# Wellhead Choke Valve

**Oil & Gas**

**Refinery**

**The article is summarized a presentation, taken for World famous Oil/Gas majors and Korea leading EPCs engineers, when I worked as SEVERN GLOCON Korea regional manager, so that it may be helpful for the engineers.**

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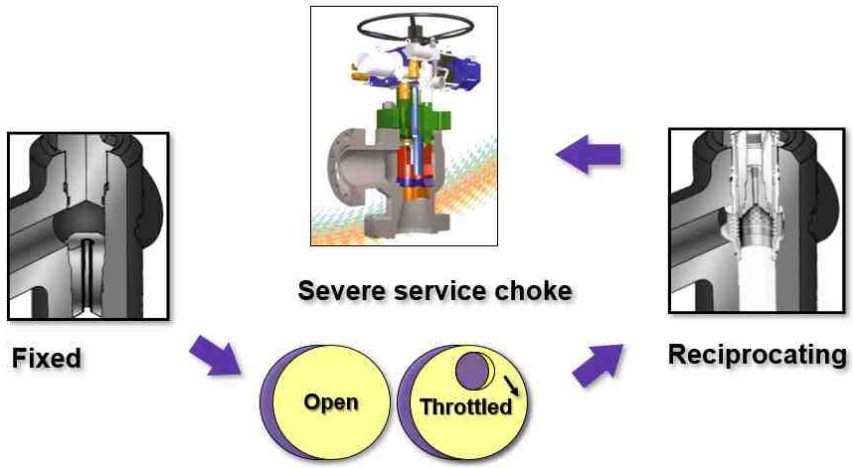
## What is a Wellhead Choke Valve?

- Control Valve for the production & processing of crude oil & natural gas
- Most of all angle valves
- Often hand operated
- Evolved along a different philosophy than control valves
- Used to control wellhead fluids or process fluids

*Severn Glocon*

## Choke Valve Hierarchy



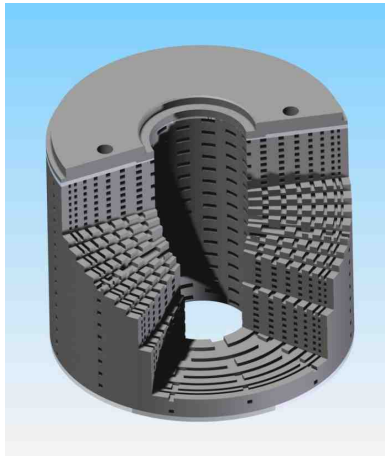

Recently, the application of Severe Service Choke valve has been required by developing deeper deep wellhead.

**Choke valve general :** It's applied to the production and processing of crude oil and natural gas, and mostly angle body type and often hand operated. Its evolution is different from control valve, and control wellhead fluid and process fluid.

**Choke valve evolution :** It has been evolved from fixed type→ rotary type→ reciprocating type to severe service choke.

# Choke Product Philosophy and Why a Severe Service Choke?

- Solid Tungsten Carbide unitised stack 1 CC to CCD(Multi-stage) of pressure reduction
- Designed for General Service & Severe Service erosive flow
- Production and Injection Choke Valves horizontal 90 deg. turns only
- Higher wellhead pressures due to deeper, more difficult to produce wells
- Higher pressure gas wells, much higher velocities through choke trim
- Increased sand production
- Demand for more precise, automatic control at the wellhead
- Requirement to reduce downtime(비가동시간)
- Advent(출현) of subsea completions
- Noise control becoming an issue

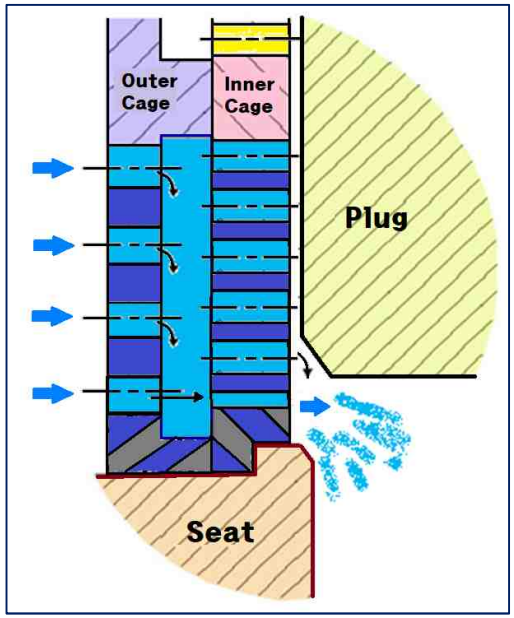


**Choke valve Concept :** 1CC to CCD trim of tungsten carbide is applied for the pressure drop, and it's designed appropriate for erosive fluid at general service and severe service condition, and mainly used for gas & oil production, injection, and designed to the horizontal disk with each path turned 90 deg. only.

