WASHINGTON PUBLIC POWER SUPPLY SYSTEM

CALCULATION COVER SHEET

BDC Page: NONE

Equipment Piece No.

HPCS-V-4, HPCS-V-15, HPCS-V-12

Project: WNP 2

Page: 1.000 Cont'd On Page: 1.100

Discipline: MECHANICAL

Calculation No.: ME-02-96-21

Quality Class: 1

Remarks:

TITLE/SUBJECT/PURPOSE

Title/Subject: MOV Pressure Locking Calculation

Purpose:

The purpose of this calculation is to determine if the calculated increase in opening thrust is great enough to prevent the above listed valves from performing their safety function.

This calculation will determine the available margin (MGC or Structural Limit to Required Opening Thrust) for those valves which have been determined to be susceptible to the pressure locking phenomena (e.g.:MOVs HPCS-V-4, HPCS-V-15 , and HPCS-V-12)

CALCULATION REVISION RECORD

REVISION NO.	STATUS/ F,P or S	REVISION DESCRIPTION	INITIATING DOCUMENTS	TRANSMITTAL NO.
0	F	INITIAL ISSUE	GL 95-07	17230

PERFORMANCE VERIFICATION RECORD

REVISION NO.	PERFORMED BY/DATE	VERIFIED BY/DATE	APPROVED BY/DATE
0	Daniel Scott Sanigar 7/10/96	J. Fellman 7/12/96	R. Hanner 7/12/96

* Study calculations shall be used only for the purpose of evaluating alternate design options or assisting the engineer in performing assessments.

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REFERENCE CROSS-INDEX RMCS INPUT SHEET

Calculation No. ME-02-96-21
Revision No. 0

INPUT INTERFACE DOCUMENTS (INP)*

	ADD	DELETE	DOCUMENT NUMBER
1			
2	X		ME-102-9121-715
3	X		ME-102-9121-719
4	X		ME-02-9124-718
5	X		E/I-102-9101-101
6			
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* NOTE TO RECORDS MANAGEMENT: If a document is listed as an INPUT INTERFACE DOCUMENT (INP) to the calculation, then the calculation should be entered into RMCS as an OUTPUT INTERFACE DOCUMENT (OUT) to the document listed as an INP.

OUTPUT INTERFACE DOCUMENTS (OUT)*

	ADD	DELETE	DOCUMENT NUMBER
1	X		TM-21Φ7
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
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21			
22			
23			

* NOTE TO RECORDS MANAGEMENT: If a document is listed as an OUTPUT INTERFACE DOCUMENT (OUT) to the calculation, then the calculation should be entered into RMCS as an INPUT INTERFACE DOCUMENT (INP) to the document listed as an OUT.

068 25405 (10/93)

RESPONSE TO REQUEST FOR PLANT SPECIFIC CALCULATION

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0

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Verification Checklist for Calculations and CMR's	1.200 - 1.200
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APPENDICES:

A: Capability Calculation for HPCS-V-4	Appendix A	4	Pages
B: Capability Calculation for HPCS-V-12	Appendix B	4	Pages
C: Capability Calculation for HPCS-V-15	Appendix C	4	Pages
Selected References	Appendix D	2	Pages
	Appendix H		Pages
	Appendix S		Pages
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WASHINGTON PUBLIC POWER SUPPLY SYSTEM	VERIFICATION CHECKLIST FOR CALCULATIONS AND CMRs	Page 1.200	Cont'd On Page 1.300

Calculation/~~CMR~~ ME-02-96-21 Revision 0 was verified using the following methods:

☐ Checklist Below ☐ Alternate Calculations

Checklist Item	Initial
Clear statement of purpose of analysis	
Methodology clearly stated and sufficiently detailed and appropriate to proposed application	
Logical consistency of analysis	
• Completeness of documenting references	
• Completeness of documenting and updating output interface documents	
Completeness of input	
Consistency of input data with approved criteria	
Completeness in stating assumptions	
Validity of assumptions	
Calculation sufficiently detailed	
• Arithmetical accuracy	
• Physical units specified and correctly used	
Reasonableness of output conclusions	
Supervisor independency check (if acting as Verifier)	
- Did not specify analysis approach	
- Did not rule out specific analysis options	
- Did not establish analysis inputs	NA
• If a computer program was used:	
- Is the program appropriate for the proposed application?	
- Have the program error notices been reviewed to determine if they pose any limitations for this application?	
- Is the program name, revision number, and date of run inscribed on the output?	
- Is the program identified on the Calculation Method form? If so, is it listed in Chapter 10 of the Engineering Standards Manual?	
Other Elements Considered	
_____	
_____	

• If a separate verifier was used for validating these functions or a portion of these functions, sign and initial below.

