CALCULATION CONTROL SHEET

CALC. NO. IP3-CALC-SI-01060 REV. 0 IP3 [X] JAF [ ]

MOD/TASK NO. _____

QA CATEGORY OF CALCULATION: I
CALCULATIONAL TYPE: PRELIMINARY: ____ FINAL: X
PROJECT/TASK: GL 89-10 MOV PROGRAM
SYSTEM NO./NAME: _____
TITLE: THRUST AND TORQUE LIMITS SI-MOV-1835B

	NAME	SIGNATURE	DATE
DESIGN ENG.:	F.A. MULCAHY	F.A. Mulcahy	3/30/94
PREPARER:	F.A. MULCAHY	F.A. Mulcahy	3/30/94
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VERIFIED: N/A [ ]	F.W. MARTSEN	[illegible]	4/01/94
APPROVED:	A.J. DECKER II	[illegible]	4/1/94

PROBLEM/OBJECTIVE/METHOD

PROVIDE STATION WITH A THRUST AND TORQUE WINDOW FOR SETTING UP VALVE SI-MOV-1835B

DESIGN BASIS/ASSUMPTIONS

STEM COEFFICIENT OF FRICTION = 0.20
VALVE FACTOR = 0.50

SUMMARY/CONCLUSIONS

SUMMARY SHEETS PROVIDED IN CALCULATION

FOR INFORMATION ONLY

REFERENCES

PROVIDED IN CALCULATION

SYSTEM: SI
QA CAT: CAT I
FILE#: 41-D-0510

AFFECTED SYSTEMS/COMPONENTS/DOCUMENTS COMP. PRINTOUT LOC: _____

SI-MOV-1835B

[ ] VOIDED OR
[ ] SUPERSEDED BY: _____ (CALC. NO.)

RECEIVED
APR 06 1994
By Doc Control
K. Jackson

TABLE OF CONTENTS

NOTE

CALCULATIONS ARE PERFORMED USING EXCEL SPREADSHEET. RESULTS REPORTED HEREIN ARE ROUNDED OFF. THEREFORE, CORRESPONDING MANUAL CALCULATIONS MAY NOT EXACTLY MATCH REPORTED RESULTS.

MOTOR OPERATED GATE VALVE SIZING ANALYSIS

1. METHODOLOGY

A. Minimum Required Thrust

The standard industry equation for determining the minimum required thrust to operate a motor operated gate valve against some differential pressure is:

$$MRT = PL + PE + DPE$$

where MRT = minimum required thrust

PL = packing load

PE = piston effect

DPE = differential pressure effect

The packing load comes from either test data or industry standard values.

The piston effect is determined as follows:

$$PE = SA \times LP$$

where SA = Stem cross sectional area

LP = Line pressure

The piston effect is negative for an opening stroke and positive for a closing stroke.

The differential pressure effect is determined as follows:

$$DPE = VF \times AS \times DP$$

where AS = mean seat area

DP = differential pressure across valve seat

VF = valve factor. This comes from industry standard data or measured test data.

The minimum available thrust (MAT) is the minimum required thrust less the packing load:

$$MAT = MRT - PL$$

B. Motor Torque Derate Due To Ambient And Motor Temperatures

The standard equation used to derate motors due to ambient or motor temperature is:

$$R_{tor} = NMS - NMS \times \left(\frac{LOSS}{27900} \times (1.8 \times RISE \times TIME \times 2 + (TEMP - 104))\right)$$

where NMS = motor starting torque - ft-lbs

LOSS = % torque loss

RISE = temperature rise - °C/sec, from motor curve

TIME = stroke time - sec

TEMP = maximum ambient temperature - °F

C. Calculation of Torque and Thrust Values

1. MAX. VALVE MFG. LIMITS (MVL)

The MVL comes from the weak link analysis or from the valve manufacturer.

2. MAX. OPER RATED CAP. (THRUST) - MORC

The MORC EQUALS 1.4 times the operator rated thrust capacity (ORC). The ORC comes from manufacturers data.

3. MAX. OPER RATED CAP. (TORQUE) - MORTC

The MORTC is derived from the operator rated torque capacity (ORTC). The ORTC comes from manufacturers data. The MORTC is found as follows:

MORTC = ORTC/SF

where SF = stem factor. The stem factor is either

assumed or measured during testing.