**Severe Service Choke :** The deeper wells developed recently, the more difficult to produce. So, the pressure and velocity passing choke valve is higher along with the entrained sand content increased. The precise and automatic control at wellhead is demanded, and requires reducing the downtime. It's a recent trend to produce the product at offshore plant like LNG/Oil FPSO, and the noise becomes an issue with severe condition (high velocity, high sand content). The fluid velocity is predominant factor in erosion. Erosion rates will vary as a third-to-fifth power function of velocity ($V^3$ to $V^5$). Example: if the fluid velocity can be reduced by a factor of two, then erosion will be reduced by a factor of between 8 and 32. The fluid velocities within the trim are typically 1/3 to 1/4 that of conventional single stage chokes. Velocity control protects the trim from erosion, and increases the trim life many fold. Another benefit of velocity control is that the noise and vibration levels of a Severe Service Choke will typically be between 1/4 and 1/10 that of conventional single stage chokes. The suppression of vibration eliminates common mechanical failure caused by fatigue and impact loads on the tungsten carbide parts. Multi-stage trim can reduce the pressure approx. 400psi (28bar) per stage.

# Fixed Area Cages

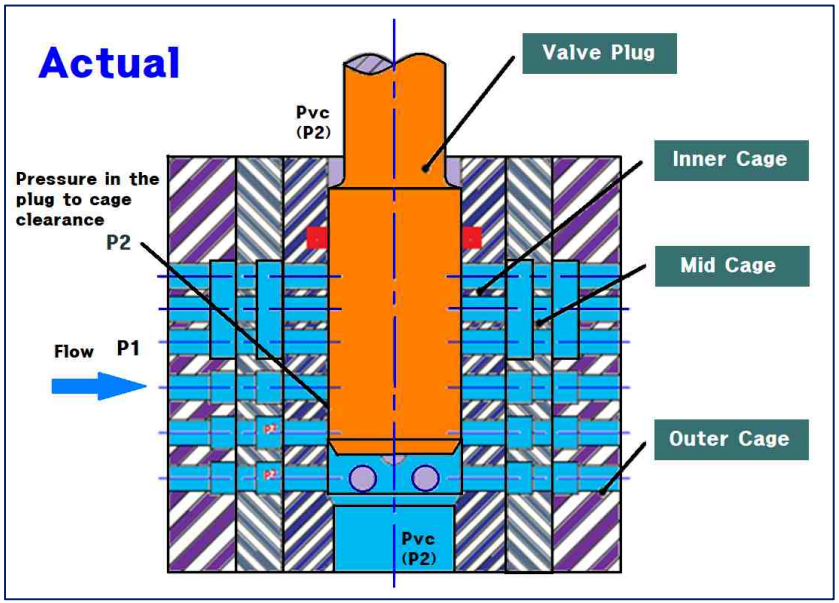
- Valves sold as multi-stage
- Area of inner cage varies
- Area of outer cage fixed
- Galleries help
- Most in-efficient at low lifts
- Well shut in pressure controlled at low lifts




# Fixed Area Cages (improved)

**- Liquid Multiple Stage Letdown**

- Improved design to provide a more affective staged pressure letdown




**A Fixed Cage type** gives most of pressure load to gallery at below 60% -70% of trim lift since the most pressure is loaded at bottom area of inner cage where the whole fluid passing the outer cage cannot but flow through the bottom holes of inner cage. The inner cage hole is clogged up at very low lift (below 10%), then it's a poor design since it's in-efficient with the full pressure loaded gallery. Severn Glocon developed the design of **Liquid multiple stage letdown** (Multi-stage trim) supplementing such problems, and all multiple stage trim utilize 'separators' restrict the Cv of the outer sleeve(s) to provide a more affective staged pressure letdown. It's designed not to force any loads to gallery as the pressure gradually drops.

## Balance Seal Failure

- Small section seals
- Large clearances
- Sand embedding of steel surfaces
- Severe vibration
- Poor or lost control

## Mechanical Failure

- Poor design
- High velocity fluid = Vibration
- Weakness due to erosion
- Impact
- System shutdown
- Uncontrolled  blow-by

The contact area of **Balance seal** is small, so sand is embedded into steel surface through the space between seal and plug and it causes the severe vibration, poor control and loss of control at last.

**Mechanical failure** is caused by poor design, and the fluid velocity is high followed by vibration. On the other hand, weakness is made due to erosion, and system shutdown takes place with impact on trim and valve failure. The catastrophic failure of a cage would create a massive increase in the volume of flow through the valve which may reach a volume greater than can be handled by the system and the safety valves used to protect the vessel.