Based on the foregoing, the calculation is adequate for the purpose intended.

Verifier Signature(s) / Date	Verifier Initials
J Tellman 7/12/96	

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CALCULATION REFERENCE LIST

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SEQUENCE NO.	AUTHOR	ISSUE DATE, EDITION OR REVISION	TITLE	DOCUMENT NO.
1	VECTRA	0	Temperature and Pressure Conditions for valve HPCS-V-4	TM 2107
2	WPPSS	0	MOV Thrust and Set Point Calculation (HPCS-V-4)	ME-02-92-75
3	Anchor/Darling	C	Valve Drawing for Anchor Darling 12" 900 # DD Gate valve	02-E22-10 SHT. 10
4	WPPSS	5/29/96	Static Test Evaluation for Valve HPCS-V-4	WO #XB8705
5	WPPSS	5/29/96	DP Test Evaluation for Valve HPCS-V-4	WO #XB8705
6	WPPSS	5	Calculation for Low Voltage System Loading	E/I 02-90-01
7	VECTRA	0	Temperature and Pressure Conditions for HPCS-V-15	TM 2107
8	WPPSS	8	MOV Master Data Sheet for HPCS-V-15	DIC 1801.3
9	Anchor/Darling	G1	Valve Drawing for Anchor Darling 900 # DD Gate Valve	02-E22-10 SHT. 3
10	WPPSS	6/26/96	DP Test Evaluation for Valve HPCS-V-15	WO# AR8246
11	WPPSS	4/26/96	Static Test Evaluation for Valve HPCS-V-15	WO# XJ0103
12	WPPSS	2	MOV Thrust and Set Point Calculation for HPCS-V-15	ME-02-92-79
13	VECTRA	0	Temperature and Pressure Conditions for HPCS-V-12	TM 2107
14	WPPSS	1	MOV Thrust and Set Point Calculation for HPCS-V-12	ME-02-92-78
15	Anchor/Darling	K	Valve Drawing for Anchor Darling 150 # DD gate valve	02-E22-10 SHT.6
16	WPPSS	6/13/96	DP Test Evaluation for Valve HPCS-V-12	WO# AP4068
17	WPPSS	5/25/94	Static Test Evaluation for Valve HPCS-V-12	WO# CP7103
18	WPPSS, T. Hoyle	6/20/96	Memo to P Young of Vectra : *Presssure Buildup in HPCS System*	Appendix D, this document

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WASHINGTON PUBLIC POWER SUPPLY SYSTEM	CALCULATION OUTPUT INTERFACE DOCUMENTS REVISION INDEX	Page 1.400	Cont On Page 2.000
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Prepared By / Date D SWANIGAN 7/10/96	GS 7/12/96	Revision No. 0	

The below listed output interface calculations and/or documents are impacted by the current revision of the subject calculation. The listed output interfaces require revision as a result of this calculation. The documents have been revised or the revision deferred with Manager approval, as indicated below.

AFFECTED DOCUMENT NO.	CHANGED BY (eg: BDC,SCN,CMR,Rev.)	CHANGE DEFERRED (RFTS NO.)	DEPT. MANAGER*
None			

* Required for deferred changes only.

WASHINGTON PUBLIC POWER SUPPLY SYSTEM	CALCULATION OUTPUT SUMMARY	Page 2.00 Con't On Page 3.000 0
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Prepared By / Date D SWANIGAN 7/10/96		Revision No. 0 REV. BAR

Discussion of results

The capability of HPCS-V-4, HPCS-V-12 and HPCS-V-15 to overcome potential pressure locking conditions was evaluated. The required opening thrust due to the potential pressure locking condition was compared to the both Structural limits and motor gearing capacity for these valves. These valves receive an open signal concurrent with the HPCS-P-1 pump being started. The HPCS-V-12 and HPCS-V-15 valves both exhibit adequate margin when comparing the pressure locking required thrust to open vs. both valve structural limits and motor gearing capability.

