DOUBLE ISOLATION AND BLEED TRUNNION MOUNTED BALL VALVES TO NEW API-6D 24th (DIB-Type B to §H12)

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About the Author

- *Mechanical Engineer, actually Technical Director of LCM Italia S.p.A., from two decades operates in design & qualification of isolation valves for Oil & Gas applications.*

- *Author of two patent application publications related to double isolation and bleed trunnion mounted ball valve, “Flexible valve seat” and “Reverse Piston Effect.*

Disclaimer

Contents	***Content of this document is based on the direct experience of the author.*** ***Nothing inside this presentation is intended with the purpose to establish or specify design acceptance criteria or design limitations.***
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References	• *No reference to end-user or EPC company or valve manufacturer is made inside the document.* • *Some patent applications publications relevant to the subject are includes as reference at the end of the document (list may be not exhaustive).*
Thanks	*Sketches & Pictures included are courtesy of LCM Italia S.p.A.*

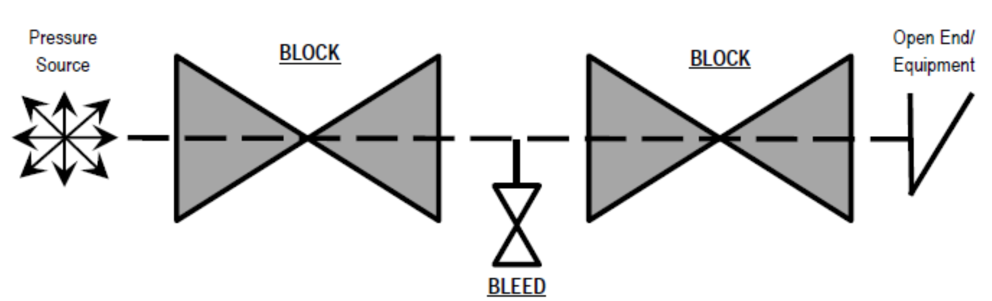
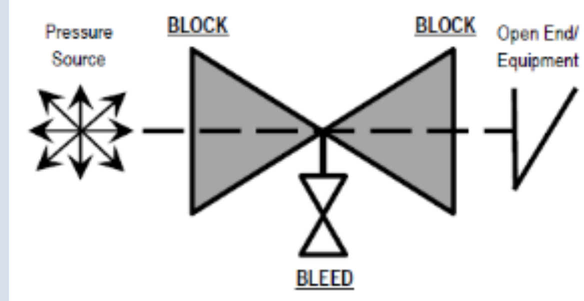
Content

- API-6D 24Ed *(relevant modification effective date 01 Agust 2015)*
  - Title: «Specification for Pipeline **and Piping** Valves»
  - Annex K: «**Isolation Valve Features**» (Informative)
  - §H12: « **Test sequence for valves required for DIB operations**» (Supplementary)

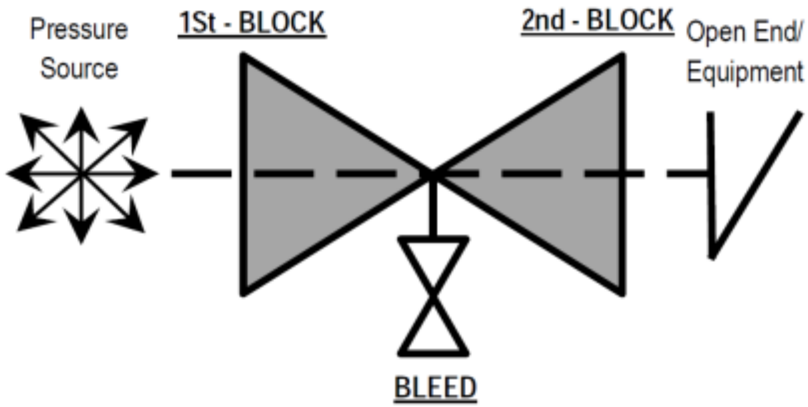
- Approach:
  - **Illustrate the problem** for Double Isolation and Bleed operations relevant to Trunnion Mounted Ball Valves that rely on single closure member (Type-B).
  - **Define boundaries and explain the available strategies** the may be adopted to solve the "new" operational requirements.
  - **Propose a design/verification methodology based on FEM simulation** able to predict if existing TMBV product, modified or innovative ones are "fit for DIB-B operations".
  - **Case histories** are reported as qualified applications of proposed methodology.

Definitions

- Double Isolation and Bleed (DIB) _ Ref to 6D-Appx.K

TYPE A (Two Valves in Series)	TYPE B (Single Valve)
	
Valve arrangement with two valves (or at least two independent closure member) with a means of venting/bleeding the cavity between the two valves (obturators). *NOTE: Often two closure member inside the a single "compact" body is also called "Double Block & Bleed" (confusing the ability to provide isolation from two pressure sources with the valve arrangement that is able to provide this feature).*	A single valve with two seating surfaces, each of which, in the closed position, provides a seal against pressure from a single source, with a means of venting/ bleeding the cavity between the seating surfaces (Ref.1_3.1.11). *NOTE: This feature can be provided in one direction or in both directions.*

DIB-Type B (Single Valve with two seating elements)



Traditional API-6D trunnion mounted ball valves equipped with bidirectional seat (e.g. double piston effect) are able to provide DIB Type B function when each seat is tested individually.