## Trim Erosion

- High velocity flow
- Erosive particles, e.g. sand
- Dual phase / droplets
- Poor or lost control
- Mechanical failure
- Excessive downtime(비 가동 시간)

## Body Erosion

- Poor Design
- High velocity flow
- Erosive particles, e.g. sand
- Dual phase / droplets
- Poor or lost control
- Mechanical failure
- Excessive downtime(비 가동 시간)

**Trim Erosion** takes place in case the fluid contains erosive particles such as sand, sometimes 2 phase fluid and water drops. The high velocity with such fluid generates erosion and makes the control poor or lost, then causes excessive downtime with mechanical failure at last.

**Body Erosion** takes place in case the fluid contains erosive particles such as sand, sometimes 2 phase fluid and water drops. Gas release to atmosphere through wall leakage or loss of pressure integrity of the body, then causes excessive downtime with mechanical failure at last.

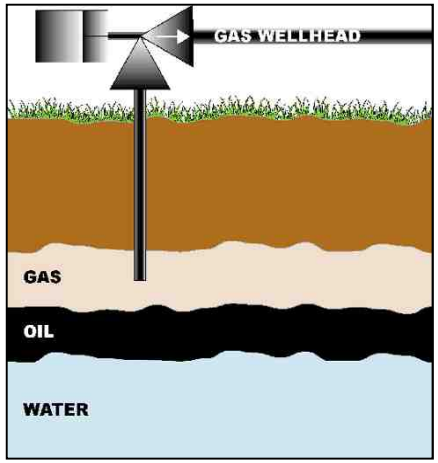
# Choke Failures

- Lost production
- High maintenance
- High inventory
- Complicated logistics
- Safety issues
- Upgrade & replacement

**Choke valve failure** is directly related to production lost and increases the maintenance cost and high inventory, and causes the complicated logistics. It's related to human safety and requires the retrofit and valve replacement.

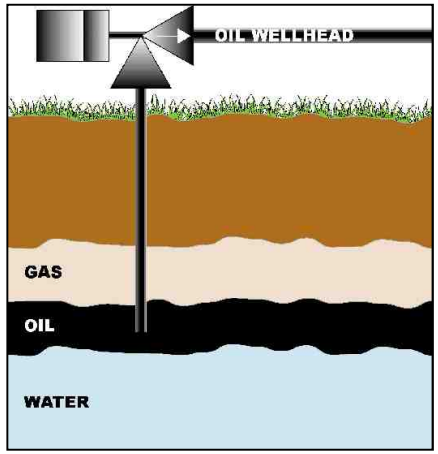
## Wellhead Applications - Gas Production

- **Gas Wellhead Control**
  - High pressure drop: Can be >10,000 PSI (700 bar)
  - High sand content: Can cause rapid erosion failure at pressure drops much below than 500 PSI (35 bar)
  - High noise levels: < 85 dBA is now commonly specified, especially on manned platforms - Often multi-phase fluid




## Wellhead Applications - Oil Production

- **Oil Wellhead Control**
  - High pressure drop: Can be > 10,000 psi (700 bar)
  - High sand content: Can cause rapid erosion failure at pressure drops much below than 800 psi (55 bar)
  - Multi-phase fluid
  - Fluids with a high “water cut” may cause cavitation damage



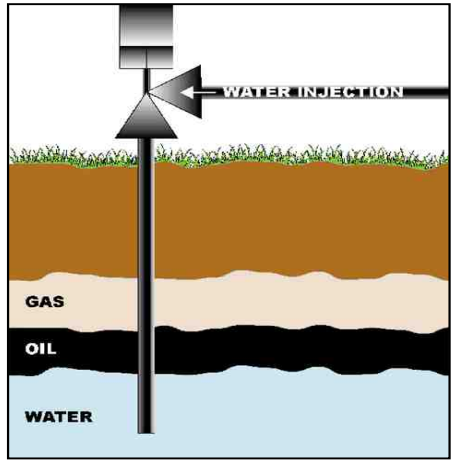

**For Wellhead Gas Production** above 10,000psi (700 bar) of high delta P often takes place to control the gas wellhead pressure, and the rapid erosion can be caused at much below 500psi (35b bar) of delta P subject to high sand content in fluid. The noise level requires below 85dBA in case the operator(s) stays on the platform. It often handles multi-phase fluid (gas, condensate, water, etc.).

