# Subsea Control Fluids

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IT'S MORE THAN JUST OIL. IT'S LIQUID ENGINEERING.

# Introduction

- Safety Moment
- Control Fluid Considerations
  - What is a Control Fluid
  - Types of Control Systems
  - System Design
  - Hydrates
- Legislation and Testing
  - Fluid Qualification
- Fluid Cleanliness
  - Cleanliness Approach

# Safety Moment - Chemical handling

See anything wrong in these photos?

# Safety Moment

## Unacceptable Sample Submission

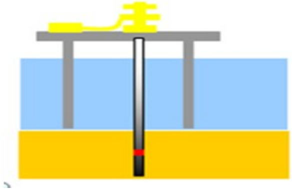

## Acceptable Sample Submission


# Control Fluid Considerations

IT'S MORE THAN JUST OIL. IT'S LIQUID ENGINEERING.

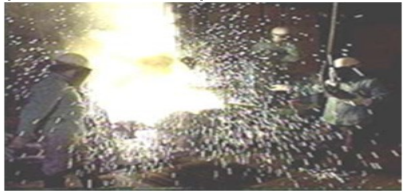
# Types of Hydraulic Systems



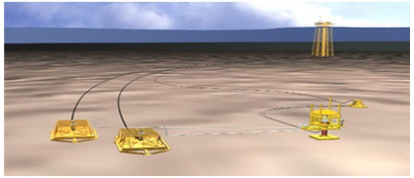
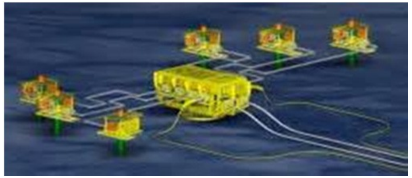
Mineral Type Hydraulic Oil (Some applications require environmentally responsible oils)

Mineral



Fire Resistant

Synthetic

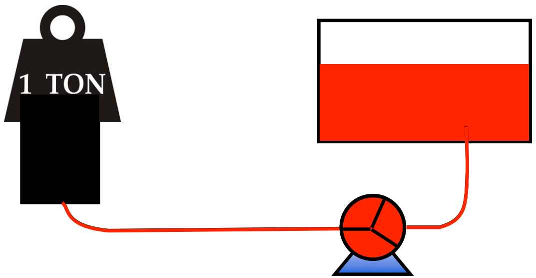
Subsea Control Fluids

# What is a Subsea Control Fluid

## Control Fluid

These fluids provide medium to hydraulically control and operate subsea hardware from drilling rigs or offshore platforms. Subsea control fluids are broadly divided into two categories, those used for Drilling, and those used for Production.

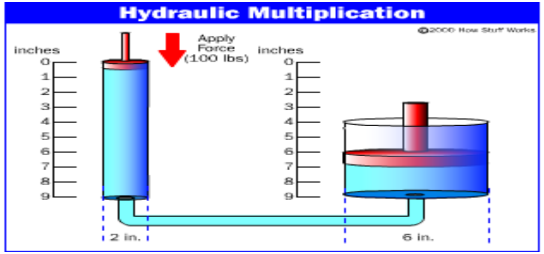
# Subsea Hydraulic Fluid Basics



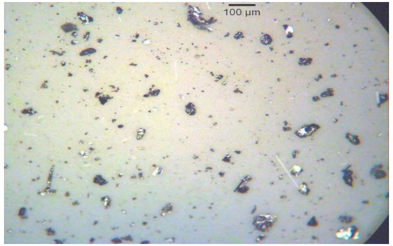

Transmit Power

- Non compressible liquid
- Excellent materials compatibility
- Low viscosity for quick response times
- Good thermal stability
- Suitable lubrication
- Low pour point
- Tolerance to contamination
- Environmental compliance
- Field life stability