In the case of the HPCS-V-4 valve, the motor gearing capability is less than the required thrust. However, the pressure from the HPCS-1 pump will alleviate trapped bonnet pressure as the upstream pressure builds. Per reference 18, the time it takes the HPCS pump to achieve maximum discharge pressure is 2.6 seconds from the initial signal. Therefore, the trapped bonnet pressure will be relieved by this time. Furthermore, increased temperature effects of high current draw will not affect the motor. Reference 18 indicates the expected temperature rise for the installed motor at 2.6 seconds of locked rotor current is small when compared to the capability of its RH insulation. Therefore, the lack of open motor gearing capacity will not preclude the MOV from performing its open safety function despite the pressure locking condition.

Conclusions:

HPCS-V-4, HPCS-V-12, and HPCS-V-15 are all capable of performing their open safety function under pressure locking conditions.

Summary

VALVE NUMBER	MOTOR GEARING CAPABILITY	STRUCTURAL LIMIT	REQUIRED THRUST	MARGIN
HPCS-V-04	151426	256193	185469	38.13%*
HPCS-V-12	30517	39274	22093	77.76%*
HPCS-V-15	32364	50500	26219	23.44%**

* margin calculated using structural limit

** margin calculated using motor gearing capability

HPCS-V-4 and HPCS-V-12: The pressure locking concern for these valves is only applicable during the relatively short period of time between the valve getting an open signal and the HPCS pump (HPCS-P-1) coming up to maximum pressure. These valves have the capability to "ride-out" this short period of time without damage to the motor. Thus, the valves will perform their safety stroke once the pump pressurizes the upstream valve port, unseats the disc, and thus relieves the pressure locking condition. Therefore, the actual concern for these valves is not their ability to open under pressure locking conditions, but whether or not the valves have potential to experience structural damage when they experience a brief locked rotor (stall) condition.

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CALCULATION METHOD

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Prepared by/Date	Verified by/Date	Revision No.
D SWANIGAN 7/10/96	7/12/96	0

Analysis Method (Check appropriate boxes)

- [x] Manual (As required, document source of equations in Reference List)
- [ ] Computer
  - [ ] Main Frame
  - [ ] Personal
    - [ ] In-House Program
    - [ ] Computer Service Bureau Program
      - [ ] BCS
      - [ ] CDC
      - [ ] PCC
      - [ ] Other _____
    - [ ] Verified Program: Code name/Revision _____
    - [ ] Unverified Program: Document in Appendix B

REV. BAR

Approach/Methodology

The computer software program MathCad 5.0 will be used for this calculation and will be treated as a hand calculation.

The methodology for calculating the thrust required to open these double disc gate valve MOVs subject to pressure locking is based upon calculating the increase in seating thrust due to differential and bonnet pressure. This thrust is then compared to the actuator capability to determine the available margin. The total force is made up of the following components:

- Pressure Locking component which is the differential pressure between the bonnet and discs acting on the disc area
- Piston Effect due to the internal pressure exceeding the outside pressure
- Static Unwedging thrust ($F_{packing}$ is included as part of the static load in this calculation)

These components will be summed and compared against either the structural limit or the available capability of the Motor Operated Valves.

Note: A "Reverse piston effect" component is typically calculated to account for pressure forces acting downward against the valve disc area. However, this component is equal to zero for the three HPCS valves in this calculation since the disc wedge angles are all zero degrees. Thus, the Reverse Piston Effect has been omitted from the methodology.

A. <u>Pressure Locking Component of Force Required to Open the Valve</u>

The double disc gate valve pressure lock force is estimated using the standard industry equation for differential pressure load and is the differential pressure between the bonnet and discs acting on the disc area (Πa^2)

$$F_{preslock} = (\text{seat reaction loads}) \times VF = \Pi a^2 (P_B - P_{u \text{ or } d}) \times VF$$

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CALCULATION METHOD
CONTINUATION PAGE

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B. Static Unseating Force

The static pullout thrust represents the open running load and the pullout force due to wedging of the valve disc during closure. These loads are superimposed on the loads due to the pressure forces which occur during pressure locking. the value for this load is based on static test data for the MOVs. The value is corrected for equipment inaccuracies to obtain the bounding value.