During in line double isolation operations, the followings step must be executed:

1) Close the valve and depressurize "downstream" line (seating load is 100% on 2nd seat).
2) Open the "bleed" and depressurize the valve body cavity (load is transferred from 2nd to 1st seat).

Before the ending of valve cavity bleeding operation unexpected leak could be detected downstream:

A) Downstream seat is progressively loosing the pressure assisted sealing action (DP x 2nd tend to 0).
B) Ball closure member change deformed shape due the transfer of seating load from 2nd to 1st seat.

A TEST PROCEDURE IS NEEDED TO VERIFY DIB VALVE PERFORMANCE IN OPERATION

API-6D §H12 “Test Sequence for DIB valve operation”

The following supplementary test may be now specified by purchaser:

Test Procedure

1) With valve partly open, fill valve with test medium and pressurize to valve design pressure.
2) Close the valve.
3) Reduce pressure on downstream side of valve to zero and monitor cavity pressure.
4) Monitor leakage between cavity and downstream side.
5) Reduce pressure in the cavity **slowly**, and monitor upstream pressure, and leakage to the downstream side.
6) Reintroduce pressure into the cavity slowly up to 145 psi (10 bar) and monitor leakage downstream side.
7) Reduce pressure in cavity slowly and monitor leakage to downstream side.
8) With cavity and downstream vented, measure upstream seat performance by monitoring leakage at the cavity port.

NOTE: If applicable to the valve configuration in subject repeat steps 1 to 8 on the opposite valve side.

Test Medium: test fluid shall be fresh water or nitrogen gas (as specified).

Acceptance Criteria:

- Soft Seated: Rate A = NVL (no visible leakage x duration of the test)
- Metal Seated: shall not exceed Rate C (in gas service to Rate D).

API-6D TMBV "Seat Types & relevant features"

- Valve features are illustrated in new Annex K.

"*User is responsible for ensuring the operational requirements are consistent with particular valve features including sealing capability and function*".

- Valve types vs features (BB, DBB, DIB) are classified within Table K.1.

Seat types definitions and their combinations for DIB Type B TMBV includes only traditional seat types classified as follow:

- "Unidirectional seat" (Ref.1_3.1.44): a seat designed to seal the pressure source in one direction only, also identified on the market as **"Single Piston Effect" (SPE)** and usually associated with **"Self-Relieving" (S-R)** feature (Ref.1_3.1.37).
- "Bidirectional seat" (Ref.1_3.1.2): a seat designed to seal against pressure source in either directions, often called as **"Double Piston Effect" (DPE)**.

The above mentioned types are not exhaustive and another definition need to be applied to cover additional possible configurations, that may offer design advantages and different features:

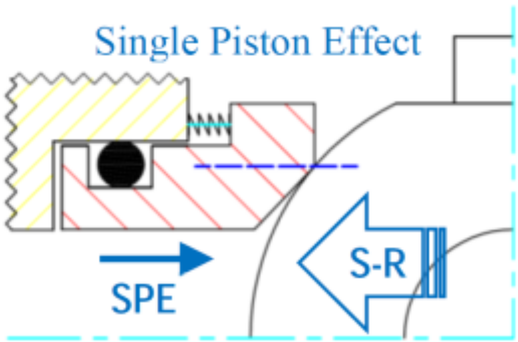
- **"Reverse Piston Effect" (RPE)** is a unidirectional floating seat (spring energized and pressure assisted) designed to provide sealing action as downstream seat (Ref.5).

  In case that RPE seat will used upstream, it will **"Self-Equalizing" (S-E)** the body cavity.

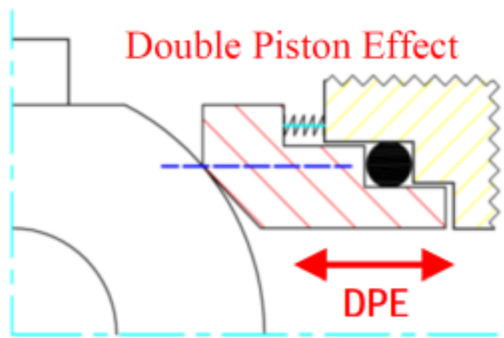
By analogy with self-relieving action also for this seat there is the possibility to set a threshold of differential pressure that activate the self-equalizing feature.

TMBV "Seat Types"

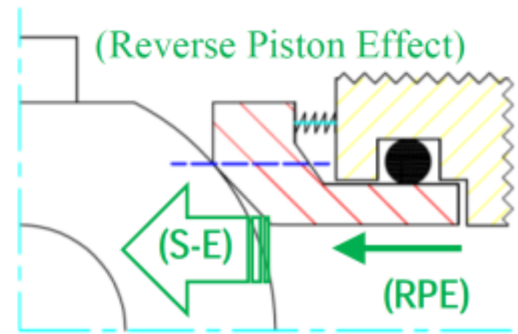
SPE = unidirectional **DPE = bi-directional** **(RPE) unidirectional**



UPSTREAM SEALING



UP&DOWN-STREAM SEAL.



