50-237 DRESDEN 2 CEC

SUMMARY OF MOTOR-OPERATED VALVE MEETING MARCH 15, AND 16, 1995 PRESENTATION

REC'D W/MEMO DTD 5/18/95...9505250312

Presentation Agenda

- Introduction
- Site Program Status
- Actuator Thrust/Torque Capability
- Motor/Gearing Capability
- Margin/Operability Methodology
- Design Basis Assumption / Grouping Methodology
- P.L. Concern for Containment Sump Valves
- Valve Factor Statistical Analysis
- Rate of Loading Analysis
- Stem Factor Analysis
- Periodic Verification

Attachment 2

ComEd

ComEd MOV Program

Presentation for Nuclear Regulatory Commission

March 15 - 16, 1995

Attachment 3

ComEd

Introduction

Presented by Roger Gavankar

ComEd

Purpose of Presentation

- Discuss ComEd Progress Toward Closure of Generic Letter 89-10 including Baseline Static and DP Testing

- Discuss ComEd Technical Initiatives
  - Motor / Gearing Capability
  - Actuator Structural Limits
  - Margin Review / Operability Evaluation Method
  - Valve Factor Grouping Method
  - Other Technical Positions

Presentation Agenda

- Introduction
- Site Program Status
- Actuator Thrust/Torque Capability
- Motor/Gearing Capability
- Margin/Operability Methodology
- Design Basis Assumption / Grouping Methodology
- P.L. Concern for Containment Sump Valves
- Valve Factor Statistical Analysis
- Rate of Loading Analysis
- Stem Factor Analysis
- Periodic Verification

PROGRAM STATUS by STATION

RISING STEM MOVS

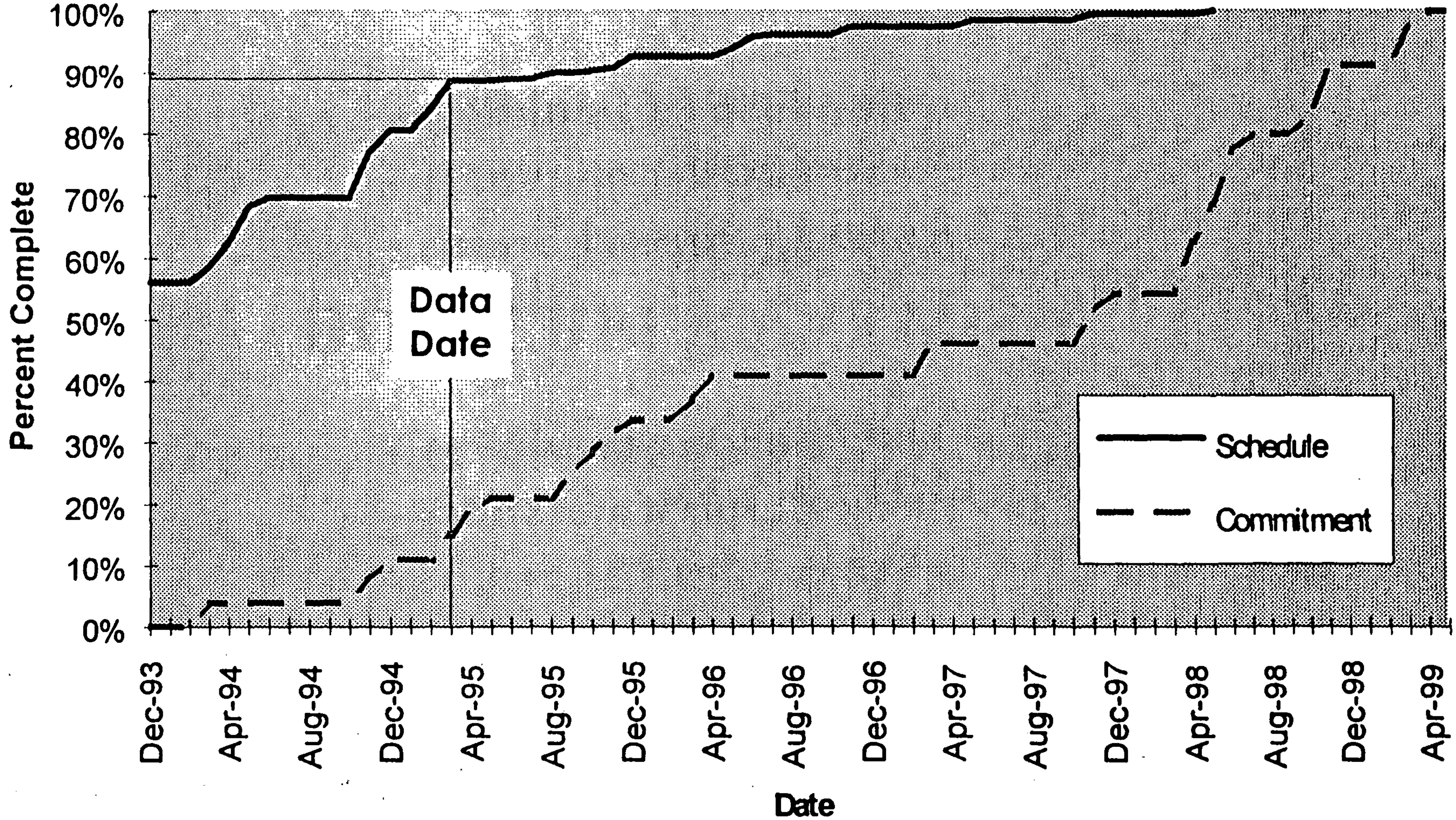
- Static Testing Progress
- Dynamic Testing Progress
- Completion Schedule

BUTTERFLY VALVES

- Static Testing Progress
- Dynamic Testing Progress
- Completion Schedule

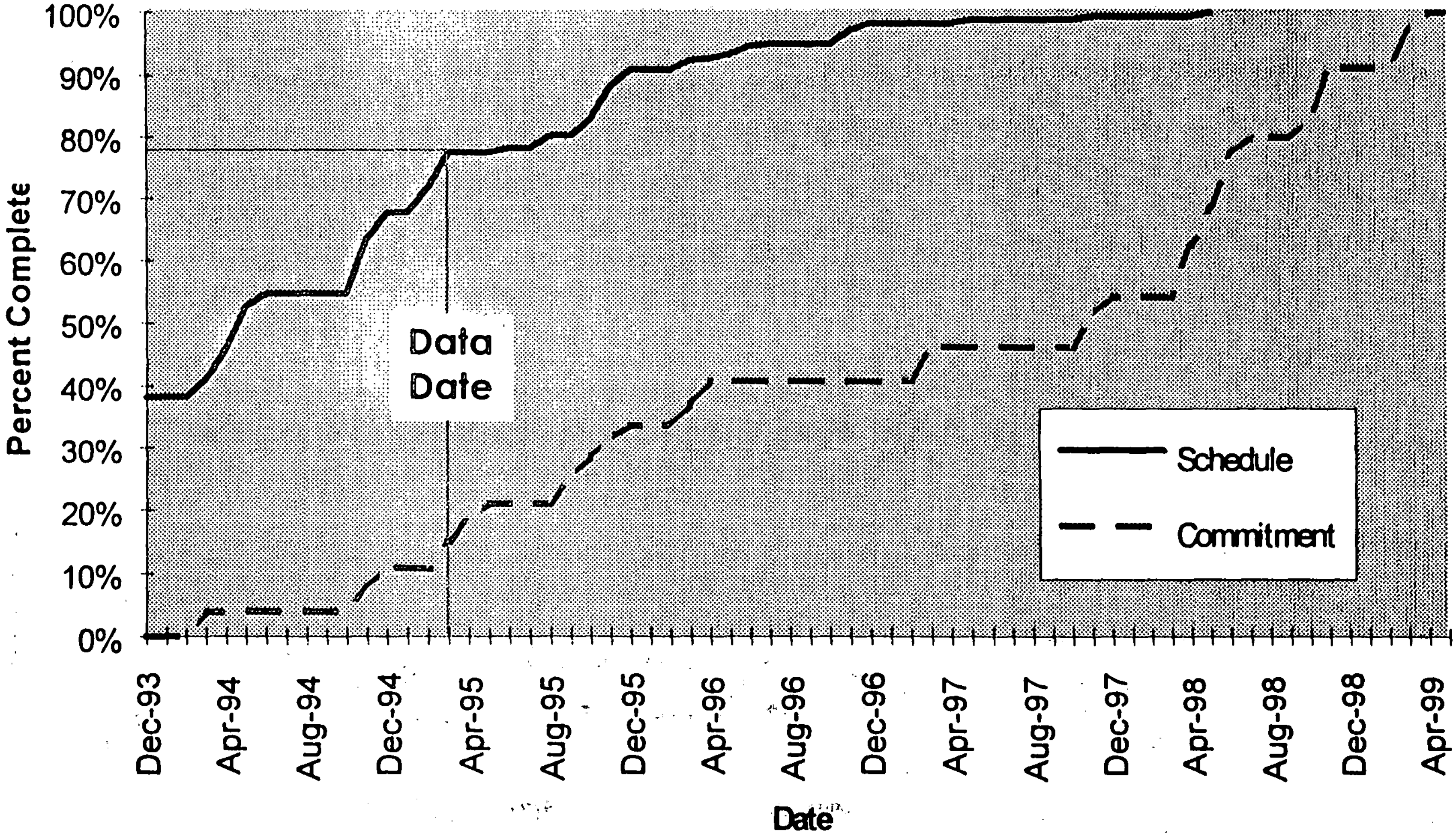
CLOSURE PLAN

Integrated ComEd MOV Schedule (Static Testing)



ComEd

Integrated ComEd MOV Schedule (Dynamic Testing)



LASALLE STATION

Presented by Baron Westphal

LaSalle
Rising Stem MOVs
Testing Status

	Unit 1	Unit 2*
Rising Stem MOVs	126	126
Static Test Completed	126	126
DP Testable Valves	47	47
DP Test Completed	39	47

* Projected status at completion of L2R06 outage (4/17/95)

ComEd

LaSalle
Rising Stem MOVs
Testing Schedule

- Baseline Static Testing COMPLETE
- 86 of 94 valves DP tested
- 1996: 8 DP tests (no static baseline tests)
- Periodic testing begins with L1R07 Outage (Spring '96)

LaSalle
Butterfly MOVs
Testing Status

	Unit 1	Unit 2
Butterfly MOVs	8	8
Static Test Completed	8	8
DP Testable Valves	4	4
DP Test Completed	4	4

ComEd

LaSalle
Butterfly MOVs
Testing Schedule

- Baseline Static Testing COMPLETE
- Baseline DP Testing COMPLETE
- Periodic testing begins with L1R07 Outage (Spring '96)

CLOSURE PLAN

LaSalle intends to issue closure letter during the summer of 1995 once all testing in the current outage is complete and the Butterfly Design Basis Assumptions have been verified using in-situ test data. The remaining DP tests (8 on unit 1) will be a completion item identified in the closure letter.

ComEd

DRESDEN

Presented by John O'Neill

Dresden
Rising Stem MOVs
Testing Status

	Unit 2	Unit 3
Rising Stem MOVs	78	78
Static Test Completed	74	77
DP Testable Valves	36	36
DP Test Completed	8	29

Dresden
Rising Stem MOVs
Testing Schedule

- December 1995: 155 of 156 valves static baseline tested
- December 1995: 70 of 72 valves DP tested
- 1996: 1 static test and 2 DP tests
- Periodic testing begins in 1996

Dresden
Butterfly MOVs
Testing Status

Dresden does not have any butterfly valves in its GL 89-10 Program.

ComEd

CLOSURE PLAN

Dresden intends to issue closure letter in December of 1995 after on line DP testing (HPCI) is completed following outage D2R14.

QUAD CITIES

Presented by Jim Wethington

Quad Cities
Rising Stem MOVs
Testing Status

	Unit 1	Unit 2
Rising Stem MOVs	79	79
Static Test Completed	75	75
DP Testable Valves	33	31*
DP Test Completed	31	26

* Two valves tested on unit 1 will not be tested on unit 2. These valves are low DP load, low safety significance, high margin MOVs which will not be tested for ALARA considerations.

Quad Cities
Rising Stem MOVs
Testing Schedule

- All unit 2 static baseline testing and DP testing will be completed during Q2R13 (by June '95)
- All unit 1 static baseline testing and DP testing will be completed during Q1R14 (by June '96)
- Periodic testing initiated during Q2R13 Outage (in progress)

ComEd

Quad Cities
Butterfly MOVs
Testing Status

Quad Cities does not have any butterfly valves in its GL 89-10 Program.

ComEd

CLOSURE PLAN

Quad Cities intends to issue its closure letter in the summer of 1996 after the Q1R14 outage. At this time, all baseline static and DP tests will have been completed.

ZION STATION

Presented by Randy Mika

Zion
Rising Stem MOVs
Testing Status at

	Unit 1	Unit 2
Rising Stem MOVs	93	93
Static Test Completed	89	93
DP Testable Valves	54	54
DP Test Completed	38	46

ComEd

Zion
Rising Stem MOVs
Testing Schedule

- December 1995: All Static Baseline Testing Complete
- December 1995: 102 of 108 valves DP tested
- 1996: 6 DP tests
- Periodic testing begins with Z2R14 Outage (Fall '96)

ComEd

Zion
Butterfly MOVs
Testing Status

	Unit		
	0	1	2
Butterfly MOVs	6	15	13
Static Test Completed	6	15	13
DP Testable Valves*	3	6	n/a
DP Test Completed	0	0	n/a

* The Zion Butterfly DP testing program will test approximately one-third of the testable valves. These designated test valves are representative of the six groups of butterfly valves in the Zion GL 89-10 Program.

ComEd

Zion
Butterfly MOVs
Testing Schedule

- All Static Baseline Testing COMPLETED in December 1993
- March 1996: 9 DP tests
- Periodic testing begins with Z2R14 Outage (Fall '96)

CLOSURE PLAN

Zion intends to issue closure letter by March, 1996 once all Unit 1 baseline static and baseline DP testing (including butterfly valves) is completed.

ComEd

BRAIDWOOD AND BYRON

Presented by Chris Bedford

Braidwood
Rising Stem MOVs
Testing Status

	Unit 1	Unit 2
Rising Stem MOVs	91	91
Static Test Completed	91	91
DP Testable Valves	46	46
DP Test Completed	46	46

Braidwood
Rising Stem MOVs
Testing Schedule

- Baseline Static Testing COMPLETE
- Baseline DP Testing COMPLETE
- Periodic Testing Begins with A1R05 Outage (Fall '95)

Braidwood
Butterfly MOVs
Testing Status

	Unit		
	0	1	2
Butterfly MOVs	11	22	22
Static Test Completed	1	0	1
DP Testable Valves	3	7	7
DP Test Completed	1	0	1

ComEd

Braidwood Butterfly MOVs Testing Schedule

The current Braidwood schedule* is outlined below. This meets the Braidwood commitment of completing all baseline testing of butterfly valves within 5 refueling outages of January 1991:

- December 1995: ~27 of 55 valves static baseline tested
- December 1995: ~9 of 17 valves DP tested
- 1996: ~15 static baseline tests and ~4 DP tests
- 1997: ~13 static baseline tests and ~4 DP tests
- Periodic testing begins with A1R07 Outage (Fall '98)

***This schedule is subject to change based on plant conditions.**

GL 89-10 CLOSURE PLAN

Braidwood intends to issue closure letter at the end of 1995 once the majority Butterfly Valve Testing is complete and the Butterfly Design Basis Assumptions have been verified.

Byron
Rising Stem MOVs
Testing Status

	Unit 1	Unit 2
Rising Stem MOVs	91	91
Static Test Completed	91	91
DP Testable Valves	49	49
DP Test Completed	49	49

Byron
Rising Stem MOVs
Testing Schedule

- Baseline Static Testing COMPLETE
- Baseline DP Testing COMPLETE
- Periodic Testing Begins with B1R07 Outage (Spring '96)

ComEd

Byron
Butterfly MOVs
Testing Status

	Unit		
	0	1	2
Butterfly MOVs*	27	24	24
Static Test Completed	1	0	0
DP Testable Valves	15	9	9
DP Test Completed	1	0	0

*12 of these 75 MOVs cannot be tested under static conditions (except during a dual unit outage).

ComEd

Byron Butterfly MOVs Testing Schedule

The current Byron schedule* is outlined below. This meets the Byron commitment of completing all baseline testing of butterfly valves within 5 refueling outages of January 1991:

- December 1995: ~5 of 63 valves static baseline tested
- December 1995: ~13 of 33 valves DP tested
- 1996: ~36 static baseline tests and ~13 DP tests
- 1997: ~15 static baseline tests and ~3 DP tests
- 1998: ~7 static baseline tests and ~4 DP tests
- Periodic testing begins with B1R09 Outage (Spring '99)

*This schedule is subject to change based on plant conditions.

ComEd

CLOSURE PLAN

Byron intends to issue closure letter at the end of 1995 once some Butterfly Valve Testing is complete and the Butterfly Design Basis Assumptions have been verified.

Important Features of ComEd MOV Program

- Questioning attitude about OEM recommendations and design values.

- ComEd Technical Positions based on first principles and supported by test data to replace unsupported vendor recommendations such as:
  - » Actuator Structural Capability
  - » Motor/Gearing Capability
  - » Valve Factors

- Development of a method to determine the amount of margin required to assure safe plant operation.

Important Features of ComEd MOV Program

- Testing Initiatives beyond Kalsi and EPRI
  - DC and AC Motor Testing
  - Crane Blowdown Testing
  - Roller Screw Stem Nut Testing
  - Motor Pinion Key Testing
  - Packing Load Adjustment Testing
  - Strain Gage Stem Coupling for Neles-Jamesbury Butterly MOVs

Important Features of ComEd MOV Program

Revised margin & operability method which considers multiple sources of uncertainty (random and bias)

- Valve Factor
- Torque and Thrust (equipment inaccuracy)
- Torque Switch Repeatability
- Springpack Relaxation
- Rate of Loading
- Stem Factor
- Packing Load
- Inertia Factor
- Motor Torque Output Uncertainty
- Actuator Efficiency Uncertainty
- Actuator Thrust & Torque Limit Uncertainty
- Valve Structural Limit Uncertainty
- Seismic Limit Uncertainty

Independent Technical Review of ComEd Position Papers by MPR

MPR Associates recently completed a review of the following ComEd technical position papers:

- WP-122 "Kalsi Thrust and Torque Limits"
- WP-125 "Enhanced Motor/Gearing Capability"
- WP-129 "Margin / Operability Review Methodology"
- WP-156 "Motor Pinion Key Torque Limits"
- WP-154, WP-160, WP-164 "Valve Factor Methodology"

In addition, MPR reviewed ComEd's overall program documentation of technical positions on industry issues.

Technical Review of ComEd Position Papers by MPR
(The Review Approach)

Review position statement for:

- well defined purpose
- clarity
- completeness
- appropriate limitations

Review technical justification for:

- logical development of position
- proper application of technical theory
- proper use of referenced technical data
- consistency with applicable codes, standards, and regulations
- sufficiency of technical basis for stated position
- convincing presentation of position

Major Changes to ComEd Position Papers resulting from Independent Review Comments

- **Actuator Structural Limits**
  - Torque limits are now based on the Kalsi Phase II report using the LTAFLA computer program.

    (original WP-122 recommendations have been verified to be appropriate using the LTAFLA program)

- **Enhanced Motor / Gearing Capability**
  - Motor capacity is now verified by testing
  - Actuator pullout efficiencies have now been corroborated by Texas Utilities testing
  - Other efficiency data is being solicitted
  - ComEd is identifying cases for which motor rating or actuator efficiencies should be derated from OEM values.
  - Voltage Exponent Increased based on Test Data

Major Changes to ComEd Position Papers resulting from Independent Review Comments

- Margin Review / Operability Criteria
  - All uncertainties (bias and random) are explicitly considered
  - Random uncertainties are statistically summed
  - Acceptance Criteria based on reliability and safety significance rather than percent margin

- Valve Factor Methodology
  - Valve Factor variability to be treated the same as other random uncertainties (e.g. equipment inaccuracy)
  - Some limitations on applicability and extrapolation have been added. These are based on the extent of the test data population.

Design Basis Assumptions

Presented by Paul Dietz

Difference between Design Philosophy and Margin/Operability Review Methodology

- The Margin Review / Operability Evaluation is a fluid process
  - Nominal values are constantly shifting.
  - As new information becomes available and new issues arise, the operability/margin review should be updated.
  - Part of the Margin Review process is to verify that the design window for an MOV remains valid.

- Design Basis Assumptions should be selected such that they are expected to be insensitive to new information.
  - The setpoint for the MOV should not need to be adjusted every time a diagnostic test is performed or other information becomes available.

Design Basis Values Used in Establishing Target Thrust Windows

Design Basis Parameters are set to conservative, but not necessarily bounding values. These parameters include:

- valve factor
- stem friction coefficient
- rate of loading factor
- inertia factor
- unwedging factor

ComEd

Margin in Design Basis Target Thrust Windows

Additional margin of approximately 20% to 30% is added to the calculated required thrust to account for uncertainties such as:

- ROL uncertainty
- Stem Factor Variability
- Diagnostic Equipment Inaccuracy
- Torque Switch Repeatability
- Valve Factor Uncertainty

Additional margin of approximately 10% to 15% is subtracted from the upper limits (motor/gearing capability and structural limits) to account for equipment inaccuracy and torque switch repeatability.

Grouping Methodology

Presented by Paul Dietz

Critical Attributes of a Grouping Method

- **Must be Predictive, not Reactive**
- **Must be Reasonably Stable**
- **Must be Statistically Significant**

Parameters for which Grouping Is Useful

- Valve Factor
- Rate of Loading
  - Stem lubricant appears to be the only parameter which significantly effects the average and standard deviation for ROL
- Stem Factor
  - Identification of anomalies
  - Certain valve design are more susceptible to indications of high stem factors (thrust losses)
  - The high stem factors are usually due to anti-rotation device design rather than stem friction coefficient

ComEd

Parameters for which Grouping Appears to Provide Minimal Value

Stem Friction Coefficient

- Analysis of ComEd data shows that the average and standard deviation for stem friction coefficient are independent of:
  - » valve type
  - » stem lubricant (of those used at ComEd stations)
  - » stem thread geometry
  - » load level

- ComEd will continue to review as-found, periodic test data to ensure that any trends in test data are identified

ComEd

Parameters for which Grouping Is not Useful

Since accurate valve specific values for these parameters are determined during static baseline testing, there is no need to perform grouping analysis on the following parameters:

- **Unwedging Factor**
- **Inertia Factor**

ComEd

Pressure Locking Evaluation for Byron and Braidwood Containment Sump MOVs

Presented by Paul Dietz

ComEd

Evaluation Team Members

Paul Dietz	Mechanical/Structural Engineering
Kevin Ramsden	Nuclear Fuels Services
Paul Hayes	MPR Associates
Chris Bedford	Braidwood MOV Program Lead
Kevin Passmore	Byron Support Engineering
Dan Skoza	Braidwood Support Engineering

ComEd

Evaluation Methodology
(preliminary results)

- Motor/Gearing Capability evaluated at degraded voltage and 0.15 stem friction coefficient

- Roark and Young used to analyze wedge as circular plate fixed in the center and free on the edges to determine opening forces.

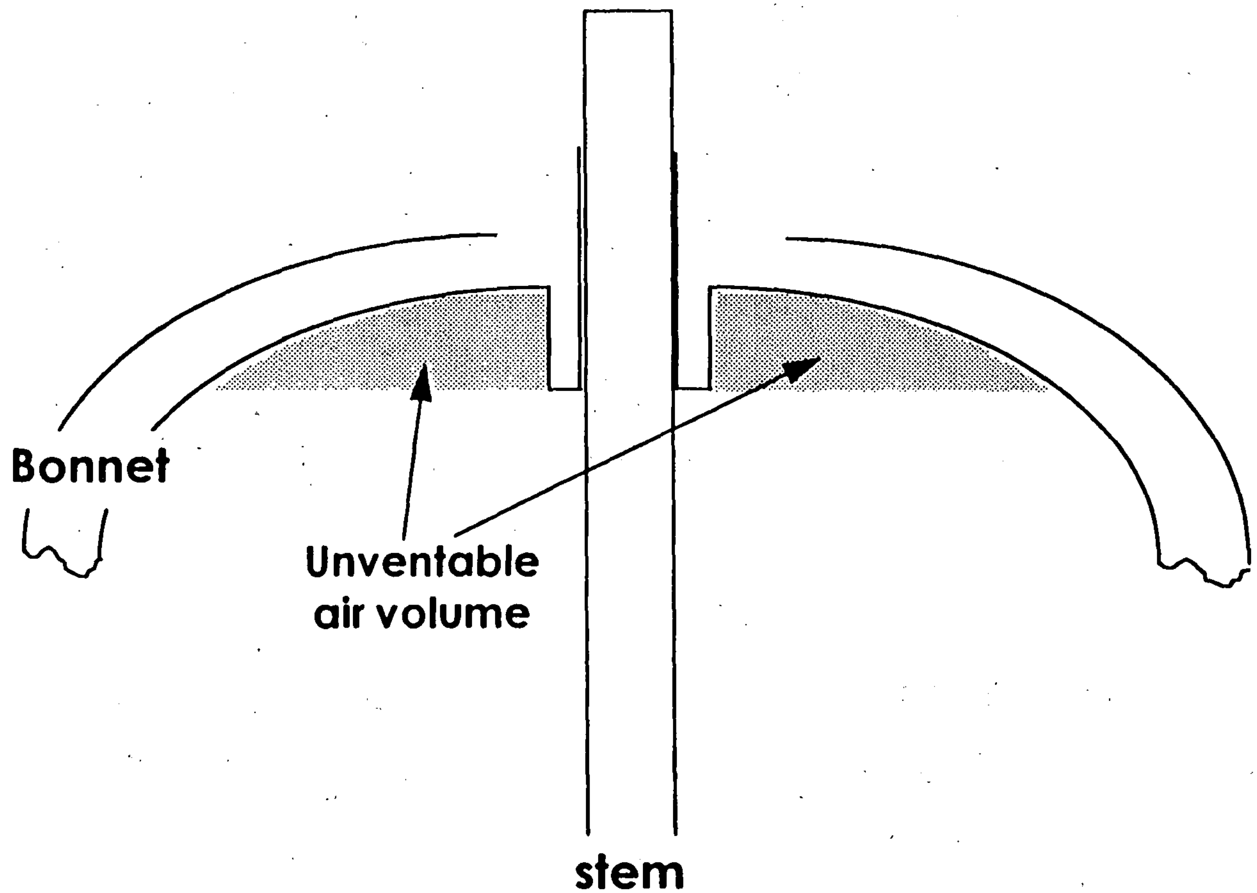
- 3-D Heat Transfer Model used to calculate the steady state temperature in the valve bonnet.

