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

PDR
See Reports

April 25, 1997

LICENSEES: ENTERGY OPERATIONS, INC. AND COMMONWEALTH EDISON

SUBJECT: SUMMARY OF PUBLIC MEETING ON FLEXIBLE-WEDGE GATE VALVE PRESSURE LOCKING THRUST METHODOLOGIES (TAC NOS. M93467, M93434, M93435, M93441, M93442, M93458, M93459, M93477, M93478, M93509, M93510, M93541, M93542)

On April 9, 1997, a public meeting was conducted at Two White Flint North to discuss the Entergy Operations, Inc. (EOI) and Commonwealth Edison (ComEd) pressure locking thrust prediction methodologies presented in submittals in response to Generic Letter (GL) 95-07, "Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves." The EOI and ComEd methodologies that predict the thrust required to open a pressure locked flexible-wedge gate valve, validation testing of these analytical methods, enhancements to the ComEd pressure locking methodology, and pressure locking tests sponsored by the NRC Office of Nuclear Regulatory Research (RES) conducted by Idaho National Engineering and Environmental Laboratory (INEEL) were discussed during the meeting. Representatives from NRC, EOI, ComEd, Southern Nuclear Operating Company, Baltimore Gas and Electric Company, Kalsi Engineering, Inc, (KEI) and INEEL attended the meeting. During the meeting, the NRC staff identified concerns associated with the use of these pressure locking analytical methods that need to be resolved prior to issuing GL 95-07 Safety Evaluations to licensees that use the EOI or ComEd analytical methods. Attachment 1 is a list of meeting participants.

EOI Pressure Locking Thrust Prediction Methodology

During the meeting, EOI discussed the development and use of its pressure locking thrust prediction methodology and the test data used to evaluate acceptability of the methodology. EOI tested a 14-inch (900-pound) William Powell valve to obtain data to support its methodology. EOI presented ComEd pressure locking test results from a 4-inch (1500-pound) Westinghouse valve; a 10-inch (900-pound) Crane valve; a 10-inch (300-pound) Borg-Warner valve; and INEEL pressure locking test results from a 6-inch (600-pound) Walworth valve to help support its methodology. The EOI presentation is enclosed in Attachment 2.

The NRC staff identified the following questions/concerns associated with the EOI pressure locking thrust prediction methodology:

1. In some instances the EOI pressure locking prediction methodology underestimated the amount of thrust required open the Crane, Walworth and Westinghouse valves during pressure locking conditions and consistently underestimated the amount of thrust required to open the Borg-Warner valve during pressure locking conditions.

CONTACT: Stephen Tingen, EMEB/DE
415-1280

DF03

9707300022 970425
PDR ADOCK 05000237
P PDR

The NRC staff questioned whether the EOI pressure locking prediction methodology is applicable to all flexible wedge gate valves or whether use of the methodology is limited to specific types of flexible wedge gate valves.

2. Using its methodology, EOI calculated the thrust required to open a pressure locked valve and compared the results to the pressure locking test results for the above valves. EOI used a 0.4 friction factor to calculate the required thrust except when test results indicated that the friction factor was greater than 0.4 and then the actual friction factor value was used. The NRC staff expressed concern that use of a 0.4 friction factor in the EOI pressure locking prediction equation (in cases when the actual friction factor was significantly less than 0.4) may not have properly validated the EOI pressure locking prediction methodology.

3. Pressure locking test results from the Walworth valve indicated that as the differential pressure between the bonnet and the downstream (or upstream) side of the valve increases, the stem thrust required to open the pressure locked valve increases (see Attachment 5, INEEL pressure locking tests numbers 208 through 215, 217, 218, 230, 231 and 232). The EOI pressure locking methodology predicted that the opposite would occur in that as the differential pressure between the bonnet and downstream (or upstream) side of the valve increased the stem thrust predicted to open the pressure locked valve decreased. Many of the INEEL tests involved upstream or downstream pressure of 0 psig or very close to 0 psig; however, in test numbers 217 and 218 the upstream and downstream pressures were significantly greater than 0 psig. During the meeting, EOI stated that it does not apply the pressure locking prediction methodology to scenarios where upstream or downstream pressure is 0 psig. However, this does not explain why the methodology is not consistent with the test data nor does it resolve the issue when upstream or downstream pressures are present. The NRC staff questioned why the EOI pressure locking thrust methodology prediction conflicts with the Walworth valve test results. Are there any differential pressure restrictions or other conditions associated with the use of the EOI pressure locking prediction methodology?

4. During its presentation, EOI used results of GL 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance," differential pressure flow tests to demonstrate that its pressure locking prediction methodology provided conservative approximations. At the end of the presentation, it remained unclear how flow testing validated EOI's pressure locking prediction methodology.

5. The EOI pressure locking prediction model did not account for disk shear forces, vertical downward force on the disk, compression of the disk hub and flexibility of the body and disk. The importance of these parameters in providing an accurate methodology needs to be addressed. EOI stated that it intended to perform more testing to validate the model but a test schedule has not been developed to accomplish this testing. EOI was requested to provide a test schedule when it is developed.

6. On March 25, 1997, EOI provided the NRC staff a copy of Test Report, "Flow Loop Differential Pressure and Pressure Lock Tests on a 14-inch William Powell Gate Valve," dated March 1, 1993. The NRC staff reviewed the test report but the information necessary to independently verify the pressure locking test results was not in the report. EOI was requested to provide the staff with the with the test data.

ComEd Pressure Locking Thrust Prediction Methodology

ComEd discussed the development and use of its pressure locking thrust prediction methodology and the test data used to evaluate acceptability of its methodology. ComEd presented its pressure locking test results from a 4-inch (1500-pound) Westinghouse valve; a 10-inch (900-pound) Crane valve; and a 10-inch (300-pound) Borg-Warner valve to support the methodology. ComEd also presented test results from INEEL on a 6-inch (600-pound) Walworth valve and from the Electric Power Research Institute on a 6-inch Velan valve to help support its methodology. ComEd stated that a pressure locking load anomaly was identified when testing the Borg-Warner valve. KEI presented enhancements being developed for the ComEd pressure locking methodology that will account for the anomaly identified when testing the Borg-Warner valve. Enhancements included valve and disk flexibility and pressurization sequence.

During the presentation, KEI discussed preliminary results of the enhanced ComEd pressure locking prediction model. The enhanced model more accurately predicted the thrust required to open a pressure locked Borg-Warner and Crane test valve. However, in some instances the enhanced model appeared to predict less accurately the thrust required to open the pressure locked Walworth test valve. The staff recognized the complexity of the enhanced ComEd pressure locking model and expressed an interest in the sensitivity of the different model parameters. Attachment 3 is the ComEd meeting presentation and Attachment 4 the KEI presentation.

The NRC identified the following questions/concerns associated with the ComEd pressure locking thrust prediction methodology:

1. In some instances the ComEd pressure locking prediction methodology underestimated the amount of thrust required to open the Walworth valve under pressure locking conditions and consistently underestimated the amount of thrust required to open the Borg-Warner valve under pressure locking conditions. The NRC staff realizes that enhancements to the ComEd pressure locking thrust prediction methodology are being evaluated. Is the ComEd pressure locking thrust prediction methodology (current or enhanced version) applicable to all flexible wedge gate valves or is the methodology limited to specific flexible wedge gate valves?

2. The ComEd pressure locking prediction model did not account for differential pressure across the disk hub. The importance of this parameter in developing an accurate methodology needs to be addressed.

3. When using its pressure locking prediction methodology, ComEd recommends a 20% to 40% (or greater) margin between actuator thrust output and the calculated thrust value. The basis for the individual elements of this margin and application requirements needs to be addressed.

INEEL Pressure Locking Test Results

During the meeting, INEEL presented the results of its Walworth 6-inch, 600 pound flexible wedge pressure locking tests sponsored by RES to assist the Office of Nuclear Reactor Regulation in the review of licensee submittals in response to GL 95-07. INEEL compared the results of this testing to EOI and ComEd pressure locking thrust methodology results. Attachment 5 is the INEEL meeting presentation. The INEEL test data indicated that the EOI and ComEd thrust prediction methodologies underpredicted the stem thrust required to open a pressure locked valve when using pressure conditions at unwedging. When using pressure conditions prior to valve motion, the EOI and ComEd thrust prediction results were more consistent with INEEL test results. Further, the test data revealed that selected trends of the EOI methodology were inconsistent with test results.

Conclusion

At the conclusion of the meeting, the NRC staff identified to the participants several unresolved items associated with the use of the EOI and ComEd pressure locking thrust prediction methodologies that need to be resolved in order for the staff to complete its GL 95-07 safety evaluations for those licensees that use the EOI or ComEd method. The NRC staff will submit information requests to EOI and ComEd in a separate letter.

David C Fischer for DT

David Terao, Chief
Components & Testing Section
Mechanical Engineering Branch
Division of Engineering
Office of Nuclear Reactor Regulation

Docket Nos. 50-456, 50-456, 50-457, 50-454, 50-455, 50-237, 50-249, 50-373, 50-374, 50-254, 50-265, 50-295, 50-304

Attachments: As stated

cc w/attachments: NRC Public Document Room
Dana Smith, EOI
Brian Bunte, ComEd

INEEL Pressure Locking Test Results

During the meeting, INEEL presented the results of its Walworth 6-inch, 600 pound flexible wedge pressure locking tests sponsored by RES to assist the Office of Nuclear Reactor Regulation in the review of licensee submittals in response to GL 95-07. INEEL compared the results of this testing to EOI and ComEd pressure locking thrust methodology results. Attachment 5 is the INEEL meeting presentation. The INEEL test data indicated that the EOI and ComEd thrust prediction methodologies underpredicted the stem thrust required to open a pressure locked valve when using pressure conditions at unwedging. When using pressure conditions prior to valve motion, the EOI and ComEd thrust prediction results were more consistent with INEEL test results. Further, the test data revealed that selected trends of the EOI methodology were inconsistent with test results.

Conclusion

At the conclusion of the meeting, the NRC staff identified to the participants several unresolved items associated with the use of the EOI and ComEd pressure locking thrust prediction methodologies that need to be resolved in order for the staff to complete its GL 95-07 safety evaluations for those licensees that use the EOI or ComEd method. The NRC staff will submit information requests to EOI and ComEd in a separate letter.

/s/

David Terao, Chief
Components & Testing Section
Mechanical Engineering Branch
Division of Engineering
Office of Nuclear Reactor Regulation

Docket Nos. 50-416, 50-456, 50-457, 50-454, 50-455, 50-237, 50-249, 50-373, 50-374, 50-254, 50-265, 50-295, 50-304

Attachments: As stated

cc w/attachments: NRC Public Document Room
Dana Smith, EOI
Brian Bunte, ComEd

Distribution: EMEB CHRON/RF VALVE LIST R. Eaton
CUMENT NAME: G:\TINGEN\MEET.MIN OFFICIAL RECORD COPY
receive a copy of this document, indicate in the box C=Copy w/o attachment/enclosure E=Copy with attachment/enclosure N = No
y

FFICE	EMEB:DE		EMEB:DE		EMEB:DE	C	EMEB:DE	C
AME	TScarbrough*		STingen*		DTerao		RWessman	
ATE	4/16/97		4/16/97		4/22/97		4/25/97	

* See previous concurrence

50-424 VOGTLE UNIT 1

50-237 CEC DRESDEN 2

SUMMARY OF PUBLIC MEETING ON FLEXIBLE-WEDGE GATE VALVE PRESSURE LOCKING THRUST METHODOLOGIES

REC'D W?LTR DTD 04/25/97....9707300022

- NOTICE -

THE ATTACHED FILES ARE OFFICIAL RECORDS OF THE INFORMATION & RECORDS MANAGEMENT BRANCH. THEY HAVE BEEN CHARGED TO YOU FOR A LIMITED TIME PERIOD AND MUST BE RETURNED TO THE RECORDS & ARCHIVES SERVICES SECTION, T5 C3. PLEASE DO NOT SEND DOCUMENTS CHARGED OUT THROUGH THE MAIL. REMOVAL OF ANY PAGE(S) FROM DOCUMENT FOR REPRODUCTION MUST BE REFERRED TO FILE PERSONNEL.

- NOTICE -

PARTICIPANTS
NRC PUBLIC MEETING
APRIL 9, 1997

NAME	ORGANIZATION
R. Wessman	NRC/NRR
D. Terao	NRC/NRR
T. Scarbrough	NRC/NRR
J. Donohew	NRC/NRR
S. Tingen	NRC/NRR
G. Weidenhamer	NRC/RES
E. Brown	NRC/AEOD
K. DeWall	INEEL
J. Watkins	INEEL
M. Holbrook	INEEL
J. Burton	EOI/Grand Gulf Nuclear Station (GGNS)
D. Smith	EOI/GGNS
R. Jackson	EOI/GGNS
B. Bunte	ComEd
P. Piet	ComEd
J. Wang	KEI
S. Reckford	Baltimore Gas and Electric Company/Calvert Cliffs
C. Myer	Southern Nuclear Operating Company/Vogtle

ATTACHMENT 1

ENTERGY

NRC Meeting to Discuss Pressure Locking Thrust Prediction Methodologies

Dana E. Smith

4/9/97

ATTACHMENT 2

ENTERGY

Topics of Discussion

- To discuss the development of the EOI Pressure Locking Thrust Prediction Methodology
- To demonstrate the use of the EOI Pressure Locking Thrust Prediction Methodology
- To show various data used to confirm acceptability of the methodology

Development of EOI Methodology

ENTERGY

- Developed in 1992 as part of the reevaluation effort for SOER 84-07
- Developed as an extension of GL 89-10 philosophies
- Developed based on first principles and NUREG/CR-5807
- Methodology initially confirmed by testing at Wyle Labs in 1993

Use of EOI Methodology

ENTERGY

- Previous/Current usage
- Boundary Conditions
- GL 95-07 Evaluation Criteria
- Examples

Previous/Current Usage

ENTERGY

- Used to address operability concerns for potentially pressure locked valves
- Used by the NRC to address potentially pressure locked valves at other utilities (Ref. IN 95-30)
- Used to evaluate the necessity of modifications during GL 95-07 evaluation

Boundary Conditions

ENTERGY

- Upstream/Downstream Pressures must not exceed the Bonnet Pressure
- Convention requires highest pressure to be specified as Upstream Pressure
- Opening/Closing Thrust data must be corrected for instrument inaccuracies
- Taking no credit for stem ejection loads increases conservatism
- Use a sliding friction factor

GL 95-07 Evaluation Criteria

ENTERGY

- Reviewed Operation and Surveillance procedures to identify potential scenarios
- Determined system conditions for each scenario (often time dependent)
- Used Methodology to determine most limiting scenario
- Nonconformance/Operability established

EOI Design Engineering

General Computation Sheet

Calc. No.

Attachment 1

ENTERGY

GATE VALVE DISC LOAD CALCULATION

Ref. Roark & Young: Formulas for Stress & Strain, Table 24, Case 2d

Wm. Powell 14": Example 0/1080/1080

Disc Characteristics

a	b	C2	C3	C8	C9	L11	L17	Hub Area	Hub Circum	lsc Circum	μ	Seat Angle
6.071	1.875	.170123	.029524	.683382	.284753	.006199	.146383	11.045	11.781	38.147	0.40	5

Loads Due to Bonnet Pressure

q (psig)	Qb	Qa
1080	4794	-1485

Loads Due to Upstream Pressure

q (psig)	Qb	Qa
1080	4794	-1485

Loads Due to Downstream Pressure

q (psig)	Qb	Qa
0	0	0

Loads Due to Differential Pressure

q (psig)	W-hub	W	W-total	Qa
1080	1013	4794	5806	1793

Seat Ring Force Calculation

Unit	Load	Force	Calc	Total
Upstrm.	Dnstrm.	Upstrm.	Dnstrm.	Force
0	3278	0	125063	125063

Thrust Calculation

EOI Calc O9 Thrust	Meas. Static Thrust	Disc Factor	EOI Calc PL Thrust
103518	55000	0.388	48518

Actual O9 Thrust Example

Variable Description:

a	=	Mean seat radius, (in.)
b	=	Hub radius, (in.)
q	=	Pressure, (psig)
W-hub	=	Hub load (#/in)
W	=	Qb differential (#/in)
W-total	=	W-hub + W
Poisson's ratio	=	0.3
C2, C3, C8, C9	=	Plate constants
L11, L17	=	Loading constants
μ	=	Coefficient of friction
Seat Angle	=	°
O9 Thrust	=	55000

Example (continued)

- To check the seat loads a force balance on the disk assembly was performed:

- The net force acting on the Upstream disk, is equal to the Upstream seat ring load times the disk circumference (38.147 inches) plus the difference between the Upstream side pressure (1080 psig) and the Downstream side pressure (0 psig) times the disk area (115.799 in2).

- Fxu = (0 lbs/in * 38.147 inches) + (1080 lbs/in2 * 115.799 in2)
  = 125062.92 lbs

- The net force acting on the Downstream disk, is equal to the Downstream seat ring load times the disk circumference (38.147 inches).

- Fxd = (3278 lbs/in * 38.147 inches)
  = 125045.87 lbs (difference attributable to rounding manual calculation results)

- Total Pressure Locking Load:

- FPL = 38.147 inches (0 lbs/in + 3278 lbs/in)(.388)
  = 38.147 inches (3278 lbs/in)(.388)
  = 125045.87 lbs(.388)
  FPL = 48517.8 lbs

- Total Required Thrust:

- TReq = TUW + FPL
  = 55000 lbs + 48517.8 lbs
  = 103517.8lbs (difference attributable to rounding manual calculations results)

EOI Design Engineering
General Computation Sheet

Calc. No.

ENTERGY

Attachment 1

GATE VALVE DISC LOAD CALCULATION

Ref. Roark & Young: Formulas for Stress & Strain, Table 24, Case 2d

Wm. Powell 14": Example 0/1080/450

Disc Characteristics

a	b	C2	C3	C8	C9	L11	L17	Hub Area	Hub Circum	Isc Circum	μ	Seat Angle
6.071	1.875	.170123	.029524	.683382	.284753	.006199	.146383	11.045	11.781	38.147	0.40	5

Loads Due to Bonnet Pressure

q (psig)	Qb	Qa
1080	4794	-1485

Loads Due to Upstream Pressure

q (psig)	Qb	Qa
450	1997	-619

Loads Due to Downstream Pressure

q (psig)	Qb	Qa
0	0	0

Loads Due to Differential Pressure

q (psig)	W-hub	W	W-total	Qa
450	422	1997	2419	747

Seat Ring Force Calculation

Unit Load		Force Calc		Total
Upstrm.	Dnstrm.	Upstrm.	Dnstrm.	Force
866	2232	33050	85160	118210

Thrust Calculation

EOI Calc O9 Thrust	Meas. Static Thrust	Disc Factor	EOI Calc PL Thrust
100860	55000	0.388	45860

Actual O9 Thrust Example

Variable Description:

a =	Mean seat radius, (in.)
b =	Hub radius, (in.)
q =	Pressure, (psig)
W-hub =	Hub load (#/in)
W =	Qb differential (#/in)
W-total =	W-hub + W
Poisson's ratio =	0.3
C2, C3, C8, C9 =	Plate constants
L11, L17 =	Loading constants
μ =	Coefficient of friction
Seat Angle =	°
O9 Thrust =	55000

Example (continued)

- To check the seat loads a force balance on the disk assembly was performed:

- The net force acting on the Upstream disk, is equal to the Upstream seat ring load times the disk circumference (38.147 inches) plus the difference between the Upstream side pressure (450 psig) and the Downstream side pressure (0 psig) times the disk area (115.799 in2).

- Fxu = (866 lbs/in * 38.147 inches) + (450 lbs/in2 * 115.799 in2)
  = 85144.8 lbs

- The net force acting on the Downstream disk, is equal to the Downstream seat ring load times the disk circumference (38.147 inches).

- Fxd = (2232 lbs/in * 38.147 inches)
  ≐ 85144.1 lbs (difference attributable to rounding manual calculation results)

- Total Pressure Locking Load:

- FPL = 38.147 inches (866 lbs/in + 2232 lbs/in)(.388)
  = 38.147 inches (3098 lbs/in)(.388)
  = 118179.41 lbs(.388)
  FPL = 45853.61 lbs

- Total Required Thrust:

- TReq = TUW + FPL
  = 55000 lbs + 45853.61 lbs
  = 100853.61 lbs (difference attributable to rounding manual calculations results)

EOI Design Engineering | Calc. No.
General Computation Sheet

ENTERGY

Attachment 1

GATE VALVE DISC LOAD CALCULATION

Ref. Roark & Young: Formulas for Stress & Strain, Table 24, Case 2d

Wm. Powell 14": Example 0/1080/0

Disc Characteristics

a	b	C2	C3	C8	C9	L11	L17	Hub Area	Hub Circum	Isc Circum	μ	Seat Angle
6.071	1.875	.170123	.029524	.683382	.284753	.006199	.146383	11.045	11.781	38.147	0.40	5

Loads Due to Bonnet Pressure

q (psig)	Qb	Qa
1080	4794	-1485

Loads Due to Upstream Pressure

q (psig)	Qb	Qa
0	0	0

Loads Due to Downstream Pressure

q (psig)	Qb	Qa
0	0	0

Loads Due to Differential Pressure

q (psig)	W-hub	W	W-total	Qa
0	0	0	0	0

Seat Ring Force Calculation

Unit	Load	Force	Calc	Total
Upstrm.	Dnstrm.	Upstrm.	Dnstrm.	Force
1485	1485	56658	56658	113315

Thrust Calculation

EOI Calc O9 Thrust	Meas. Static Thrust	Disc Factor	EOI Calc PL Thrust
98961	55000	0.388	43961

Actual O9 Thrust Example

Variable Description:

a =	Mean seat radius, (in.)
b =	Hub radius, (in.)
q =	Pressure, (psig)
W-hub =	Hub load (#/in)
W =	Qb differential (#/in)
W-total =	W-hub + W
Poisson's ratio =	0.3
C2, C3, C8, C9 =	Plate constants
L11, L17 =	Loading constants
μ =	Coefficient of friction
Seat Angle =	°
O9 Thrust =	55000

Example (continued)

- To check the seat loads a force balance on the disk assembly was performed:
- The net force acting on the Upstream disk, is equal to the Upstream seat ring load times the disk circumference (38.147 inches) plus the difference between the Upstream side pressure (0 psig) and the Downstream side pressure (0 psig) times the disk area (115.799 in2).
- Fxu = (1485 lbs/in * 38.147 inches) + (0 lbs/in2 * 115.799 in2)
  = 56648.29 lbs
- The net force acting on the Downstream disk, is equal to the Downstream seat ring load times the disk circumference (38.147 inches).
- Fxd = (1485 lbs/in * 38.147 inches)
  = 56648.29 lbs (difference attributable to rounding manual calculation results)
- Total Pressure Locking Load:
- FPL = 38.147 inches (1485 lbs/in + 1485 lbs/in)(.388)
  = 38.147 inches (2970 lbs/in)(.388)
  = 113296.59 lbs(.388)
  FPL = 43959 lbs
- Total Required Thrust:
- TReq = TUW + FPL
  = 55000 lbs + 43959 lbs
  = 98959 lbs (difference attributable to rounding manual calculations results)

EOI Design Engineering | Calc. No.