DOWNSTREAM SEALING

"Unidirectional seat" (Ref.1_3.1.44): a seat designed to seal the pressure source in one direction only, also identified on the market as **"Single Piston Effect" SPE** and usually associated with:

"Self-Relieving" (S-R) feature (Ref. 1_3.1.37).

"Bidirectional seat" (Ref.1_3.1.2): a seat designed to seal against pressure source in either directions, often called **"Double Piston Effect" DPE**.

"Reverse Piston Effect" (RPE) is a unidirectional floating seat (spring energized and pressure assisted) designed to provide sealing action as downstream seat only (Ref.5).

In case that RPE seat will used upstream, it will **"Self-Equalizing" (S-E)** the body cavity

NOTE:
Arrow over seat type indicate versus of pressure assisted sealing force .
Definitions in brackets are not present in API-6D (Reverse Piston Effect with Self-Equalizing feature).

DIB-B TMBV – "Cavity Relief requirements"

DIB-B valves may intrinsically trap fluid into the body cavity, therefore in case that upstream seat do not perform the self-relieving action <u>**a cavity relief system MUST BE installed from the valve manufacturer if not otherwise agreed.**</u>

Users should evaluate this aspect because it may influence DIB valve configuration and features.

"Cavity Relief " (CR) system for DIB valves should release eventual overpressure outside the valve pressure boundaries (when permitted) or into the upstream conduit through additional piping circuit.

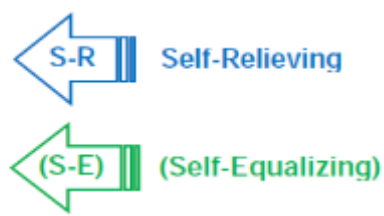
- <u>Valves designated for gas service</u> (e.g. excluding any presence of liquid or condensing phases), <u>may avoid CR</u> requirement, but this need to be clearly specified (Ref.1 §5.8).
- <u>External CR</u> system will not interfere with eventual symmetric sealing configuration of the valve (e.g. DIB-1 remain as not oriented installation), but in this case is strongly recommended that user specify provisions to facilitate testing/ calibration in service.

CR arrangement and eventual auxiliary connection should be specified by user in order to have a company standard procedure to verify safely the integrity of both the seats in service.
For additional indications refer to (Ref.2, Ref.6).

The symbols here-below are adopted to describe the following DIB-B TMBV configurations and relevant features.

Seat Sealing Action

Unidirectional Seat Feature

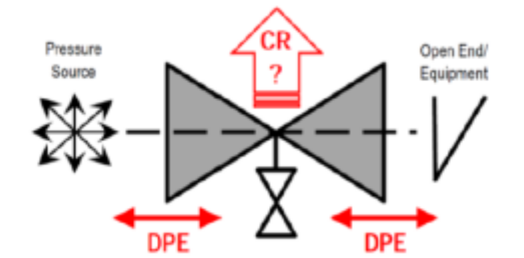
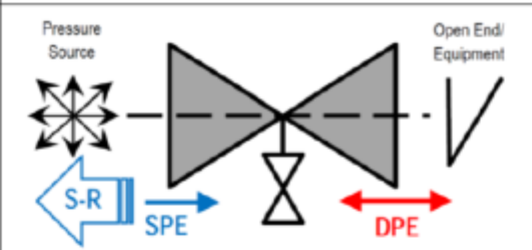
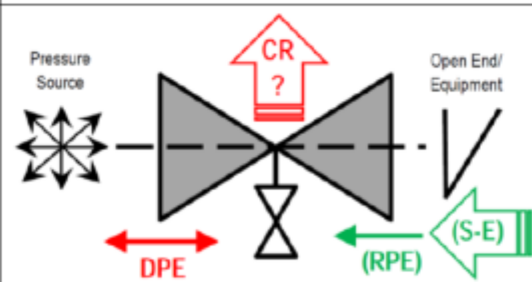


when DP is reverse and over threshold setting

Cavity Relief System

<u>User to MUST specify requirements</u>

DIB-B TMBV – “Valve configurations & features”

Valve Configuration		Bidirectional & Installation	Block & Bleed	Double Block & Bleed	Double Isolation & Bleed	Cavity Relief ?	Self Equalizing
DIB-1		YES ------ & ------ Installation need to be oriented as function of CR system adopted (if any)	YES	YES depending on detailed design	YES depending on detailed design and ability to achieve testing per H.12 ------- Bidirectional DIB depends from CR system adopted.	NO manufacturer MUST provide external cavity relief if not otherwise specified ---------- user to specify detailed requirements	NO
DIB-2		YES ------ & ------ Installation need to be oriented for DIB	YES	YES depending on detailed design	YES (unidirectional) depending on detailed design and ability to achieve testing per H.12	YES SELF-RELIEVING (to upstream conduit)	NO
(DIB-3)		YES ------ & ------ Installation need to be oriented for DIB and BB	YES (unidirectional) only upstream.	NO	YES (unidirectional) depending on detailed design and ability to achieve testing per H.12	NO manufacturer must provide external cavity relief if not otherwise specified ---------- user to specify detailed requirements	YES (unidirectional) Only when RPE seat is upstream.