ComEd

SI-8811 Minimum Capability (preliminary results)

Maximum Pullout including measurement inaccuracy	22,717 lbf
Minimum MGC at degraded voltage and elev. temperature	77,375 lbf
Minimum Available Capability	54,658 lbf
Maximum Bonnet Pressure at Minimum Capability	250 psig

Borg-Warner Valve Bonnet Design



Unventable Air volume is calculated to be approximately 3% of trapped volume.

Correlation between Temperature Increase and Bonnet Pressure (preliminary evaluation)

- A temperature increase of 80 degrees Fahrenheit would be required to collapse a 2.5% air volume.

- This would only result in a 100 psid increase to the bonnet pressure.

- A detailed 3-D heat transfer analysis indicates that the maximum expected increase in the bonnet fluid temperature is only 35 degrees Fahrenheit.

Description of 3-D Heat Transfer Model
(preliminary evaluation)

- RWST Temperature of 95° F
- Accident Containment Sump Peak Temp. of 250° F (suction line slopes to valve)
- Mass of Valve 8900 lbs.
- Not modeled:
  - Valve enclosure
  - heat transfer from assembly
  - heat loss to containment fluid prior to reaching MOV
  - valve packing leakage
  - T-head clearance
  - actuator hammer blow

ComEd

Conclusion
(preliminary evaluation)

The postulated pressure locking phenomena is considered to be unlikely. Continued plant operation is justified pending long term resolution of this issue.

ComEd Valve Factor Methodology and Statistical Analysis Results

Presented by Brian Bunte

ComEd

ComEd Valve Factor Grouping Criteria and Valve Factor Statistical Analysis

- Used for selecting Design Valve Factors for all MOVs

- Used for determining Operability Valve Factors for MOVs which have not been DP Tested

Valve Factor Values used in Margin Review / Operability Evaluations

DP Tested MOVs:

- Nominal Valve Factor is measured value
- Uncertainty to allow for measurement inaccuracy and the potential change in valve factor over time

Non-DP Tested MOVs:

- Nominal Valve Factor is average for group
- Uncertainty based on measured valve-to-valve variability for valve group (@ 2 sigma)

ComEd

Valve Factor Methodology

ComEd has adjusted its valve factor methodology recently.

The revised valve factor method is designed to be consistent with the new Margin Review / Operability Evaluation Methodology.

A nominal and a conservative (2 sigma) valve factor are determined for untested MOVs. (The previous method was based on using a single conservative valve factor value.)

Other changes suggested by MPR concerning extrapolation and applicability have also been incorporated.

GENERAL FORM OF VALVE FACTOR RELATIONSHIP WITH TEST DP AND VALVE SIZE

ComEd Methodology was first suggested by a detailed review of Valve Factors from EPRI Testing

ComEd found that the Valve Factors typically decreased with Size and DP for a Vendor/Pressure Class Group

$$VF_{class}^{vendor} \Rightarrow VF_0 - \alpha\ Size - \beta\ DP_{test}$$

ComEd

Test Data Used in Valve Factor Analysis

- EPRI Test Data
  - Accurate, on-line measurement of thrust and DP
  - Multi-point DP data
  - Limited population of valves
- ComEd Test Data
  - Wide range of DP loads
  - Large population of valves
  - DP data not collected on-line
  - Thrust data accuracy not as high as for EPRI data
- Other Utility Test Data
  - Characteristics similar to those of ComEd data
  - Less access to plant records makes outlier review difficult

ComEd

VF Measurement Inaccuracy

VF measurement inaccuracy results from:

- **DP and LP Measurement**
- **Thrust Measurement**
- **Static to DP Test Correlation**

This random inaccuracy causes the calculated valve to valve variability for valve factor to be greater than it actually is.

$$VF\,Variability_{calculated} = \sqrt{\left(VF\,Variability_{actual}\right)^2 + \sum_{measurements}\left(Inaccuracy\right)^2}$$

ComEd

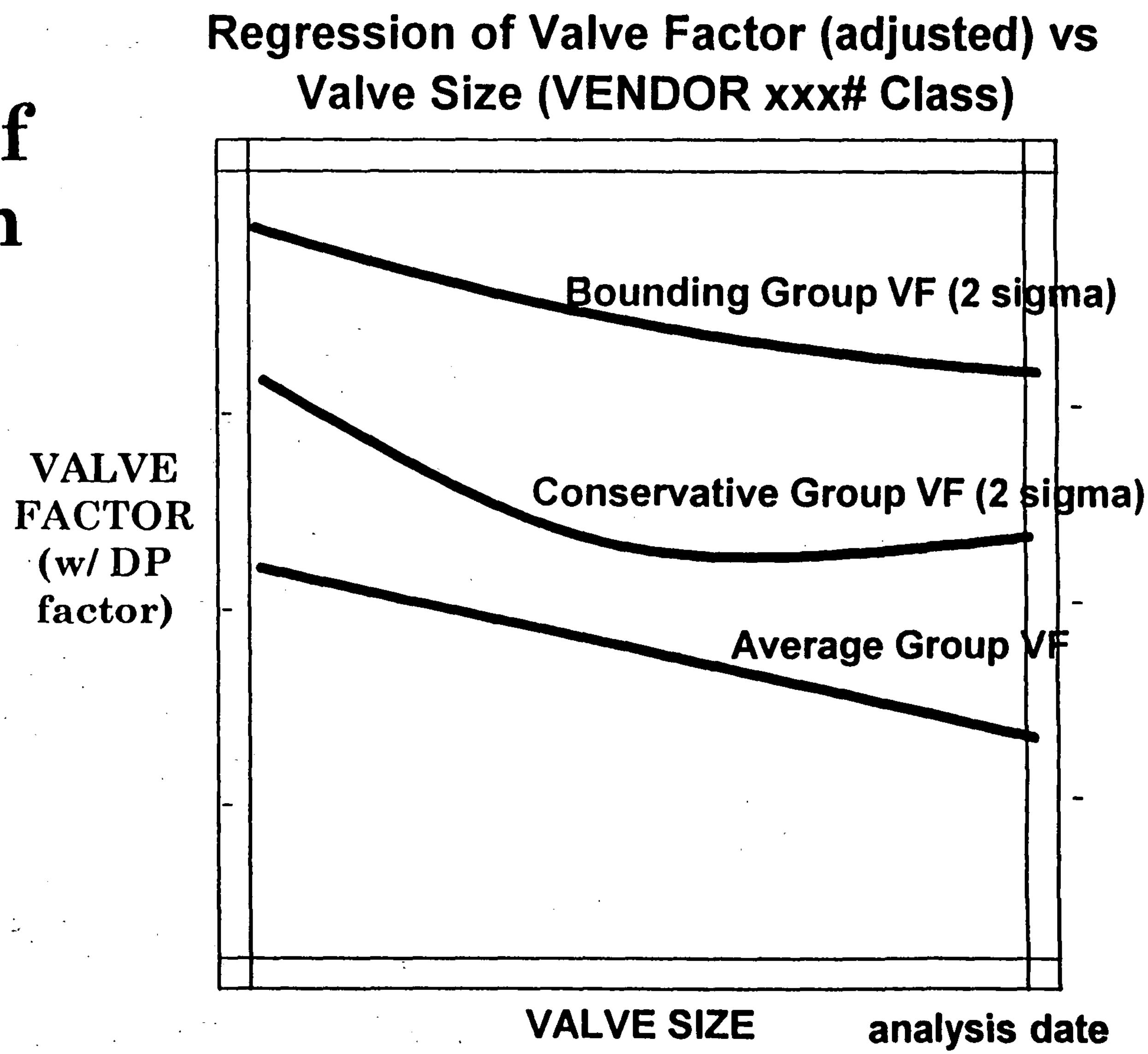
Valve Factor Equation and Sources of Inaccuracy

$$VF = \frac{\left(MRT_{DP\,Test} - Run_{DP\,Test}\right) - \left(C11_{static} - Run_{static}\right) - \frac{\pi}{4} D_{stem}^2 \left(LP_{DP\,Test}^{close} - LP_{DP\,Test}^{open}\right)}{\frac{\pi}{4} D_{seat}^2 \times DP_{test}}$$

- **Thrust measurement accuracy ($MRT_{DP\ test}$ - $Run_{DP\ test}$) due to Calibration accuracy (~9%)**
- **Other thrust measurement accuracy effects**
  - **Noise**
  - **Cyclic Loading (yoke oscillation)**
- **DP measurement accuracy (~10%)**
- **Potential Valve Condition Load ($C11_{static}$ - Run_{static}) change between static and dynamic tests**

ComEd

Example of Regression Output



ComEd

Empirical Methodology based on Test Data and Engineering First Principals

Statistical (regression) Analysis has been applied to ComEd, EPRI, and other utility data to model valve factor

Average Group Valve Factor:

Most likely (average) value for valve factor (after DP factor adjustment)

Bounding Group Valve Factor:

97.5% (2 sigma) Confidence Bound on valve factor for all valves

Conservative Group Valve Factor:

97.5% Confidence Bound on Valve Factor for predictable valves (no static indications of a potentially high valve factor

DP Factor:

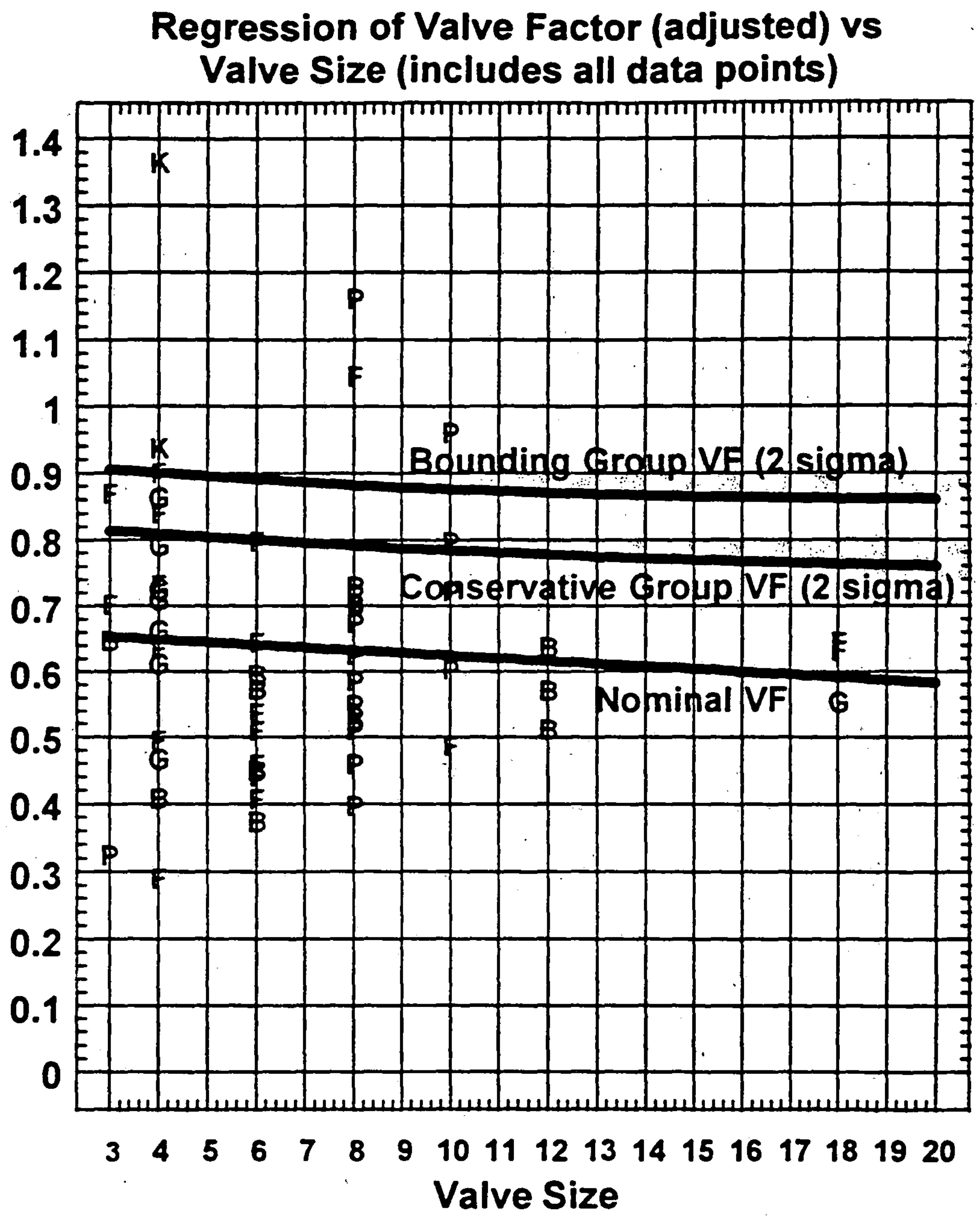
Estimated change (reduction) in valve factor per psid increase in the design DP

Static Indicators of High Valve Factors

- Static indications of potential high valve factors are being validated. These include:
  - unusual unwedging factors
  - high valve condition loads (a.k.a. parasitic effects)
  - anomaly factors (IP)
  - maintenance practices
  - service conditions
  - orientation
  - combinations of the above.

- ComEd is putting in place a program based on static testing and maintenance history that will be used to identify valves for which the Bounding Group Valve Factor must be considered.

Final Valve Factor Regression Curve



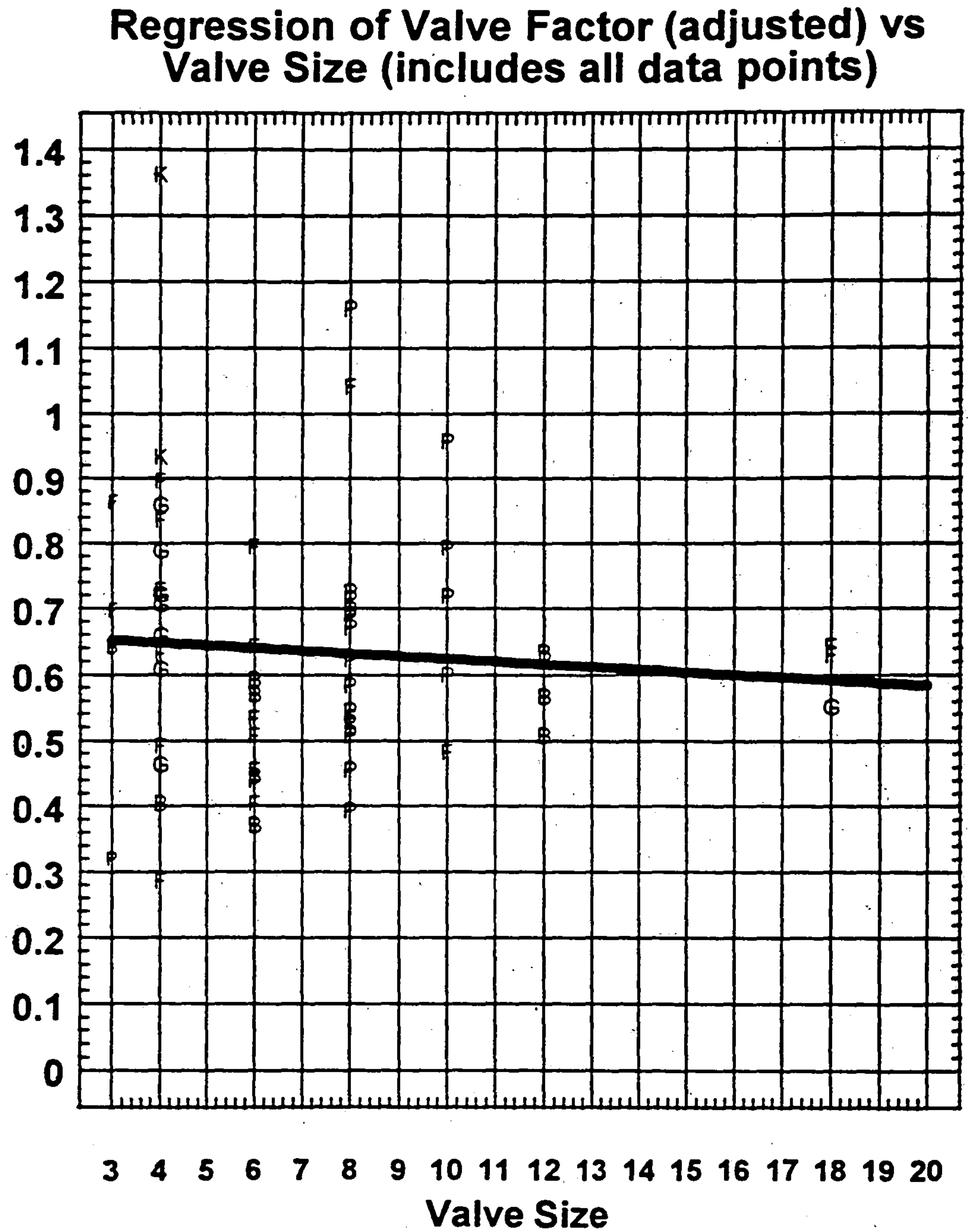
Selection of Data Sets for Determining the Nominal Valve Factor Regression Curve

- **Low DP load data is included in determining the nominal valve factor line**
  - **The inaccuracies are random and do not bias the average.**

ComEd

Developing a Valve Factor Regression Curve

Plotting the Nominal VF Line



ComEd

Plotting the Bounding and Conservative Group Valve Factors

The Regression Equation for confidence bounds is:

$$VF_{\text{bound}}(size) = VF_{\text{nominal}} + t\sqrt{\psi^2 + \phi^2(size - k)^2}$$

- t represents the "Student's T" value corresponding to the desired confidence level and the size of data set
- ϕ represents the uncertainty in the regression curve slope (k is the average valve size for the test sample)
- ψ (standard error of estimate) represents the standard deviation for valve to valve variability (and measurement inaccuracy)

ComEd

Selection of Data Sets for Determining the Bounding Valve Factor Regression Curve

Low DP load test data is excluded in measuring the ψ value for valve to valve variability

- Measurement inaccuracy for this data is very high and would artificially inflate the valve to valve variability terms.

Data points for valves with static test indications of high valve factors

- Are included in measuring the ψ value for the Bounding Group Valve Factor.

Effect of DP Load on Valve Factor Accuracy

- Tests for which the expected DP load exceeds 4000 lbf are designated High DP Load Tests by ComEd.

- Valve Factor inaccuracy due to noise, cyclic loading, and valve condition load inconsistency are generally not significant for high DP load tests.
  - These sources of inaccuracy are much smaller than the thrust calibration inaccuracy when large thrust values are being measured.
  - Consequently, the overall inaccuracy for valve factors from high DP load tests is typically within +/- 20%.

- For low DP Load tests, the valve factor inaccuracy due to noise, cyclic loading, and valve condition load consistency often exceeds 40% of the measured DP load.

ComEd

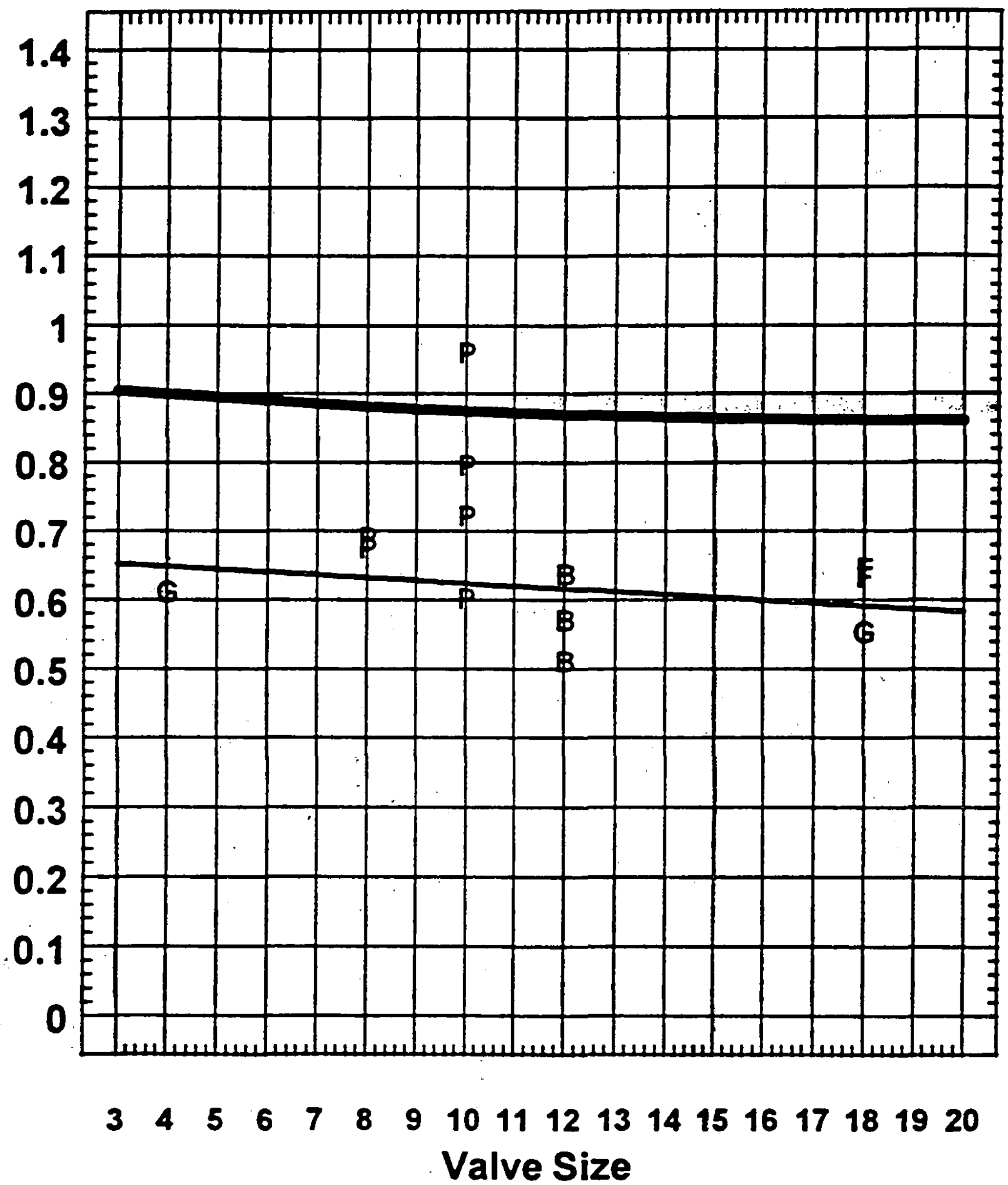
Basis for Defining Low DP Load Tests as less than 4000 lbf DP Load (ComEd White Paper 166)

- The required thrust for MOVs with DP Loads less than 4000 lbf is relatively insensitive to valve factor.
- Valve Factors for globe valves which should always equal approximately 1.0 vary significantly from 1.0 for DP loads below 4000 lbf.
- When Valve Factor variability is plotted against DP Load, the amount of scatter stabilizes after 4000 lbf.
- Only approximately one-half of the DP test data is excluded by this criteria.