**For Wellhead Oil Production** above 10,000psi (700 bar) of high delta P often takes place to control the oil wellhead pressure, and the rapid erosion can be caused at much below 800psi (55b bar) of delta P subject to high sand content in fluid. It often handles multi-phase fluid (gas, condensate, water, etc.). The term “high water cut” refers to oil with a high % of water generally far more erosive than pure oil flowing wells and may cause cavitation damage

# Wellhead Applications

## Water Injection

- High pressure drop
- High cavitation potential: Especially at start-up
- High rangeability: Often required
- Tungsten Carbide trim: Often not required

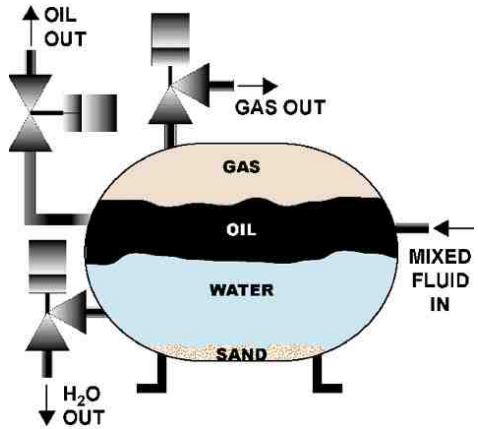



**For Wellhead Water Injection**, the wellhead pressure gradually goes down as the oil is produced and the pressure of depressurized well goes up by injecting the water into the well through an injection pump. The cavitation takes place due to the high delta P of pump discharge pressure and wellhead pressure, particularly at initial stage.

The Cv is very low at initial injection (low flow rate, high delta P), the Cv is very high at valve full open (high flow rate- maximum, low delta P). Another case of high rangeability is various seasonal consumption of flow rate(high peak in winter and low peak in summer : normally Case 1 for summer, 2 for spring, 3 for autumn, 4 for winter on the data sheet), or the operation concept how much produces at each well and how to operate if there are many wells. Tungsten carbide trim is not required unless the injection water contains the hard particles such as sand.

# Separator Level Control

- Often sandy service: Separator may collect sand from many wells
- High cavitation potential
- Dissolved gases may flash
- Potentially corrosive




The multi-phase fluid often contains sand, which comes from the wellhead platform to the **Separators (i.e. slug catcher).** Choke valve is applied to this case, and the fluid containing oil and water generates cavitation, and the dissolved gas may take place flash, and it's corrosive as the acid is not eliminated.

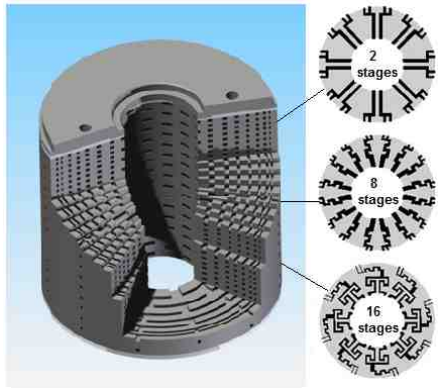
Hydrocarbon liquid is extremely expanded by flashing condition (approx. 600 times), however water and sand remain not evaporated and the velocity of water and sand is increased, causes the serious damage on valve trim and body inside(particularly sand). The clear data for fluid is required to do correct valve sizing as multi-material (Hydrocarbon liquid, Water, Sand) may generates the most serious damage in case flashing takes place with high delta P.

There is very few sand and moisture entrained in the fluid at early operation phase of wellhead platform, in case of the multi-phase fluid mixed with hydrocarbon liquid, gas, moisture, sand, etc., however the later operation phase the more moisture and sand is entrained in the fluid. The lifetime of valve trim is predicted to much shorter at actual plant operation, particularly later operation phase, in case that inappropriate material such as Duplex is applied taking into account sand content in the fluid at only early operation phase (Trouble on Choke valve happens in a week due to erosion by sand since the velocity of fluid is very high with high delta P). Therefore, analysis and prediction for sand content in the fluid from wellhead shall be carefully carried out beforehand for suitable trim material selection.

## Non-wellhead Applications

- Gas lift
- Dump valves: Separator dump valves: K.O. drum dump valves
- Water injection pump recycle*: Overboard dump*