General Computation Sheet

ENTERGY

Attachment 1

GATE VALVE DISC LOAD CALCULATION

Ref. Roark & Young: Formulas for Stress & Strain, Table 24, Case 2d

Wm. Powell 14": Example 450/1080/1080

Disc Characteristics

a	b	C2	C3	C8	C9	L11	L17	Hub Area	Hub Circum	isc Circum	μ	Seat Angle
6.071	1.875	.170123	.029524	.683382	.284753	.006199	.146383	11.045	11.781	38.147	0.40	5

Loads Due to Bonnet Pressure

q (psig)	Qb	Qa
1080	4794	-1485

Loads Due to Upstream Pressure

q (psig)	Qb	Qa
1080	4794	-1485

Loads Due to Downstream Pressure

q (psig)	Qb	Qa
450	1997	-619

Loads Due to Differential Pressure

q (psig)	W-hub	W	W-total	Qa
630	591	2796	3387	1046

Seat Ring Force Calculation

Unit	Load	Force	Calc	Total
Upstrm.	Dnstrm.	Upstrm.	Dnstrm.	Force
0	1912	0	72954	72954

Thrust Calculation

EOI Calc O9 Thrust	Meas. Static Thrust	Disc Factor	EOI Calc PL Thrust
83302	55000	0.388	28302

Actual O9 Thrust Example

Variable Description:

a =	Mean seat radius, (in.)
b =	Hub radius, (in.)
q =	Pressure, (psig)
W-hub =	Hub load (#/in)
W =	Qb differential (#/in)
W-total =	W-hub + W
Poisson's ratio =	0.3
C2, C3, C8, C9 =	Plate constants
L11, L17 =	Loading constants
μ =	Coefficient of friction
Seat Angle =	°
O9 Thrust =	55000

Example (continued)

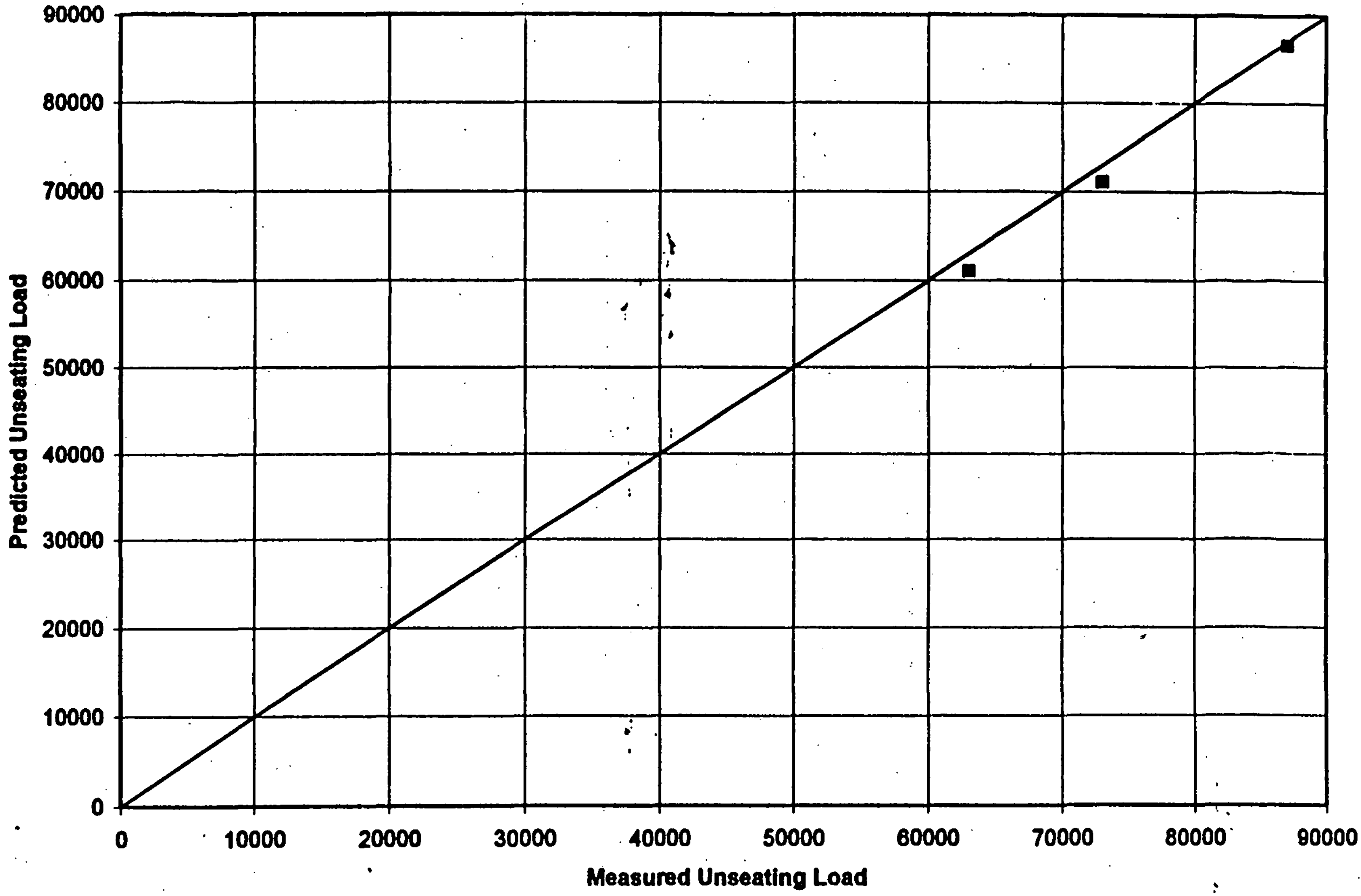
- To check the seat loads a force balance on the disk assembly was performed:
- The net force acting on the Upstream disk, is equal to the Upstream seat ring load times the disk circumference (38.147 inches) plus the difference between the Upstream side pressure (1080 psig) and the Downstream side pressure (450 psig) times the disk area (115.799 in2).
- Fxu = (0 lbs/in * 38.147 inches) + (630 lbs/in2 * 115.799 in2)
  = 72953.37 lbs
- The net force acting on the Downstream disk, is equal to the Downstream seat ring load times the disk circumference (38.147 inches).
- Fxd = (1912 lbs/in * 38.147 inches)
  = 72937 lbs (difference attributable to rounding manual calculation results)
- Total Pressure Locking Load:
- FPL = 38.147 inches (0 lbs/in + 1912 lbs/in)(.388)
  = 38.147 inches (1912 lbs/in)(.388)
  = 72937 lbs(.388)
  FPL = 28299.5 lbs
- Total Required Thrust:
- TReq = TUW + FPL
  = 55000 lbs + 28299.5 lbs
  = 83299.5lbs (difference attributable to rounding manual calculations results)

Review of Data

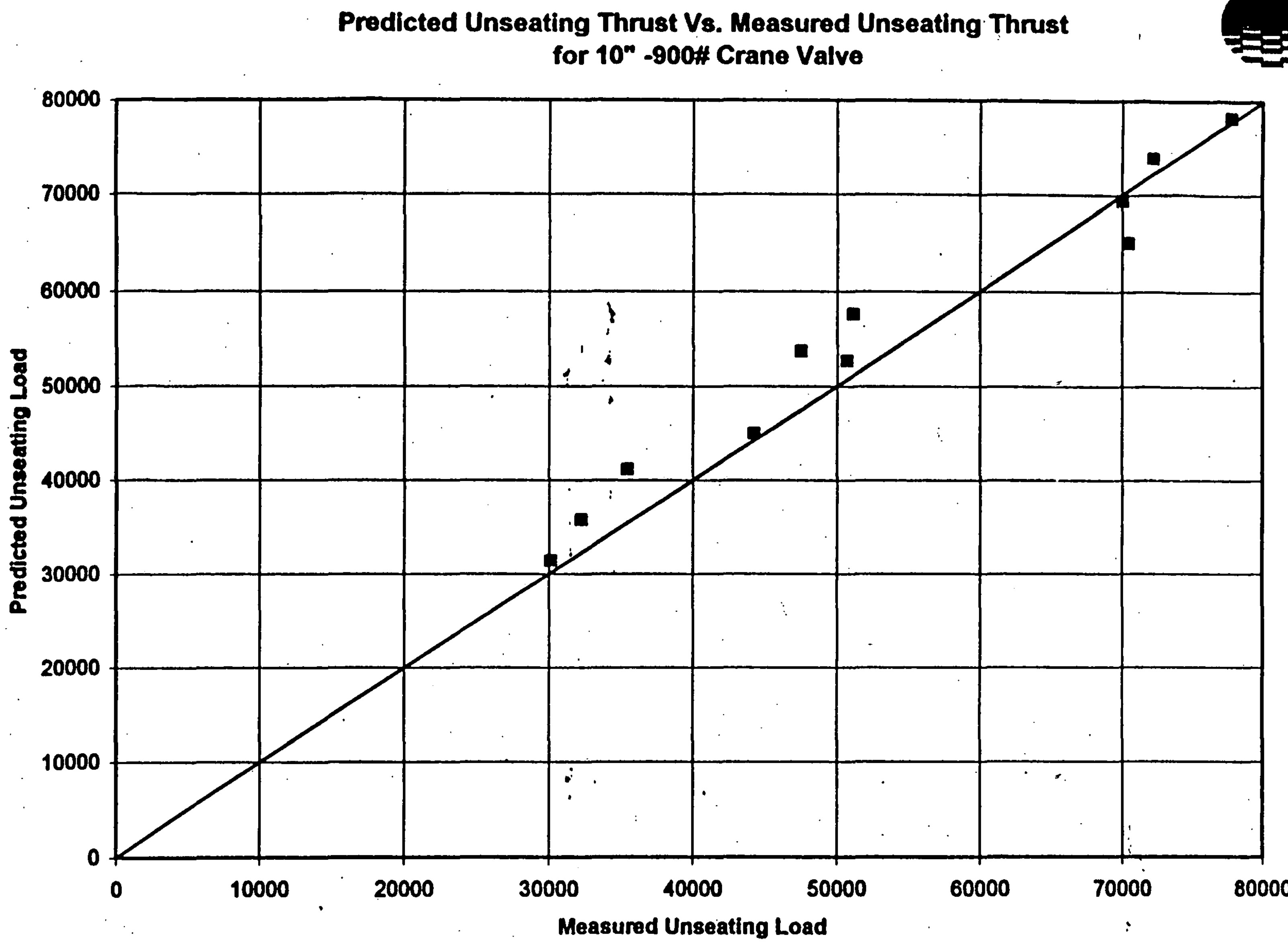
ENTERGY

- 14” -900# Powell
- 10” -900# Crane
- 4” - 1500# Westinghouse
- 10” - 300# Borg-Warner
- 6” -600# Walworth
- 4” -300# Powell (3 valves) - DP data
- 18” - 300# Powell - DP data
- 18” - 900# Powell - DP data

Predicted Unseating Thrust Vs. Measured Unseating Thrust for 14" -900# Powell Valve

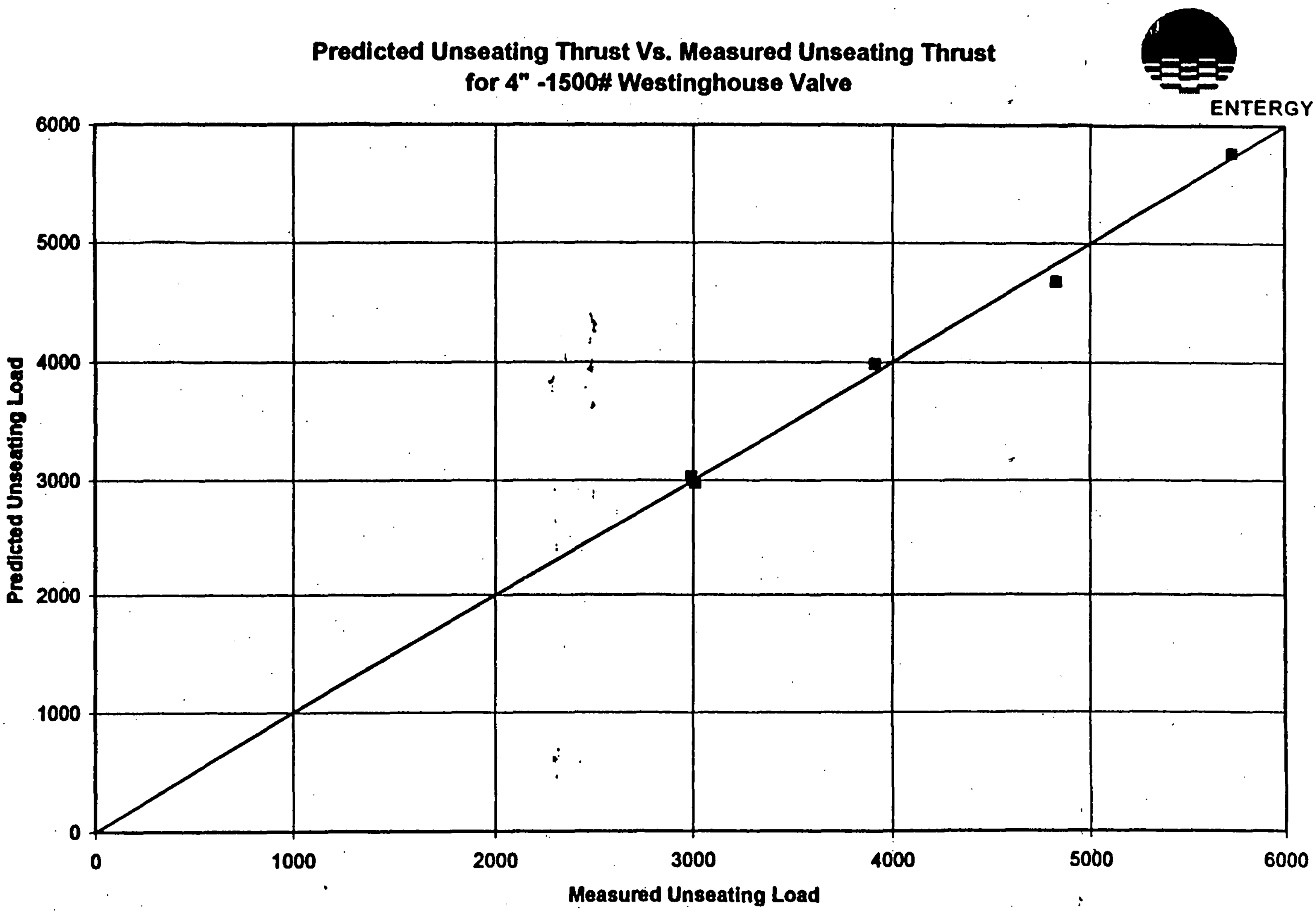


ENTERGY

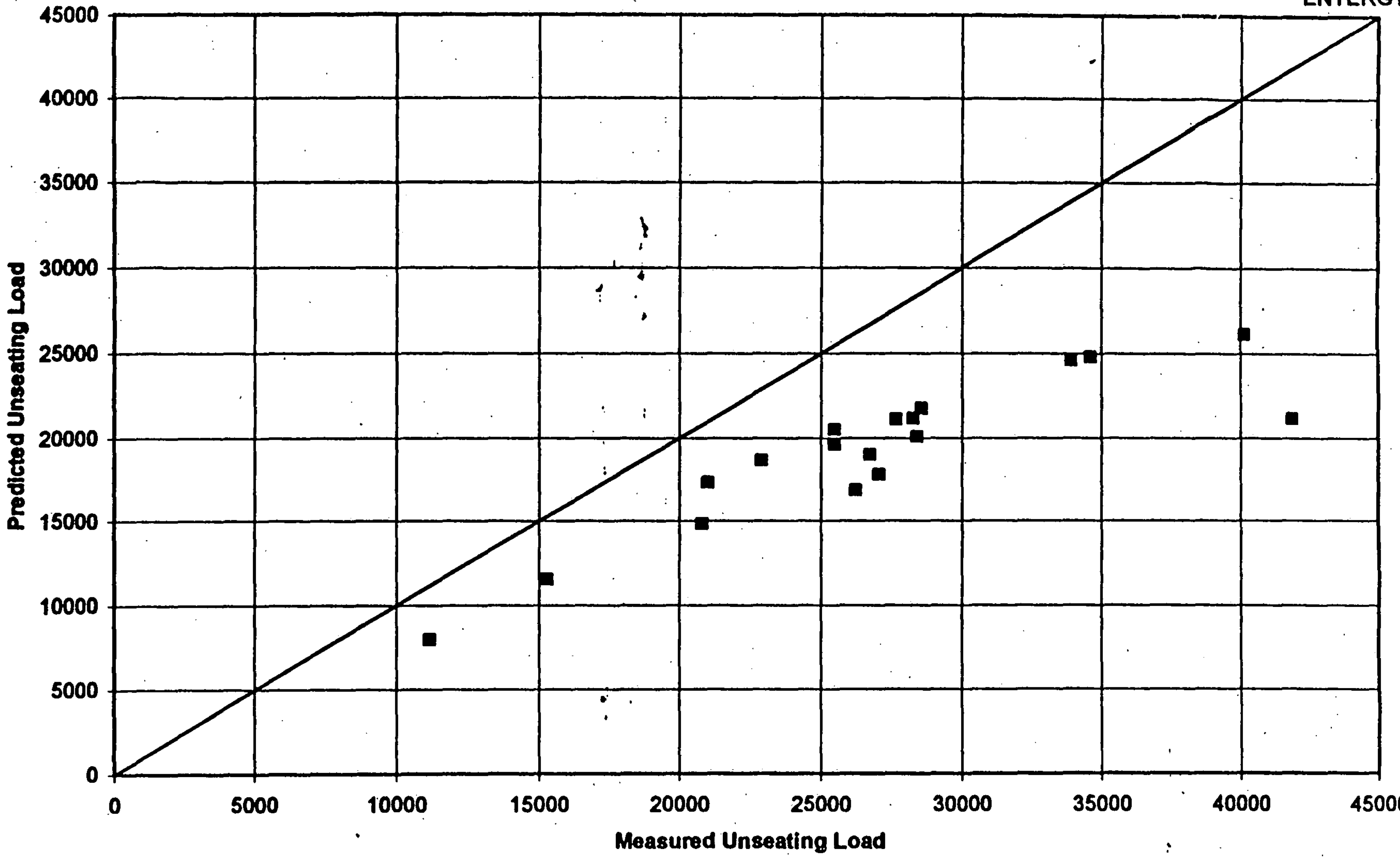


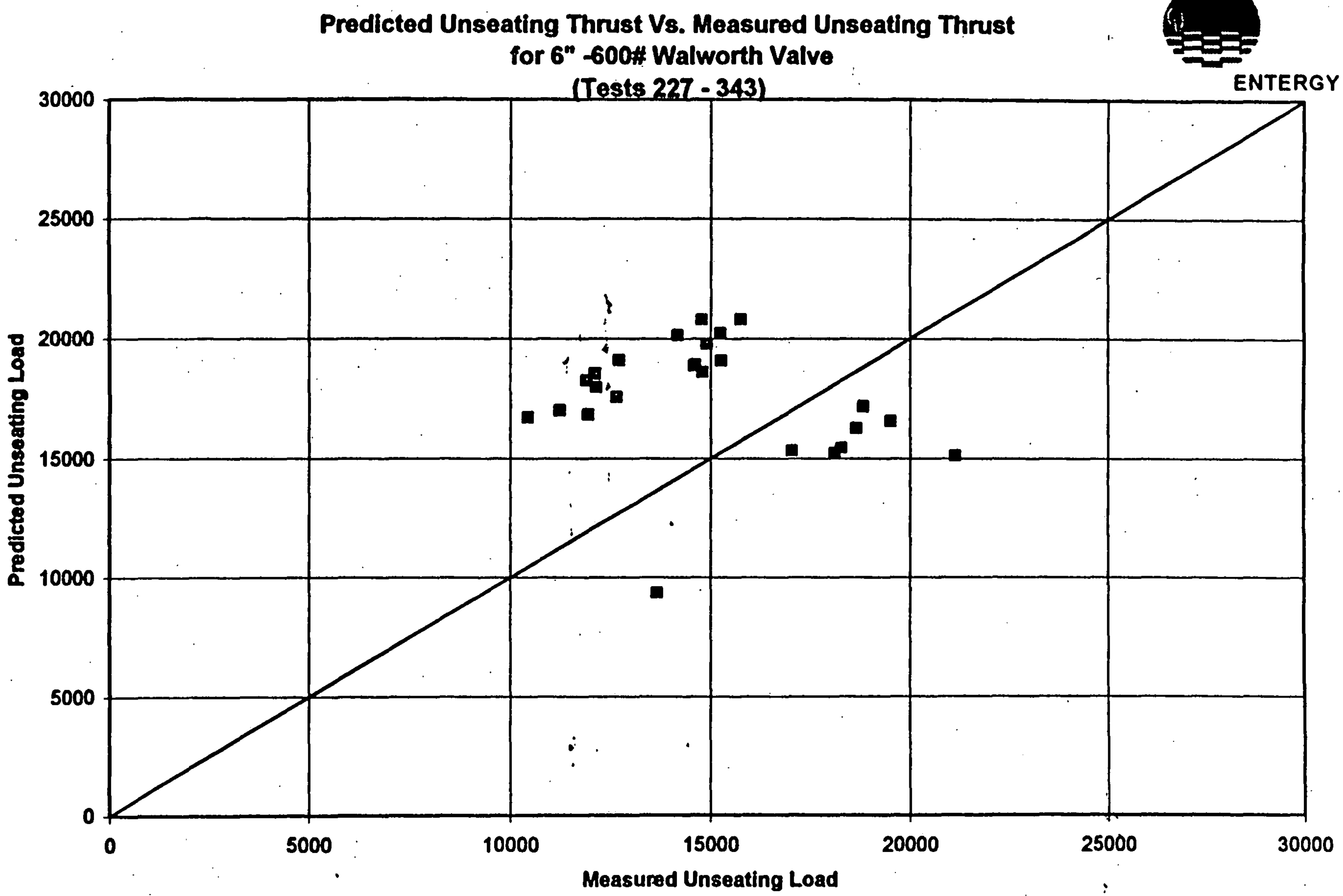
Predicted Unseating Thrust Vs. Measured Unseating Thrust
for 10" -900# Crane Valve
Predicted Unseating Load
80000
70000
60000
50000
40000
30000
20000
10000
0
0
10000
20000
30000
40000
50000
60000
70000
80000
Measured Unseating Load

Predicted Unseating Thrust Vs. Measured Unseating Thrust for 4" -1500# Westinghouse Valve

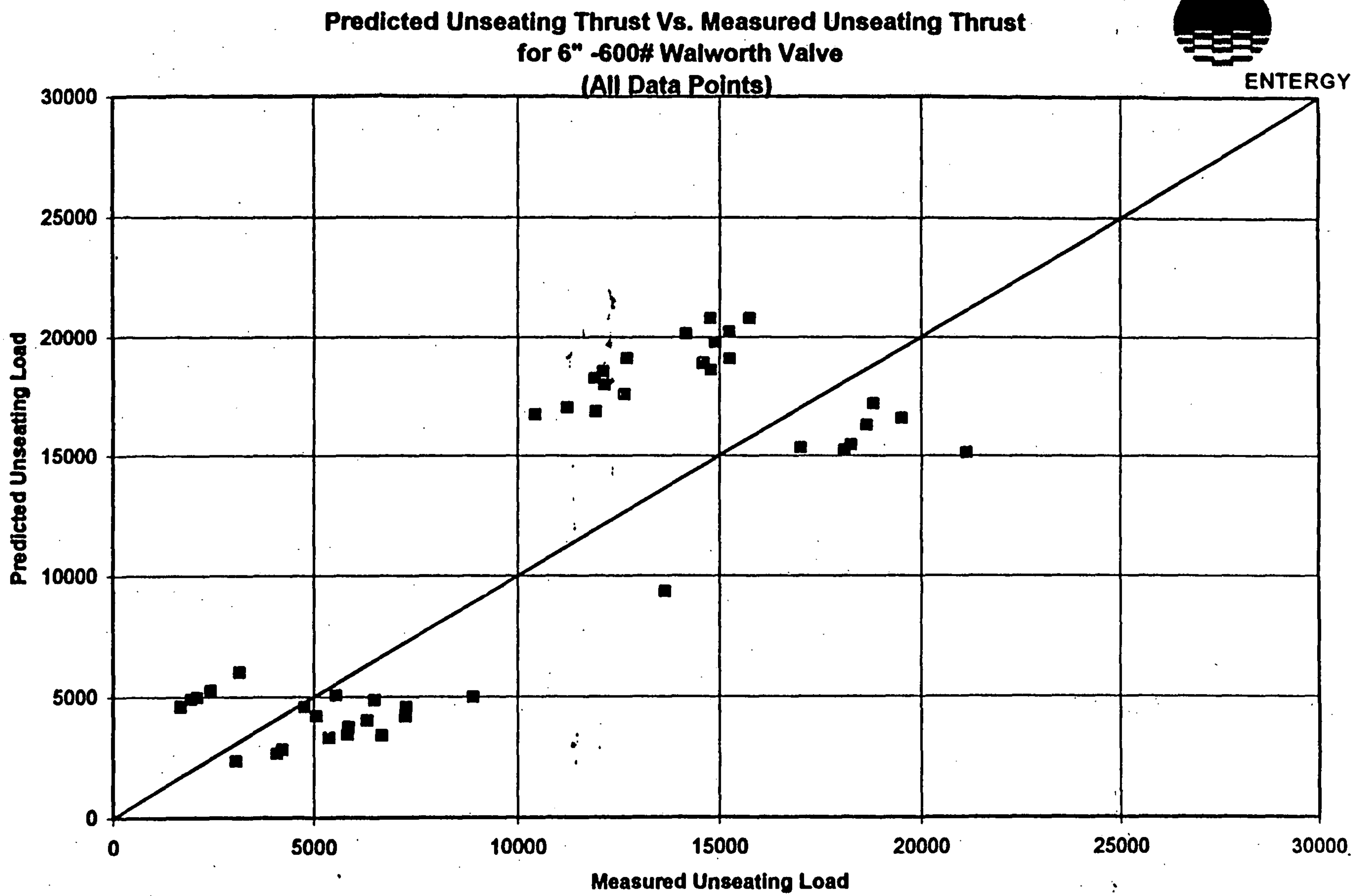


Predicted Unseating Thrust Vs. Measured Unseating Thrust for 10" -300# Borg-Warner Valve

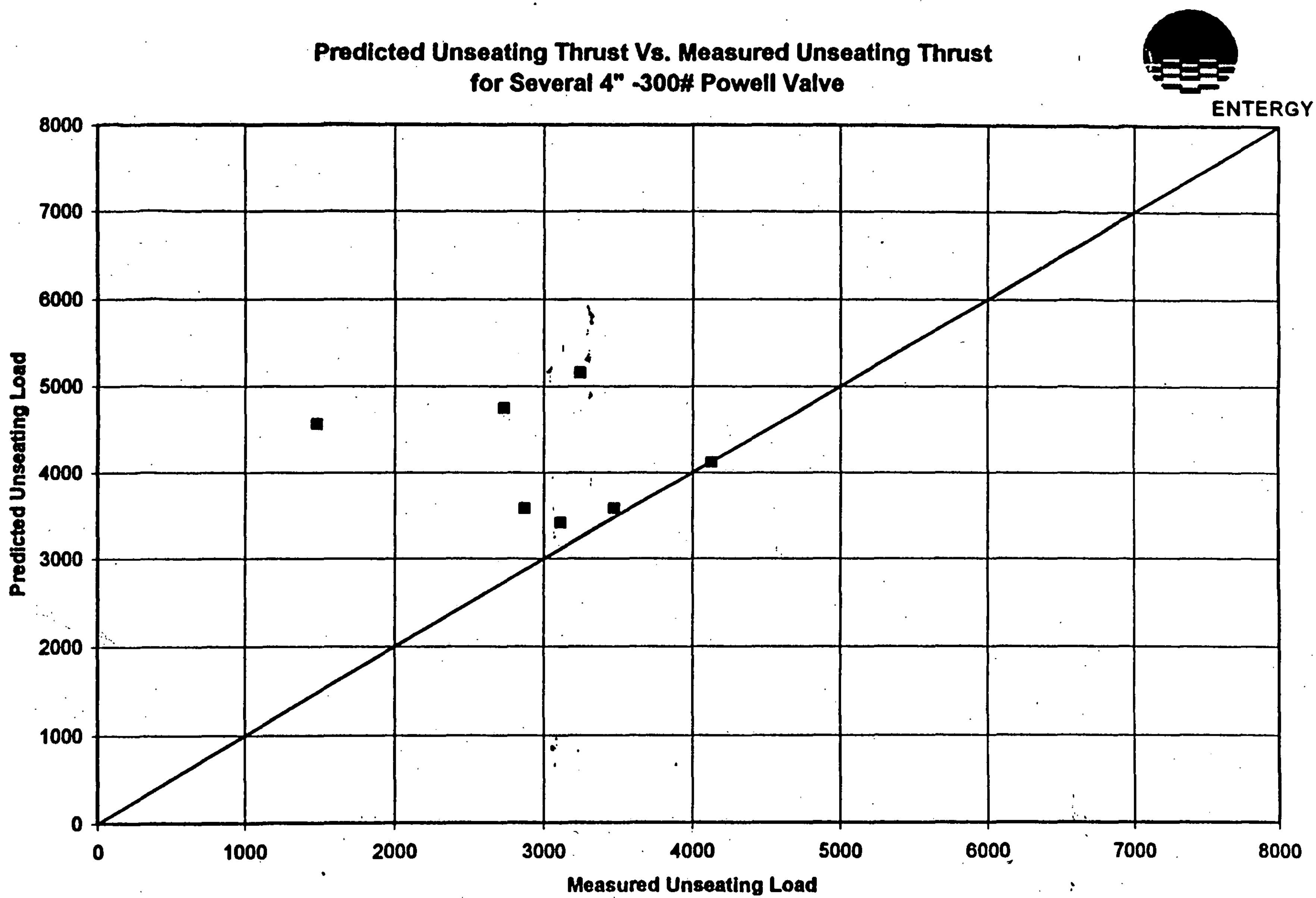




Predicted Unseating Thrust Vs. Measured Unseating Thrust
for 6" -600# Walworth Valve
(Tests 227 - 343)
ENTERGY
30000
25000
20000
15000
10000
5000
0
Predicted Unseating Load
0
5000
10000
15000
20000
25000
30000
Measured Unseating Load