C. Piston Effect

The piston effect due to valve internal pressure exceeding outside pressure is calculated using the standard industry equation. This force assists movement of the valve stem in the open direction.

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

where: P_{atm} generally equals 0 psig.

D. Total Force Required to Overcome Pressure Locking

As mentioned previously, the total stem force (tension) required to overcome pressure locking is the sum of the three components discussed above. All of the terms are positive with the exception of the piston effect component.

$$F_{total} = -F_{piston} + F_{preslock} + Static\ Pullout\ Force$$ (unwedging & Running forces)

E. Determination of Motor Gearing Capability

Next the motor gearing capability available to overcome static unseating forces is determined using the expected stem factor (based on the coefficient of friction given for each valve), the pullout efficiency, the temperature factor, and test data.

$$MGC_{open} = \frac{MR_{breakaway} \times (1 - Temp\ Factor) \times OAR \times Eff_{pullout} \times RVF}{Stem\ Factor}$$

F. Determination of Open Valve Factor

These valves have been tested under differential pressure conditions. Open valve factors were calculated in references 5,10, and 16 based on the applicable test data.

G. Acceptance Criteria

For operability, a positive margin between the estimated required force to open and the available motor gearing capacity for HPCS-V-15 or valve/actuator structural limits for HPCS-V-4 and HPCS-V-12 is acceptable.

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CALCULATION METHOD CONTINUATION PAGE

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3.0 Assumptions

1. Valve is a double disc valve, therefore, the entire inside disc surface is subjected to the bonnet pressure.

2. The coefficient of friction between the valve seat and disk is assumed to be the same under pressure locking conditions as it is under the differential pressure test conditions. The open valve factors for these MOVs are derived from DP test data evaluations (references 5, 10, and 16) assuming no diagnostic error.

3. The stem factor is based on coefficient of friction as measured during static testing. (See references 4, 11, and 17 for test reviews).

4. HPCS-V-4 and HPCS-V-12: The pressure locking concern for these valves is only applicable during the relatively short period of time between the valve getting and open signal and the HPCS pump (HPCS-P-1) coming up to maximum pressure. These valves have the capability to "ride-out" this short period of time without damage to the motor. Thus, the valves will perform their safety stroke once the pump pressurizes the upstream valve port, unseats the disc, and thus relieves the pressure locking condition. Therefore, the actual concern for these valves is not their ability to open under pressure locking conditions, but whether or not the valves have potential to experience structural damage when they experience a brief locked rotor (stall) condition.

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B. CALCULATION

This calculation evaluates the Motor Operated Valve's (MOV) ability to overcome potential pressure locking. The MOV considered below is a parallel double disk gate valve.

Valve Tag No.	:	MOV HPCS-V-04
Valve Mfg.	:	Anchor/Darling
Valve Drawing	:	02-E22-10 Sht. 10, Rev.C
Type / Size / Class	:	Gate / 12 " / 900
Operator	:	Limitorque SB-4
Media	:	Water

B.1 INPUT VARIABLES:

Pressure downstream, psi	$P_d := 7 \cdot psi$	[Ref.1]
Pressure upstream, psi	$P_u := 0 \cdot psi$	[Ref.1]
Pressure in the bonnet, psi	$P_B := 1446 psi$	[Ref.1]
Mean seat contact radius, in.	$a := 5.6825 in$	[Ref. 2]
Stem diameter, in.	$D_s := 2.25 in$	[Ref. 2]
Valve Factor, dimensionless	$VF := 0.5$	[Ref. 5]
Measured static unwedging thrust w/o error, lbf.	$T_{uw} := 37299 lbf$	[Ref. 4]
Measured unwedging reading error w/o TSR	$Err_{read} := 0.09954$	[Ref. 4]
Measured unwedging full scale error	$Err_{fs} := 0 \cdot lbf$	[Ref. 4]
Measured running thrust, lbf	$T_{run} := 3118 lbf$	[Ref. 4]
Valve structural thrust limit, survivable number(to open), lbf	$T_{struct} := 256193 lbf$	[Ref. 2]
Motor torque Nameplate, lbf * ft	$MR := 200 lbf \cdot ft$	[Ref. 2]
Unit Overall Ratio	$OAR := 48.45$	[Ref. 2]
Temperature Factor	$TF := 0.005$	[Ref. 2]
Stem Factor, ft	$SF := 0.0296 ft$	[Ref. 4]
Pullout efficiency	$Eff_{pullout} := .65$	[Ref. 2]
Reduce Voltage Factor	$RVF := 0.8457$	[Ref. 6]