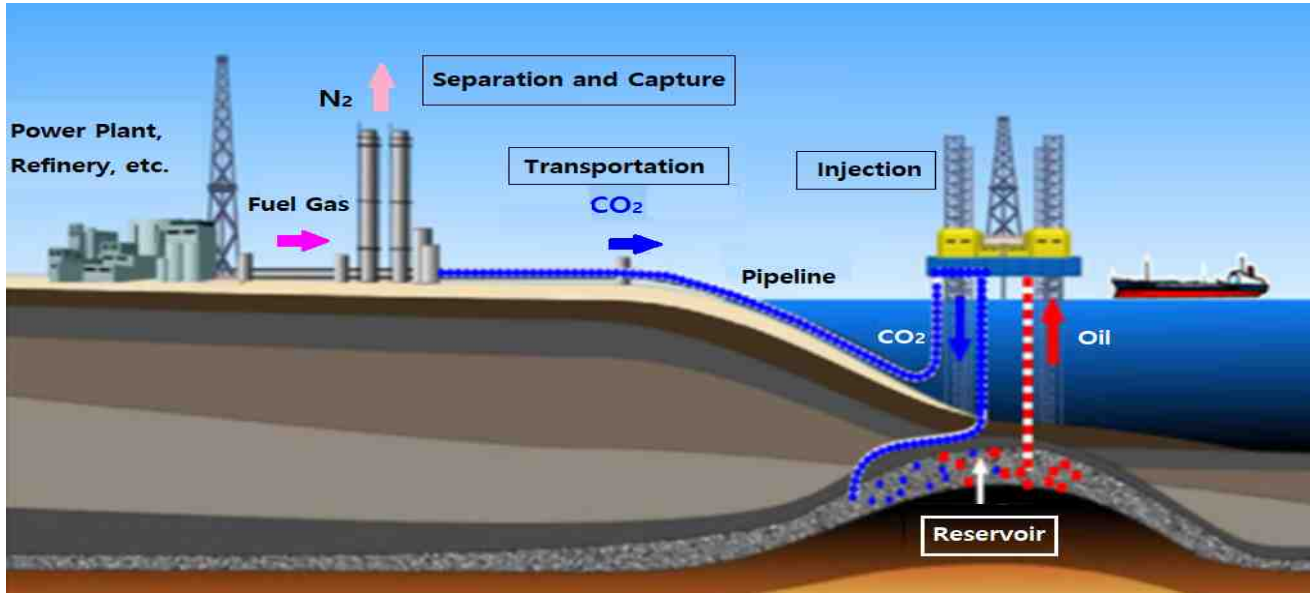
* Usually designated as control valve applications




## Combined Disks to solve the problem

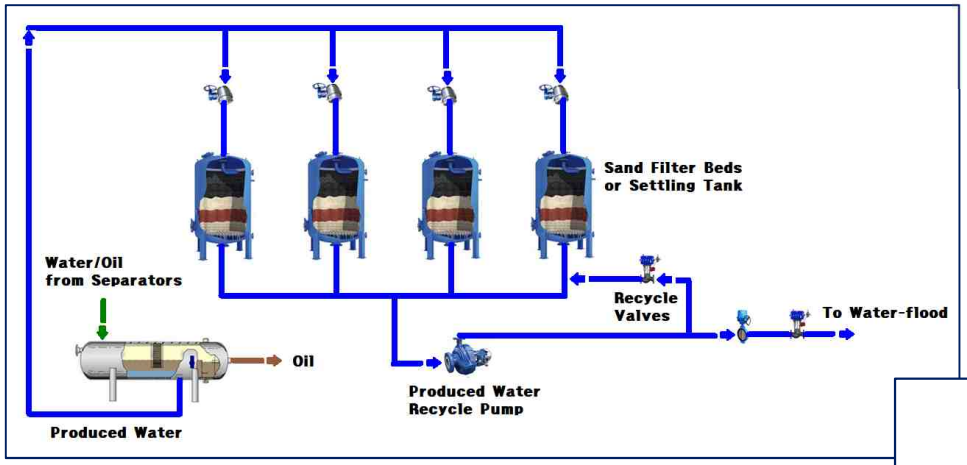
- All disks may not be the same
- Can provide precise linear flow vs. variable pressure drop over the full range of the valve

■ **The case of Choke valve for Non-Wellhead** application is, CO2 is separated from the production at slug catcher and injected into the well, and then it increases well pressure. The environmental issue can be solved at the same time as CO2 gas to atmosphere is reduced (Refer to below picture).



