

MOVATS APPROACH TO RESOLUTION OF OPEN/CLOSE THRUST ERROR / BIAS ISSUE

PROBLEM

REASON FOR IMPROVEMENT

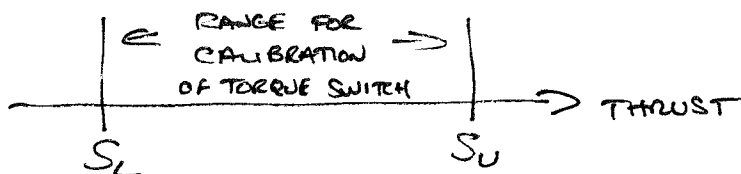
MOTOR OPERATED VALVES (MOV's) HAVE BEEN TESTED USING THE MOVATS TEST EQUIPMENT. OF PARTICULAR INTEREST IS THE CALIBRATION OF A TORQUE SWITCH THAT SHUTS DOWN THE ACTUATOR WHEN THE VALVE IS CLOSED (LIMIT SWITCHES SHUT DOWN THE VALVE WHEN IT OPENS)

THE TORQUE SWITCH IS CALIBRATED AGAINST THE THRUST DEVELOPED BY THE ACTUATOR. THE THRUST HAS A LOWER AND UPPER LIMIT:

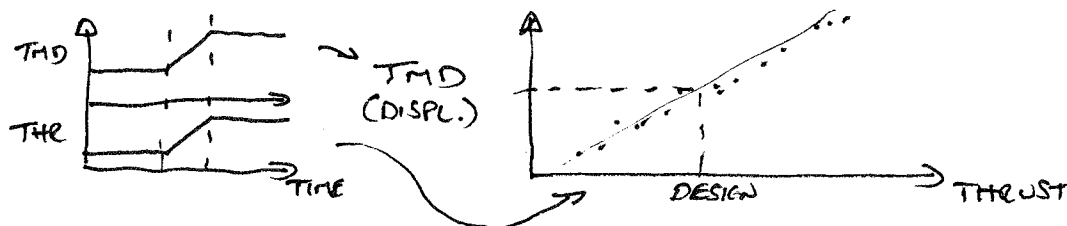
LOWER LIMIT: ACTUATOR MUST DEVELOP SUFFICIENT THRUST TO CLOSE AGAINST FRICTION FORCES AND FLUID (O/P) FORCES
(S_L)

UPPER LIMIT: ACTUATOR MUST SHUT OFF BEFORE TOO MUCH THRUST IS GENERATED TO AVOID VALVE / ACTUATOR DAMAGE
(S_U)

S_L, S_U CAN VARY FOR VALVE, UTILITY, PLANT



CALIBRATION METHOD: THE MOVATS METHOD MOUNTS A LOAD CELL ABOVE THE ACTUATOR. THE VALVE IS CYCLED OPEN UNTIL THE VALVE STEM STOPS AGAINST THE LOAD CELL. THE THRUST DEVELOPED BY THE STEM IS MEASURED AND RECORDED. AT THE SAME TIME, THE DISPLACEMENT OF THE VALVE'S SPRING PACK (AS IT IS COMPRESSED BY THE WORM GEAR / STEM NUT / STEM CONNECTION) IS RECORDED. THIS DATA IS CORRELATED:



THE DISPLACEMENT AT WHICH THE TORQUE SWITCH IS SET IS THEN OBTAINED FROM THE DESIRED THRUST (DESIGN)

THE ASSUMPTION IS (WAS) MADE THAT THE TORQUE DEVELOPED BY THE VALVE AS IT CLOSED WAS THE SAME AS IT OPENED.

ACCURACY: MOVATS DEVELOPED AN ACCURACY FOR THEIR TESTING PROCESS BASED ON STATED EQUIPMENT ACCURACIES THAT COMPOSE THE SYSTEM. THE LARGEST CONTRIBUTOR TO ACCURACY IS THE LIMITORQUE ACTUATOR'S REPEATABILITY (~5%)

CURRENT SITUATION

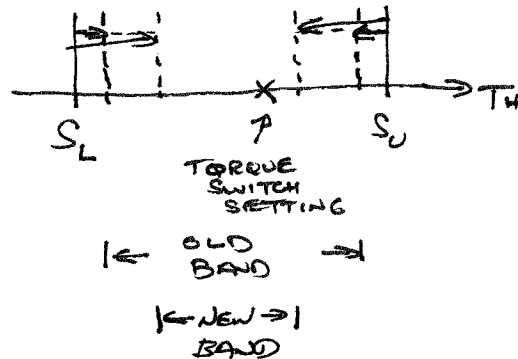
MOST VALVES TESTED USING MOVATS EQUIPMENT HAVE BEEN TORQUE SWITCH CALIBRATED USING THE OPEN-LOAD CELL METHOD.