4. MAX. OPER SPRING CAP. AND MIN. OPER SPRING CAP. are taken from manufacturers data or measured directly.

5. MAX. OPER MOTOR CAPACITY - FULL VOLTAGE (MC100) is derived as described in B above and then converted to a thrust value as follows:

   $MC100 = R_{tor} \times UR \times E \times AF/SF$

   where R_{tor} = degraded motor torque at 100% voltage

   UR = unit ratio. This is valve dependent.

   E = pullout efficiency if valve is opening or running efficiency if valve is closing.

   AF = Application Factor

6. MAX. OPER MOTOR CAPACITY - DEGRADED VOLTAGE (MCUV) is derived from MC100 as follows:

   $MCUV = MC100 \times UVF$

   where UVF = under voltage factor. $UVF = (V_d/V_r)^2$ for AC motors and V_d/V_r for DC motors.

   V_d = degraded voltage - volts

   V_r = rated voltage - volts

7. MAX. OUTPUT @ MOTOR STALL (MOMS)

   The MOMS is calculated as follows:

   $MOMS = NMS \times 1.1 \times UR \times SE/SF$

   where NMS = motor torque at 100% voltage

   1.1 = stall factor

   UR = unit ratio

   SE = stall efficiency

   SF = stem factor

2. ASSUMPTIONS

Valve Factor = 0.5

Coefficient of Friction = 0.2

A TTC is used to measure torque and thrust

Torque switch setting is >1

Actuator output is > 50 ft-lbs

Peerless motor output torque derated based on worst case Reliance motor data specified in Reference 7.

Open differential and line pressures based on Reference 13.

3. VALVE DATA

Valve I.D.	SI-MOV-1835B
Valve Manufacturer	ANCHOR DARLING
Valve Nominal Size - in	4
Valve Type	GATE
Valve ANSI Rating - psi	1500
Operator Manufacturer	LIMITORQUE
Operator Size	SMB-00
Nominal Motor Size - ft-lbs	25
Motor RPM	1750
Motor Type	AC
Motor Manufacturer	PEERLESS
Spring Pack No.	60-600-0022

4. INPUT VALUES

I	VARIABLE	DESCRIPTION	UNITS	VALUE	REF.
1	DSTEM	Valve Stem Diameter	Inches	1.625	8
2	DSEAT	Valve Mean Seat Diameter	Inches	4.063	12
3	TPI	No. Of Stem Threads Per Inch	Thrd/In	3	8
4	TS	No. Of Thread Starts	None	1	8
5	PL	Assumed Packing Load	lbs	2500	4
6	VMo	Valve Maximum Limit Open	lbs	22875	1
7	VMc	Valve Maximum Limit Close	lbs	22875	1
8	ORC	Operator Rated Thrust Capacity	lbs	14000	4
9	ORTC	Operator Rated Torque Capacity	ft-lbs	250	4
10	$MXSPC_{tor}$	Maximum Spring Pack Capability	ft-lbs	240	4
11	$MNSPC_{tor}$	Minimum Spring Pack Capability	ft-lbs	82	4
12	LPo	Line Pressure Open	psig	1515	3
13	DPo	Differential Pressure Open	psi	1515	3
14	LPc	Line Pressure Close	psig	242	13
15	DPc	Differential Pressure Close	psi	242	13
16	VF	Valve Factor	None	0.5	-
17	COF	Coefficient Of Friction	None	0.2	-
18	NMS	Nominal Motor Size	ft-lbs	25	8
19	LOSS	% Motor Torque Loss	%	30.8	7
20	RISE	Motor Temperature Rate Of Rise	°C/sec	0.06	5
21	TEMP	Maximum Ambient Temperature	°F	85	2
22	TIMEo	Stroke Time Open	sec	10	15
23	TIMEc	Stroke Time Close	sec	10	15
24	AF(UV)	Application Factor At UV	None	1	7
25	UR	Unit Overall Ratio	None	23	14
26	Vd/Vr	Degraded Voltage Fraction	None	0.88	6
27	PO	Pullout Efficiency	None	0.4	4
28	RE	Running Efficiency	None	0.5	4
29	SE	Stall Efficiency	None	0.6	4