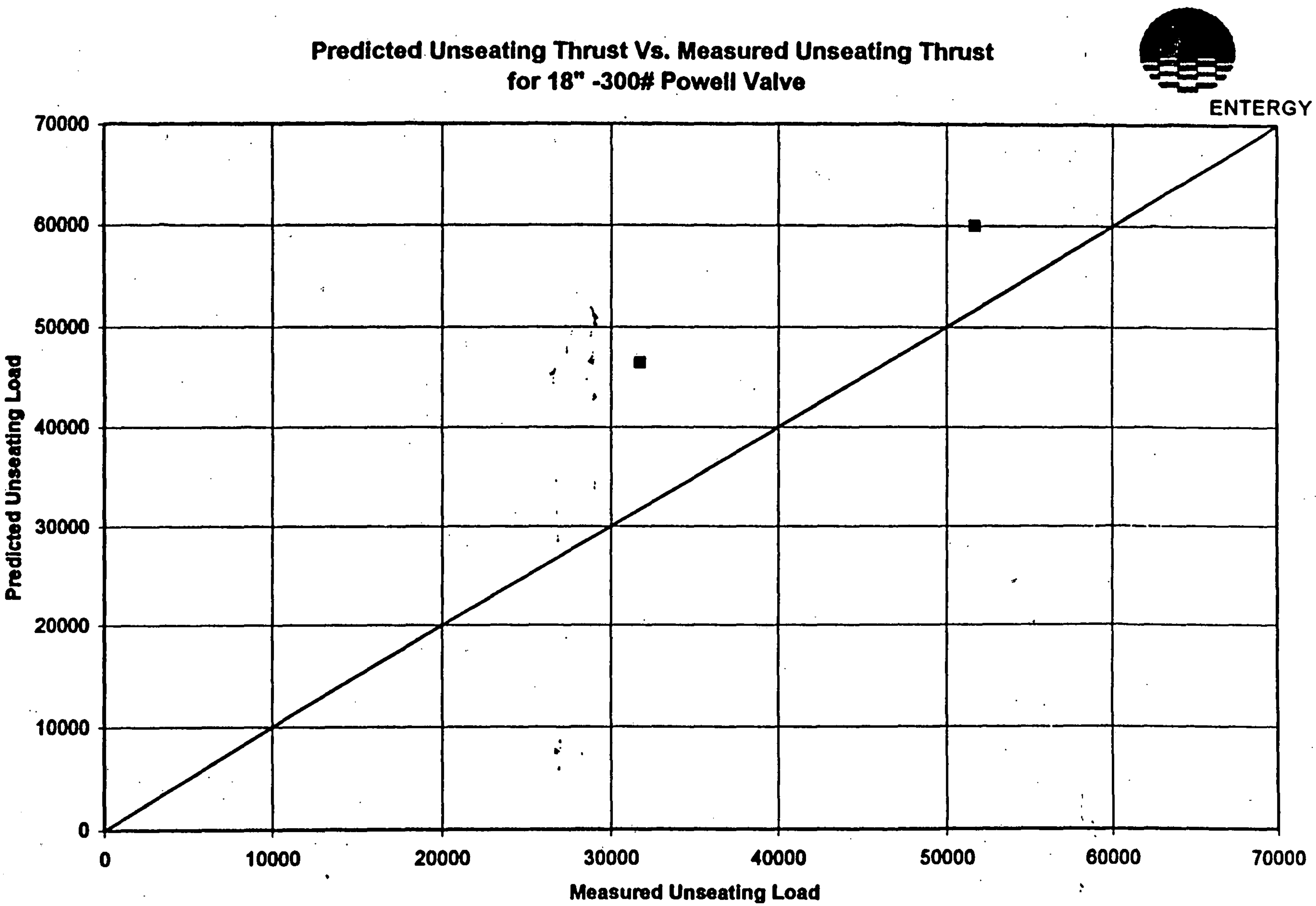


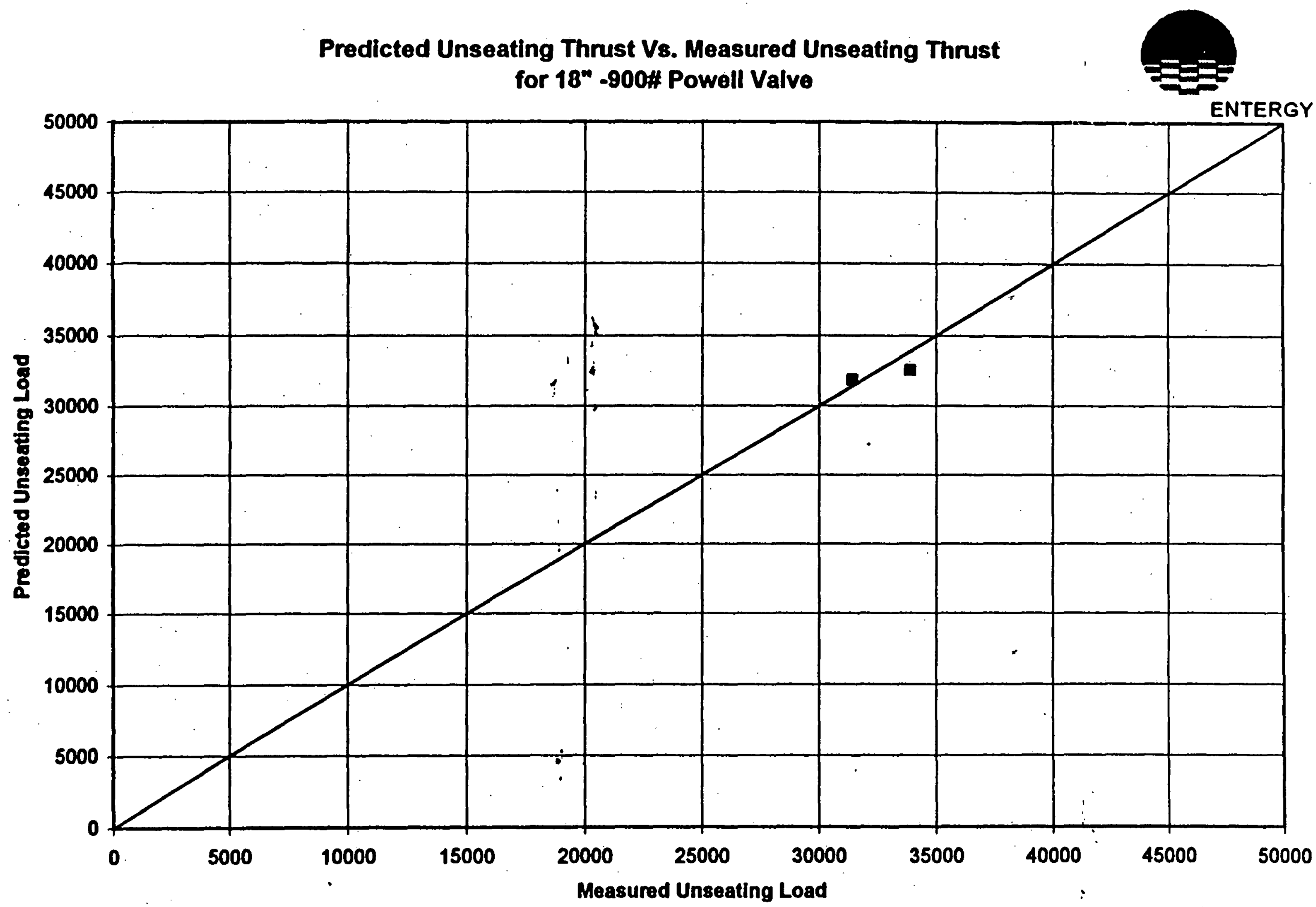
Predicted Unseating Thrust Vs. Measured Unseating Thrust
for 6" -600# Walworth Valve
(All Data Points)
ENTERGY
Predicted Unseating Load
Measured Unseating Load
0
5000
10000
15000
20000
25000
30000



Predicted Unseating Thrust Vs. Measured Unseating Thrust
for Several 4" -300# Powell Valve
ENTERGY
Predicted Unseating Load
Measured Unseating Load
0
1000
2000
3000
4000
5000
6000
7000
8000

Predicted Unseating Thrust Vs. Measured Unseating Thrust for 18" -300# Powell Valve




Predicted Unseating Thrust Vs. Measured Unseating Thrust
for 18" -900# Powell Valve
ENTERGY
Predicted Unseating Load
Measured Unseating Load
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000

What This Means

ENTERGY

- The EOI Pressure Locking Thrust Prediction Methodology provides overall conservative approximations
- Good agreement exists between prediction and measured thrusts for a diverse sample of valve sizes and manufacturers

Next Steps

ENTERGY

- EOI plans additional valve testing under laboratory conditions
- EOI plans to evaluate other pressure locking data, when available
- EOI plans to evaluate other DP data, when available

ComEd PRESSURE LOCKING METHODOLOGY AND TEST PROGRAM

Brian Bunte - Commonwealth Edison

April 9, 1997

U.S. Nuclear Regulatory Commission
Rockville, MD

ATTACHMENT 3

METHODOLOGY TO CALCULATE PRESSURE LOCKING UNSEATING FORCE

Superposition of Static Unseating Forces and Pressure Forces

- Static Unseating Force
- Piston Effect
- Vertical Downward DP Force on Disk
- Pressure Locking Load

Static Unseating Force

The unseating thrust measured during static testing consists of:

- **The thrust required to overcome open packing load**
- **The force required to overcome the seat to disk contact load.**

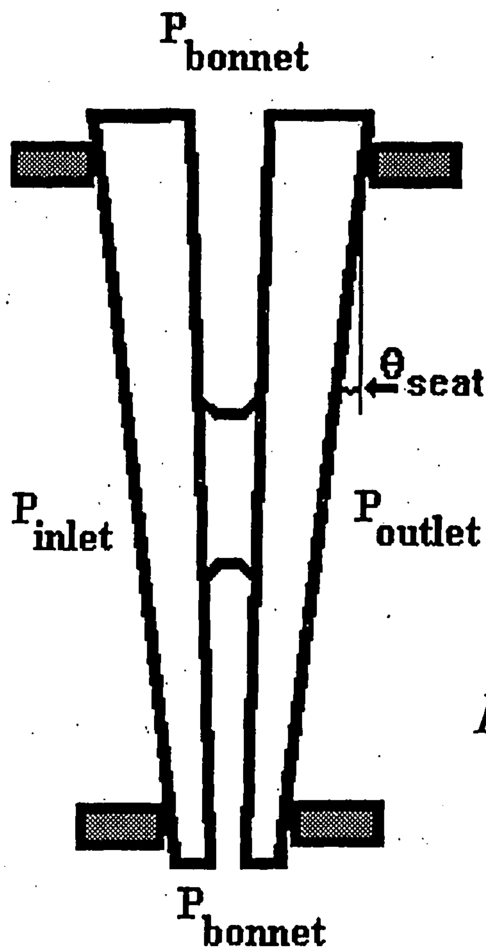
These same loads still exist when the valve is unseated under pressure locking conditions.

Piston Effect

- The difference between the bonnet pressure and the ambient pressure outside the valve body results in a stem ejection force (or piston effect). This force is in the direction which assist valve opening. The magnitude of this force is calculated using the equation below:

$$F_{piston\,effect} = \frac{\pi}{4} \times D_{stem}^2 \times \left(P_{bonnet} - P_{atm}\right)$$

Vertical Downward Force on Disk

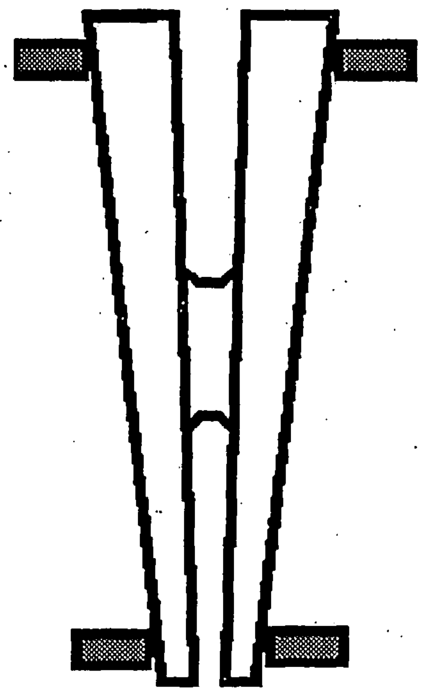


Pressure exerts a downward force on the valve disk. This force is calculated for each side of the disk by multiplying the vertical projected area of the valve disk times the differential pressure across that disk face. The equation below is used:

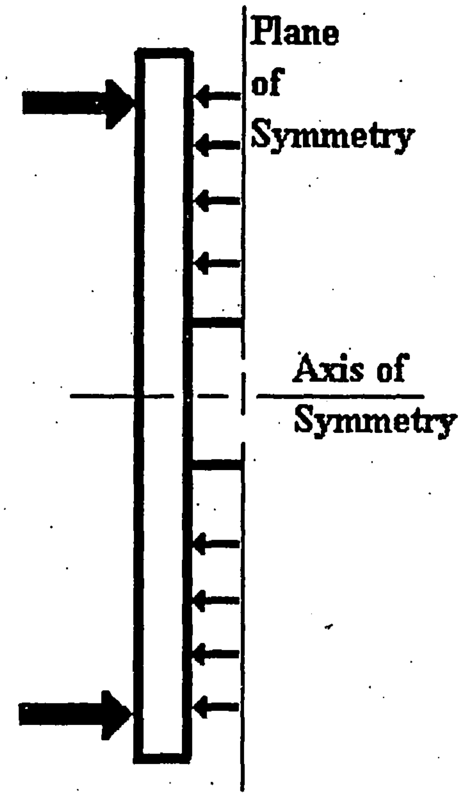
$$F_{vert} = \frac{\pi}{4} \times D_{seat}^2 \times \sin(\theta_{seat}) \times \left[2P_{bonnet} - P_{inlet} - P_{outlet}\right]$$

Pressure Locking Force

- Disk Modeled as Axi-Symmetric Plate with Hub

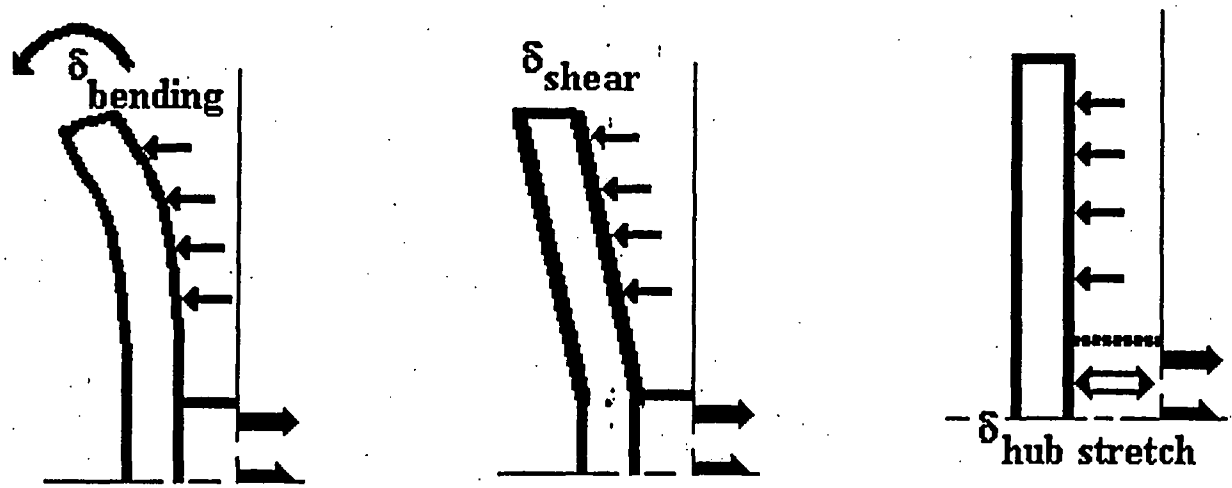


Modeled As:



Pressure Locking Force (continued)

- Roark's Equations Used to Calculate Deflection at Disk Edge Due to Pressure Forces
  - Due to Bending (Table 24, Case 2L)
  - Due to Shear (Table 25, Case 2L)
- Deflection from Hub Stretch is also Calculated
- Deflections are summed using superposition



Pressure Locking Force (continued)

- Roark's Equations Used to Calculate the Deflection Due to Edge Contact Load Between the Seat and Disk
  - Edge Contact Load and Bending (Table 24, Case 1L)
  - Edge Contact Load and Shear Stress (Table 25, Case 1L)
- Deflection from Hub Compression is also Calculated
- The edge contact load has units of lbf/in
- The total deflection <u>per unit contact load</u> is calculated using superposition
- The contact load is then calculated by dividing the total deflection due to pressure forces by the deflection per unit contact load due to edge loading.

Pressure Locking Force (continued)

- **The Pressure Locking Force is Calculated using the Equation Below:**

$$F_{seat\ contact}^{total}(lbf) = \pi \times D_{seat} \times F_{contact\ load}(lbf/in)$$

$$F_{pres\ lock} = 2 \times F_{seat\ contoct}^{total} \times \left[mu_{seat} \times \cos(\theta_{seat}) - \sin(\theta_{seat}) \right]$$

List of Inputs Used in Pressure Locking Calculation

- Design Basis Pressure Conditions
- Valve Disk Geometry
- Valve Disk Material Properties
- Valve Stem Diameter
- Static Unseating Thrust
- Coefficient of Friction between Disk and Seat

Baselining Pressure Locking Methodology
EPRI Valve 24 (6" Velan FW Gate Valve)

Calculation of Pressure Locking Unseating Thrust
(excerpt from MathCad calculation)

$F_{po} = 2.636 \cdot 10^{4} \cdot lbf$ (static unseating thrust)

$F_{s} = 1.969 \cdot 10^{4} \cdot lbf$ (total contact load between disk and seats due to pressure)

$F_{piston} := \frac{\pi}{4} \cdot D_{stem}{}^{2} \cdot P_{bonnet}$ $F_{piston} = 3.367 \cdot 10^{3} \cdot lbf$

$F_{vert} := \pi \cdot a^{2} \cdot \sin(theta) \cdot \left(2 \cdot P_{bonnet} - P_{up} - P_{down}\right)$ $F_{vert} = 7.583 \cdot 10^{3} \cdot lbf$

$F_{preslock} := 2 \cdot F_{s} \cdot (mu \cdot \cos(theta) - \sin(theta))$ $F_{preslock} = 1.74 \cdot 10^{4} \cdot lb$

$F_{total} := -F_{piston} + F_{vert} + F_{preslock} + F_{po}$

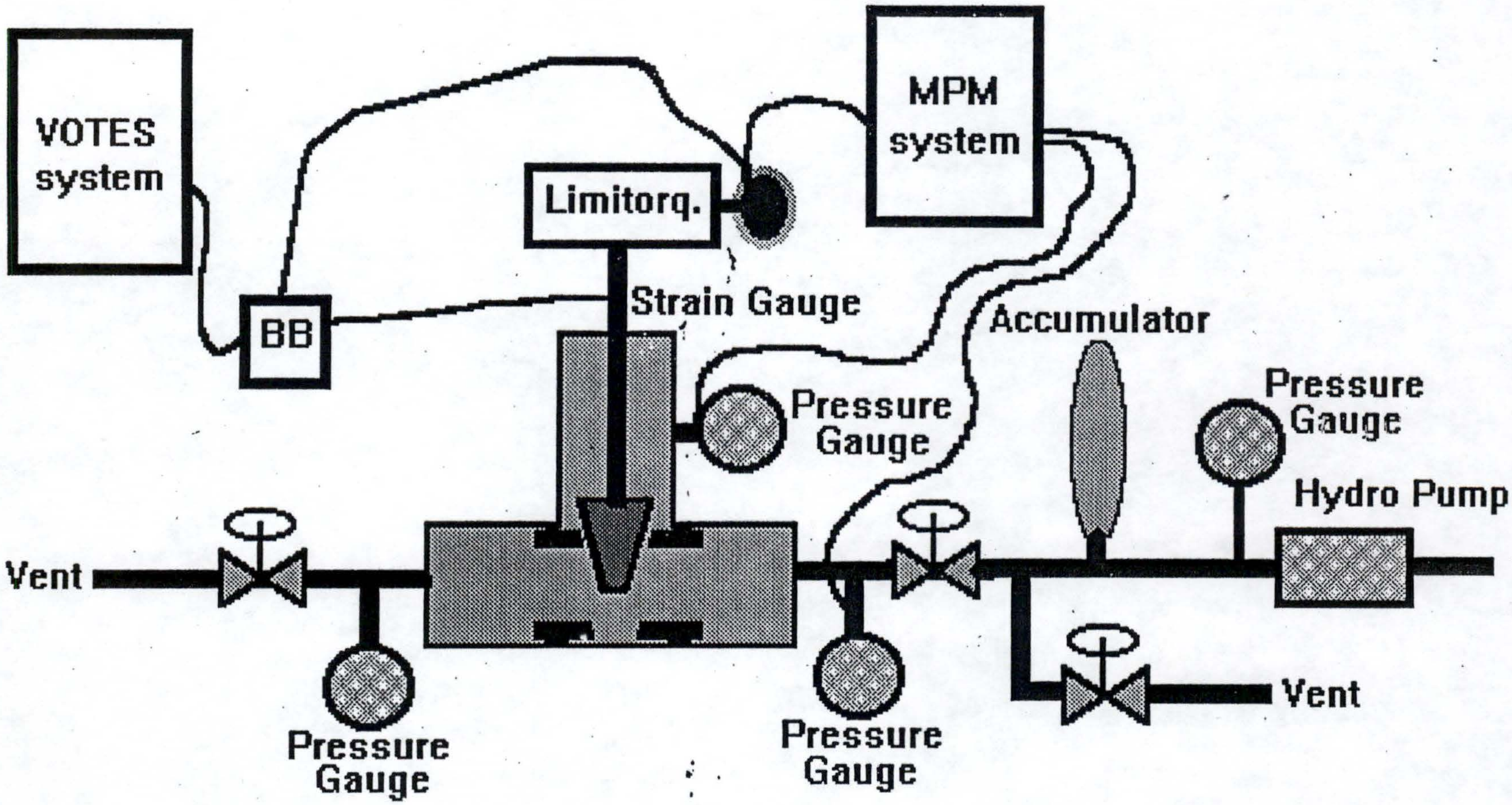
$F_{total} = 4.797 \cdot 10^{4} \cdot lbf$ Result is within 1% of measured pressure locking force of 48,272 lbf.

ComEd TEST PROGRAM FOR VALIDATION OF PRESSURE LOCKING MODEL

Overview of Test Results

- **Crane 10" 900# Class Gate Valve**
  - Pressure Locking Loads Predictable
- **Westinghouse 4" 1500# Class Gate Valve**
  - Pressure Locking Loads Predictable
- **Borg-Warner 10" 300# Class Gate Valve**
  - Pressure Locking Load Anomaly Identified, Pressure Locking Load was otherwise predictable
- **Walworth 6" 900# Class Gate Valve (INEL Test Data)**
  - Pressure Locking Loads Predictable