VISUAL LEGENDA *(Arrow over seat type indicate versus of pressure assisted sealing force _ unidirectional valves not included _ definitions in brackets are not present in API-6D)*

Problem Boundaries for DIB-B

A. Reliable double barrier on the same spherical closure member, require that sealing capability of the **seats should be "independent"** from the ball deformations under variable loading conditions (ratio of Differential Pressure applied to 1st and 2nd barrier) in operation.

B. The expected sealing performance of the valve involve also **the capability of the seat seals to assure a perfect sealing between seat and the body** including their ability to switch their sealing action when required by operational requirements (DPE, S-R or S-E).

User need to be aware that the above mentioned points are intrinsically connected and should require that DIB-B operational performance are validated with the specific valve configuration (seat types & relevant seat seal type, seating, cavity relief systems ect…) required to isolate the specific flow stream (fluid type, operating/design condition, presence of solid particles or other foreign matters and eventual chemicals or other aggressive substances that may be present into the line).

Manufacturer need a design/verification criteria to predict DIB-B performance, but can't implement direct testing of all the possible configuration with all the variants involved.

A SIMULATION OF TRIM BEHAVIOUR MAY BE APPROACHED WITH FEA.

IN ANY CASE A SEMPLIFICATION OF PROBLEM BOUNDARIES IS NEEDED.

… Problem Boundaries for DIB-B

Characteristic	Simplified Discussion	Proposed Boundaries & Notes
Trim Design	Seat supported floating ball coupled with upstream floating seats not considered due to limitation imposed by size/pressure operations. Unidirectional valves may offer benefits in liquid service but still excluded from this document.	Bidirectional **dual seated TMBV with floating seats** spring energized & pressure assisted for seating action. *Others possible, but not considered.*
Seat Configuration	Table 1 try to illustrate isolation features, user need to adopt appropriate configuration consistent with service and operational requirements adopted.	**User to select required seat configurations.** *Alternative solutions may provide design advantages.*
Seating	The most critical seating configuration need to be selected as benchmark: Metal to Metal. Hardest "soft" seated performance should to be verified with specific testing (PEEK seated valves).	**Metal to Metal seated.** PEEK seated should be validated. *Achievable leak rate is not included in the scope of this document*

… Problem Boundaries for DIB-B

Characteristic	Simplified Discussion	Proposed Boundaries & Notes
Size/Class	Downstream spherical ball strains mainly depends from (ball/ bore ratio) that for traditional valve sizing is normally selected as function of size/class and required seating type of the valve in subject. Small valves may not suffer of the problem in subject due to the fact that driving train requirement may already impose ball rigidity suitable for intended DIB-B operation. For low pressure applications (150# and 300#) traditional trims (typically sized for 600#) are considered already suitable for DIB application. L-XL sizes in Class 600# should be investigated/validated. *DIB capability depends from specific design and sizing criteria.*	**Validation based on size/ class scaling** is a sound engineering practice already implemented by mature user (Ref.2). *Traditional isolation TMBV could be already suitable also for DIB-B application (XS-S and LP-MP).*
TMBV executions	Ball pivoting function may be obtained in several configurations: e.g. …integral ball & stem, external trunnions, trunnions integral with the ball. *DIB capability depends from specific trim execution.*	**Each** trim design **execution/** configuration **should to be validated**.
Seals types	Suitability of specific seat seal type versus handled fluid, low & high temperature range, dirty service should be assessed. *Seat seals it's the most complex issue (taking into account eventual redundancy and individual testing capability), that may affect DIB reliability and method of use (see also Ref.3).*	**Specific seal design/material should to be validated**. *As minimum thermoplastic / elastomeric seal classification to be implemented.*

Approach with FEM

The most indicative parameter that may anticipate good or bad performance and/or long term reliability is the accurate profile of contact pressure between the seats and the ball all around the sealing circle with frictional sliding contact.

The model need to include both upstream and downstream seat with relevant contacts.