5. CALCULATION

A. Packing Load

PL = 2500 lb_f

B. Piston Effect

SA = 0.7854 X $(DSTEM)^2$

SA = 0.7854 X $(1.625)^2$

SA = 2.074 in^2

Open Direction

LPo = 1515 psig

PEo = SA X LPo

PEo = 2.074 X 1515

PEo = 3142 lb_f

Close Direction

LPc = 242 psi

PEc = SA X LPc

PEc = 2.074 X 242

PEc = 502 lb_f

C. Differential Pressure Effect

DSEAT = 4.063 in

AS = 0.7854 X $(DSEAT)^2$

AS = 0.7854 X $(4.063)^2$

AS = 12.965 in^2

Open Direction

DPo = 1515 psi

DPEo = VF X AS X DPo

DPEo = 0.5 X 12.965 X 1515

DPEo = 9821 lb_f

Close Direction

DPc = 242 psi

DPEc = VF X AS X DPc

DPEc = 0.5 X 12.965 X 242

DPEc = 1569 lb_f

D. Minimum Required Thrust And Minimum Available Thrust

1. Valve Open Stroke

$MRT_o = PL - PEo + DPEo$

MRT_o = 2500 - 3142 + 9821

MRT_o = 9179 lb_f

$MAT_o = MRT_o - PL$

MAT_o = 6679 lb_f

2. Valve Close Stroke

$MRT_c = PL + PEc + DPEc$

MRT_c = 2500 + 502 + 1569

MRT_c = 4571 lb_f

$MAT_c = MRT_c - PL$

MAT_c = 2071 lb_f

E. Stem Factor

LEAD = TS/TPI

LEAD = 1 / 3

LEAD = 0.3333

PITCH = 1/TPI

PITCH = 1/ 3

PITCH = 0.3333

d = DSTEM - [0.5 X PITCH]

d = 1.625 - [0.5 X 0.3333]

d = 1.4584

t = LEAD/[π X d]

t = 0.3333 / [π X 1.4584]

t = 0.0727

num = d X [(0.96815 X t) + COF)

num = 1.4584 X [(0.96815 X 0.0727) + 0.2]

num = 0.3943

denom = 24 X [0.96815 - (COF X t)]

denom = 24 X [0.96815 - (0.2 X 0.0727)]

denom = 22.887

SF = num / denom

SF = 0.3943 / 22.887

SF = 0.0172

F. Reduced Motor Output Torque

NMS = 25 ft-lbs

LOSS = 30.8 %

RISE = 0.06 °C/sec

TIME = 10 sec

TEMP = 85 °F

R1 = LOSS/27900

R1 = 30.8 / 27900

R1 = 0.001104

R2 = 3.6 X RISE X TIME

R2 = 3.6 X 0.06 X 10

R2 = 2.2

R3 = TEMP - 104

R3 = 85 - 104

R3 = 0 IF TEMP < 104 THEN R3 = 0

R4 = R2 + R3

R4 = 2.2 + 0

R4 = 2.2

R5 = R1 X R4

R5 = 0.001104 X 2.2

R5 = 0.002429

R6 = NMS X R5

R6 = 25 X 0.002429

R6 = 0.061

R_{tor} = NMS - R6

R_{tor} = 25 - 0.061

R_{tor} = 24.94 ft-lbs

G. Thrust Calculations

Inputs:

SF = 0.0172

AF(UV) = 1

AF(100% V) = 0.9

UR = 23

VMo = 22875 lbs

VMc = 22875 lbs

ORC = 14000 lbs

ORTC = 250 ft-lbs

V_d/V_r = 0.88

1. MAX. OPER RATED CAP. (THRUST) - MORC

ORC = 14000 lbs

ORC_{tor} = ORC X SF

ORC_{tor} = 14000 X 0.0172

ORC_{tor} = 240.8 ft-lbs

MORC = 1.4 X ORC

MORC = 1.4 X 14000

MORC = 19600 lbs

2. MAX. OPER RATED CAP. (TORQUE) - MORTC

MORTC = ORTC/SF

MORTC = 250 / 0.0172

MORTC = 14535 lbs

3. MAX. OPER MOTOR CAPACITY - FULL VOLTAGE(100%) - MC100

Open

$MC100o_{tor} = R_{tor}$ X UR X PO X AF(100%)