# Fluid Functions

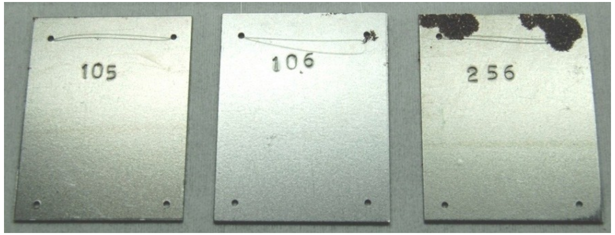



Fluid Flow and Pressure Transfer



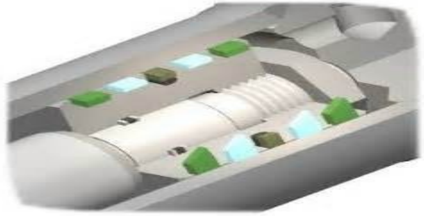

Transport Debris

Lubricate and Cool



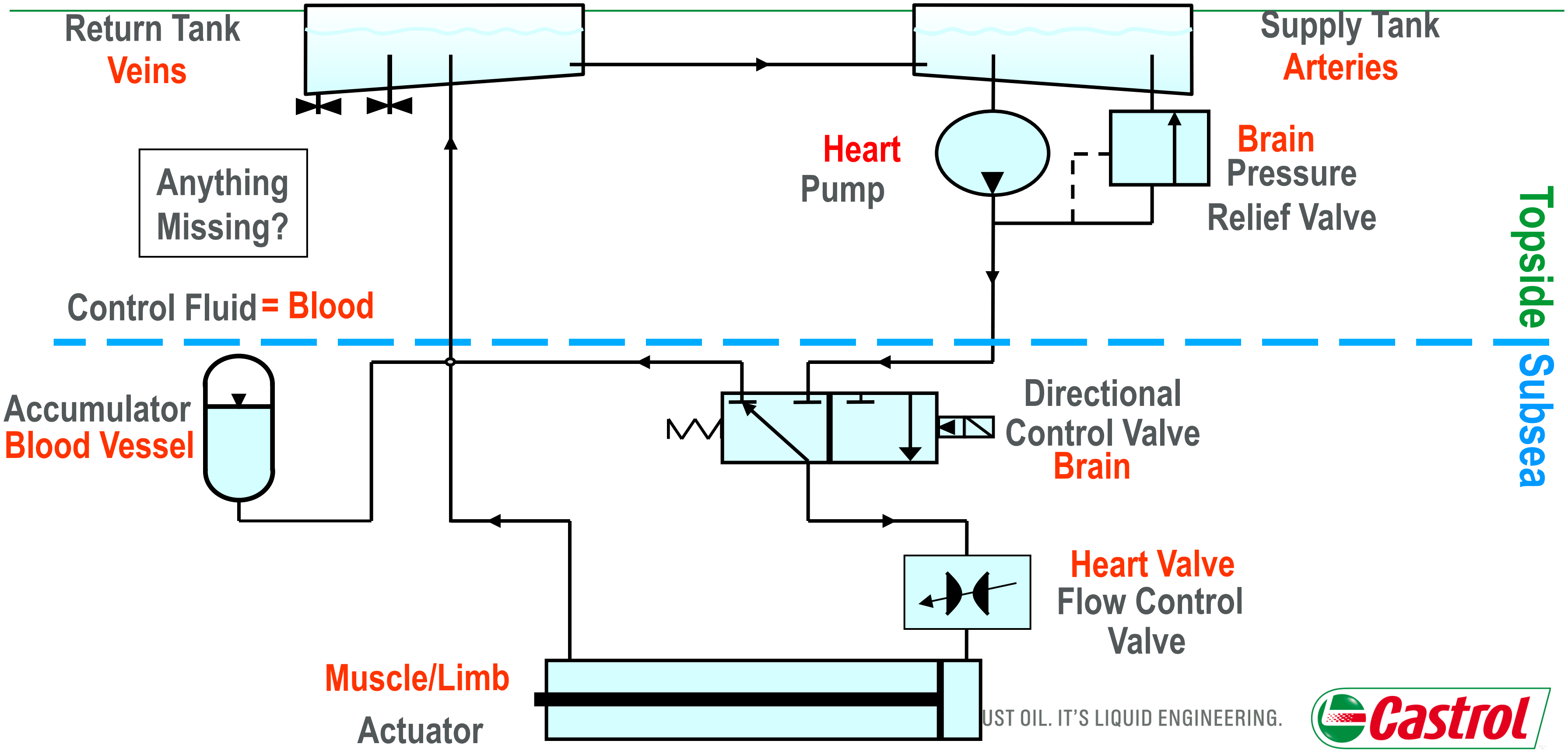

Corrosion Protection

Material Compatibility

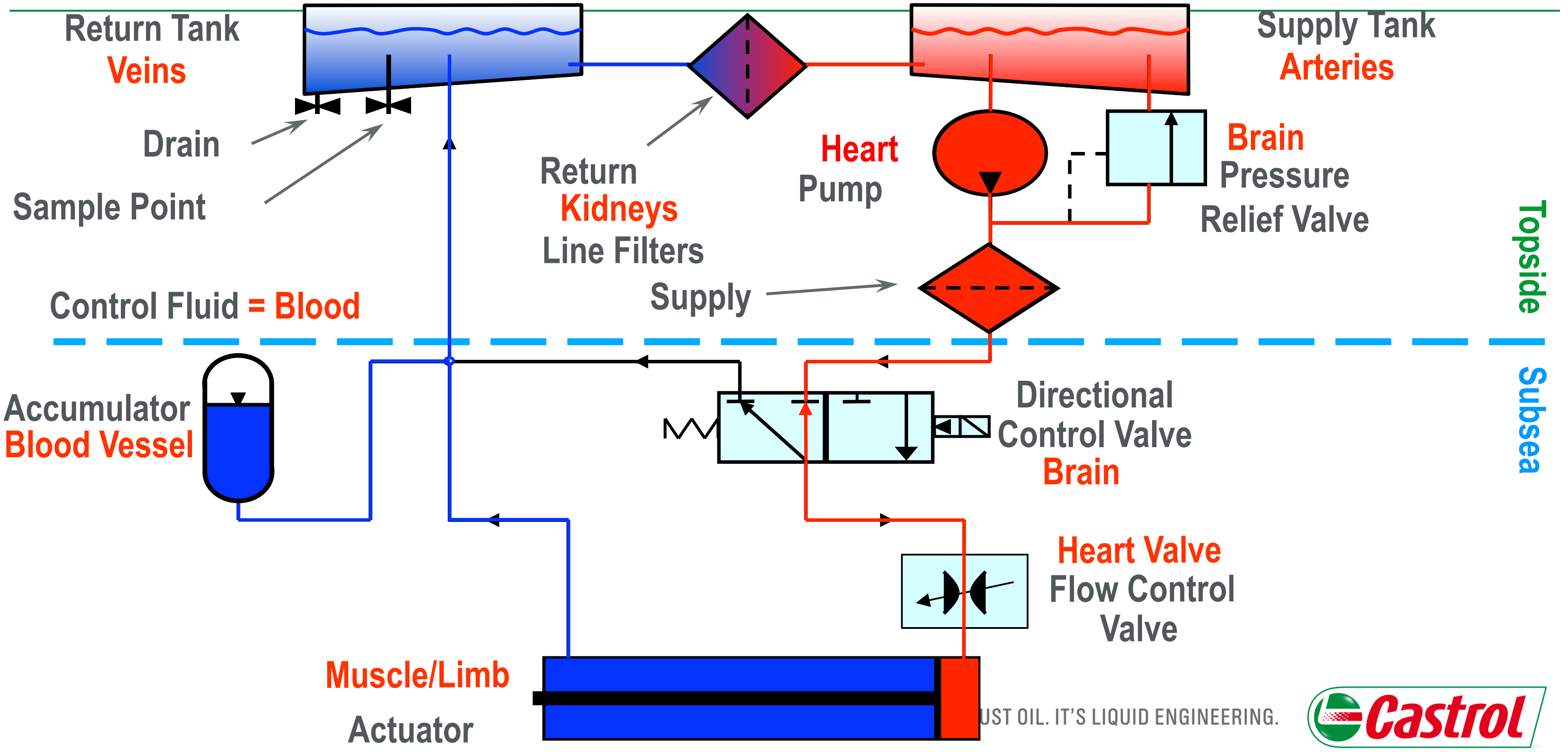


Sealing

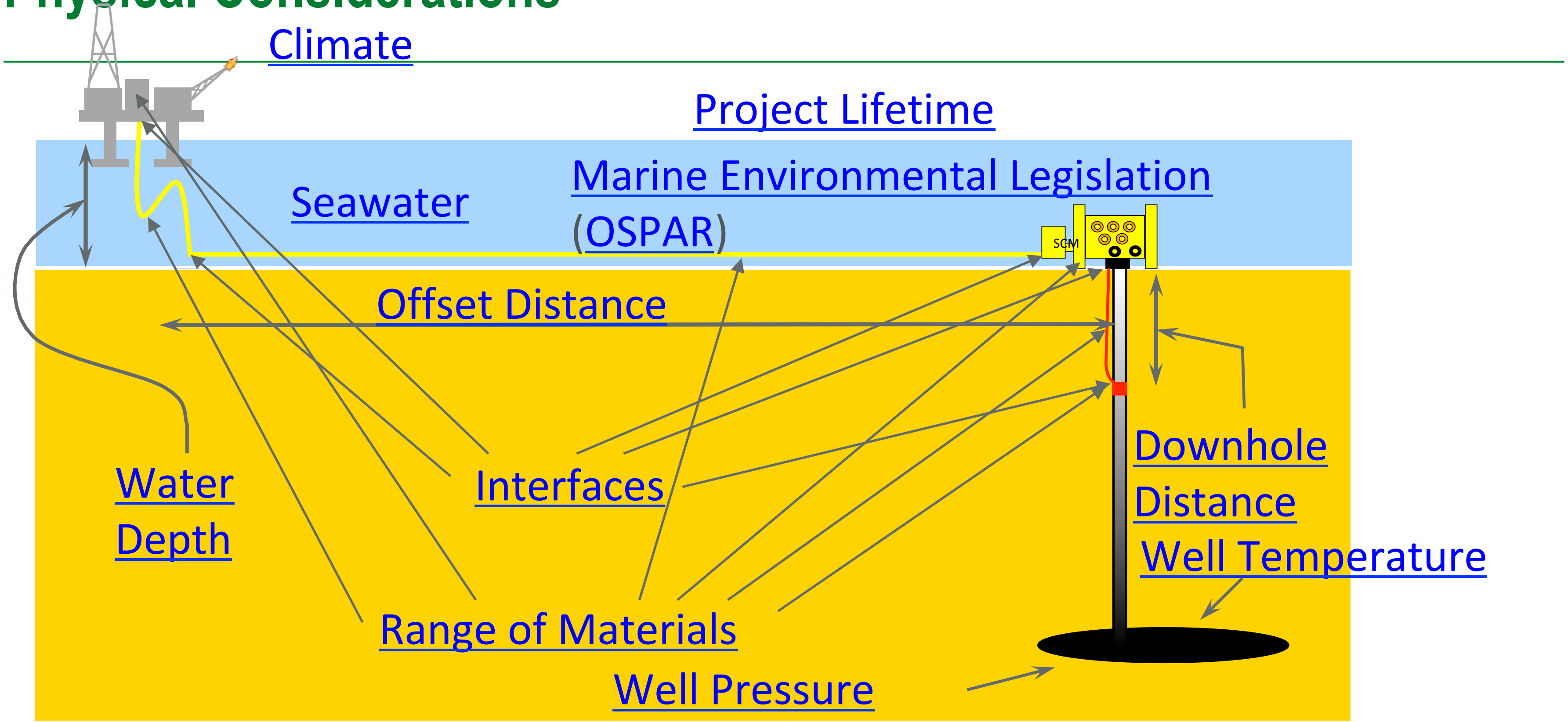
# System Schematic



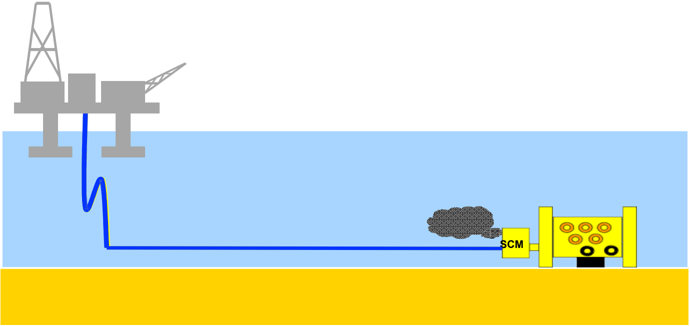
# System Schematic



# Physical Considerations



# Types of Control Systems




## Open Loop (Total Loss)

- Return vented to sea
- 90% of Projects Worldwide
- Water/Glycol based fluids


## Closed Loop

- From HPU to SCM and back to HPU
- 10% of Projects Worldwide
- Either Synthetic or Water/Glycol based fluid (Synthetics over 95%)
- Filled for life!

# Water Depth

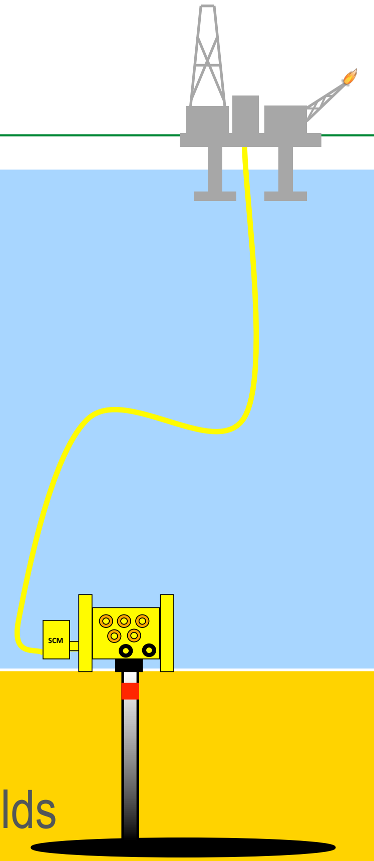
Effects of density difference between Control Fluid and Seawater need only be considered at depths > 1000m

**+ve head** – back pressure may affect valve closures

**-ve head** - sea water leaks into the system

> 4°C

Other issue is the low sea bed water temperatures which increase the risk of hydrate formation, especially for Gas fields

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# Deep Water

**Hydrostatic Pressure (P) = Density (ρ) x Gravity (g) x Depth (h)**

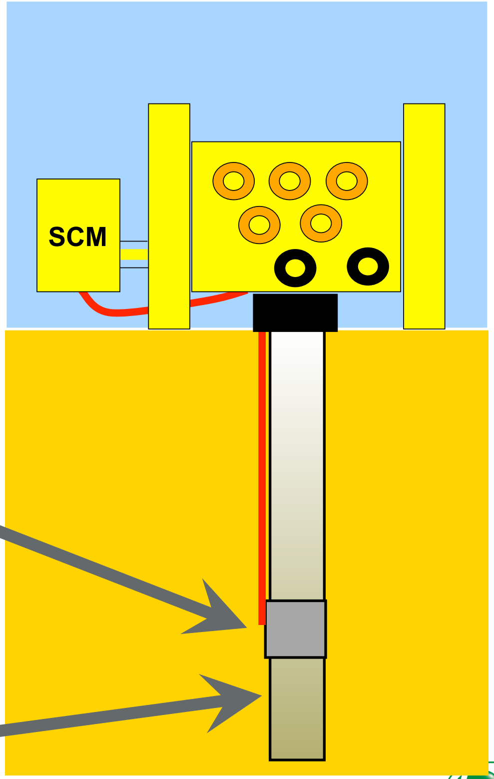
**Density Comparison**

| | | |
|---|---|---|
| **Synthetic Fluid** | **0.82** | |
| **Water** | **1.00** | |
| **Seawater** | **1.025** | **(varies across the world)** |
| **Aqueous Fluid** | **1.07** | |

| Fluid | Synthetic Fluid | Aqueous Fluid |
|---|---|---|
| Seawater Hydrostatic Pressure (@ 3000m) | 302 Bar | 302 Bar |
| Fluid Hydrostatic Pressure (@ 3000m) | 241 Bar | 316 Bar |
| Δ Pressure | - 61 Bar | +14 Bar |

