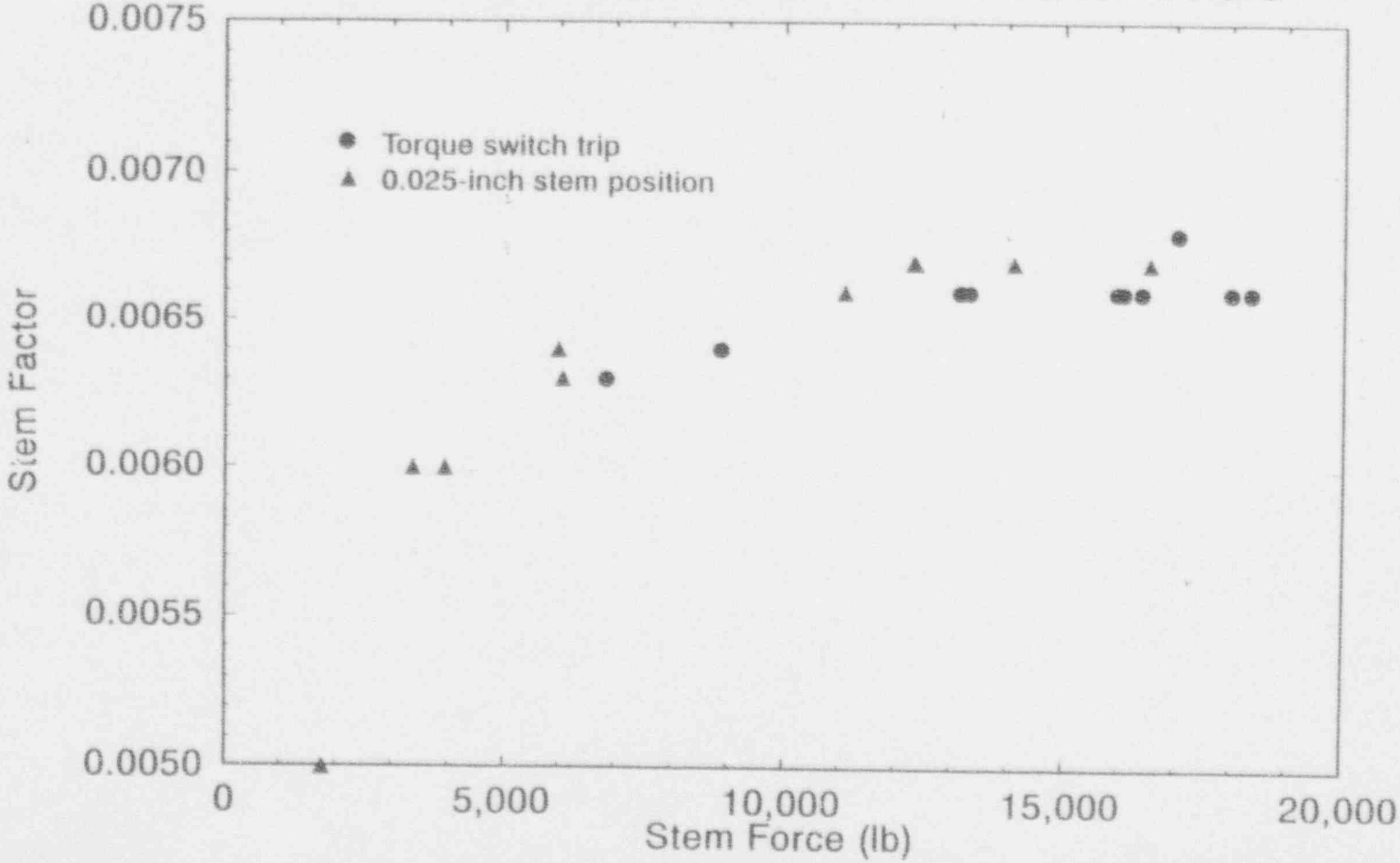
Stem 2 Coefficient of Friction vs Stem Force (Moly 101)



M921 rs 0693 07b


Stem 7 Coefficient of Friction vs Stem Force (EP-1)
Test Steps 2 - 6; 0.025-in. stem position
Coefficient of Friction
0.075
0.070
0.065
0.060
0
1,000
2,000
3,000
4,000
5,000
Stem Force (lb)
Z013 rs 0993 10a