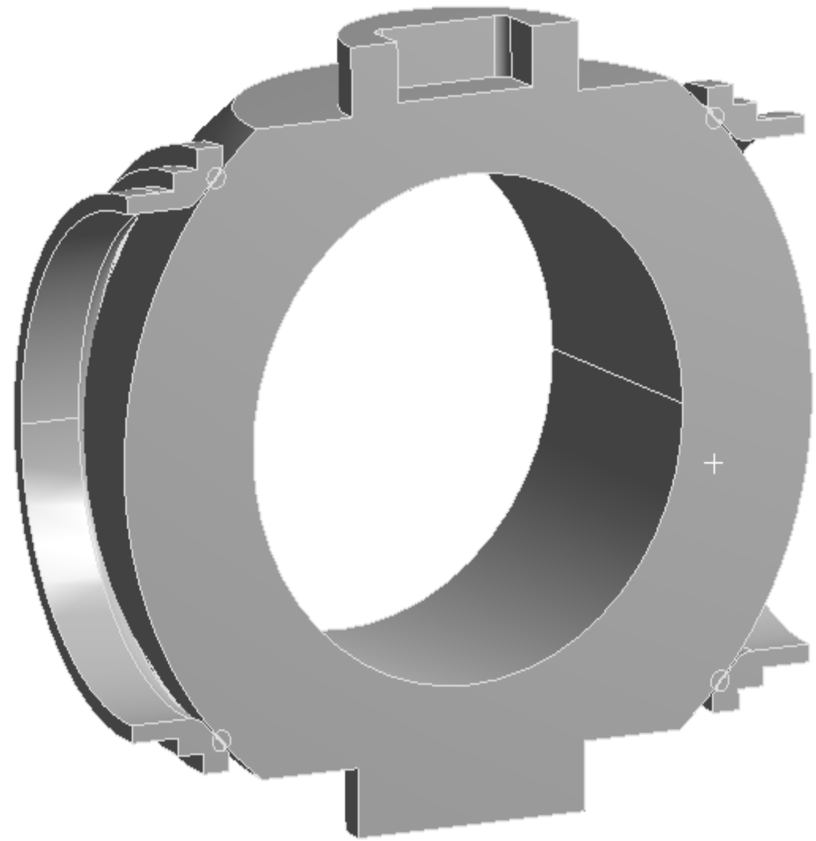


Fig.1 Dual seated TMBV model
(CL vertical plane as unique plane of symmetry)

… seat contact mesh

Contact surfaces need to be adequately refined to be display accurate contact pressure profile on the metal to metal contact lip.

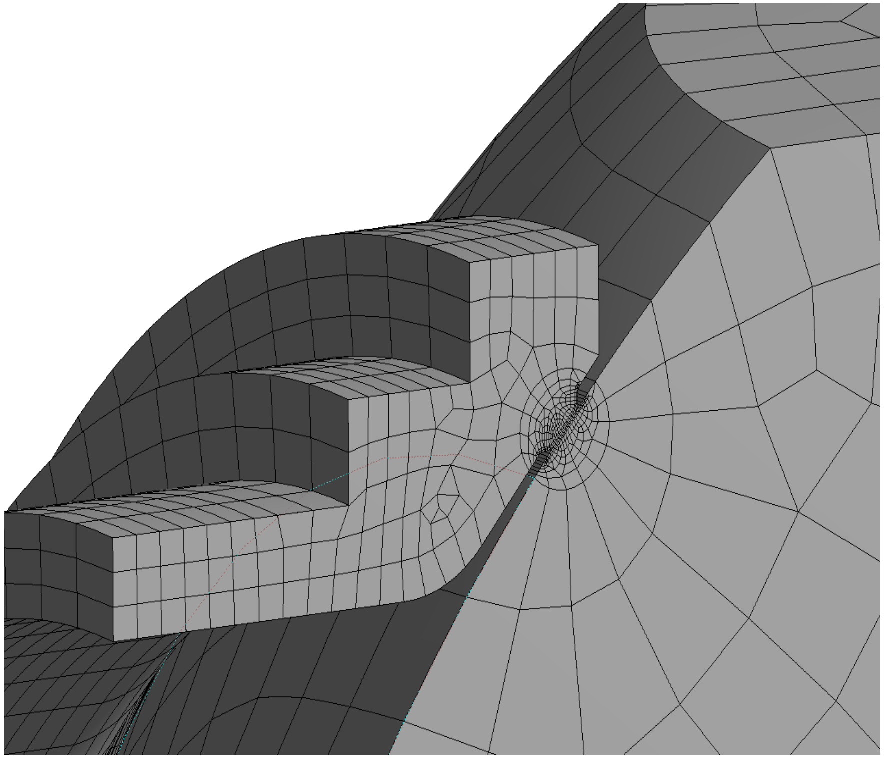


Fig.2 Seats/Ball contact mesh

… constraints & loads

Constraints and loads need to be assigned to all the parts of the model and need to physically represent the specific load scenario under investigation.

For DIB-B application design differential pressure need to be applied across the upstream seat as minimum.

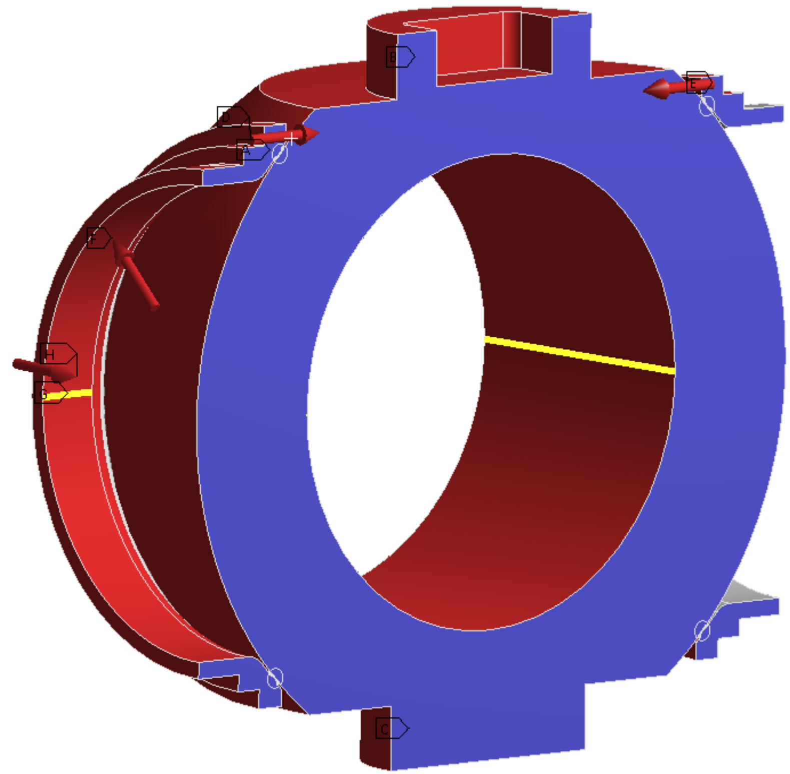


Fig.3 _ Application of constraints and loads for DIB to simulate H12 test condition.