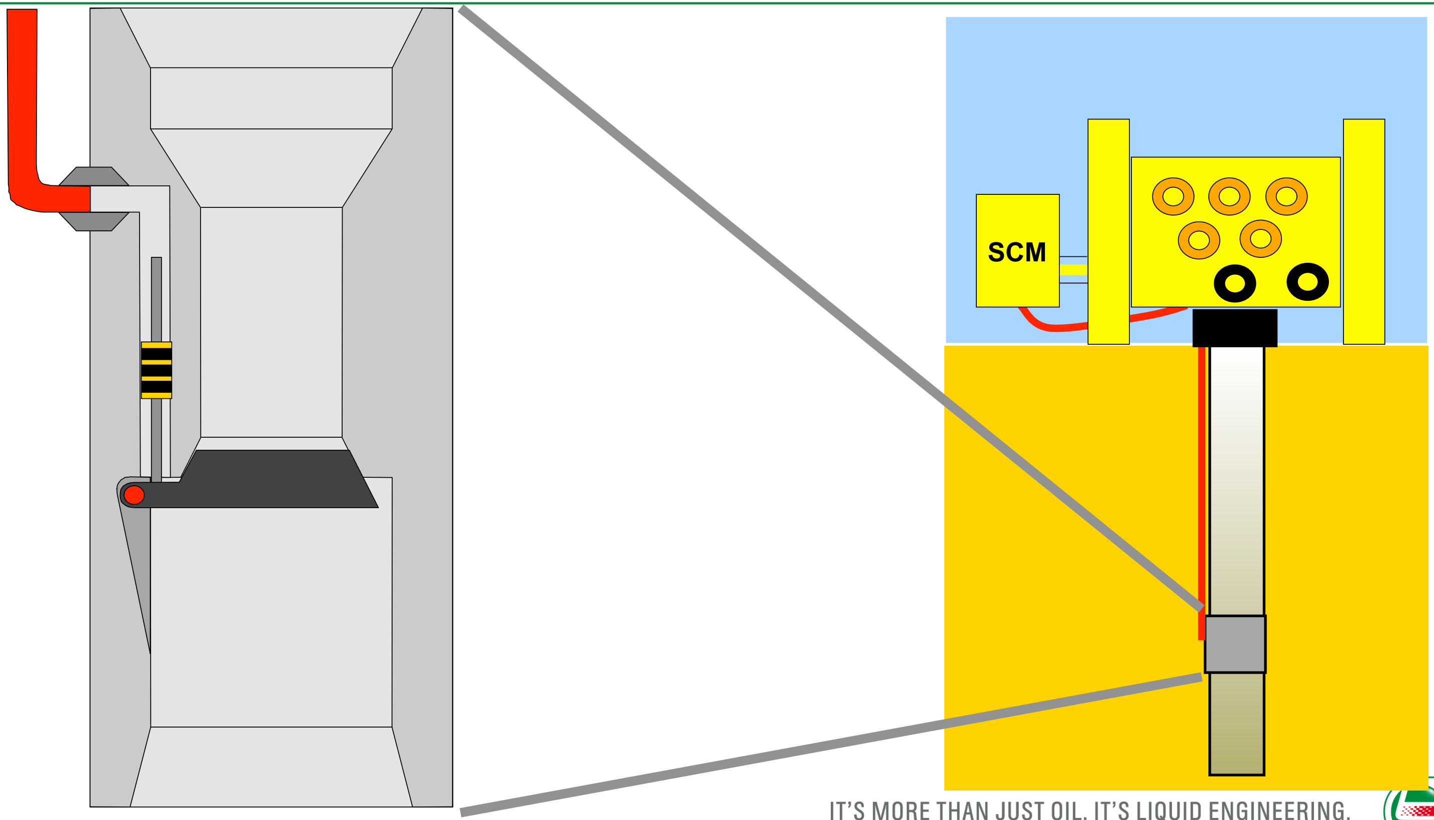
# Gas Hydrates

## Mechanism by which Hydrates Form in the Control System?

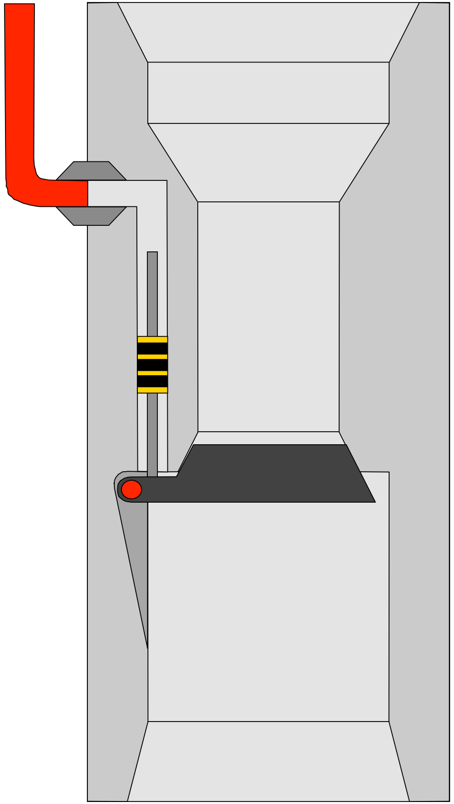



2. You need a **failure** in a piece of equipment (i.e. Surface Controlled Subsurface Safety Valve (SCSSV))
1. You need **Gas** in the production string

# Gas Hydrates

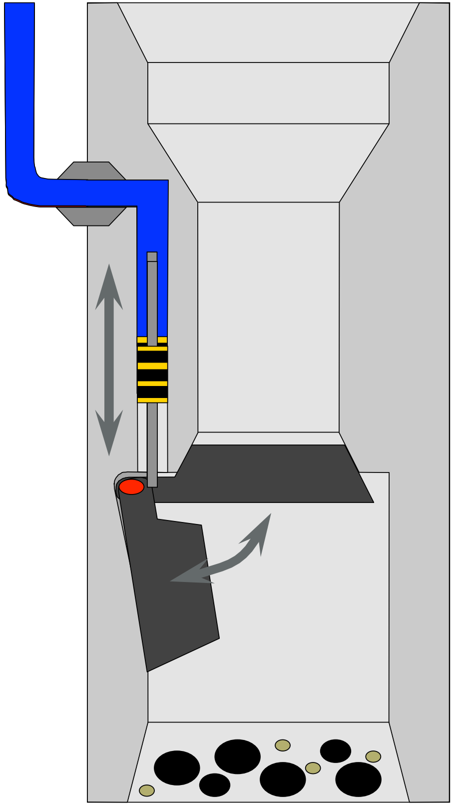


# Gas Hydrates



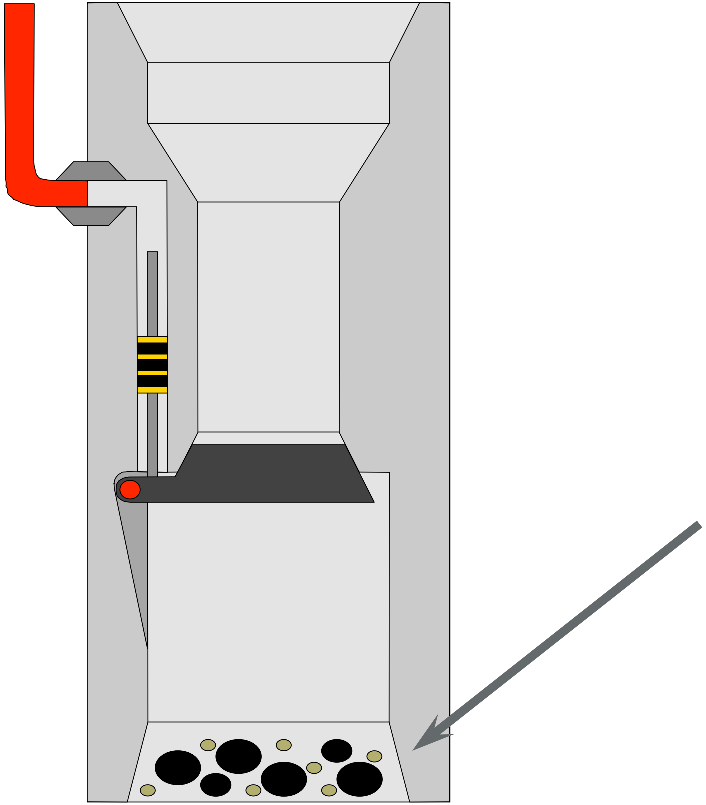
So what is the actual failure mechanism in the SCSSV that can cause hydrates to form?

# Gas Hydrates



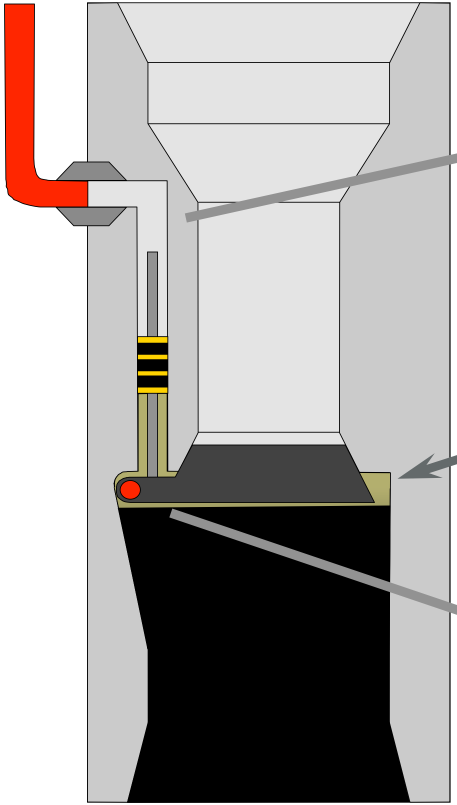
1. To open the flapper, pressure is applied to the piston. (Note: This applied pressure needs to be regulated during the field life to maintain the same differential across the seals as reservoir pressure depletes.
2. When the flapper is opened the Oil and Gas begin to flow.
3. To close the flapper, pressure is removed from the piston.
4. As the Flapper and Piston operate the seals wear.

# Gas Hydrates

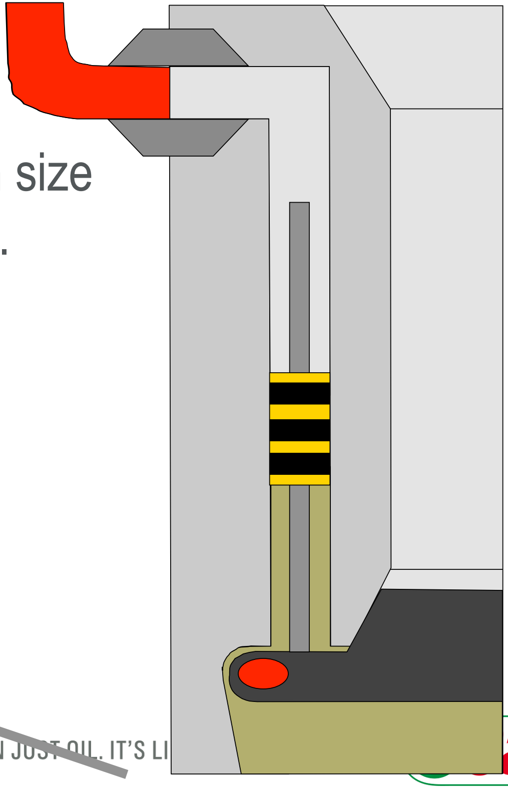


When the flapper is closed the Oil and Gas begin to build up.  The gas starts to form a gas cap.

# Gas Hydrates

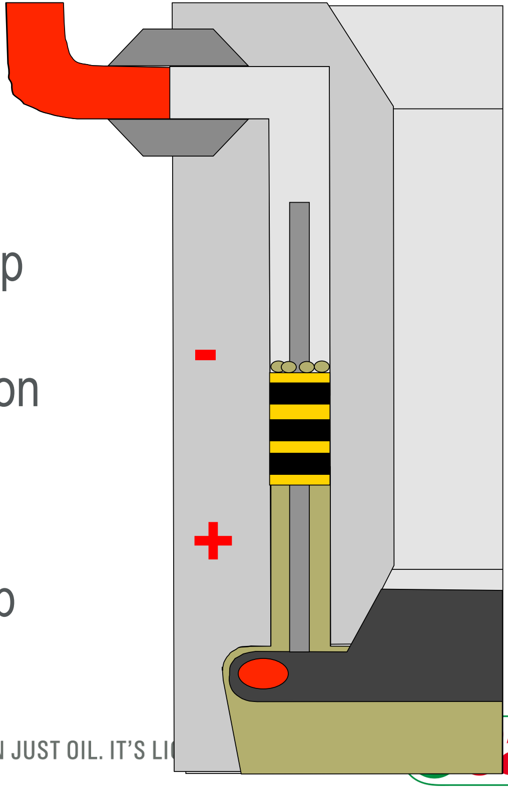


This gas cap increases in size in line with time of shut in.

