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Methods of Evaluation for Sealing Load of Air Operated Globe Valves at Closing Stroke in Nuclear Power Plants

Je-Wook Lee[a*], Jin-A Jang[a]
[a]*PSA&PSR Business Department, KEPCO E&C, 269 Hyeoksin-ro, Gimcheon-si, Gyeongsangbuk-do, 39660, Republic of Korea*
[*]*Corresponding author: bluemon@kepco-enc.com*

1. Introduction

The air operated valve should be tested to verify the valve is set up properly after a margin calculation in design basis analysis. This testing is usually performed under static test conditions (no process pressure or flow).

It is important to develop test acceptance criteria to verify the key input used in the margin calculation and to ensure the valve is set up to achieve the desired capability and structural margins.

The sealing load of air operated globe valves at closing stroke is one method of specifying test acceptance criteria to accomplish this objective.

The sealing load is the thrust required to prevent fluid leaking through the port when the valve is fully closed. The sealing load is only applicable for closing strokes and only at the fully seated position. If the closing stroke of air operated globe valves is a safety function, the sealing load from a static diagnostic test shall have to meet test acceptance criteria.

This study describes techniques to verify required sealing load calculation of air operated globe valves and determine test acceptance criteria for sealing load from the static diagnostic test.

2. Methods and Results

2.1 Methods of sealing load calculation

The required sealing load (F_{SL}) under design basis conditions can be calculated using either the circumferential load method or the contact stress method, based on EPRI air operated valve evaluation guide.

The circumference load method is using the following equation.

$$F_{SL} = D_{Seat} \pi \, L_{Seat} \quad (1)$$

where,
D_{Seat} : Disk to seat contact diameter, (in)
L_{Seat} : Required load per unit length of seat contact, (lb/in)

ANSI/FCI 70-2 standards provide leakage class definitions based on allowable leakage versus port diameter. Typical required loads per unit length of seat contact to achieve the leakages classes are estimated based on Table 1. The stem thrust required to seal the AOV can be calculated using the circumferential method associated with a leakage class.

Table 1. Required seating force ANSI/FCI 70-2

ANSI B16.104 Leakage Class	Permissible Leakage	EPRI Reference(for DP < 1,000 psi)	
		lb/in	N/mm
Class I	Buyer/seller agreement		
Class II	0.5% of rate capacity	20-42	0.18-0.37
Class III	0.1% of rate capacity	40-103	0.35-0.91
Class IV	0.01% of rate capacity	60-150	0.53-1.33
Class V	0.0005 ml per in. of seat diameter per psi	100-220	0.89-1.95
Class VI	Soft seats	NA	NA

The contact stress method is using following equations.

$$F_{SL} = (S_{Seat} \times A_{Seat})(\sin\theta + \mu_s \cos\theta) \quad (2)$$

$$A_{Seat} = \frac{\pi}{4} \times (OD^2{}_{Seat} - ID^2{}_{Seat}) \quad (3)$$

where,
S_{Seat} : Require seat stress, (psi)
A_{Seat} : Seat interface contact area, (in^2)
μ_s : Disk to seat friction coefficient, (dimensionless)
θ : Valve body seat angle, (degree)
OD_{Seat} : Seat outside diameter, (inch)
ID_{Seat} : Seat inside diameter, (inch)

Typical values of S_{Seat} are shown in Table 2.

Table 2. Required seat stress

Pressure to be sealed (psi)	Required seat stress (psi)
0 - 500	4000
501 - 1000	6000
1001 - 2500	8000

The value of disk to seat friction coefficient (μ_s) can be obtained from valve specification or conservative estimation in Table 3.