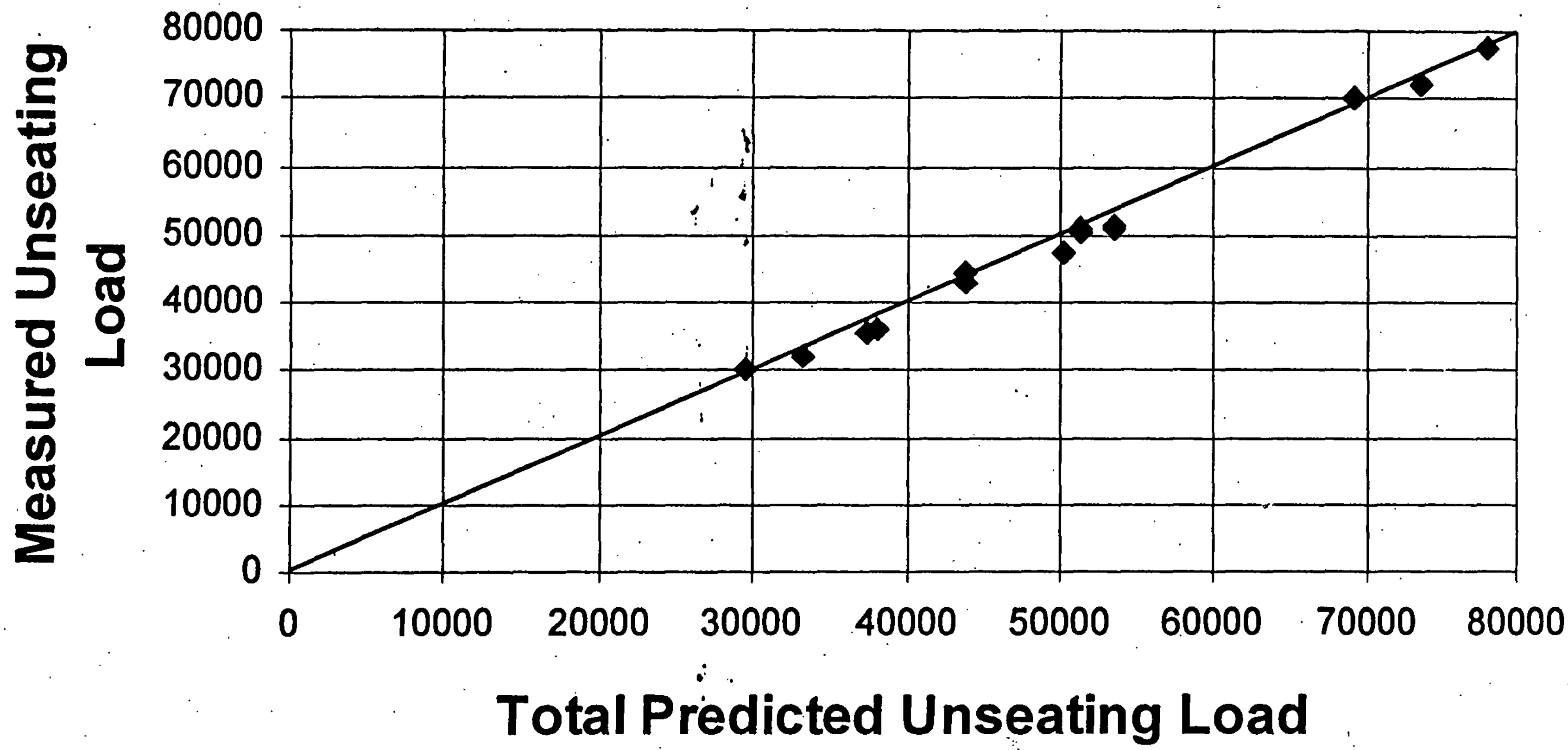
ComEd Test Fixture



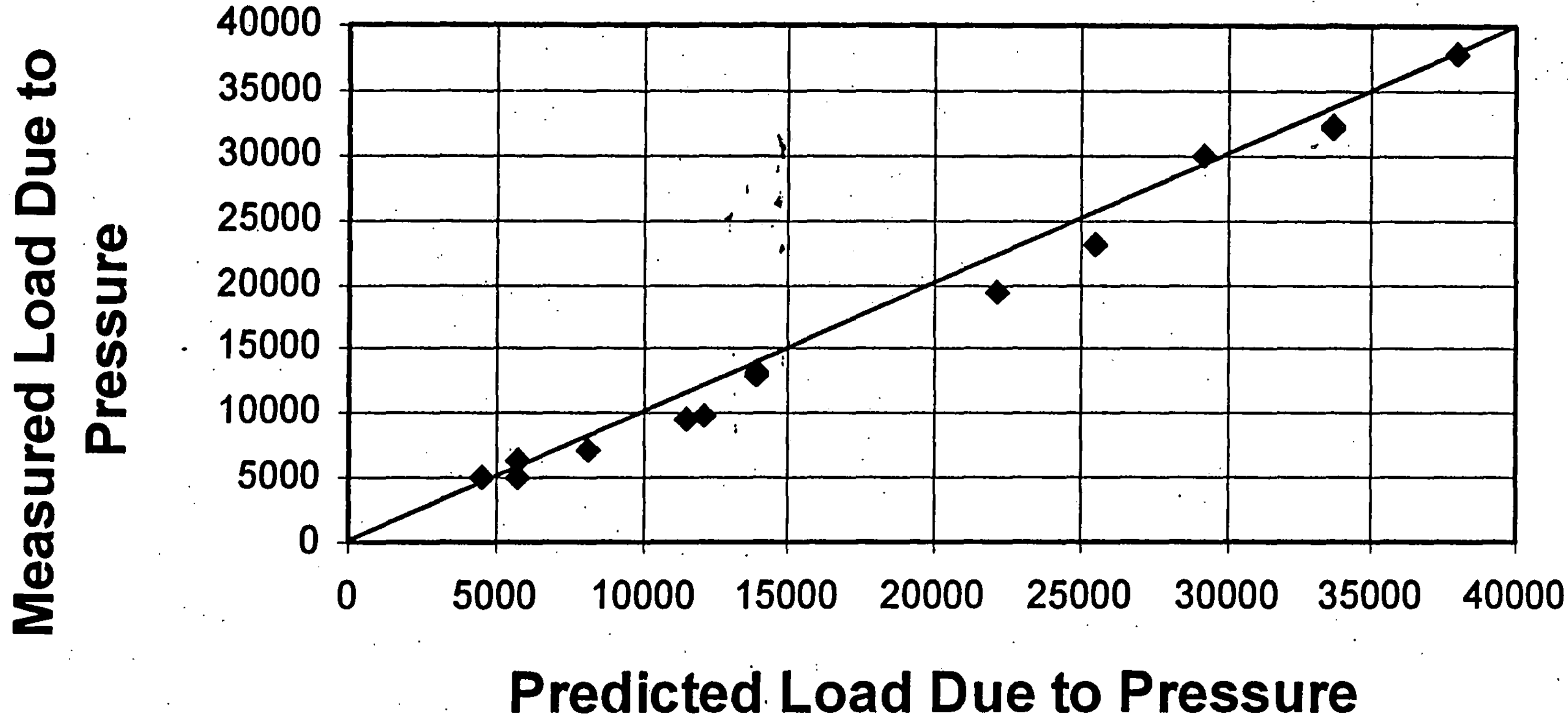
Test Sequence

- Static (Baseline) Tests
- LLRT of Test Valve
- Hydro-Pump DP Tests to determine seat to disk friction coefficient
- Bonnet Pressure Decay Tests
- Alternating Static (Baseline) Tests and Pressure Locking Tests at various bonnet/outlet pressure combinations
- Repeat of Test Sequence at different torque switch setting(s)
- Thermally Induced Bonnet Pressurization Tests
- Thermal Binding Test for Valve Cool Down Effect

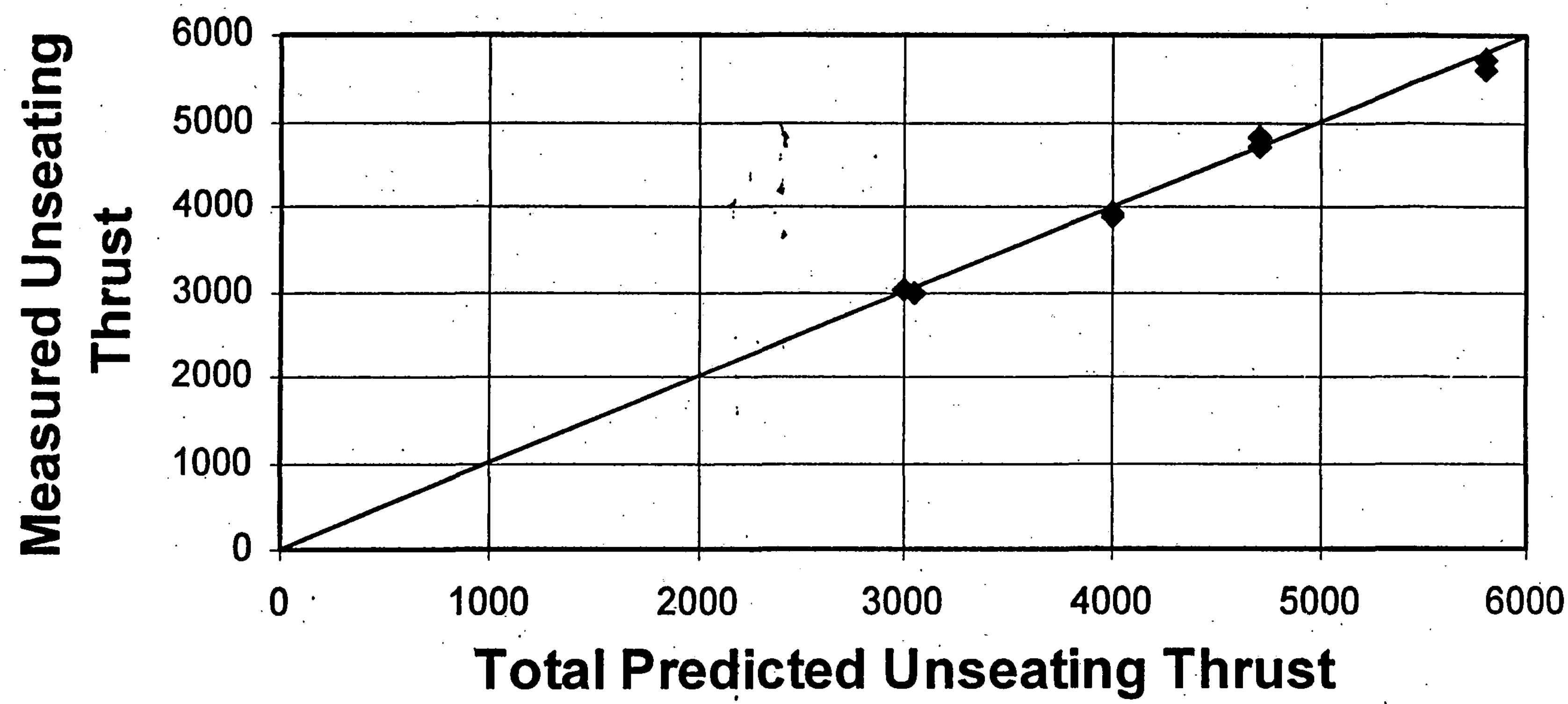
Predicted Unseating Thrust Versus Measured Pressure Locking Unseating Force for Crane Valve



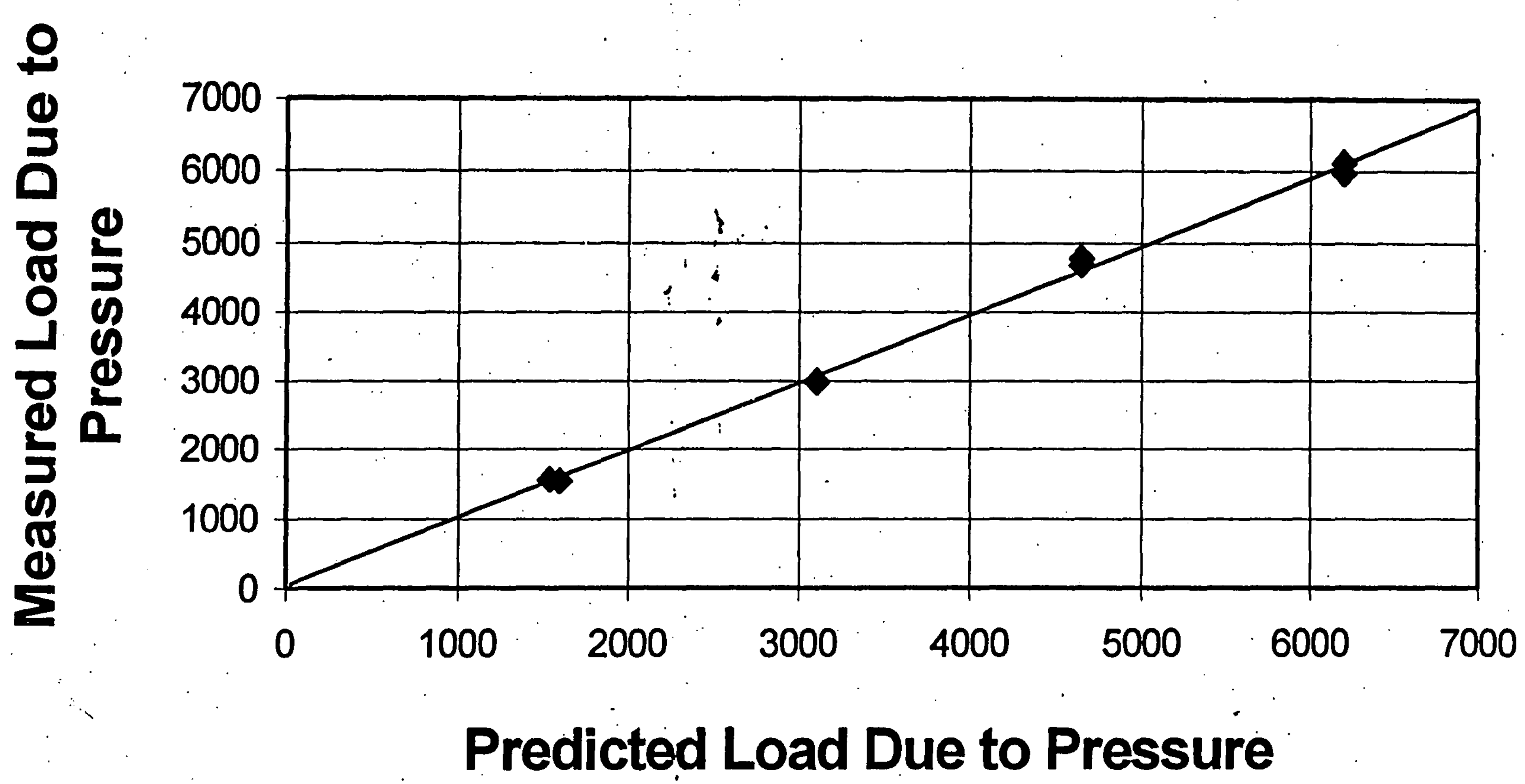
Predicted Versus Measured Portion of Pressure Thrust Due to Pressure Forces for Crane Valve



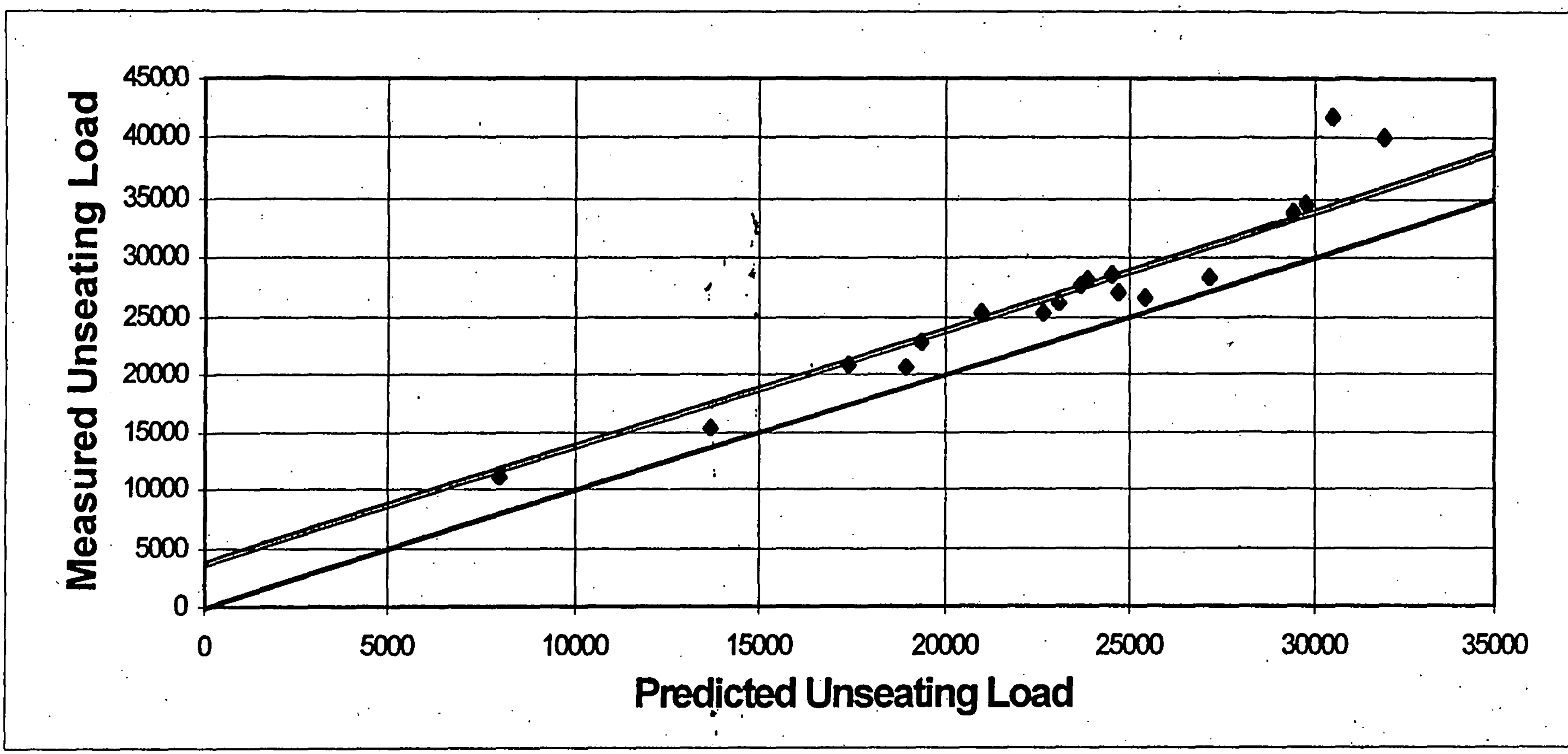
Predicted Unseating Thrust Versus Measured Pressure Locking Unseating Thrust for Westinghouse Valve



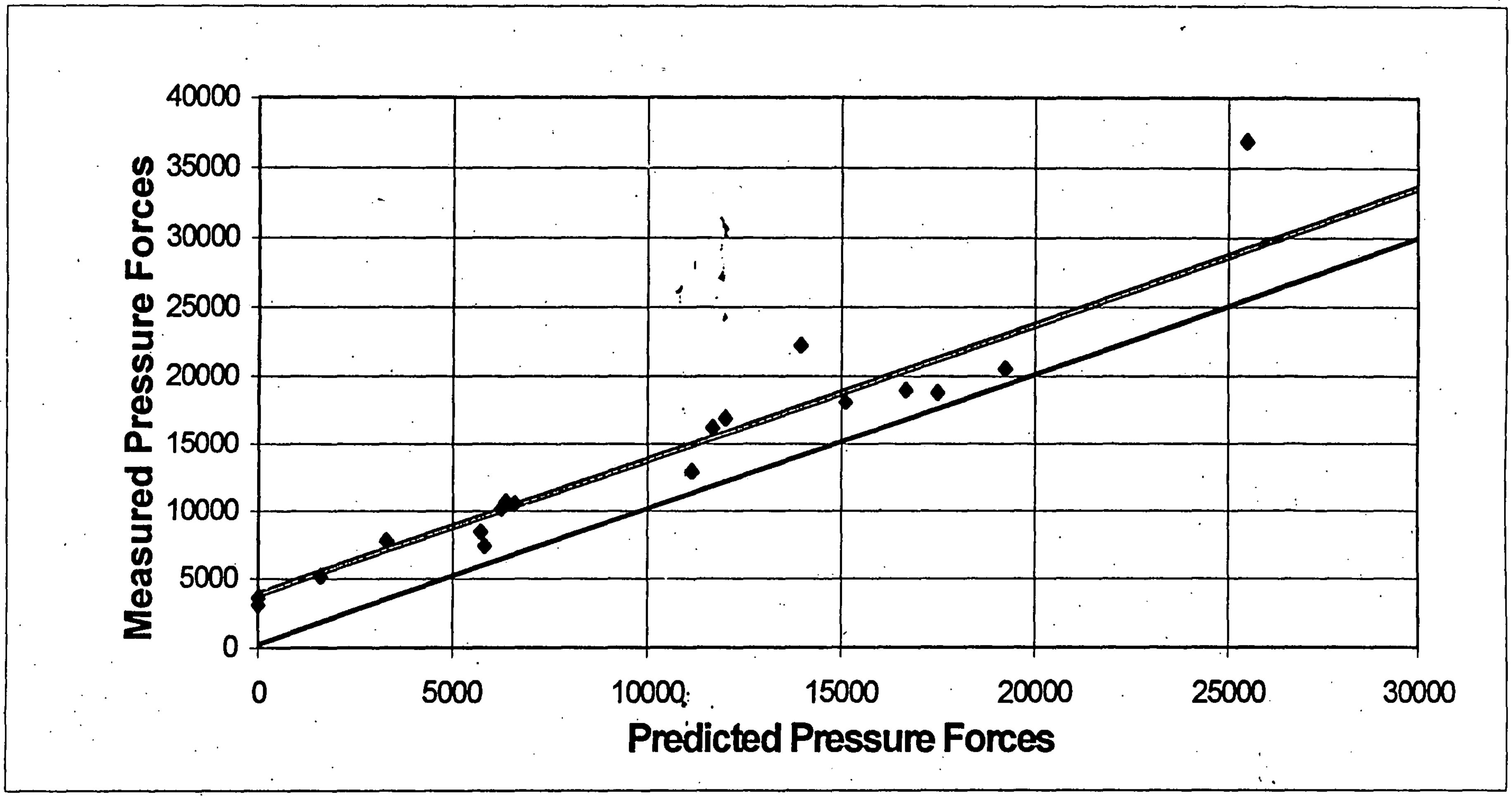
Predicted Versus Measured Portion of Unseating Thrust Due to Pressure Forces for Westinghouse Valve



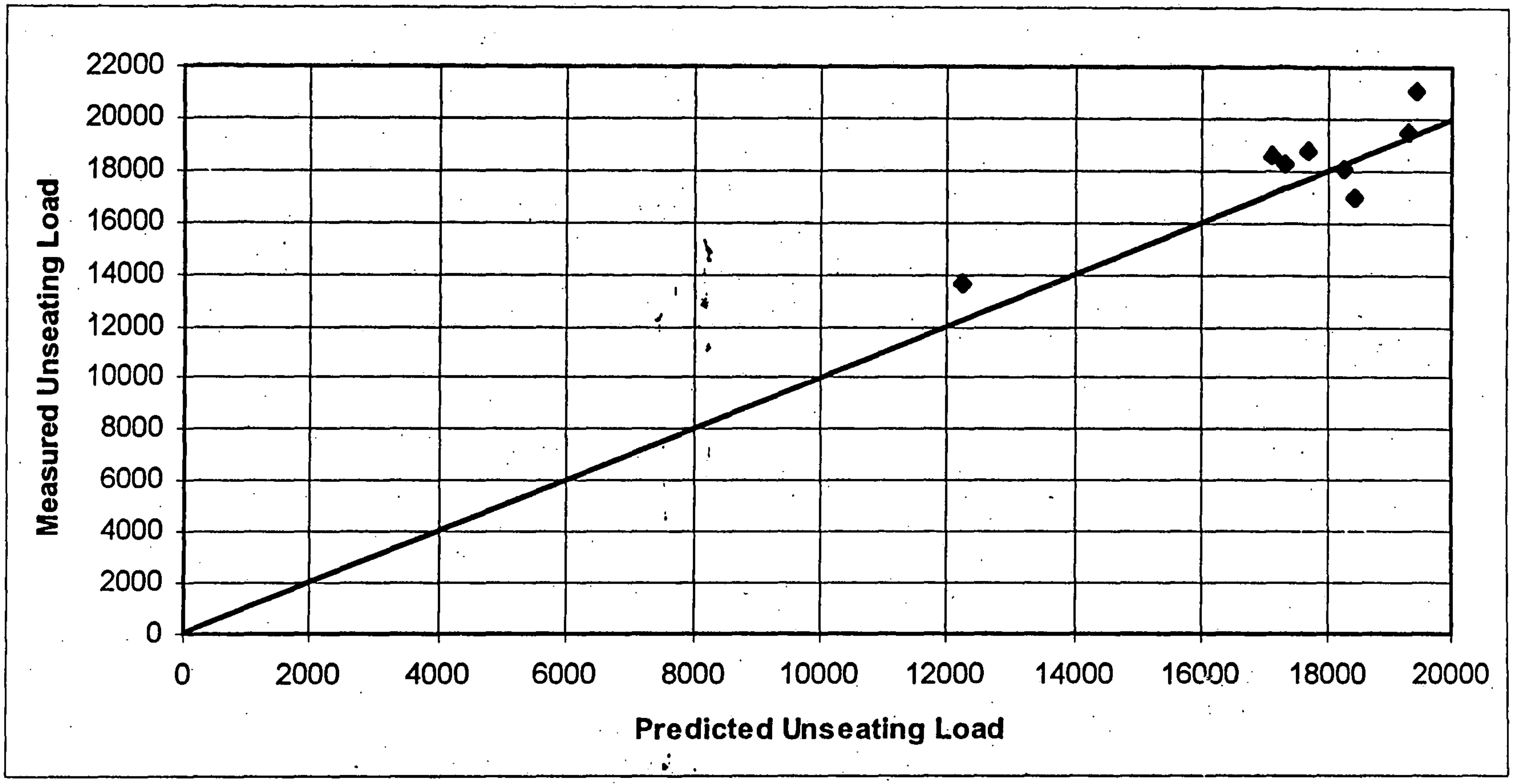
Predicted Unseating Thrust Versus Measured Pressure Locking Unseating Thrust for Borg-Warner Valve



Predicted Versus Measured Portion of Unseating Thrust Due to Pressure Forces for Borg-Warner Valve



Predicted Unseating Thrust Versus Measured Pressure Locking Unseating Thrust for Walworth Valve



Based on initial review of INEL Test Data currently available in NRC Public Document Room

Independent Review and Enhancement of the ComEd Pressure Locking Methodology to Include Disk Pinching Caused by Body Flexibility

Proposal Submitted
for Review and Evaluation to

BWR Owners' Group
Valve Technical Resolution Group

August 7, 1996

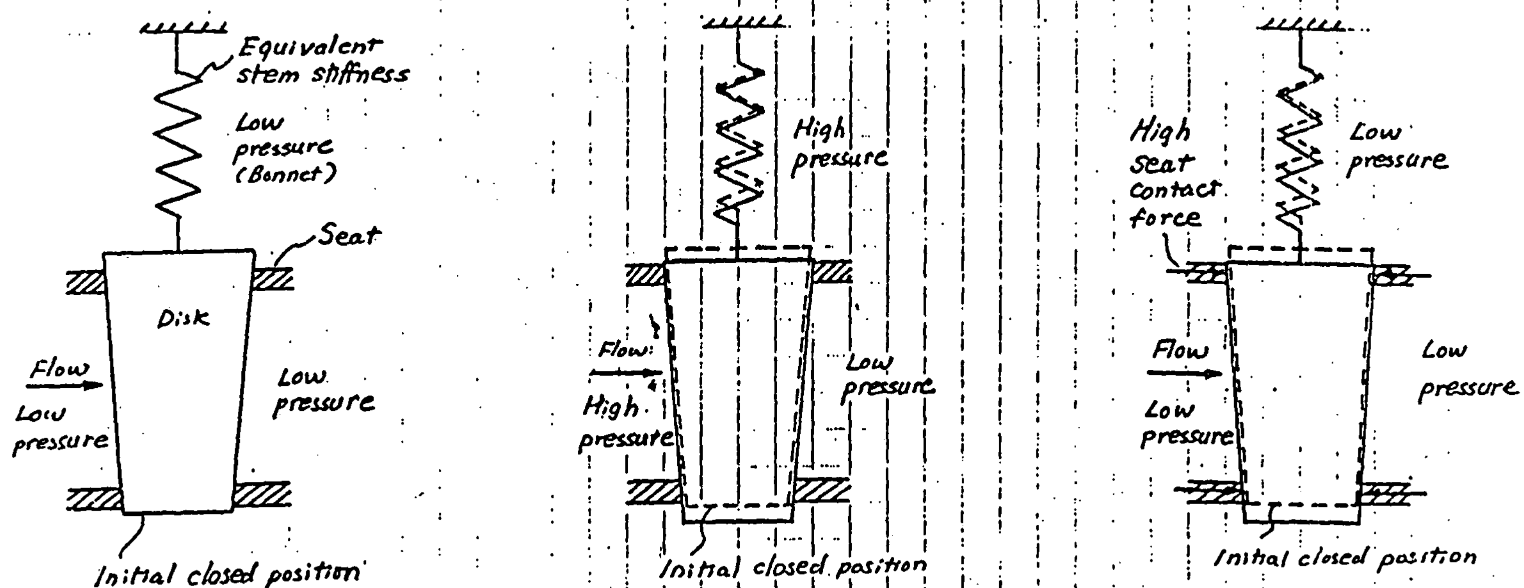
Proposal Submitted by

Kalsi Engineering, Inc.

ATTACHMENT 4

Case History of a Recent Severe Binding Problem & Its Root Cause

Utility:	*NUSCO*
System and Valves:	*Shutdown Cooling System Valves 1-SD-2A/2B*
Valve Type:	*Solid Wedge Gate*
Size/Pressure:	*12", Class 600*
Manufacturer:	*Crane Chapman*
Design ΔP (for Valve Operation):	*150 PSI (appx)*
Maximum Upstream Pressure:	*1,050 PSI (appx)*
Temperature:	*From Ambient to 350°F*



- Valve closed at low pressure
- Stem strained under max. thrust

- High upstream and bonnet pressure at full power due to leakage of upstream valve
- High pressure caused seat faces to move apart
- Disk wedged further from strained stem

- Upstream and bonnet pressures returned to original low level.
- Body tried to return to its original shape
- further wedged disk prevent seat faces from moving back, resulted in high disk binding force.