$MC100o_{tor}$ = 24.94 X 23 X 0.4 X 0.9

$MC100o_{tor}$ = 206.5 ft-lbs

MC100o = $MC100o_{tor}$ / SF

MC100o = 206.5 / 0.0172

MC100o = 12006 lbs

Close

$MC100c_{tor} = R_{tor}$ X UR X RE X AF(100%)

$MC100c_{tor}$ = 24.94 X 23 X 0.5 X 0.9

$MC100c_{tor}$ = 258.1 ft-lbs

MC100c = $MC100c_{tor}$ / SF

MC100c = 258.1 / 0.0172

MC100c = 15006 lbs

4. MAX. OPER MOTOR CAPACITY - UNDER VOLTAGE - MCUV

Open

$MCUVo_{tor} = MC100o_{tor}$ X UVF X AF(UV)/AF(100%)

$MCUVo_{tor}$ = 206.5 X $(0.88)^2$ X 1 / 0.9

$MCUVo_{tor}$ = 177.7 ft-lbs

MCUVo = $MCUVo_{tor}$ /SF

MCUVo = 10331 lbs

Close

$MCUVc_{tor}$ = $MC100c_{tor}$ X UVF X AF(UV)/AF(100%)

$MCUVc_{tor}$ = 258.1 X $(0.88)^2$ X 1 / 0.9

$MCUVc_{tor}$ = 222.1 ft-lbs

MCUVc = $MCUVc_{tor}$ /SF

MCUVc = 12913 lbs

5. MAX. OUTPUT @ MOTOR STALL (MOMS)

$MOMS_{tor}$ = NMS X 1.1 X UR X SE

$MOMS_{tor}$ = 25 X 1.1 X 23 X 0.6

$MOMS_{tor}$ = 379.5 ft-lbs

MOMS = $MOMS_{tor}$ /SF

MOMS = 379.5 / 0.0172

MOMS = 22064 lbs

6. Spring Pack Capability

$MXSPC_{tor}$ = 240 ft-lbs

MXSPC = $MXSPC_{tor}$ / SF

MXSPC = 240 / 0.0172

MXSPC = 13953 lbs

$MNSPC_{tor}$ = 82 ft-lbs

MNSPC = $MNSPC_{tor}$ / SF

MNSPC = 82 / 0.0172

MNSPC = 4767 lbs

SUMMARY SHEET

OPEN DIRECTION

	THRUST lbs	STEM TORQUE ft-lbs
Minimum Required Thrust	9179	157.9
Maximum Valve Limit	22875	393.5
Maximum Operator Limit (Thrust)	14000	240.8
Maximum Operator Limit (Torque)	14535	250
Maximum Operator Spring Pack Capability	13953	240
Minimum Operator Spring Pack Capability	4767	82
Maximum Operator Motor Capacity		
Full Voltage (100%)	12006	206.5
Under Voltage (88%)	10331	177.7
Maximum Output At Motor Stall	22064	379.5

Minimum Available Thrust	6679	
Minimum Spring Pack Capability	4767	

	CST	TT
Maximum Valve Limit - lbs	22875	22875
Maximum Operator Limit (Thrust) - lbs	14000	19600
Maximum Operator Limit (Torque) - lbs	14535	14535
Maximum Spring Pack Capability - lbs	13953	
Motor At Under Voltage - lbs	10331	

New York Power Authority
Calculation No. IP3-CALC-SI-01060 Revision 0
Project GL 89-10 MOV Program Page 16 of 22
Title Thrust & Torque Limits SI-MOV-1835B Date 03/30/94
Preliminary _____ Prepared By F.A. MULCAHY Date 03/30/94
Final X Checked By C.P. Ho Date 04/01/94