Table 3. Disk to seat friction coefficient (μ_s)

Design Basis Temperature, °F	Disc-to-seat friction coefficient, μ_s	
	Water Flow	Steam Flow
< 100	0.61	
101 - 200	0.60	
201 – 300	0.55	0.55
301 - 400	0.52	0.52
401 - 500	0.50	0.48
501 - 600	0.48	0.45
601 - 650	0.44	0.42

Then, the measured sealing load ($F_{SL,msrd}$) from a static diagnostic test is calculated by subtracting the measured running thrust just before seating from the measured maximum thrust at closing stroke.

$$F_{SL,msrd} = F_{CMax,msrd} - F_{R,msrd} \qquad (4)$$

where,
$F_{CMax,msrd}$: Measured maximum actuator thrust at closing stroke, (lbf)
$F_{R,msrd}$: Measured running thrust at closing stroke, (lbf)

2.2 Determination of test acceptance criteria

The required stem thrust at closing stroke (F_C) for air operated globe valves is calculated using the following equation.

$$F_C = F_{DS} + F_P + F_{SR} + F_{DF} + F_{DP} + F_{SL} \qquad (5)$$

where,
F_{DS} : Disk and stem weight, (lbf)
F_P : Packing friction load, (lbf)
F_{SR} : Stem ejection load, (lbf)
F_{DF} : Disk-to-body / cage friction load, (lbf)
F_{DP} : DP load, (lbf)

To ensure valve's operability and effective sealing at closing stroke, Actuator output thrust (F_{act}) has to be greater than required stem thrust. In other words, net actuator stem thrust ($F_{act,net}$) has to be greater than required sealing load. That is,

$$F_{act} > F_C = F_{DS} + F_P + F_{SR} + F_{DP} + F_{DF} + F_{SL} \qquad (6)$$

$$F_{act,net} = F_{act} - (F_{DS} + F_P + F_{SR} + F_{DP} + F_{DF}) \qquad (7)$$

$$F_{act,net} > F_{SL} \qquad (8)$$

In case of AOV static diagnostic test, fluid is not pressurized so F_{DP} and F_{SR} are zero. For this reason, the net actuator stem thrust ($F_{act,net,static}$) from a static test is different from actual sealing load under design basis conditions. This can be expressed as below.

$$F_{act,net,static} = F_{act} - (F_{DS} + F_P + F_{DF}) \qquad (9)$$

Parts of equation (7) and (8) can be substituted by using equation (9). That is,

$$F_{act,net} = F_{act,net,static} - (F_{SR} + F_{DP}) > F_{SL} \qquad (10)$$

From equation (10), the net actuator stem thrust (i.e., the measured sealing load) at closing stroke in a static diagnostic test can be expressed as follow.

$$F_{act,net,static} > F_{SL} + F_{SR} + F_{DP} \qquad (11)$$

The test acceptance criteria for sealing load (TAC_{SL}) at closing stroke in AOV static diagnostic test is given by equation (12).

$$TAC_{SL} = F_{SL,msrd} - F_{SL} - F_{SR} - F_{DP} > 0 \qquad (12)$$

2.3 Results of calculation and evaluation

Table 4 shows the methods of calculation and evaluation for sealing load of air operated globe valves at closing stroke using the above mentioned methods.

The design basis sealing load (F_{SL}) and the measured sealing load ($F_{SL,msrd}$) from a static diagnostic test are calculated by equation (1) and (4), respectively. And the test acceptance criteria for sealing load (TAC_{SL}) at closing stroke in AOV static diagnostic test is calculated by equation (12).

Table 4. Sealing load evaluation

Item	Valve A
D_{Seat} (inch)	A_1
L_{Seat} (lb/in)	A_2
F_{SL} (lbf)	A_3 ($A_1 \times \pi \times A_2$)
$F_{CMax,msrd}$ (lbf)	A_4
$F_{R,msrd}$ (lbf)	A_5
$F_{SL,msrd}$ (lbf)	A_6 ($A_4 - A_5$)
F_{SR} (lbf)	A_7
F_{DP} (lbf)	A_8
TAC_{SL}	$A_6 - A_3 - A_7 - A_8 > 0$

3. Conclusions

This study describes methods of calculations for required sealing load under design basis conditions and for measured sealing load from a static diagnostic test, and the method of determining acceptance criteria of the sealing load at closing stroke.

The measured sealing load calculated in a static diagnostic test is the net actuator thrust acting on the seat. Overall, based on the equations (6) ~ (12), when combined with valve DP load and stem ejection load, the measured sealing load has to be greater than required sealing load.

In conclusion, when determining test acceptance criteria for sealing load of air operated globe valves, it is necessary to consider the DP load and the stem ejection load because no process pressure or flow under static test conditions.

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