Pressure-Induced Disc Pinching Effect

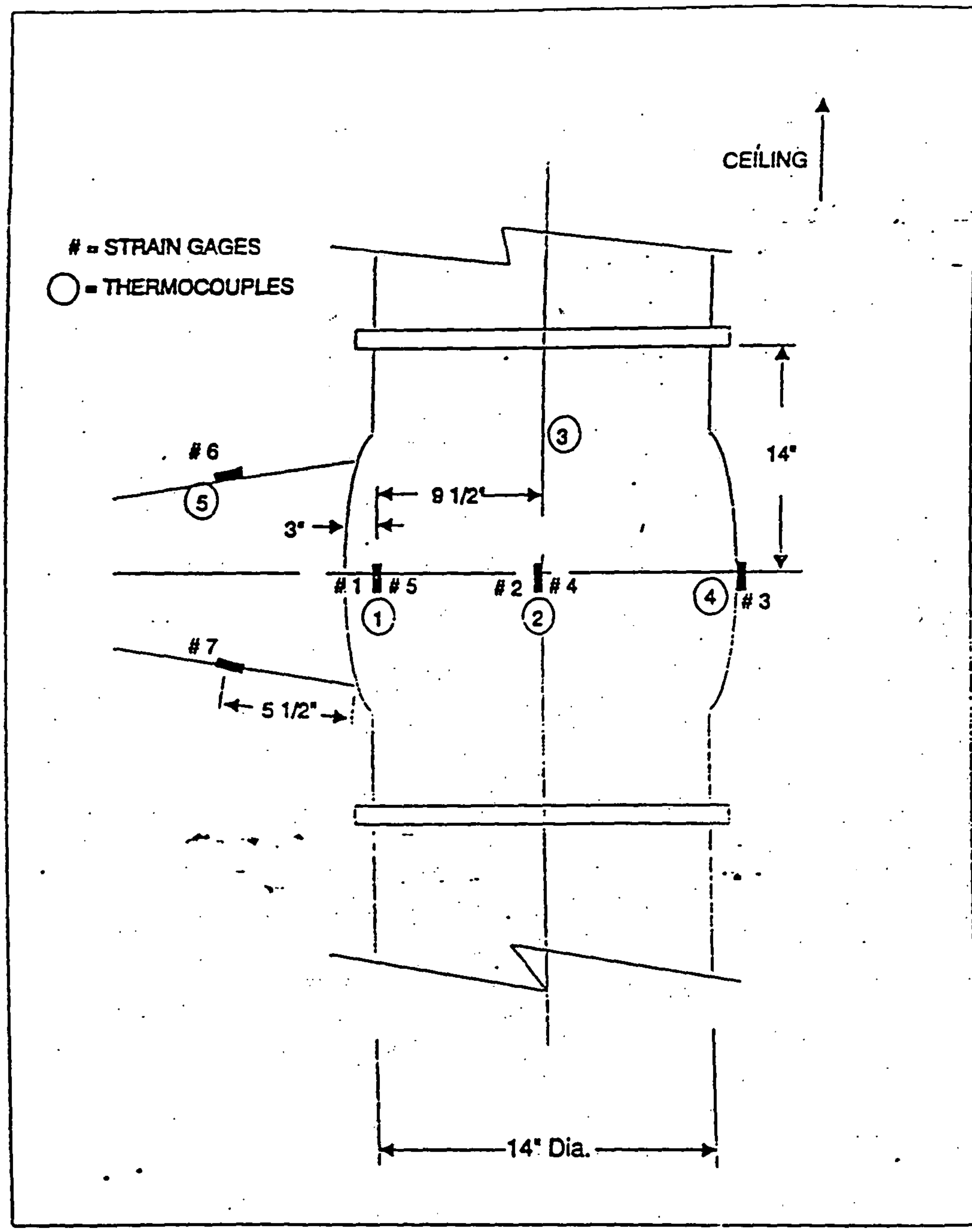


Figure C.1b - Location of Thermocouples/Strain Gages for 1-SD-2B

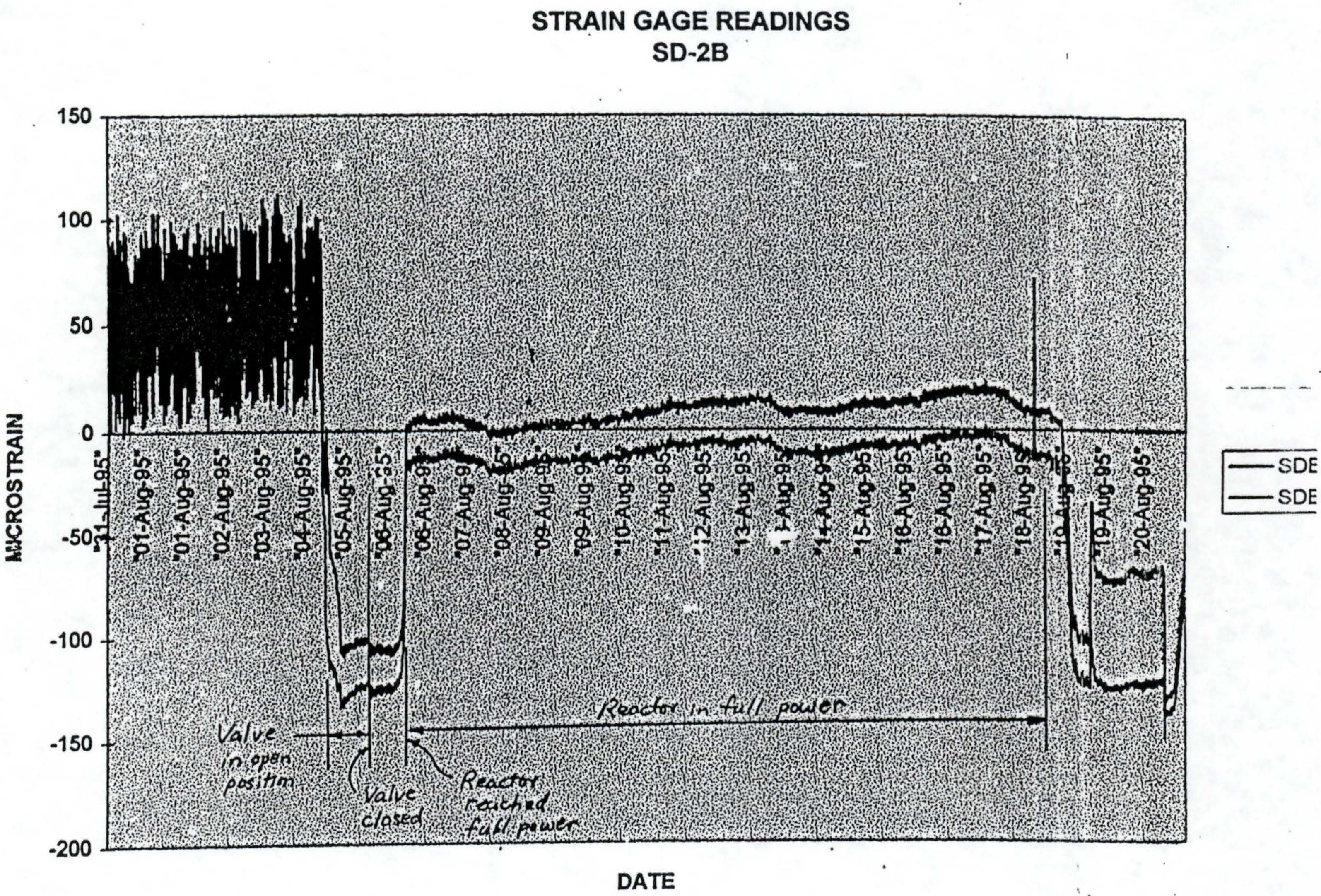


Figure 4
Body Strain Gage (#1) Readings for Valve 1-SD-2B from July 31 to August 20, 1995

KALSI ENGINEERING, INC.
MECHANICAL DESIGN & ANALYSIS

STRAIN GAGE READINGS
SD-2B

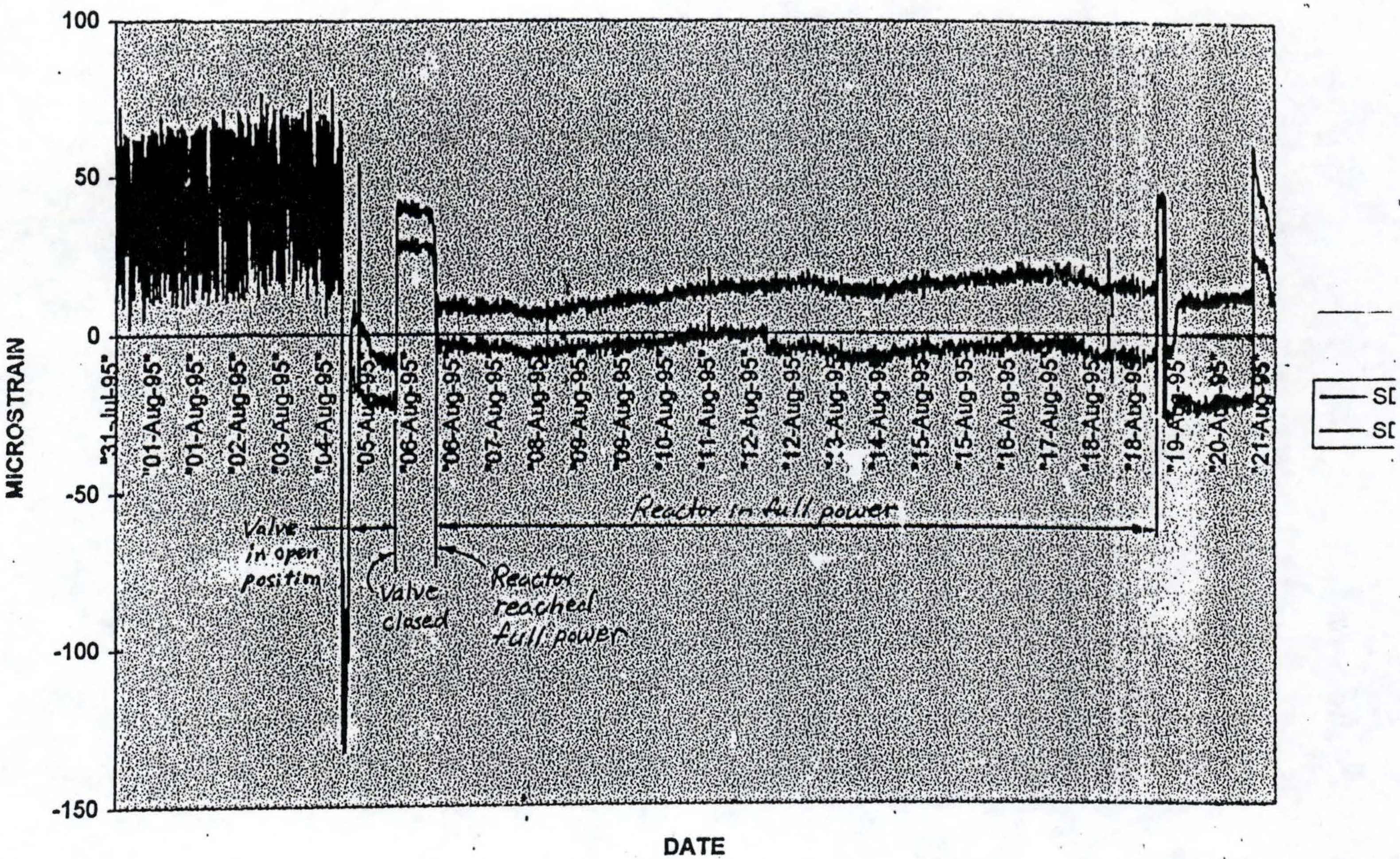


Figure 5
Yoke Strain Gage (#6) Readings for Valve 1-SD-2B from July 31 to August 20, 1995

Review of
ComEd Pressure Locking Methodology and Test Data

ComEd Methodology

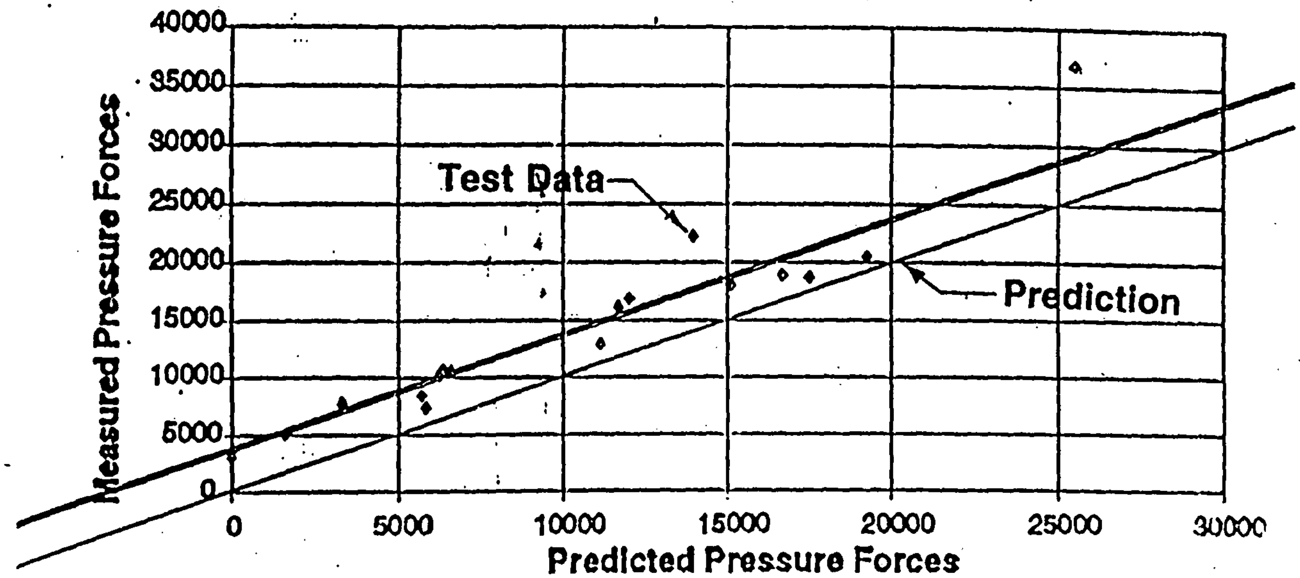
- Disc flexibilities under seat load and differential pressure were considered using Roark's equations. Valve body and seats were assumed to be rigid.
- Seat contact force was calculated to determine PL force.
- Total opening thrust is the sum of four components:
  - PL force,
  - Downward pressure load on disc due to bonnet pressure over disc projected areas,
  - Stem piston effect force (negative), and
  - Static unseating force (including stem packing friction and disc weight).

Test Data

- ComEd performed PL tests on three valves:
  - Crane 10" x 900# flex wedge gate valve,
  - Westinghouse 4" x 1500# flex wedge gate valve, and
  - Borg-Warner 10" x 600# flex wedge gate valve.
- Sequence of pressurization was different on each valve:
  - Crane: bonnet pressurized through upstream,
  - Westinghouse: valve pressurized before closing
  - Borg-Warner: bonnet pressurized through upstream for majority of cases (with 2 exceptions)
- ComEd PL methodology predictions showed good agreement with test results for Crane and Westinghouse valves. Predictions were unconservative for Borg-Warner Valve.

GRAPH 6

Predicted Versus Measured Portion of Unseating Thrust Due to Pressure Forces for Borg-Warner Valve



- **Errors in ComEd's Prediction vs. Test Results for Valve 3 as high as 60%**
- **Predictions unconservative**

Enhancement of ComEd Pressure Locking Methodology

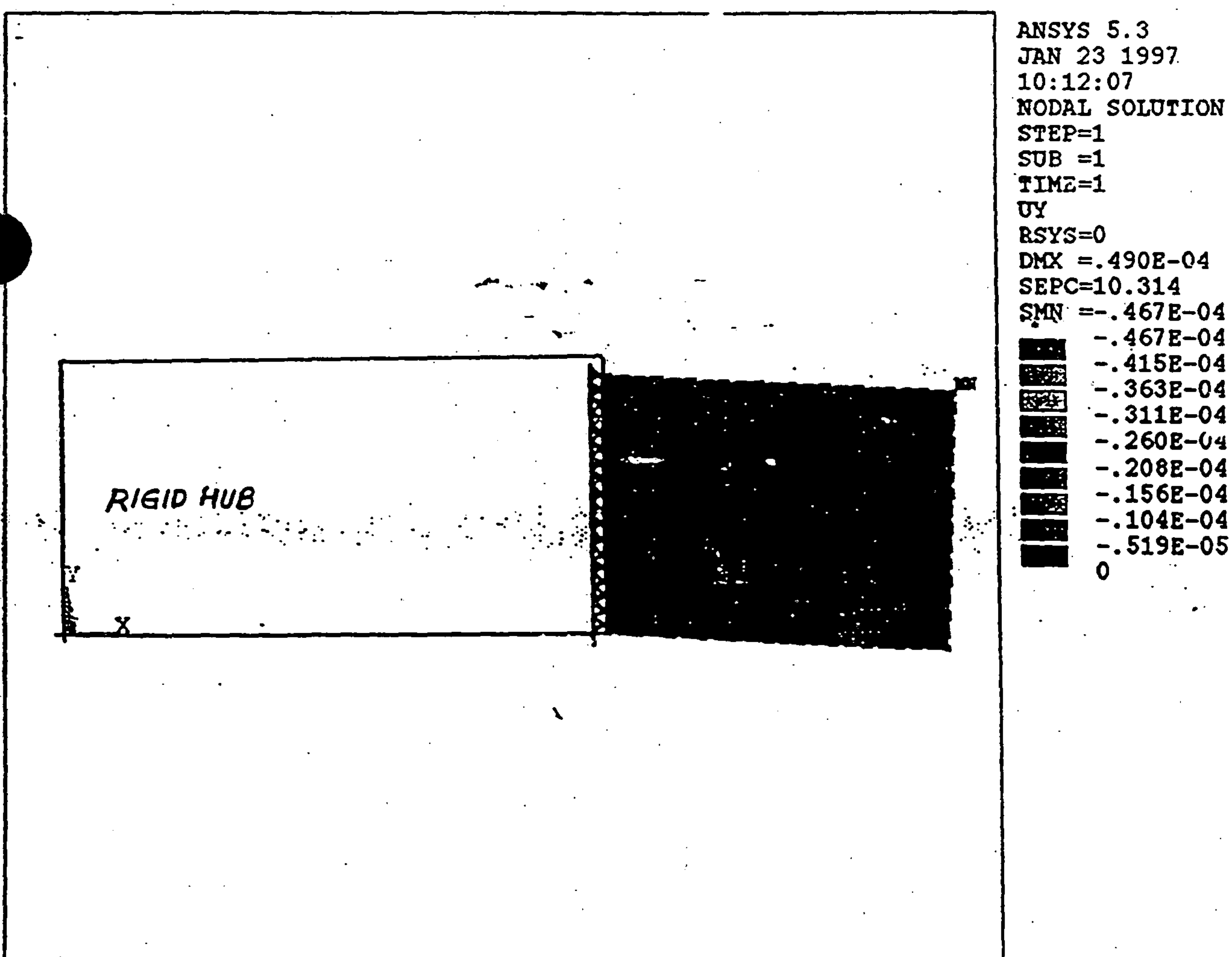
- Developed general force equilibrium equations that can be applied to different sequences of operation
- Accounted for sequence of operation
- Included body and seat flexibilities
- Included stem and yoke flexibilities
- Refined disc flexibility estimate

General Force Equilibrium Equations

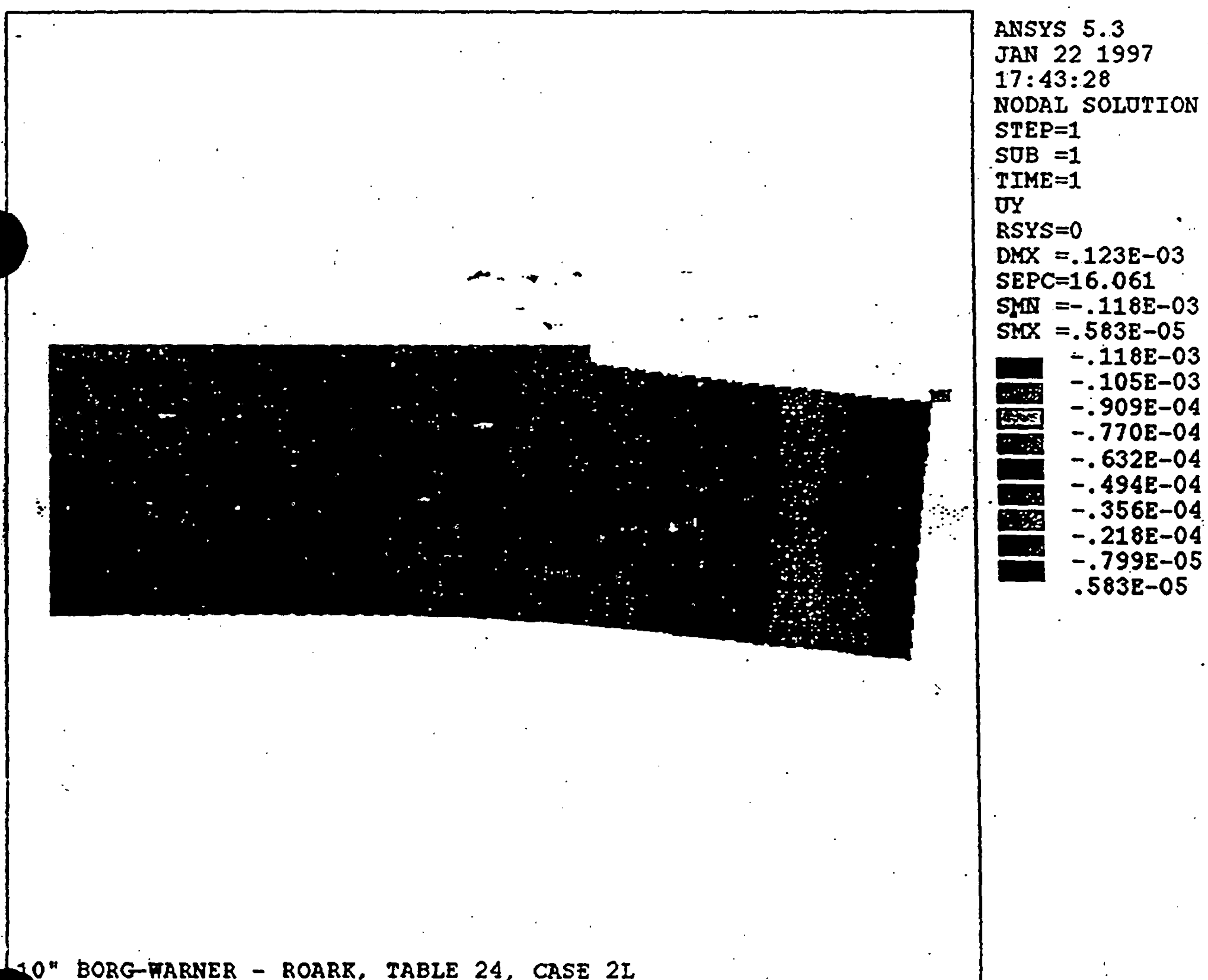
- Static wedging/unwedging equations
- General disc force equilibrium equations applicable to different sequences of operation
- Opening thrust equations

Disc Flexibility

- Roark's equations vs. FEA results
  - FEA model with the same fixed edge at hub O.D.: Results from both methods are close, within 5%.
  - FGA model including hub flexibility: Hub flexibility contribution is significant (see table of comparison).
- Opening thrust calculations showed that disc flexibility has small effect on the predicted thrust using ComEd PL methodology. Because the change in stiffness affects both disk deflections due to pressure and seat load.
- Roark's disc flexibility estimate can be improved using a reduced hub diameter to account for the hub elasticity.