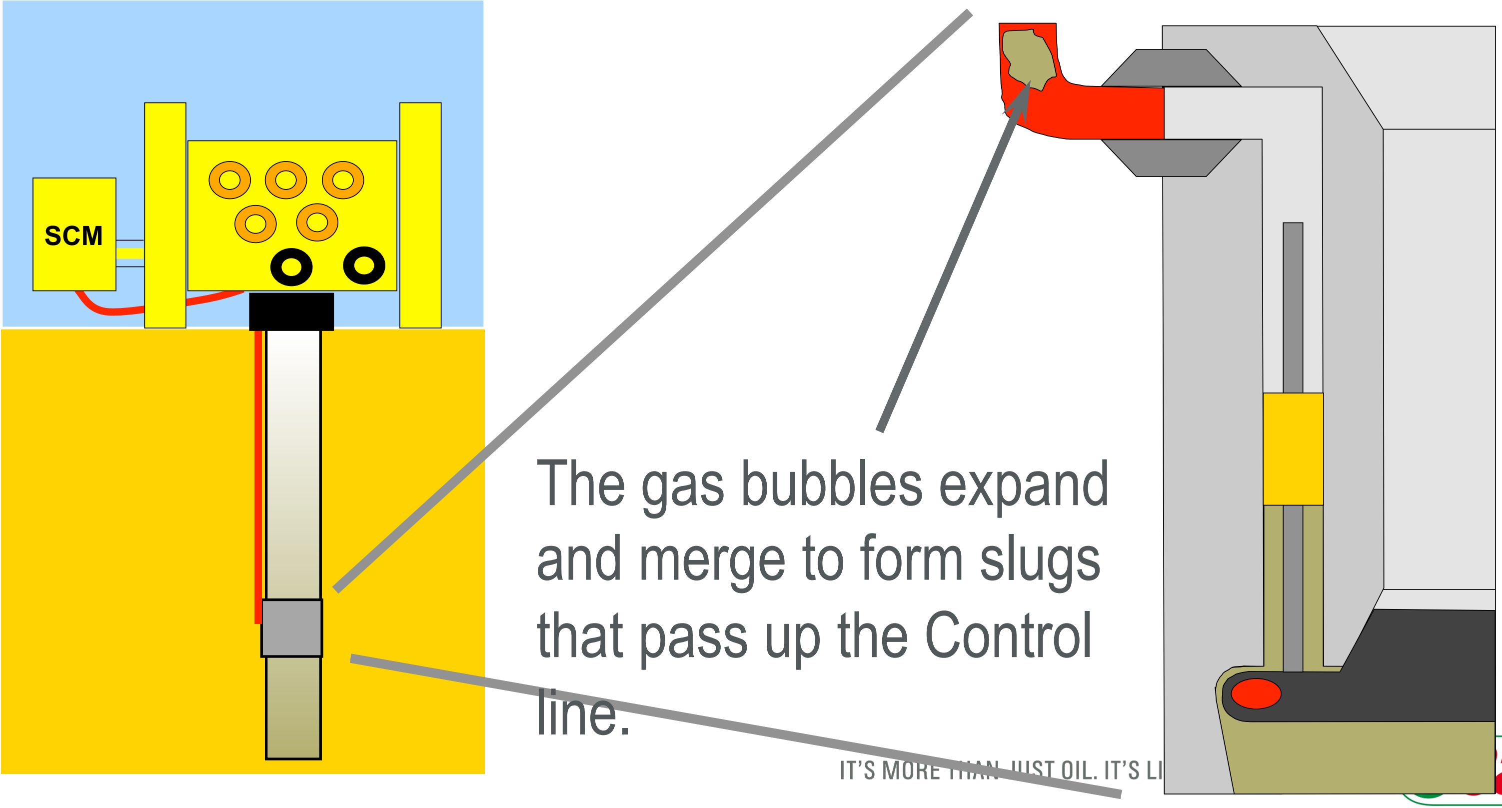


# Gas Hydrates

1. As stated earlier when the flapper is closed, pressure is bled off.  If this pressure is below the reservoir pressure it creates a negative pressure drop across the seals.
2. The combination of seal wear and the altering direction of pressure drop across the seals can cause **Seal Failure**
3. This failure combined with the negative pressure drop across piston from the control line allows the gas bubbles to percolate up the control line.

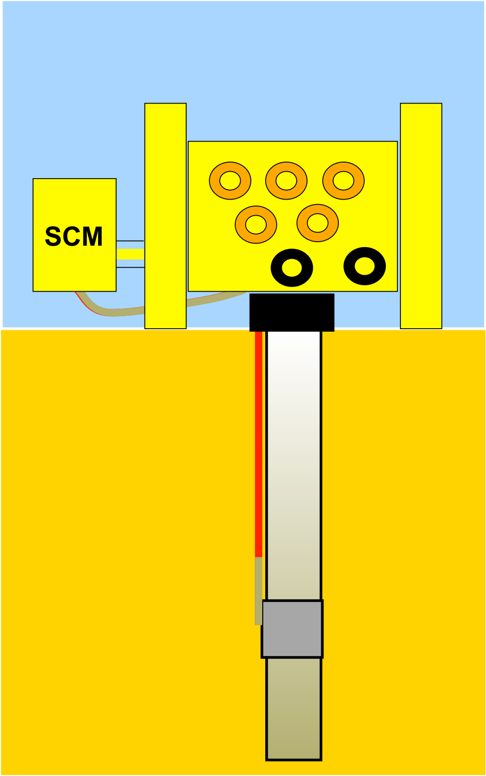


# Gas Hydrates




The gas bubbles expand and merge to form slugs that pass up the Control line.

# Gas Hydrates

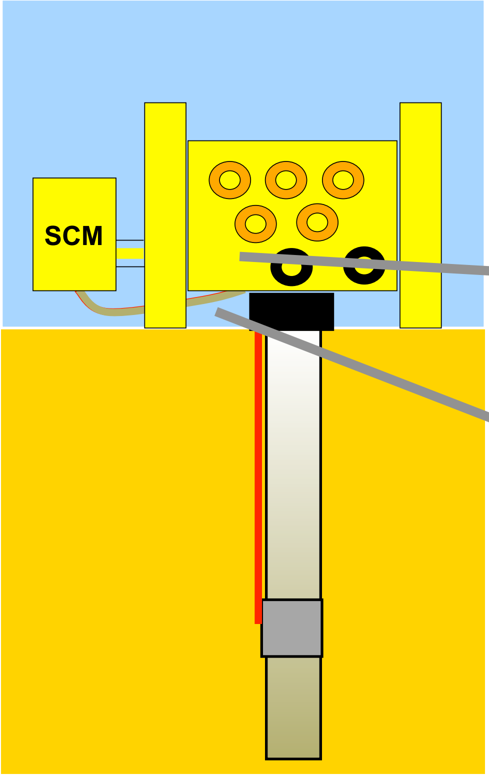



1. The gas continues to percolate past the damaged seals and bubble up the control line expanding as it goes forming slugs of gas

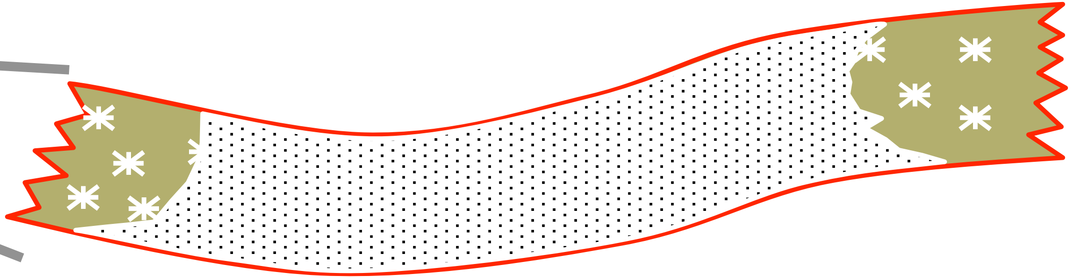
2. The gas eventually passes through the Tubing Hanger (TH) and X-Tree (XT), and enters control lines external to XT going to the Subsea Control Module Mounting Base (SCMMB)

3. These control lines are surrounded by sea water @ temperatures between 15˚C to -2˚C. (Norm is around 4˚C)

# Gas Hydrates

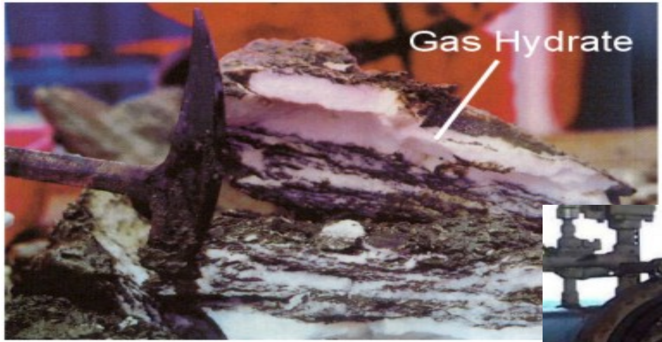



1. If **<u>High Pressure</u>** is then re-applied to open the SCSSV in the presence of **<u>Gas</u>**, free **<u>Water</u>** (in the control fluid) and the **<u>Cold</u>** temperature (caused by the surrounding Sea Water) then **<u>Hydrates</u>** will form.