Developing a Valve Factor Regression Curve

Plotting the Bounding VF Curve

Regression of Valve Factor (adjusted) vs Valve Size (excludes low DP load data points)



ComEd

Selection of Data Sets for Determining the Conservative Group Valve Factor Regression Curve

Low DP load test data is excluded in measuring the ψ value for valve to valve variability

Data points for valves with static test indications of high valve factors

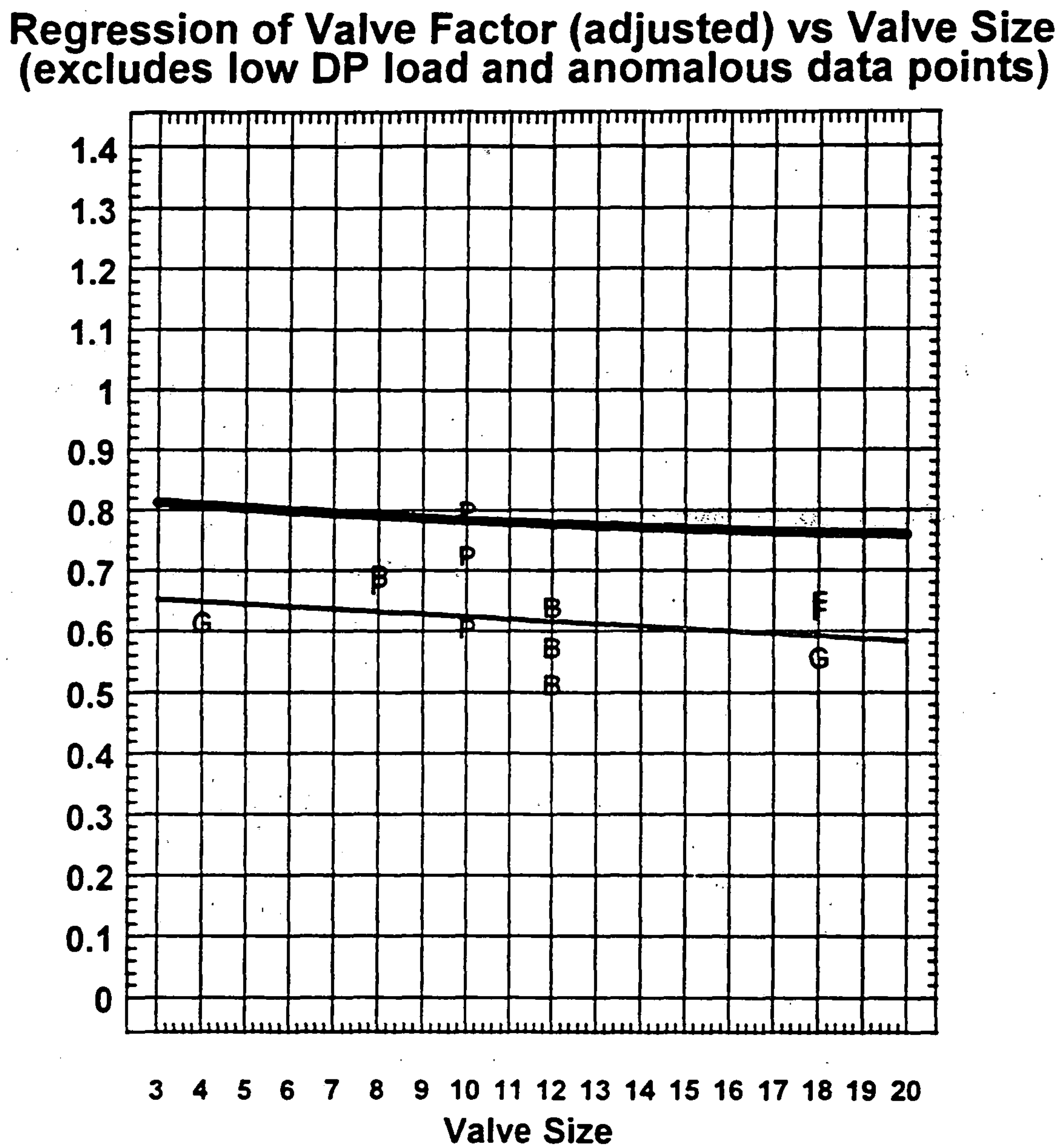
- Are excluded from measuring the ψ value for the Conservative Group Valve Factor

Valves with extremely low valve factors

- Are excluded from measuring the ψ value for the Conservative Group Valve Factor if they are the dominant contributors to the valve factor confidence band width.

Developing a Valve Factor Regression Curve

Plotting the Conservative Group VF Curve



ComEd

Developing a Valve Factor Regression Curve

Determining the DP Factor

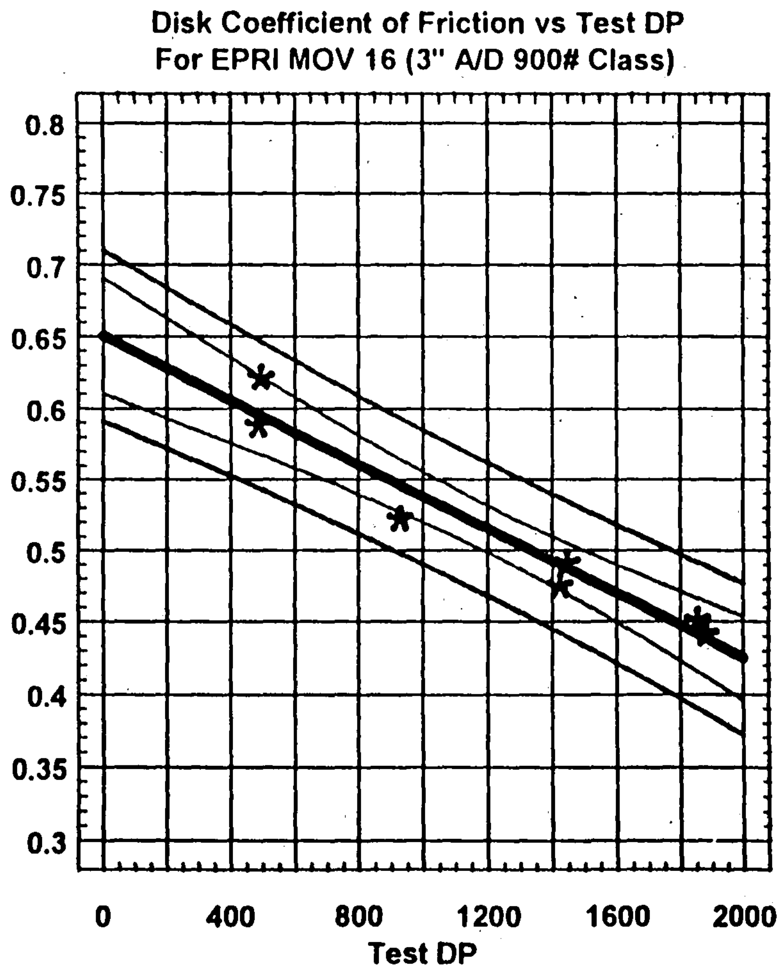
- Regression analysis are performed for the quantity [$VF_{measured}$ + \$ x DP_{test}] as a function of valve size for different values of \$.
- The \$ value which minimizes the variability of the data about the regression line is the best estimate for the DP factor (\$).
- Inaccuracy in selecting the DP factor would result in additional random uncertainty (scatter between the measured values and predicted values).
- The standard error of estimate is a measure of the variability for a regression analysis (equivalent to the standard deviation for scalar statistical analysis).

EXAMPLE:

DP Factor (\$)	Standard Error of Estimate
0.00000	0.2071
0.00005	0.2016
0.00010	0.2003
0.00015	0.1981
0.00014	0.1975

ComEd

Example of Valve Factor Dependence on Differential Pressure (EPRI MOV # 16)



ComEd White Paper 170 provides an analysis of the remaining EPRI Test Data and shows similar DP dependence for all other EPRI MOVs.

ComEd

Methodology Uses a Linear Model with respect to Valve Size and DP

- Inherently Conservative since any inaccuracy in assuming a linear model will manifest itself in wider confidence bounds

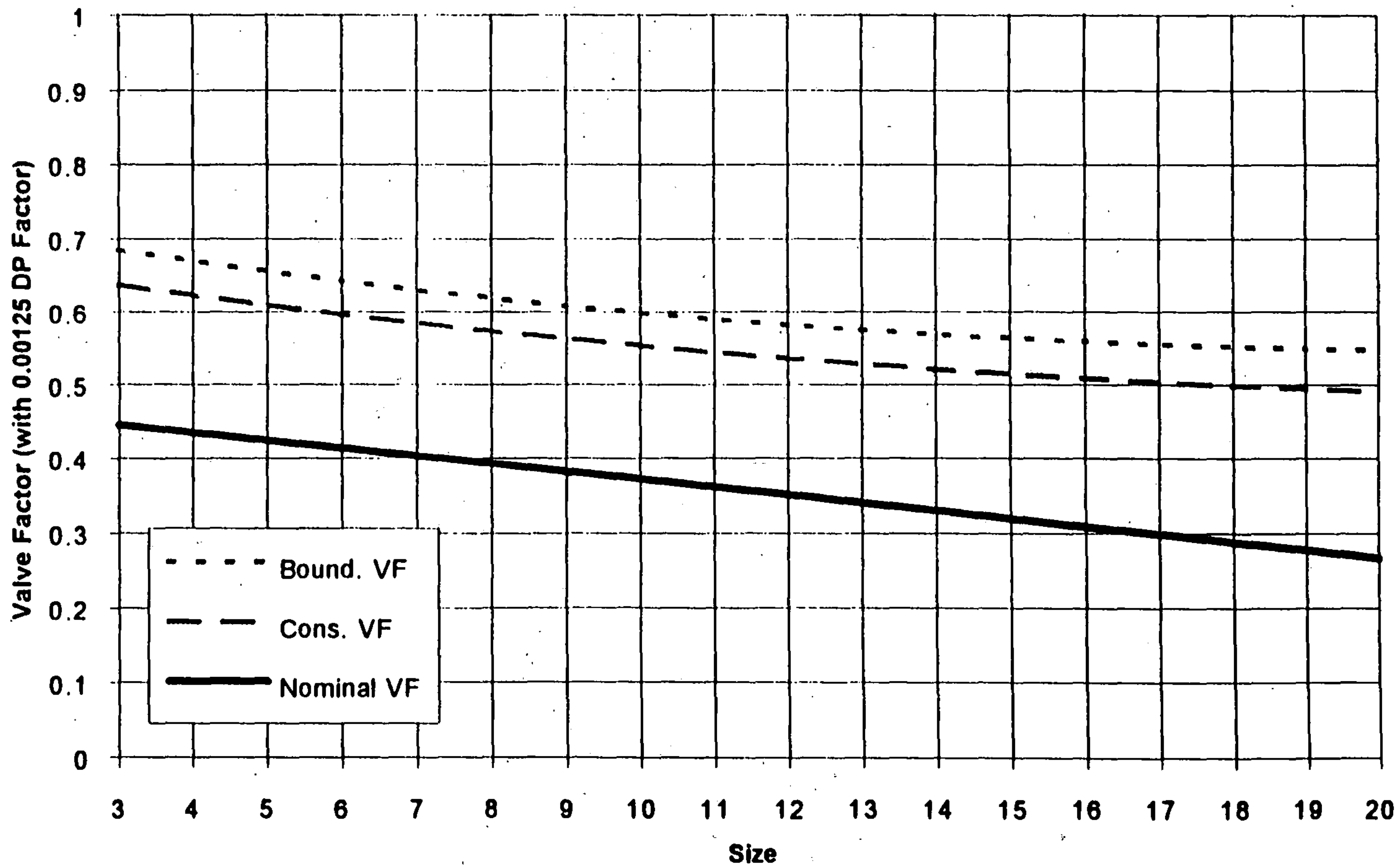
- Non-Linear Relationships were investigated and did not decrease the confidence band widths (data scatter)

ComEd

Anchor/Darling Flex-Wedge Gate Valve Example (150 # Class)

PRELIMINARY

PRELIMINARY

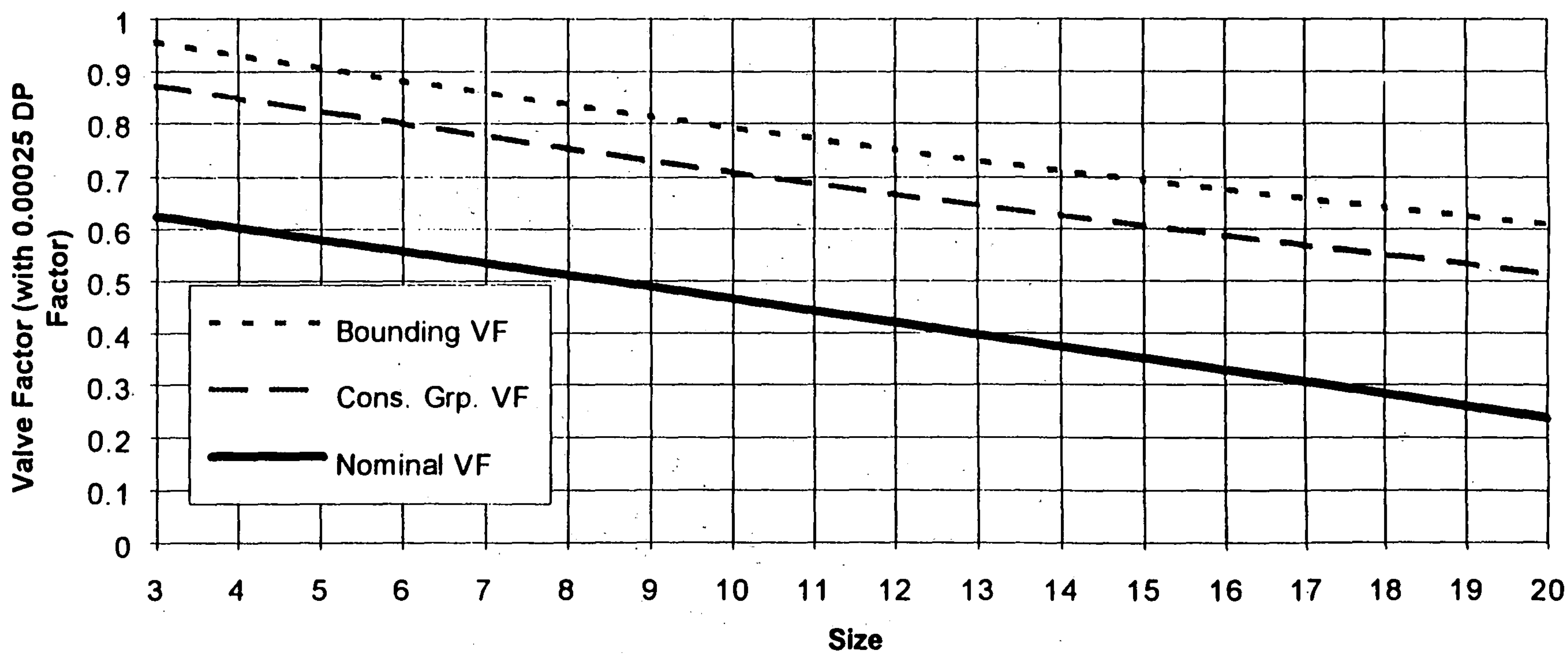


ComEd

Anchor/Darling Flex-Wedge Gate Valve Example (300 # Class)

PRELIMINARY

PRELIMINARY

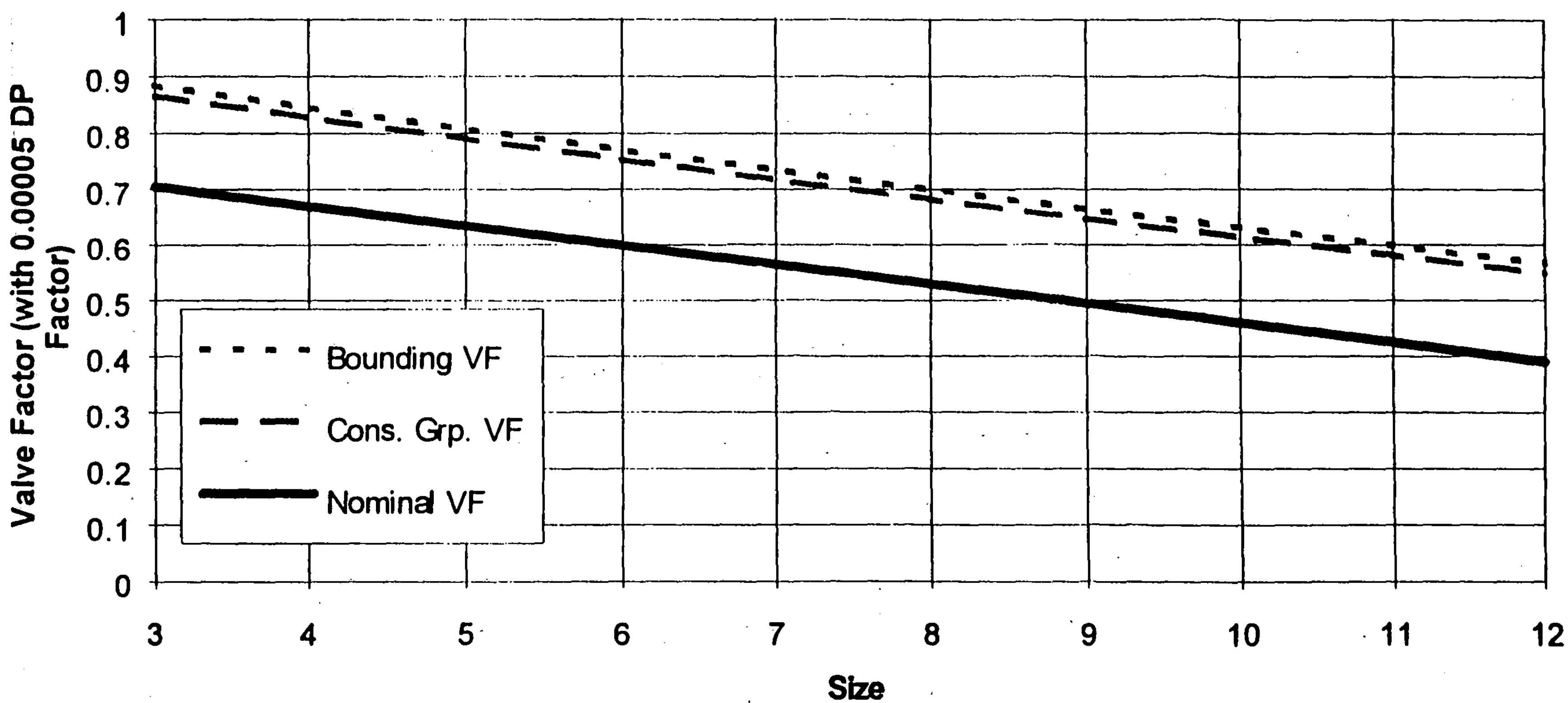


ComEd

Anchor/Darling Flex-Wedge Gate Valve Example (900 # Class)

PRELIMINARY

PRELIMINARY

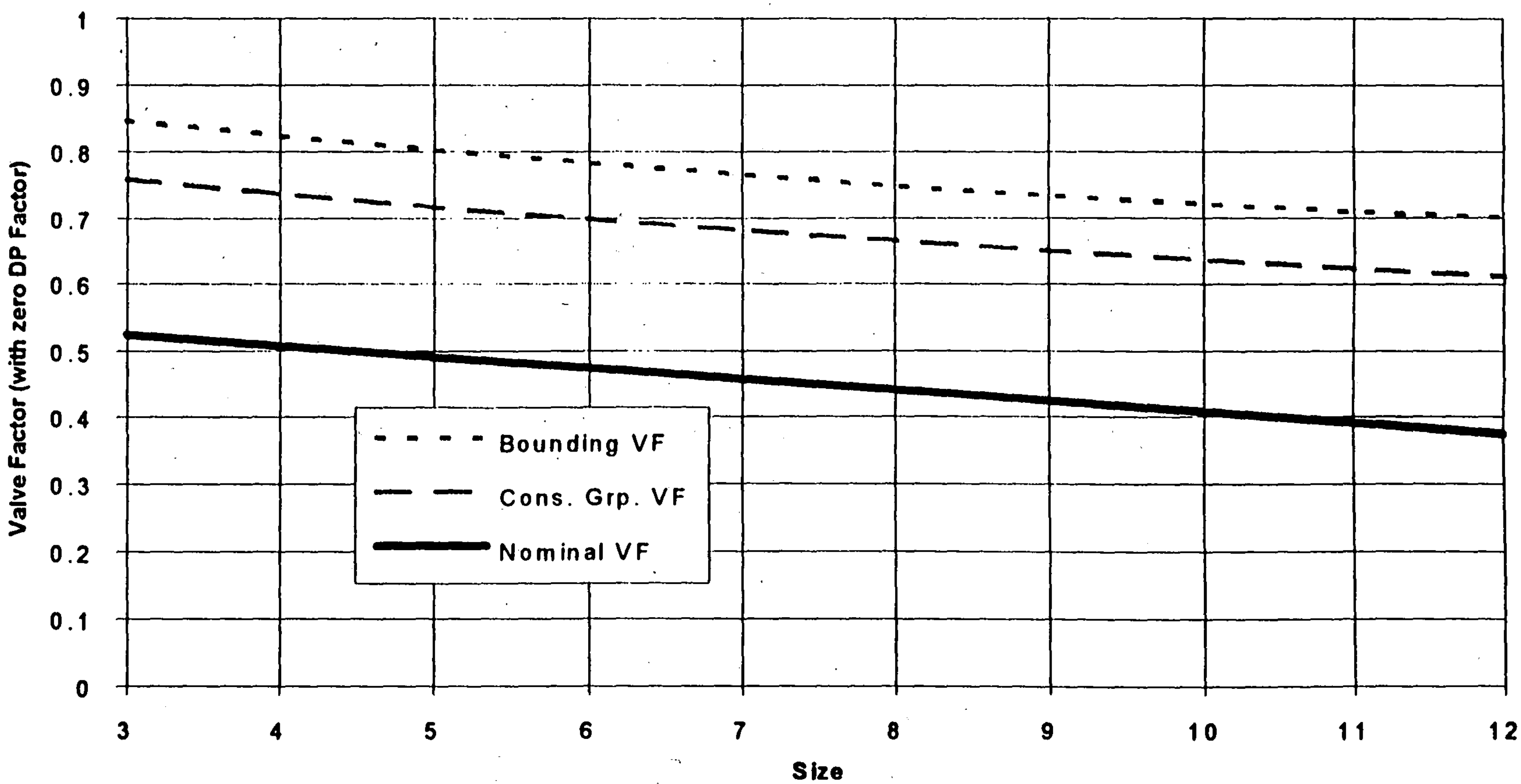


ComEd

Anchor/Darling Double-Disk Gate Valve Examples (cold water, all classes)

PRELIMINARY

PRELIMINARY

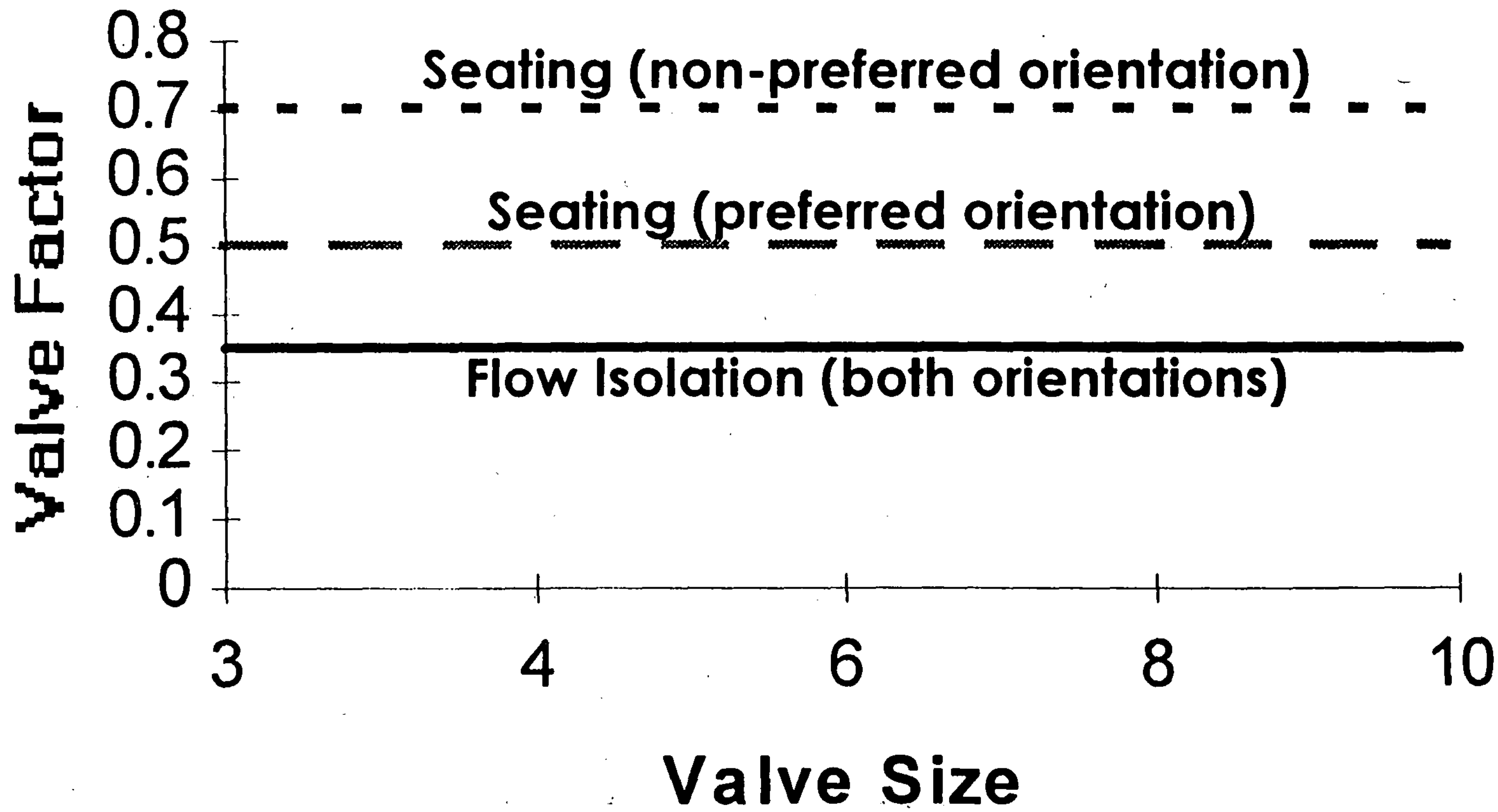


ComEd

PRELIMINARY

Anchor/Darling Double-Disk Gate Valve Examples (hot blowdown, 900# classes)