10" BORG-WARNER - ROARK, TABLE 24, CASE 2L (RIGID HUB)


ANSYS 5.3
JAN 22 1997
17:43:28
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
UY
RSYS=0
DMX =.123E-03
SEPC=16.061
SMN =-.118E-03
SMX =.583E-05
-.118E-03
-.105E-03
-.909E-04
-.770E-04
-.632E-04
-.494E-04
-.356E-04
-.218E-04
-.799E-05
.583E-05
10" BORG-WARNER - ROARK, TABLE 24, CASE 2L

DISK FLEXIBILITY COMPARISON

ROARK'S EQUATIONS VS. FEA RESULTS

for Table 24, Case 1L

	ROARK'S EQUATIONS Deflection *in/(lb/in)*	FEA RESULTS Deflection *in/(lb/in)*	RATIO Roark / FEA
10" x 900# Crane	9.05E-07	1.17E-06	77%
4" x 1500# Westinghouse	2.98E-07	5.28E-07	56%
10" x 600# Borg-Warner	5.69E-07	1.20E-06	47%

Note: Hub flexibility contribution is very small

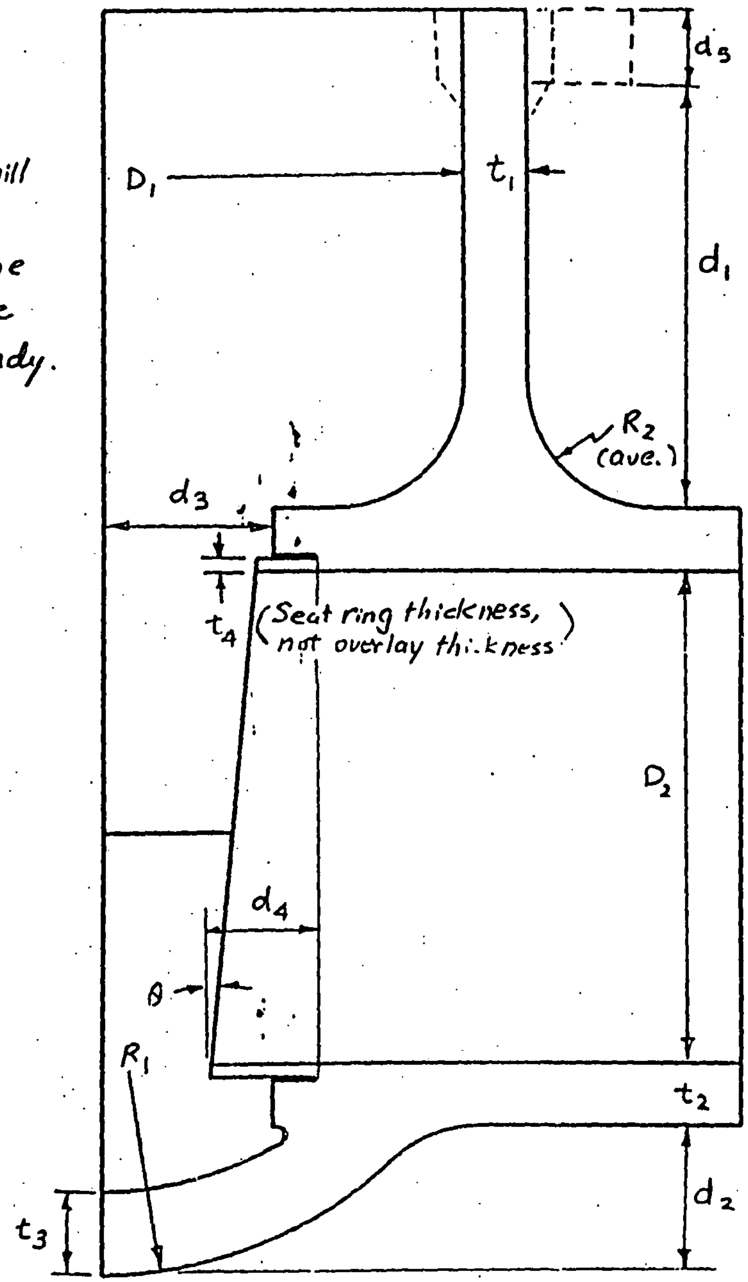
4/?/97 Kalsi ENGINEERING

COMED. PI[illegible]
1/24/97
S. Averitt

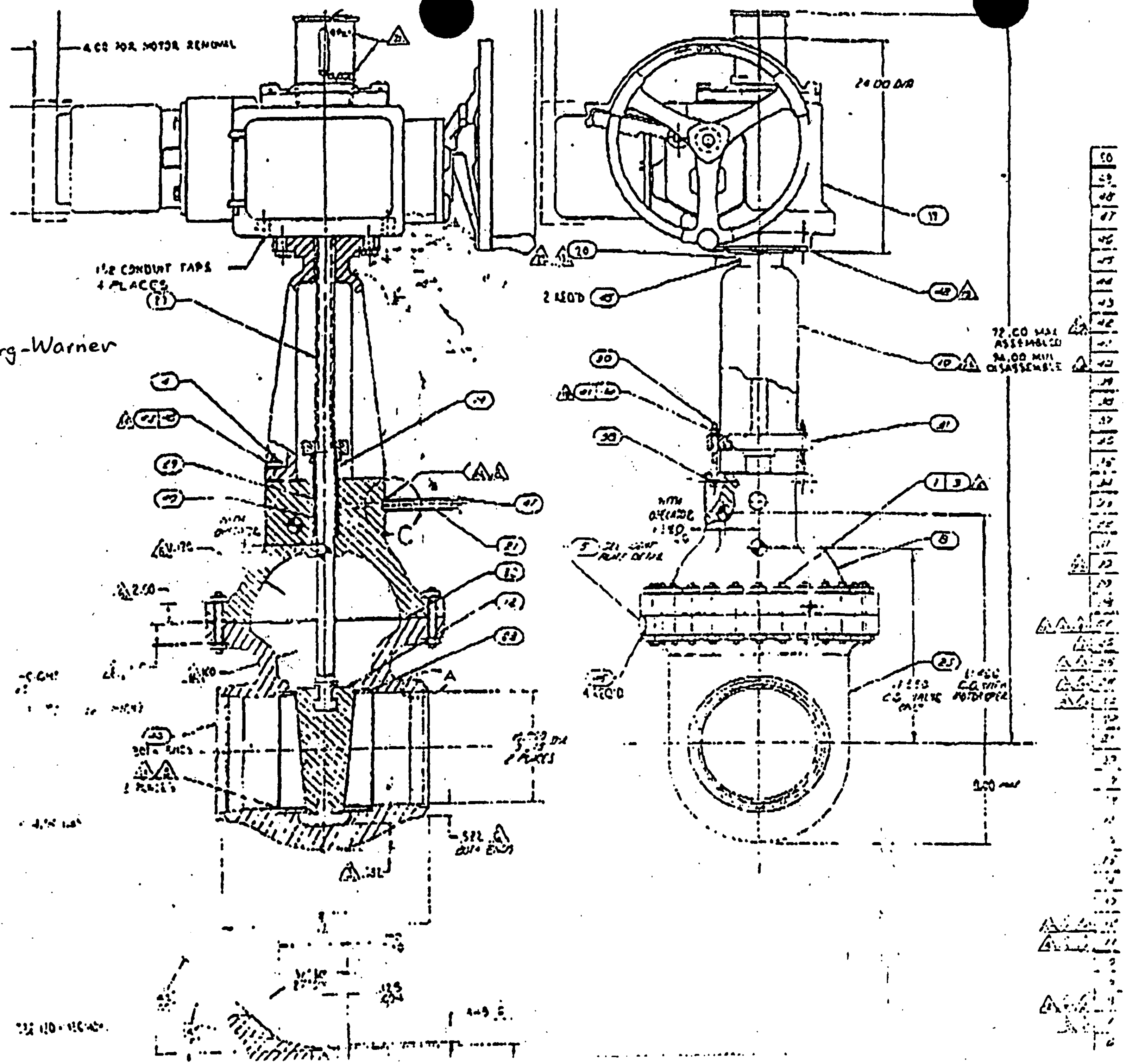
Kalsi Engineering, Inc.

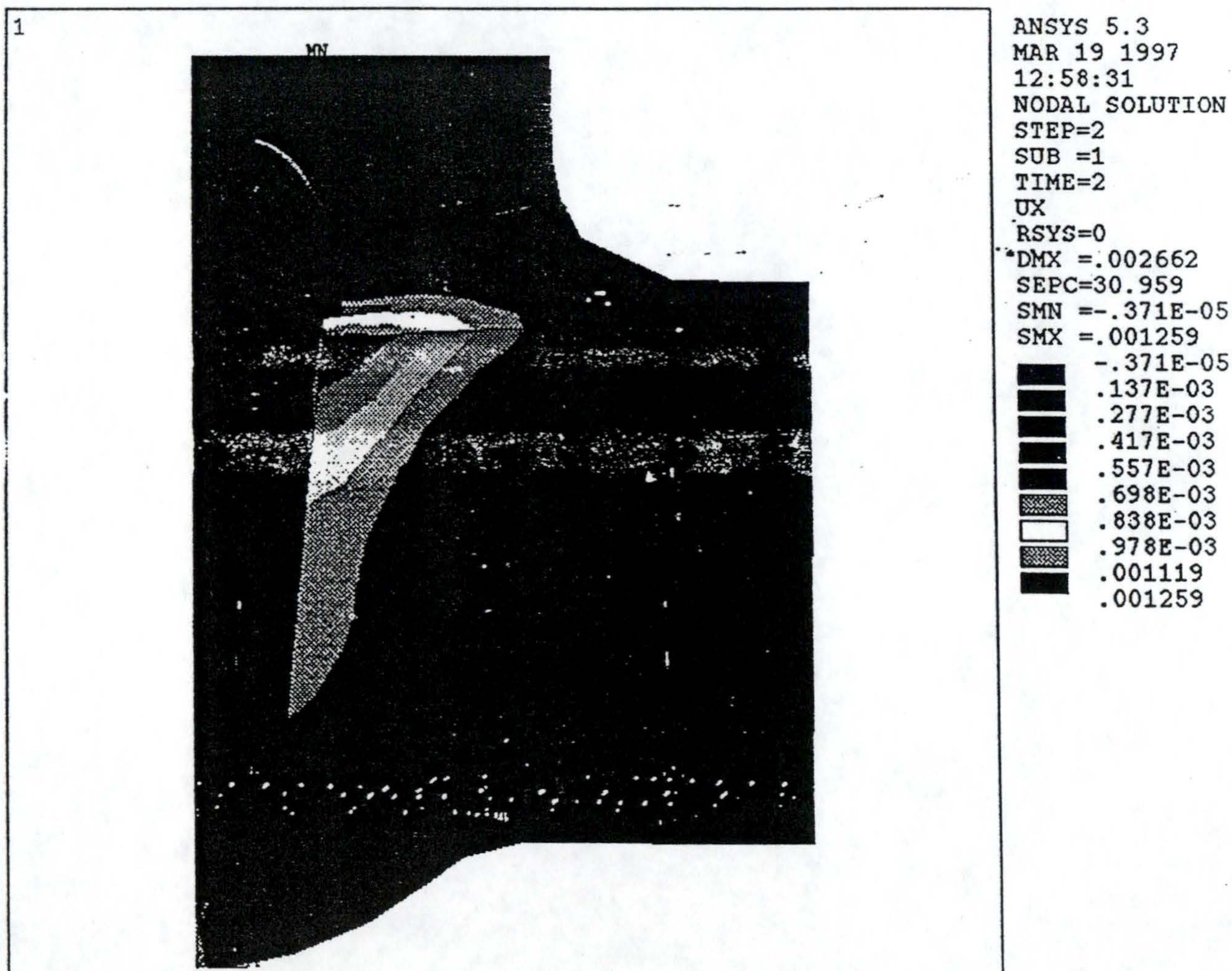
Dimensions for Valve Stiffness Evaluation

Note: Final key dimensions will be reduced to three or four dimensions for the body stiffness estimate after sensitivity study.



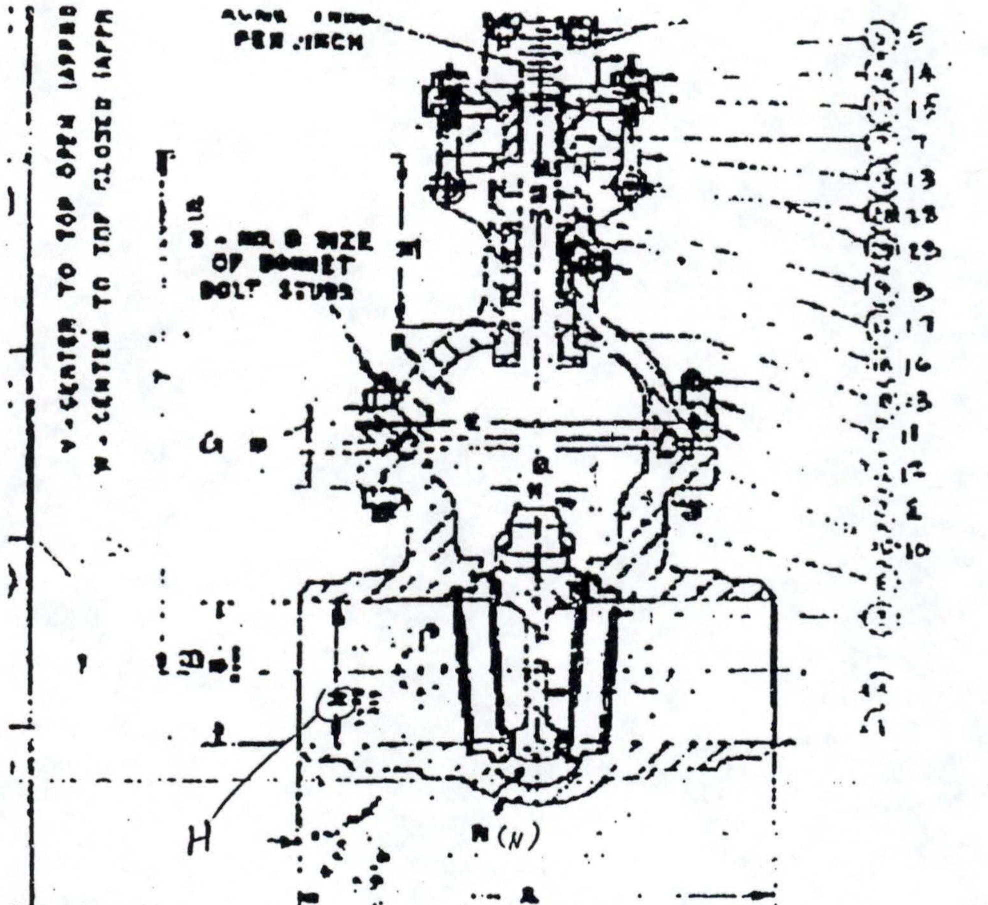
Com Ed
10"X600# Borg-Warner





10" BORG-WARNER 3D FEA -- CASE 2

Est. for 10"x900# Crane

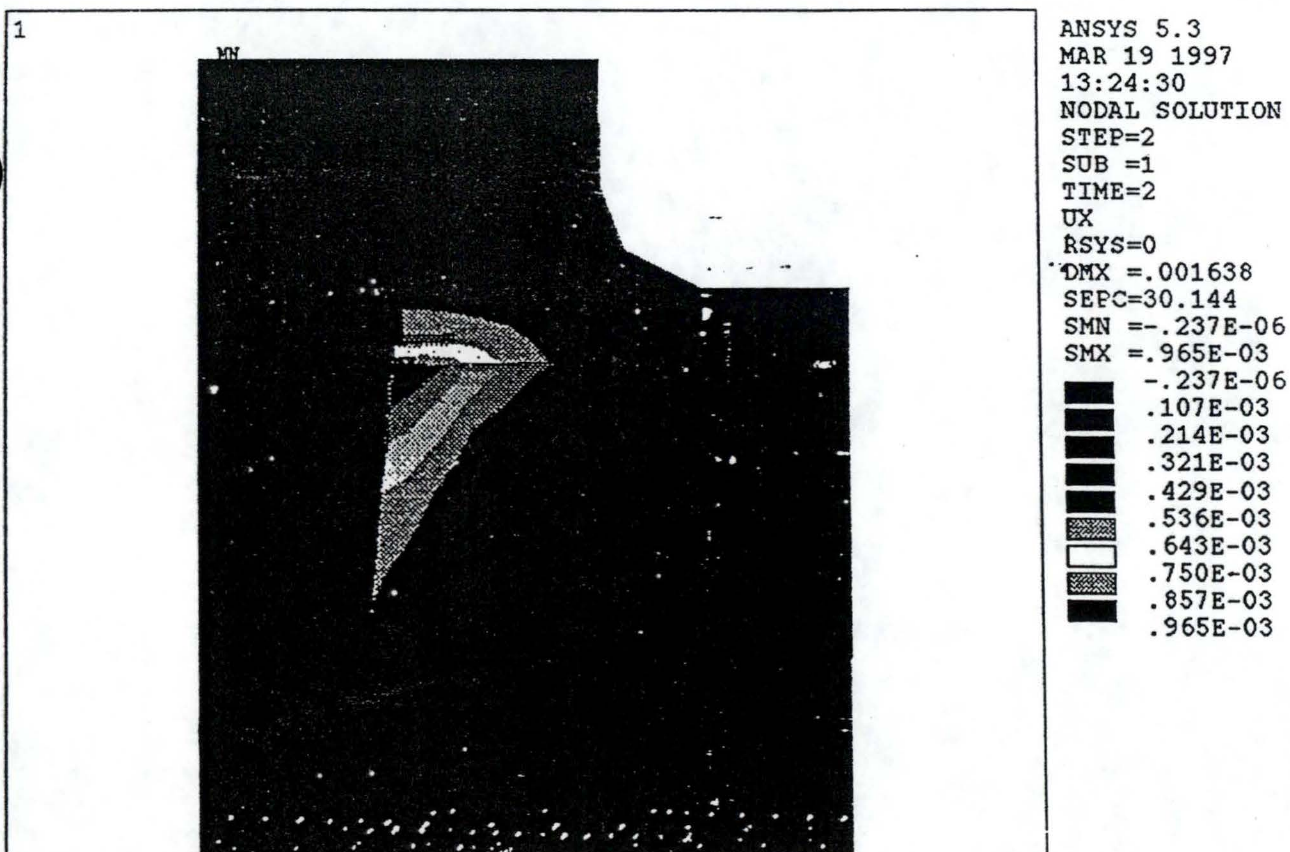


NOTES

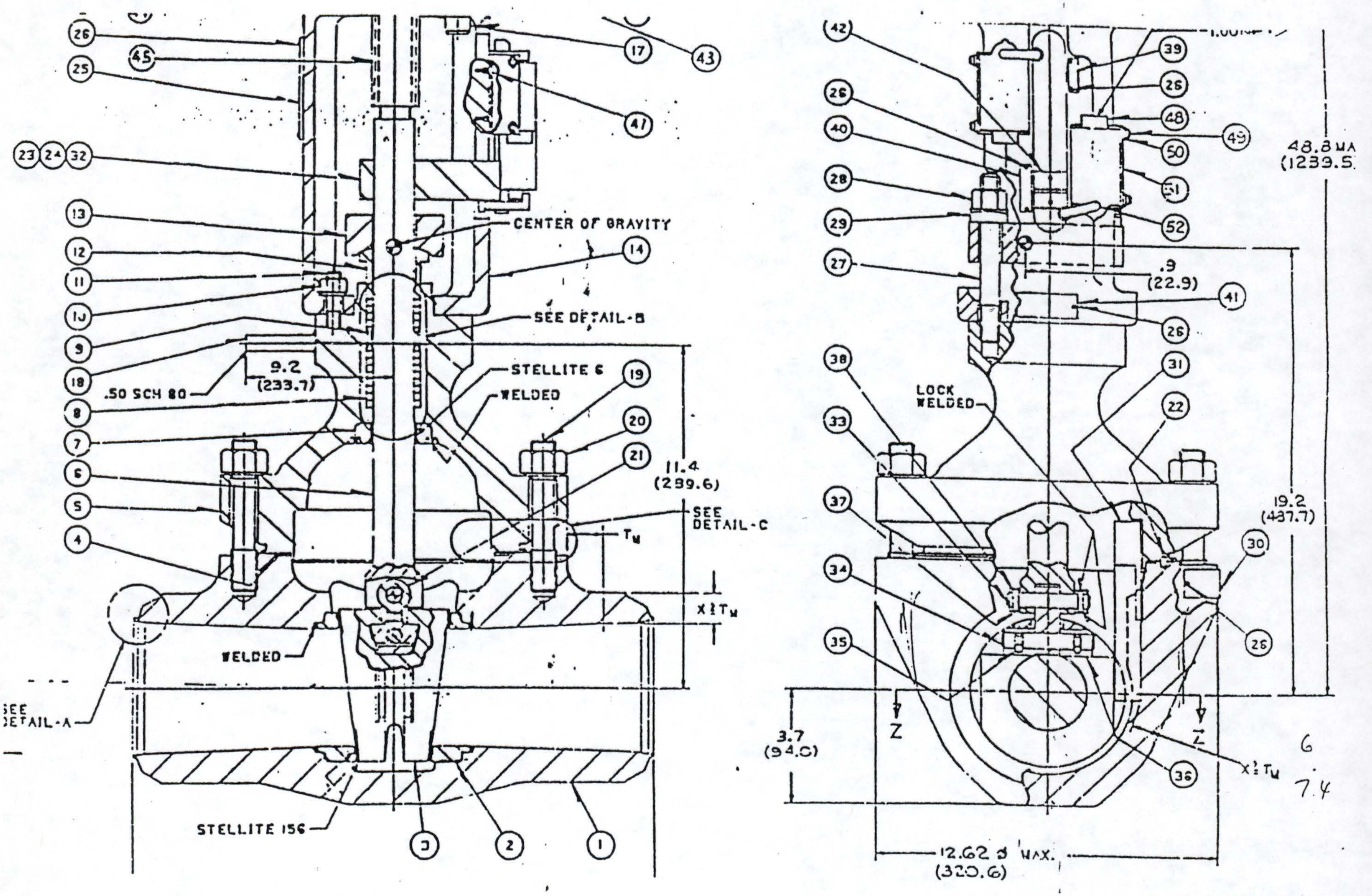
1. WELDING ENDS BORE PER EBASCO DWG. B-187473 REV. 2 "B" DIM. FOR DETAIL 1(D) & 2(A) ONLY

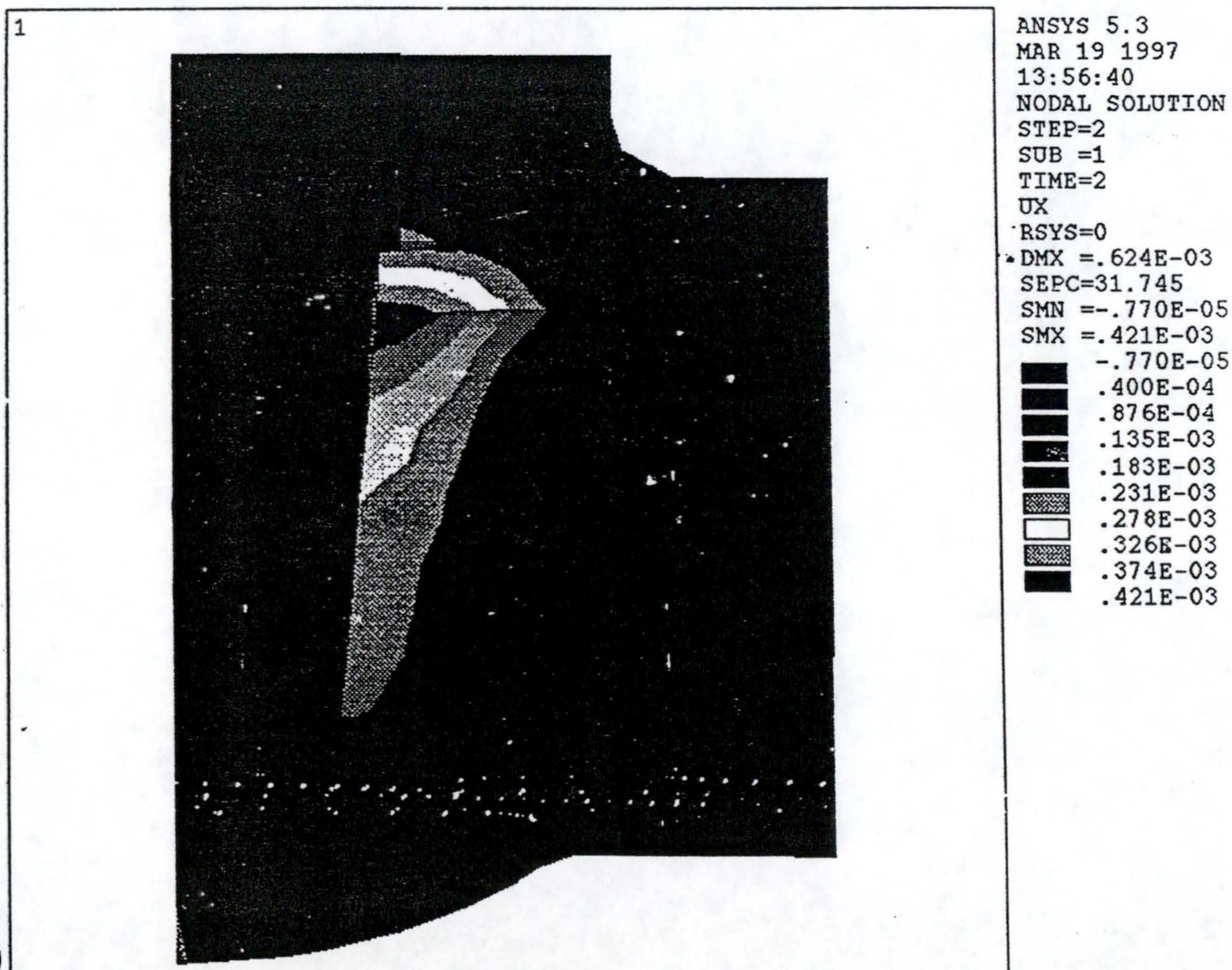
3. NOT SHOWN ON DWG.