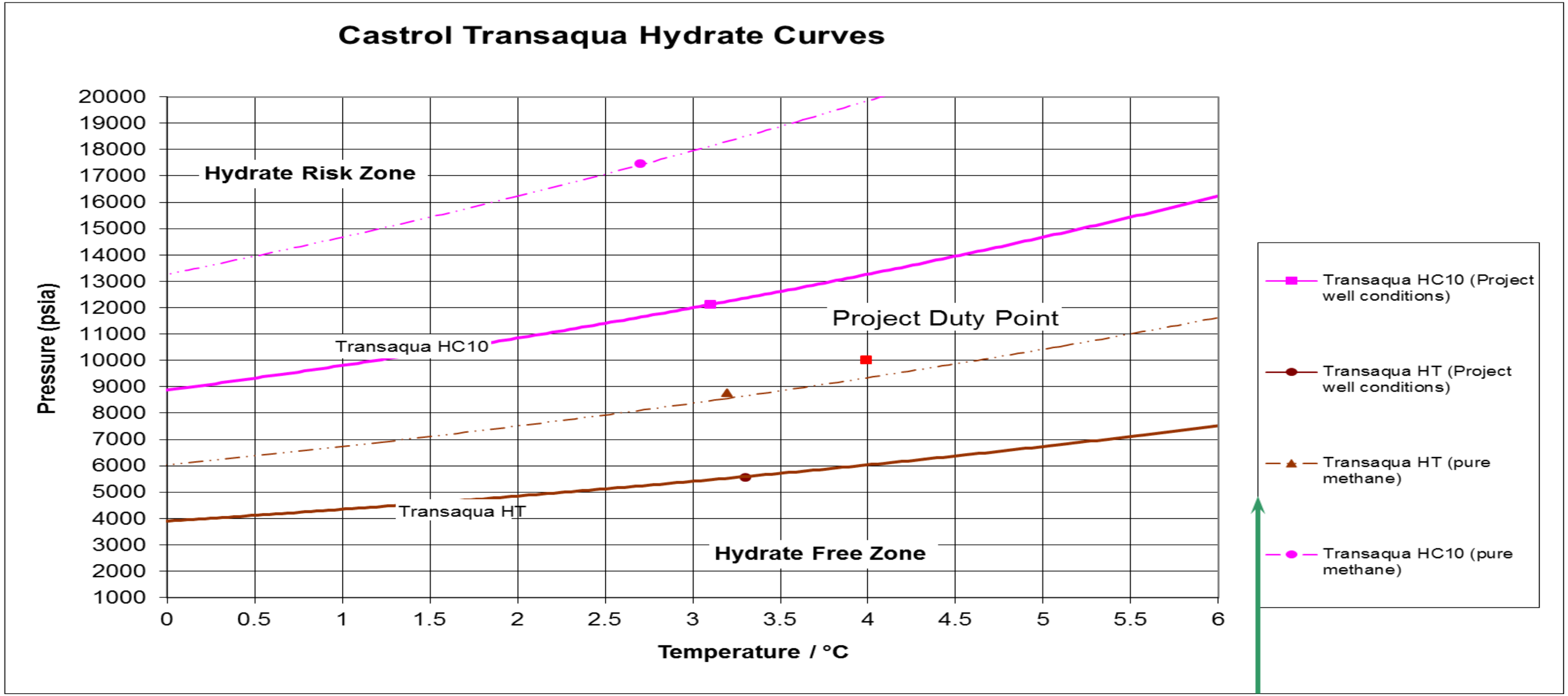
2. In severe case this could completely block the line, causing loss of communication and control of the SCSSV. Worst case it happens in the Subsea Control Module (SCM) and you lose control of the XT.

# Gas Hydrates




Crystalline solid compounds
(water & light gases)

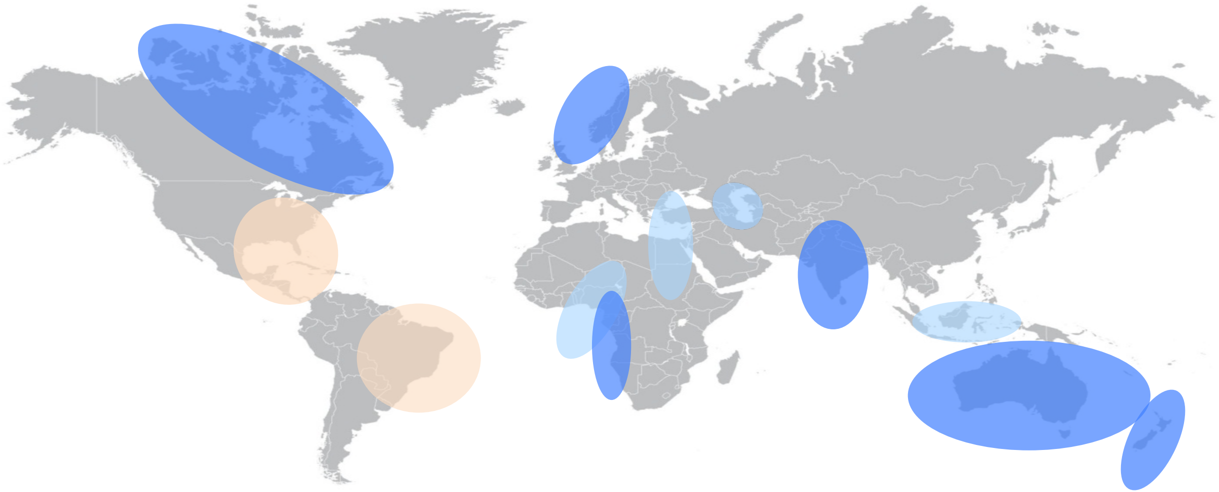
# Example of Hydrate Analysis with Actual Project Conditions



# Legislation and Testing

# Offshore Environmental Legislation (TRL 2)

*Commitment to reduce the discharge of non-compliant chemicals*



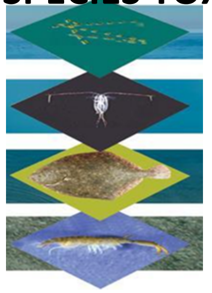
**North East Atlantic (OSPAR)**
UK, Norway, Netherlands + others

Each component testing for:-
- MARINE BIODEGRADATION
- BIOACCUMULATION
- MARINE TOXICITY

**GULF OF MEXICO**
Product level toxicity testing only
No sheen on water surface
**BRAZIL** – No specific environmental testing for subsea control fluids

**Emerging Legislation**
No specific offshore legislation.
Drive for OSPAR compliance

## SPECIES TOXICITY TESTING



ALGAE

CRUSTACEANS

FISH

SEDIMENT REWORKERS

## REGIONAL PRODUCT/CHEMICAL RATINGS

UK OCNS - RATING - A B C D E

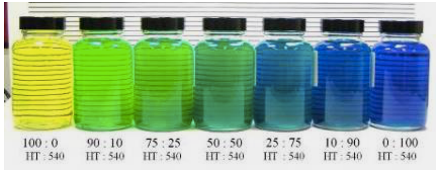
Decreasing Environmental Hazard

| Norwegian Colour Rating for chemicals | |
|---|---|
| Green | Compliant (no testing required) |
| Yellow | Compliant |
| Red | Substitution Plan Required |
| Black | May not be discharged |

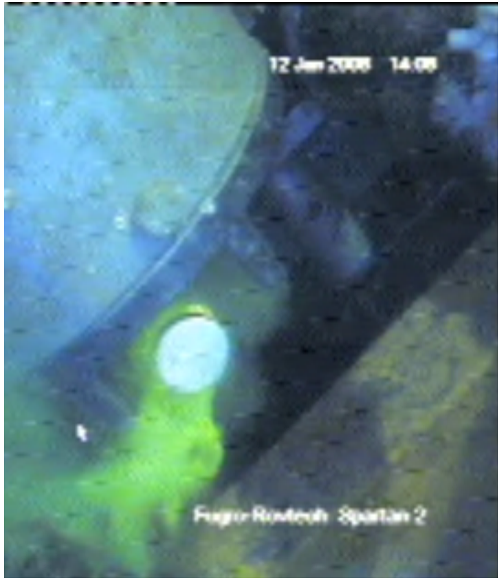
# ISO/API Testing (TRL 2)

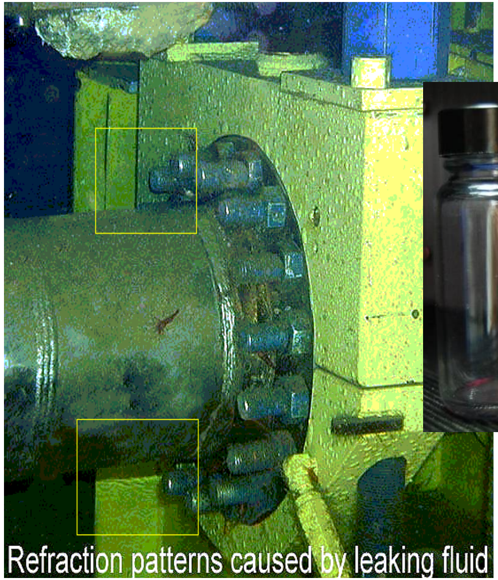
Carry out qualification testing to ISO13628-6 /API 17F Annex C

- Thermal Stability – High/Low temperature and High temperature in the presence of seawater
- Fluid compatibility – Seawater, other Control Fluids, Completion Fluid and Operational Fluids**
- Material Compatibility – Metals, Elastomer and Thermoplastics
- Filterability
- **Examples: Wellbore acids, methanol or compensation fluid, silicon or insulating oil



# Subsea Leak Detection




ROV mounted floodlights showing fluid leak - visible spectrum (approx 200 L / day)

# Materials Compatibility

Typical, long-term materials compatibility testing can include:

60+ Metals

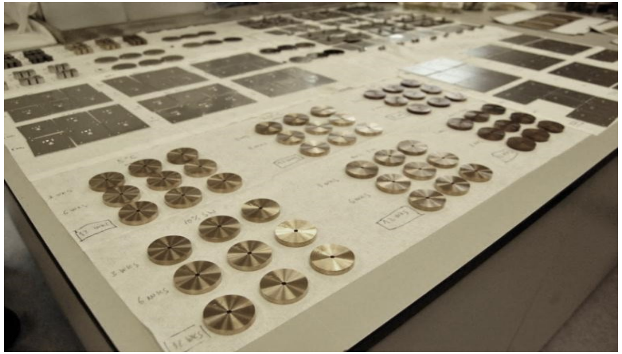
Including key materials groups – Ferritic steels, stainless steels, yellow metals, tungsten carbide and nickel alloys

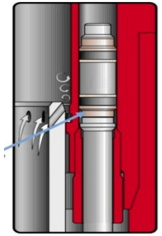
60+ Elastomers and Polymers

Specific grade to be tested from various key suppliers

30+ Coatings and Platings

Including phosphating, ENi plated components, resin and PTFE based coatings





**OEM MATERIAL LISTS**

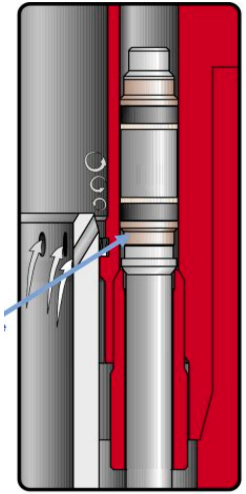
FMC
AKER
GE
ROTATOR
HALLIBURTON
SCHLUMBERGER BAKER

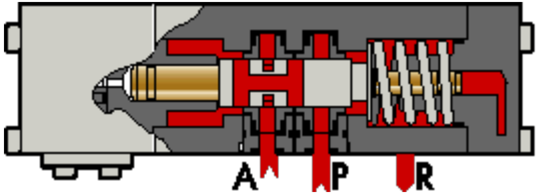
# Functional Equipment Testing (TRL 4)