PRELIMINARY

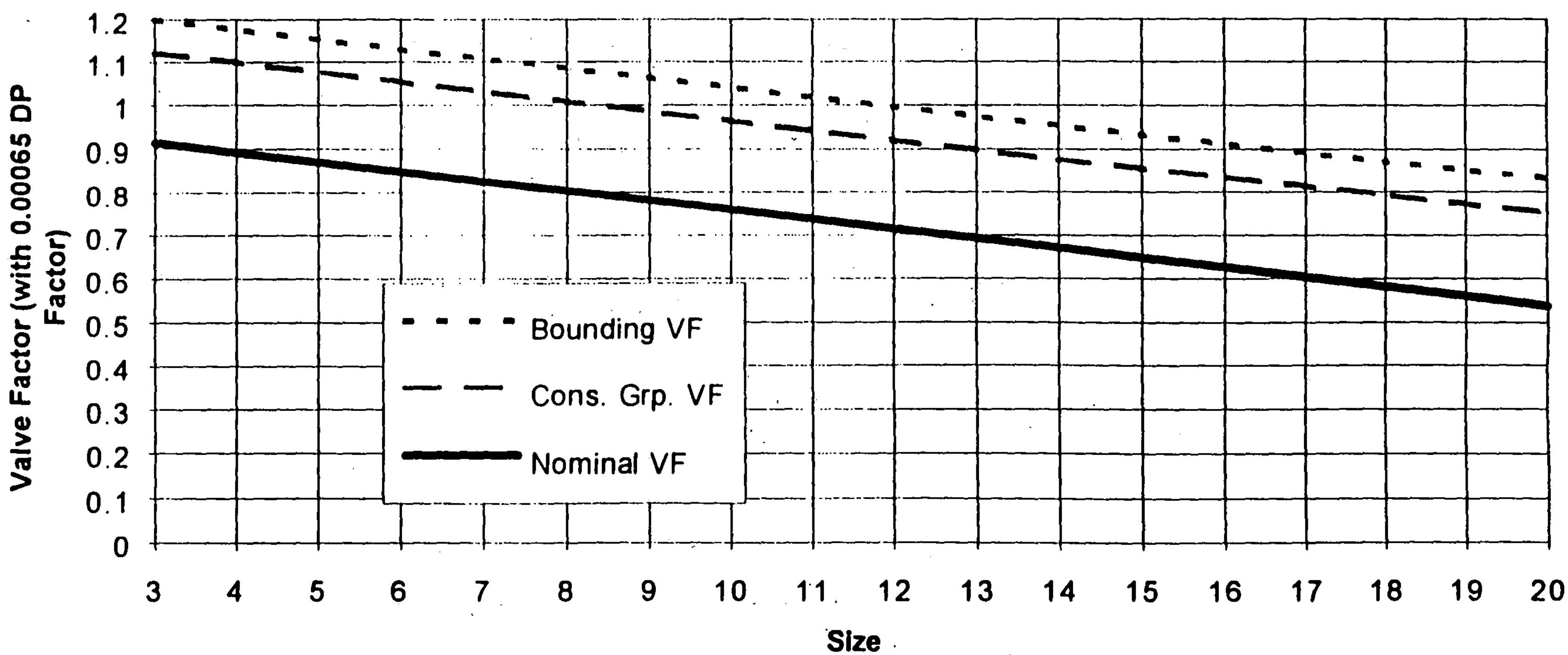


ComEd

Crane Flex-Wedge Gate Valve Examples (300 # Class)

PRELIMINARY

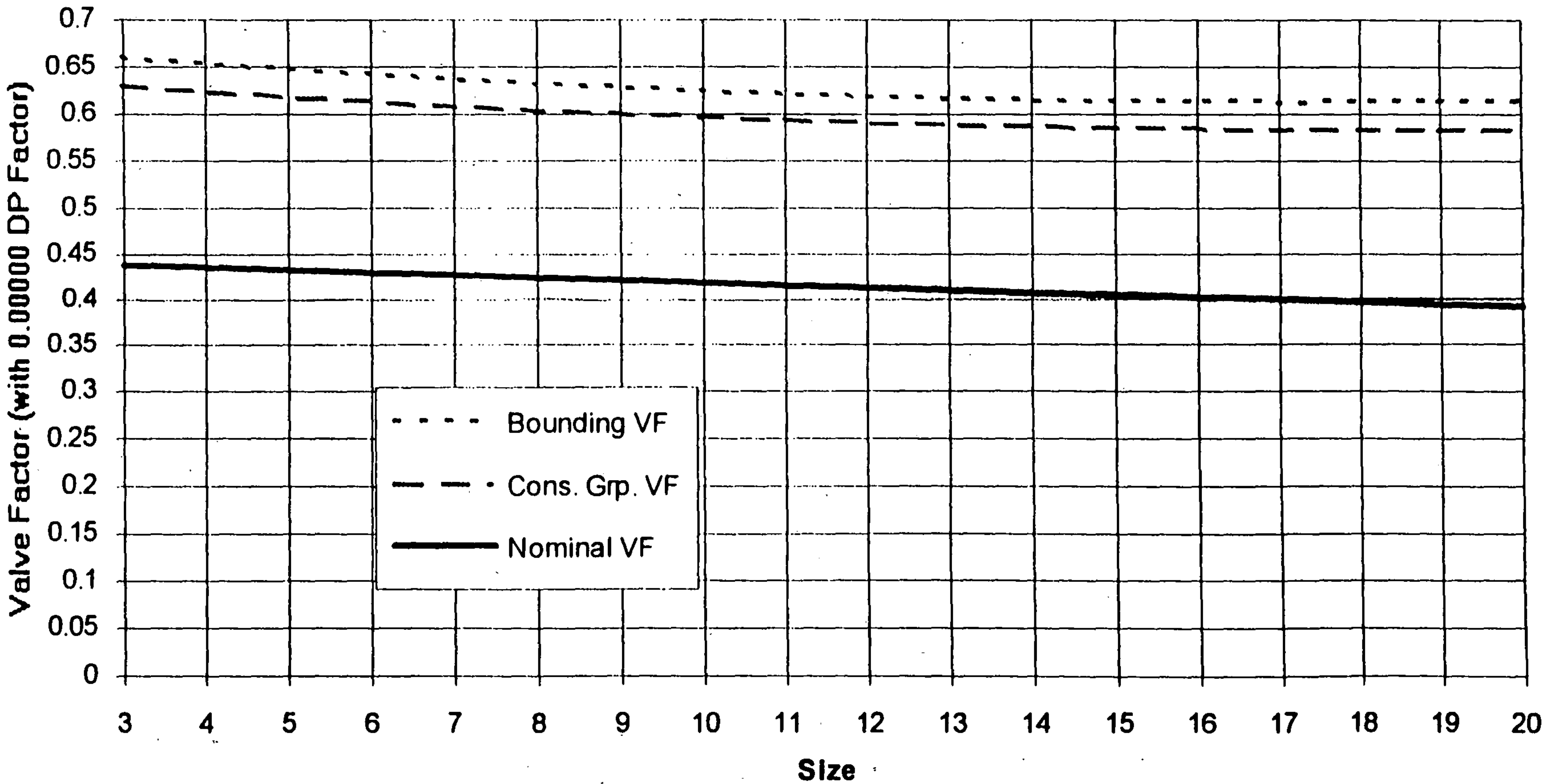
PRELIMINARY



Crane Flex-Wedge Gate Valve Examples (900 # Class)

PRELIMINARY

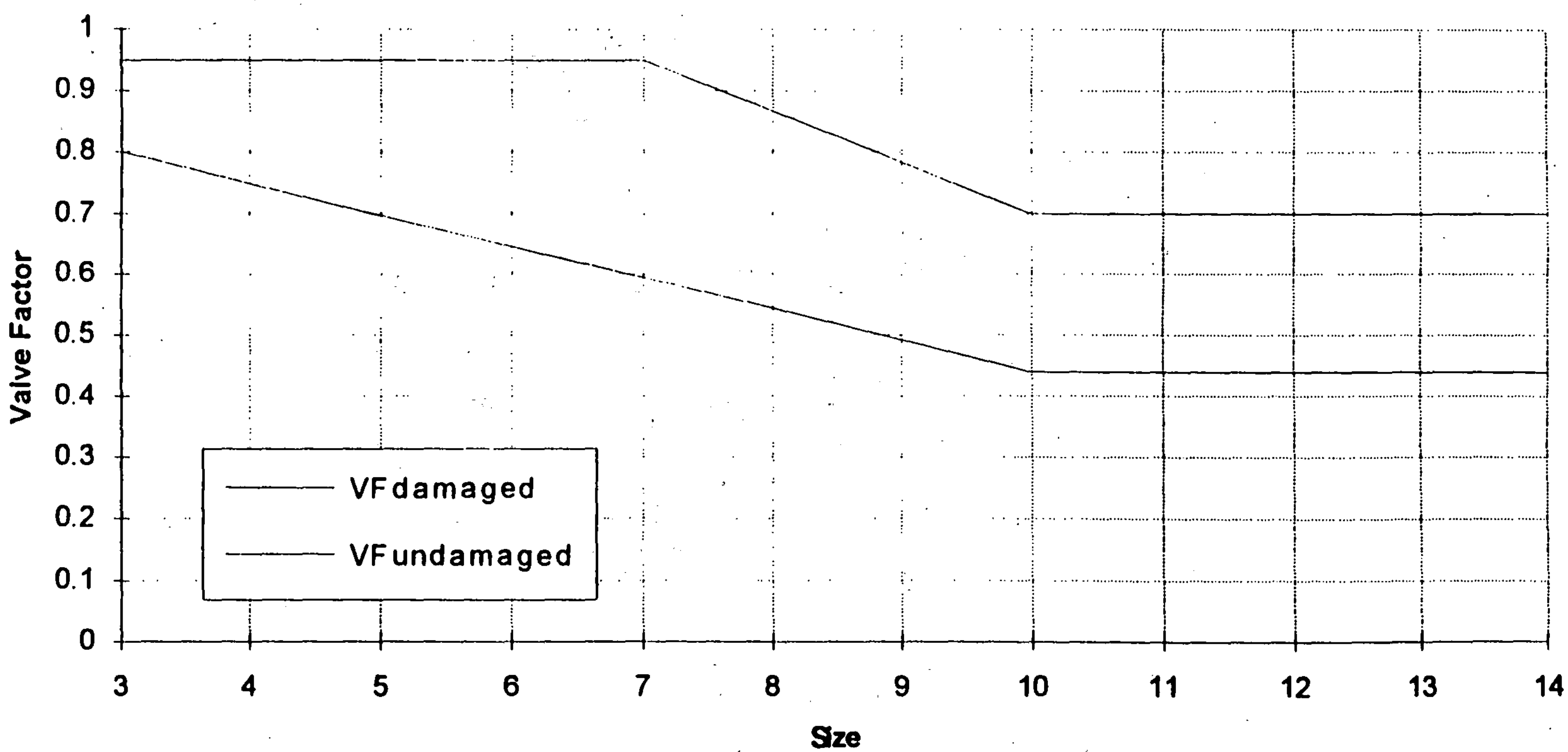
PRELIMINARY



PRELIMINARY

Crane Flex-Wedge Gate Valve Example (900# Class Blowdown)

PRELIMINARY

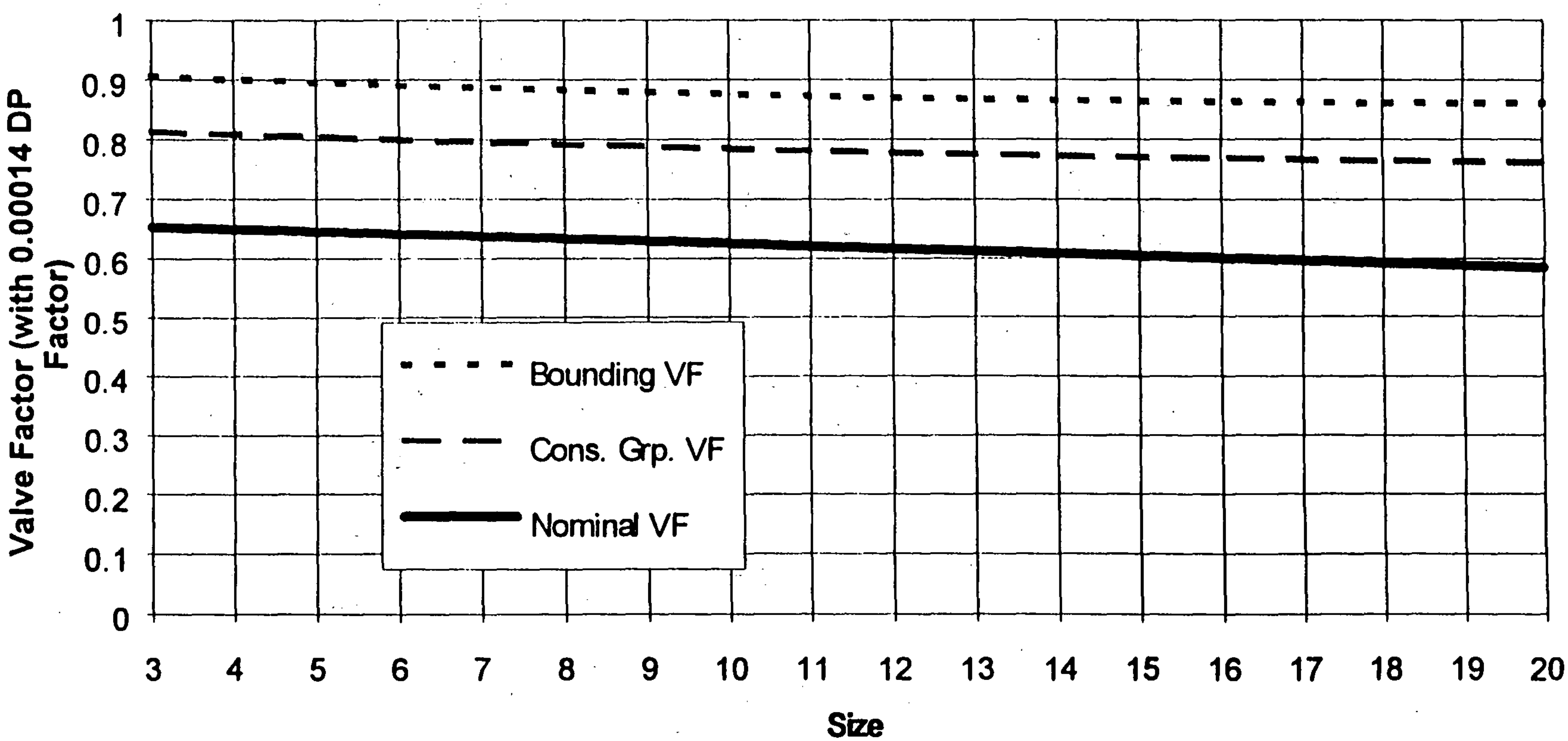


ComEd

PRELIMINARY

Powell Solid-Wedge Gate Valve Example (150# and 300# Classes)

PRELIMINARY



Valve Groups for Which Regression Analysis will not be Performed

Groups for which data is not available for a range of sizes

- Westinghouse pressure classes other than 1500# Class valves
- Velan pressure classes other than 150# Class valves

Untested Groups and Groups for which amount of Test Data is Insufficient to Perform Statistical Analysis

- Crane 150# Class valves
- WKM Double-Disk gate valves
- Copes-Vulcan Double-Disk gate valves
- Crane-Chapman Split-Wedge gate valves
- Aloyco Split-Wedge gate valve

Valve Specific Valve Factors

- To determine a nominal valve factor for an MOV from the regression curve, the average valve factor for the valve size is reduced by the quantity [β x DP_{design}]. To be conservative, the DP adjustment is limited to the DP Factor times the maximum DP from the test population.

- To determine a bounding valve factor, the static test is examined for high valve factor indicators. Depending on the results of this review, the worst case valve factor is set equal to either the Conservative Group Valve Factor or the Bounding Group Valve Factor reduced by the quantity [β x DP_{design}].

ComEd

Extension of Valve Factor Regression Curves to Untested Valve Sizes

- Interpolation of regression curves to intermediate untested valve sizes is allowed.

- Extrapolation of regression curves to valves significantly smaller than the smallest tested valve in the group is not appropriate.

- Extrapolation of regression curves to valves significantly larger than the largest tested valve is done by applying the valve factors for the largest tested valve size to the untested valve.
  - This is considered conservative since test data indicates that the valve factor for larger valve sizes is generally less than for smaller valves.

Valve Factor Equation Technical Basis

Presented by Brian Bunte

ComEd

ComEd Valve Factor Basis
Hard Seat Contact Valve Factor

- **Based on Maximum Thrust up to and including hard seat contact**

- **ComEd Valve Factor (White paper 131) methodology**
  - **Valve Condition Load is removed from apparent DP load**
  - **Stem Ejection Force variation is also removed**
  - **Methodology is insensitive to zeroing uncertainty**

$$VF = \frac{\left(MRT_{DP\,Test} - Run_{DP\,Test}\right) - \left(C11_{static} - Run_{static}\right) - \frac{\pi}{4} D_{stem}^{2}\left(LP_{DP\,Test}^{close} - LP_{DP\,Test}^{open}\right)}{\frac{\pi}{4} D_{seat}^{2} \times DP_{test}}$$

ComEd

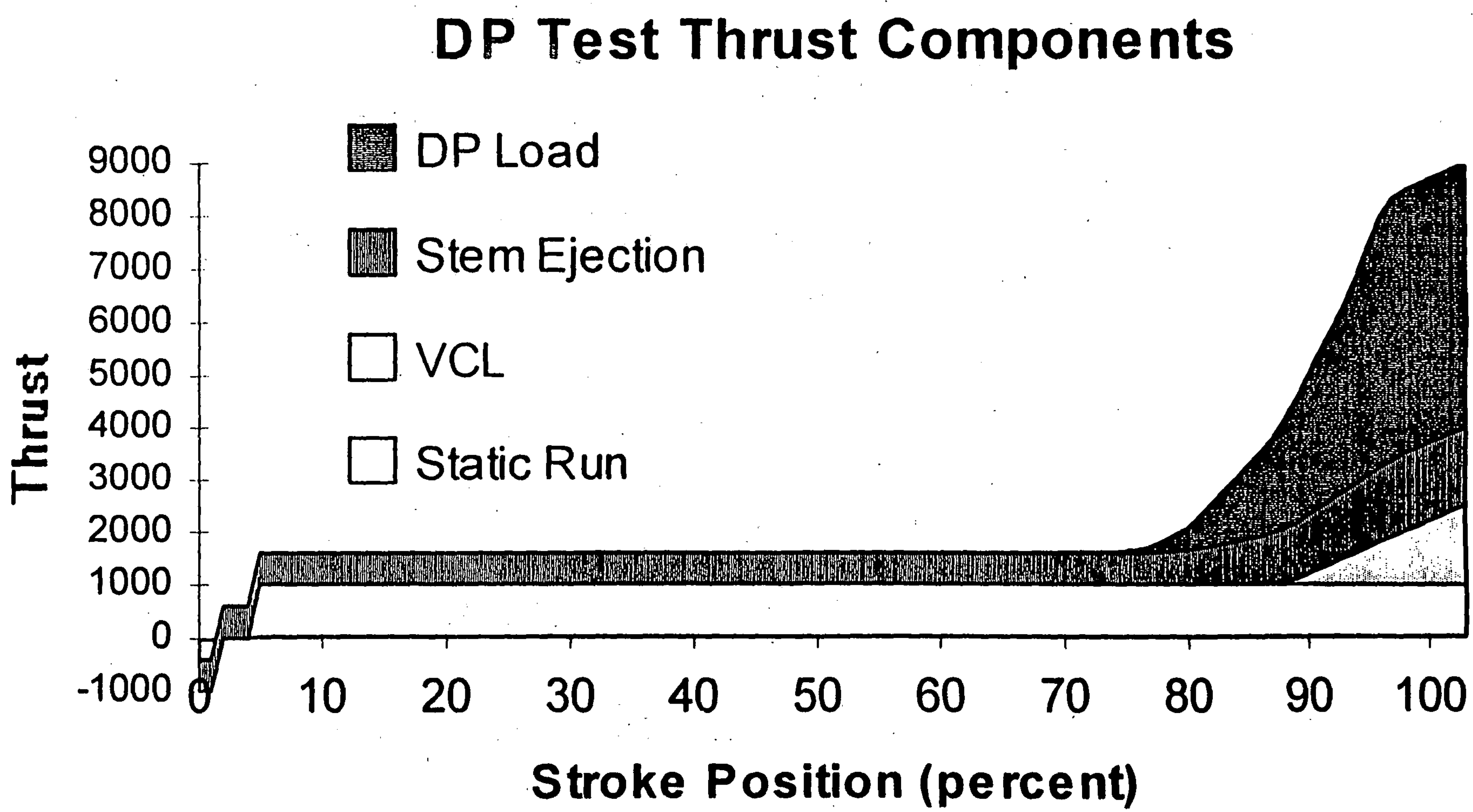
ComEd Valve Factor Basis
Hard Seat Contact Valve Factor

The ComEd Methodology for calculating Valve Factor is based on the Required Thrust for an MOV consisting of 4 independent effects.

- Static Running Loads (packing, disk & stem weight, etc.)
- Stem Ejection Force (a.k.a. Piston Effect)
- DP Load
- Valve Condition Load (static loads which occur at the end of the closing valve stroke)

These loads are considered to be independent of each other and are superimposed upon each other during the course of the MOV stroke as shown on the next slide.

ComEd Valve Factor Basis
Hard Seat Contact Valve Factor



ComEd Valve Factor Basis
Origins of Valve Condition Load

- VCL was first identified by reviewing globe valve DP tests
  - Many thrust traces for static tests are rounded at the end of the stroke.
  - This is believed to be the result of a "soft" seating effect. The stiffness of the valve seat / disk / stem / yoke assembly appears to gradually (over 50 to 300 ms) build up after seating for some valve designs.
  - Since hard seat contact for DP tests is marked at the end of rounding in the thrust trace, this soft seating effect would be treated as part of the DP load by the standard industry valve factor equation.
  - Consequently, the standard industry equation was frequently calculating valve factors significantly greater than 1.0 for globe valves under low DP load conditions.
  - Once the valve factor equation was adjusted to account for VCL, the valve factors for globe valves randomly varied about 1.0 for low DP load tests.

ComEd Valve Factor Basis
Valve Condition Load

- Gate valve static tests also show indications of Valve Condition Load.
- VCL is typically less than 400 lbf, but has been observed to be greater than 10,000 lbf on occasion.
- Some valve designs such as large Crane 900# Class valves appear to be more susceptible to high VCL values. However, the value of VCL can vary significantly for these groups.
- ComEd considers that this load should not be ignored by marking the point of seating at the beginning of the VCL effect on the static and DP traces.

ComEd Valve Factor Basis
Valve Condition Load

- Similarly, ComEd does not consider that the VCL should be ignored in the MRT equation while calculating valve factor using the standard industry equation and the thrust at the end of the VCL effect.

- On the other hand, ComEd does not consider it to be appropriate to double count the VCL by including it in the MRT equation while calculating valve factor using the standard industry equation and the thrust at the end of the VCL effect.

- The ComEd valve factor methodology is based on the theory that all loads which occur under static conditions also occur under dynamic conditions. For this reason, the VCL is included in the MRT equation, and the valve factor equation removes the VCL from the DP load.