WT. LBS APPR.	SIZE	A	B (40* / 80)	E	G	H	J	K	L	M	N	P	R	S	T	V	W
610	6	22	6.065 / 5.761	15 1/8	1 7/8	6	3 1/4	1 5/8	4	2 15/32	7 1/4	20	3/4	16 - 7/8	21 11/16	42 3/4	35 3/4
1080	8	26	7.981 / 7.625	18 3/4	2 3/16	7 7/8	3 3/4	1 7/8	3 1/2	2 21/32	7 7/8	24	1	20 - 1	26	52 1/4	43
1510	10	31	10.020 / 9.564	22	2 1/2	9 3/4	4 1/4	2 1/8	3 1/2	3 1/32	9	27	1 1/8	20 - 1 1/8	30 13/16	62 1/4	51
2240	12	33	11.938	25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]


1
MN
ANSYS 5.3
MAR 19 1997
13:24:30
NODAL SOLUTION
STEP=2
SUB =1
TIME=2
UX
RSYS=0
DMX =.001638
SEPC=30.144
SMN =-.237E-06
SMX =.965E-03
-.237E-06
.107E-03
.214E-03
.321E-03
.429E-03
.536E-03
.643E-03
.750E-03
.857E-03
.965E-03
10" CRANE 3D FEA -- CASE 2

Westinghouse 4" x 1500# Flex Wedge gate



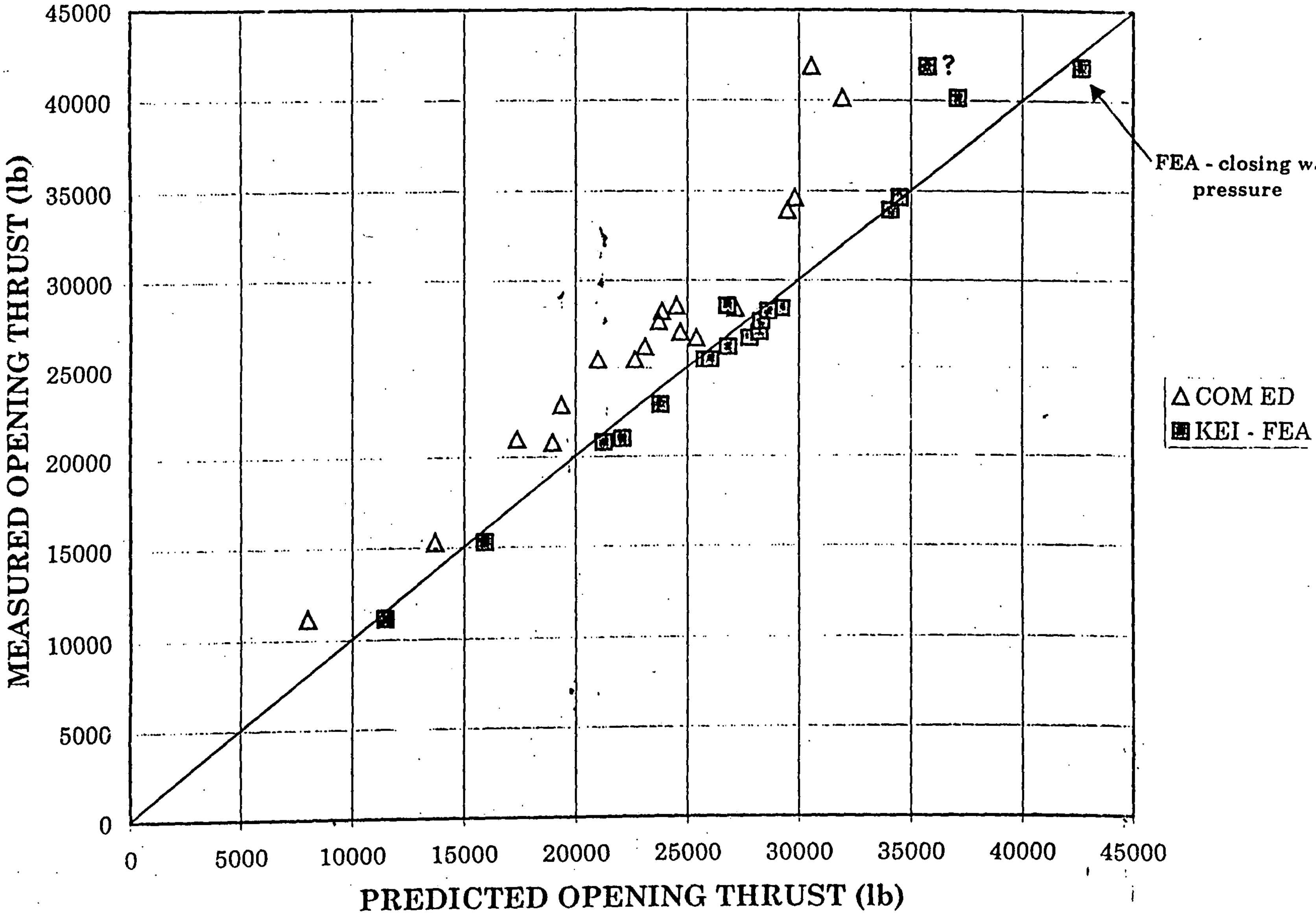


4" WESTINGHOUSE 3D FEA -- CASE 2

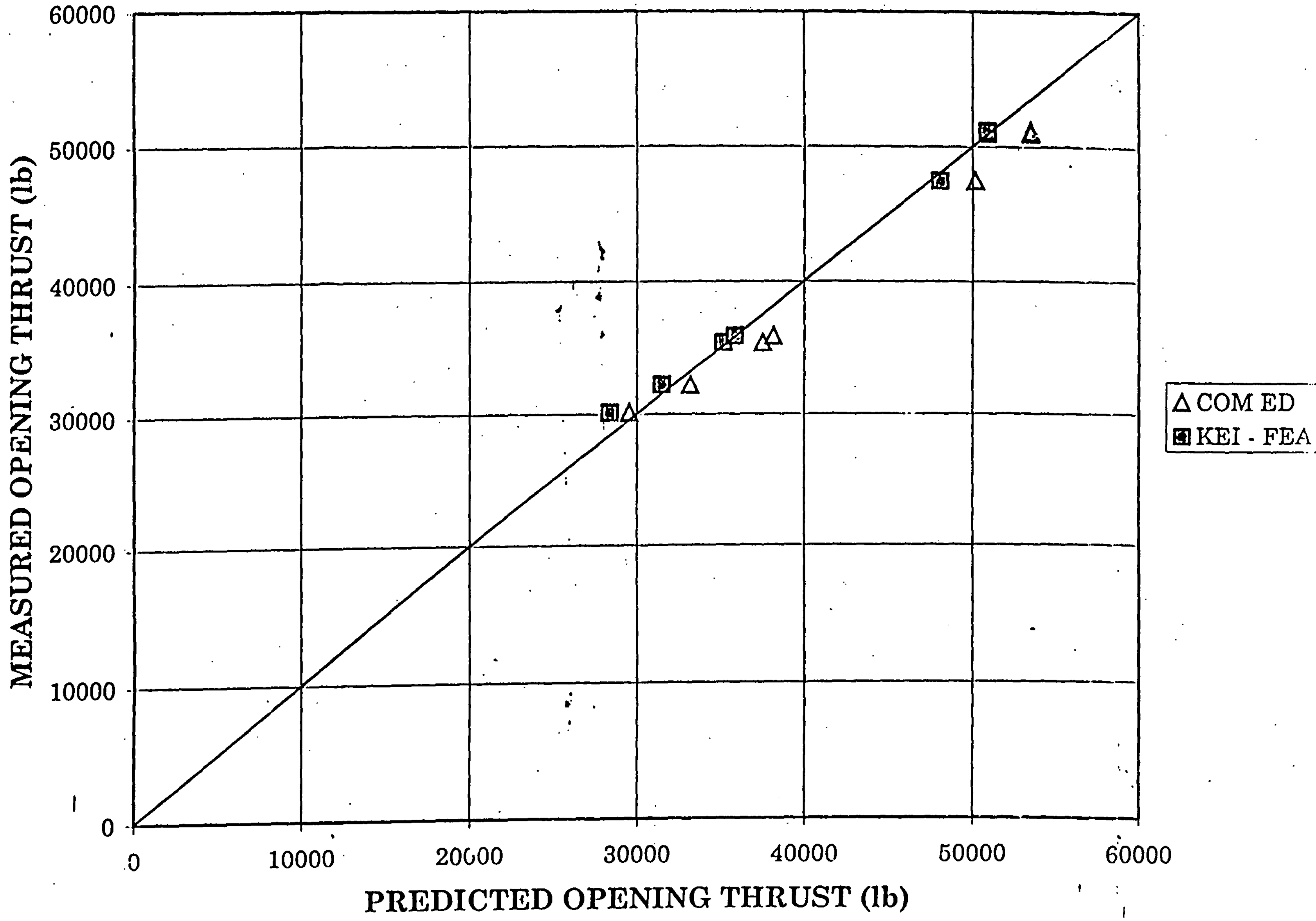
Applying Enhanced Methodology to ComEd and INEL Tested Valves

- Borg-Warner valve
  - Overall improvement in thrust predictions
  - Test #56
  - Valve closed with pressure
- Crane valve
  - Good agreement for both methods
- Westinghouse valve
  - Good agreement for both methods
- Walworth valve (INEL)
  - Some improvement using enhanced method
- Stiffness sensitivity study

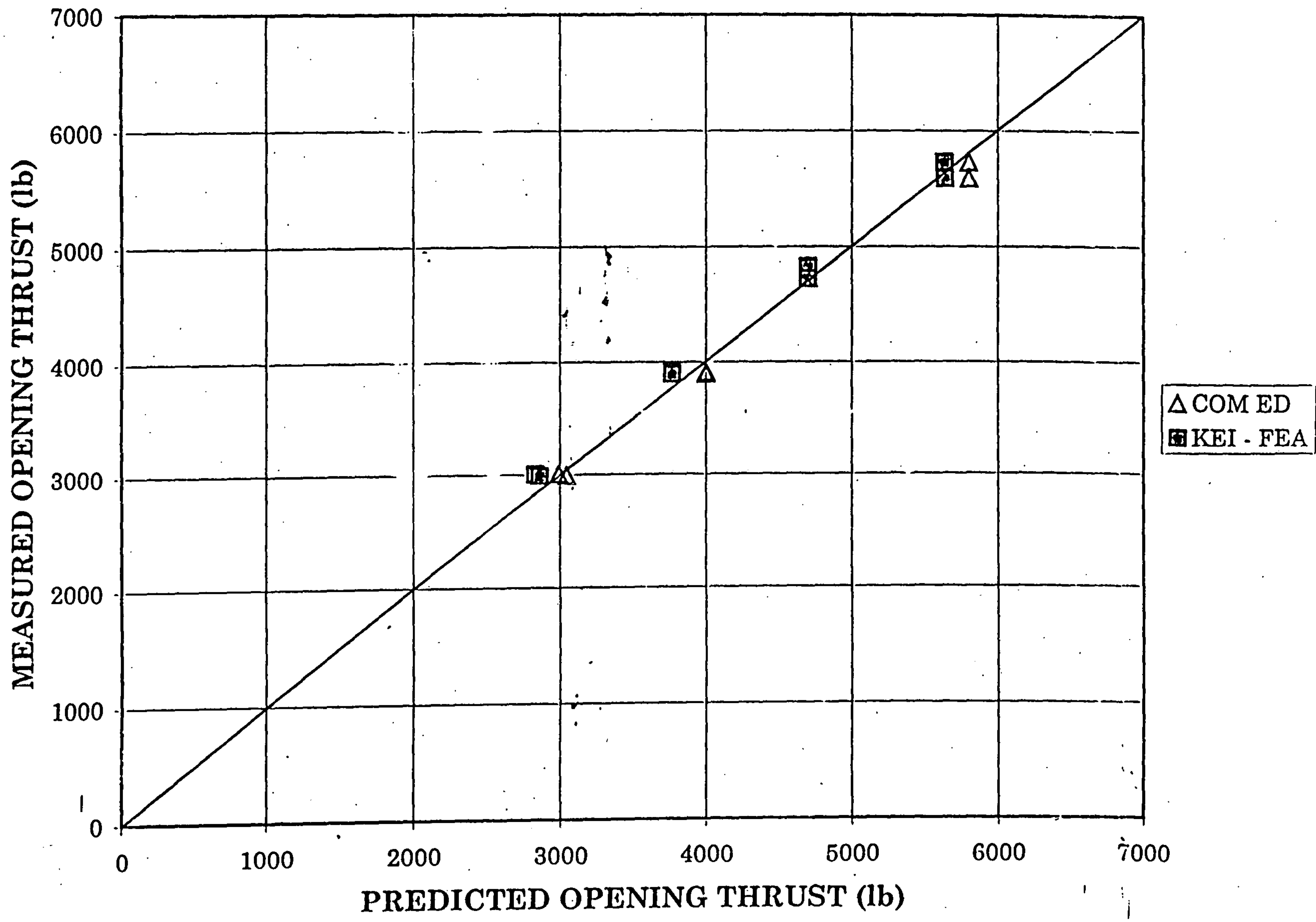
10" x 600# BORG-WARNER VALVE
(TSS=1 & 2)



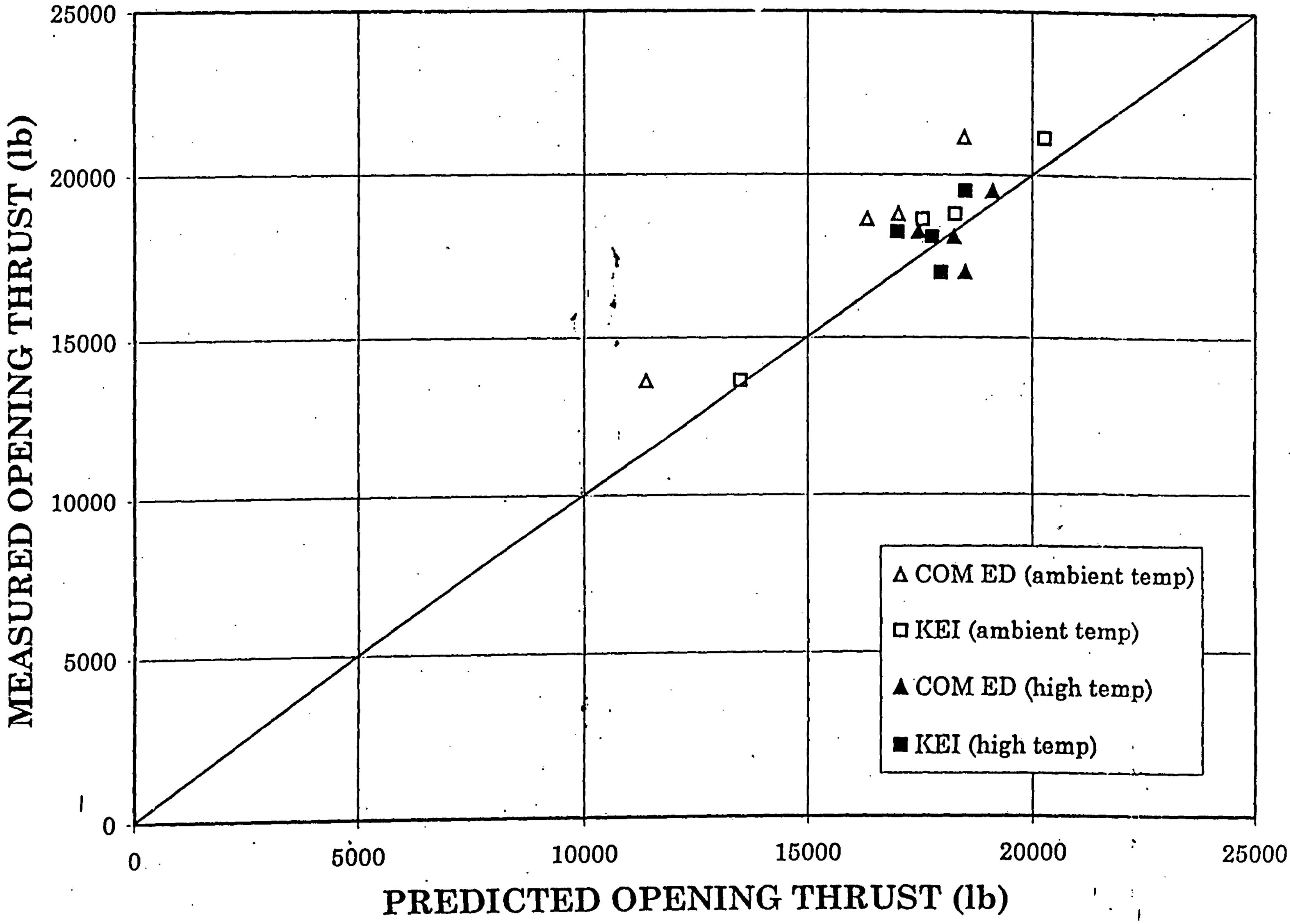
10" x 900# CRANE VALVE



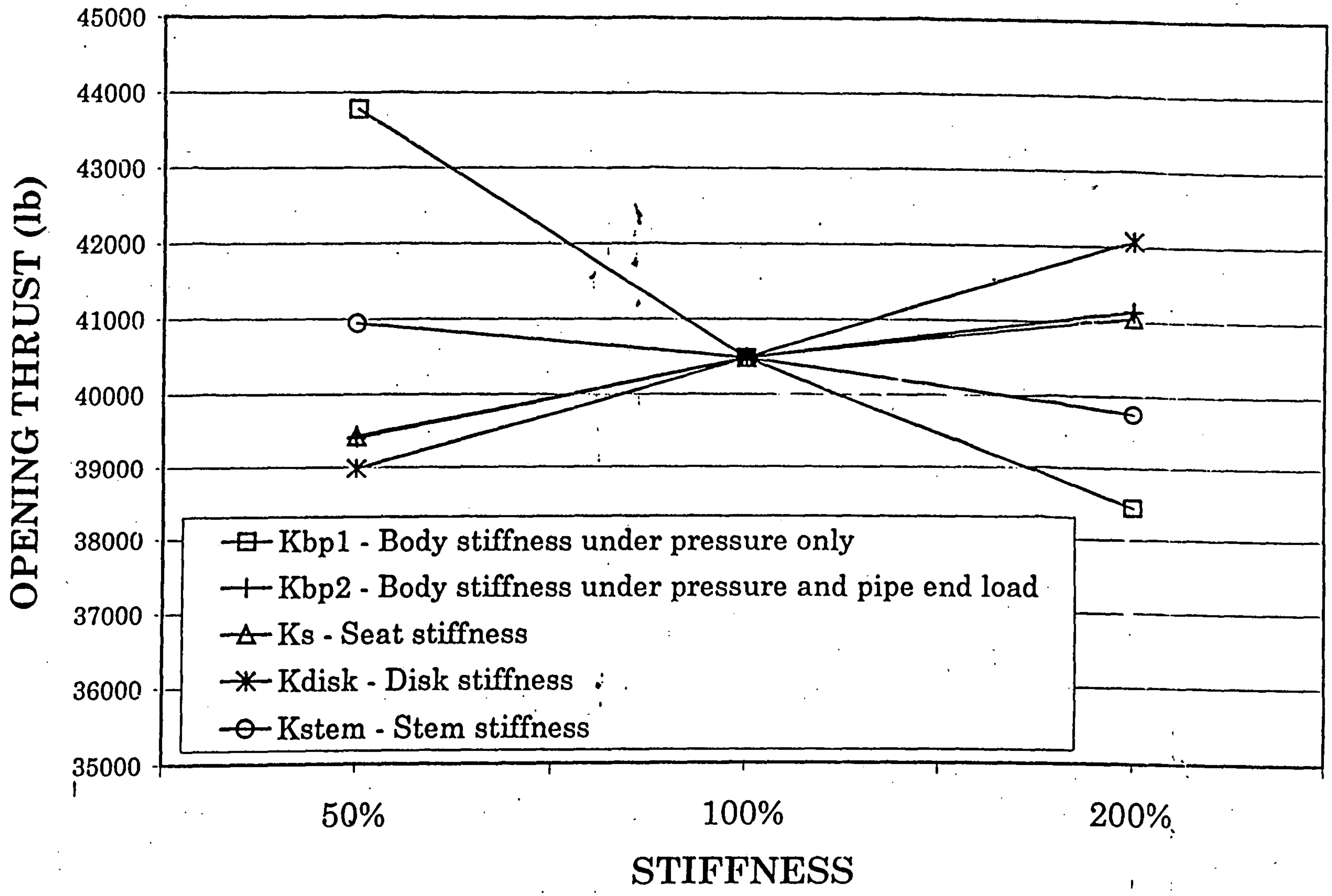
4" x 1500# WESTINGHOUSE VALVE



6" x 600# WALWORTH VALVE (INEL)



SENSITIVITY STUDY
on different valve component stiffnesses



Summary

- Opening thrust calculations without accounting for body flexibility and sequence of operation can cause significant error. The magnitude of error depends upon the body flexibility, disk flexibility, and sequence of operation.
- Work in progress to calculate body flexibility without detailed FEA. Simplified hand calculation equations (using only 3 or 4 key dimensions) are being developed through a matrix of finite element analyses to systematically cover variations in valve body shapes due to differences in manufacturer designs, sizes, and pressure classes.

Idaho
National
Engineering
Laboratory

Pressure Locking Analysis Methods

John C. Watkins
Kevin G. DeWall

USNRC Technical Monitor
Dr. G. H. Weidenhamer

Public Meeting on Flexible-Wedge Gate Valve Pressure Locking Thrust Methodologies
April 9, 1997

ATTACHMENT 5

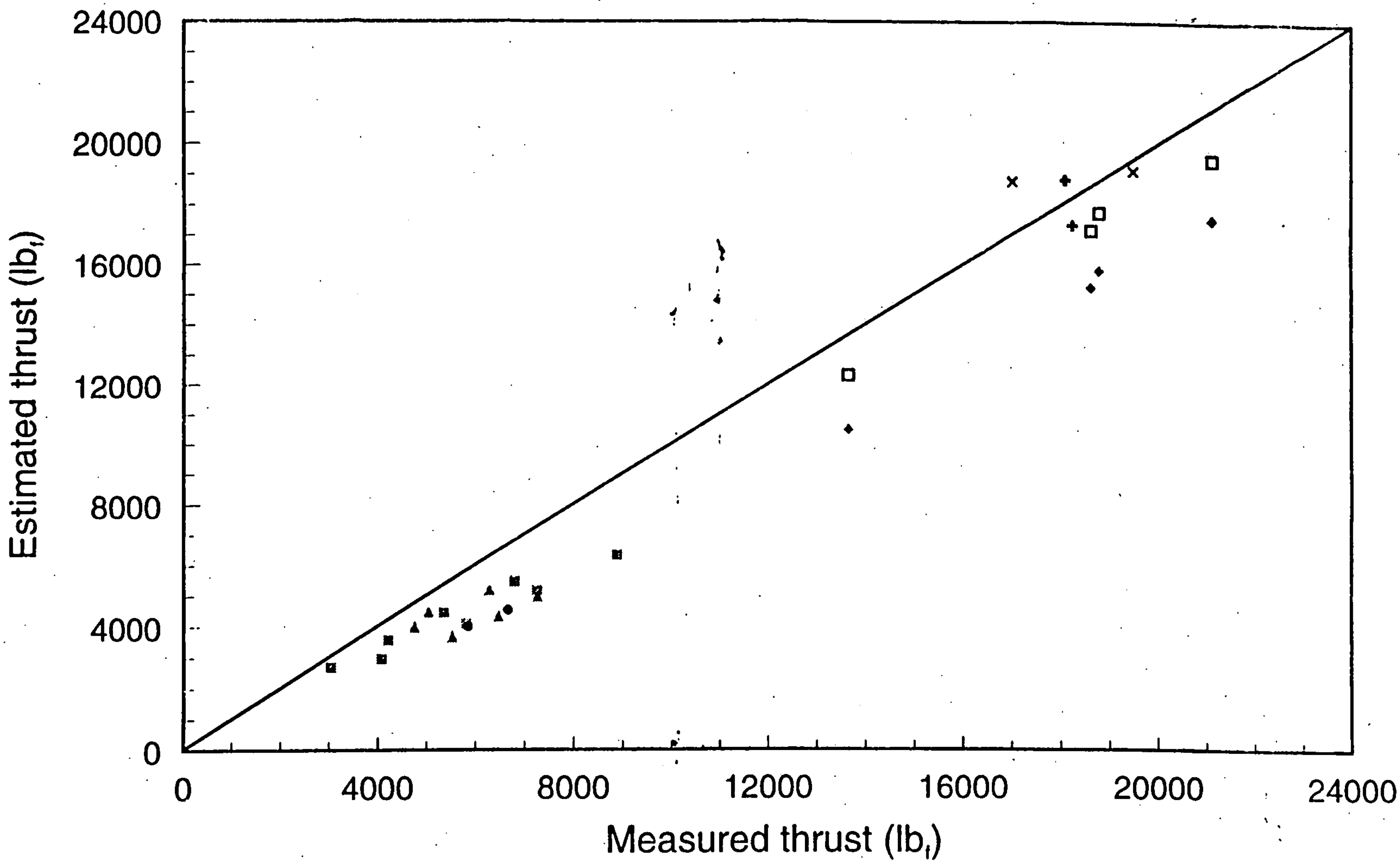
C97 0238

Characteristics of INEEL Walworth Valve Tested Against Pressure Locking Conditions

Valve	Walworth, 6-inch, 600-lb
Disc thickness (one disc)	0.520 in.
Mean seat diameter	5.515 in.
Stem diameter	1.250 in.
Hub diameter	2.580 in.
Hub length	0.928 in.
Wedge angle	5°0'
Poisson's ratio	0.3
Modulus of elasticity	29,700 ksi