## Working with Equipment Manufacturers

System approach

- DCV
- Pumps
- SSSV
- Umbilical's
- Couplings
- Actuators
- Materials






# Fluid Cleanliness

# Understanding Cleanliness

| "ISO 11171 Calibration" | > 4 µm(c) | > 6 µm(c) | > 14 µm(c) | > 21 µm(c) | > 38 µm(c) | > 70 µm(c) | "corresponding to ISO class 6, 14 µm©" |
|---|---|---|---|---|---|---|---|
| SAE CODE | A | B | C | D | E | F | |
| 3 | 6,250 | 2,430 | 432 | 76 | 13 | 2 | 12/9 |
| 4 | 12,500 | 4,860 | 864 | 152 | 26 | 4 | 13/10 |
| 5 | 25,000 | 9,730 | 1,730 | 306 | 53 | 8 | 14/11 |
| 6 | 50,000 | 19,500 | 3,460 | 612 | 106 | 16 | 15/12 |
| 7 | 100,000 | 38,900 | 6,920 | 1,220 | 212 | 32 | 16/13 |
| 8 | 200,000 | 77,900 | 13,900 | 2,450 | 424 | 64 | 17/14 |
| 9 | 400,000 | 156,000 | 27,700 | 4,900 | 848 | 128 | 18/15 |
| 10 | 800,000 | 311,000 | 55,400 | 9,800 | 1,700 | 256 | 19/16 |
| 11 | 1,600,000 | 623,000 | 111,000 | 19,600 | 3,390 | 512 | 20/17 |
| 12 | 3,200,000 | 1,250,000 | 222,000 | 39,200 | 6,780 | 1,020 | 21/18 |

*Cleanliness classes according to SAE AS4059 and conversion to corresponding cleanliness classes according to NAS 1638 and ISO 4406*

# Understanding Cleanliness

**ISO 4406:1999 Code Chart**

| Range Code | Particles per milliliter | |
|---|---|---|
| | More than | Up to / Including |
| 24 | 80000 | 160000 |
| 23 | 40000 | 80000 |
| 22 | 20000 | 40000 |
| 21 | 10000 | 20000 |
| 20 | 5000 | 10000 |
| 19 | 2500 | 5000 |
| 18 | 1300 | 2500 |
| 17 | 640 | 1300 |
| 16 | 320 | 640 |
| 15 | 160 | 320 |
| 14 | 80 | 160 |
| 13 | 40 | 80 |
| 12 | 20 | 40 |
| 11 | 10 | 20 |
| 10 | 5 | 10 |
| 9 | 2.5 | 5 |
| 8 | 1.3 | 2.5 |
| 7 | 0.64 | 1.3 |
| 6 | 0.32 | 0.64 |

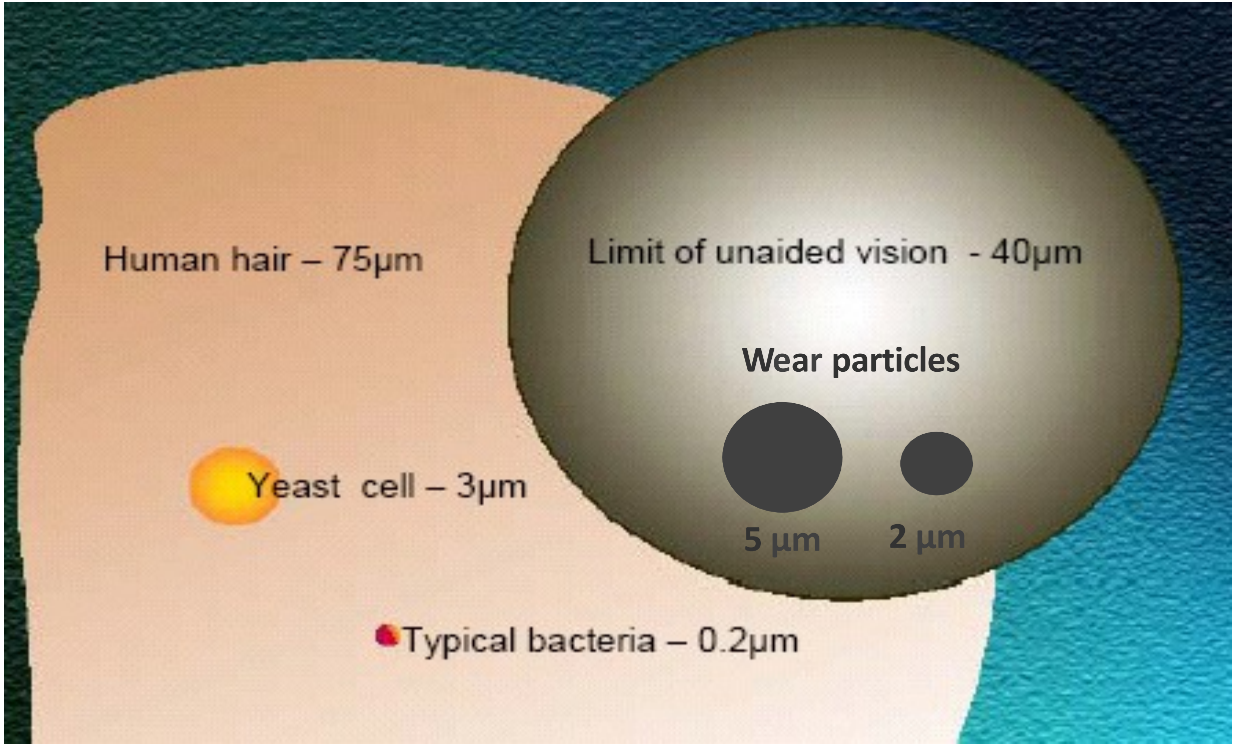
Fluid sample with:
1000 particles > 4 µm

Fluid sample with:
200 particles > 6 µm

Fluid sample with:
15 particles > 14 µm

ISO Class 17/15/11

# Relative Sizes of Small Particles

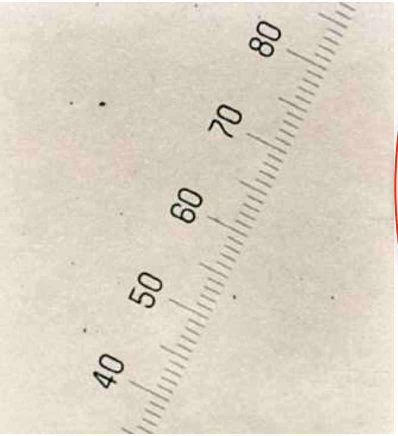


# Cleanliness levels

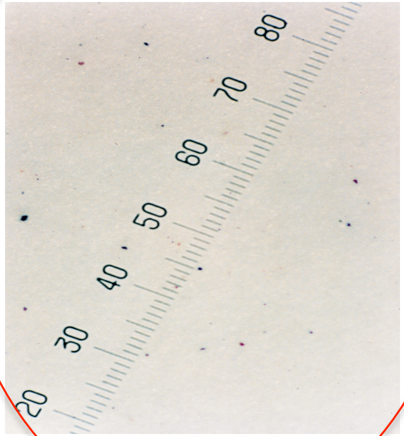
There are 2 main cleanliness standards used in the Offshore industry

- SAE AS4059 6b-f (replaces NAS class 6)
- ISO 4406

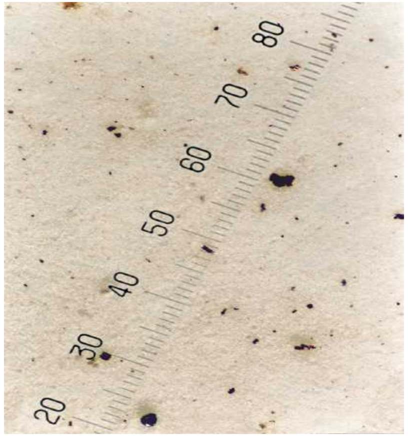
AS4059 Class 4b-f



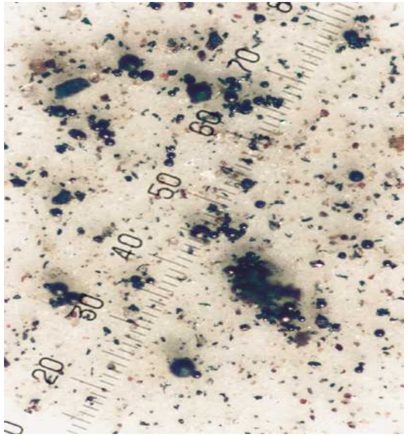

AS4059 Class 6b-f



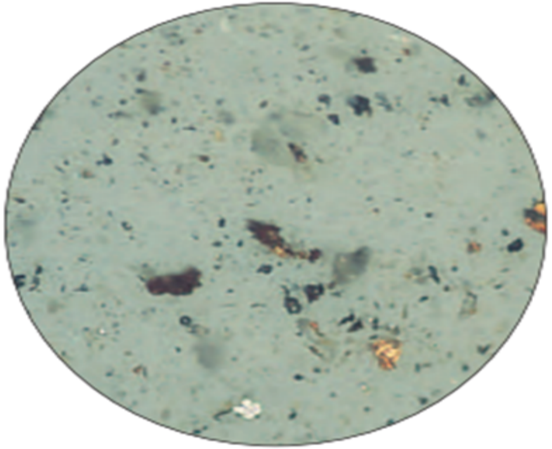

AS4059 Class 8b-f




AS4059 Class 10b-f



# Understanding Cleanliness



ISO 21 / 19 / 17 fluid (magnification 100x)

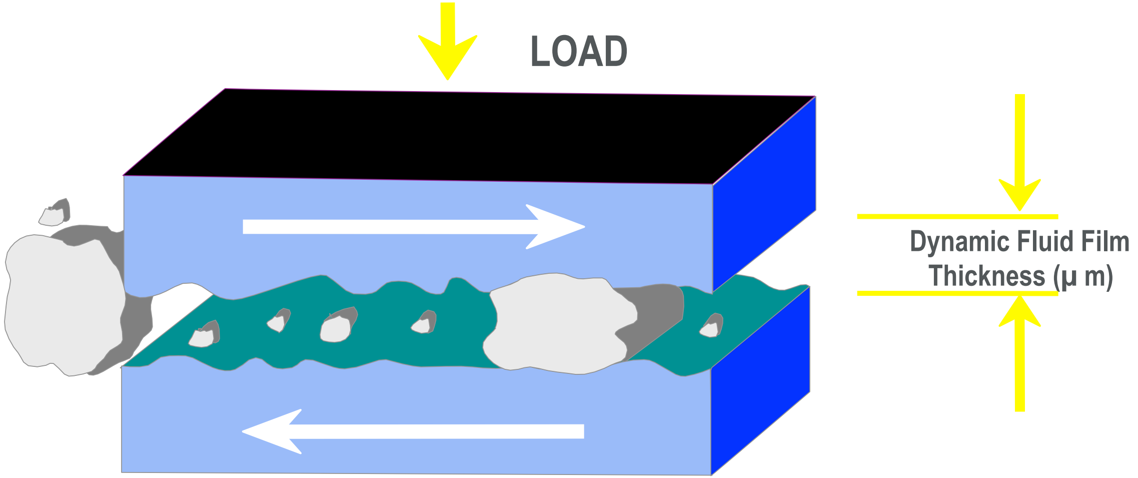
ISO 16 / 14 / 11 fluid (magnification 100x)