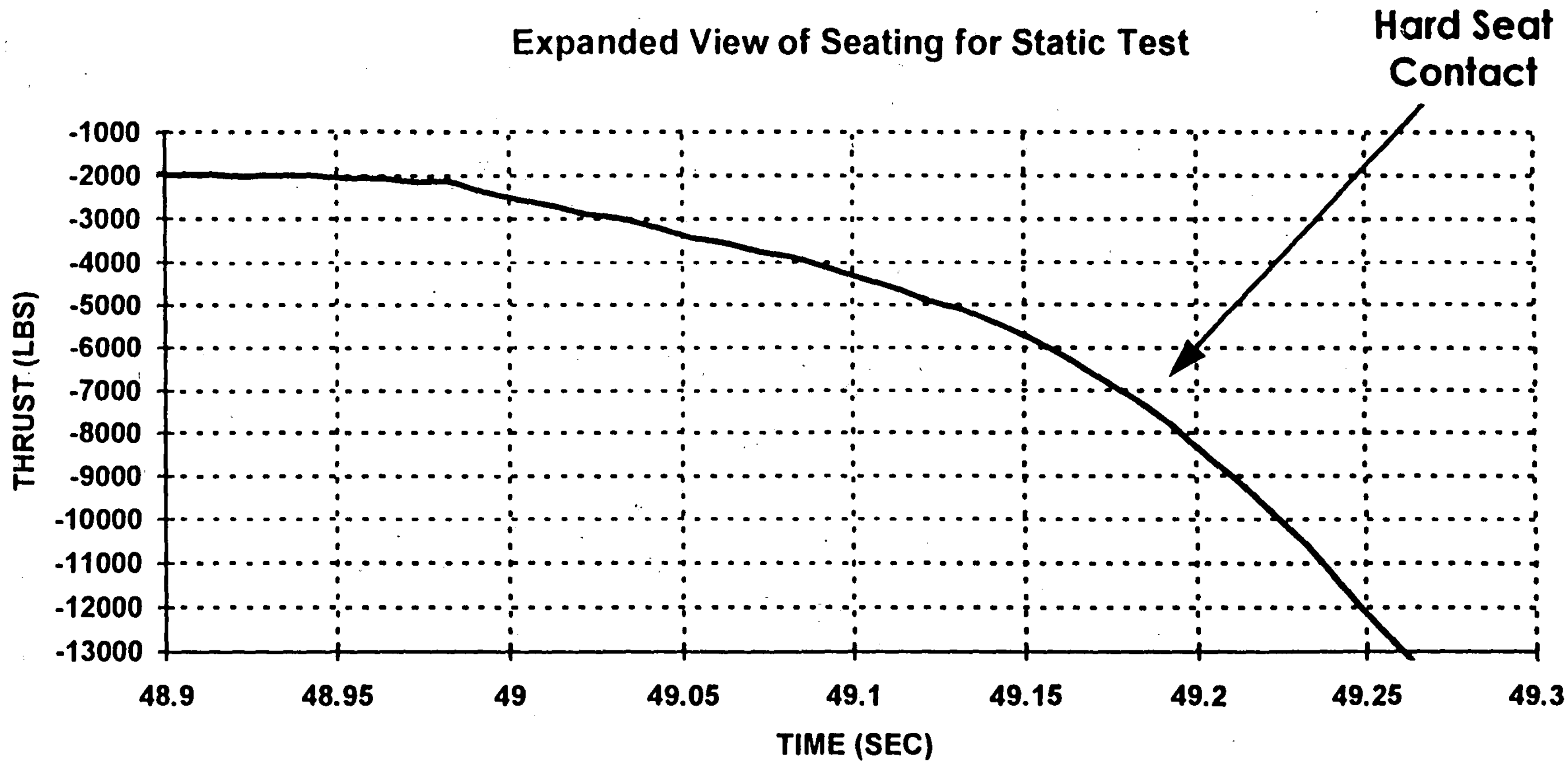
ComEd Valve Factor Basis
Valve Condition Load
(continued)

- A review of ComEd test data suggests that this assumptions is a very good first order approximation.
  - For MOVs which have a substantial valve condition load, the thrust profile on the DP traces often show loading between flow isolation and hard seat contact with is consistent with the valve condition load profile.

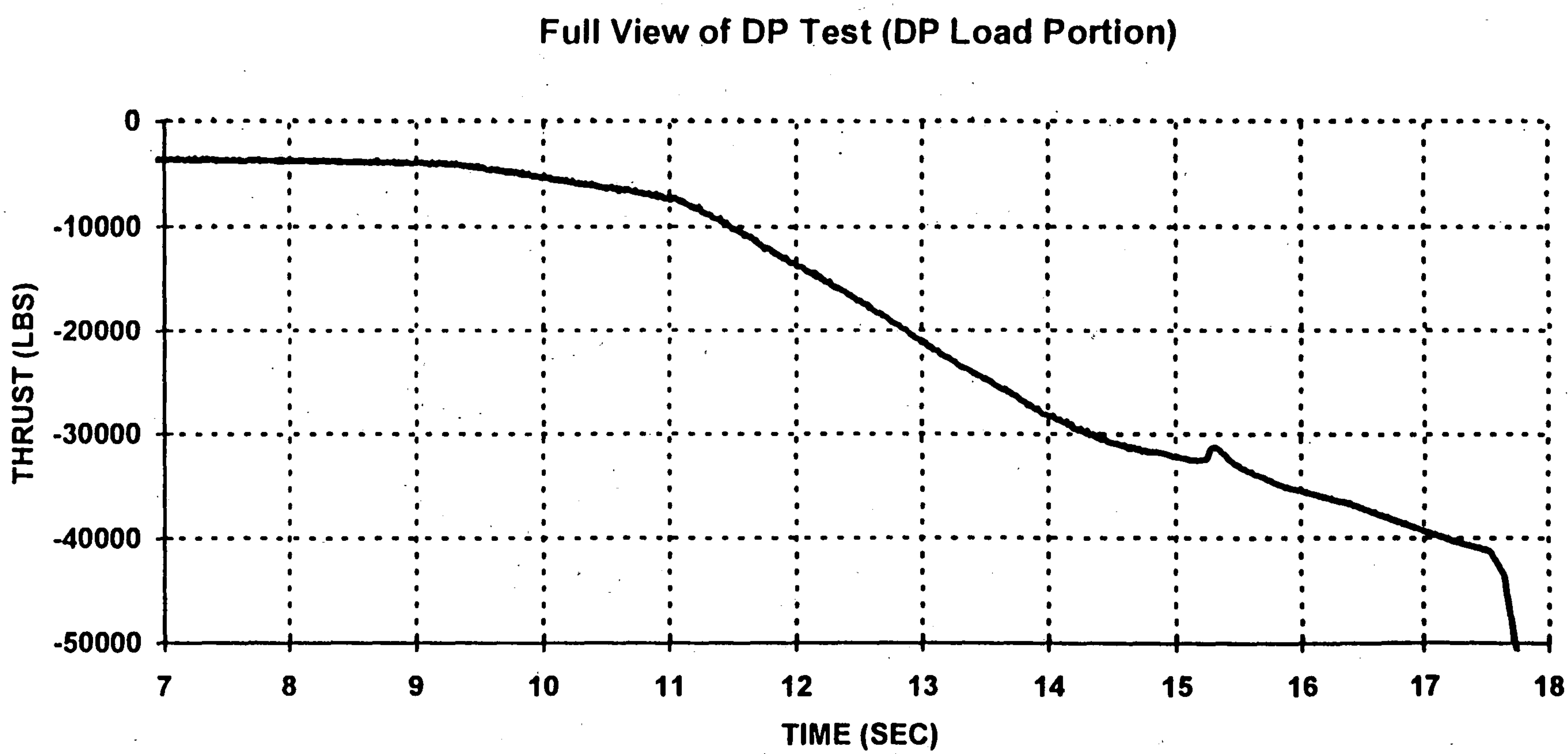
- The second order inaccuracy in assuming the valve condition load is the same under dynamic and static conditions should result in greater variability in the range of measured valve factors.

- This inaccuracy will manifest itself by increasing the magnitude of the 2 sigma valve factor value. This value is used in the margin review / operability evaluation method.

ComEd Valve Factor Basis
Valve Condition Load

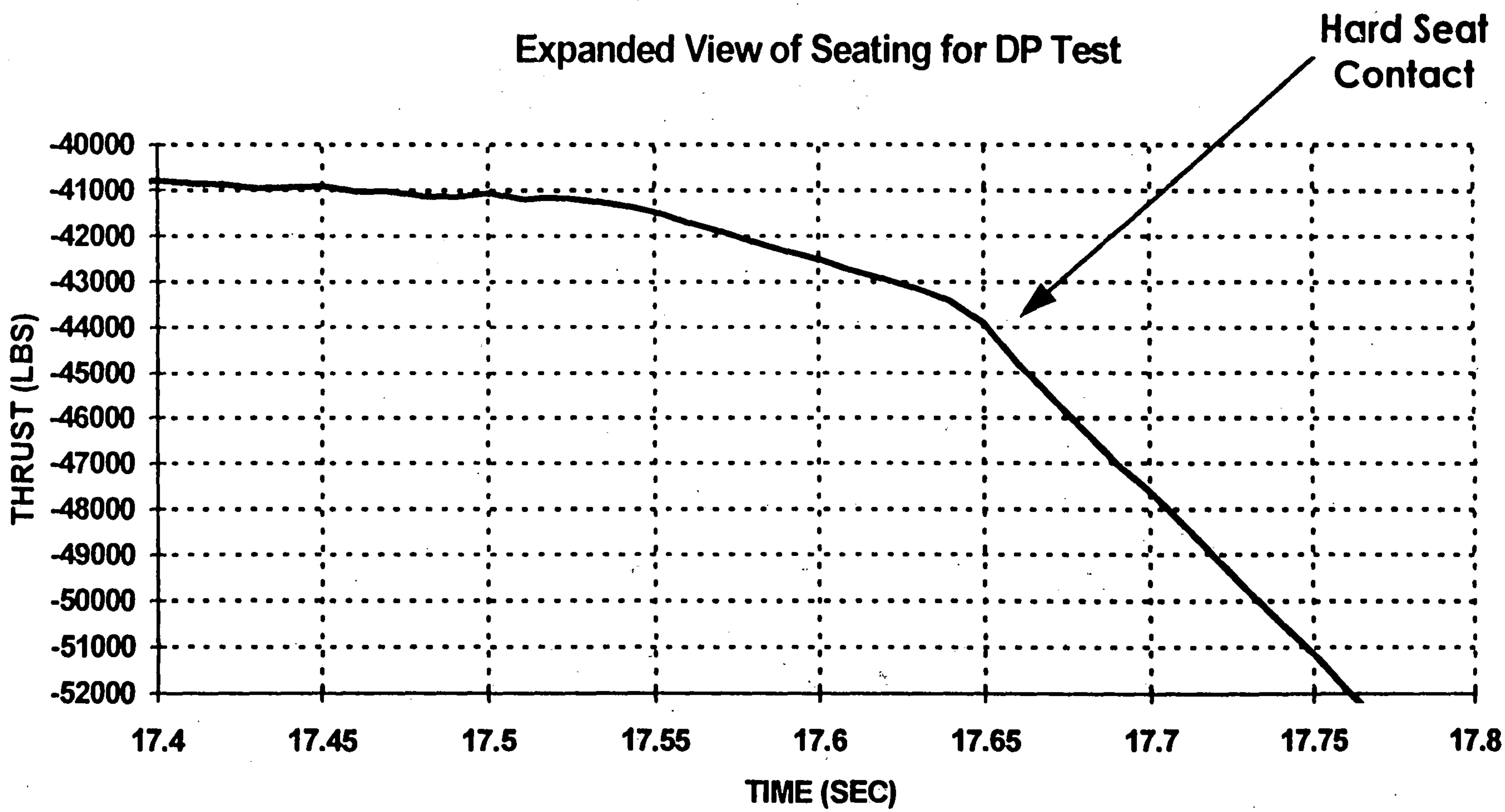


ComEd Valve Factor Basis
Valve Condition Load



ComEd

ComEd Valve Factor Basis
Valve Condition Load



ComEd

Technical Basis for Flow Isolation Valve Factors and Use of Flow Isolation Valve Factors

Presented by Brian Bunte

ComEd

Use of Flow Isolation Valve Factors

- Used for operability evaluations when margin criteria is not satisfied for hard seat contact valve factors.

- Only appropriate for valves for which the design function does not require leak tight seating

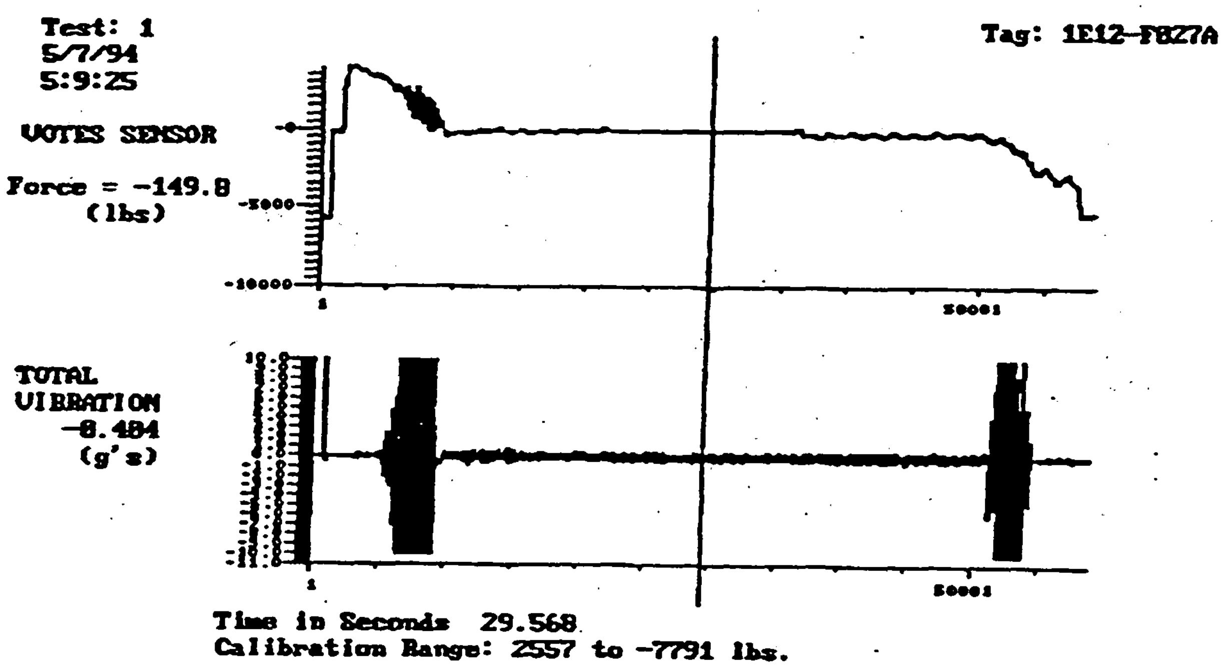
ComEd

ComEd Valve Factor Basis
Flow Isolation Valve Factor

- Based on Maximum Thrust up to and including flow isolation
- Flow Isolation Point determined using accelerometer traces
- White Paper 131 Methodology is used to calculate the isolation valve factor. However, valve condition load is not removed from apparent DP Load when the static test indicates that this load occurs after flow isolation (the normal occurrence).

Identifying Flow Isolation and Initiation Using Accelerometer Traces

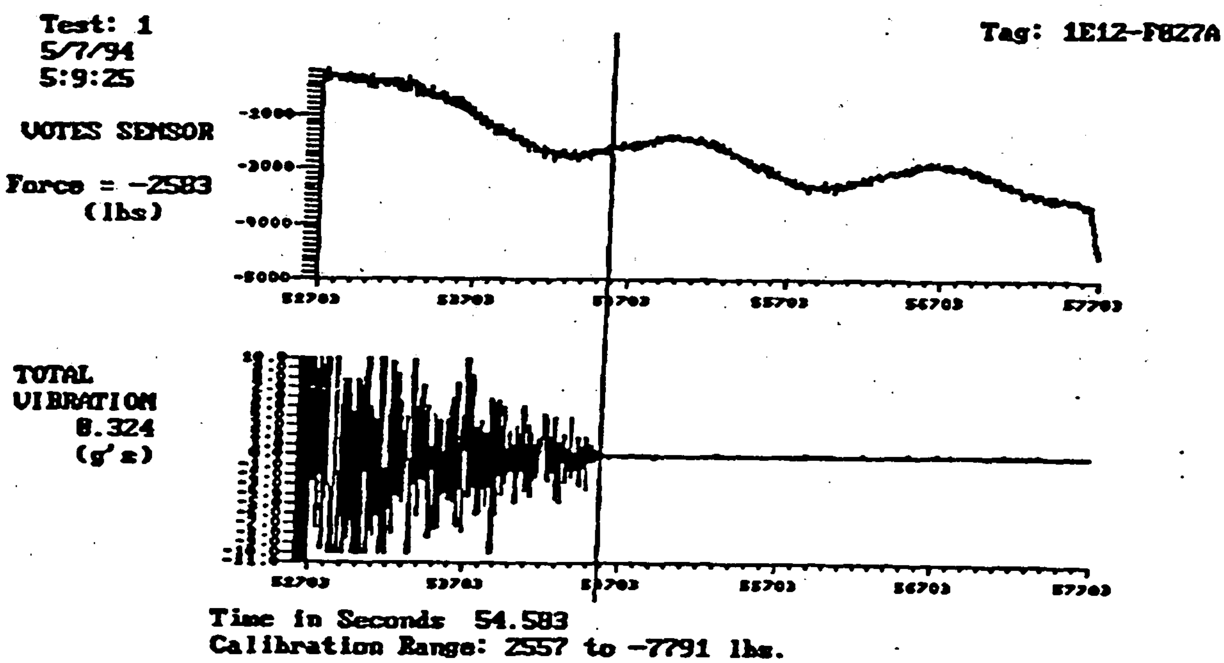
Typical Thrust and Accelerometer Trace for an MOV under a moderate flow rate condition. Cavitation noise at beginning of open stroke and end of close stroke can be used to determine the points of flow initiation and isolation.



ComEd

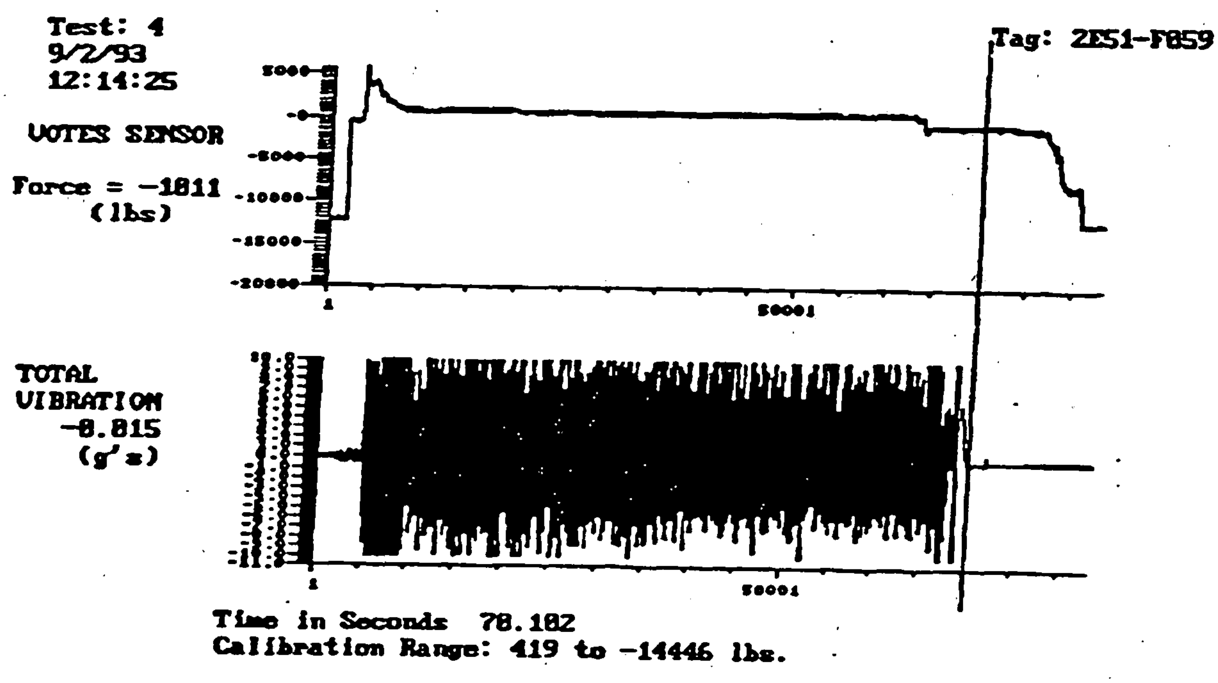
Identifying Flow Isolation and Initiation Using Accelerometer Traces

Expanded view of flow isolation region from previous trace. Caviation noise abruptly ends at flow isolation.



Identifying Flow Isolation and Initiation Using Accelerometer Traces

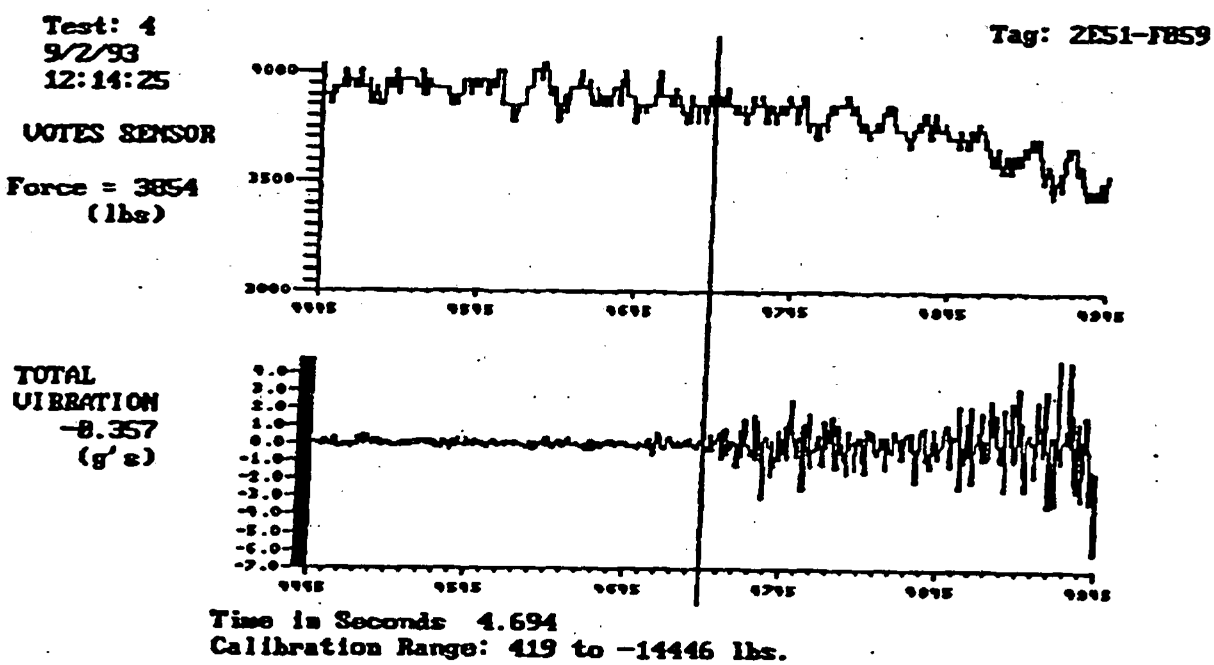
Typical Thrust and Accelerometer Trace for an MOV under a high flow rate condition. Flow related noise occurs throughout the stroke and can be used to determine the points of flow initiation and isolation. (For this particular test, the accelerometer broke free during the closure portion of stroke.)



ComEd

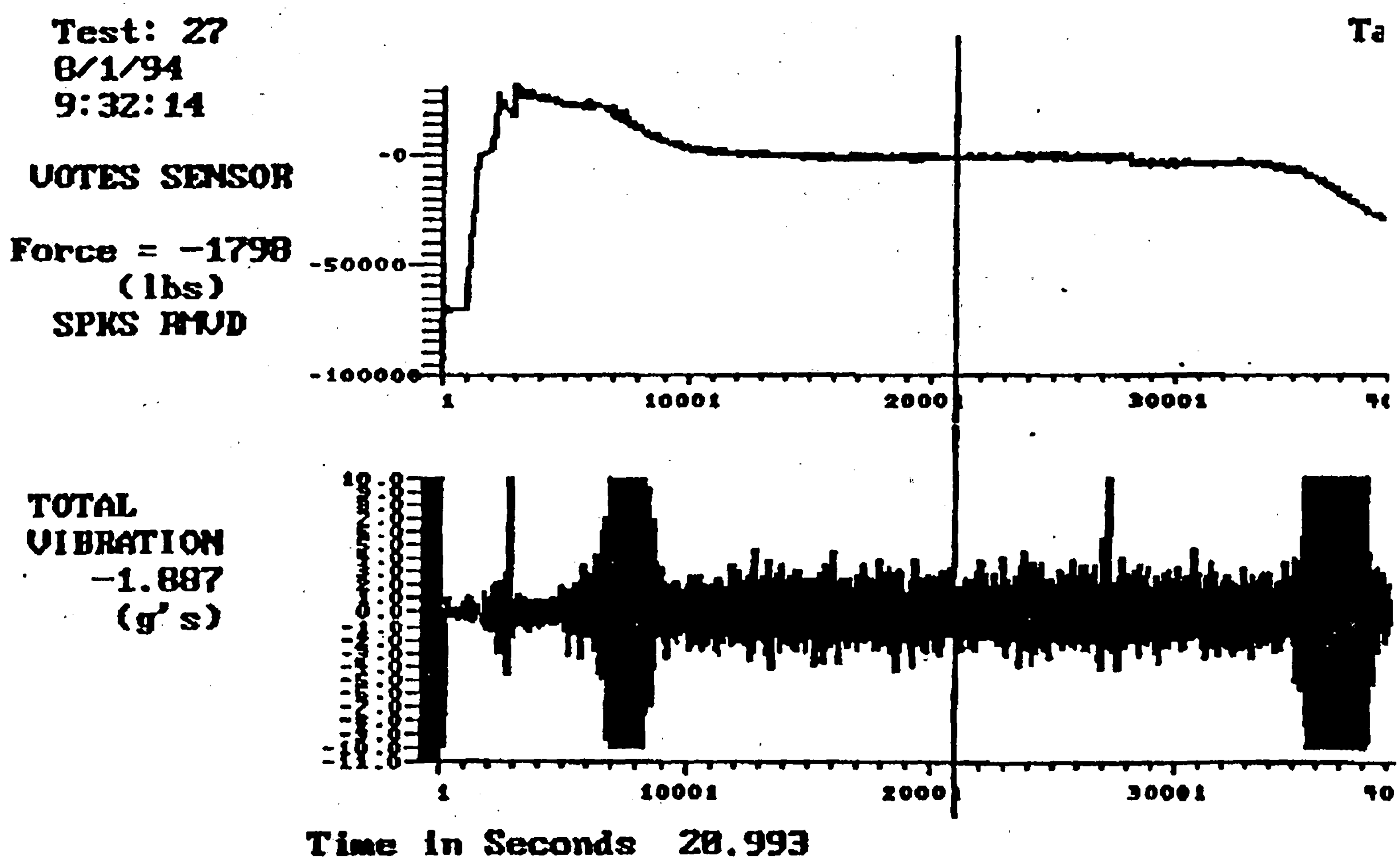
Identifying Flow Isolation and Initiation Using Accelerometer Traces

Expanded view of flow initiation region from previous trace. Caviation noise abruptly starts at flow initiation.