SUMMARY SHEET

CLOSE DIRECTION

	THRUST lbs	STEM TORQUE ft-lbs
Minimum Required Thrust	4571	78.6
Maximum Valve Limit	22875	393.5
Maximum Operator Limit (Thrust)	14000	240.8
Maximum Operator Limit (Torque)	14535	250
Maximum Operator Spring Pack Capability	13953	240
Minimum Operator Spring Pack Capability	4767	82
Maximum Operator Motor Capacity		
Full Voltage (100%)	15006	258.1
Under Voltage (88%)	12913	222.1
Maximum Output At Motor Stall	22064	379.5

Minimum Available Thrust	2071	
Minimum Spring Pack Capability	4767	

	CST	TT
Maximum Valve Limit - lbs	22875	22875
Maximum Operator Limit (Thrust) - lbs	14000	19600
Maximum Operator Limit (Torque) - lbs	14535	14535
Maximum Spring Pack Capability - lbs	13953	
Motor At Under Voltage - lbs	12913	

ERROR ANALYSES - CLOSE DIRECTION

EQUIPMENT ERRORS	THRUST		TORQUE	
MEASUREMENT COMPONENT	% READING	CONSTANT	% READING	CONSTANT
TTC	0.01	117	0.02	2.2
MAIN FRAME	0.02		0.02	
POSITION	0.05	421	0.05	3.9

ERRORS

THRUST	LIMIT (LBS)	ERROR (LBS)	READING (LBS)
MIN AVAIL REQ'D	2071	714	2784
VALVE LIMIT	22875	1580	21295
ACTUATOR THRUST RATING	14000	1123	12877
ACTUATOR TORQUE RATING	14535	1150	13385
SPRING PACK CAPABILITY	13953	1120	12833
TOR CAPABILITY	12913	1067	11846
TOTAL THRUST			
VALVE LIMIT	22875	1580	21295
ACTUATOR THRUST RATING	19600	1411	18189
ACTUATOR TORQUE RATING	14535	1150	13385

TORQUE	LIMIT (FT-LBS)	ERROR (FT-LBS)	READING (FT-LBS)
OPERATOR TORQUE	250	18	232.4
MAX SPRING PACK	240	17	223
MIN SPRING PACK	82	10	91.6
MOTOR @ 100% V	258.1	18	240.1
MOTOR @ UV	222.1	16	206
MOTOR STALL	379.5	25	354.9

CONVERGENCE CRITERION = 0.01
UATOR THRUST MULTIPLIER = 1.40
UATOR TORQUE MULTIPLIER = 1.00
STEM FACTOR = 0.0172

ERROR ANALYSES - OPEN DIRECTION

EQUIPMENT ERRORS	THRUST		TORQUE	
MEASUREMENT COMPONENT	% READING	CONSTANT	% READING	CONSTANT
TTC	0.01	117	0.02	2.2
MAIN FRAME	0.02		0.02	
POSITION	0.05	421	0.05	3.9

ERRORS

THRUST	LIMIT (LBS)	ERROR (LBS)	READING (LBS)
MIN AVAIL REQ'D	6679	975	7654
VALVE LIMIT	22875	1580	21295
ACTUATOR THRUST RATING	14000	1123	12877
ACTUATOR TORQUE RATING	14535	1150	13385
SPRING PACK CAPABILITY	13953	1120	12833
TOR CAPABILITY	10331	935	9397
TOTAL THRUST			
VALVE LIMIT	22875	1580	21295
ACTUATOR THRUST RATING	19600	1411	18189
ACTUATOR TORQUE RATING	14535	1150	13385

TORQUE	LIMIT (FT-LBS)	ERROR (FT-LBS)	READING (FT-LBS)
OPERATOR TORQUE	250	18	232.4
MAX SPRING PACK	240	17	223
MIN SPRING PACK	82	10	91.6
MOTOR @ 100% V	206.5	15	191.3
MOTOR @ UV	177.7	14	164
MOTOR STALL	379.5	25	354.9

CONVERGENCE CRITERION = 0.01
ATOR THRUST MULTIPLIER = 1.40
ATOR TORQUE MULTIPLIER = 1.00
STEM FACTOR = 0.0172

LIMITING FACTORS WITHOUT DIAGNOSTIC EQUIPMENT ERRORS

MINIMUM REQUIRED AVAILABLE THRUST: Open: 6679

Close: 2071

THRUST LIMITS

		CONTROL SWITCH TRIP	TOTAL
OPEN	COMPONENT	MOTOR	ACTUATOR
	THRUST LIMIT	10331	14535
CLOSE	COMPONENT	MOTOR	ACTUATOR
	THRUST LIMIT	12913	14535

TORQUE LIMITS

		CONTROL SWITCH TRIP	TOTAL
OPEN	COMPONENT	MOTOR	ACTUATOR
	TORQUE LIMIT	177.7	250
CLOSE	COMPONENT	MOTOR	ACTUATOR
	TORQUE LIMIT	222.1	250

TORQUE AND THRUST LIMITS INCLUDING DIAGNOSTIC EQUIPMENT ERRORS

Errors are calculated using an iterative calculational process and the square root of the sum of the squares methodology.

Errors for individual diagnostic system components are assumed to be of the following form:

$$\text{Error } (E) = A*R + C$$

Where E = component error

A = some % of measured reading

R = measured reading

C = some % of instrument full scale reading

For these calculations an error is applied to the calculated thrust and torque limits to determine a reading. Therefore, an iterative process is used to solve the equations for the reading R. The results are as follows:

OPEN:

MINIMUM AVAILABLE THRUST - lbs	7654
MAXIMUM CST THRUST - lbs	9397
MAXIMUM CST TORQUE - ft-lbs	164
MAXIMUM TOTAL THRUST - lbs	13385
MAXIMUM TOTAL TORQUE - ft-lbs	232

CLOSE:

MINIMUM AVAILABLE THRUST - lbs	2784
MAXIMUM CST THRUST - lbs	11846
MAXIMUM CST TORQUE - ft-lbs	206
MAXIMUM TOTAL THRUST - lbs	13385
MAXIMUM TOTAL TORQUE - ft-lbs	232

TORQUE AND THRUST WINDOWS

OPEN LIMITS

PARAMETER	OPEN LIMIT	BASES
MAX TOTAL THRUST	18189 lb_f	ACTUATOR THRUST RATING
MIN AVAIL THRUST AT CST	7655 lb_f	MIN REQUIRED THRUST
MAX TOTAL TORQUE	232.4 $ft\text{-}lb_f$	ACTUATOR TORQUE RATING
MAX TORQUE AT CST	164.0 $ft\text{-}lb_f$	MOTOR AT UV

CLOSE LIMITS

PARAMETER	CLOSE LIMIT	BASES
MAX TOTAL THRUST	18189 lb_f	ACTUATOR THRUST RATING
MIN AVAIL THRUST AT CST	2785 lb_f	MIN REQUIRED THRUST
MAX TOTAL TORQUE	232.4 $ft\text{-}lb_f$	ACTUATOR TORQUE RATING
MAX TORQUE AT CST	206.0 $ft\text{-}lb_f$	MOTOR AT UV

6. REFERENCES

1. Calculation 93162-C-08 Rev. 1, ALTRAN, Weak Link Evaluation

2. Calculation, 51-1224659-00, B&W, Flow And Temperature

3. Calculation, 32-1200110-02, B&W, Differential Pressure

4. Limitorque Selection Manual, SEL NOs 1 through 15.

5. Electrical Calculation 32-1200470-03, BWNT

6. Electrical Calculation 32-1200483-04, BWNT

7. Limitorque Technical Update 93-03, 9/93

8. IP3 Nuclear Power Plant Motor Operated Valve Walkdown Data Sheets, MOV:SI-MOV-1835B, Rev. 08/06/92

9. Limitorque Maintenance Update 92-2

10. ITI MOVATS Engineering Report - 5.0, ITI MOVATS Incorporated Equipment Accuracy Summary, Rev. 6.

11. NYPA Report No. COM-RPT-00001, Recommendations For Limitorque Actuator Thrust And Torque Limits, Rev. 0.

12. Anchor Darling Calculation E5071-13, Allowed and Required Actuator Thrust With Seismic Loading Considerations, NYPA File No. S-90-00199-11A.

13. Letter IP-TCS-94-099, dated 2/24/94, Changes to B&W DP Calculation 32-1200110-02.

14. Limitorque Data Sheet

15. Westinghouse Equipment Specification G-67258