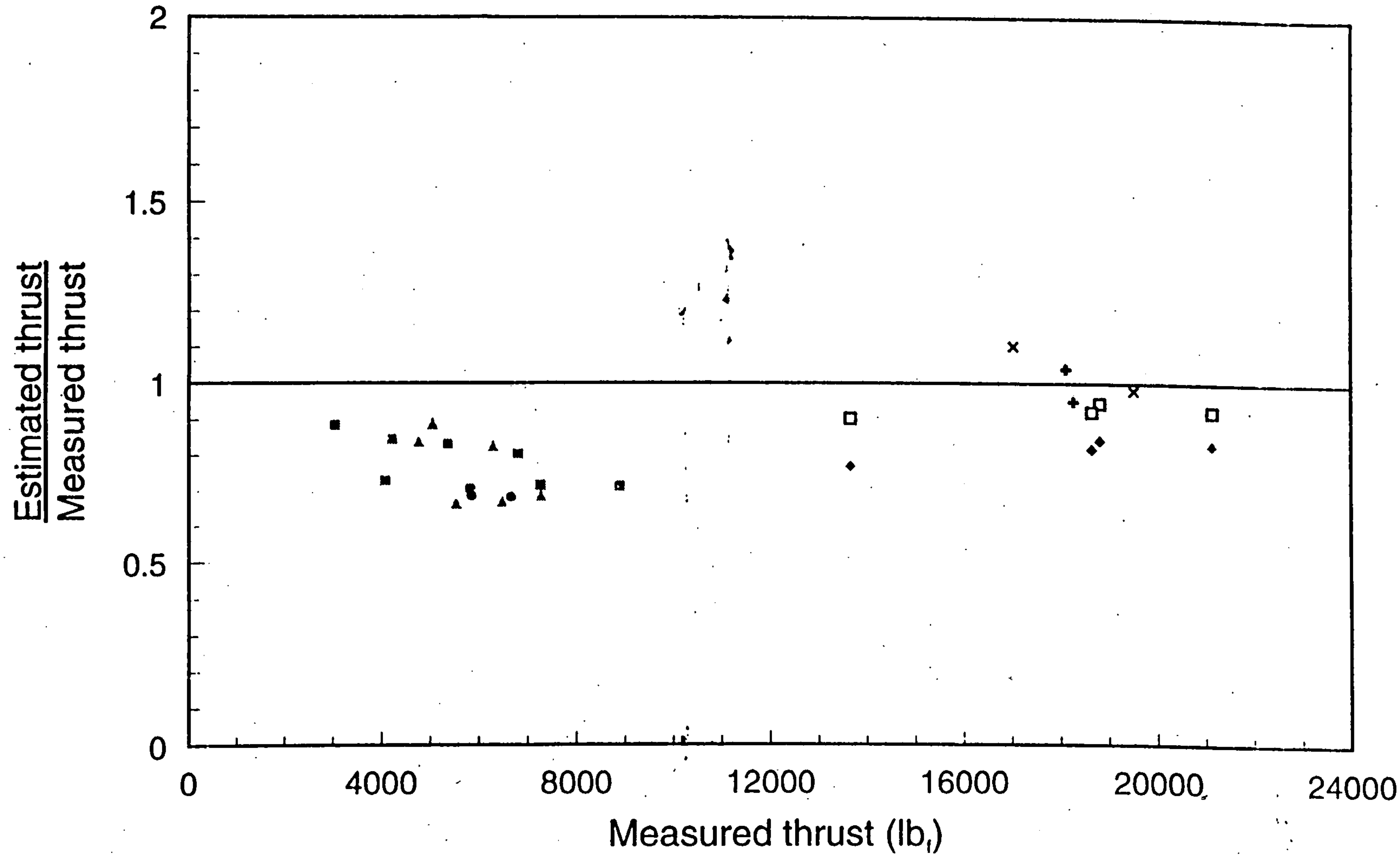
C97 0247

ComEd Method
Walworth Valve @ Unwedging



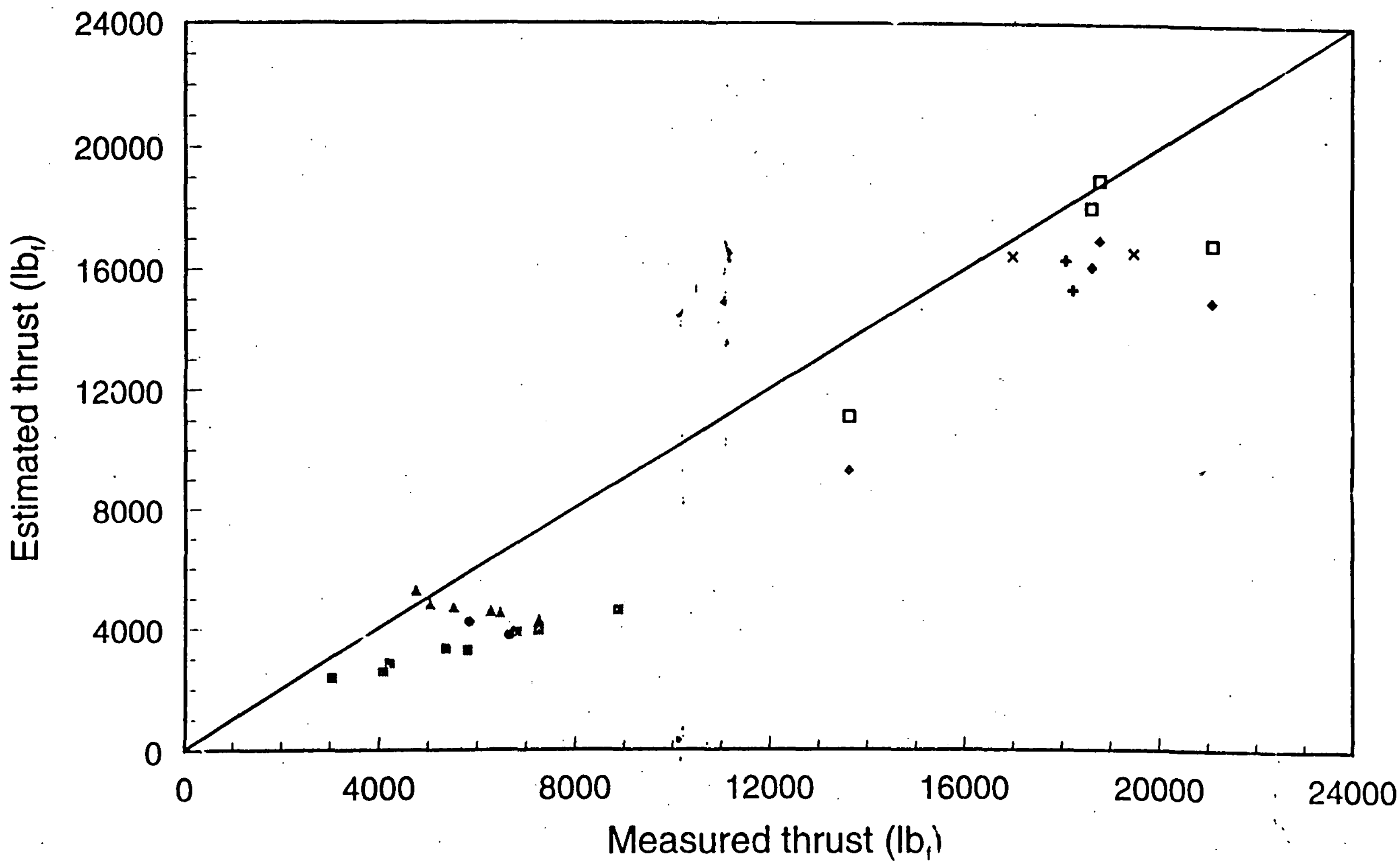
C97 0250

ComEd Method
Walworth Valve @ Unwedging



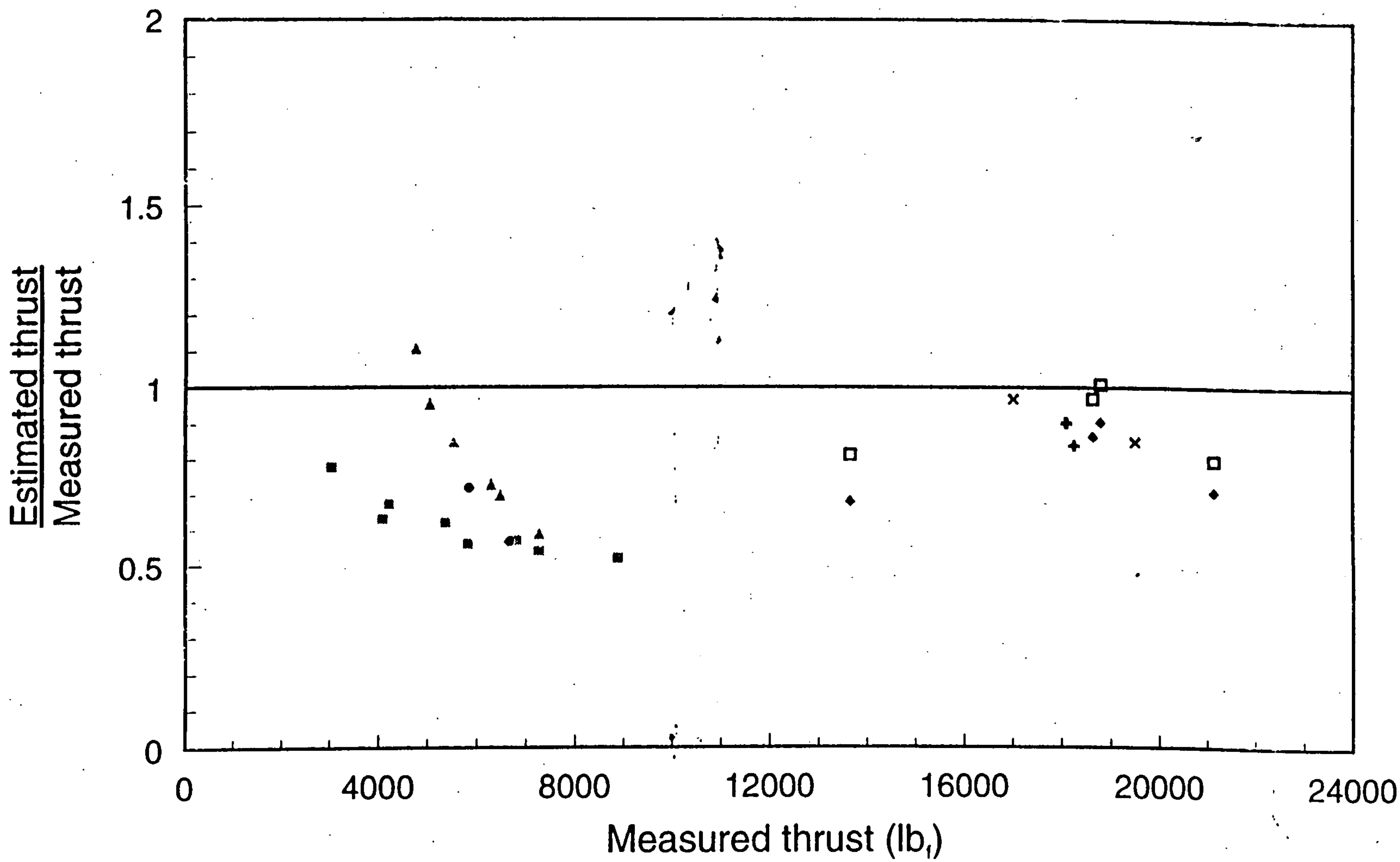
C97 0251

Grand Gulf Method
Walworth Valve @ Unwedging



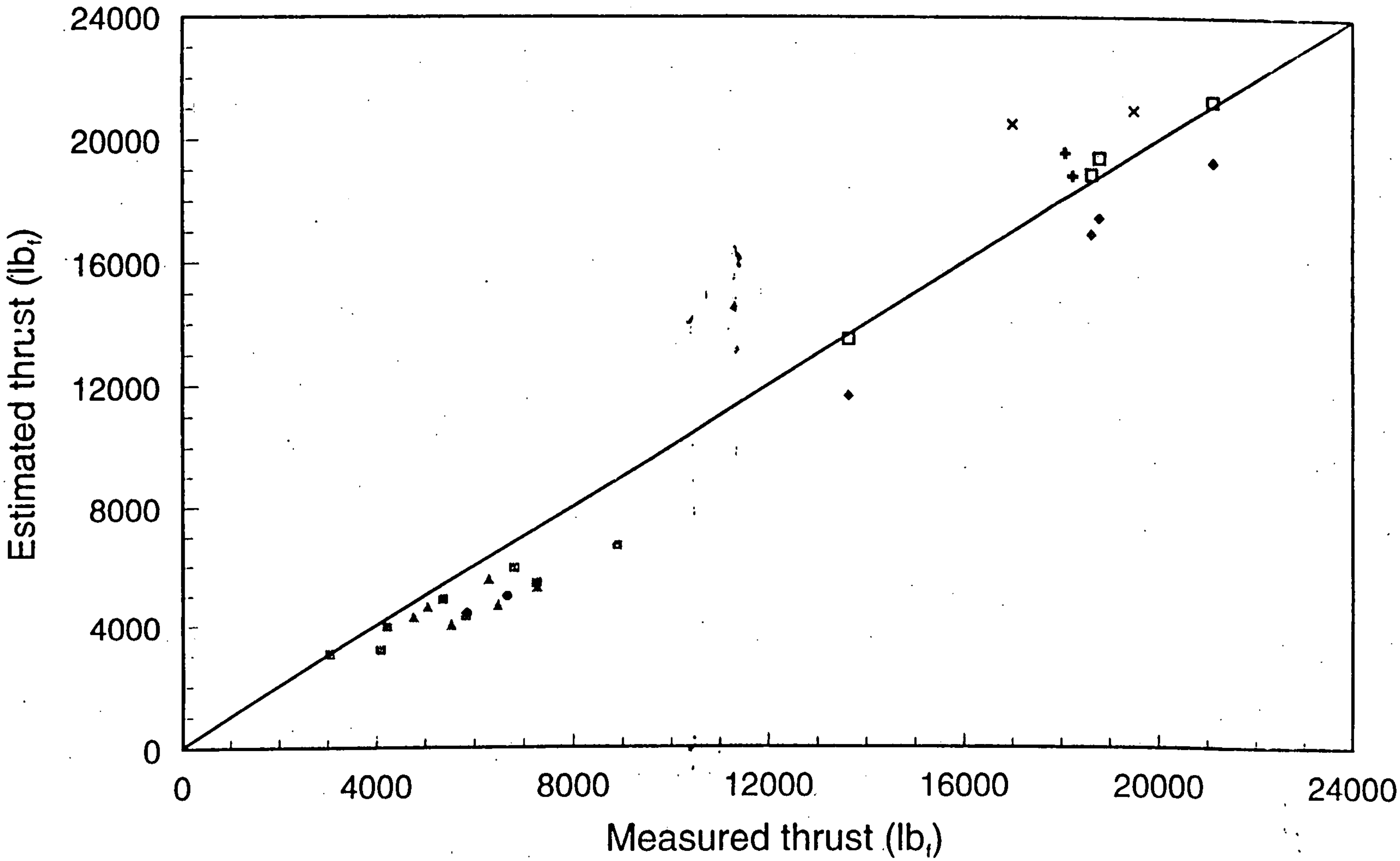
C97 0256

Grand Gulf Method
Walworth Valve @ Unwedging



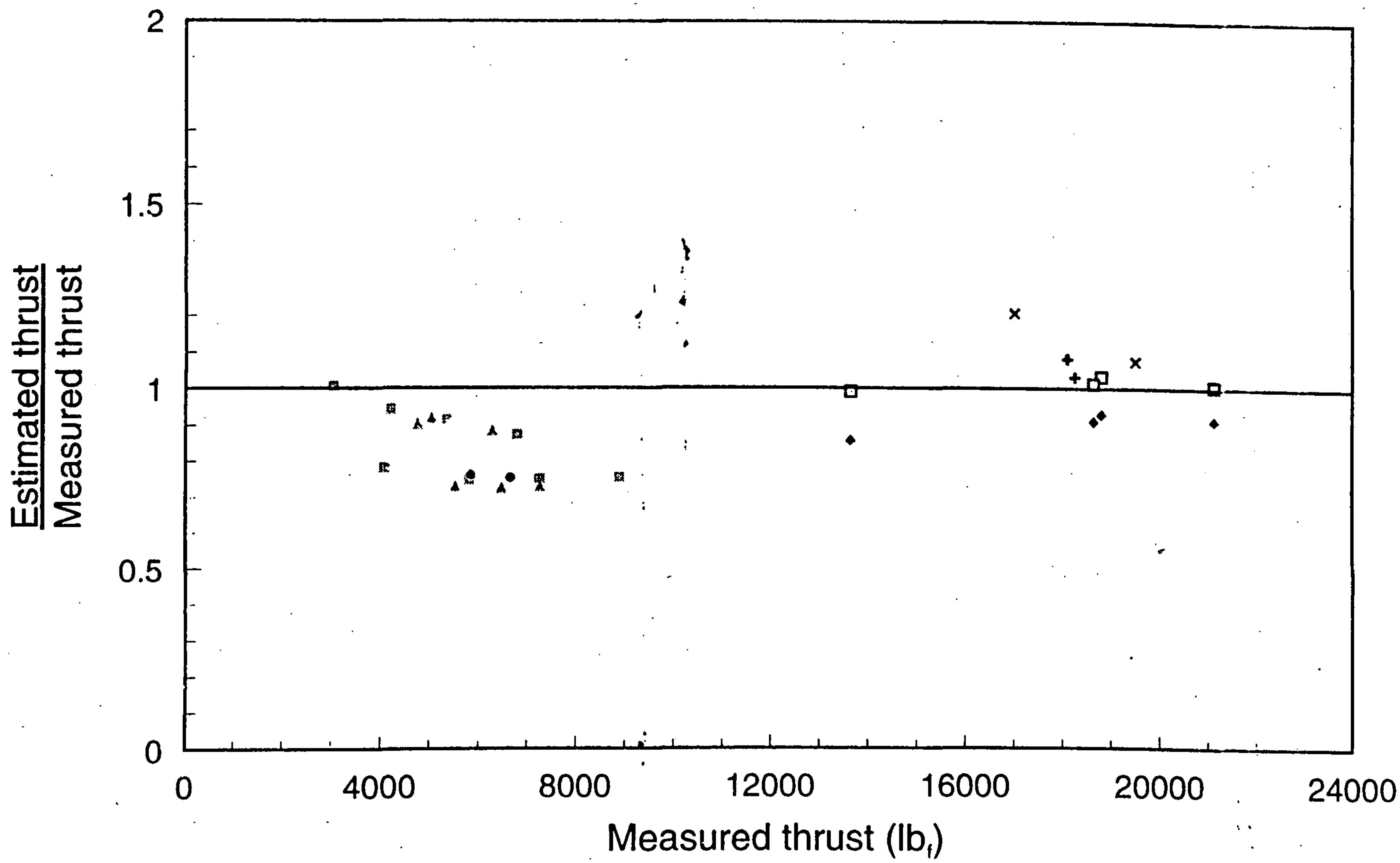
C97 0257

ComEd Method
Walworth Valve Prior to Motion



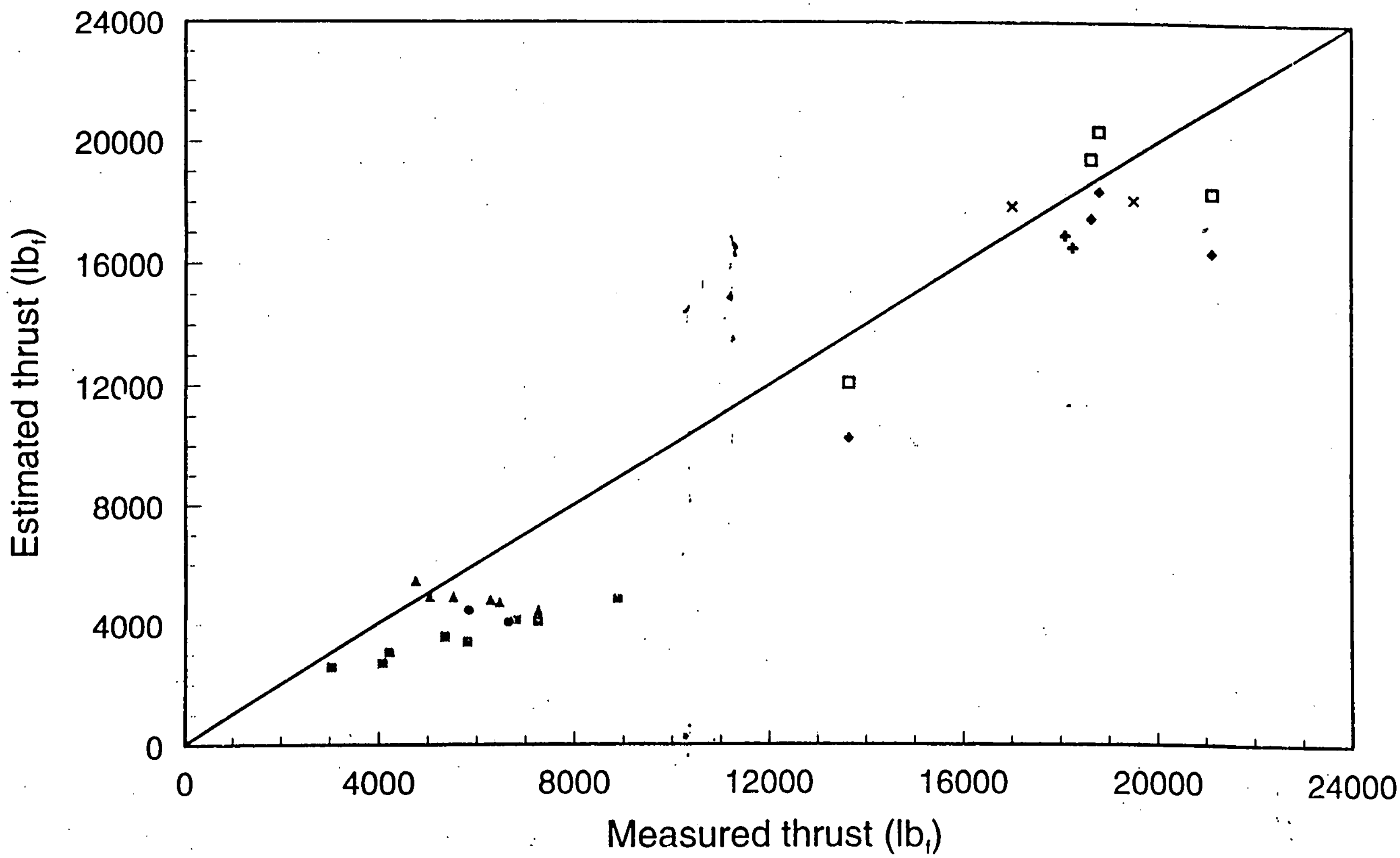
C97 0252

ComEd Method
Walworth Valve Prior to Motion



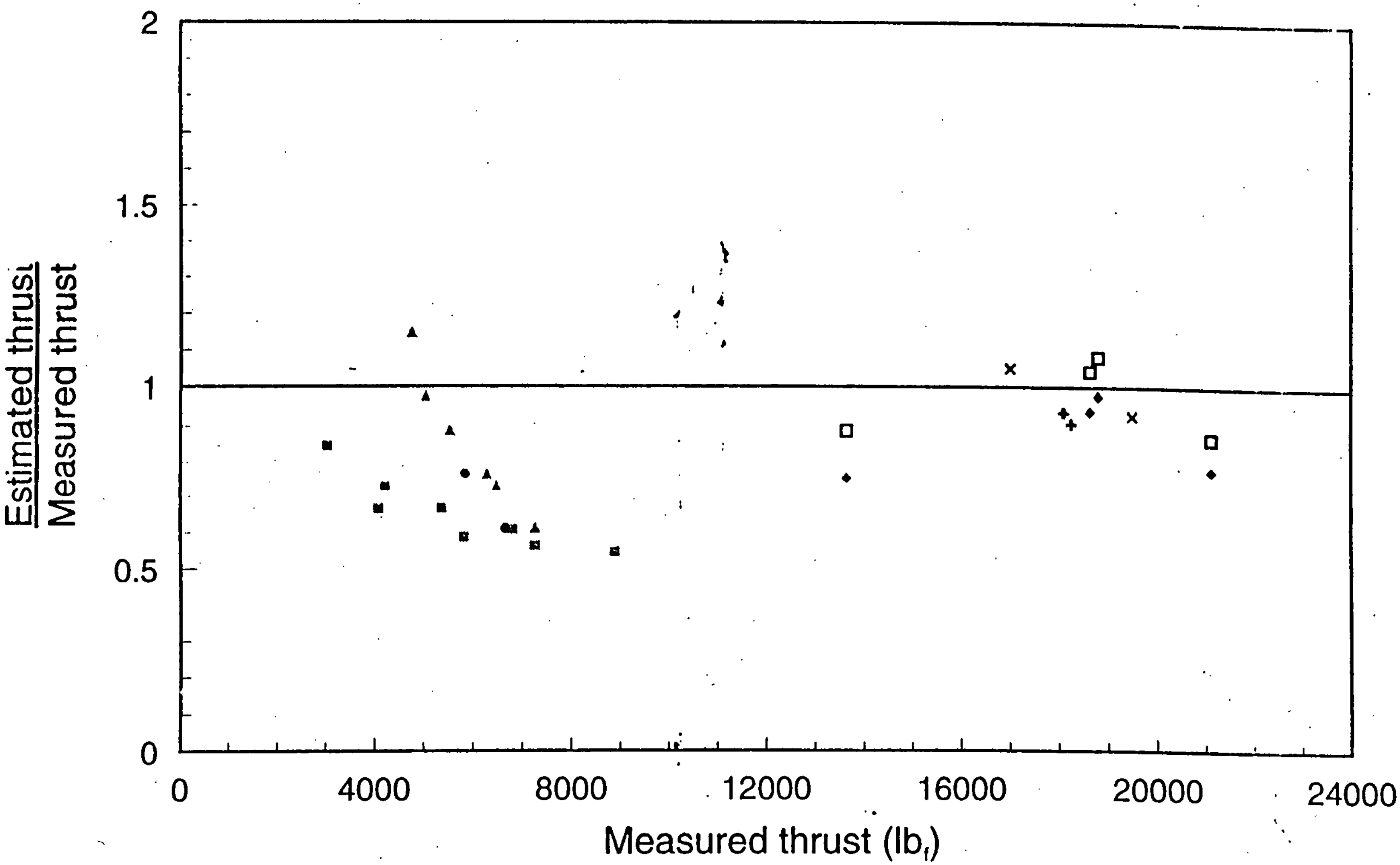
C97 0253

Grand Gulf Method
Walworth Valve Prior to Motion



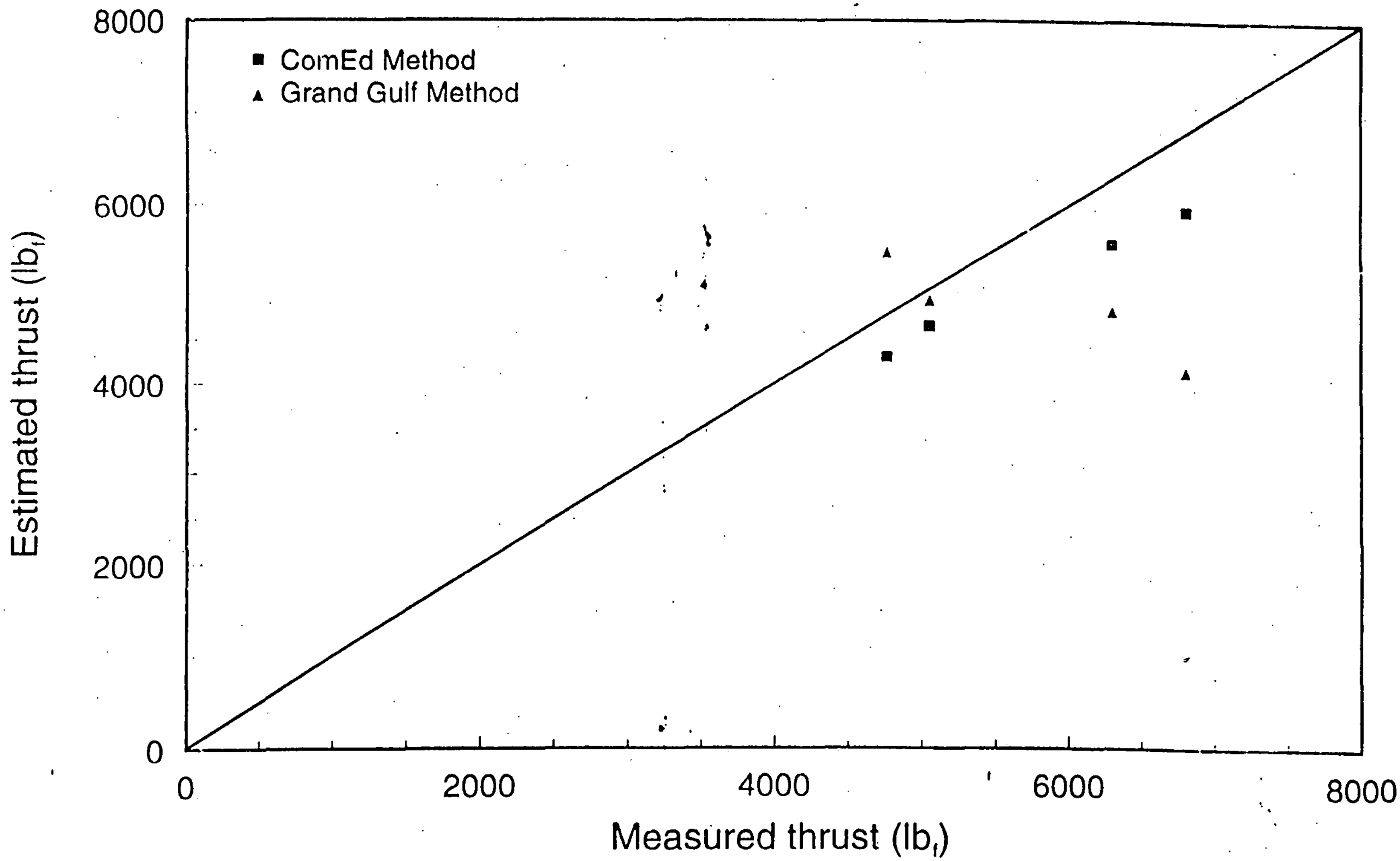
C97 0265

Grand Gulf Method
Walworth Valve Prior to Motion



C97 0266

Thrust Trends Using Both the ComEd and Grand Gulf Methods



C97 0272

Conclusions

- Both methods underestimate the stem thrust required to open a valve that is pressure locked.
- Both methods underestimate less using conditions prior to valve motion.
- Selected trends of the Grand Gulf Method are inconsistant with test data.

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