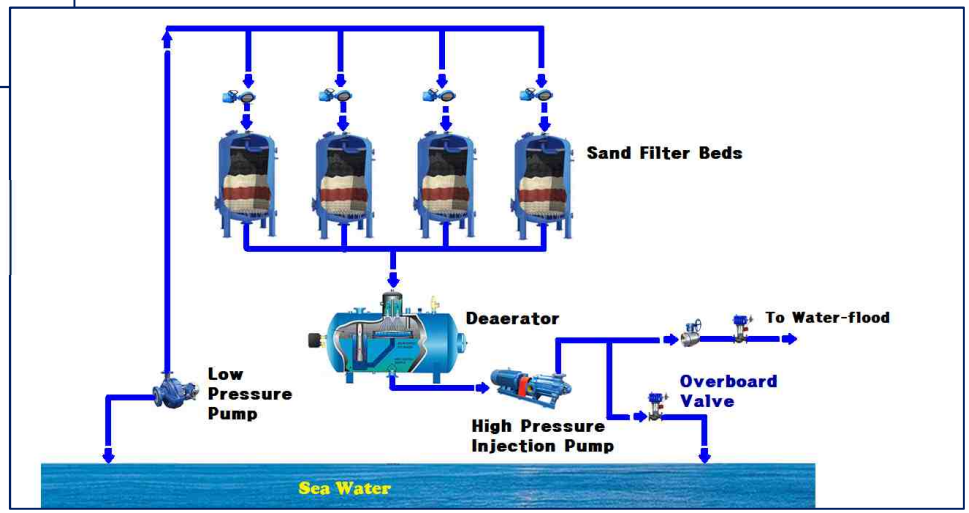
■ **Gas injection compressor**(s) is installed at the offshore platform to inject the gas into the subsea cavern, where the empty cavern is normally utilized as a storage tank after extracting the gas from the well. In this case the delta P between compressor discharge and inside of the empty cavern at initial stage is extremely high, so the condition is very severe.
At initial injection stage the Cv (very high delta P, low flow rate) is very low, however at the valve full open (low delta P, high flow rate) the Cv would be very high by filling the empty cavern up, so high rangeability is required.

■ **The other case** is to install API10000 of high pressure rating with angle design for 4 stages Gas Injection Compressor with high compression ratio so as to boost reservoir pressure up by injecting N2 gas into wellhead. So, Hot Gas Bypass valve with angle design of API10000 for anti-surge is required normally designed in compliance with API 6A. However, it is not actually Choke valve.