… stress & deformations

Seat stresses and ball deformations need to be accurately evaluated with a frictionless contact mode.

Seat deformations should be also verified against selected seal type, cross section & housings machining tolerances.

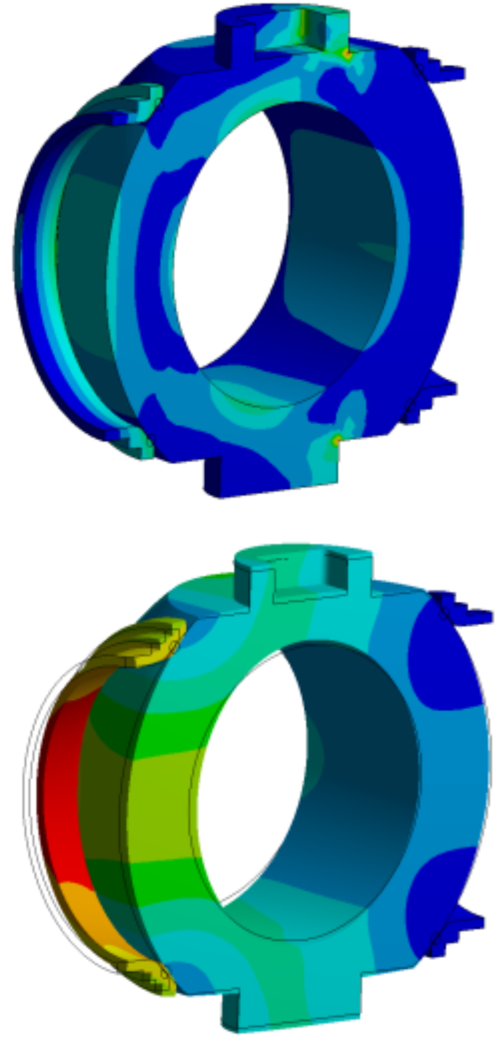


Fig.4 _ Equivalent Stress & Total deformations.

… typical contact failure location

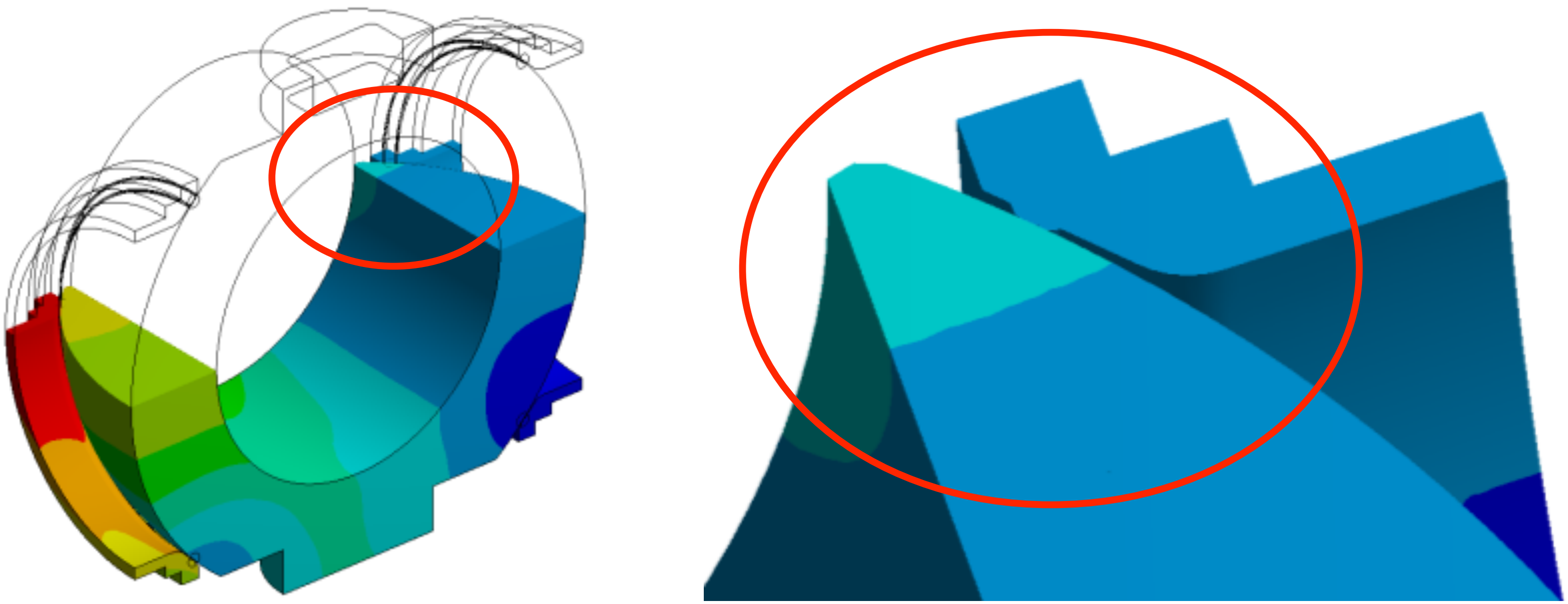


Fig.5 _ Total deformations at the horizontal plane section / downstream seat detail.

Downstream ball deformation in correspondence of the horizontal plane section may evidence a gap of missing contact.

Ball rigidity or seat flexibility should be improved.

… up & down stream contact pressure profiles

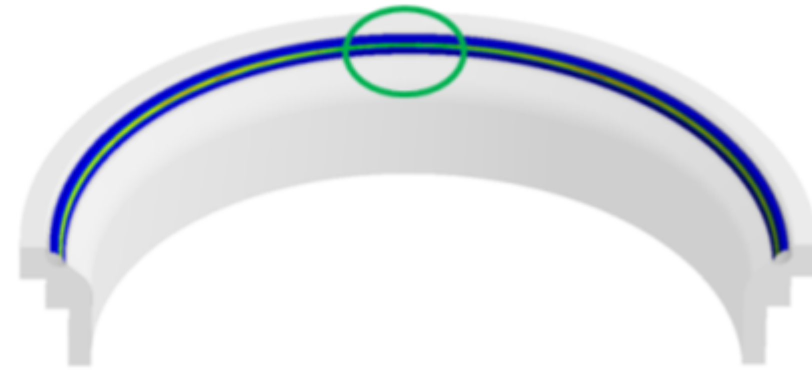


Fig.6a _ Upstream Seat _ Contact Pressure Profile

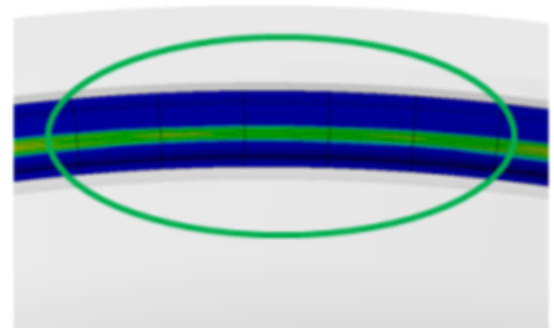


Fig. 6b _ UP-S detail (Fig.6a)

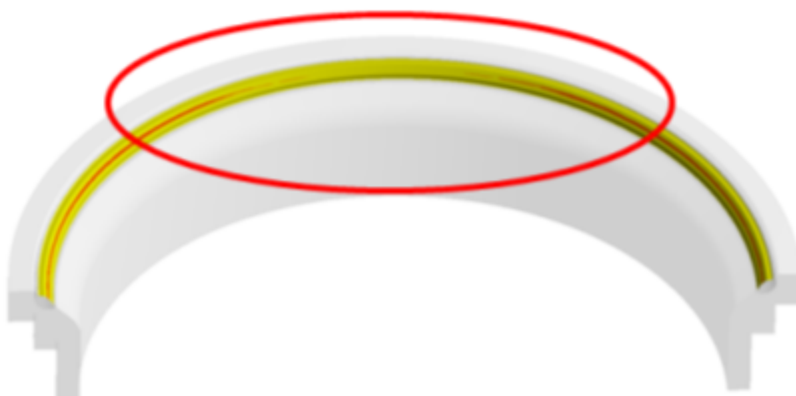


Fig.7a _ Downstream Seat _ Missing Contact check

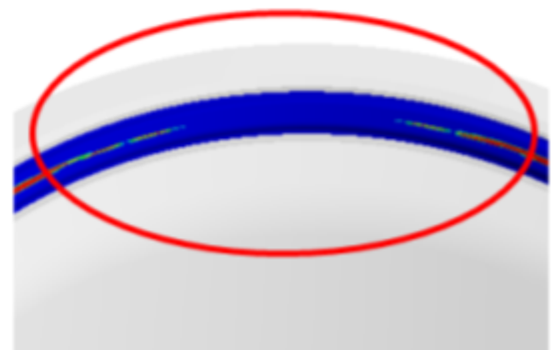


Fig.7b _ DWN-S contact press. detail

Missing downstream contact is clearly displayed (probable failure to §H12 test)

… model capability

LOAD CASE	Upstream	Cavity	Downstream
BB _ Block and Bleed	X	0	0
BB (in case of asymmetric seat)	0	0	X
DBB _ Double Block and Bleed	X	0	X
DBB _ (in open position *)	(X*)	0	(X*)
DIB _ Std test API-6D 23th	X	X	0
DIB _ Oper. test API-6D 24th §H12	X	**Variable**	0
Cavity Overpressure (closed)	0	X	0
Cavity Overpressure (open *)	0	(X*)	0
(X*) Seating capability in Open Position for Metal to Metal or Peek seated to be discussed.			