ComEd

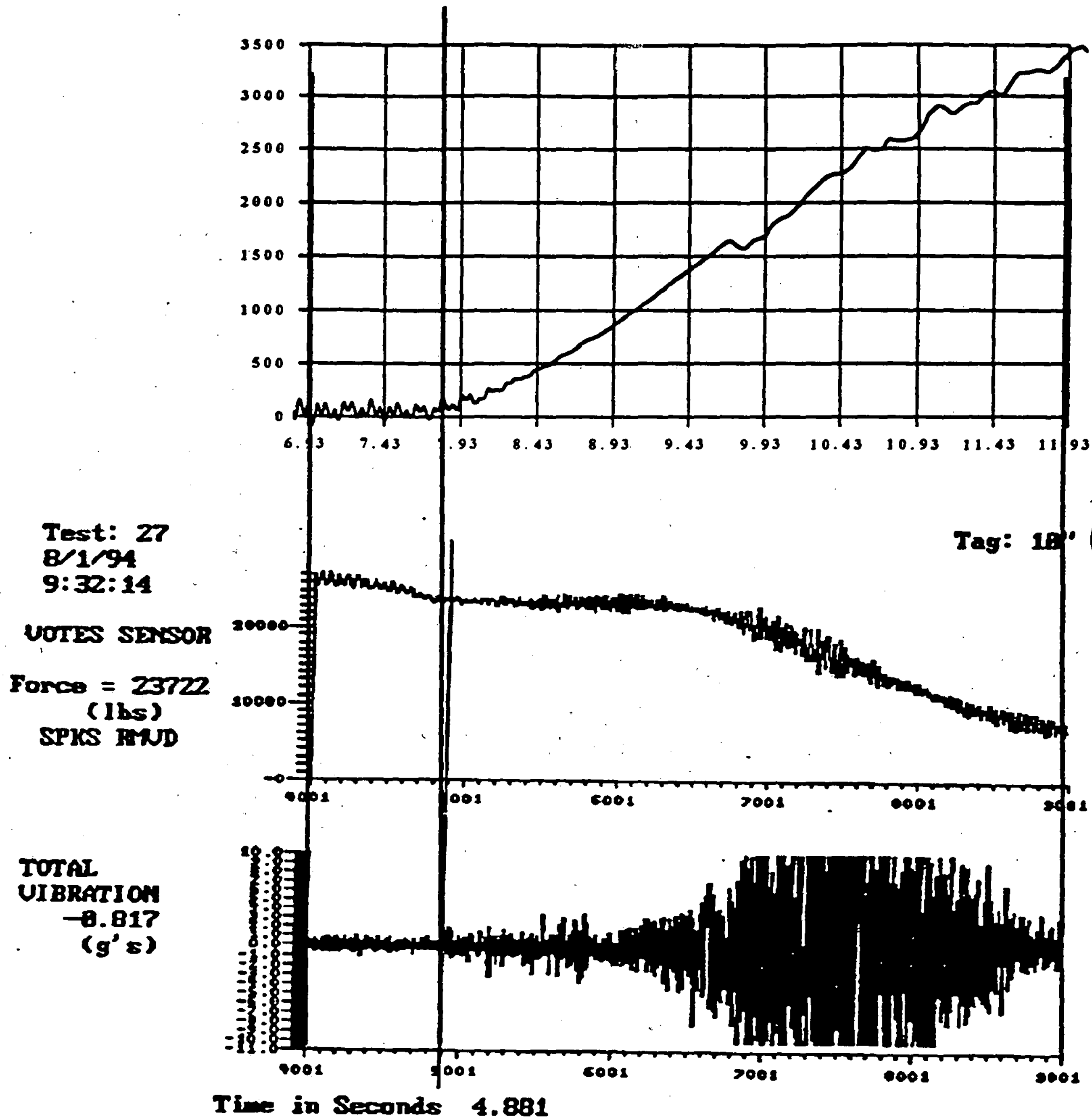
Cold Water DP Test
Thrust and Vibration Traces



ComEd

Cold Water (Opening) - Flow Initiation
Flow Meter vs. Vibration

FLOW (GPM)

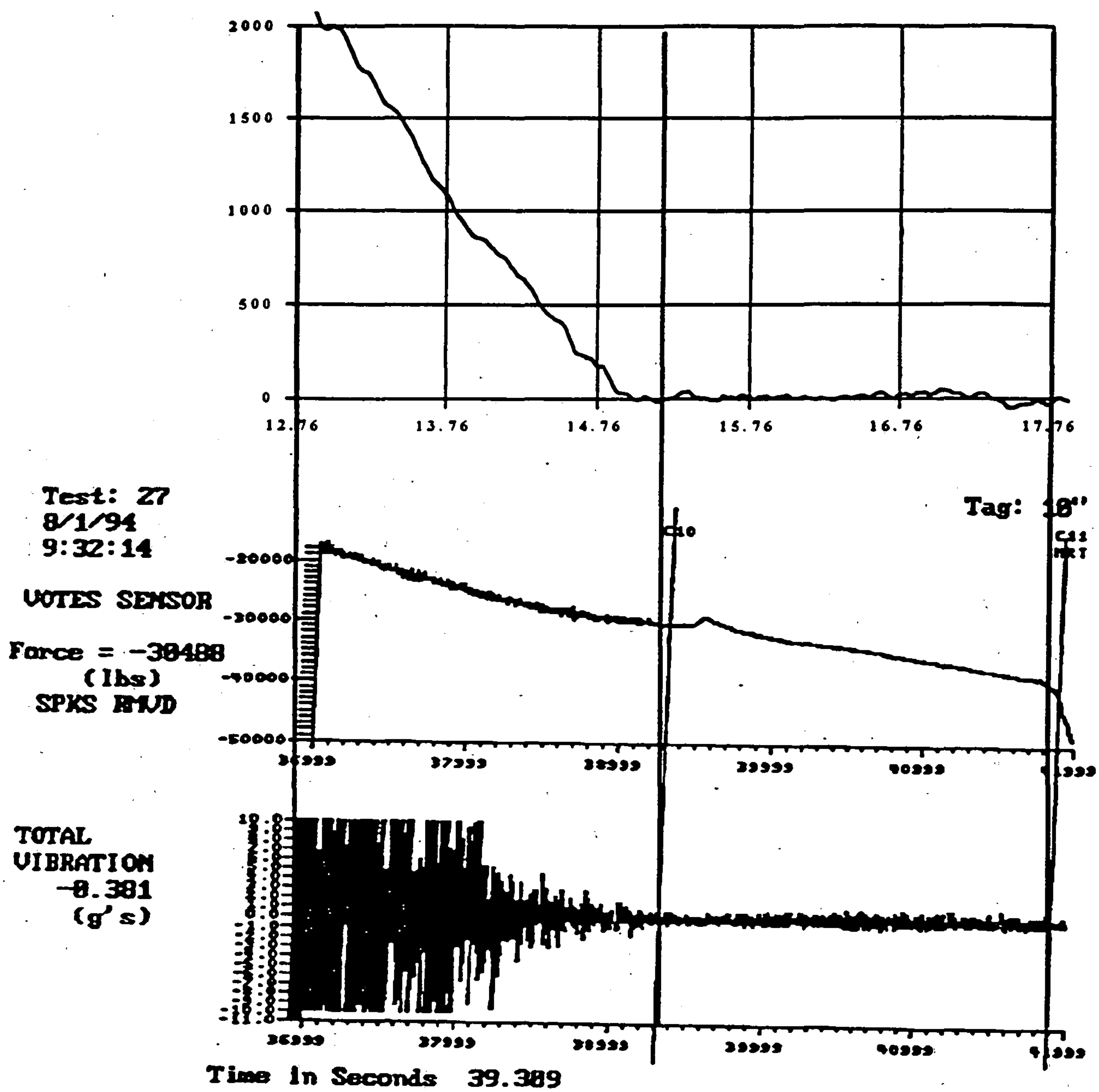


Time		Motor Start	Graph Start
Scale	Flow	3.00 s	6.93 s
Reconciliation:	VOTES	0.07 s	4.00 s

ComEd

Cold Water (Closing) - Flow Isolation
Flow Meter vs. Vibration

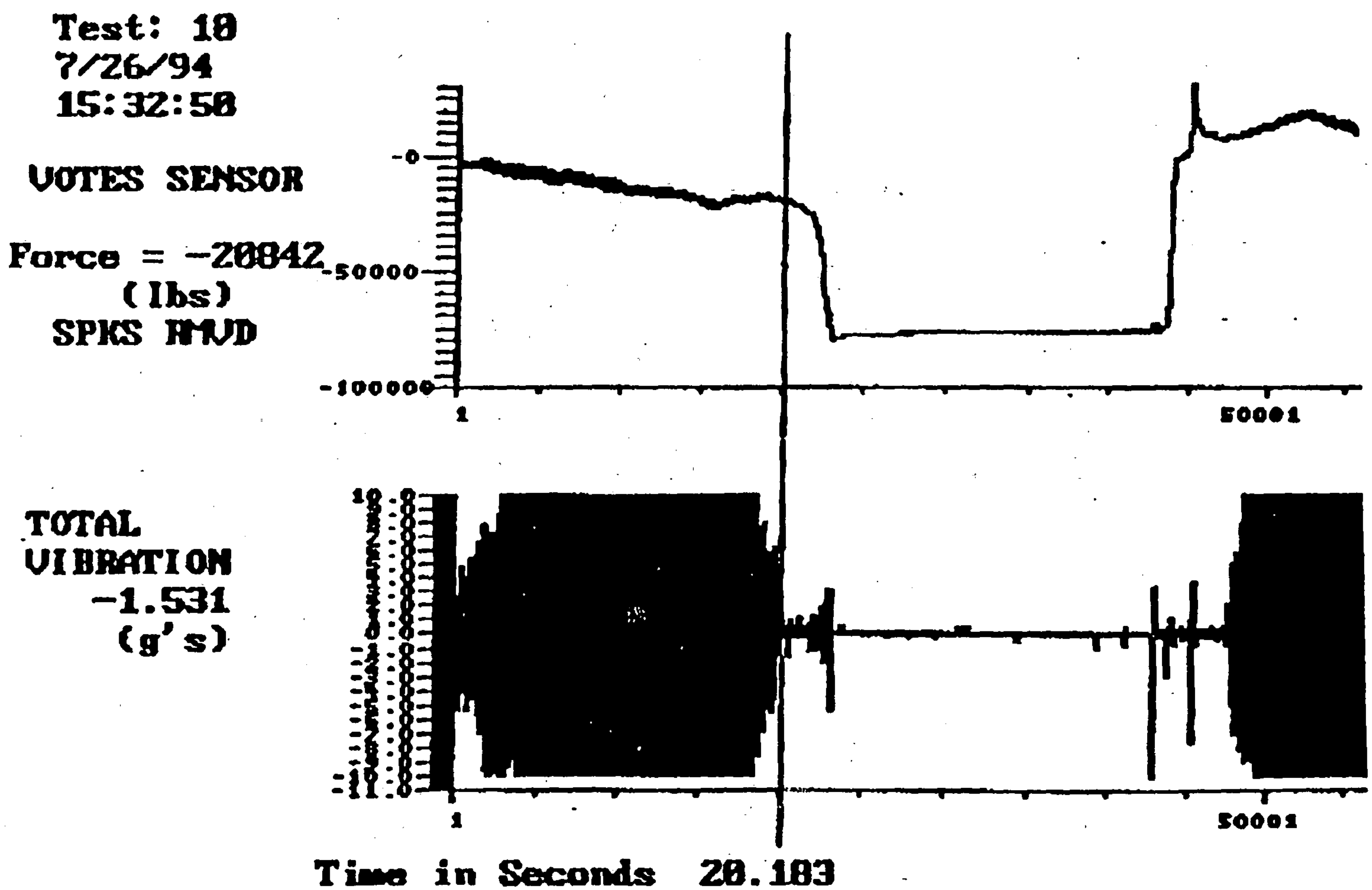
FLOW (GPM)



Time Scale Reconciliation:		Motor Start	Graph Start
	Flow	3.00 s	20.95 s
	VOTES	27.24 s	37.00 s

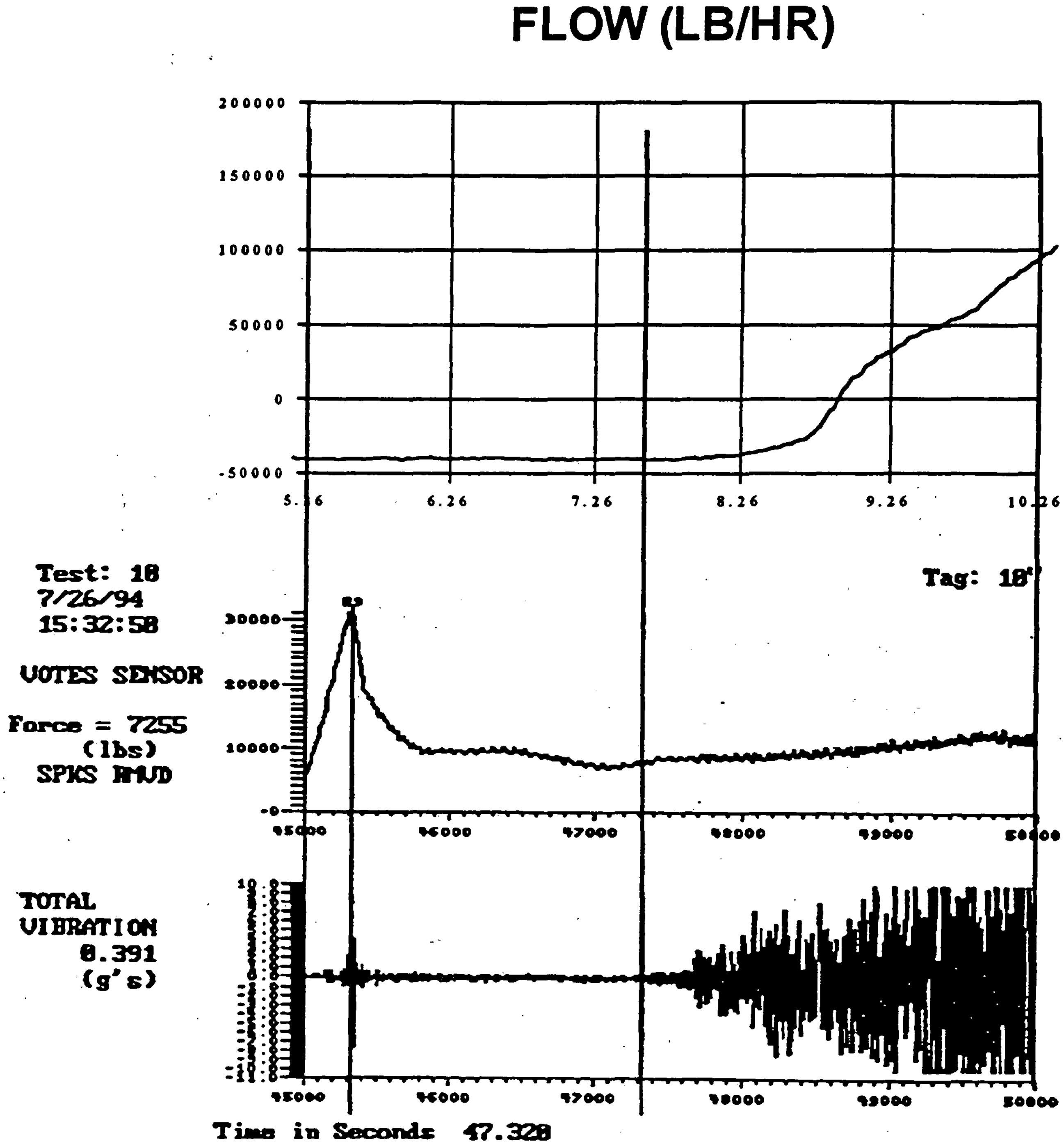
ComEd

Steam Blowdown DP Test Thrust and Vibration Traces



ComEd

Steam Blowdown (Opening) - Flow Initiation
Flow Meter vs. Vibration

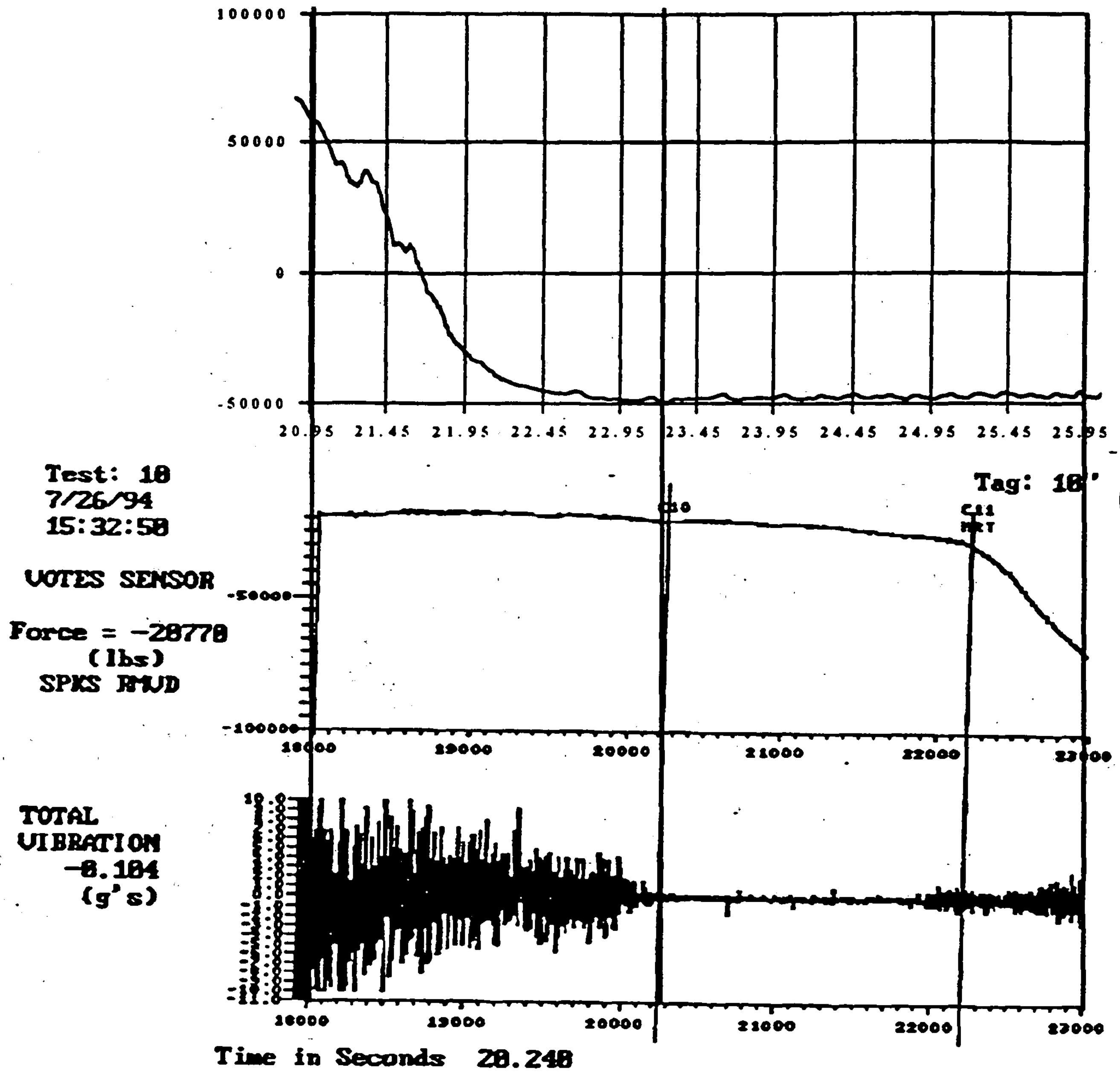


		Motor Start	Graph Start
Time			
Scale	Flow	3.00 s	5.26 s
Reconciliation:	VOTES	42.74 s	45.00 s

ComEd

Steam Blowdown (Closing) - Flow Isolation
Flow Meter vs. Vibration

FLOW (LBS/HR)



Time		Motor Start	Graph Start
Scale	Flow	3.00 s	20.95 s
Reconciliation:	VOTES	0.05 s	18.00 s

ComEd

EPRI Valve Factor Basis

<u>Hard Seat Contact Valve Factor</u>

- The Maximum Thrust up to and including hard seat contact is used to determine the valve factor.

<u>Flow Isolation Valve Factor</u>

- Flow isolation point based on disk position at which hydro-pressure bleeds off when valve is opened

- Flow, Pressures, and Stem Position are recorded during DP test and can be used to verify flow isolation point.

- The Maximum Thrust up to and including Flow Isolation Point is used to determine the valve factor.

Related ComEd Documents

- White Paper 131 (rev 0)
  "Valve Factor Calculation Methodology"
- White Paper 134 (rev 0)
  "EPRI Valve Factor Data"
- White Paper 154 (rev 1 - in preparation)
  "Anchor/Darling Flex-Wedge Gate Valve Factors"
- White Paper 160 (rev 0 - in preparation)
  "Crane Gate Valve Factors"
- White Paper 164 (rev 1 - in preparation)
  "Anchor/Darling Double-Disk Gate Valve Factors"
- White Paper 172 (rev 0 - in preparation)
  "Powell Gate Valve Factors"
- White Paper 173 (rev 0 - in preparation)
  "Westinghouse Gate Valve Factors"
- White Paper 174 (rev 0 - in preparation)
  "Velan Gate Valve Factors"

RATE OF LOADING (LOAD SENSITIVE BEHAVIOR)

Presented by Brian Bunte

ComEd

Rate of Loading (ROL)

- For DP Tested MOVs, the measured ROL value is used in design basis calculations and in operability/margin evaluations. However, when the measured ROL value is negative, zero is used for design and margin/operability.
- In addition, uncertainty due to measurement inaccuracy and due to potential change in ROL over time (+/- 5%) is included for margin/operability evaluations.
- Future repeat DP Testing will be used to validate the use of +/- 5% for variability of DP Tested MOVs.

Rate of Loading (ROL)

Extrapolation of ROL for Partial DP Tests

- EPRI Data Provides Solid Basis for Determining Whether ROL is independent of DP Load (for significant DP loads)
- ComEd is Evaluating EPRI data to determine whether ROL extrapolation is required.
- If extrapolation is warranted, ComEd will determine whether a threshold DP load exists above which ROL is stable.

Rate of Loading (ROL)

For MOVs not DP tested, the Nominal ROL (bias) is average for ComEd MOVs using the same stem lubricant (1% for Nebula EP, 5% for Fel-Pro N-5000, and 7% for Mobilux EP). The table below shows a summary of the recent ComEd ROL data.

Lubricant	Average ROL	Std. Dev. for ROL, EI & TSR	Std. Dev. for ROL alone	Population Size
Nebula EP	0.91%	8.06%	7.40%	57
Mobilux EP	6.91%	6.61%	5.78%	42
N-5000	5.02%	8.25%	7.60%	95
All Lubricants	4.22%	8.15%	7.49%	194

- Only data collected after 1992 is included in this analysis to avoid concerns associated with VOTES Part 21 issues and because some stations were in the process of changing lubricants prior to 1992.
- The average and standard deviations for ROL do not vary appreciably between stations which share use of same lubricants.

Rate of Loading (ROL)

- The measured ROL variability includes the effects of torque switch repeatability and equipment inaccuracy.
- These effects are removed as shown below.
- The assumed values for torque switch repeatability, and equipment inaccuracy are 5% and 4%, respectively.

$$Overall\ Std\ Dev. = \sqrt{(ROL\ Variability)^2 + (Torque\ Sw.\ Rep.)^2 + (Eq.\ Inacc.)^2}$$

Therefore, the uncertainty due strictly to ROL variability can be solved for as follows:

$$ROL\ Variability = \sqrt{(Overall\ Std\ Dev.)^2 - (Torque\ Sw.\ Rep.)^2 - (Eq.\ Inacc.)^2}$$

ComEd White Paper 124 provides further details on ROL.

Rate of Loading (ROL)

Data Analysis suggests that ROL is independent of stem geometry, thread form, actuator type, and valve type. This is shown in the table below for thread form and valve type. (ComEd White Paper 124 (rev. 1) discusses this in more detail.)