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B.2 SEAT REACTION FORCES DUE TO PRESSURE LOADS

B .2.1 Reaction Force Due to Downstream Pressure:

$R_u := \pi \cdot a^2 \cdot (P_B - P_d)$ Total reaction force on upstream seats (R_u) in lbs.

$R_u = 145979\,lbf$

B.2.2 Reaction Force Due to Upstream Pressure:

$R_d := \pi \cdot a^2 \cdot (P_B - P_u)$ Total reaction force on downstrem seats (R_d) in lbs.

$R_d = 146689\,lbf$

B.2.3 Total Pressure Locking Forces:

$R_{ud} := R_u + R_d$ Total reaction force due to bonnet pressure loads upstream and downstream (R_{ud}) in lbs.

$R_{ud} = 292668\,lbf$

B.3 REQUIRED UNSEATING FORCES:

$F_{piston} := \frac{\pi}{4} \cdot D_s^2 \cdot (P_B - 0 \cdot psi)$ Piston effect (F_{piston}) due to internal pressure exceeding outside pressure. This force assists movement of the valve stem in the open direction.

$F_{piston} = 5749\,lbf$

$T_{po} := \frac{T_{uw} + T_{run}}{1 - Err_{read}} + Err_{fs}$ Static pullout thrust (T_{po}) corrected by reading error without torque switch repeatability and full scale error.

$T_{po} = 44885\,lbf$

$R_{tot} := |R_{ud}|$ Total reaction force on the seats (R_{tot})

$R_{tot} = 292668\,lbf$

$F_{PressLock} := R_{tot} \cdot VF$ Pressure locking force due to reaction forces ($F_{PressLock}$).

$F_{PressLock} = 146334\,lbf$

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B.4 TOTAL THRUST REQUIRED TO OPEN VALVE

$$T_{req} := -F_{piston} + F_{PressLock} + T_{po}$$

$$T_{req} = 185469\,lbf$$

Total thrust required to overcome piston effects, reaction forces, and unwedging (T_{req}).

B.5 MOTOR GEARING CAPABILITY

The motor gearing capability ($T_{mgc.open}$) available to overcome static unseating forces is determined using the expected stem factor, the pulllout efficiency, the temperature factor, and test data.

$MR_{breakdown}$	= Motor Torque, ft*lbs	RVF	= Reduced Voltage Factor
TF	= Temperature Factor	SF	= Max. Stem Factor, ft
OAR	= Overall Ratio		
$Eff_{pullout}$	= Pullout Efficiency		

$$T_{mgc.open} := \frac{MR \cdot (1 - TF) \cdot OAR \cdot Eff_{pullout} \cdot RVF}{SF}$$

$$T_{mgc.open} = 151426\,lbf$$

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B.6 TOTAL THRUST AVAILABLE TO OPEN VALVE

The total available thrust to open the valve will be set equal to the structural limit.

T_{lmt} = Limiting thrust available to open the valve is T_{struct}

$T_{mgc.open} = 151426\,lbf$ $\quad$ $T_{struct} = 256193\,lbf$

$T_{lmt} := T_{struct}$ $\quad$ $T_{lmt} = 256193\,lbf$

Note that the motor gearing capability is shown only for completeness.

The total available thrust is larger than the total required thrust to open the valve.

$T_{lmt} = 256193\,lbf \quad > \quad T_{req} = 185469\,lbf$

THEREFORE, VALVE WILL OPEN IN PRESENCE OF PRESSURE LOCKING EFFECTS.

The available margin to open the valve is:

$$Margin_{open} := \left(\frac{T_{lmt} - T_{req}}{T_{req}}\right) \qquad Margin_{open} = 38.13\,\%$$

Attachment 2

Pressure Locking Evaluation for RCIC-V-31