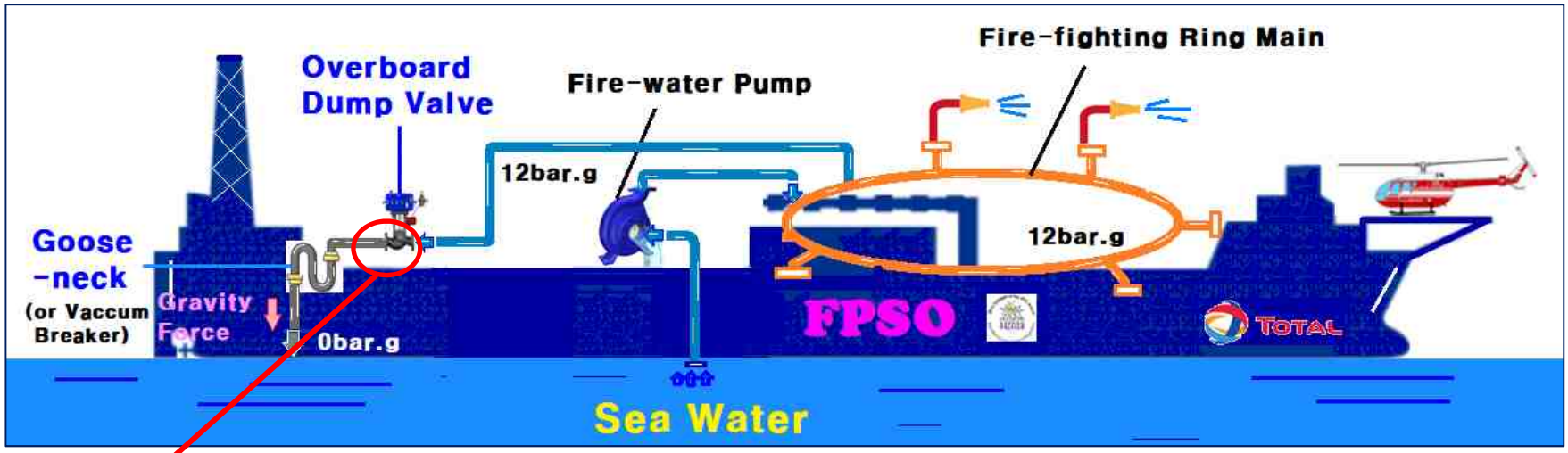


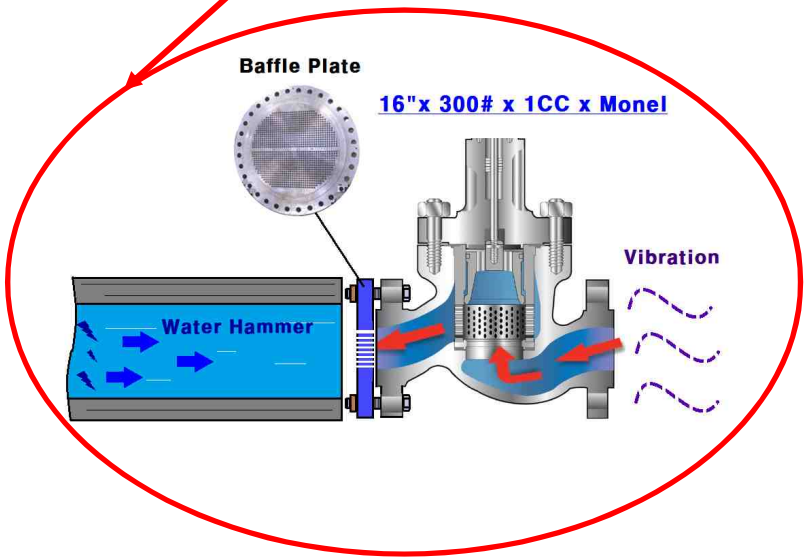

**Water Injection**

**Overboard Dump Valve**



# Overboard Dump Valve - DSME. TOTAL Pazflor FPSO




► For human safety, a certain amount of water had to be overboard-dumped into the sea to keep the pressure on the ring-main 12bar or less.

**Overboard Dump Valve** demands specific design taking into account not only delta P at valve but also gravity force at downstream pipeline. i.e., delta P is quietly related to trim design only, however vacuum pressure due to gravity at downstream pipeline heading for sea generates water hammering after fluid passing the valve since the water falls overboard through downstream pipeline.

The valve design shall take into account an altitude head (Z factor of below formula) from Bernoulli's Theorem. – Outlet Baffle Plate and Goose-neck on Downstream Pipeline ensure that outlet pressure is always positive (see figure).

$$\partial Z_1 + P_1 + \partial V_1/2g = \partial Z_2 + P_2 + \partial V^2/2g$$

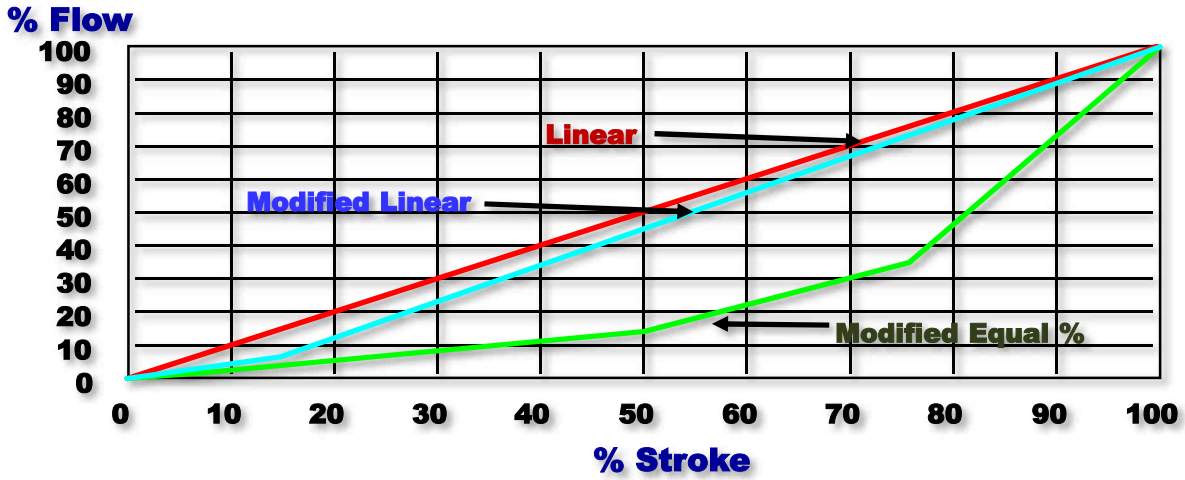
The valve was connected to the fire-water pump by pipeline, which caused considerable vibration. Therefore, it was designed as 1CC which can absorb delta P. Monel Trim/Baffle Plate, and Monel overlay body for cost-effective.

# Multi-stage/Multi-path Trim

## - Velocity control for specific applications

### Linear stack

- All disks have the same number of passages, stages & flow area
- Flow is directly proportional to the valve's stroke at constant differential pressure




**Various linear characteristic curve** can be made based on operating condition in case MLT or CCD trim of multi-path, multi-stage is applied, where it can be achieved if the disk stack is designed taking into account the number of path and number of stage, the flowing area.

# Trim Design to application guide

- **CC (Concentric Cage) Range**
  - ► Low pressure recovery with drilled hole
  - ► Available for both clean and dirty service
  - ► Relatively high pressure differential

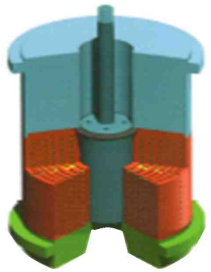
- **MLT (Multi Labyrinth) Disk Stack Range**
  - ► Ultra pressure recovery with multi-path/ multi-stage letdown
  - ► Available for only clean service(up-down path), not erosive fluid
  - ► Extremely high pressure differential water injection to well application

*(Severn Glocon)*

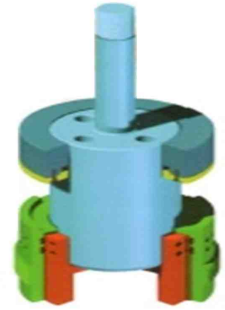
Severn Glocon produces several designs compatible with the fluid and operation conditions of wellhead,
**CC(Concentric cage) trim :** applies to the low pressure recovery and available for both fluids of dirty and clean, and to relatively high pressure differential.