The same simple model (with minor modifications), may also permit to simulate/ investigate dual seated TMBV behavior versus additional load cases.

Available strategies to solve the problem

Several solutions are available to obtain a fit for purpose DIB-B TMBV.

End-user, in collaboration with manufacturer, should define the operational requirements and select the most indicated configuration, taking into account eventual connection to body cavity to verify sealing integrity of both seats and requirement to isolate the cavity relief system (when applicable).

The following design strategies may be adopted singularly or in combination.

1) BALL OVERSIZING/OPTIMIZATION.
It's the main factor that assure performance new as per H12 on traditional valve design.

Advantages:

- May easily improve sealing performance for other load cases like DBB (robust).
- Traditional seat design concepts are saved (consolidated experience).
- May have less limitations in operating the valve under full differential pressure.

Disadvantages:

- May increase trim dimensions with impact on existing pattern (design, costs).
- May results in not standardized end to end dimensions (interchangeability).
- May increase valve required torques and increase size of valve operators.

…. Available strategies to solve the problem

2) IMPROVE SEAT FLEXIBILITY

As per ball optimization, may permit to improve existing design with less impact on pressure containing parts and operators.

Advantages:

- Should permit to adopt std. pressure containing parts (save design/patterns).
- Standard overall dimensions and face to face (compact and interchangeable).
- Less impact on valve operating torques (standard actuators).

Disadvantages:

- Seat design is more sophisticated and complex.
- Stroking under full differential pressure could be limited.
- May increase valve required torques and increase size of valve operators.

Alternative seat type (RPE) may offer huge design benefits in improving seat flexibility, may permit redundant seat seal configurations and may simplify eventual external equalizing systems and extend sealing life of the sealing barrier.

…. Available strategies to solve the problem

3) INCREASE SEATING ENERGIZING

May upgrade existing product that are close to be fit for purpose (increase seat springs).

Advantages:

- Minimized modification at the traditional products (body & trim).

Disadvantages:

- Positive effect on L-XL sizes or HP application could be negligible.
- Running and ending torques will increase, consequently also wear of sealing areas.
- Actuators sizing for low and medium pressure valves may be affected.

Any additional strategies that are able to reduce ball downstream deformation (when full differential pressure is acting on upstream seat) and/or improve downstream seat capability in this condition is candidate to solve the problem (see also Ref.3).

Case History

All strategies, applied singularly or in combination, using FEA optimization have proved to be able to solve the problem.

Case history below are direct experience of the author:

Valve/Service/Year	Configuration	Performance Validation
16”÷18”-2500 (Uprated) **Seawater Injection / 2009**	DIB-1 Metal Seated “Flexible Seat” (Ref.4)	§H12 (down to 1 barg air) Rate B, Hydro @ 560barg
Up to 16”-900# **Oil, Gas / 2009÷2010**	(DIB-3) Metal Seated “Reverse piston” (Ref.5)	§H12 (down to 1 barg N2) Rate B, HP gas test 110%
12”-900# (PN160) **Gas “Dirty” / 2014**	DIB-1 Metal Seated “Optimized Traditional”	§H12 (down to 1barg N2) **Rate A @ 160barg HP gas test (*)**

(*) Rate A reached, after built-in controlled stroking procedure and more than 200 cycling at full differential pressure (100% of valve rated pressure).

Conclusions

- Validation of results remain a fundamental step that need to be executed with appropriate testing to correlate simulations with experimental data.
- Large sizes in high pressure applications should be always designed using FEA simulation and validated during FAT with the test fluid that represent the effective service condition.
- Project specific requirement should always reflect realistic design parameter and operational requirement and selection of the appropriate isolation configuration need to be accurately evaluated by users in collaboration with selected manufacturers.

… Benefits of DIB-B ball valves

Reliable DIB Type B isolation ball valves are possible and competitive when compared with Type A equivalents or other valve types with expanding obturators.

Single TMBV is normally preferred for PIPELINE and “PIPING” applications:

- Compact, simple and reliable and with reduced maintenance requirement.
- Good sealing performance at low and high differential pressure.
- Minimal pressure drop (through conduit, capable to be “scraped/pigged”).
- Self-revolution operations without fluid displacement inside body cavity.
- Available with reliable low fugitive emission stem seals.
- High structural integrity (e.g. forged axial-symmetric body, also easy to be cladded).
- Low energy demands for operation and easy to be actuated (1/4 turn).
- Capable to handle moderate “dirty” fluids (metal seated with proven dynamic seals).

References

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2	STATOIL TR2000, Piping and Valve specification VSK 850, Trunnion Mounted Ball Valves with Double Piston Seats
3	US 2010/0276620 A1, Double Piston TMBV and methods of use. US Patent Application Publication, Mark Ezekiel
4	US 2011/0024662 A1, TMBV with a Flexible valve seat US Patent Application Publication, Alberto Seveso, Gabriel Ivanescu
5	US 2011/0147635 A1, TMBV with a Reverse Piston Effect US Patent Application Publication, Alberto Seveso, Gabriel Ivanescu
6	US 2011/0290337 A1, Intelligent pressure relief device for a double isolation valve US Patent Application Publication, Roberto Pozzati

THANKS FOR YOUR ATTENTION

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QUESTION TIME