	Average	Standard Deviation	Population
All MOVs	5.02%	7.83%	194
Standard Acme Thread	5.13%	7.82%	126
Stub Acme Thread	4.81%	7.89%	68
Gate Valves	5.33%	8.13%	130
Globe Valves	4.38%	7.19%	64

STEM FACTOR

Presented by Ivo Garza

ComEd

Stem Types and Stem Lubricants Applicable to ComEd Stations

- **Stem Types**
  - Standard ACME Threads
  - Stub ACME Threads
- **Stem Lubricants**
  - Fel-Pro N-5000
  - Mobilux EP-1
  - Nebula EP-1

Design Basis Stem Friction Coefficient Basis

- Since MOV torque switches are setup under static, as-left conditions, the friction coefficient in design basis calculations for most MOVs should correspond to the static, as-left value (White Paper 139).

- For limit closed MOVs which do not use torque switch control, the design basis stem friction coefficient should correspond to the dynamic, as-found friction coefficient value.

ComEd

Measuring Stem Friction Coefficient

The apparent Stem Friction Coefficient can be calculated based on the stem geometry and on the thrust and torque measured at CST.

- **VTC Testing is the most accurate method used by ComEd for obtaining torque data. Therefore, this data is used to calculate the nominal and bounding stem friction coefficient values.**

- **White Paper 101 provides the results of this analysis and shows that a nominal stem friction coefficient of 0.12 with a 2 sigma bound of 0.18 is generally appropriate to all stem geometries and lubricants.**

- **This white paper also demonstrates that the average stem friction coefficient for other torque measurement methods is 0.12. However, the 2 sigma bound cannot be determined using this data since the amount of variability due to equipment inaccuracy is unknown.**

Stem Friction Coefficient in Design Calculations

- For design calculations, a conservative, but not bounding stem friction coefficient of 0.15 is generally used.

- The trade-off of 0.03 bias margin (0.15-0.12) in these calculations versus 0.06 (2 sigma) random margin is considered appropriate since the margin review process will ensure that the MOV is properly setup. In addition, torque is usually measured during MOV setup making this a non-issue.

- This is consistent with the previously discussed design method of using conservative, but not necessarily bounding values for design assumptions.

ComEd

Stem Factor Variability
(Definition)

Stem Factor Variability results from changes in static Stem Mu between the time of MOV setup and the time at which the MOV is called upon to perform its function.

Rate of Loading Effects are considered separate from the stem factor variability effect.

Stem Factor Variability
(ComEd Test Results to Date)

ComEd as-found test data suggests that stem mu variation is a random rather than a bias effect. On average, no degradation is observed.

After removing the effects of torque switch repeatability and equipment inaccuracy, the magnitude of stem mu variability (2 sigma) is approximately +/- 0.025.

This data is very limited and is primarily for a lubrication period of approximately 18 months.

Stem Factor Variability
(EPRI Separate Effects Testing)

EPRI Testing showed that stem mu improved with MOV cycles for the three lubricants (Fel-Pro N-5000, Mobelux EP, and Nebula EP) used at ComEd stations.

This laboratory testing did not include the effects of aging and temperature. These effects could tend to cause the stem mu to degrade and may explain why ComEd in-situ data indicates that the average change in stem mu is approximately zero.

Stem Factor Variability (Future ComEd Testing)

A large portion of the previously performed as-found testing at ComEd Stations can not be used to accurately assess stem factor performance. This is caused by a lack of information such as stem torque or initial lubricant condition.

To ensure future testing is of sufficient quality to determine stem factor change over time, ComEd White Paper 175 provides guidance on performing Stem Factor Variation Testing.

The results of the ComEd testing will be used to establish the required stem lubrication frequency for ComEd stations.

Sample of Margin Review / Operability Evaluation Worksheet

INPUT DATASHEET Valve Number: 2AF017A Station: Braidwood

3/14/95
8:21 AM

	Nominal	Bounding
Close Valve Factor (seating):	0.327	0.59
Close Valve Factor (isolation):	0.327	0.59
Seat Diameter:	5.91	n/a
Seat Angle:	5	n/a
Stem Diameter:	1.000	n/a
Stem Pitch:	0.333	n/a
Stem Lead:	0.667	n/a
Stem Thread:	stub	
Close DP (design):	90	n/a
Close LP (design):	90	n/a
Open DP (design):	90	n/a
Motor Rating (ft-lbs):	5	n/a
Temperature Factor:	1	n/a
OAR:	40	n/a
Close Efficiency:	50%	n/a
Open Efficiency:	40%	n/a
Nominal Voltage:	460	n/a
Degraded Voltage:	419	n/a
Voltage Exponent (AC=2):	2	n/a

	Nominal	Bounding
Close (C14) Thrust Inaccuracy:	0%	10%
Close (C14) Torque Basis:	G	
(V=VTC, T=Tested Spring Pack, G=Generic Spring Pack)		
Torque (C14) Inaccuracy (IAW basis):	0%	30%
Open (O9) Thrust Inaccuracy:	0%	52%
Stem Mu Variation:	0.000	0.0250
Rate of Loading:	5.0%	20.5%
Torque Switch Repeatability:	0%	5%
Spring Pack Relaxation:	5%	n/a
Close Running Load (static):	743	calculated
Valve Condition Load (static):	60	calculated
CST Thrust (static):	3508	calculated
CST Torque (static):	66.5	calculated
C16 Thrust (static):	4980	calculated
Open Running Load (static):	580	calculated
O9 Thrust (static):	2200	calculated

Torque Switch Bypassed beyond C10? (Y/N): N

Valve Type (DD Gate, FW Gate, or Globe): fw gate

Enhanced Motor/Gearing Capability Inputs

	Nominal	Bounding
Motor Rating (ft-lbs):	5.9	6.31
Close Efficiency:	45%	40%
Open Efficiency:	45%	40%
Voltage Exponent (testing):	2.199	n/a

DP Tested? (Y/N): N

Setup Point Adjusted after DP Test (Y/N/na): NA

Flow Direction GLOBES ONLY (over, under, or na): NA

Structural Limits for Valve and Actuator

	Nominal	Bounding
Actuator Thrust Limit:	8800	8800
Actuator Torque Limit:	99	99
Valve Structural Limit (close):	28296	28296
Valve Structural Limit (open):	14340	14340
Valve Seismic Limit:	10400	10400

Prepared By: ____________________ / /

Reviewed By: ____________________ / /

SUMMARY OF MARGIN RESULTS

MARGIN	APPLICABLE	SIGMA	RELIABILITY	#FORCE SIGMA	FT-LB SIGMA
TORQUE CLOSED, SEATING VF		3.14	99.9%	474	-
TORQUE CLOSED, FLOW ISOLATION VF		3.27	99.9%	473	-
LIMIT CLOSED, SEATING VF	No	3.95	100.0%	835	-
LIMIT CLOSED, ENHANCED MGC, SEATING VF	No	3.48	100.0%	864	-
LIMIT CLOSED, FLOW ISOLATION VF	No	4.06	100.0%	831	-
LIMIT CLOSED, ENHANCED MGC, FLOW ISOL. VF	No	3.55	100.0%	863	-
CLOSE MGC, LIMITORQUE		3.24	99.9%	-	8
CLOSE MGC, ENHANCED MGC		2.90	99.8%	-	11
OPEN MGC, LIMITORQUE		3.44	100.0%	750	-
OPEN MGC, ENHANCED MGC		4.14	100.0%	971	-
OPEN STRUCTURAL LIMITS (thrust : torque)		11.54 : 7.69	100% : 100%	572	9
CLOSE STRUCTURAL LIMITS (thrust : torque)		11.11 : 1.66	100% : 95.2%	344	12

EVALUATION OF TST MARGIN FOR Braidwood 2AF017A USING SEATING VALVE FACTOR

Parameter	Row	Values: Average	Values: Worst Case	Parameter Runs: Nominal Case	High Packing & VC	High VF	High Stem Mu Degrad.	High LSB	High TSR	High Eq. Inacc (thrust)	Design Sum of Squares
Valve Factor (seating)	(A)	0.327	0.59	0.327	0.327	0.59	0.327	0.327	0.327	0.327	
DP	(B)	90		90	90	90	90	90	90	90	
Seat Diameter	(C)	5.906		5.906	5.906	5.906	5.906	5.906	5.906	5.906	
DP Load	(D)			806	806	1455	806	806	806	806	
LP	(E)	90		90	90	90	90	90	90	90	
Piston Effect	(F)			71	71	71	71	71	71	71	
Static Running Load	(G)	743	943	743	943	743	743	743	743	743	
Valve Condition Load	(H)	60	72	60	72	60	60	60	60	60	
Total Static Load	(I)			803	1015	803	803	803	803	803	
Total Load	(J)			1680	1892	2328	1680	1680	1680	1680	
Stem Pitch	(K)	0.3333		0.333	0.333	0.333	0.333	0.333	0.333	0.333	
Stem Lead	(L)	0.6667		0.667	0.667	0.667	0.667	0.667	0.667	0.667	
Stem Dia	(M)	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Stem Thread	(N)	stub		stub	stub	stub	stub	stub	stub	stub	
Static CST Thrust (meas.)	(O)	3508	3157	3508	3508	3508	3508	3508	3508	3157	
CST Torque (Generic SP)	(P)	55.6		55.6	55.6	55.6	55.6	55.6	55.6	55.6	
Static Stem Factor	(Q)			0.0158	0.0158	0.0158	0.0158	0.0158	0.0158	0.0176	
Static (as-left) Stem Mu	(R)			0.1633	0.1633	0.1633	0.1633	0.1633	0.1633	0.2022	
ROL (change in thrust)	(S)	5.0%	20.5%	5.0%	5.0%	5.0%	5.0%	20.5%	5.0%	5.0%	
Dynamic CST Thrust	(T)			3333	3333	3333	3333	2789	3333	2999	
Dynamic Stem Factor (w/o Degradation)	(U)			0.0167	0.0167	0.0167	0.0167	0.0199	0.0167	0.0185	
Dynamic (as-left) Stem Mu	(V)			0.1819	0.1819	0.1819	0.1819	0.2523	0.1819	0.2223	
Stem Mu Variation	(W)	0.0000	0.0250	0.0000	0.0000	0.0000	0.0250	0.0000	0.0000	0.0000	Sigma
Dynamic (as-found) Mu	(X)			0.1819	0.1819	0.1819	0.2069	0.2523	0.1819	0.2223	Level
Dyn. (as-found) Stem Fact.	(Y)			0.0167	0.0167	0.0167	0.0178	0.0199	0.0167	0.0185	3.14
TSR (torque change)	(Z)	0%	5%	0%	0%	0%	0%	0%	5%	0%	
Spring Pack Relaxation	(AA)	5%		5%	5%	5%	5%	5%	5%	5%	
Dyn. (as-found) CST Torq.	(BB)			53	53	53	53	53	50	53	Conf.
Dyn. (as-found) CST Thrust	(CC)			3166	3166	3166	2964	2649	3008	2849	Level
											99.91%
Margin (percent)	(DD)			88.5%	75.8%	49.9%	76.4%	57.7%	79.0%	69.6%	32.0%
effect in % change	(EE)				12.6%	38.6%	12.1%	30.7%	9.4%	18.8%	56.4%

General Notes:
Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects.
Running load inaccuracy assumed to be the greater of +/- 20% or +/- 200 lbf. Valve Condition load inaccuracy assumed to be +/-20%.
This analysis does not consider conservatism in DP & LP
For flow over the seat globe valves, valve factor is set to zero.

Valve Specific Notes:
Worst case value assumed for spring pack relaxation.

3/14/95
8:21 AM

EVALUATION OF TST MARGIN FOR Braidwood 2AF017A USING FLOW ISOLATION VALVE FACTOR

Parameter	Row	Values: Average	Values: Worst Case	Parameter Runs: Nominal Case	High Packing	High VF	High Stem Mu Degrad.	High LSB	High TSR	High Eq. Inacc (thrust)	Design Sum of Squares
Valve Factor (seating)	(A)	0.327	0.59	0.327	0.327	0.59	0.327	0.327	0.327	0.327	
DP	(B)	90		90	90	90	90	90	90	90	
Seat Diameter	(C)	5.906		5.906	5.906	5.906	5.906	5.906	5.906	5.906	
DP Load	(D)			806	806	1455	806	806	806	806	
LP	(E)	90		90	90	90	90	90	90	90	
Piston Effect	(F)			71	71	71	71	71	71	71	
Static Running Load	(G)	743	943	743	943	743	743	743	743	743	
Total Load	(J)			1620	1820	2268	1620	1620	1620	1620	
Stem Pitch	(K)	0.3333		0.333	0.333	0.333	0.333	0.333	0.333	0.333	
Stem Lead	(L)	0.6667		0.667	0.667	0.667	0.667	0.667	0.667	0.667	
Stem Dia	(M)	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Stem Thread	(N)	stub		stub	stub	stub	stub	stub	stub	stub	
Static CST Thrust (meas.)	(O)	3508	3157	3508	3508	3508	3508	3508	3508	3157	
CST Torque (Generic SP)	(P)	55.6		55.6	55.6	55.6	55.6	55.6	55.6	55.6	
Static Stem Factor	(Q)			0.0158	0.0158	0.0158	0.0158	0.0158	0.0158	0.0176	
Static (as-left) Stem Mu	(R)			0.1633	0.1633	0.1633	0.1633	0.1633	0.1633	0.2022	
ROL (change in thrust)	(S)	5.0%	20.5%	5.0%	5.0%	5.0%	5.0%	20.5%	5.0%	5.0%	
Dynamic CST Thrust	(T)			3333	3333	3333	3333	2789	3333	2999	
Dynamic Stem Factor	(U)			0.0167	0.0167	0.0167	0.0167	0.0199	0.0167	0.0185	
(w/o Degradation)											
Dynamic (as-left) Stem Mu	(V)			0.1819	0.1819	0.1819	0.1819	0.2523	0.1819	0.2223	
Stem Mu Variation	(W)	0.0000	0.0250	0.0000	0.0000	0.0000	0.0250	0.0000	0.0000	0.0000	Sigma
Dynamic (as-found) Mu	(X)			0.1819	0.1819	0.1819	0.2069	0.2523	0.1819	0.2223	Level
Dyn. (as-found) Stem Fact.	(Y)			0.0167	0.0167	0.0167	0.0178	0.0199	0.0167	0.0185	3.27
TSR (torque change)	(Z)	0%	5%	0%	0%	0%	0%	0%	5%	0%	
Spring Pack Relaxation	(AA)	5%		5%	5%	5%	5%	5%	5%	5%	
Dyn. (as-found) CST Torq.	(BB)			53	53	53	53	53	50	53	Cont.
Dyn. (as-found) CST Thrust	(CC)			3166	3166	3166	2964	2649	3008	2849	Level
											99.95%
Margin (percent)	(DD)			95.4%	83.1%	55.4%	82.9%	63.6%	85.7%	75.9%	37.1%
effect in % change	(EE)				12.3%	40.0%	12.5%	31.9%	9.8%	19.5%	58.4%

General Notes:
Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects. Running load inaccuracy assumed to be the greater of +/- 20% or +/- 200 lbf. Valve Condition load is not applicable since it typically occurs after flow isolation.
This analysis does not consider conservatism in DP & LP
For flow over the seat globe valves, valve factor is set to zero.

Valve Specific Notes
Worst case value assumed for spring pack relaxation

Limit Close, Seating is N/A, Do Not Use This Sheet

Parameter	Row	Values		Parameter Runs							Design Sum of Squares
		Average	Worst Case	Nominal Case	High Packing & VC	High Close VF	High Stem Mu Degrad.	High LSB	High Eq. Inacc. (torque)	High Eq. Inacc. (thrust)	
Valve Factor (isolation)	(A)	0.327	0.59	0.327	0.327	0.59	0.327	0.327	0.327	0.327	
DP	(B)	90		90	90	90	90	90	90	90	
Seat Diameter	(C)	5.91		5.91	5.91	5.91	5.91	5.91	5.91	5.91	
DP Load	(D)			806	806	1455	806	806	806	806	
LP	(E)	90		90	90	90	90	90	90	90	
Piston Effect	(F)			71	71	71	71	71	71	71	
Static Running Load	(G)	743	943	743	943	743	743	743	743	743	
Valve Condition Load	(H)	60	72	60	72	60	60	60	60	60	
Total Static Load	(I)			803	1015	803	803	803	803	803	
Total Load	(J)			1680	1892	2328	1680	1680	1680	1680	
Stem Pitch	(K)	0.333		0.333	0.333	0.333	0.333	0.333	0.333	0.333	
Stem Lead	(L)	0.667		0.667	0.667	0.667	0.667	0.667	0.667	0.667	
Stem Dia	(M)	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Stem Thread	(N)	stub		stub	stub	stub	stub	stub	stub	stub	
Static CST Thrust (meas.)	(O)	3508	3157	3508	3508	3508	3508	3508	3508	3157	
CST Torque (estimated)	(P)	55.6	72.28	56	56	56	56	56	72	56	
Static Stem Factor	(Q)			0.0158	0.0158	0.0158	0.0158	0.0158	0.0206	0.0176	
Static (as-left) Stem Mu	(R)			0.1633	0.1633	0.1633	0.1633	0.1633	0.2664	0.2022	
ROL (change in thrust)	(S)	5%	20.5%	5%	5%	5%	5%	20.5%	5%	5%	
Dynamic CST Thrust	(T)			3333	3333	3333	3333	2789	3333	2999	
Dynamic Stem Factor (w/o Degradation)	(U)			0.0167	0.0167	0.0167	0.0167	0.0199	0.0217	0.0185	
Dynamic (as-left) Stem Mu	(V)			0.1832	0.1832	0.1832	0.1832	0.2545	0.2919	0.2242	
Stem Mu Variation	(W)	0.0000	0.0250	0.0000	0.0000	0.0000	0.0250	0.0000	0.0000	0.0000	
Dynamic (as-found) Mu	(X)			0.1832	0.1832	0.1832	0.2082	0.2545	0.2919	0.2242	
Dynamic As-Found SF	(Y)			0.0167	0.0167	0.0167	0.0178	0.0199	0.0217	0.0185	
Motor Rating	(Z)	5		5	5	5	5	5	5	5	
Temperature Factor	(AA)	1		1	1	1	1	1	1	1	
OAR	(BB)	40		40	40	40	40	40	40	40	Sigma
Close Efficiency	(CC)	50%		50%	50%	50%	50%	50%	50%	50%	Level
Degraded Voltage	(DD)	419		419	419	419	419	419	419	419	3.95
Nominal Voltage	(EE)	460									
exponent (AC=2)	(FF)	2		2	2	2	2	2	2	2	Conf.
Close MGC	(GG)			4973	4973	4973	4658	4162	3825	4476	Level
											100.00%
Margin (percent)	(HH)			196.0%	183.4%	157.4%	177.3%	147.7%	127.7%	166.4%	96.7%
effect in % change	(II)				12.6%	38.6%	18.7%	48.3%	68.3%	29.6%	99.4%

General Notes.

Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects.

Running load inaccuracy assumed to be the greater of +/- 20% or +/- 200 lbf. Valve Condition load inaccuracy assumed to be +/-20%

MGC for AC motors based on current Limitorque Guidance (1.0 application factor with temperature factor and degraded voltage)

Minimum static as-left stem mu = 0.06. This analysis does not consider conservatism in degraded voltage, DP & LP

For flow over the seat globe valves, valve factor is set to zero

Valve Specific Notes.

Limit Close, Flow Isolation is N/A, Do Not Use This Sheet

Parameter	Row	Values: Average	Values: Worst Case	Parameter Runs: Nominal Case	High Packing	High Close VF	High Stem Mu Degrad.	High LSB	High Eq. Inacc. (torque)	High Eq. Inacc. (thrust)	Design Sum of Squares
Valve Factor (isolation)	(A)	0.327	0.59	0.327	0.327	0.59	0.327	0.327	0.327	0.327	
DP	(B)	90		90	90	90	90	90	90	90	
Seat Diameter	(C)	5.91		5.906	5.906	5.906	5.906	5.906	5.906	5.906	
DP Load	(D)			806	806	1455	806	806	806	806	
LP	(E)	90		90	90	90	90	90	90	90	
Piston Effect	(F)			71	71	71	71	71	71	71	
Static Running Load	(G)	743	943	743	943	743	743	743	743	743	
Total Load	(J)			1620	1820	2268	1620	1620	1620	1620	
Stem Pitch	(K)	0.333		0.333	0.333	0.333	0.333	0.333	0.333	0.333	
Stem Lead	(L)	0.667		0.667	0.667	0.667	0.667	0.667	0.667	0.667	
Stem Dia	(M)	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Stem Thread	(N)	stub		stub	stub	stub	stub	stub	stub	stub	
Static CST Thrust (meas.)	(O)	3508	3157	3508	3508	3508	3508	3508	3508	3157	
CST Torque (estimated)	(P)	55.6	72.28	56	56	56	56	56	72	56	
Static Stem Factor	(Q)			0.0158	0.0158	0.0158	0.0158	0.0158	0.0206	0.0176	
Static (as-left) Stem Mu	(R)			0.1633	0.1633	0.1633	0.1633	0.1633	0.2664	0.2022	
ROL (change in thrust)	(S)	5.0%	20.5%	5.0%	5.0%	5.0%	5.0%	20.5%	5.0%	5.0%	
Dynamic CST Thrust	(T)			3333	3333	3333	3333	2789	3333	2999	
Dynamic Stem Factor	(U)			0.0167	0.0167	0.0167	0.0167	0.0199	0.0217	0.0185	
(w/o Degradation)											
Dynamic (as-left) Stem Mu	(V)			0.1819	0.1819	0.1819	0.1819	0.2523	0.2891	0.2223	
Stem Mu Variation	(W)	0.0000	0.0250	0.0000	0.0000	0.0000	0.0250	0.0000	0.0000	0.0000	
Dynamic (as-found) Mu	(X)			0.1819	0.1819	0.1819	0.2069	0.2523	0.2891	0.2223	
Dynamic As-Found SF	(Y)			0.0166	0.0166	0.0166	0.0177	0.0198	0.0216	0.0185	
Motor Rating	(Z)	5		5	5	5	5	5	5	5	
Temperature Factor	(AA)	1		1	1	1	1	1	1	1	
OAR	(BB)	40		40	40	40	40	40	40	40	Sigma
Close Efficiency	(CC)	50%		50%	50%	50%	50%	50%	50%	50%	Level
Degraded Voltage	(DD)	419		419	419	419	419	419	419	419	4.06
Nominal Voltage	(EE)	460									
exponent (AC=2)	(FF)	2		2	2	2	2	2	2	2	Conf.
Close MGC	(GG)			4992	4992	4992	4675	4184	3849	4496	Level
											100.00%
Margin (percent)	(HH)			208.1%	195.8%	168.1%	188.6%	158.3%	137.6%	177.6%	105.5%
effect in % change	(II)				12.3%	40.0%	19.6%	49.9%	70.5%	30.6%	102.6%

General Notes

Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects. Running load inaccuracy assumed to be the greater of +/- 20% or +/- 200 lbf. Valve Condition load is not applicable since it typically occurs after flow isolation.

MGC for AC motors based on current Limitorque Guidance (1.0 application factor with temperature factor and degraded voltage).