FOR EACH VALVE, UTILITIES WILL HAVE:

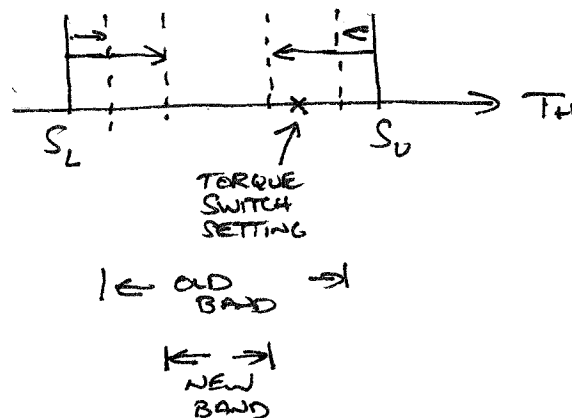
- UPPER SPEC LIMIT
- LOWER SPEC LIMIT
- VALVE PARAMETERS / DESIGN FEATURES
- TORQUE SWITCH SETTING

IF A NEW ERROR OR BIAS IS REPORTED BY MOVATS (LARGER THAN EXISTING SPECIFIED ERROR) UTILITIES WILL HAVE TO EVALUATE THE TORQUE SWITCH CALIBRATION AS FOLLOWS

a) NO CHANGE REQUIRED :

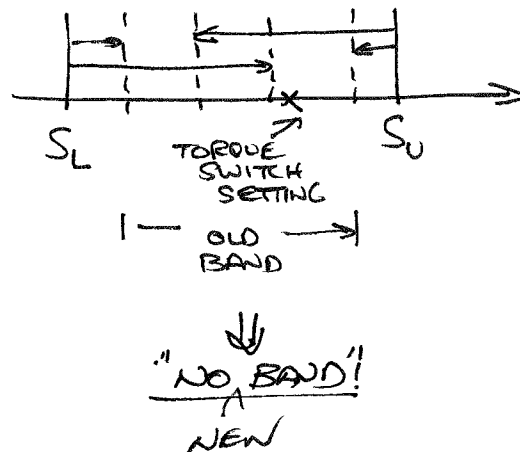


b) REVISE / RECALIBRATE TORQUE SWITCH :



ACTION: REDUCE SETTING TO FALL WITHIN NEW BAND

c) WIDEN SPEC LIMITS (e.g. S_U) OR BETTER ERROR/BIAS ANALYSIS



REANALYZE — (LIMITING)
OR FULL-DATE TEST
DESIGN CHANGE ←

FACTORS AFFECTING ERROR/BIAS

THE ERROR/BIAS COULD DIFFER AS A FUNCTION OF

ACTUATOR SIZE/TYPE

(e.g. SMB, SB, SBD, 000, 00, 0, 1, ... 3)

VARIOUS PARAMETERS SPECIFIC TO THE VALUE

- STEM (P, L, D) D
- SPRING PACK D
- MOTOR SPEED D
- GASKET THICKNESS M
- LUBRICATION M
- RATE OF LOAD O/C D
- OTHERS

D = Design Factor

M = Maintenance Factor.

- THRUST

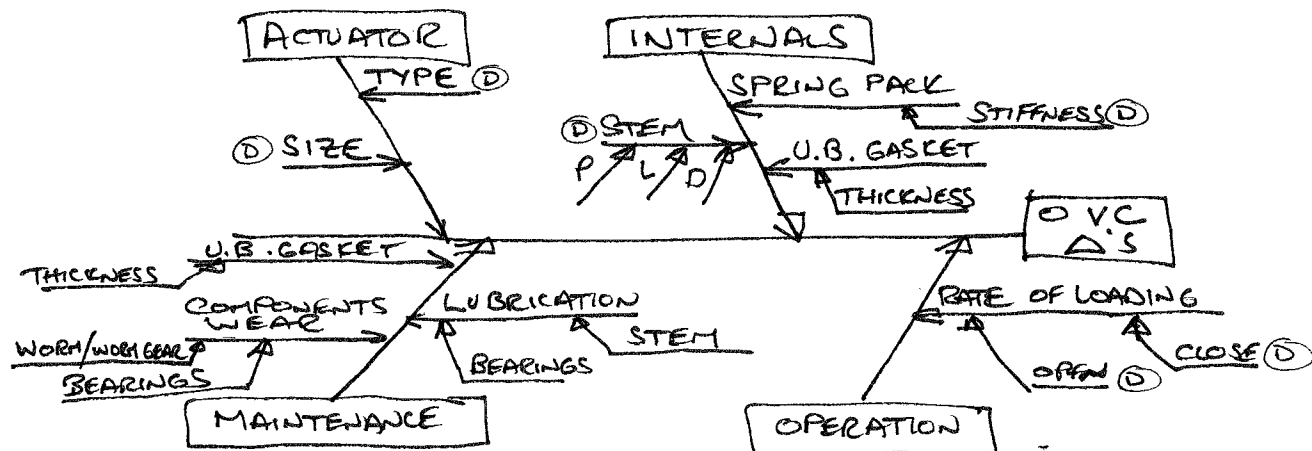
MOV'S
IN
NUCLEAR
INDUSTRY
(SR, HE D/P
CONDITIONS)

PROBLEM STATEMENT

- ① UNDERSTAND THE MAGNITUDE OF ERROR/BIAS AS A FUNCTION OF ACTUATORS/ PARAMETERS
- ② DEVELOP A PREDICTION MODEL SO UTILITIES CAN
 - a) ANALYZE THE EFFECT OF THE ERROR/BIAS
 - b) TAKE CORRECTIVE ACTION IF NEEDED.

ANALYSIS

I.D. POTENTIAL FACTORS AFFECTING OPEN/CLOSE ERROR :

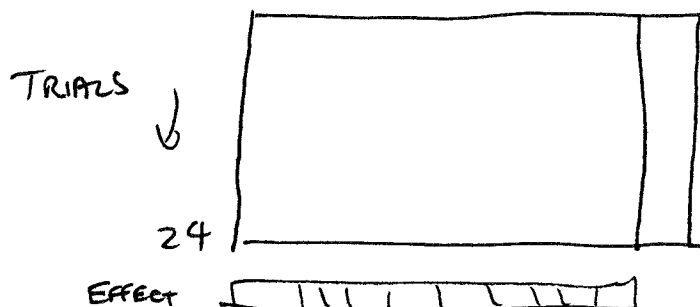


FOR THIS EFFORT, THE VALVES WILL BE ASSUMED TO BE IN GOOD CONDITION, WITH NO EXCESSIVE WEAR, PROPERLY MAINTAINED AND LUBRICATED. ONLY THOSE FACTORS LABELLED "D" WILL BE EXAMINED FOR PURPOSES OF PREDICTION (DEGRADED CONDITIONS WILL BE LOOKED AT FOR "GEE WHIZ" PURPOSES, EPRI'S PROGRAM WILL ANALYZE THESE CONDITIONS)

DETERMINE SIGNIFICANT FACTORS AFFECTING O/C BIAS/ERROR.

FRACTIONAL FACTORIAL EXPERIMENTAL DESIGN (PACKETT-BURMAN)

FACTORS = 10 EFFECT



FACTORS - OVC 1

STEM	LUBE	M	
WORM		D	M =
MOTOR RPM		D	MAINT
SPRING PACK		D	
S.P. PRELOAD		M	D =
RUN LOAD		D	DESIGN
U.B. GASKET		M	
U.B. LUBE		M	
OPEN ROL		D	
CLOSE ROL		D	

FOR OVC-1, SIGNIFICANT FACTORS :

STEM	LUBE	M
SPRING PACK		D
U.B. LUBE		M
ROL (CLOSE)		D

$$\text{EFFECT} = \frac{\text{CLOSE} - \text{OPEN}}{\text{OPEN}} \text{ THURST} \times 100$$

OVC-1 DESIGNED EXPERIMENT - TAGUCHI

① FACTORS (See Matrix)

NO: 10

INT'S 0

② # LEVELS : 2 / FACTOR

③ OA SELECTION

$$d.f._{\text{FACTORS}} = 2 - 1 = \underline{1}$$

$$d.f._{\text{INT'S}} = (2 - 1)(2 - 1) = \underline{1}$$

$$\begin{aligned} \# \text{ factors} &= 10 \\ \# \text{ INT'S} &= \frac{0}{10} = \sqrt{\text{REQ'D}} \end{aligned}$$

CRITERIA:

$$V_{LN} \geq V_{\text{REQUIRED}} = 10$$

$$V_{LN} = N - 1 \quad N = \# \text{ TRIALS}$$

$$N = 2LW + 1 \geq 11$$

$$N \geq 11 \quad \text{Nearest} = \boxed{L12} \quad (2 \text{ FACTOR})$$

④ FACTOR ASSIGNMENT

OVC-4 vs OVC-6

OPEN / CLOSE ROL
COMBINATION

AGREEMENT

COMMENT

F V M

Seems to be OK

H-SP > L-SP

F V S

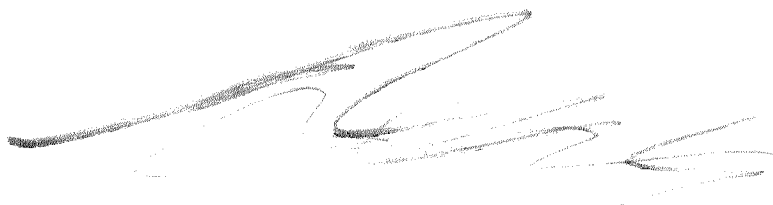
"

Fast Thrusts OVC-6
< FT's OVC-4

OVC-5 vs OVC-6

F V M

General, OK



NOTE: ① WITH 24 TRIALS, INTERACTIONS COULD BE DETECTED
(NONE CALC'D)

② CALC METHOD SIMPLIFIED, (NO ANOVA)

③ REPLICATIONS (AT LEAST 5/TRIAL) DONE, NO AVG EFFECT CALC'D

④ OVC-2 DONE, STEM VARIED, BUT DATA BAD.
DETAILED (REFINING EXP'S) TO ~~BE~~ INCLUDE
STEM VARIATION

SCREENING

ANALYSIS RESULTS:

IMPORTANT FACTORS (DESIGN)

ACTUATOR SIZE
STEM
SPRING PACK
ROL

REFINING EXPERIMENTS

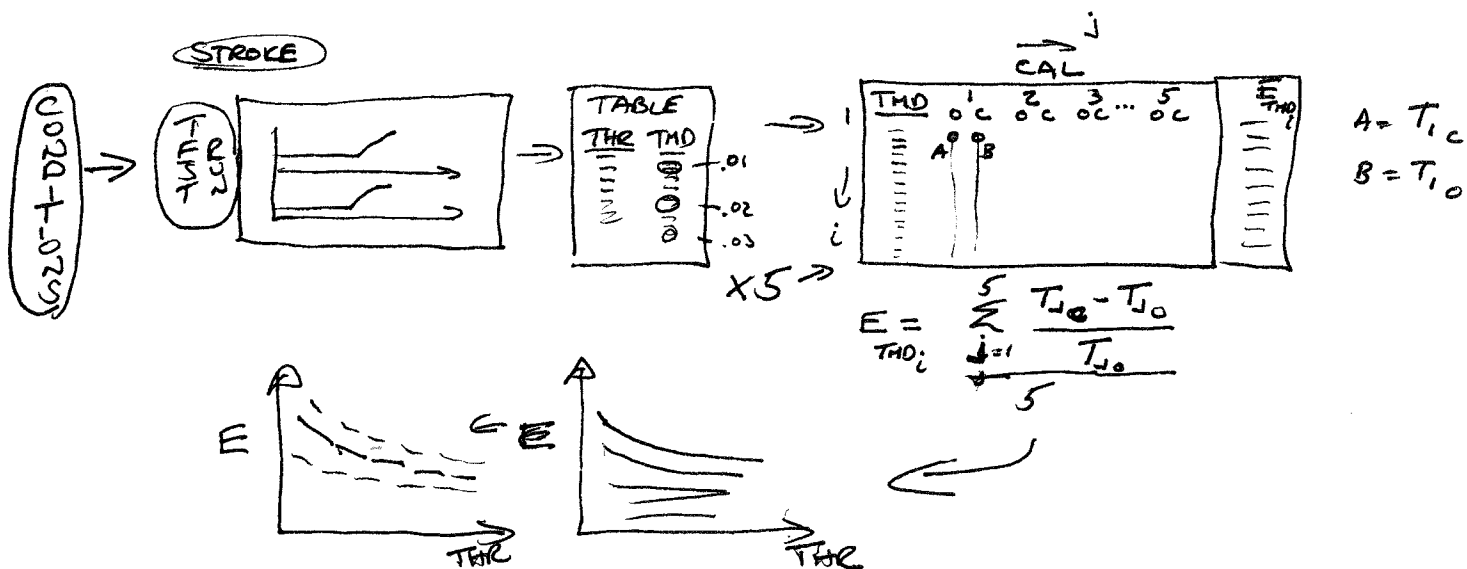
OBJECTIVE: TEST VARIOUS COMBINATIONS OF IMPORT
FACTORS AT DIFFERENT LEVELS

- DEVELOP UNDERSTANDING OF BEHAVIOR OF
VALUE AT VARIOUS FACTOR LEVELS / COMBINATIONS
- DEVELOP PREDICTION MODEL FOR FACTOR LEVELS
NOT TESTED
- UNDERSTAND BEHAVIOR AS A FUNCTION OF THRUST

METHOD

SIMILAR TO SCREENING ANALYSIS

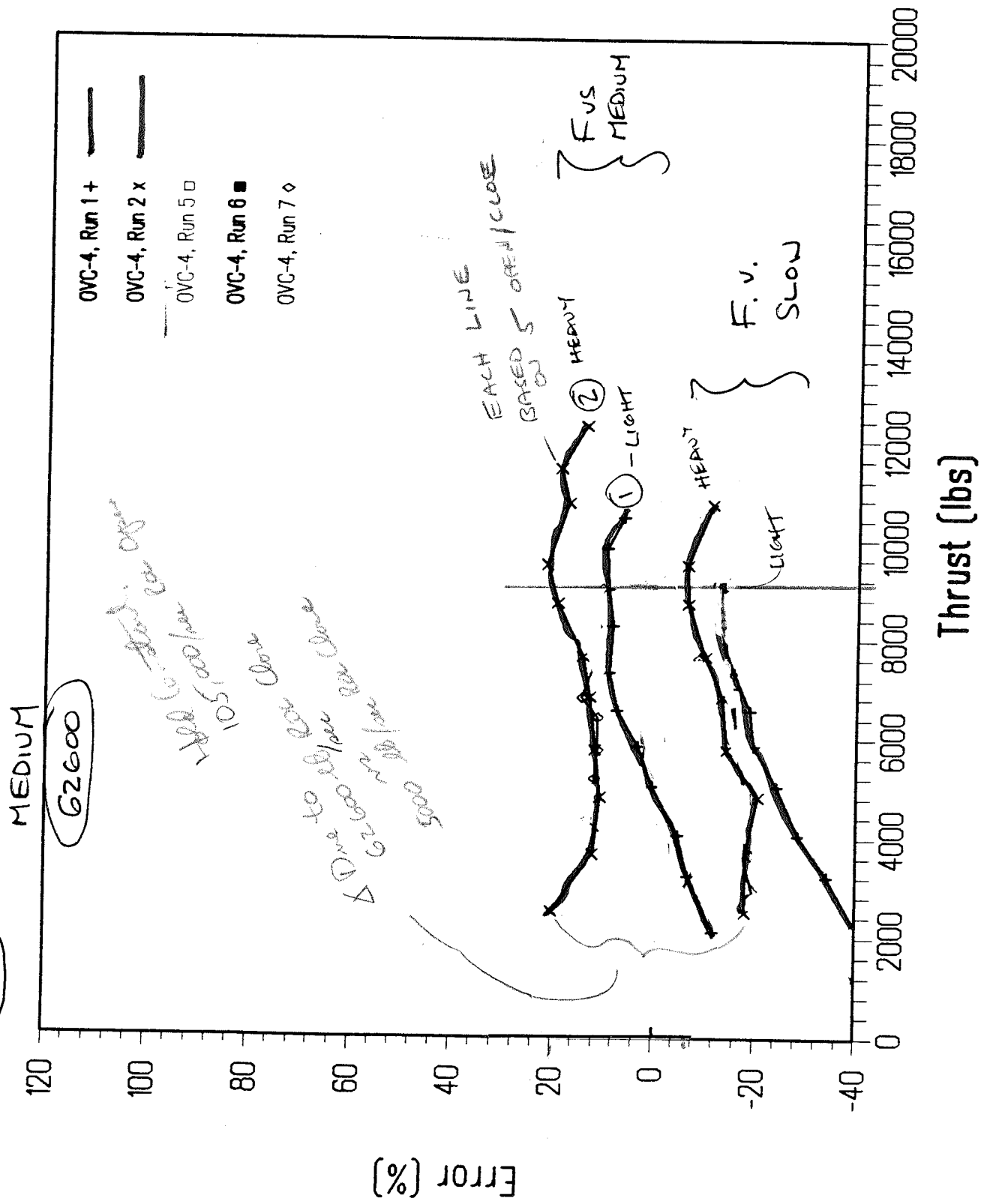
- 5 OPEN, 5 CLOSED CALIBRATIONS



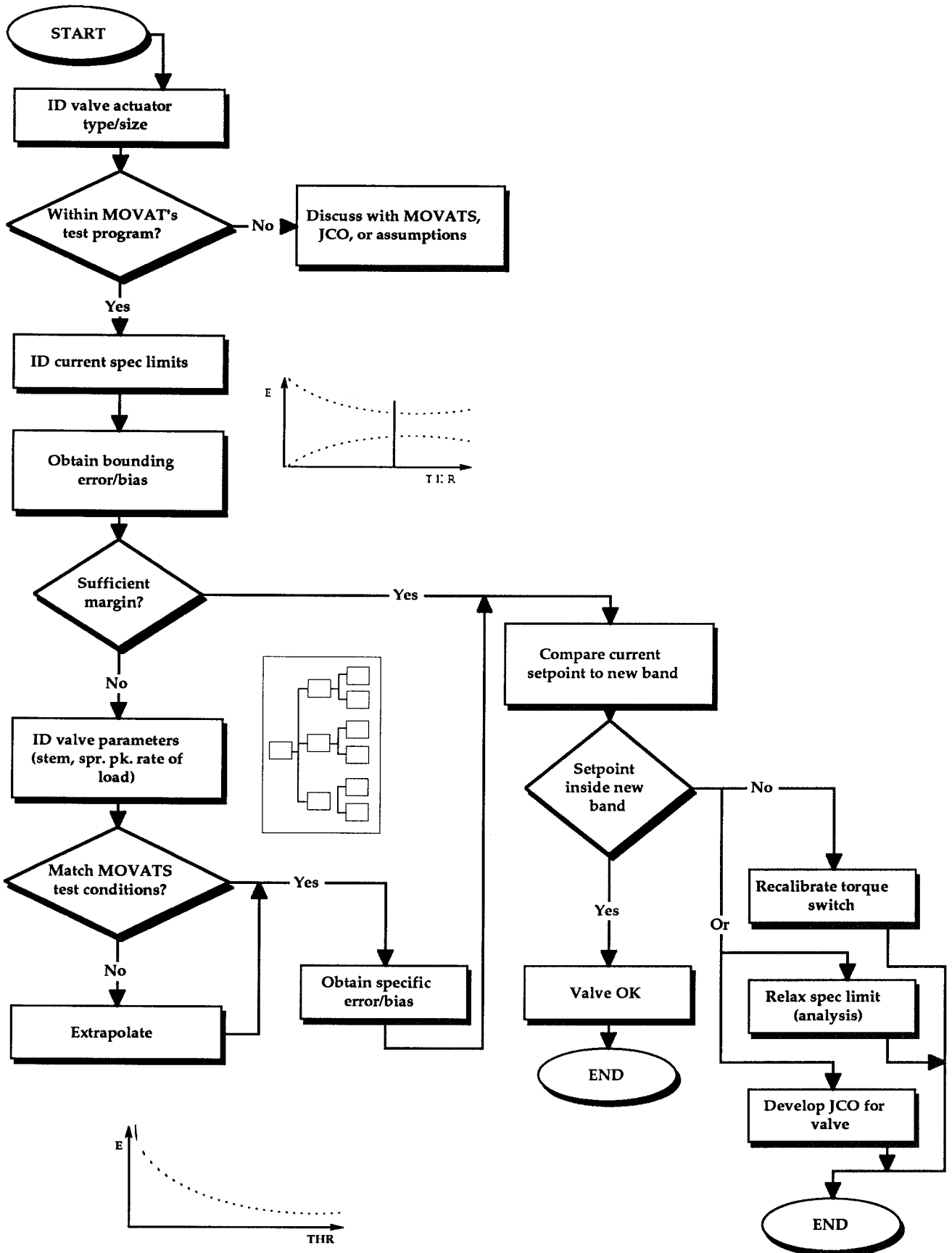
FUNCTIONAL RELATIONSHIP

$$E = \frac{T_{HRC} - T_{HRO}}{T_{HRO}} \equiv f \left(\begin{array}{l} \text{ACTUATOR, STEM, SPRING, THRUST} \\ \text{SIZE, (P,L,D), PACK, (THR)} \\ \text{MODEL, STIFFNESS} \end{array} \right. \\ \left. \begin{array}{l} \text{OPEN ROL, CLOSE ROL, ERROR} \\ \text{(}\dot{T}_{HRO}\text{), (}\dot{T}_{HRC}\text{), (OTHER} \\ \text{TERMS)} \end{array} \right)$$

Test Matrix OVC-4



LIMITORQUE ACTUATOR CLOSE/OPEN THRUST BIAS DETERMINATION



Phase I Sensitivity Testing

- 1) Sensitivity study on one SMB-00 and one SMB-0. **APPROXIMATELY 1,000 STROKES.**
Parameters varied included:

Stem lubrication
Stem characteristics
Upper bearing clearance
Upper bearing lubrication
Motor speed
Worm/Worm gear ratio
Spring pack stiffness
Spring pack preload
Rate of loading
Running load

Plackett Burman screening matrix used
to identify key parameters

- 2) Actuators in the test program consisted of used actuators with no broken or excessively worn components.

TEST MATRIX OVC-1
ACTUATOR SIZE SMB-0

STEM LUBE	WORM	MOTOR RPM	SPRING PACK	S.P. PRELOAD	RUN LOAD	U.B. GASKT	U.B. LUBE	OPEN ROL	CLOSE ROL	AVG ERROR
---	---	---	---	---	---	---	---	---	---	---
DRY	15.66	1700	LIGHT	NONE	3000	THIN	GREASE	SLOW	SLOW	14.9
DRY	15.66	3400	LIGHT	NRML	1000	NRML	GREASE	SLOW	SLOW	13.9
DRY	95	1700	LIGHT	NRML	1000	NRML	GREASE	FAST	FAST	13.6
GREASE	95	1700	HEAVY	NONE	1000	NRML	GREASE	SLOW	SLOW	11.5
DRY	95	1700	HEAVY	NRML	3000	NRML	DRY	SLOW	SLOW	7.4
GREASE	95	3400	LIGHT	NRML	1000	THIN	DRY	SLOW	SLOW	7.1
GREASE	15.66	1700	HEAVY	NRML	1000	THIN	GREASE	SLOW	FAST	6.9
GREASE	95	1700	HEAVY	NONE	3000	THIN	DRY	FAST	FAST	6.7
GREASE	95	3400	LIGHT	NONE	3000	NRML	GREASE	SLOW	FAST	4.0
DRY	95	3400	HEAVY	NRML	3000	THIN	GREASE	SLOW	FAST	3.2
DRY	15.66	3400	HEAVY	NONE	1000	NRML	DRY	SLOW	FAST	2.2
GREASE	15.66	3400	HEAVY	NONE	3000	THIN	DRY	SLOW	SLOW	1.8
GREASE	15.66	1700	LIGHT	NRML	3000	NRML	DRY	SLOW	FAST	1.0
GREASE	95	3400	HEAVY	NRML	1000	NRML	DRY	FAST	FAST	-0.2
GREASE	15.66	1700	LIGHT	NONE	1000	NRML	DRY	FAST	SLOW	-0.8
GREASE	15.66	3400	LIGHT	NONE	1000	THIN	GREASE	FAST	FAST	-1.7
GREASE	95	1700	LIGHT	NRML	3000	THIN	GREASE	FAST	SLOW	-4.6
DRY	95	1700	LIGHT	NONE	1000	THIN	DRY	SLOW	FAST	-5.3
DRY	15.66	1700	HEAVY	NRML	1000	THIN	DRY	FAST	SLOW	-6.7
DRY	15.66	1700	HEAVY	NONE	3000	NRML	GREASE	FAST	FAST	-7.2
DRY	95	3400	HEAVY	NONE	1000	THIN	GREASE	FAST	SLOW	-8.8
GREASE	15.66	3400	HEAVY	NRML	3000	NRML	GREASE	FAST	SLOW	-9.7
DRY	15.66	3400	LIGHT	NRML	3000	THIN	DRY	FAST	FAST	-12.2
DRY	95	3400	LIGHT	NONE	3000	NRML	DRY	FAST	SLOW	-17.5