**MLT(Multi-Labyrinth Trim) :** applies to multi-path, multi-stage letdown with ultra high pressure recovery, and to extreme high pressure differential water injection to well. This type of trim “up/down” multiple stages cannot be used on a mixed phase or sand contaminated duty as severe erosion is created.

- **CCD Range**
  - ► Ultra low pressure recovery with multi-path/multi-stage letdown(Horizontal path)
  - ► Available for both clean and dirty service , and first choice for extremely high differential dirty flow application, particularly erosive fluid with sand



- **MP-CC(Concentric Cage) Range**
  - ► Low pressure recovery with drilled hole at initial opening
  - ► Available for both clean and dirty service
  - ► First choice for low pressure production wells with relatively high TLP (Tube Lock- in Pressure) values

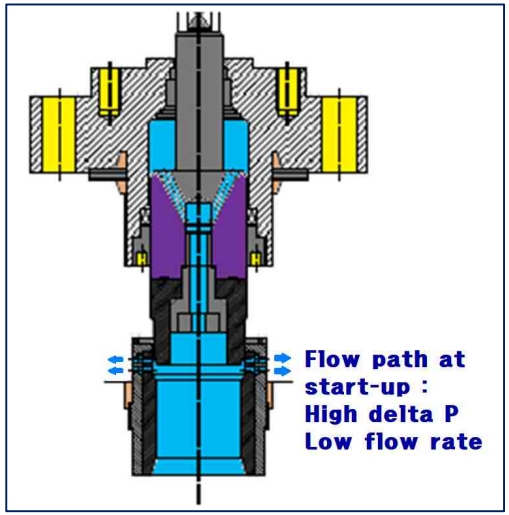


*(Severn Glocon)*

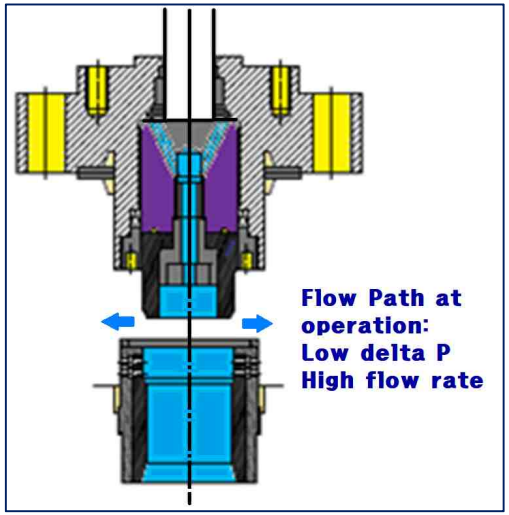
**CCD Trim** applies to multi-path, multi-stage letdown with ultra low pressure recovery, and available for both fluids of dirty and clean however prefers to apply to the fluid of high pressure drop and dirty service. This trim utilizes a flow path that introduces horizontal turns to the flow and can be produced in carbide.

**MP- CC Trim** is a high-bred trim designed to offer a single or multiple stage low recovery trim for only a portion of the travel(usually below 50% of the full travel). At higher flows the plug travels out of the cage to provide the maximum flowing Cv within the selected body size. The trim is offered on wells where the pressure drop across the valve is high on initial opening but falls rapidly at higher flows. For M.P. Choke a seat is designed to screw thread to increase the seat bore maximum. It's developed to handle significant pressure drops during well start-up with TLP (Tube Lock-in Pressure: the pressure kept in between wellhead and valve inlet when closing the valve), whilst providing minimum flow restriction during production.

## MP-CC(Concentric Cage) Range- Trim Performance




**Start-up/Significant Pressure Drop**




**During Production** *(Severn Glocon)*

The **MP Choke** is designed as a screw thread on the seat to maximize seat bore. Although the wellhead pressure is low, it is applied when the TLP (Tube Lock-in Pressure: when the valve is closed, the pressure locked to the wellhead pressure and the valve inlet) is large. During initial start-up, the flow rate is small, the delta P is very large, the flow rate is large and the delta P is small during normal operation.

## Industry Standards

- ANSI B16.34
- API 6A
- ISO 9000/9001
- Governmental agencies
- Customer specifications

Worldwide leading oil/gas majors requires the standard & code for their projects.