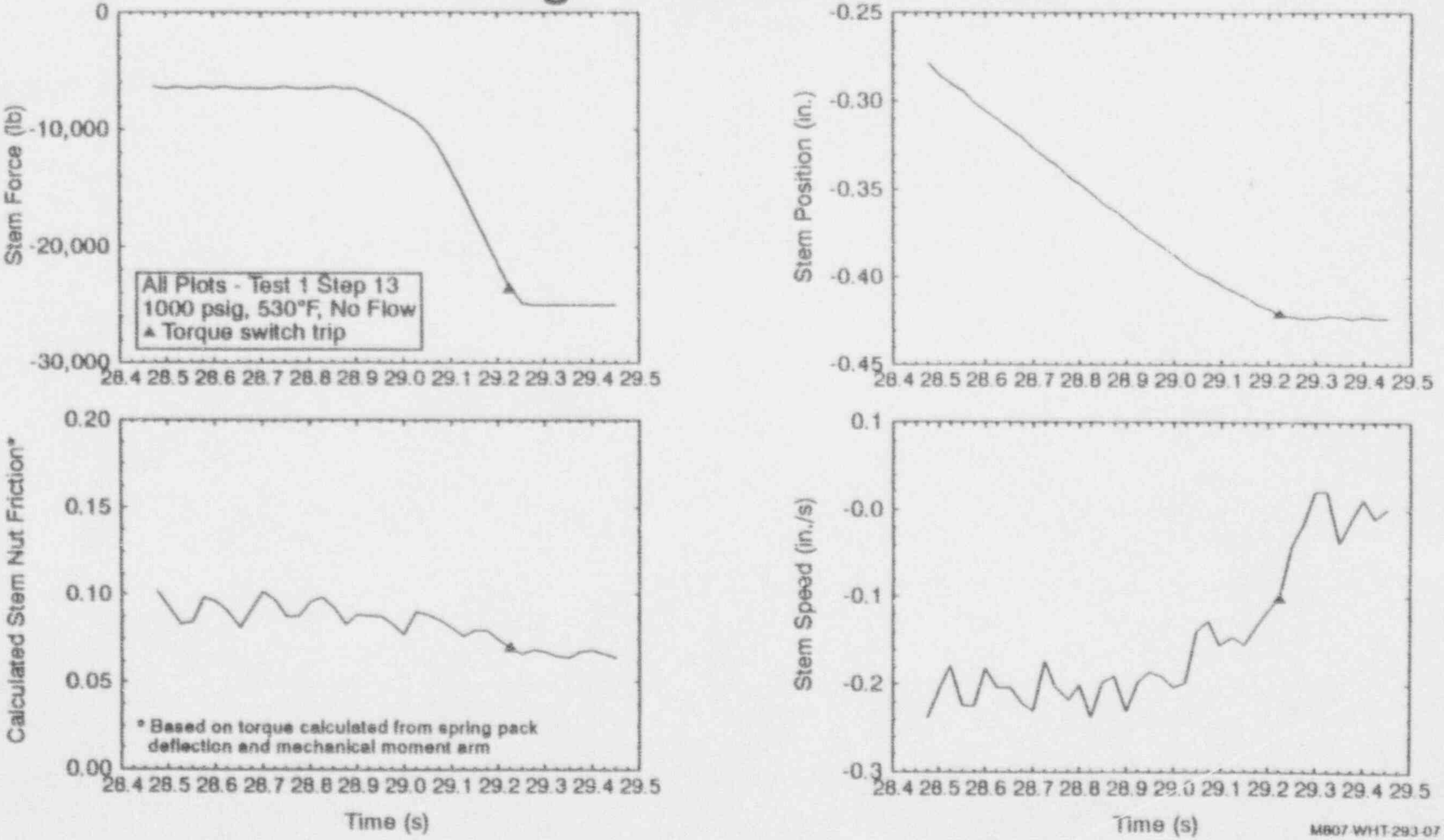
Stem 9 Ball Screw Stem Nut



Z013 rs 0993 09

Flow Loop Results

A Closer Look at Valve 2 Performance during a Pressurized Closure



M807-WHT-293-07

Conclusions for Stem Factor Issues

Can load sensitive behavior be predicted without a test? *No.*

Can load sensitive behavior be predicted from a static test or a hand wheel test? *No.*

Can the extent of load-sensitive behavior be predicted at less than 100% running load? *Maybe!*

Is load sensitive behavior always present? *Yes.*

Is load sensitive behavior always a problem? *No, it depends on the available margins. If an MOV's capability is close to what is required, then knowing the stem factor and extrapolating it to design basis conditions is important.*

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The opinions presented here today are those of the authors and not necessarily endorsed by our sponsor, the USNRC.