# Wear Mechanisms

| TYPE | PRIMARY CAUSE |
| --- | --- |
| ABRASIVE WEAR | Particles between adjacent moving surfaces |
| EROSIVE WEAR | Particles and high fluid velocity |
| ADHESIVE WEAR | Metal to Metal contact (Loss of oil film) |
| FATIGUE WEAR | Particle damaged surfaces subjected to repeated stress |
| CORROSIVE WEAR | Water or Chemical |

# Abrasive Wear

'Particles between adjacent moving surfaces'

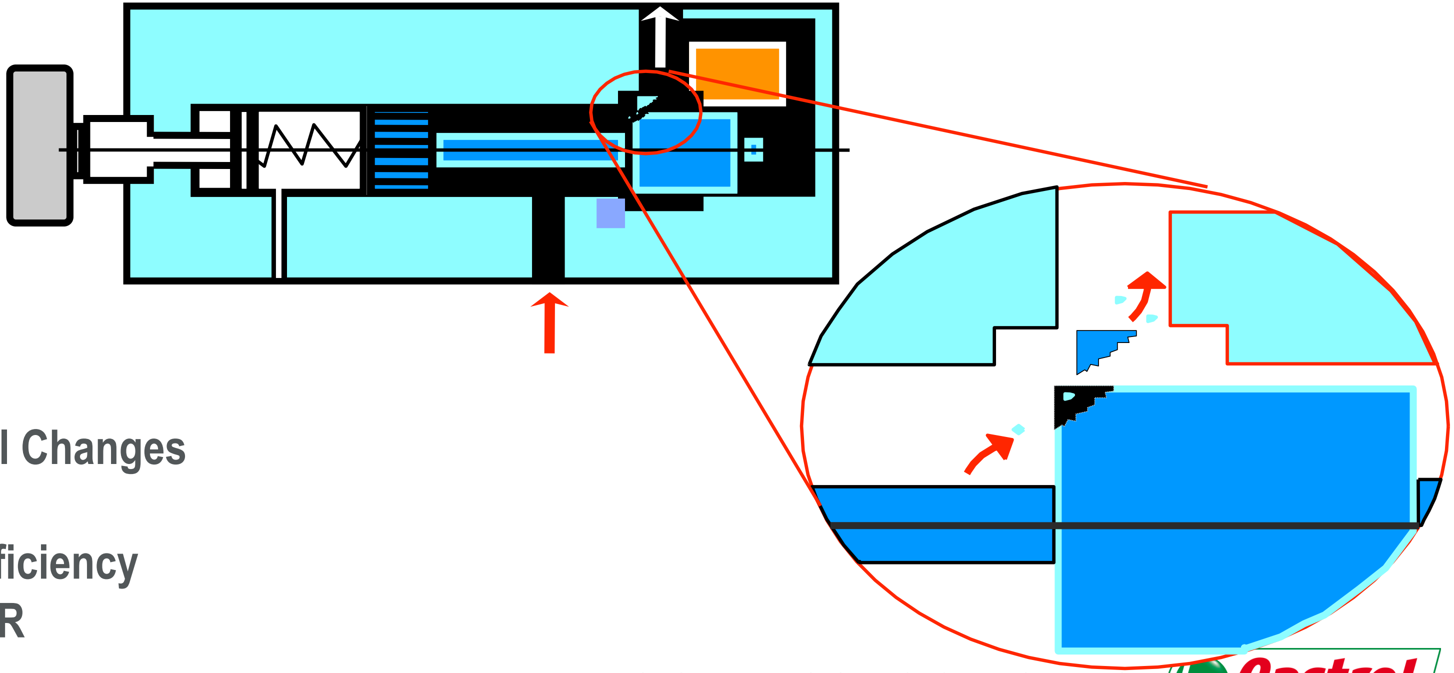



**Effects:**

- Dimensional Changes
- Leakage
- Reduced Efficiency
- MORE WEAR

# Erosive Wear

'Particles impinge on the component surface or edge and remove material due to momentum effects'



Effects:

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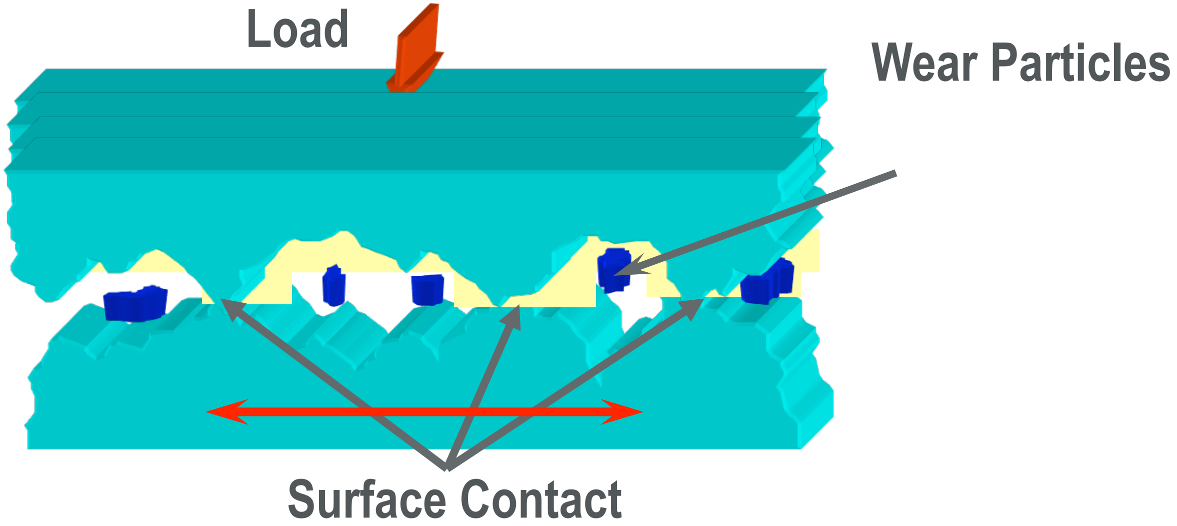
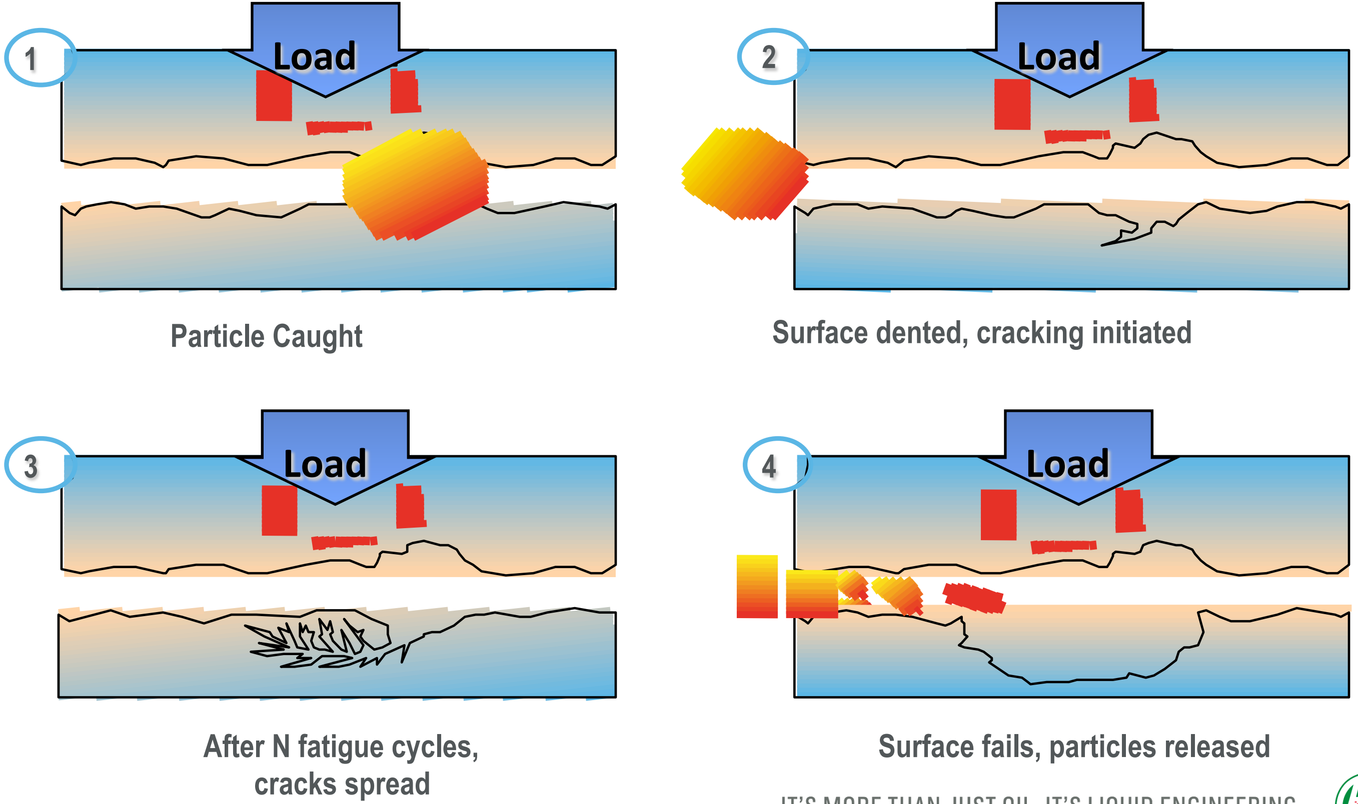
- MORE WEAR

# Adhesive Wear




Shearing of welded surface peaks leading to the detachment of loose particles

# Fatigue Wear of Surfaces (e.g. needle or roller bearing)



# Chain Reaction of Wear

- The wear process produces particles which themselves generate more debris
- Wear increases with particle hardness and the number of particles
- If particle contamination is not controlled a chain reaction of wear will result

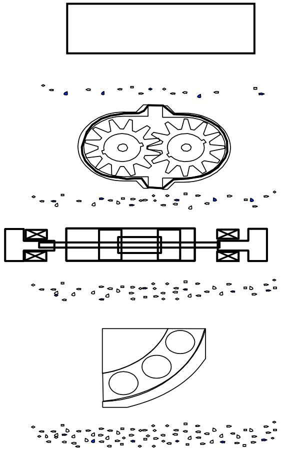
# Chain Reaction of Wear

Reservoir

Gear Pump

Solenoid Activated
Spool Valve

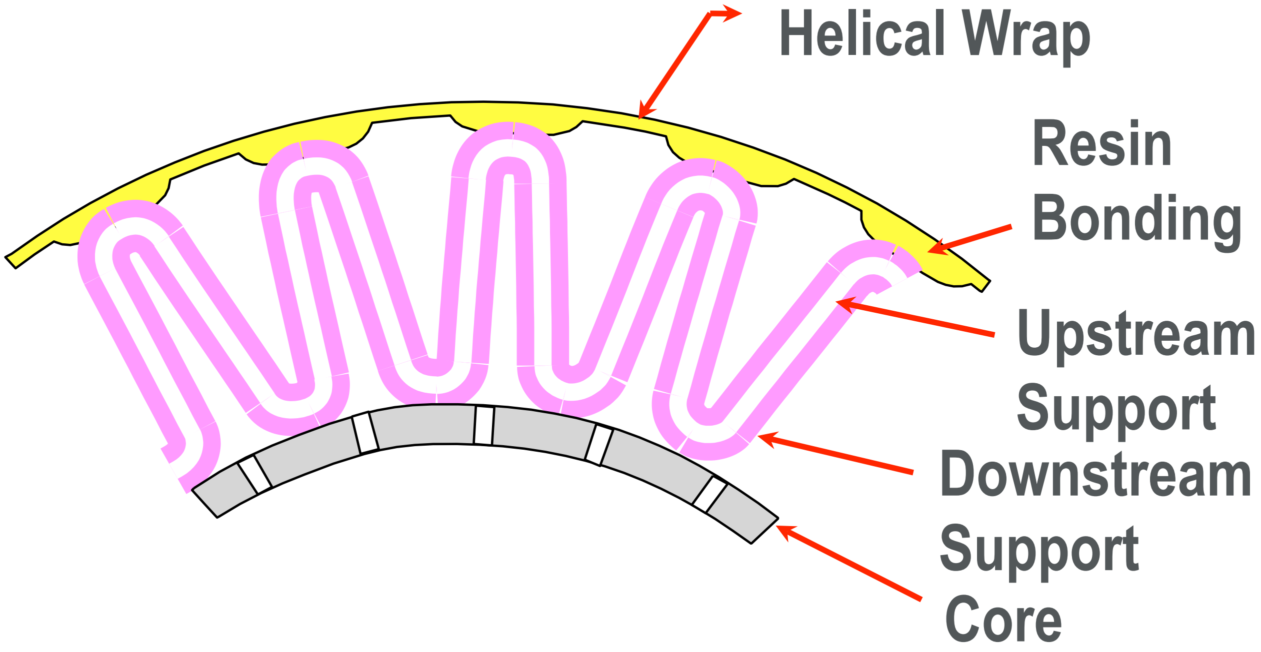
Bearings



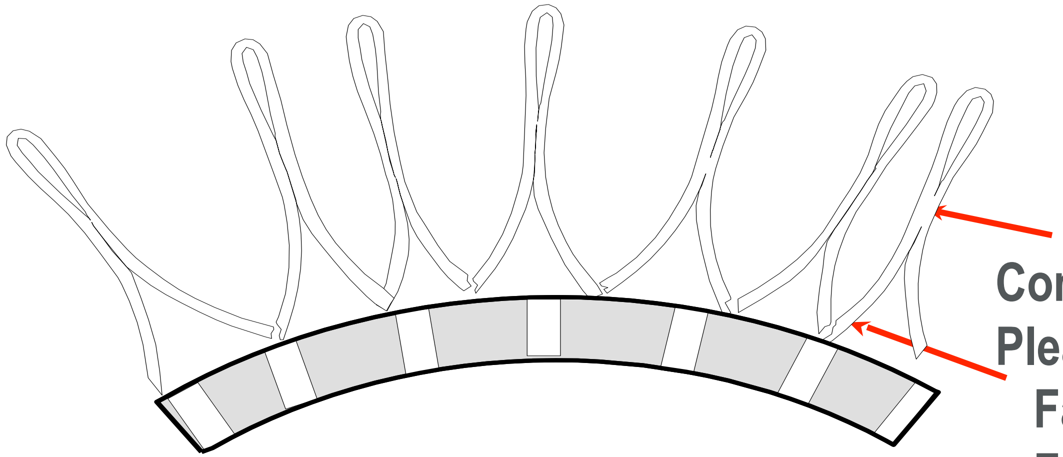
*Breaking the Chain Reaction of Wear*

High Performance Filter
Rated bx = 1000

# Filtration Media - Supported Filter Element



# Filtration Media - Unsupported Filter Element



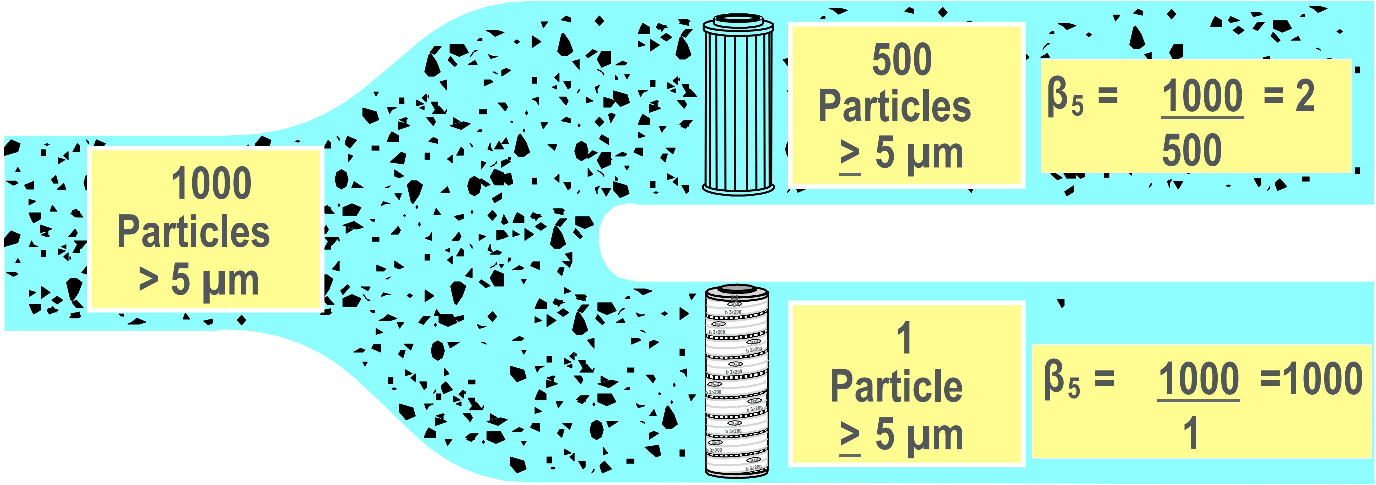

Cyclic flows, pressure and increasing differential pressure cause unsupported medium to fail and pass harmful contaminants

# Measuring filter performance

- Nominal Rating
  - An arbitrary micrometer value, based on weight percent removal, indicated by the filter manufacturer.
- Absolute Rating
  - The diameter of the largest hard spherical particle that will pass through a filter under specified test conditions. This is indication of the largest opening in the filter element.
- Filtration Ratio (ßx)
  - The ratio of the number of particles equal to or greater than a given size (x) in the influent fluid to the number of particles equal to and greater than the same size (x) in the effluent fluid

# Filtration ratio βx

$$= \frac{\text{Number of upstream particles x µm and larger}}{\text{Number of downstream particles x µm and larger}}$$




IT'S MORE THAN JUST OIL. IT'S LIQUID ENGINEERING.

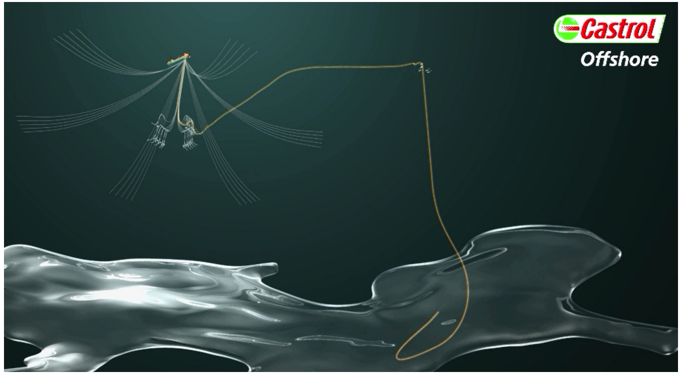
# The Importance of Filter - Efficiency Ratings

| Filter Efficiency | 1ST Pass | 2ND Pass | 3RD Pass | 4TH Pass | 5TH Pass |
|---|---|---|---|---|---|
| $\beta_5 = 2$ | 500000 | 250000 | 125000 | 67500 | 33750 |
| $\beta_5 = 10$ | 100000 | 10000 | 1000 | 100 | 10 |
| $\beta_5 = 1000$ | 1000 | 1 | | | |

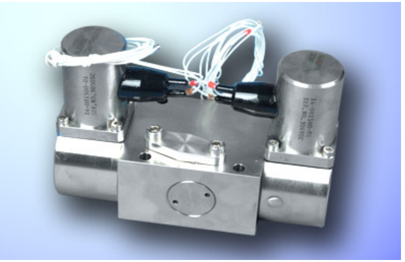
1,000,000 initial particles > 5µm

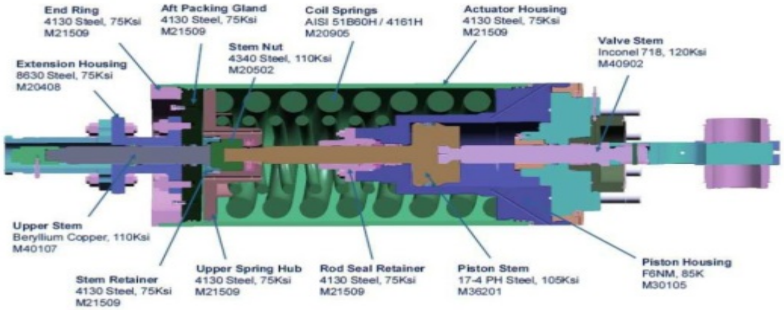
# DCV Internals

# Taking a system approach to cleanliness







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# Quick Checks Before Use

## Routine Checking

- Subsea control fluids are required to be in excellent condition for use in operation, it is more than just a NAS class.
- Take a sample and compare it against a known clean sample for visible differences (Colour, Condition)
- Check for Cleanliness
- Check for any phase separation or haziness, if unsure Photograph both against a white graduated piece of card to show clarity.
- Check pH, Transaqua HT2 should be around 8.9
- If it doesn't feel right contact your technical services engineer


[redacted]

# Questions?

# Synthetic Fluid vs Aqueous Fluid


Brayco Micronic SBF(Dyed) introduced into Sea Water


Control Fluid (Dyed) introduced into Sea Water

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