EFFECT:

STEM LUBE	WORM	MOTOR RPM	SPRING PACK	S.P. PRELOAD	RUN LOAD	U.B. GASKT	U.B. LUBE	OPEN ROL	CLOSE ROL
---	---	---	---	---	---	---	---	---	---
3.8	0.6	0.2	2.8	0.1	0.9	1.4	2.6	0.8	2.8

Belville
ATTACHMENT 3
Too Thin $\Rightarrow$ Pre-Load Bars
Round $\Rightarrow$ Room to Move
Rate of Load
500 lb/in = SL
Drg
FA $\Rightarrow$ Solid Stop
Possible Interaction
REPEATABILITY
LIMIT TORQUE ERROR
Test runs ordered by
error magnitude
ROL $\Rightarrow$ I
UB. Carl + Luke $\Rightarrow$ I
Ab. Value
5 open
5 close

TEST MATRIX OVC-1
ACTUATOR SIZE SMB-0

6880

STEM	WORM	MOTOR	SPRING	S.P.	LOAD	U.B.	U.B.	OPEN	CLOSE	AVG
LUBE	B	RPM	PACK	PRELOAD	LOAD	GASKT	LUBE	ROL	ROL	ERROR
DRY	15.66	1700	LIGHT	NONE	3000	THIN	GREASE	SLOW	SLOW	14.9
DRY	15.66	3400	LIGHT	NRML	1000	NRML	GREASE	SLOW	SLOW	13.9
DRY	95	1700	LIGHT	NRML	1000	NRML	GREASE	FAST	FAST	13.6
GREASE	95	1700	HEAVY	NONE	1000	NRML	GREASE	SLOW	SLOW	11.5
DRY	95	1700	HEAVY	NRML	3000	NRML	DRY	SLOW	SLOW	7.4
GREASE	95	3400	LIGHT	NRML	1000	THIN	DRY	SLOW	SLOW	7.1
GREASE	15.66	1700	HEAVY	NRML	1000	THIN	GREASE	SLOW	FAST	6.9
GREASE	95	1700	HEAVY	NONE	3000	THIN	DRY	FAST	FAST	6.7
GREASE	95	3400	LIGHT	NONE	3000	NRML	GREASE	SLOW	FAST	4.0
DRY	95	3400	HEAVY	NRML	3000	THIN	GREASE	SLOW	FAST	3.2
DRY	15.66	3400	HEAVY	NONE	1000	NRML	DRY	FAST	FAST	2.2
GREASE	15.66	3400	HEAVY	NONE	3000	THIN	DRY	SLOW	SLOW	1.8
GREASE	15.66	1700	LIGHT	NRML	3000	NRML	DRY	SLOW	FAST	1.0
GREASE	95	3400	HEAVY	NRML	1000	NRML	DRY	FAST	FAST	-0.2
GREASE	15.66	1700	LIGHT	NONE	1000	NRML	DRY	FAST	SLOW	-0.8
GREASE	15.66	3400	LIGHT	NONE	1000	THIN	GREASE	FAST	FAST	-1.7
GREASE	95	1700	LIGHT	NRML	3000	THIN	GREASE	FAST	SLOW	-4.6
DRY	95	1700	LIGHT	NONE	1000	THIN	DRY	SLOW	FAST	-5.3
DRY	15.66	1700	HEAVY	NRML	1000	THIN	DRY	FAST	SLOW	-6.7
DRY	15.66	1700	HEAVY	NONE	3000	NRML	GREASE	FAST	FAST	-7.2
DRY	95	3400	HEAVY	NONE	1000	THIN	GREASE	FAST	SLOW	-8.8
GREASE	15.66	3400	HEAVY	NRML	3000	NRML	GREASE	FAST	SLOW	-9.7
DRY	15.66	3400	LIGHT	NRML	3000	THIN	DRY	FAST	FAST	-12.2
DRY	95	3400	LIGHT	NONE	3000	NRML	DRY	FAST	SLOW	-17.5

EFFECT:

STEM	WORM	MOTOR	SPRING	S.P.	LOAD	U.B.	U.B.	OPEN	CLOSE
LUBE		RPM	PACK	PRELOAD	LOAD	GASKT	LUBE	ROL	ROL
3.8	0.6	0.2	2.8	0.1	0.9	1.4	2.6	0.8	2.8

CONFIDENTIAL

PROPRIETARY