Minimum static, as-left stem mu = 0.08 This analysis does not consider conservatism in degraded voltage. DP & LP

For flow over the seat globe valves, valve factor is set to zero

Valve Specific Notes:

ALUATION OF CLOSE MOTOR/GEARING MARGIN FOR Braidwood 2AF017A (LIMITORQUE METHODOLOGY)

Parameter	Row	Values: Average	Values: Worst Case	Parameter Runs: Nominal Case	High TSR	High Eq. Inacc. (torque)					Design Sum of Squares
Stem Pitch	(A)	0.333		0.333	0.333	0.333					
Stem Lead	(B)	0.667		0.667	0.667	0.667					
Stem Dia	(C)	1.000		1.000	1.000	1.000					
Stem Thread	(D)	stub		stub	stub	stub					
Meas CST Torq. (Generic SP)	(E)	56	72	56	56	72					
CST Torque (@ 0.08 cof)	(F)	43		43	43	43					
TSR	(G)	0%	5%	0%	5%	0%					
CST Torque (w/TSR)	(H)			56	58	72					Close
											MGC
Motor Rating	(I)	5		5	5	5					Sigma
Temperature Factor	(J)	1.000		1.000	1.000	1.000					Level
OAR	(K)	40.0		40.0	40.0	40.0					3.24
Close Efficiency	(L)	50%		50%	50%	50%					
Degraded Voltage	(M)	419		419	419	419					Conf.
Nominal Voltage	(N)	460		460	460	460					Level
exponent (AC=2)	(O)	2		2	2	2					99.94%
Close MGC (torque)	(P)			83	83	83					
Close MGC											
Margin (percent)	(Q)			49.2%	44.2%	19.2%					18.8%
effect in % change	(R)				5.0%	30.0%					30.4%

General Notes:
Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects.
MGC for AC motors based on current Limitorque Guidance (1.0 application factor with temperature factor and degraded voltage).
This analysis does not consider conservatism in degraded voltage, DP & LP
Valve Specific Notes:

UATION OF CLOSE MOTOR/GEARING MARGIN FOR Braidwood 2AF017A (ENHANCED MGC METHODOLOGY)

Parameter	Row	Values: Average	Values: Worst Case	Parameter Runs: Nominal Case	High TSR	High Eq. Inacc. (torque)	Low Motor Torque	Low Close Effic.			Design Sum of Squares
Stem Pitch	(A)	0.333		0.333	0.333	0.333	0.333	0.333			
Stem Lead	(B)	0.667		0.667	0.667	0.667	0.667	0.667			
Stem Dia	(C)	1.000		1.000	1.000	1.000	1.000	1.000			
Stem Thread	(D)	stub		stub	stub	stub	stub	stub			
Meas. CST Torq. (Generic SP)	(E)	56	72	56	55.6	72	55.6	55.6			
CST Torque (@ 0.08 cof)	(F)	43		43	43	43	43	43			
TSR	(G)	0%	5%	0%	5%	0%	0%	0%			
CST Torque (w/TSR)	(H)			56	58	72	56	56			Close
											MGC
Motor Rating	(I)	6	5.31	6	6	6	5	6			Sigma
Temperature Factor	(J)	1.000		1.000	1.000	1.000	1.000	1.000			Level
OAR	(K)	40.0		40.0	40.0	40.0	40.0	40.0			2.90
Close Efficiency	(L)	45%	40%	45%	45%	45%	45%	40%			
Degraded Voltage	(M)	419		419	419	419	419	419			Conf.
Nominal Voltage	(N)	460		460	460	460	460	460			Level
exponent	(O)	2.20		2.20	2.20	2.20	2.20	2.20			99.81%
Close MGC (torque)	(P)			86	86	86	78	77			
Close MGC											
Margin (percent)	(Q)			55.6%	50.6%	25.6%	40.0%	38.3%			17.3%
effect in % change	(R)				5.0%	30.0%	15.6%	17.3%			38.3%

General Notes:
Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects.
This worksheet assumes a minimum static, as-left stem mu = 0.08. If measured stem mu is less than 0.08,
then CST torque is increased to correspond to CST thrust and 0.08 stem mu.
MGC for AC motors based White Paper 125 (1.0 application factor with temperature factor and degraded voltage).
This analysis does not consider conservatism in degraded voltage, DP & LP
Valve Specific Notes:

3/14/95
8:21 AM

ALUATION OF OPEN MOTOR/GEARING MARGIN FOR Braidwood 2AF017A (LIMITORQUE METHODOLOGY)

Parameter	Row	Values: Average	Values: Worst Case	Parameter Runs: Nominal Case	High Open Stem Mu	High Open Packing	High Eq. Inacc. (thrust)	High Open VF			Design Sum of Squares
Stem Pitch	(A)	0.333		0.333	0.333	0.333	0.333	0.333			
Stem Lead	(B)	0.667		0.667	0.667	0.667	0.667	0.667			
Stem Dia	(C)	1.000		1.000	1.000	1.000	1.000	1.000			
Stem Thread	(D)	stub		stub	stub	stub	stub	stub			
Motor Rating	(I)	5		5	5	5	5	5			
Temperature Factor	(J)	1.000		1.000	1.000	1.000	1.000	1.000			
OAR	(K)	40.0		40.0	40.0	40.0	40.0	40.0			
Degraded Voltage	(M)	419		419	419	419	419	419			
Nominal Voltage	(N)	460		460	460	460	460	460			
exponent (AC=2)	(O)	2		2	2	2	2	2			
Max. Static Closing Thrust	(S)	4980		4980	4980	4980	4980	4980			
Open Equipment Inaccuracy	(T)	52%									
Open Unwedging Thrust	(U)	2200	3344	2200	2200	2200	3344	2200			
Seat Angle (degrees)	(V)	5		5	5	5	5	5			
Open Valve Factor	(W)	0.31	0.53	0.31	0.31	0.31	0.31	0.53			
Open Running Load	(X)	580	780	580	580	780	580	580			
Open Design DP	(Y)	90		90	90	90	90	90			Open
Open MRT	(Z)			1343	1343	1543	1343	1899			MGC
Max. Open Req. Thrust	(AA)			2200	2200	2200	3344	2200			Sigma
											Level
Open Stem Mu	(BB)	0.12	0.20	0.12	0.20	0.12	0.12	0.12			3.44
Open Stem Factor	(CC)			0.0139	0.0174	0.0139	0.0139	0.0139			
Open Efficiency	(DD)	40%		40%	40%	40%	40%	40%			Cont.
Open MGC (thrust)	(EE)			4777	3807	4777	4777	4777			Level
											99.97%
Open MGC											
Margin (percent)	(FF)			117.1%	73.0%	117.1%	65.1%	117.1%			48.9%
effect in % change	(GG)				44.1%	0.0%	52.0%	0.0%			68.2%

General Notes

Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects.
Worst Case unwedging thrust equal to lessor of 80% of max. closing thrust or measured unwedging thrust plus equipment inaccuracy
Open valve factor (VF) is function of close seating VF and seat angle (see Chron 210928 for discussion). For flow under seat globes, VF set to zero.
Minimum static, as-left stem mu = 0.08. Open stem mu is not measured during testing due to equipment limitations. Therefore, average (0.12) and 95% confidence level (0.20) values for close stem mu (from VTC test data) are used for this parameter.
MGC for AC motors based on current Limitorque Guidance (1.0 application factor with temperature factor and degraded voltage).
This analysis does not consider conservatism in degraded voltage, DP & LP

Valve Specific Notes:

UATION OF OPEN MOTOR/GEARING MARGIN FOR Braidwood 2AF017A (ENHANCED MGC METHODOLOGY)

Parameter	Row	Values		Parameter Runs							Design
		Average	Worst Case	Nominal Case	Low Motor Torque	Low Open Effic.	High Open Stem Mu	High Open Packing	High Eq. Inacc. (thrust)	High Open VF	Sum of Squares
Stem Pitch	(A)	0.333		0.333	0.333	0.333	0.333	0.333	0.333	0.333	
Stem Lead	(B)	0.667		0.667	0.667	0.667	0.667	0.667	0.667	0.667	
Stem Dia	(C)	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Stem Thread	(D)	stub		stub	stub	stub	stub	stub	stub	stub	
Max. Static Closing Thrust	(E)	4980		4980	4980	4980	4980	4980	4980	4980	
Open Equipment Inaccuracy	(F)	52%									
Open Unwedging Thrust	(G)	2200	3344	2200	2200	2200	2200	2200	3344	2200	
Seat Angle (degrees)	(H)	5		5	5	5	5	5	5	5	
Open Valve Factor	(I)	0.31	0.53	0.31	0.31	0.31	0.31	0.31	0.31	0.53	
Open Running Load	(J)	580	780	580	580	580	580	780	580	580	
Open Design DP	(K)	90		90	90	90	90	90	90	90	
Open MRT	(L)			1343	1343	1343	1343	1543	1343	1899	
Max. Open Req. Thrust	(M)			2200	2200	2200	2200	2200	3344	2200	
Motor Rating	(N)	6	5.31	6	5	6	6	6	6	6	
Temperature Factor	(O)	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	
OAR	(P)	40.0		40.0	40.0	40.0	40.0	40.0	40.0	40.0	
Open Efficiency	(Q)	45%	40%	45%	45%	40%	45%	45%	45%	45%	
Degraded Voltage	(R)	419		419	419	419	419	419	419	419	
Nominal Voltage	(S)	460		460	460	460	460	460	460	460	Open
exponent	(T)	2.20		2.20	2.20	2.20	2.20	2.20	2.20	2.20	MGC
Open MGC (torque)	(U)			86	78	77	86	86	86	86	Sigma
											Level
											4.14
Open Stem Mu	(V)	0.12	0.20	0.12	0.12	0.12	0.20	0.12	0.12	0.12	
Open Stem Factor	(W)			0.0139	0.0139	0.0139	0.0174	0.0139	0.0139	0.0139	Conf.
Open MGC (thrust)	(X)			6224	5602	5533	4960	6224	6224	6224	Level
											100.00%
Open MGC											
Margin (percent)	(Y)			182.9%	154.6%	151.5%	125.5%	182.9%	130.9%	182.9%	94.6%
effect in % change	(Z)			-	28.3%	31.4%	57.5%	0.0%	52.0%	0.0%	88.3%

General Notes:

Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects.

Worst Case unwedging thrust equal to lessor of 80% of max. closing thrust or measured unwedging thrust plus equipment inaccuracy.

Open valve factor (VF) is function of close seating VF and seat angle (see Chron 210928 for discussion). For flow under seat globes, VF set to zero.

Open stem mu is not measured during testing due to equipment limitations. Therefore, average (0.12) and 95% confidence level (0.20) values for close stem mu (from VTC test data) are used for this parameter.

MGC for AC motors based on White Paper 125 (1.0 application factor with temperature factor and degraded voltage).

This analysis does not consider conservatism in degraded voltage and open DP.

Valve Specific Notes:

EVALUATION OF STRUCTURAL LIMIT MARGINS FOR Braidwood 2AF017A (OPEN DIRECTION)

Parameter	Row	Values: Average	Values: Worst Case	Parameter Runs: Nominal Case	High Stem Mu	Low Act.Th. Capab.	Low Valve Capab.	Low Act.Tq. Capab.	High Valve Factor	High Packing Load	High Eq. Inacc (thrust)	Design Sum of Squares
Actuator Thrust Limit	(A)	8800	8800	8800	8800	8800	8800	8800	8800	8800	8800	
Actuator Torque Limit	(B)	99	99	99	99	99	99	99	99	99	99	
Valve Structural Limit	(C)	14340	14340	14340	14340	14340	14340	14340	14340	14340	14340	
Worst Case Torque Limit	(D)			99	99	99	99	99	99	99	99	
Worst Case Thrust Limit	(E)			8800	8800	8800	8800	8800	8800	8800	8800	
Open Stem Mu	(F)	0.12	0.20	0.12	0.20	0.12	0.12	0.12	0.12	0.12	0.12	
Stem Pitch	(G)	0.3333		0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	Thrust
Stem Lead	(H)	0.6667		0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	Sigma
Stem Dia	(I)	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	Level
Stem Thread	(J)	stub		stub	stub	stub	stub	stub	stub	stub	stub	11.54
Open Stem Factor	(K)			0.0139	0.0175	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	
												Conf Level
Max. Closing Thrust	(L)	4980		4980	4980	4980	4980	4980	4980	4980	4980	100.00%
Open Equipment Inaccura	(M)	0%	52%	0%	0%	0%	0%	0%	0%	0%	52%	
Open Unwedging Thrust	(N)	2200	3344	2200	2200	2200	2200	2200	2200	2200	3344	
Seat Angle (degrees)	(O)	5										
Open Valve Factor	(P)	0.31	0.53	0.31	0.31	0.31	0.31	0.31	0.53	0.31	0.31	
Open Running Load	(Q)	580	780	580	580	580	580	580	580	780	580	
Open Design DP	(R)	90		90	90	90	90	90	90	90	90	Torque
Open MRT	(S)			1343	1343	1343	1343	1343	1899	1543	1343	Sigma
												Level
												7.69
Max. Open Req. Thrust	(T)			2200	2200	2200	2200	2200	2200	2200	3344	
Max. Open Req. Torque	(U)			31	39	31	31	31	31	31	47	
												Conf.
												Level
												100.00%
Thrust Margin (percent)	(V)			300.0%	300.0%	300.0%	300.0%	300.0%	300.0%	300.0%	248.0%	248.0%
effect in % change	(W)				0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	52.0%	52.0%
Torque Margin (percent)	(X)			223.1%	197.4%	223.1%	223.1%	223.1%	223.1%	223.1%	171.1%	165.1%
effect in % change	(Y)				25.7%	0.0%	0.0%	0.0%	0.0%	0.0%	52.0%	58.0%

General Notes.
Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects.
For gate valves, worst case unwedging thrust equal to lessor of 80% of max. closing thrust or measured unwedging thrust plus equipment inaccuracy. When the measured unwedging thrust exceeds 80% of the max closing thrust, 105% of measured thrust is used. For globe valves, 30% is used instead of 80%.
Open valve factor (VF) is function of close seating VF and seat angle (see Chron 210928 for discussion). For flow under seat globes, VF set to zero.
Open stem mu is not measured during testing due to equipment limitations. Therefore, average (0.12) and 95% confidence level (0.20) values for close stem mu (from VTC test data) are used for this parameter
This analysis does not consider conservatism in DP

Valve Specific Notes:

EVALUATION OF STRUCTURAL LIMIT MARGINS FOR Braidwood 2AF017A (CLOSE DIRECTION)

Parameter	Row	Values		Parameter Runs									Design Sum of Squares
		Average	Worst Case	Nominal Case	High Inertia	Low Act.Th. Capab.	Low Valve Capab.	Low Act.Tq. Capab.	Stem Mu Decr.	High TSR	High Eq. Inacc. (torque)	High Eq. Inacc (thrust)	
Actuator Thrust Limit	(A)	8800	8800	8800	8800	8800	8800	8800	8800	8800	8800	8800	
Actuator Torque Limit	(B)	99	99	99	99	99	99	99	99	99	99	99	
Valve Structural Limit	(C)	28296	28296	28296	28296	28296	28296	28296	28296	28296	28296	28296	
Valve Seismic Limit	(D)	10400	10400	10400	10400	10400	10400	10400	10400	10400	10400	10400	
Worst Case Torque Limit	(E)			99	99	99	99	99	99	99	99	99	
Worst Case Thrust Limit	(F)			8800	8800	8800	8800	8800	8800	8800	8800	8800	
													Thrust
Static CST Thrust (meas.)	(G)	3508	3859	3508	3508	3508	3508	3508	3508	3508	3508	3859	Sigma
CST Torque (Generic SP)	(H)	55.6	72	55.6	55.6	55.6	55.6	55.6	55.6	55.6	72.3	55.6	Level
Static Stem Factor	(I)			0.0158	0.0158	0.0158	0.0158	0.0158	0.0158	0.0158	0.0206	0.0144	11.11
Stem Pitch	(J)	0.3333		0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	Cont.
Stem Lead	(K)	0.6667		0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	Level
Stem Dia	(L)	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	100.00%
Stem Thread	(M)	stub		stub	stub	stub	stub	stub	stub	stub	stub	stub	
Static (as-left) Stem Mu	(N)			0.1633	0.1633	0.1633	0.1633	0.1633	0.1633	0.1633	0.2664	0.1309	
Stem Mu Variation	(O)	0.000	0.0250	0.000	0.000	0.000	0.000	0.000	0.025	0.000	0.000	0.000	
As Found Stem Mu	(P)			0.1633	0.1633	0.1633	0.1633	0.1633	0.1383	0.1633	0.2664	0.1309	Torque
As Found Stem Fact.	(Q)			0.0158	0.0158	0.0158	0.0158	0.0158	0.0147	0.0158	0.0206	0.0144	Sigma
TSR (torque change)	(R)	0%	5%	0%	0%	0%	0%	0%	0%	5%	0%	0%	Level
Spring Pack Relaxation	(S)	0%		0%	0%	0%	0%	0%	0%	0%	0%	0%	1.66
As Found CST Torq.	(T)			56	56	56	56	56	56	58	72	56	
As Found CST Thrust	(U)			3508	3508	3508	3508	3508	3773	3683	3508	3859	
Inertia Factor	(V)	1.41961	1.46157	1.41961	1.46157	1.41961	1.41961	1.41961	1.41961	1.41961	1.41961	1.4196123	Cont.
Maximum Thrust	(W)			4980	5127	4980	4980	4980	5356	5229	4980	5478	Level
Maximum Torque	(X)			79	81	79	79	79	79	83	103	79	95.20%
Thrust Margin (percent)	(Y)			43.4%	41.7%	43.4%	43.4%	43.4%	39.1%	40.6%	43.4%	37.7%	35.6%
effect in % change	(Z)				1.7%	0.0%	0.0%	0.0%	4.3%	2.8%	0.0%	5.7%	7.8%
Torque Margin (percent)	(AA)			20.3%	17.9%	20.3%	20.3%	20.3%	20.3%	16.3%	-3.6%	20.3%	-4.1%
effect in % change	(AB)				2.4%	0.0%	0.0%	0.0%	0.0%	4.0%	23.9%	0.0%	24.4%

General Notes:

Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects.

For conservatism, no spring pack relaxation considered. This analysis does not consider conservatism in DP & LP

Inertia Factor variability assumed to be +/- 5%

Minimum Stem Mu of 0.08 used in analysis when apparent (measured) static stem mu is less than 0.08)

Valve Specific Notes:

Worst case value assumed for spring pack relaxation.

Limit Close, Seating, Enhanced MGC is N/A, Do Not Use This Sheet

Parameter	Row	Values: Average	Values: Worst Case	Parameter Runs: Nominal Case	High Packing & VC	High Close VF	High Stem Mu Degrad.	High LSB	High Eq. Inacc. (torque)	High Eq. Inacc. (thrust)	Low Motor Torque	Low Close Effic.	Design Sum of Squares
Valve Factor (isol.)	(A)	0.327	0.59	0.327	0.327	0.59	0.327	0.327	0.327	0.327	0.327	0.327	
DP	(B)	90		90	90	90	90	90	90	90	90	90	
Seat Diameter	(C)	5.91		5.91	5.91	5.91	5.91	5.91	5.91	5.91	5.91	5.91	
DP Load	(D)			806	806	1455	806	806	806	806	806	806	
LP	(E)	90		90	90	90	90	90	90	90	90	90	
Piston Effect	(F)			71	71	71	71	71	71	71	71	71	
Static Running Load	(G)	743	943	743	943	743	743	743	743	743	743	743	
Valve Condition Load	(H)	60	72	60	72	60	60	60	60	60	60	60	
Total Static Load	(I)			803	1015	803	803	803	803	803	803	803	
Total Load	(J)			1680	1892	2328	1680	1680	1680	1680	1680	1680	
Stem Pitch	(K)	0.333		0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	
Stem Lead	(L)	0.667		0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	
Stem Dia	(M)	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Stem Thread	(N)	stub		stub	stub	stub	stub	stub	stub	stub	stub	stub	
Static CST Thrust (meas.)	(O)	3508	3157	3508	3508	3508	3508	3508	3508	3157	3508	3508	
CST Torque (estimated)	(P)	55.6	72.28	56	56	56	56	56	72	56	56	56	
Static Stem Factor	(Q)			0.0158	0.0158	0.0158	0.0158	0.0158	0.0206	0.0176	0.0158	0.0158	
Static (as-left) Stem Mu	(R)			0.1633	0.1633	0.1633	0.1633	0.1633	0.2664	0.2022	0.1633	0.1633	
ROL (change in thrust)	(S)	5.0%	20.5%	5.0%	5.0%	5.0%	5.0%	20.5%	5.0%	5.0%	5.0%	5.0%	
Dynamic CST Thrust	(T)			3333	3333	3333	3333	2789	3333	2999	3333	3333	
Dynamic Stem Factor	(U)			0.0167	0.0167	0.0167	0.0167	0.0199	0.0217	0.0185	0.0167	0.0167	
(w/o Degradation)													
Dynamic (as-left) Stem Mu	(V)			0.1819	0.1819	0.1819	0.1819	0.2523	0.2891	0.2223	0.1819	0.1819	
Stem Mu Variation	(W)	0.0000	0.0250	0.0000	0.0000	0.0000	0.0250	0.0000	0.0000	0.0000	0.0000	0.0000	
Dynamic (as-found) Mu	(X)			0.1819	0.1819	0.1819	0.2069	0.2523	0.2891	0.2223	0.1819	0.1819	
Dynamic As-Found SF	(Y)			0.0166	0.0166	0.0166	0.0177	0.0198	0.0216	0.0185	0.0166	0.0166	
Motor Rating	(Z)	5.9	5.31	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.31	5.9	
Temperature Factor	(AA)	1		1	1	1	1	1	1	1	1	1	
OAR	(BB)	40		40	40	40	40	40	40	40	40	40	Sigma Level
Close Efficiency	(CC)	45%	40%	45%	45%	45%	45%	45%	45%	45%	45%	40%	
Degraded Voltage	(DD)	419		419	419	419	419	419	419	419	419	419	3.48
Nominal Voltage	(EE)	460											
exponent	(FF)	2.199		2.199	2.199	2.199	2.199	2.199	2.199	2.199	2.199	2.199	Conf. Level
Close MGC	(GG)			4683	4683	4683	4386	3925	3611	4219	4215	4163	
													99.97%
Margin (percent)	(HH)			178.8%	166.2%	140.2%	161.1%	133.6%	114.9%	151.1%	150.9%	147.8%	75.9%
effect in % change	(II)				12.6%	38.6%	17.7%	45.1%	63.8%	27.7%	27.9%	31.0%	102.8%

General Notes:

Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects.

Running load inaccuracy assumed to be the greater of +/- 20% or +/- 200 lbf. Valve Condition load inaccuracy assumed to be +/-20%.

MGC is based on enhanced MGC equation. The uncertainty due to motor torque capability and actuator efficiency is considered.

Minimum static, as-left stem mu = 0.08. This analysis does not consider conservatism in degraded voltage, DP & LP

For flow over the seat globe valves, valve factor is set to zero.

Valve Specific Notes:

Limit Close, Flow Isolation, Enhanced MGC is N/A, Do Not Use This Sheet

Parameter	Row	Values: Average	Values: Worst Case	Parameter Runs: Nominal Case	High Packing	High Close VF	High Stem Mu Degrad.	High LSB	High Eq. Inacc. (torque)	High Eq. Inacc. (thrust)	Low Motor Torque	Low Close Effic.	Design Sum of Squares
Valve Factor (isol.)	(A)	0.327	0.59	0.327	0.327	0.59	0.327	0.327	0.327	0.327	0.327	0.327	
DP	(B)	90		90	90	90	90	90	90	90	90	90	
Seat Diameter	(C)	5.91		5.906	5.906	5.906	5.906	5.906	5.906	5.906	5.906	5.906	
DP Load	(D)			806	806	1455	806	806	806	806	806	806	
LP	(E)	90		90	90	90	90	90	90	90	90	90	
Piston Effect	(F)			71	71	71	71	71	71	71	71	71	
Static Running Load	(G)	743	943	743	943	743	743	743	743	743	743	743	
Total Load	(J)			1620	1820	2268	1620	1620	1620	1620	1620	1620	
Stem Pitch	(K)	0.333		0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	
Stem Lead	(L)	0.667		0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	
Stem Dia	(M)	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Stem Thread	(N)	stub		stub	stub	stub	stub	stub	stub	stub	stub	stub	
Static CST Thrust (meas.)	(O)	3508	3157	3508	3508	3508	3508	3508	3508	3157	3508	3508	
CST Torque (estimated)	(P)	55.6	72.28	56	56	56	56	56	72	56	56	56	
Static Stem Factor	(Q)			0.0158	0.0158	0.0158	0.0158	0.0158	0.0206	0.0176	0.0158	0.0158	
Static (as-left) Stem Mu	(R)			0.1633	0.1633	0.1633	0.1633	0.1633	0.2664	0.2022	0.1633	0.1633	
ROL (change in thrust)	(S)	5.0%	20.5%	5.0%	5.0%	5.0%	5.0%	20.5%	5.0%	5.0%	5.0%	5.0%	
Dynamic CST Thrust	(T)			3333	3333	3333	3333	2789	3333	2999	3333	3333	
Dynamic Stem Factor	(U)			0.0167	0.0167	0.0167	0.0167	0.0199	0.0217	0.0185	0.0167	0.0167	
(w/o Degradation)													
Dynamic (as-left) Stem Mu	(V)			0.1819	0.1819	0.1819	0.1819	0.2523	0.2891	0.2223	0.1819	0.1819	
Stem Mu Variation	(W)	0.0000	0.0250	0.0000	0.0000	0.0000	0.0250	0.0000	0.0000	0.0000	0.0000	0.0000	
Dynamic (as-found) Mu	(X)			0.1819	0.1819	0.1819	0.2069	0.2523	0.2891	0.2223	0.1819	0.1819	
Dynamic As-Found SF	(Y)			0.0166	0.0166	0.0166	0.0177	0.0198	0.0216	0.0185	0.0166	0.0166	
Motor Rating	(Z)	5.9	5.31	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.31	5.9	
Temperature Factor	(AA)	1		1	1	1	1	1	1	1	1	1	
OAR	(BB)	40		40	40	40	40	40	40	40	40	40	Sigma
Close Efficiency	(CC)	45%	40%	45%	45%	45%	45%	45%	45%	45%	45%	40%	Level
Degraded Voltage	(DD)	419		419	419	419	419	419	419	419	419	419	3.55
Nominal Voltage	(EE)	460											
exponent	(FF)	2.199		2.199	2.199	2.199	2.199	2.199	2.199	2.199	2.199	2.199	Conf.
Close MGC	(GG)			4683	4683	4683	4386	3925	3611	4219	4215	4163	Level
													99.98%
Margin (percent)	(HH)			189.1%	176.8%	149.1%	170.8%	142.3%	122.9%	160.4%	160.2%	157.0%	82.5%
effect in % change	(II)				12.3%	40.0%	18.3%	46.8%	66.2%	28.7%	28.9%	32.1%	106.5%

General Notes.
Sum of Squares Margin is equal to nominal margin minus the square-root of the sum of the squares of the individual effects. Running load inaccuracy assumed to be the greater of +/- 20% or +/- 200 lbf. Valve Condition load is not applicable since it typically occurs after flow isolation.
MGC is based on enhanced MGC equation. The uncertainty due to motor torque capability and actuator efficiency is considered.
Minimum static, as-left stem mu = 0.08. This analysis does not consider conservatism in degraded voltage, DP & LP
For flow over the seat globe valves, valve factor is set to zero

Valve Specific Notes: