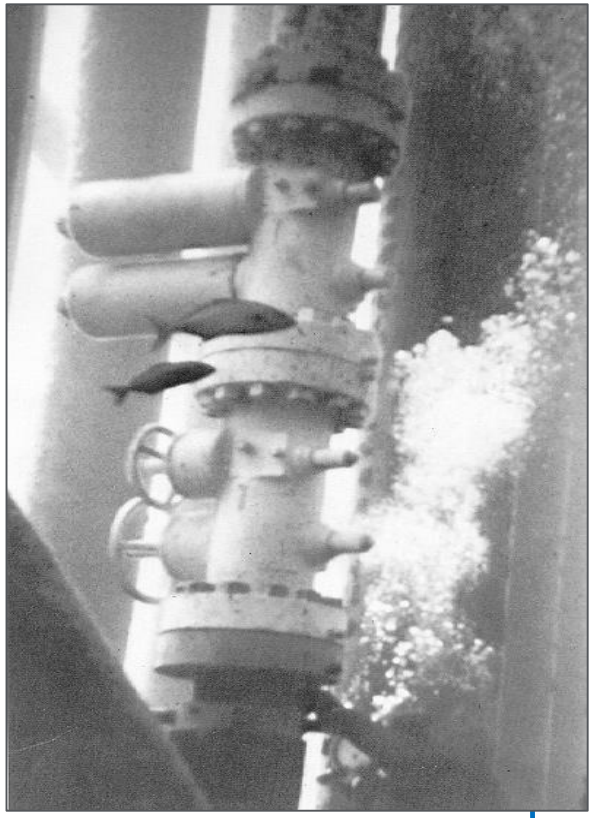
TechnipFMC

Subsea Tree Systems

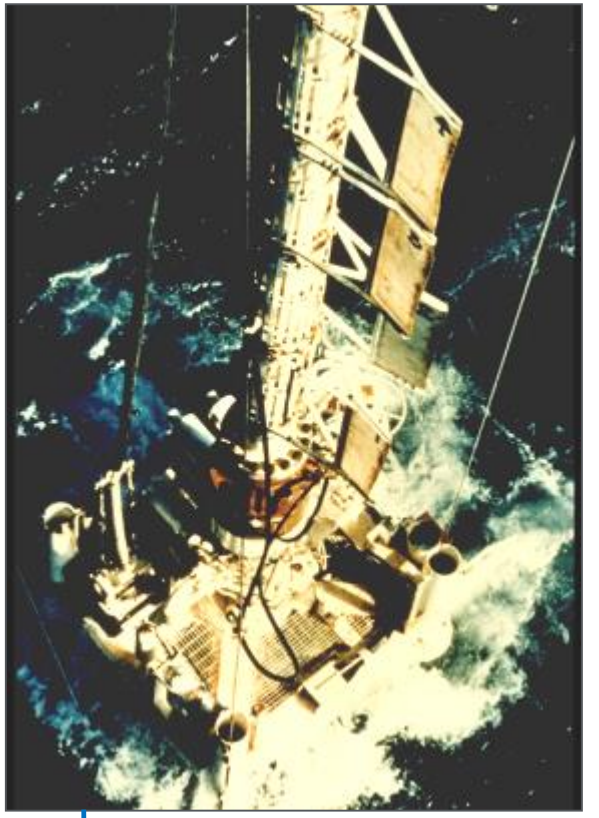
Evolution of Subsea Trees

Fire Safe “USV’s” under a Platform



Diver Intensive Mudline

Diver Assist Tree



1960’s → **1970’s** → **1980’s**

Evolution of Subsea Trees

Vertical

10K

15K

1980's

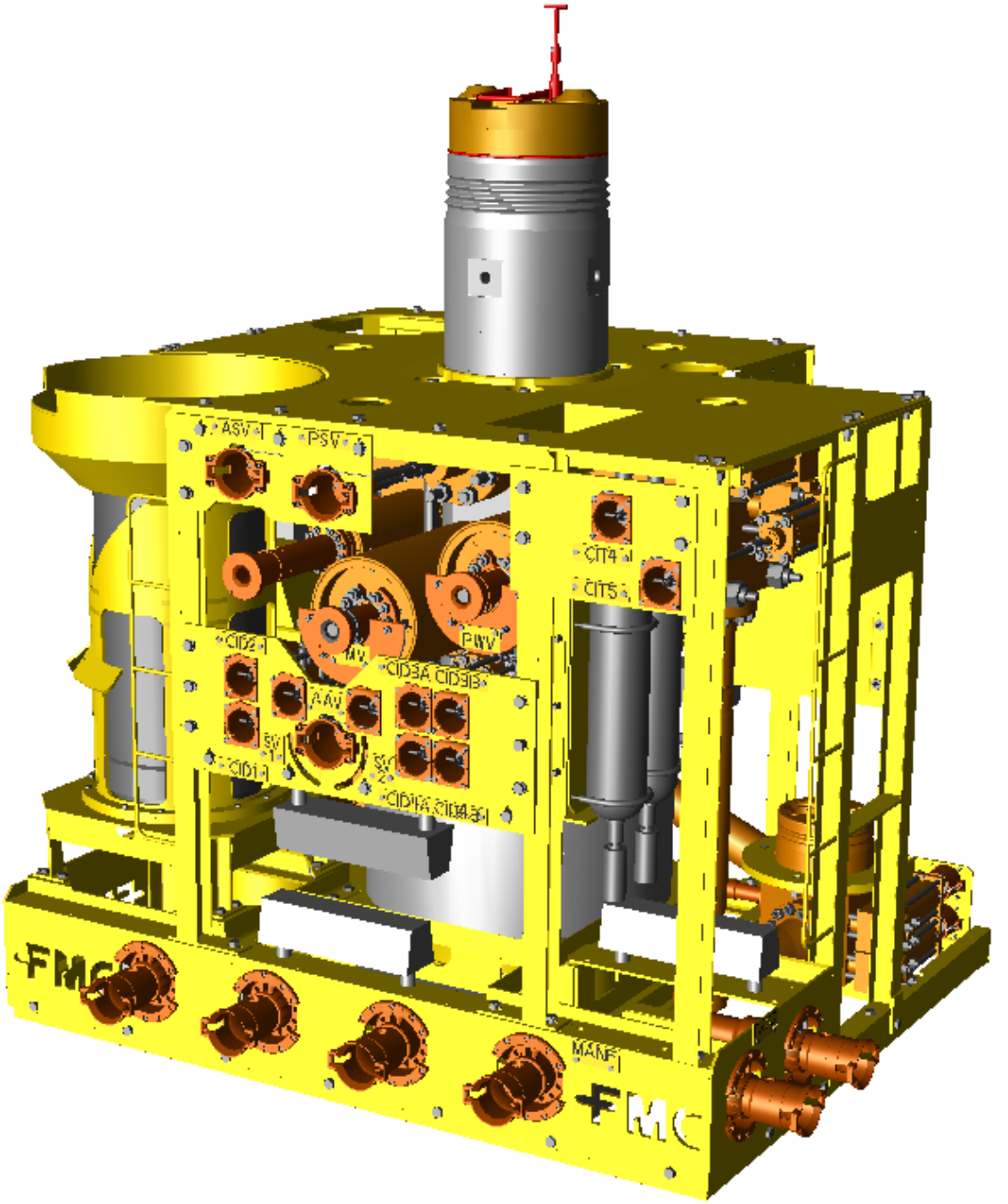
1990's

2000's

Horizontal

Main Sub assemblies for a Subse

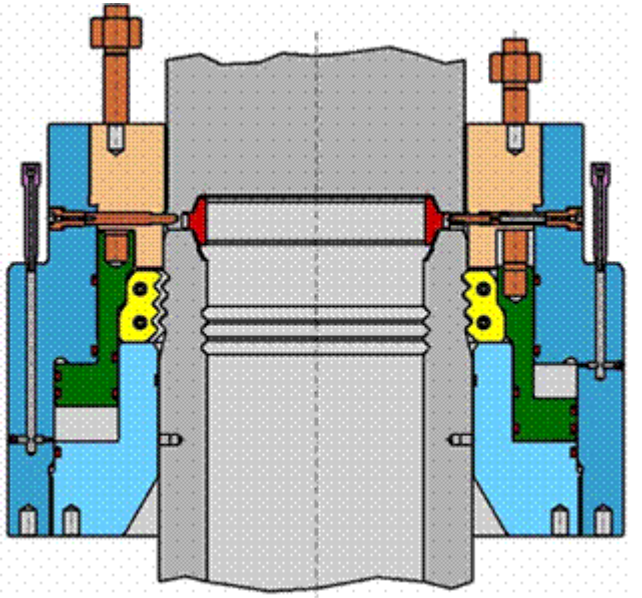
- **Torus IV 15K Connector**
- **M3000 Valves**
- **Chokes (FMC F500, Electric, Masterflo)**
- **Tubing Hanger**
- **Flow Module**
- **Tree Mounted Controls**



Torus IV 15K Connector

18-3/4” 15K Torus IV Connector

- Tree to Wellhead or Tubing Head to Wellhead
- Mates with H4 Hub profile
- Flat to flat design maintains preload once set without need for additional anti-backoff device
- Preload set at factory and adjustable
- Operating pressure = 3,000 psi
- Mechanical override system
- Seal material life tested for 20 year life in control fluid
- Rated to 5.8 MM ft-lb at 300 kips top tension plus 10,000 psi internal pressure @ 80% of ultimate capacity
- Tested to failure point for verification

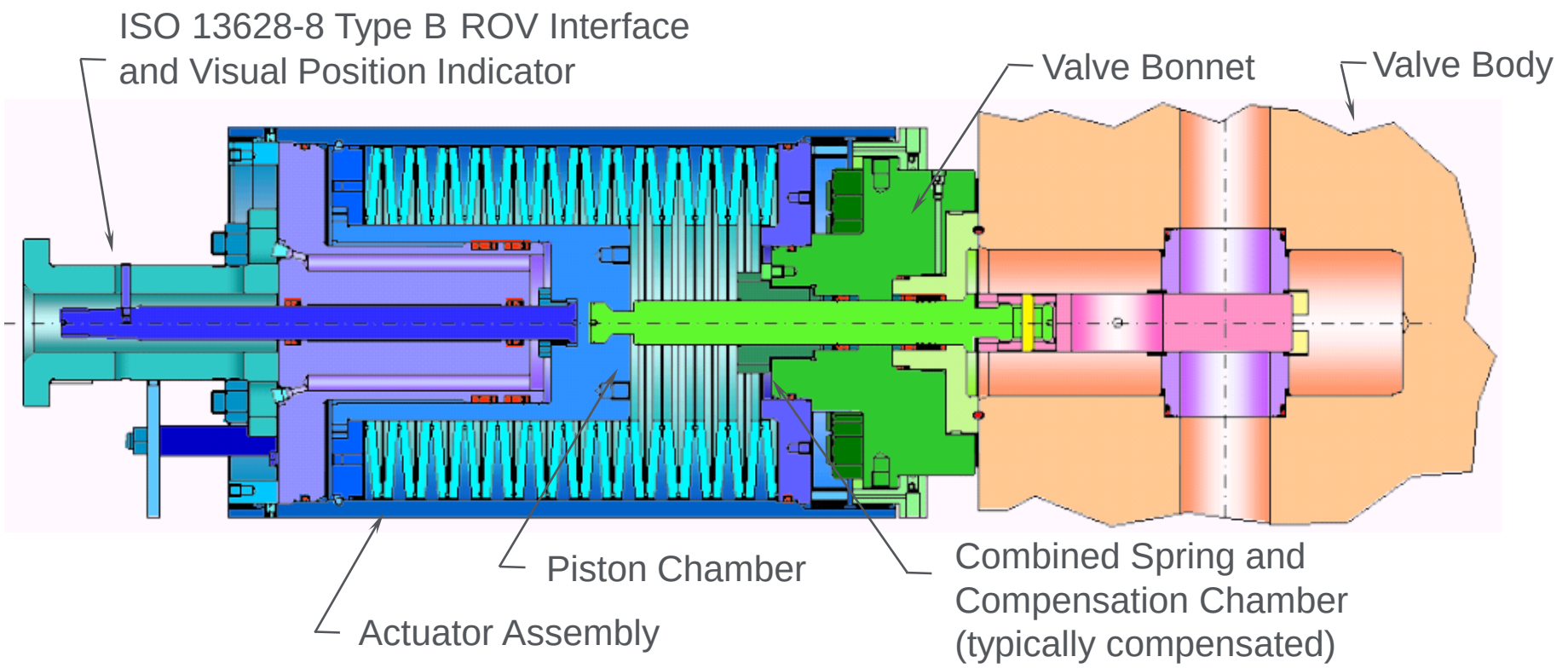


Tree Valves

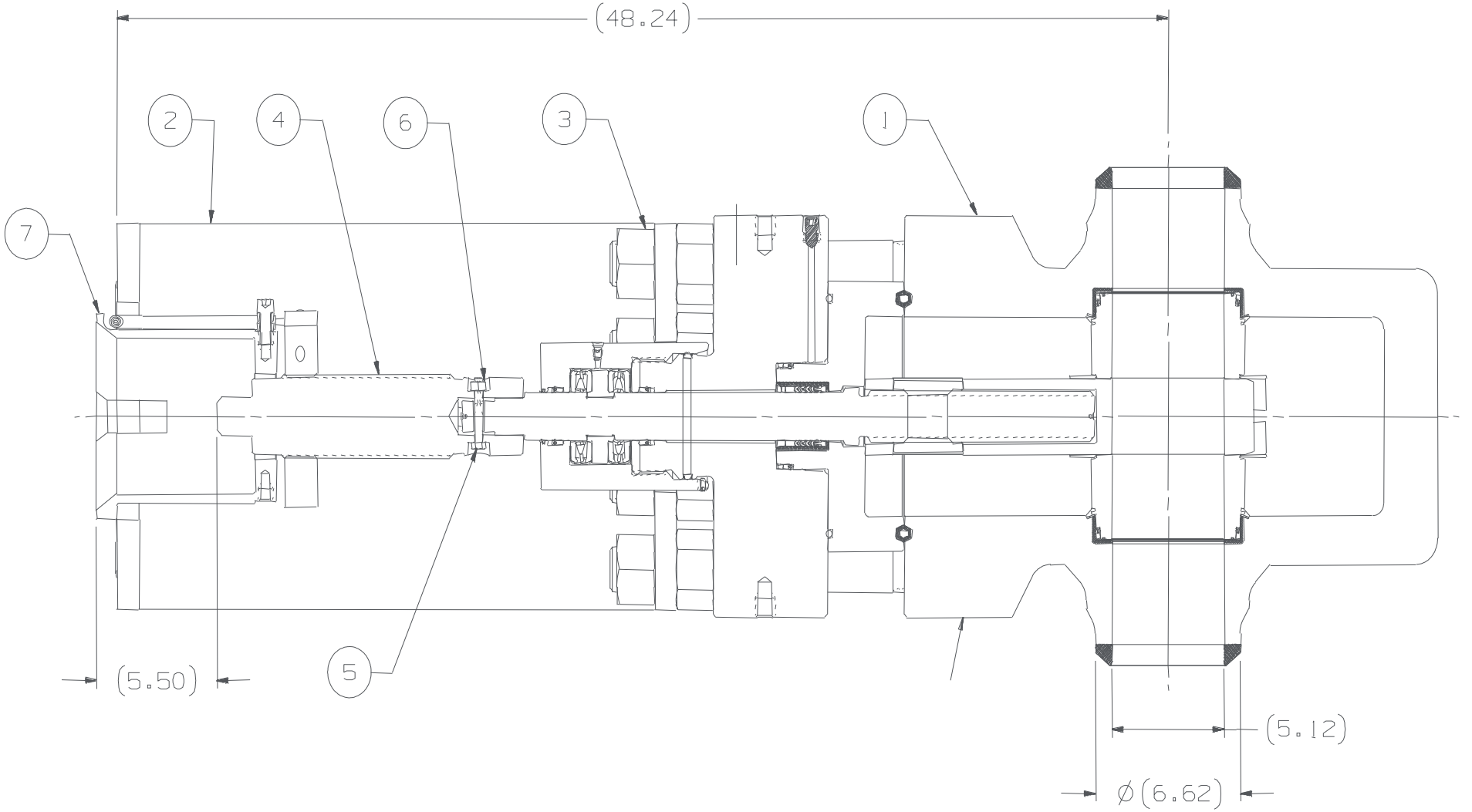
- M3000 Large Bore Gate Valve (2”, 5” and 7”)
- Chemical Injection Valves
- Valve Override Tools

M3000 Actuated Gate Valve

3000 meters WD rated (10,000 ft) and 15,000 PSI wp



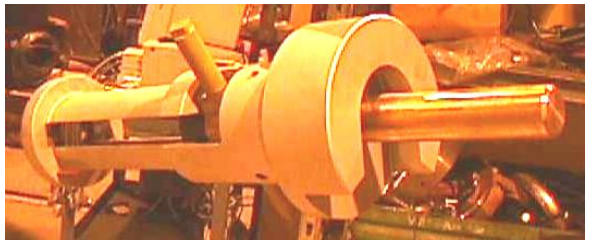
FMC GATE VALVES – M3000 Manual Valve



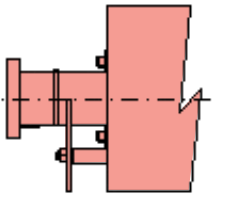
M175 Chemical injection Valve

- Actuator pressure 6,000 psi max
- 3,400 psi @ max differential pressure
- Rated to 10,000 ft of water depth
- Manual override 5 ¼ turns
  - Max operating torque 50 ft-lbs
  - Damage torque of 400 ft-lbs
- Valve is interchangeable with M140 valves
- ASY100004412 Assembly procedure
- Bi-directional metal to metal sealing fail safe close valve
- 0.5 inch bore
- 0-250 degrees F
- Rated to 17,500 psi working pressure

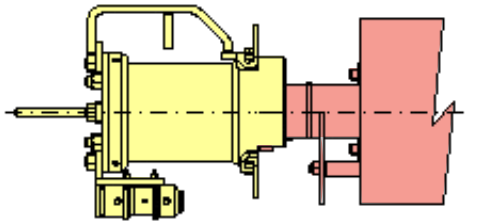
M3000 Linear Override ROV Tooling Options



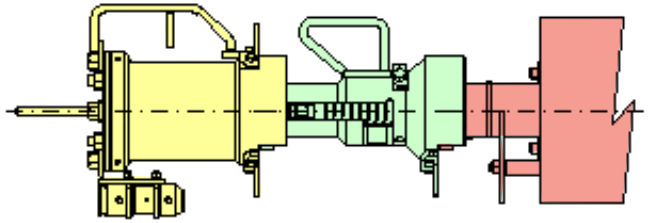
ROV Interface Flange



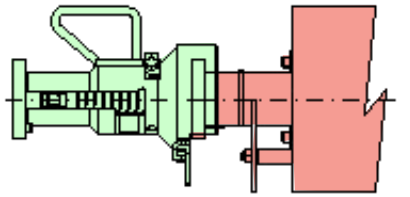
ROV Interface Flange with LOT



ROV Interface Flange
with LOLA & LOT



ROV Interface flange with LOLA



Watch animation during break

How a Gate Valve Works

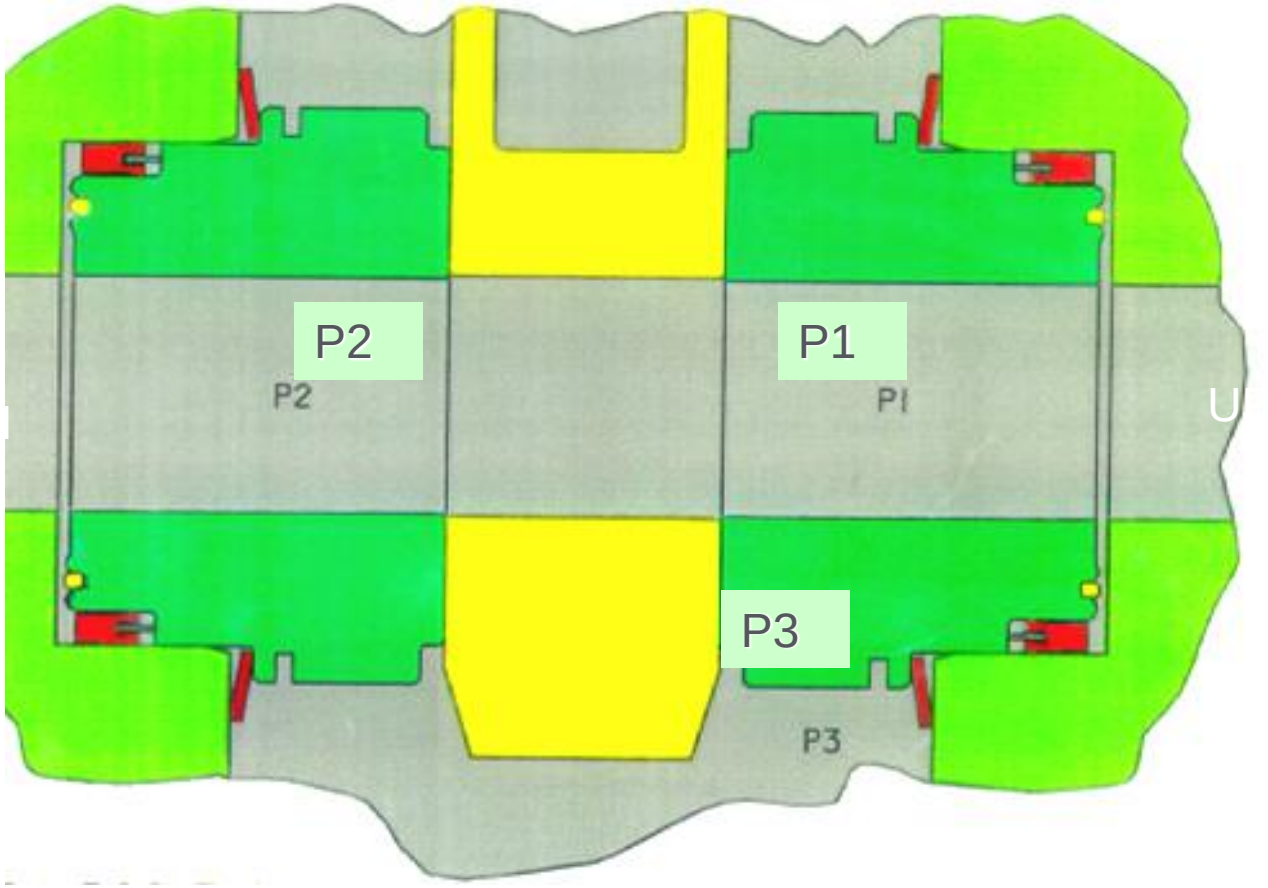
Basic Principals:

- Downstream sealing valves
- One piece or slab style gate
- Spring energized seats
- Keeps debris out of sealing areas
- Self bleeding cavity

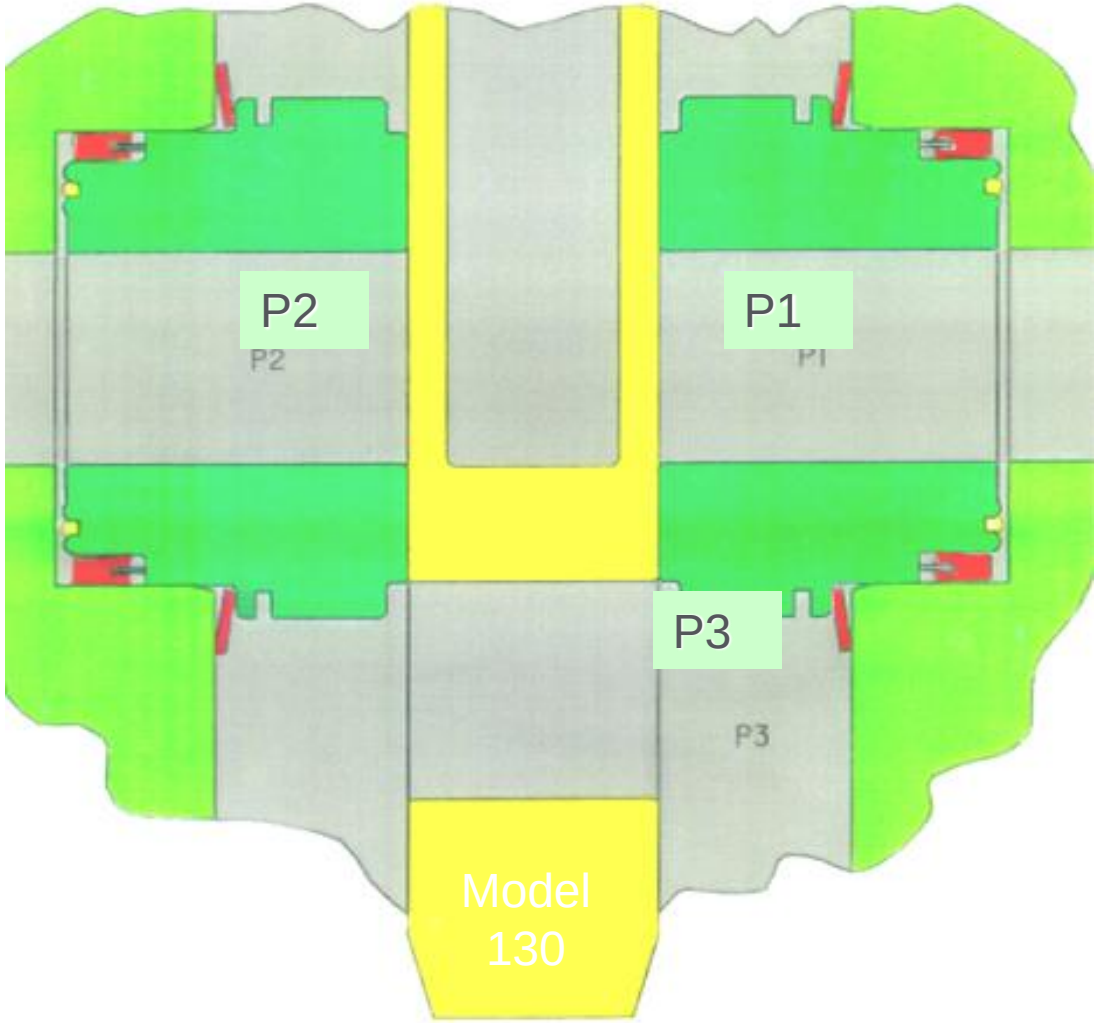
Qualification:

- PR-2 qualified and beyond
- Test valves beyond API PR-2 requirements on each sizes. Minimum cycles is 500 cycles compared to 200 cycles per API.
- FMC does not use scaling to qualify.
- Valves have been qualified in ranges from -75F to 400F (-59C to 204C)
- Zero gas leakage criteria through out testing
- Field proven and extensively tested UV stem packing

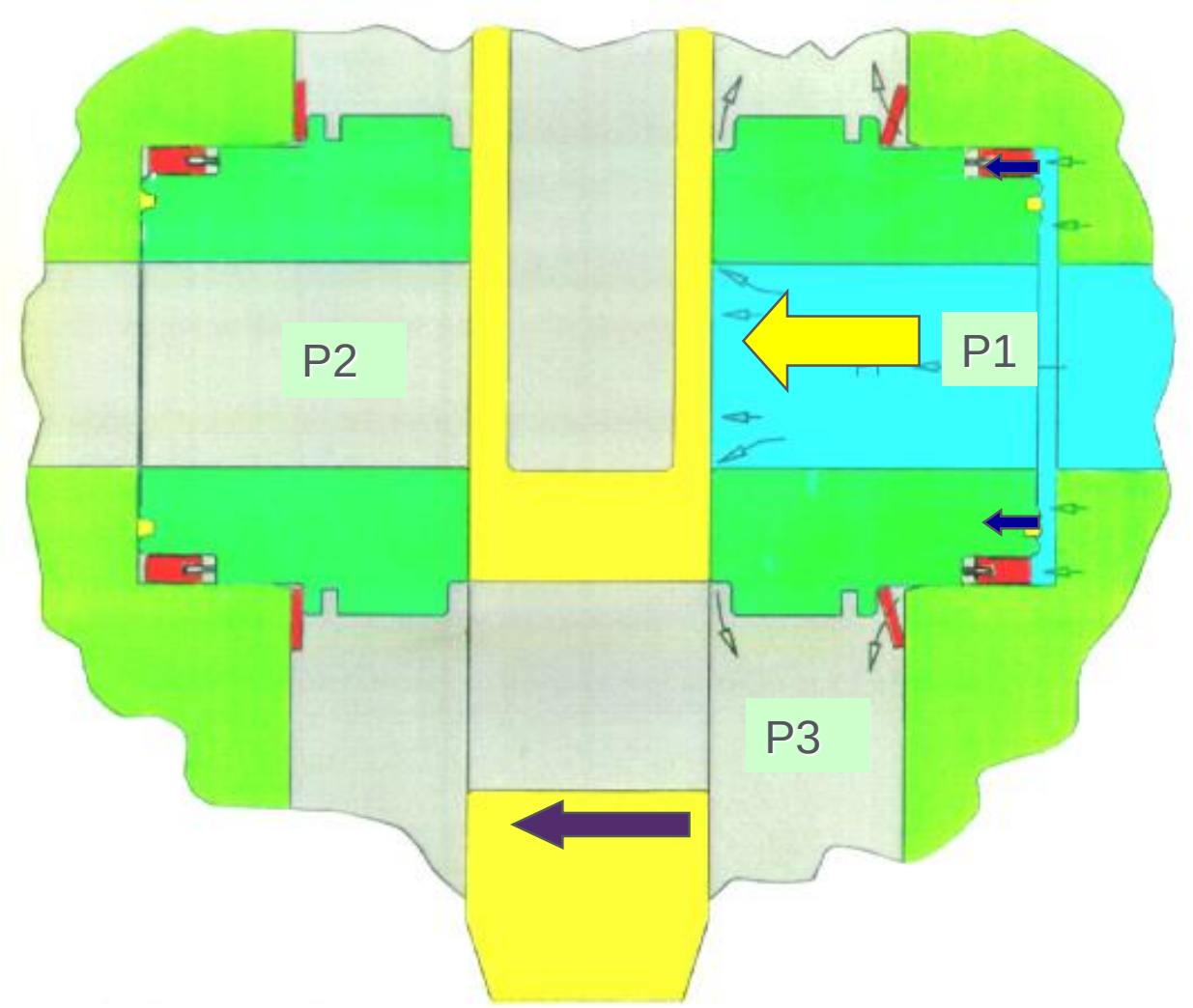
OPEN POSITION-SEQUENCE 1



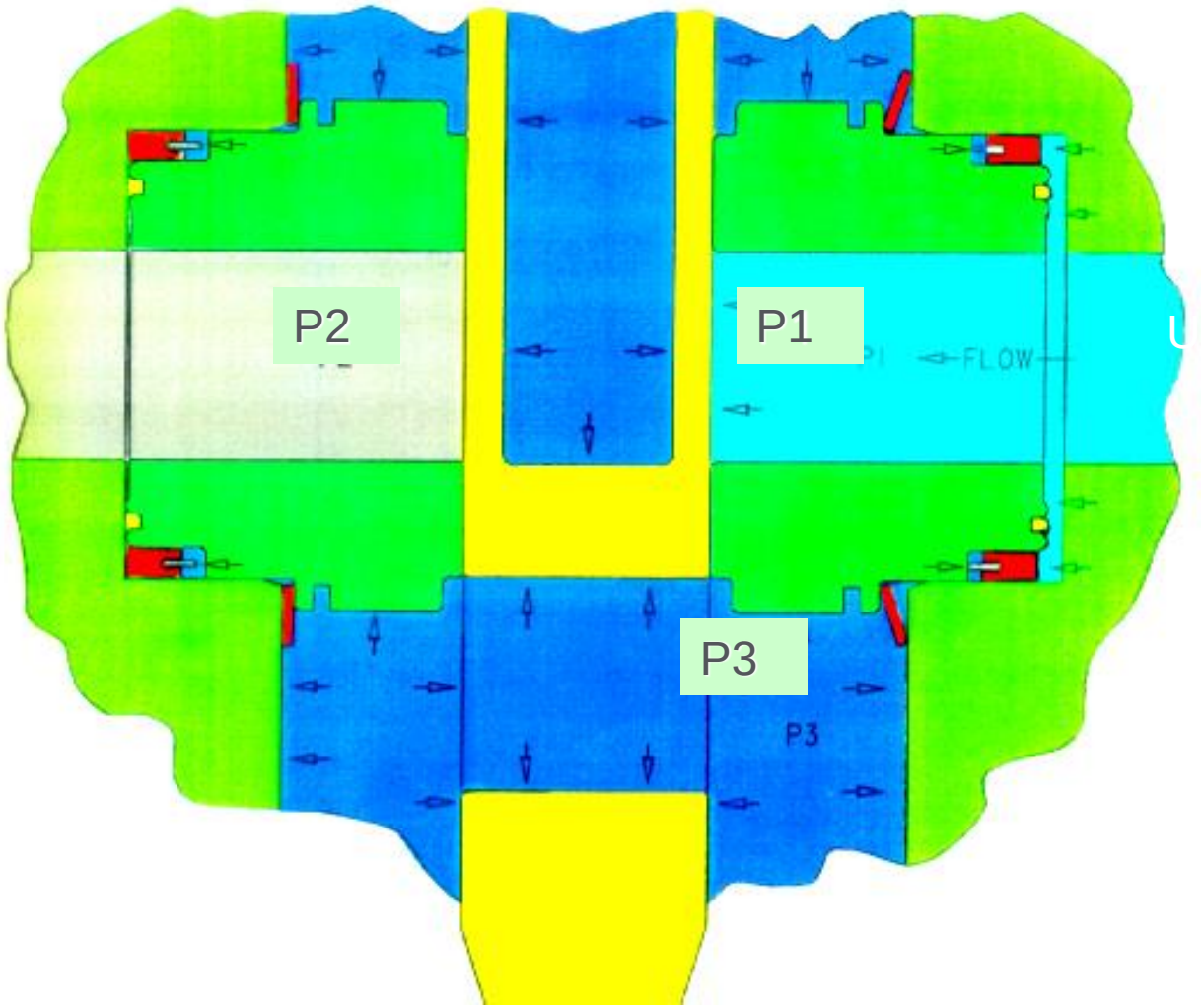
CLOSED POSITION-SEQUENCE 2



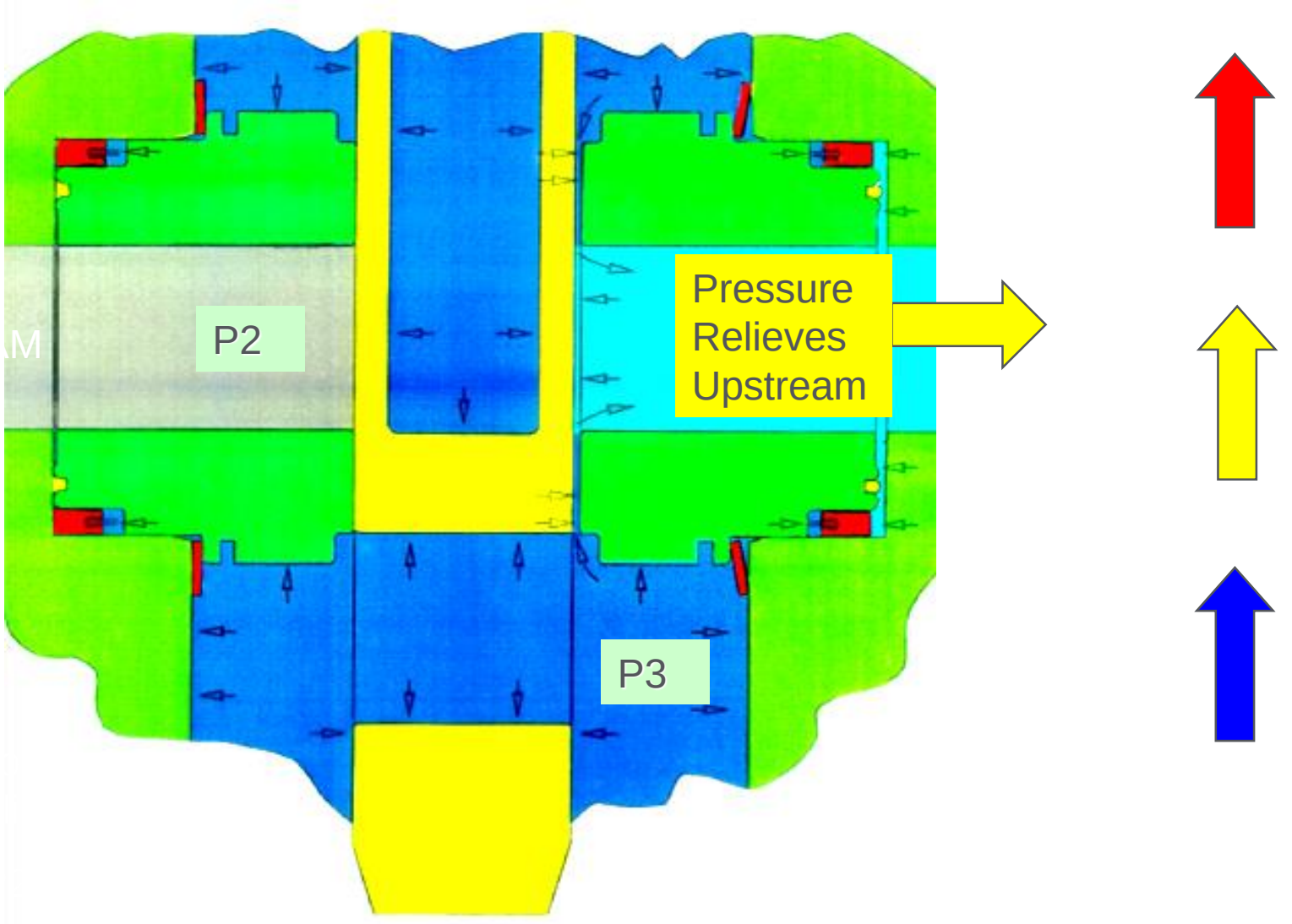
CLOSED POSITION-SEQUENCE 3



CLOSED POSITION-SEQUENCE 4



CLOSED POSITION-SEQUENCE 5



Chokes

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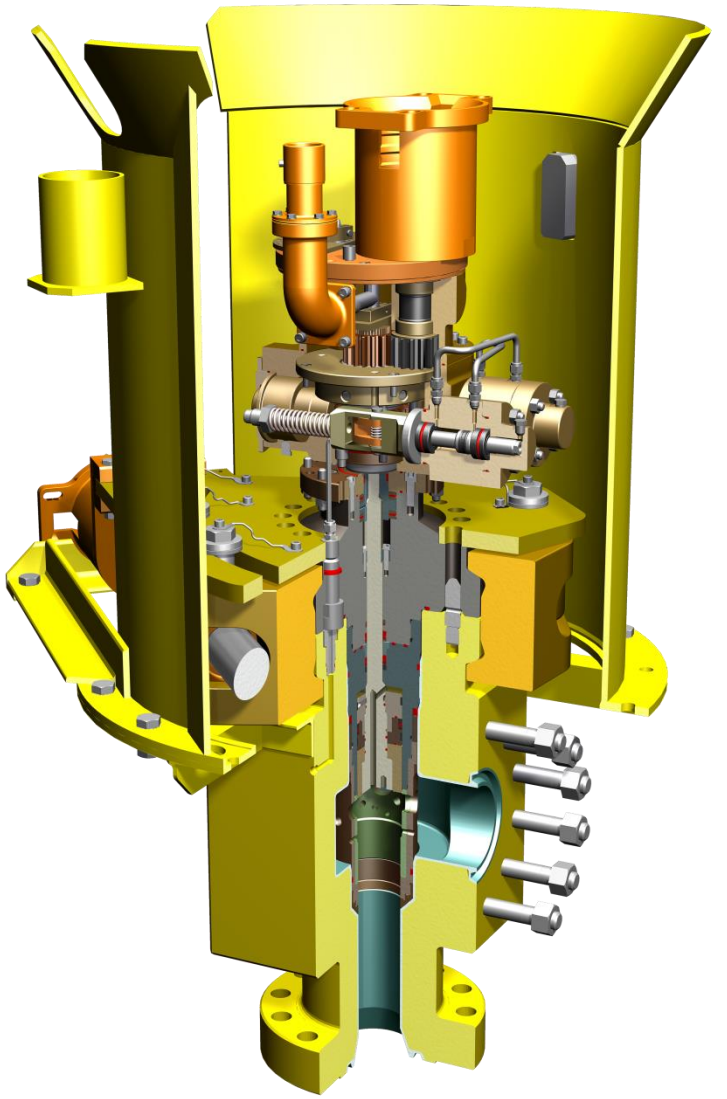
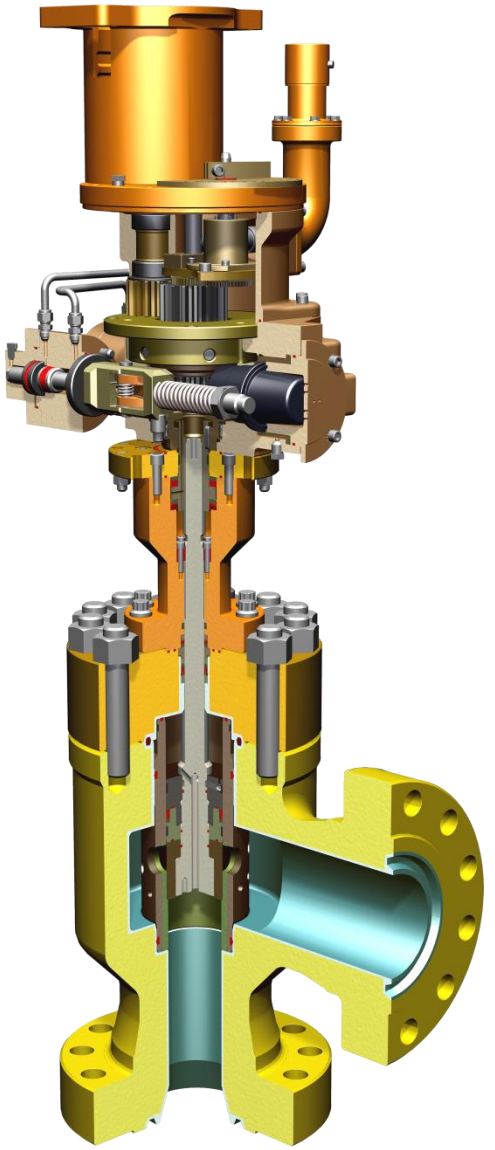
FMC Insert Retrievable Subsea Choke

- Production / Water / Gas Injection
- Typically Tree Mounted
- Two segment FMC hinged clamp connector with horizontal ROV interface
- Funnel type guide structure to interface with the choke running tool
- Funnel equipped with an ROV grab bar and electrical parking receptacle
- Choke body with two off stab type wet-mate hydraulic couplers
- Insert replaceable while body remains on Tree



FMC Non-Retrievable Subsea Choke

- Typically installed in a Flow / Choke Module
- Entire assembly replaced with Module
- Large body gallery to prevent premature body erosion
- Multi-hole tungsten carbide plug and cage with stainless steel protective jacket around the cage
- Fully guided, pressure balanced plug, rigidly attached to the stem to resist flow induced vibration damage
- Body outlet designed to accept a full tungsten carbide liner for complete wear protection



Tubing Hanger

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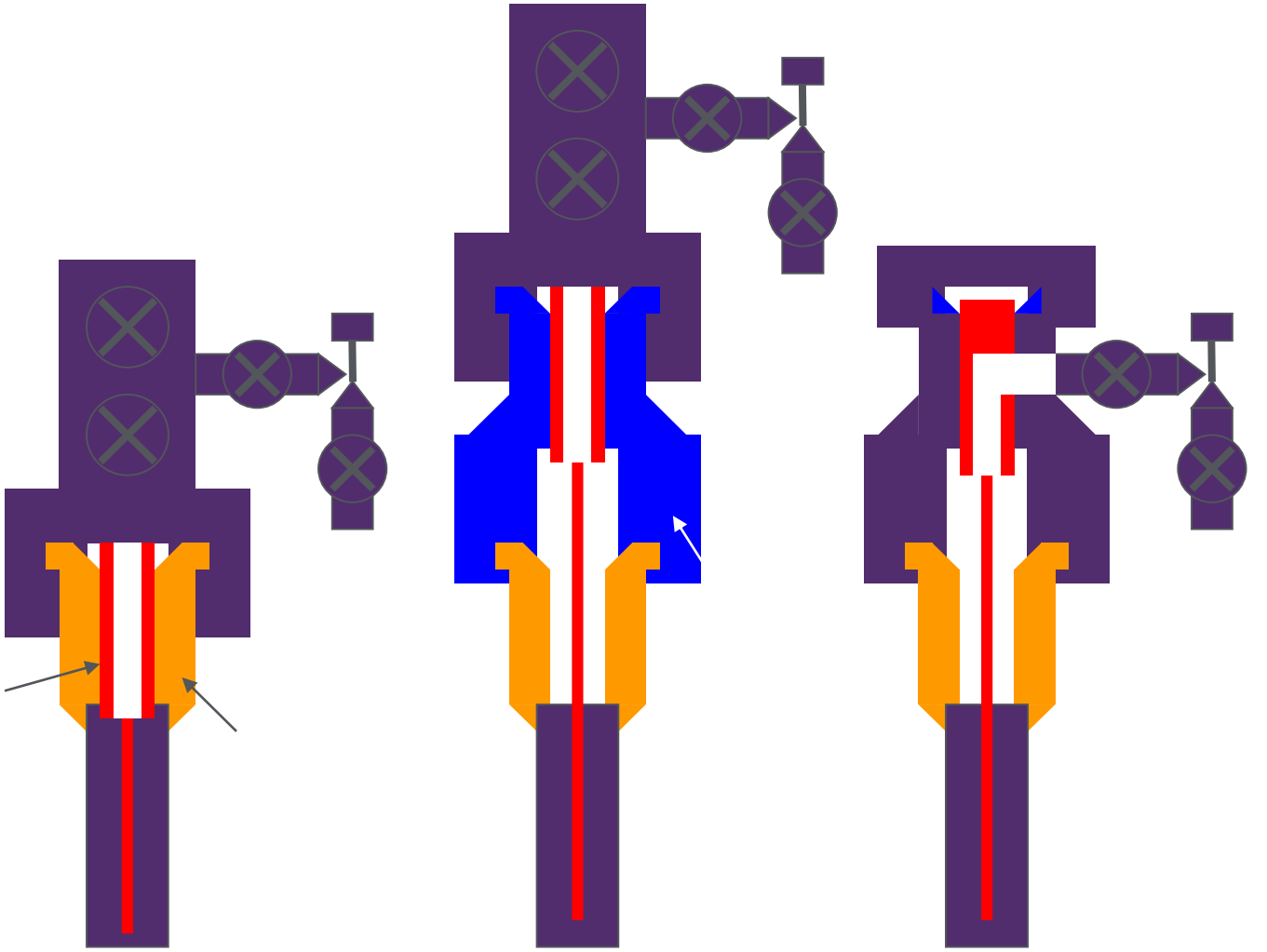
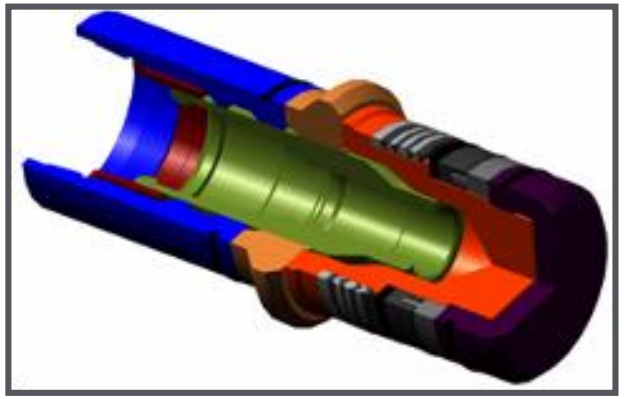
Vertical (VXT/ EVDT) & Horizontal Trees (HXT / EHXT)



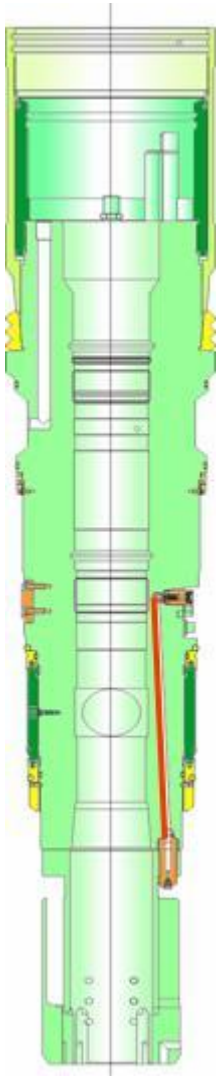
Tubing Hanger Features

- Can accommodate up to 7” completion tubing size
- Provides hang load capacity of 1,000,000 lbs
- Common components between 10K & 15K systems
- Is passively orientated in tree during installation by key/helix arrangement
- Features FMC SBMS-II metals seals
- Features two Halliburton SSP crown plugs with FMC SBMS-II metal seals
- Is run on hydraulic THRT with pressure balanced pistons
- Enables running up to 9 downhole lines (hydraulic + 3 max electric)
- Allows continuous monitoring of 5 downhole lines during installation

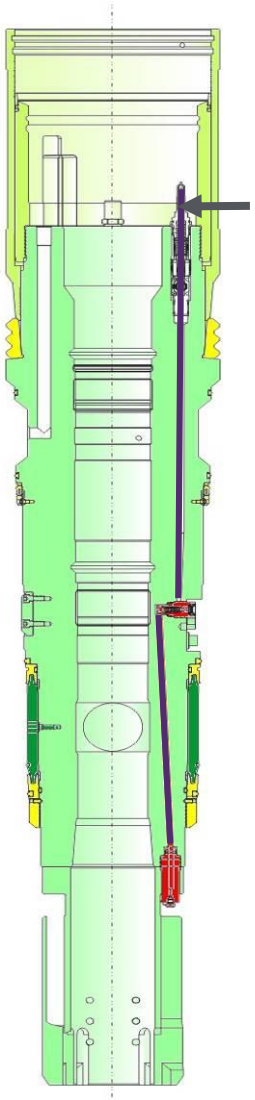


Crown Plugs

Downhole Control / Chemical Line Access through Tubing Hanger



Standard Side Access



Optional top access through “poppet gate valve” allows monitoring of downhole lines while running TH

Flow Modules

Retrievable Flow Module

Wide range of configuration options satisfies life-of-field functionality requirements

"Future proofs" the system

Functionality can be modified without pulling tree

Add a flow meter or booster pump

Perform a scale squeeze

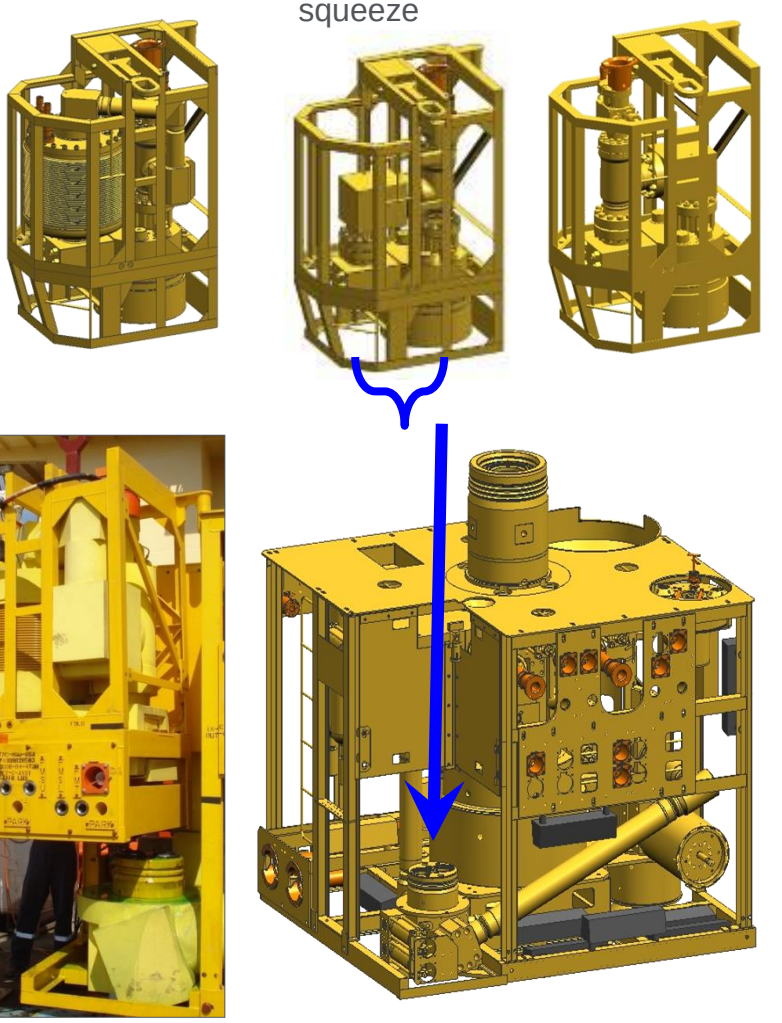
Convert a producer into an injector

Full 5" or 7" inlet and outlet in multi-bore hub; no flow restriction

Production flow module with multiphase flow meter and choke

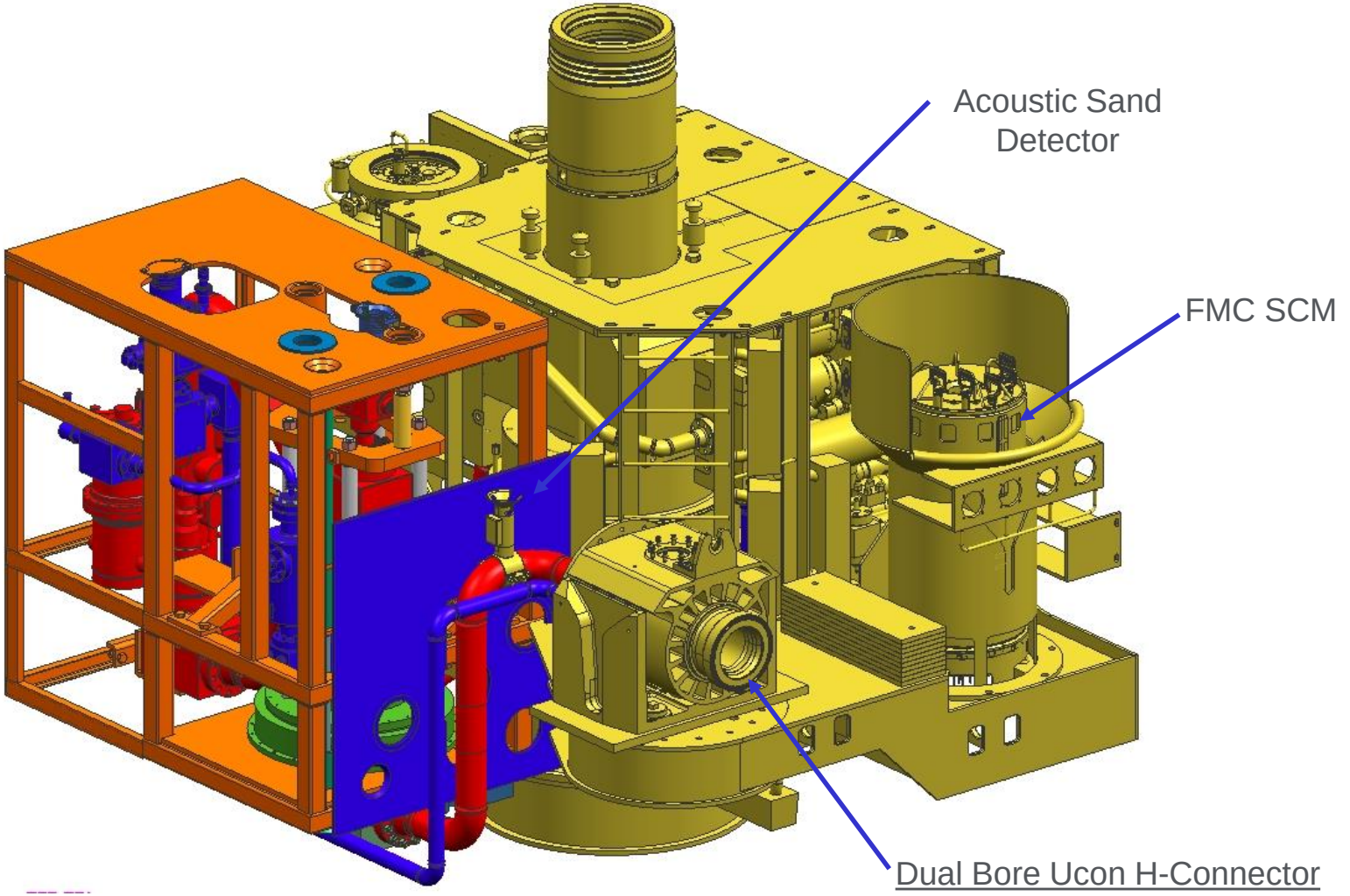
Intervention Module e.g. Scale squeeze

Injection flow module with just choke



Tree assembly

Production Trees with Flow Module



Tree Types

Horizontal Trees (HXT & EHXT)
Vertical Trees (VXT, EVDT & Tubing Heads)

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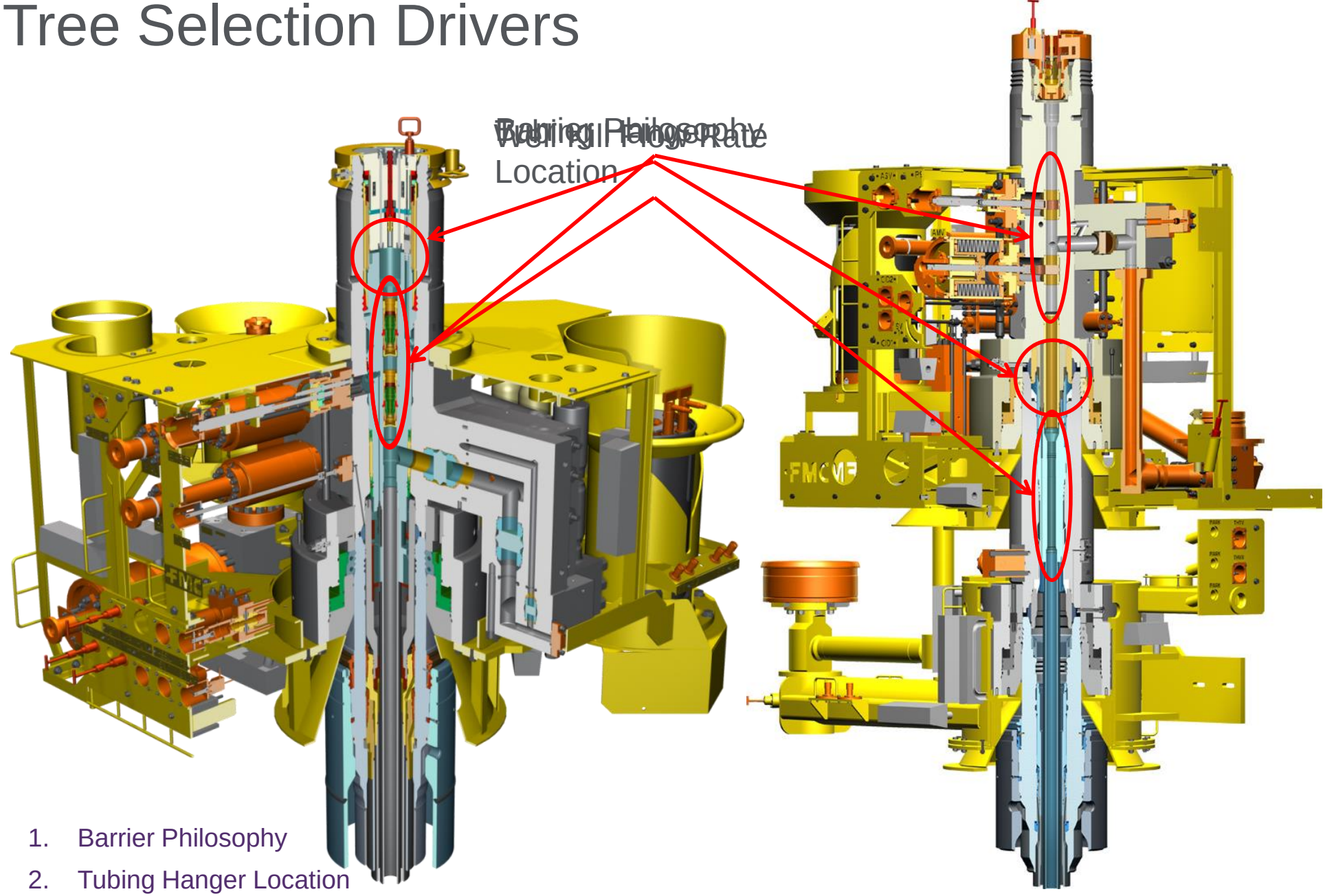
Tree Selection Drivers

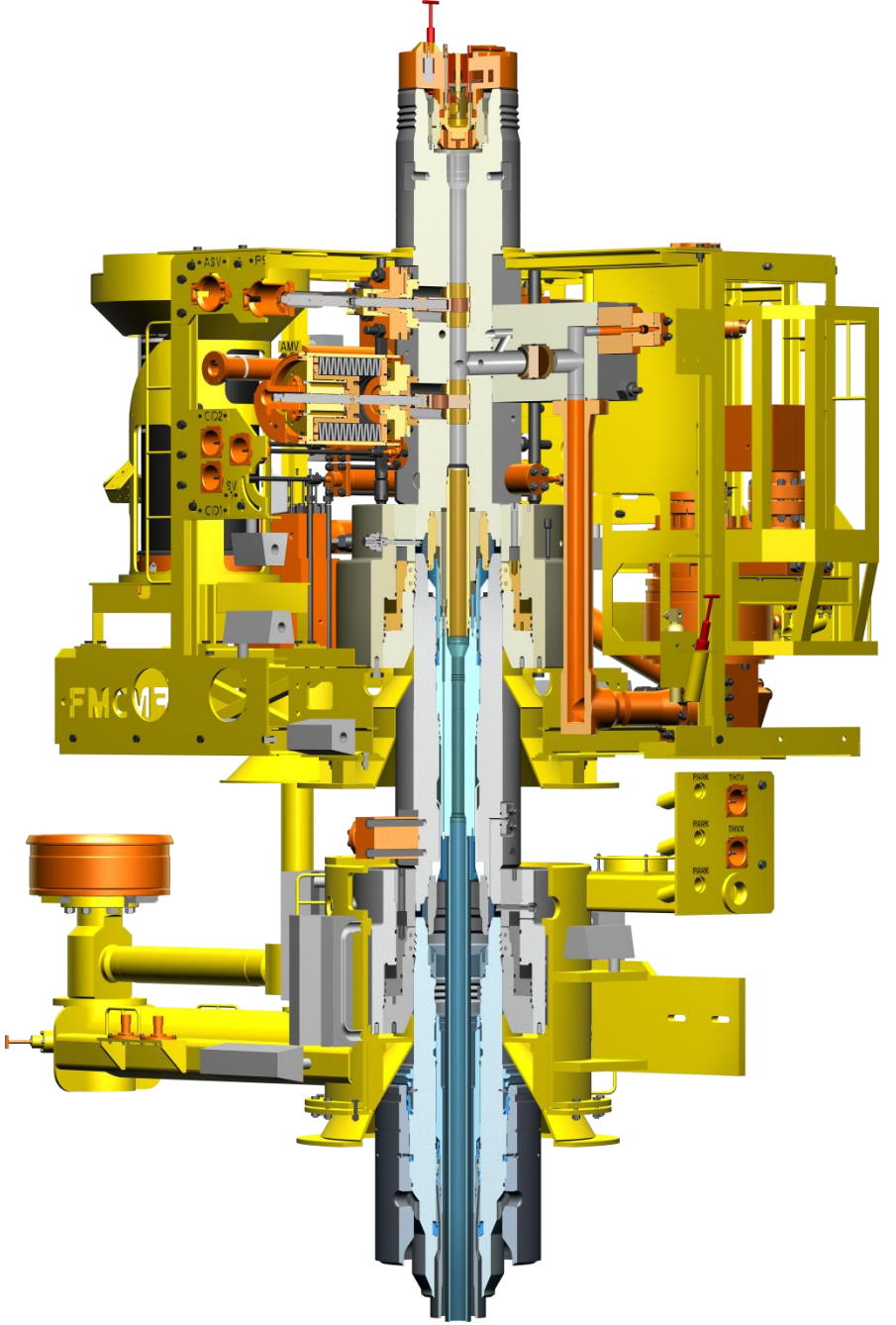


1. Barrier Philosophy
2. Tubing Hanger Location
3. Well Kill Flow Rate

Vertical vs. Horizontal

Vertical

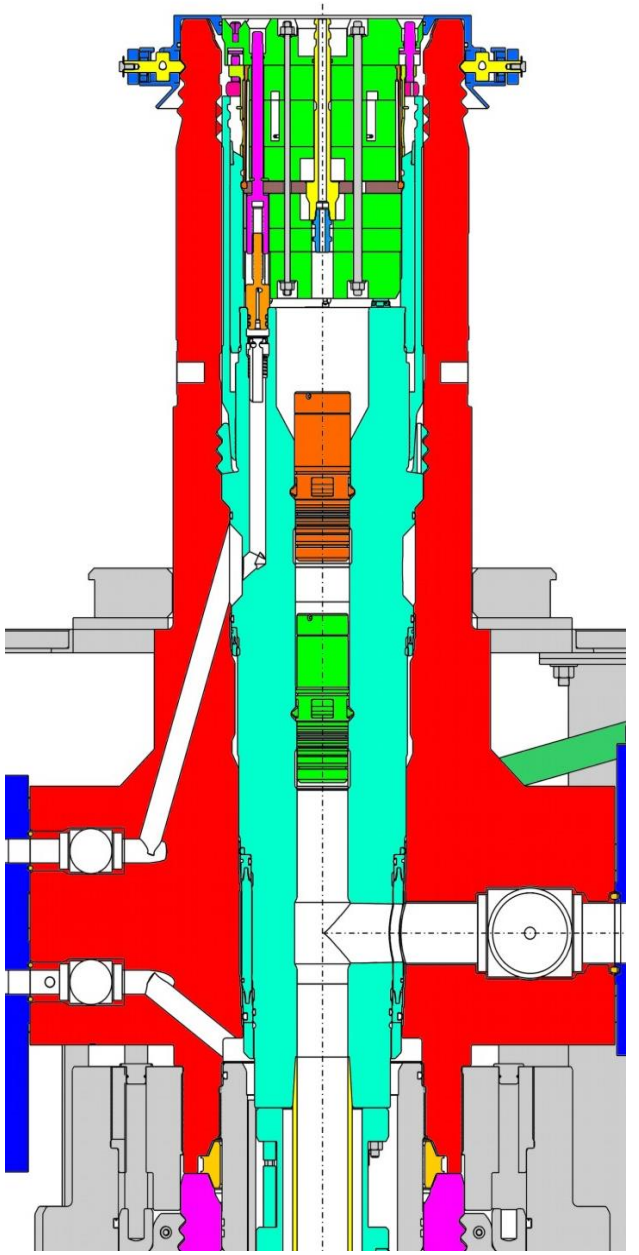
- Tree valves stacked vertically on top of tubing hanger
- Downhole functions provided through the bottom of the tree to the top of the tubing hanger through hydraulic / electric connections
- Production tubing and tubing hanger installed prior to Vertical Tree



Vertical vs. Horizontal

Horizontal

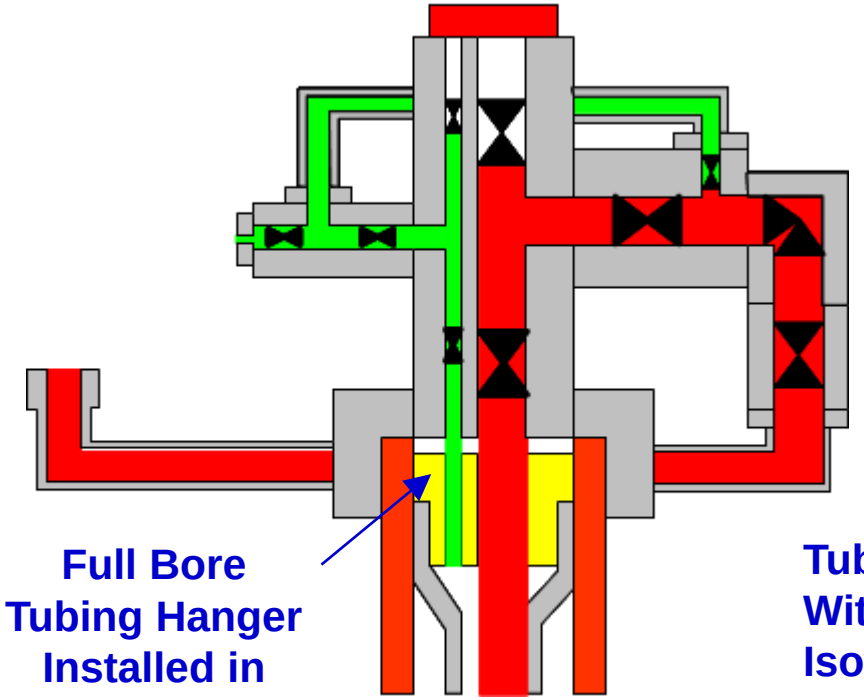
- Production fluid flows from side of tubing hanger through production flowline with horizontal valve configuration
- Downhole functions provided through radial penetrators on the side of the tubing hanger
- Tree installed prior to production tubing and tubing hanger



Enhance Vertical Trees

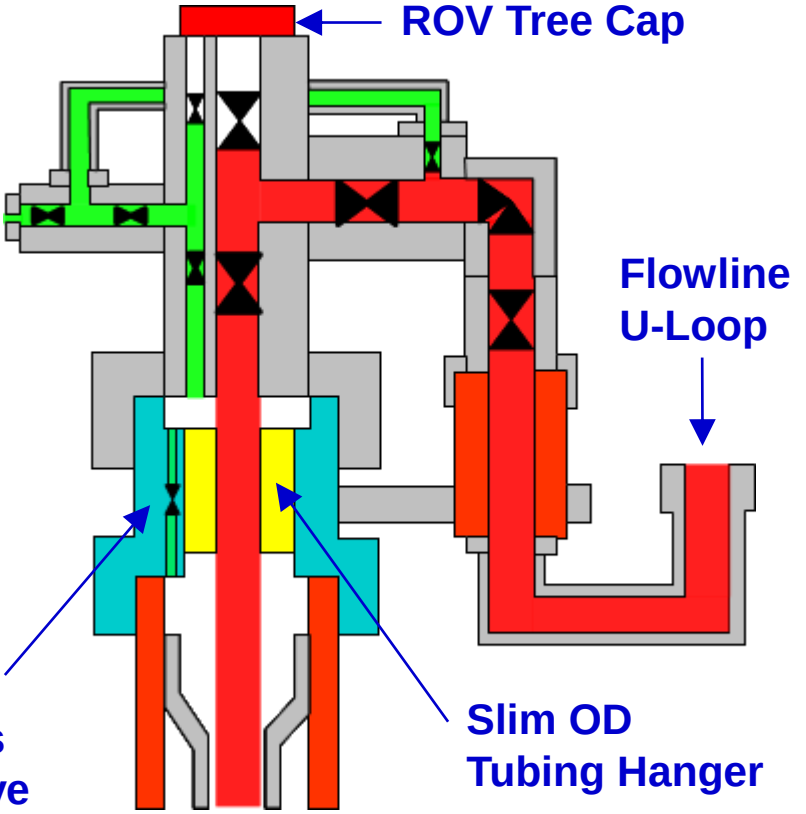
Enhanced Vertical Deep Water Tree
Subsea 2.0 Tree

EVXT-DB and EVXT-MB



Full Bore
Tubing Hanger
Installed in
Wellhead

EVXT-DB
(WEL OTS, bp Angola,)



EVXT-MB

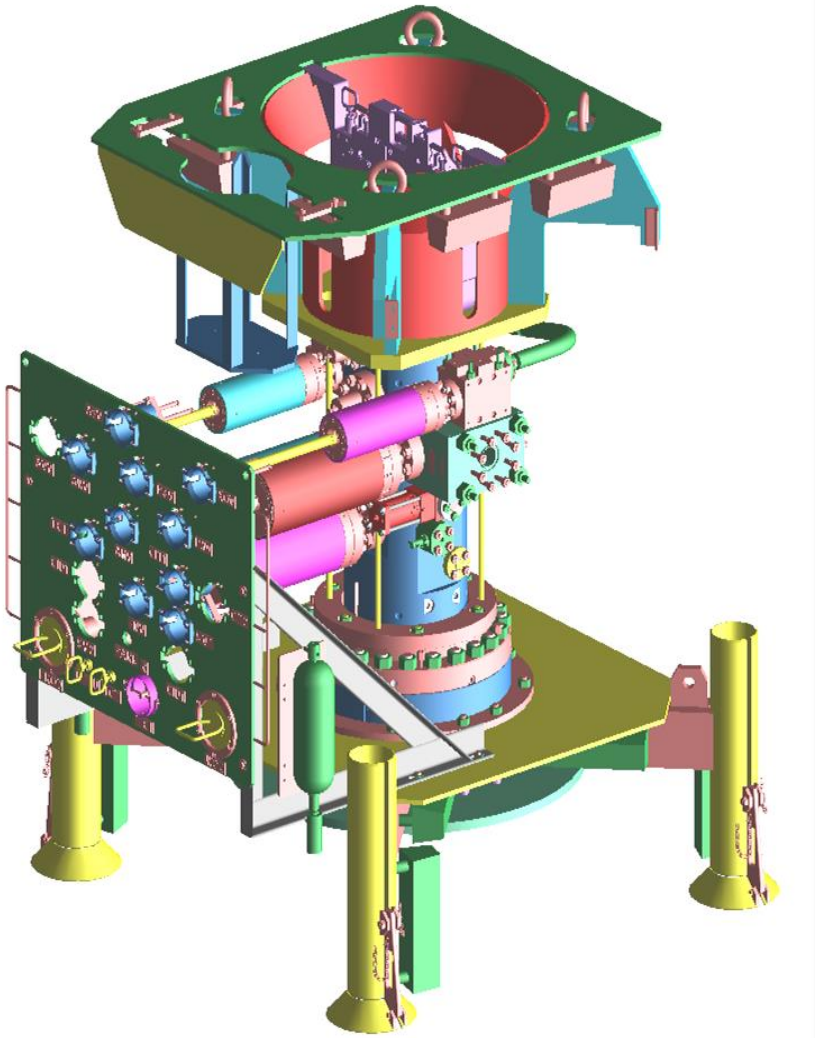
(Shell USA)

Vertical GL Tree w/o Tubing Head

Base design system:

Guideline (GL)

ROV or Diver intervention methodology



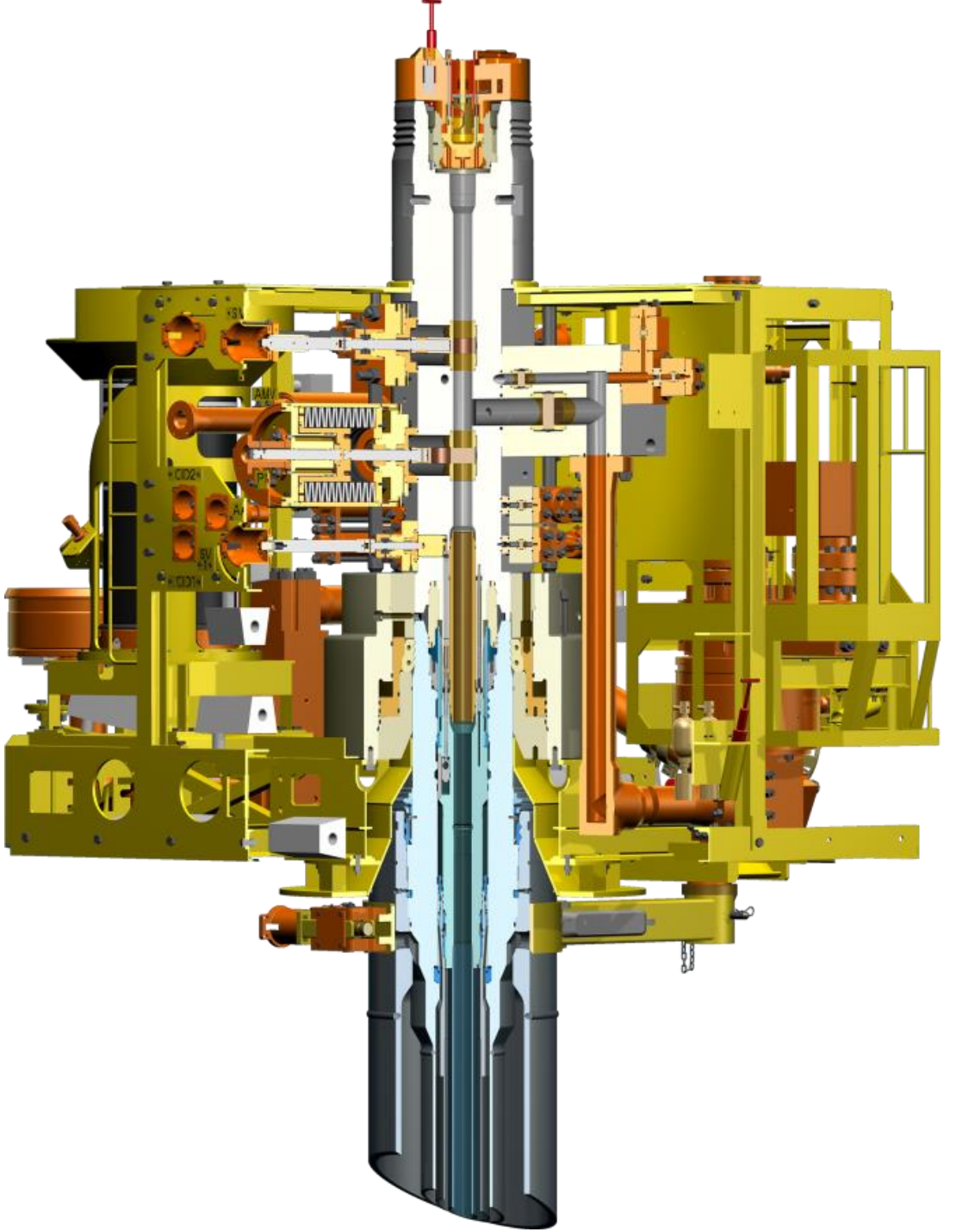
EVDT On Wellhead

Flow Module

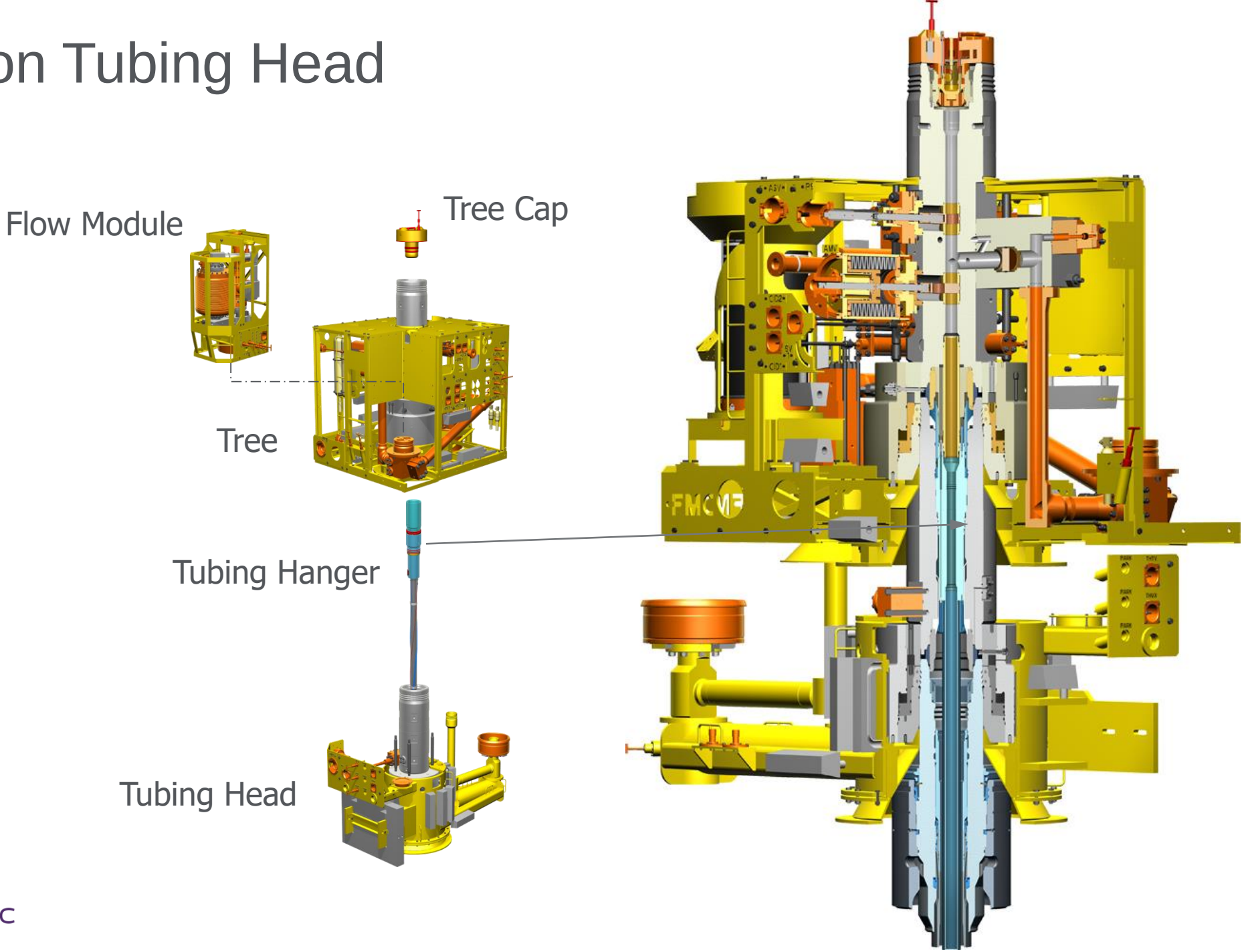
Tree Cap

Tree Assembly

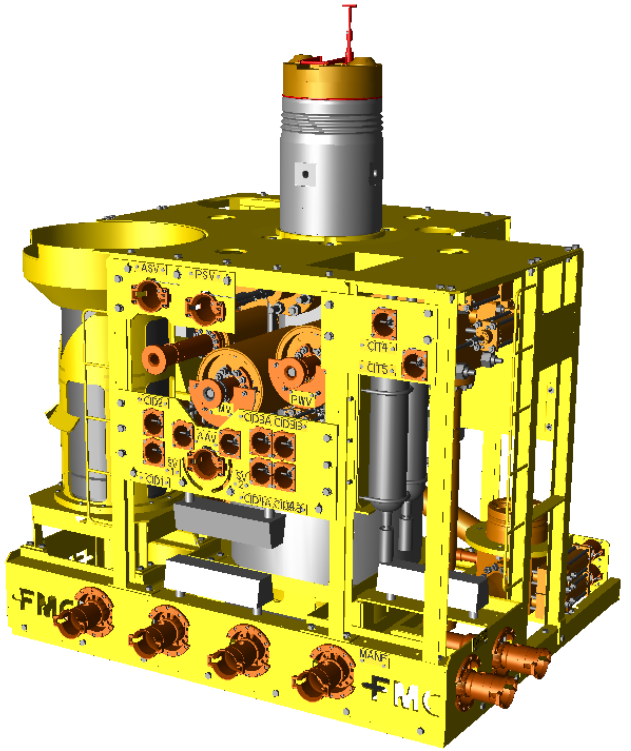
Tubing Hanger



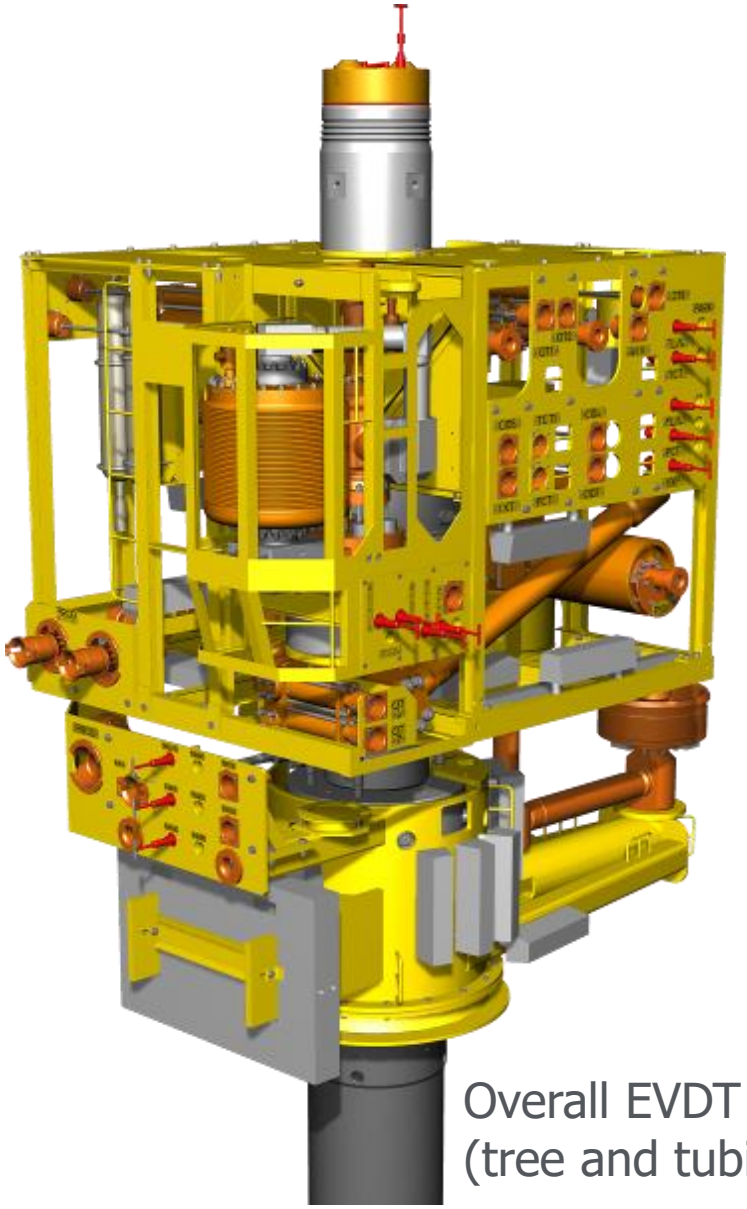
EVDT on Tubing Head



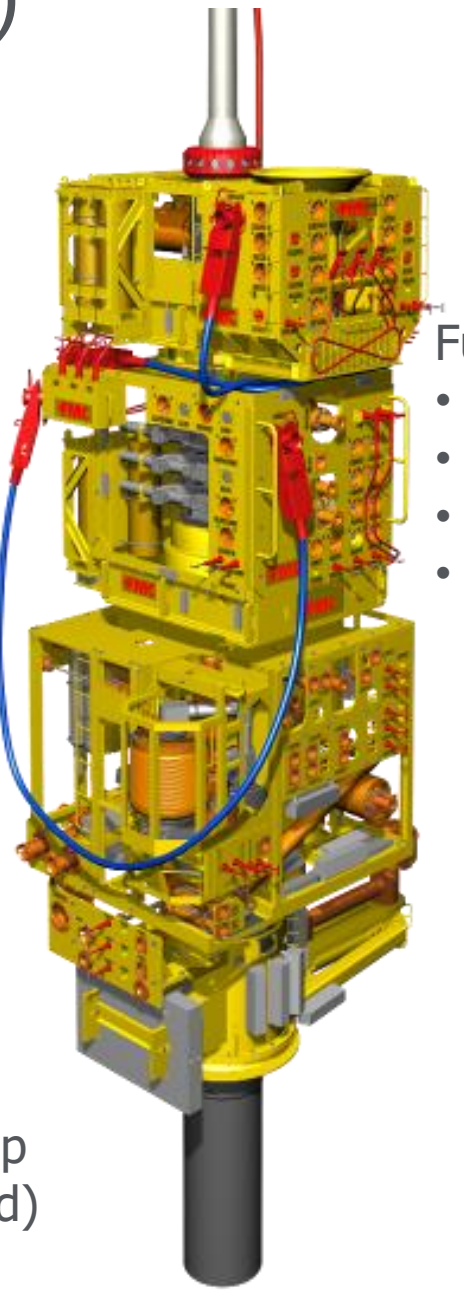
Enhanced Vertical Deepwater Tree (EVDT)



EVDT Tree (only)



Overall EVDT stack-up
(tree and tubing head)

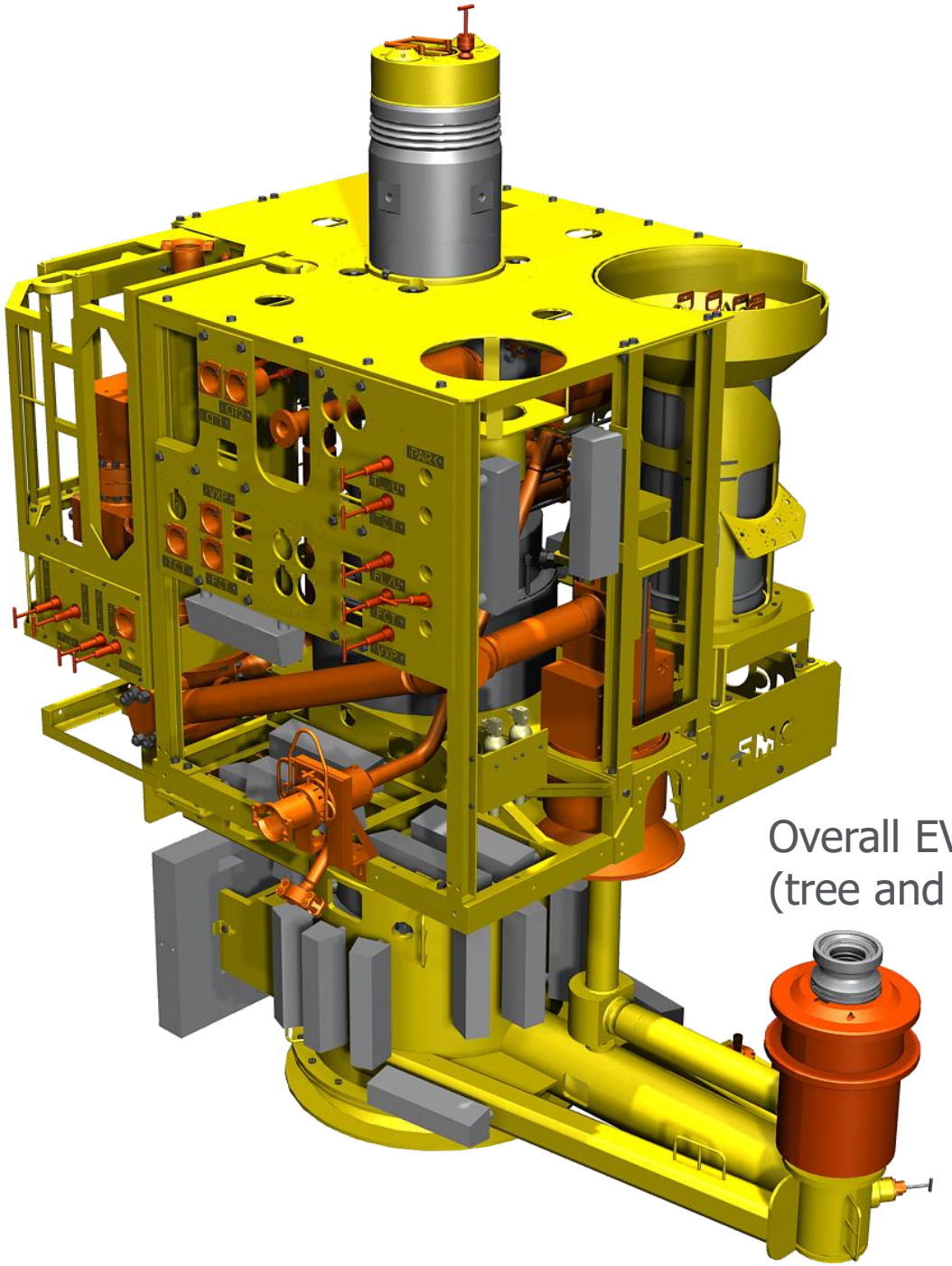


Full Stack-Up w/

- CWOR
- EVDT
- Tubing Hanger
- Wellhead

EVDT Advantages

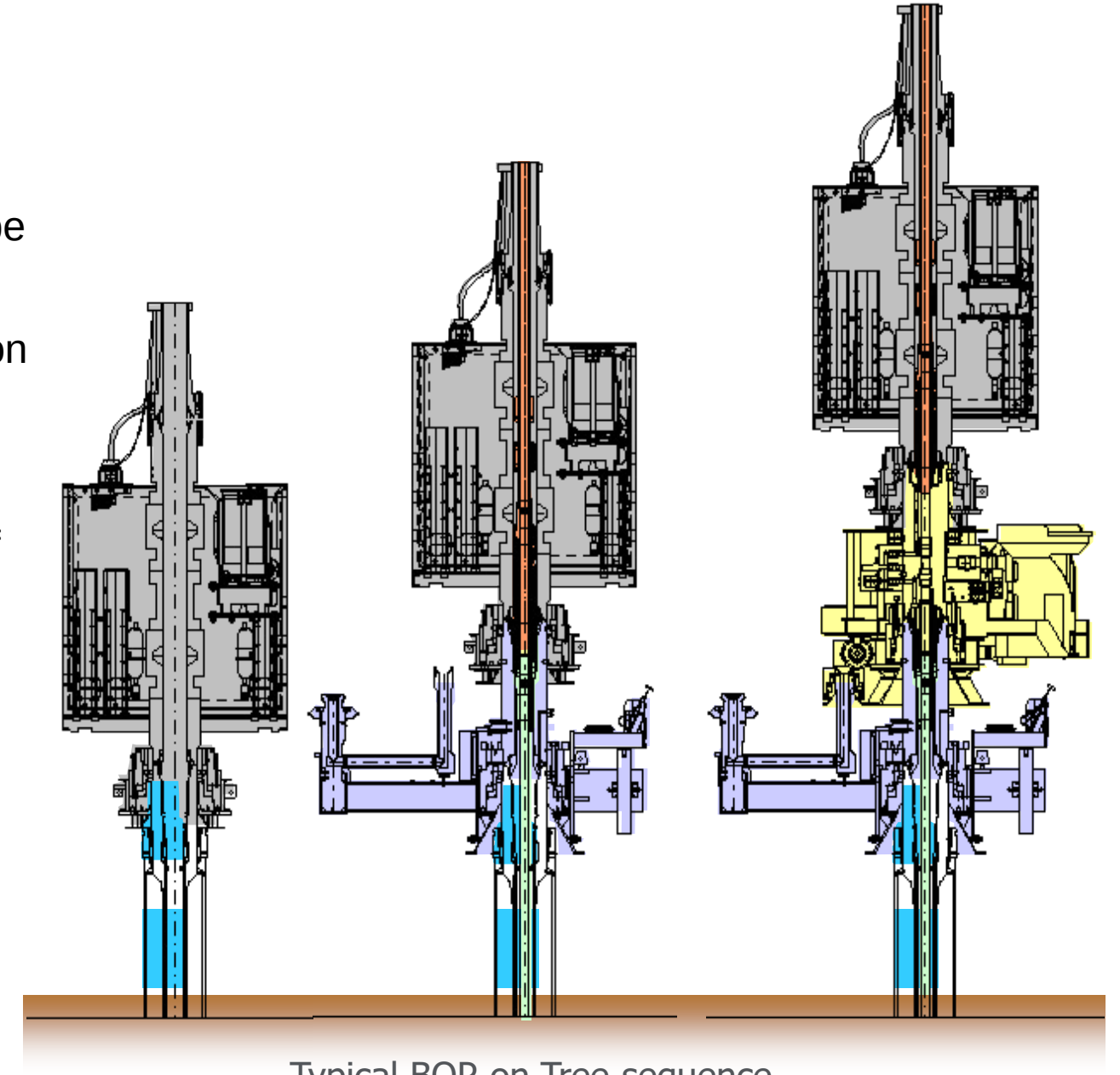
- **Merges most desirable features of horizontal and vertical trees into state-of-art design**
- **Unparalleled operational versatility**
- **Lower risk**



Overall EVDT stack-up (tree and tubing head)

BOP-on-Tree Interface

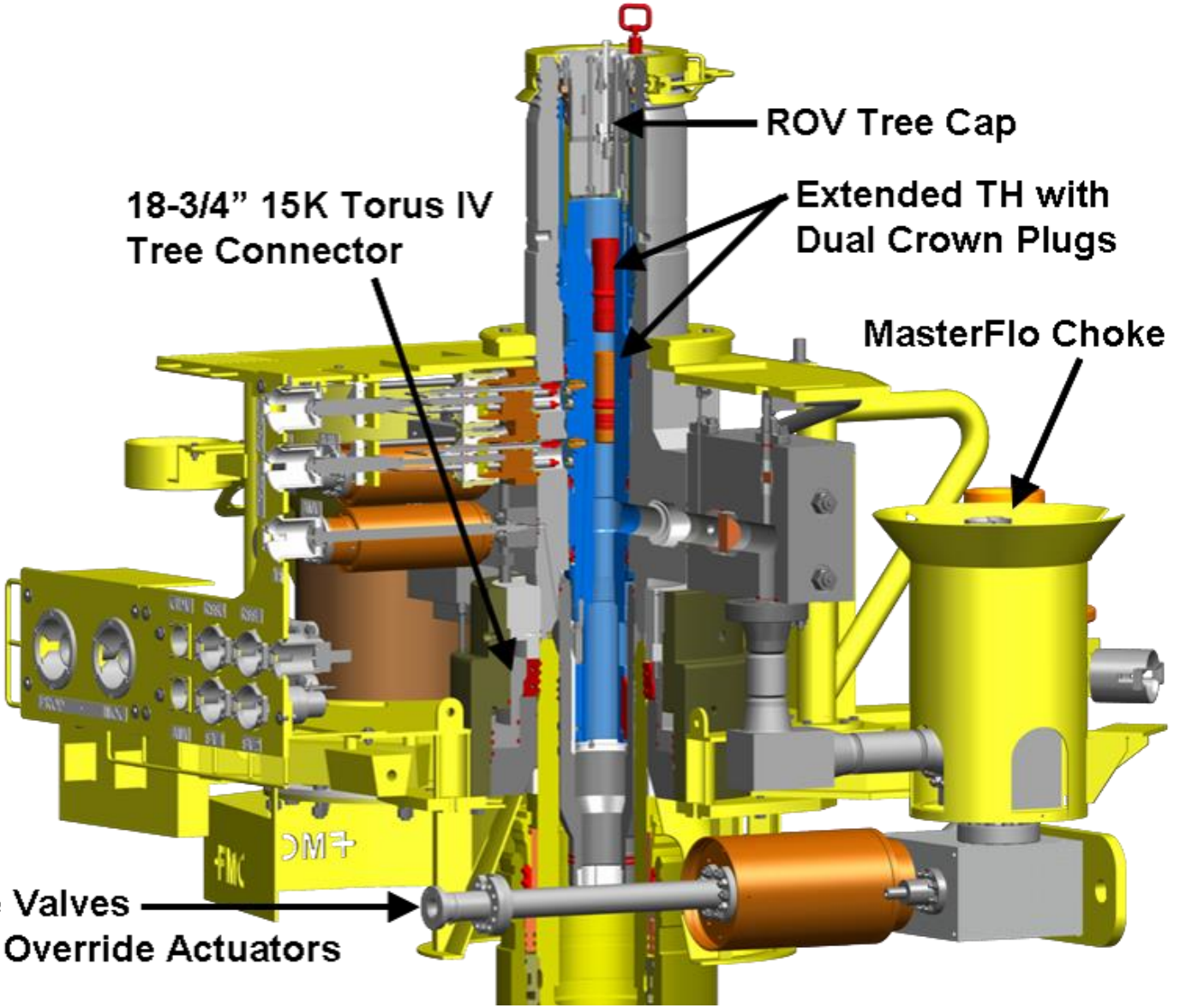
- EVDT allows Subsea BOP and marine riser to be landed on tubing head and tree
- BOP on tubing head for tubing hanger installation
- BOP on tree for through tree interventions with landing string system (similar to horizontal tree)
    - Tubing hanger running tool locks into top of tree



Typical BOP-on-Tree sequence

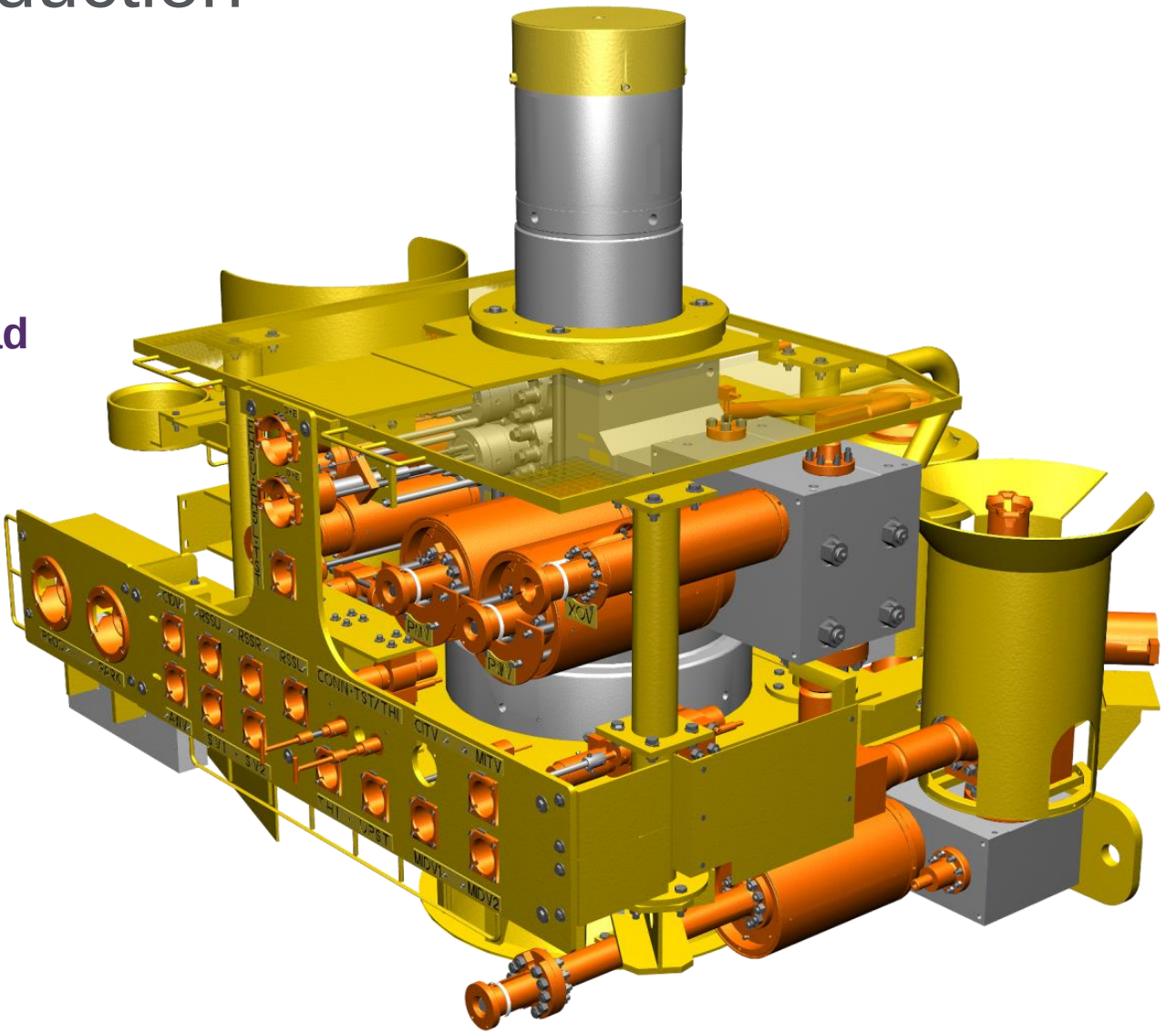
Enhanced Horizontal Tree (EHXT)

Enhanced Horizontal GLL Tree Components

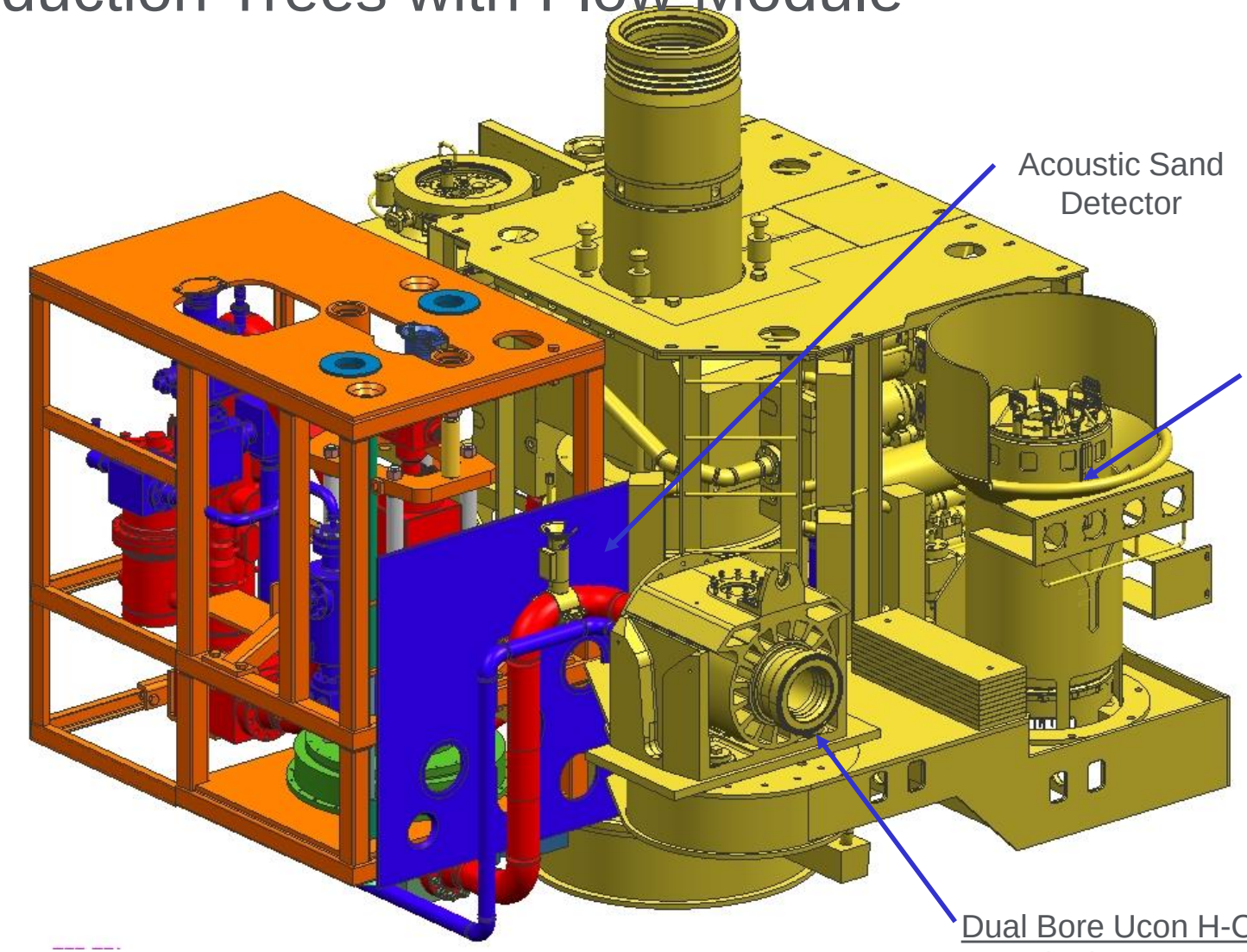


FMC 5”x 2”-10K EHXT - Production

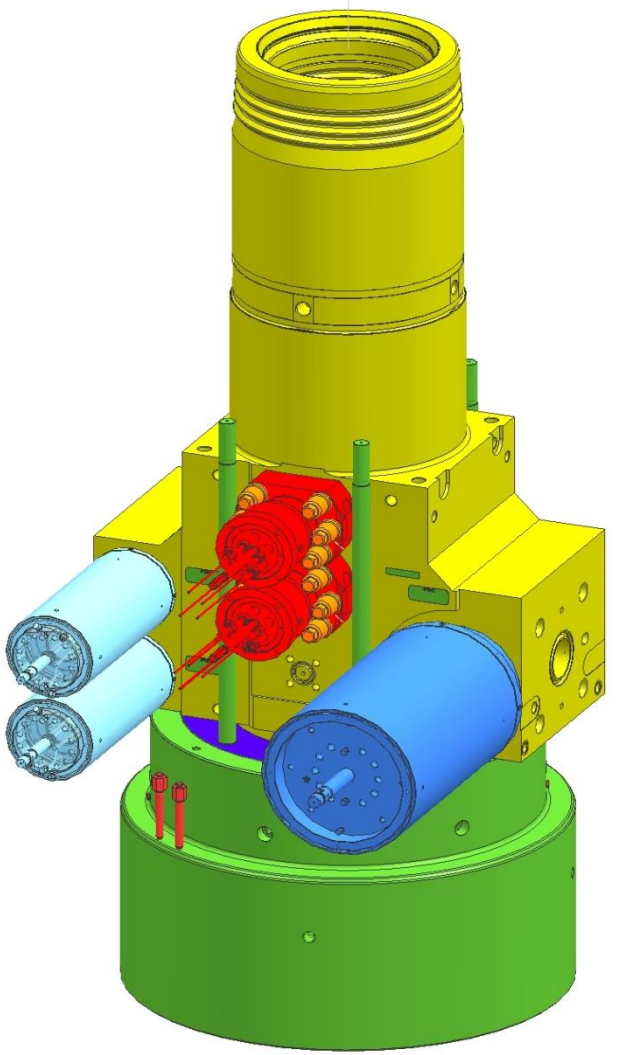
- **FF Prod, EE Annulus, PSL 3G**
- **5”-10K vertical Max-8 hub**
- **18 ¾”-15K Torus IV connector for H4 wellhead profile**
- **2 CID, 2 SV’s, 1 DHPT, 3 smart well functions**
- **1 CIT between PMV & PWV with additional points available**
- **3 sensors:**
  1 Annulus PT
  1 Production upstream PT
  1 Production downstream PT
- **Silicon based Novolastic™ insulation**
- **Qty 2 dual core chemical metering valves (optional)**

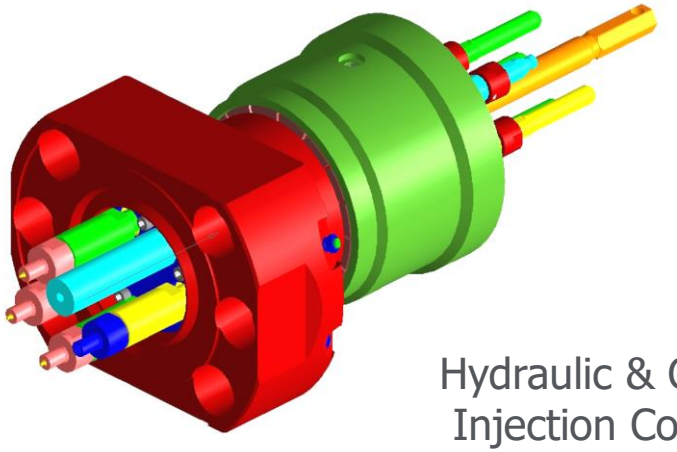


Production Trees with Flow Module

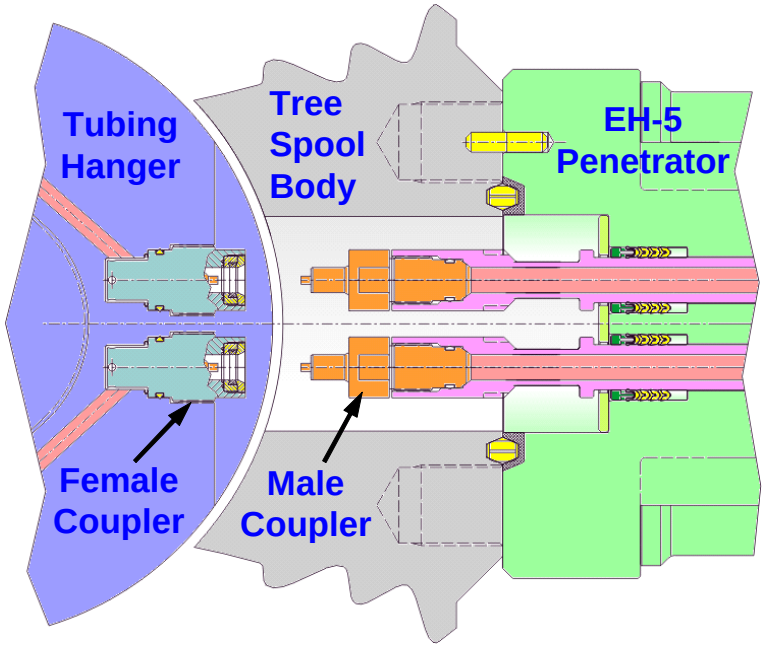


EH-5 Assembly

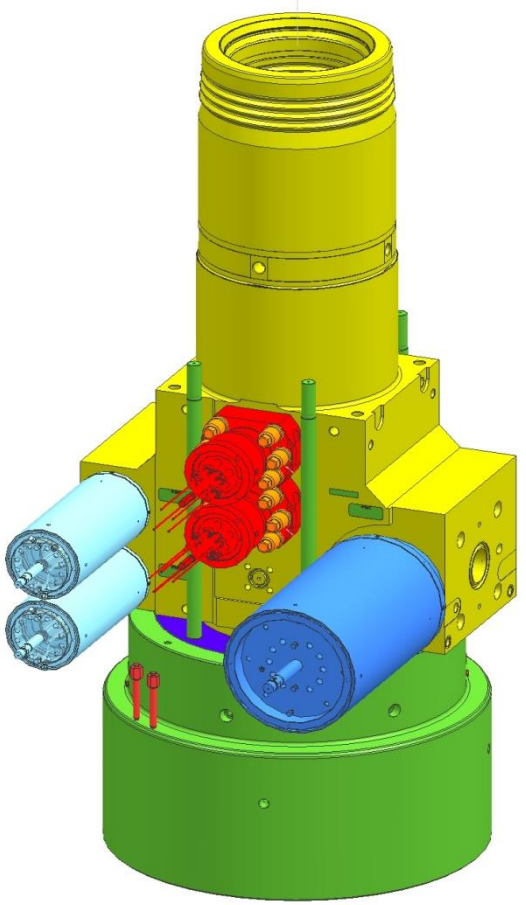


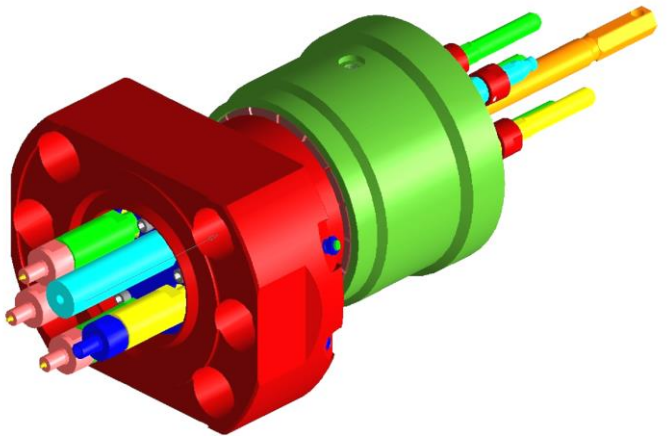


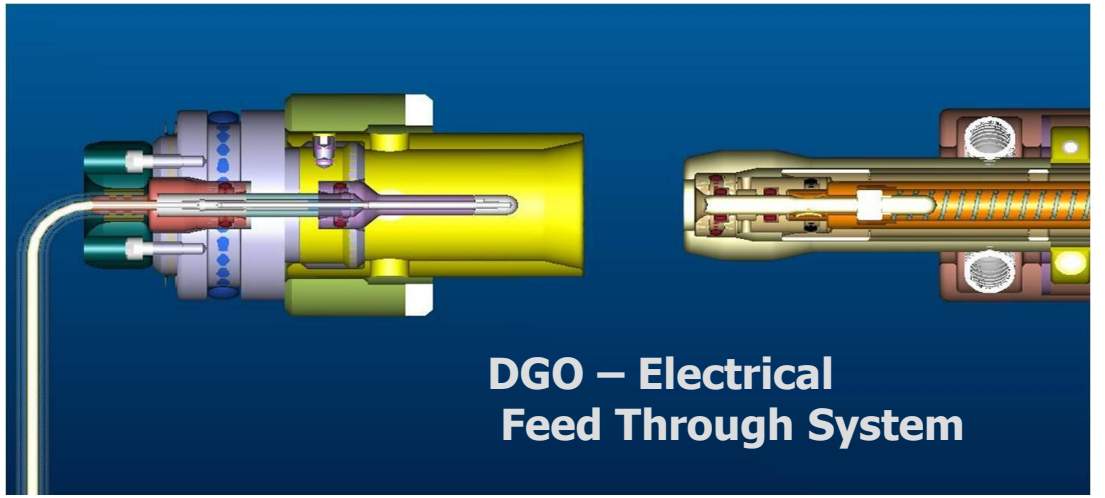
Hydraulic & Chemical
Injection Couplers



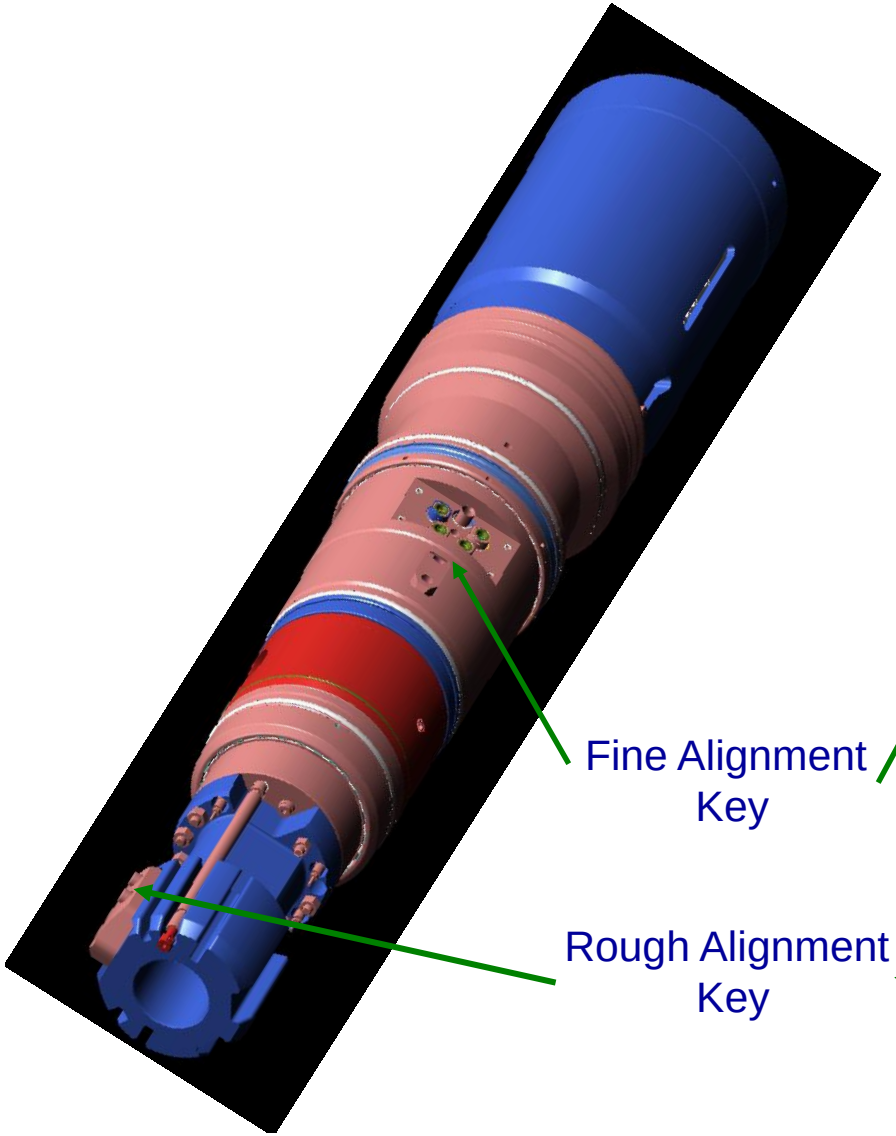
EH-5 Assembly

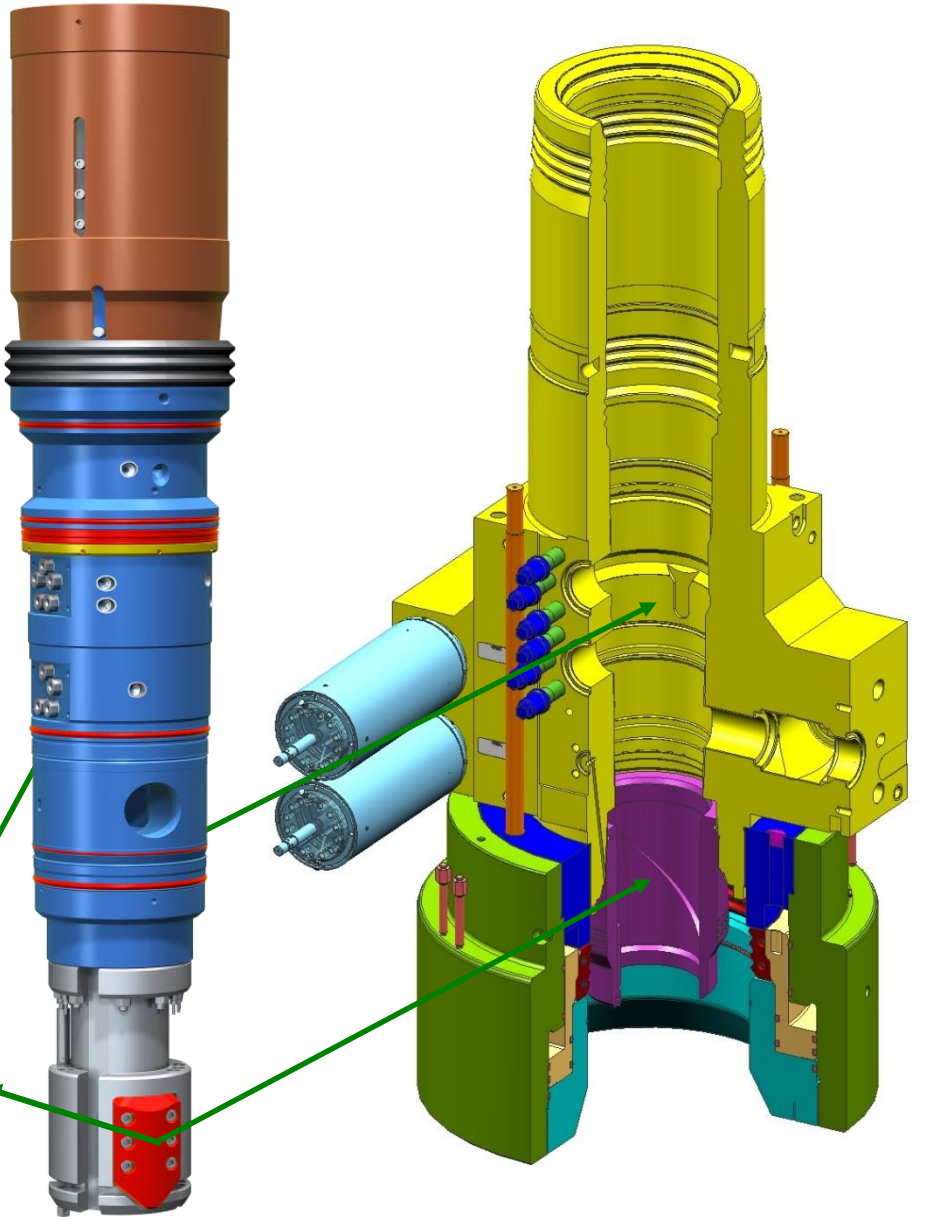




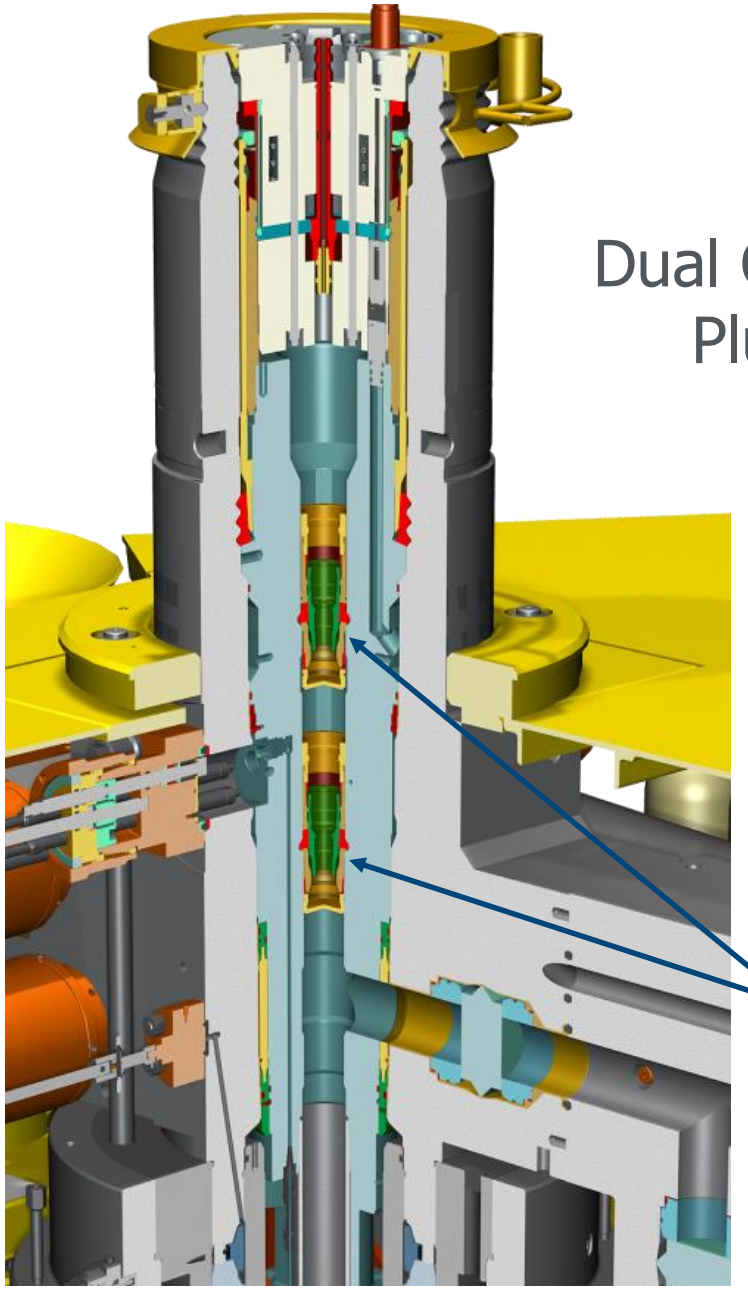


EHXT Tubing Hanger

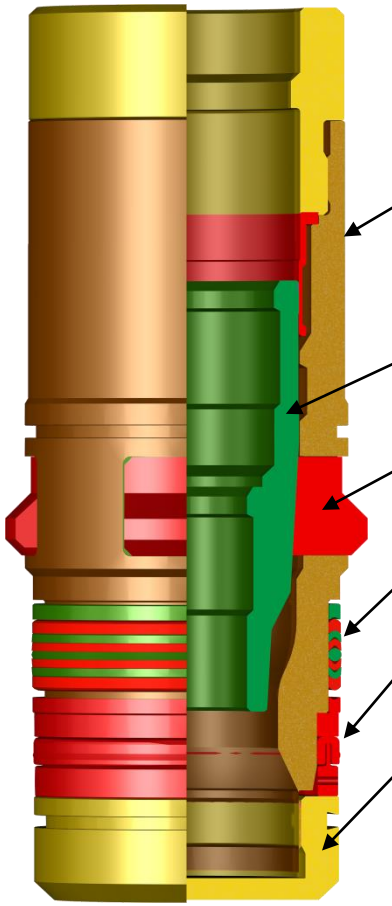


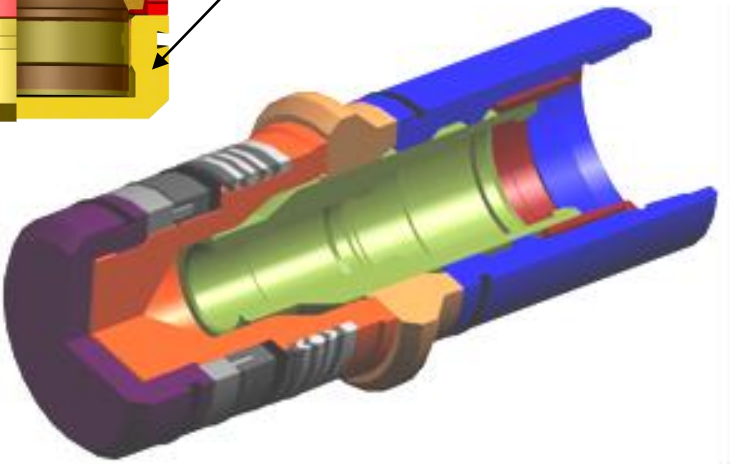


Dual Crown Plugs



Dual Inline Crown Plugs



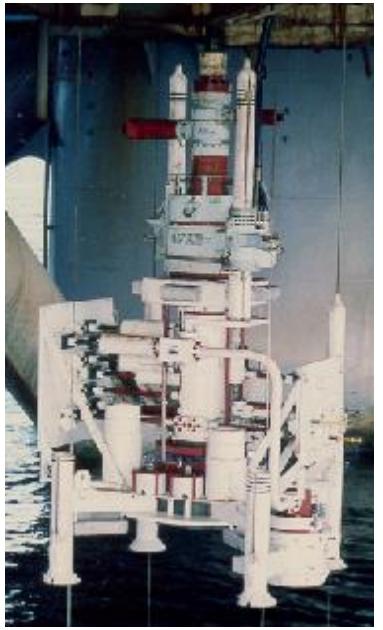


Subsea Tree – History & Examples

49

Subsea Tree Technology

1992

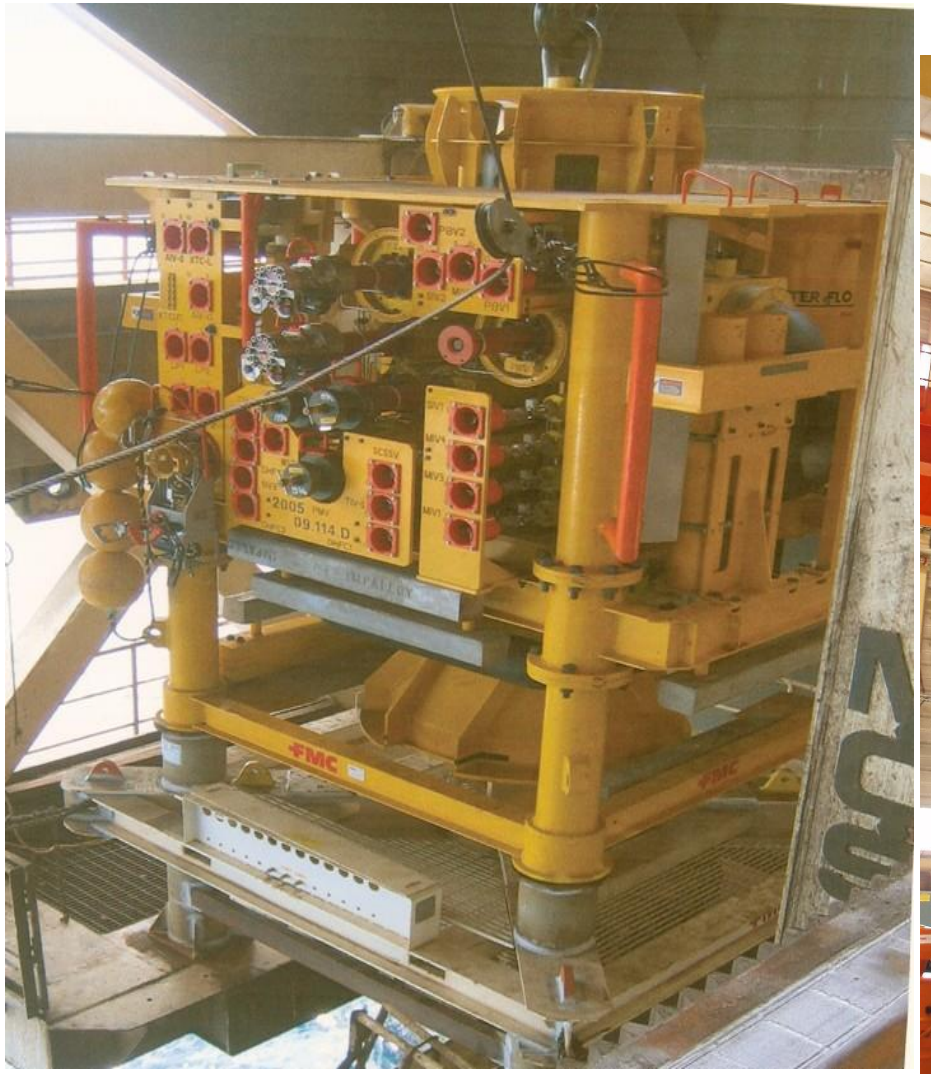


1994

1996-1998

2000

2010



5” x 2” 10K EVST-DB

BP Block 18 Angola

7” x 2” 10K EVST-DB

Woodside - Australia

7” x 2” 10K EHXT + EDP/LRP

Hydro Ormen Lange - Norway

5” x 2” 5K EVST-DB + EDP/LRP
Total Rosa - Angola

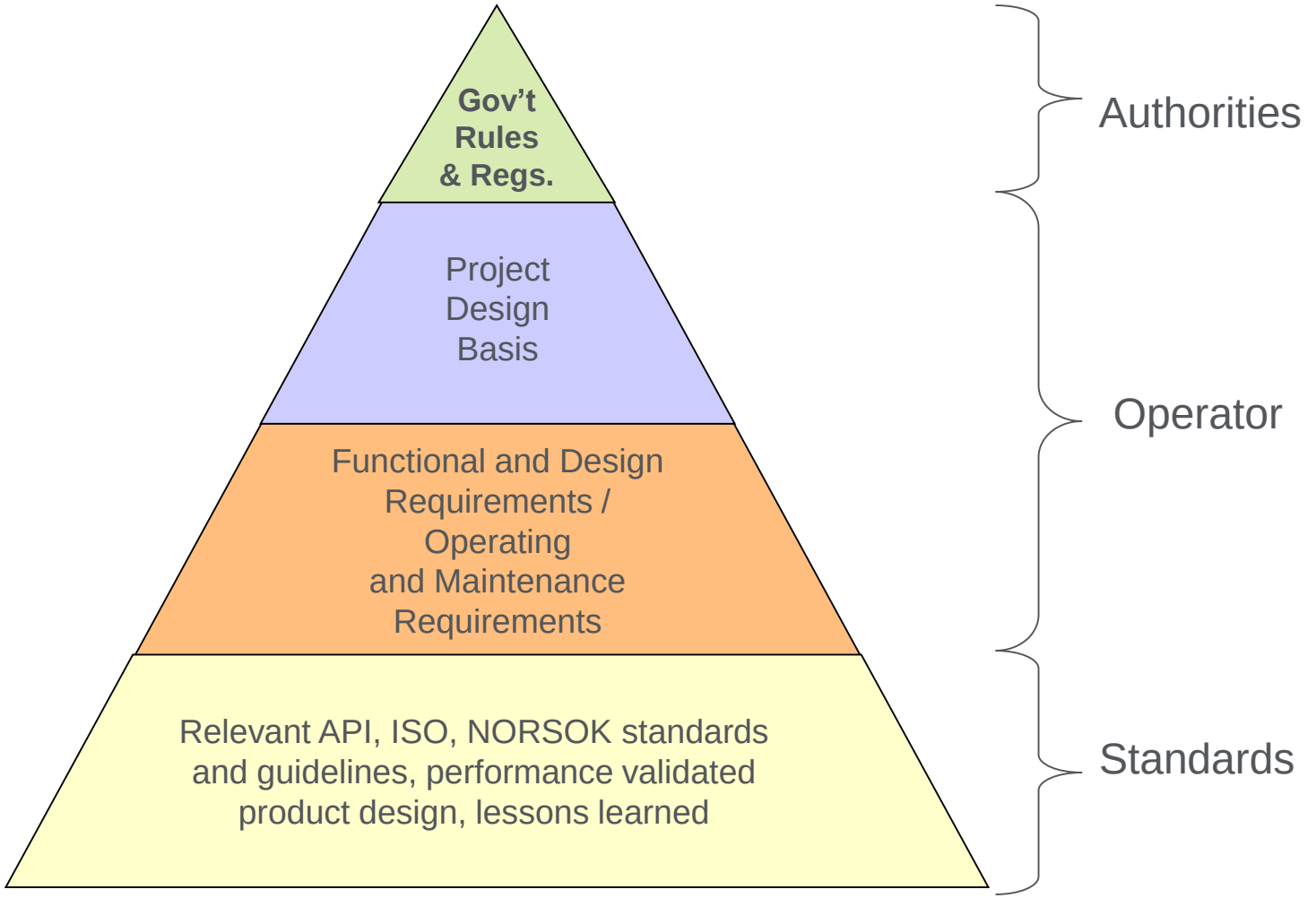
Can a tree Fly?

Prestwick Airport Scotland UK to South Africa 6th June 2006

Subsea Tree variations (Houston Nov 2010)

Reference Material
- Subsea Tree Design & Manufacturing Requirements

Standards, Rules and Regulations



The Major Specifications

Early API Standards

Standard materials and dimensions

API Specification 6A / ISO 10423

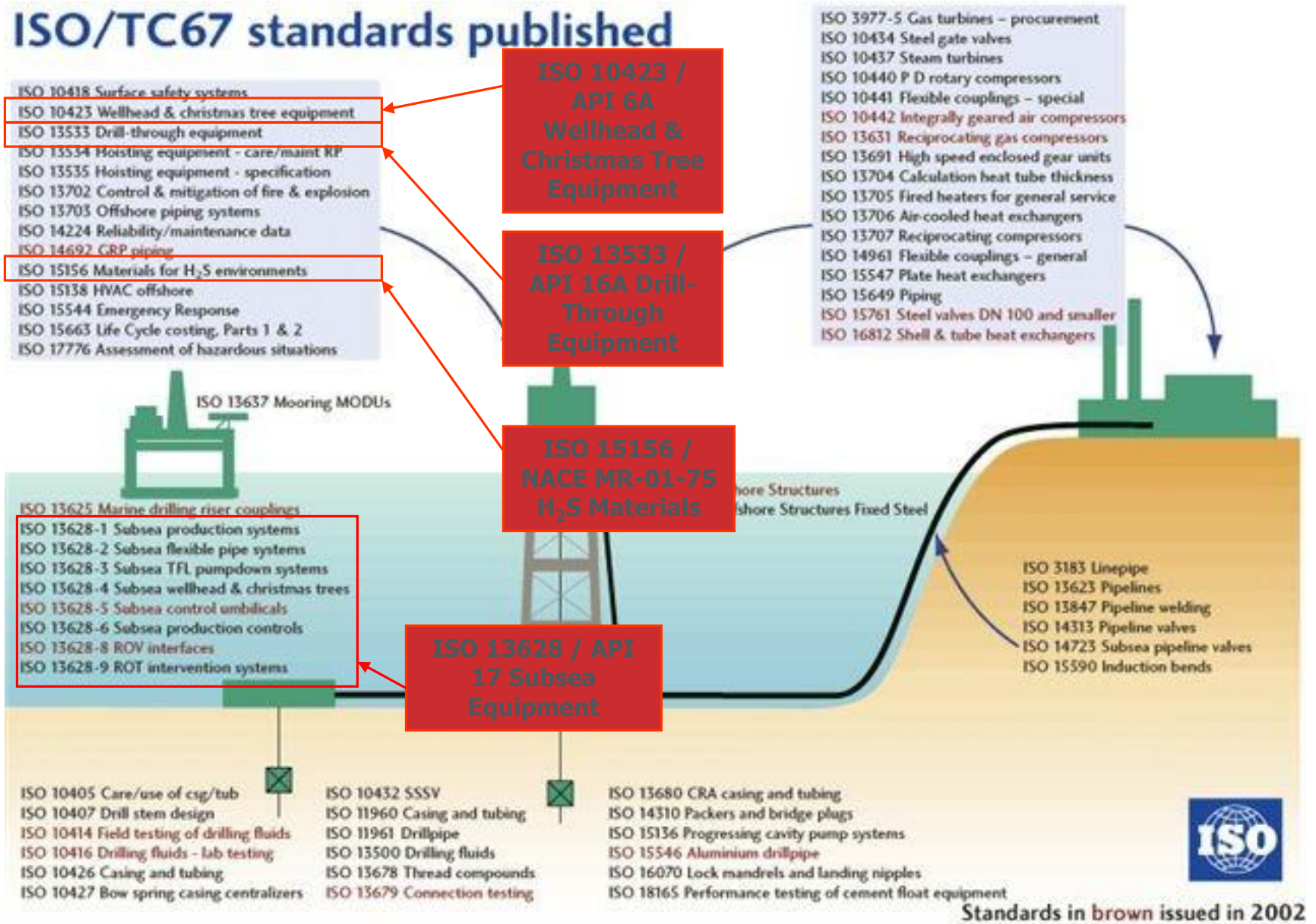
Its development and design rules

API Specification 16A / ISO 13533

What are the differences from 6A – clamps, hubs, BOP equipment

API Specification 17D / ISO 13628-4

Different applications and scope


ISO/TC67 standards published
ISO 10418 Surface safety systems
ISO 10423 Wellhead & christmas tree equipment
ISO 13533 Drill-through equipment
ISO 13534 Hoisting equipment - care/maint RP
ISO 13535 Hoisting equipment - specification
ISO 13702 Control & mitigation of fire & explosion
ISO 13703 Offshore piping systems
ISO 14224 Reliability/maintenance data
ISO 14692 GRP piping
ISO 15156 Materials for H2S environments
ISO 15138 HVAC offshore
ISO 15544 Emergency Response
ISO 15663 Life Cycle costing, Parts 1 & 2
ISO 17776 Assessment of hazardous situations
ISO 10423 / API 6A Wellhead & Christmas Tree Equipment
ISO 13533 / API 16A Drill-Through Equipment
ISO 15156 / NACE MR-01-75 H2S Materials
ISO 3977-5 Gas turbines – procurement
ISO 10434 Steel gate valves
ISO 10437 Steam turbines
ISO 10440 P D rotary compressors
ISO 10441 Flexible couplings – special
ISO 10442 Integrally geared air compressors
ISO 13631 Reciprocating gas compressors
ISO 13691 High speed enclosed gear units
ISO 13704 Calculation heat tube thickness
ISO 13705 Fired heaters for general service
ISO 13706 Air-cooled heat exchangers
ISO 13707 Reciprocating compressors
ISO 14961 Flexible couplings – general
ISO 15547 Plate heat exchangers
ISO 15649 Piping
ISO 15761 Steel valves DN 100 and smaller
ISO 16812 Shell & tube heat exchangers
ISO 13637 Mooring MODUs
ISO 13625 Marine drilling riser couplings
ISO 13628-1 Subsea production systems
ISO 13628-2 Subsea flexible pipe systems
ISO 13628-3 Subsea TFL pumpdown systems
ISO 13628-4 Subsea wellhead & christmas trees
ISO 13628-5 Subsea control umbilicals
ISO 13628-6 Subsea production controls
ISO 13628-8 ROV interfaces
ISO 13628-9 ROT intervention systems
ISO 13628 / API 17 Subsea Equipment
ISO 3183 Linepipe
ISO 13623 Pipelines
ISO 13847 Pipeline welding
ISO 14313 Pipeline valves
ISO 14723 Subsea pipeline valves
ISO 15590 Induction bends
ISO 10405 Care/use of csg/tub
ISO 10407 Drill stem design
ISO 10414 Field testing of drilling fluids
ISO 10416 Drilling fluids - lab testing
ISO 10426 Casing and tubing
ISO 10427 Bow spring casing centralizers
ISO 10432 SSSV
ISO 11960 Casing and tubing
ISO 11961 Drillpipe
ISO 13500 Drilling fluids
ISO 13678 Thread compounds
ISO 13679 Connection testing
ISO 13680 CRA casing and tubing
ISO 14310 Packers and bridge plugs
ISO 15136 Progressing cavity pump systems
ISO 15546 Aluminium drillpipe
ISO 16070 Lock mandrels and landing nipples
ISO 18165 Performance testing of cement float equipment
Standards in brown issued in 2002

Reference Material
Design & Interface Consideration

Tree Interface Considerations

Four interfaces govern tree design:

The Well

Tubing Size, Pressure, Temperature, Material Class

Controls

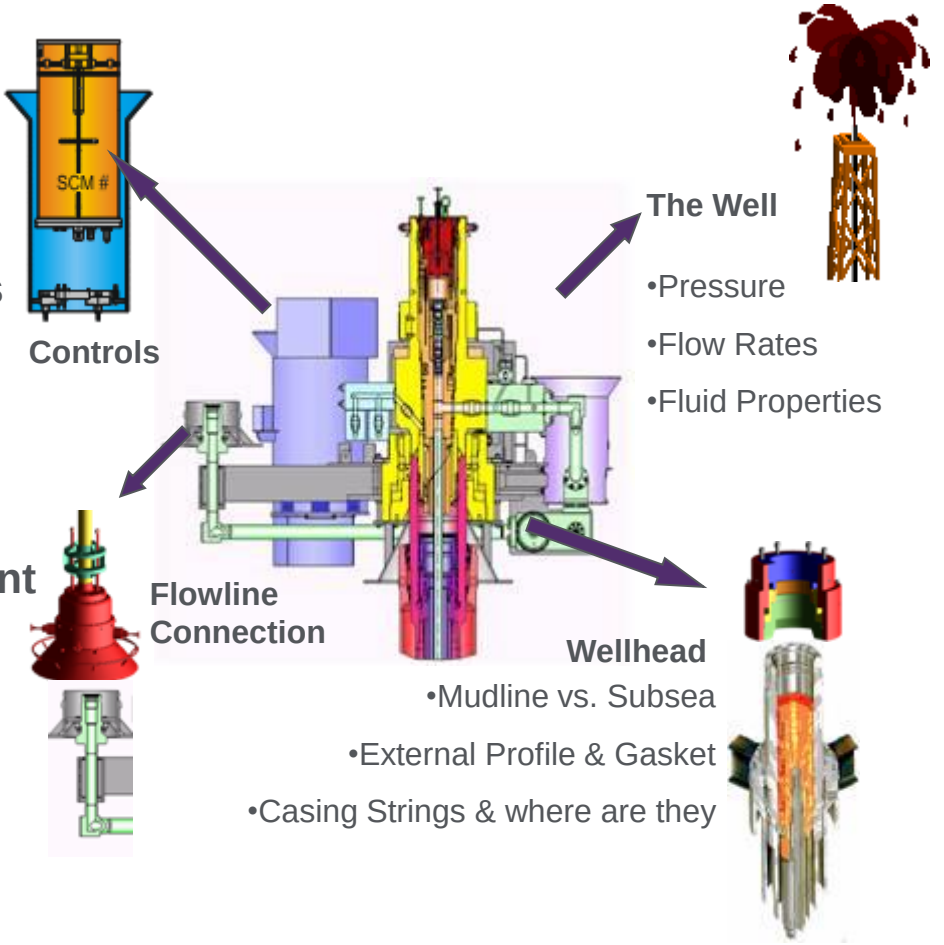
Direct, Piloted, E-H, Different Vendors

Flowlines

Pipeline Size, Pressure, Connection Type, Different Vendors

The Wellhead

Mudline, Clamp Hub, Mandrel, Different Vendors



Effects of Partial Pressure on Material Choices

Material Class based on partial pressure of corrosive mediums

(API partial pressure limit) x 1000000 / well bore pressure = parts per million limit

(API partial pressure limit) x 100 / well bore pressure = mol % limit

For H_2S API defines sour service as >.05 psi pp

For CO_2 API defines normal service as <7 psi pp and very corrosive >30 psi pp

Standard offering for most [Gulf of Mexico] service is FF

.05 < H_2S < 3 psi pp

7 < CO_2 < 30 psi pp

> 20,000 ppm Cl_2

Upper limit on H_2S to 3 psi pp based on 410 and F6NM base materials

Other mitigating factors – NACE MR-01-75 is changing all the rules

Other Effects of Materials & Temperature - HPHT

- **API 6A and 17D have 6 material classes based on H_2S and CO_2 levels – AA BB CC DD EE FF HH**
- **ISO 13628-XX series**
- **AA – CC are for Sweet Service**
- **DD- HH are for Sour Service, HH is Severe Service**
- **> 250^o degrades non-metalics, > 300^o degrades metal strength**
- **Thermal Expansion / Contraction**

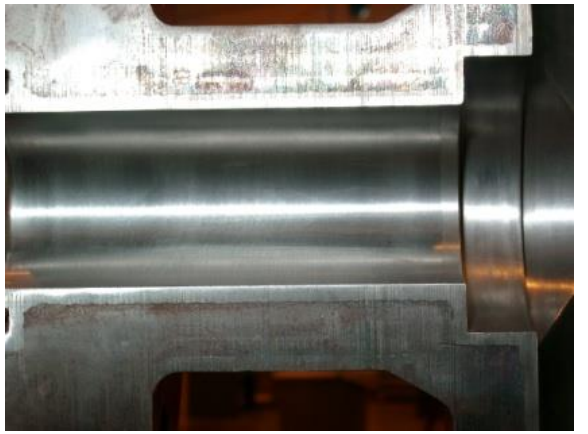
Cladding

- Why is it done?

- Internal wellbore environment different from external world
  - Cathodic protection doesn't like dissimilar metals
  - Ring grooves and seal pockets always [depends on supplier] inlaid to prevent pitting between CRA metal gaskets and seal surface

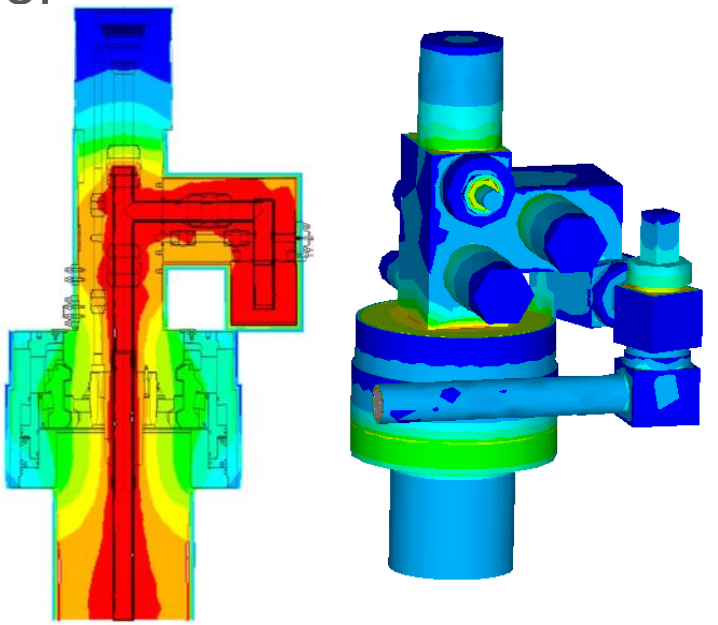
- Solid CRA materials may be difficult to machine in large size / cost

- Further cost savings may be gained by "selectively" cladding in areas that are "wetted surfaces"
  - Other areas may remain base metal or protected by simple coatings


Design & Interface Consideration
Subsea Tree Insulation
(Hydrate Remediation)

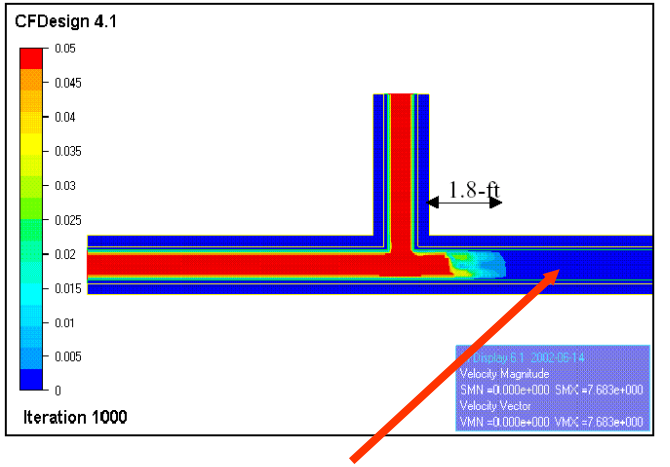
Thermal Insulation Analysis & Materials for Subsea Equipment



Insulation

Insulation bottles up more wellbore temperature and allows it to migrate more uniformly through component

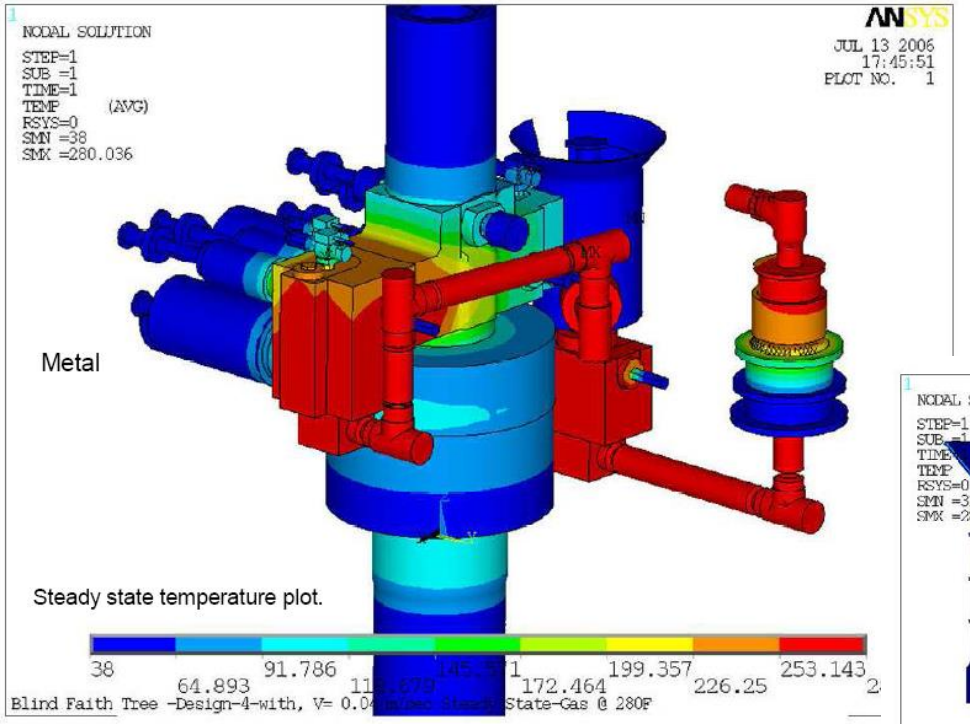
Some components designed to take advantage of cold water for operating through most temperature ranges

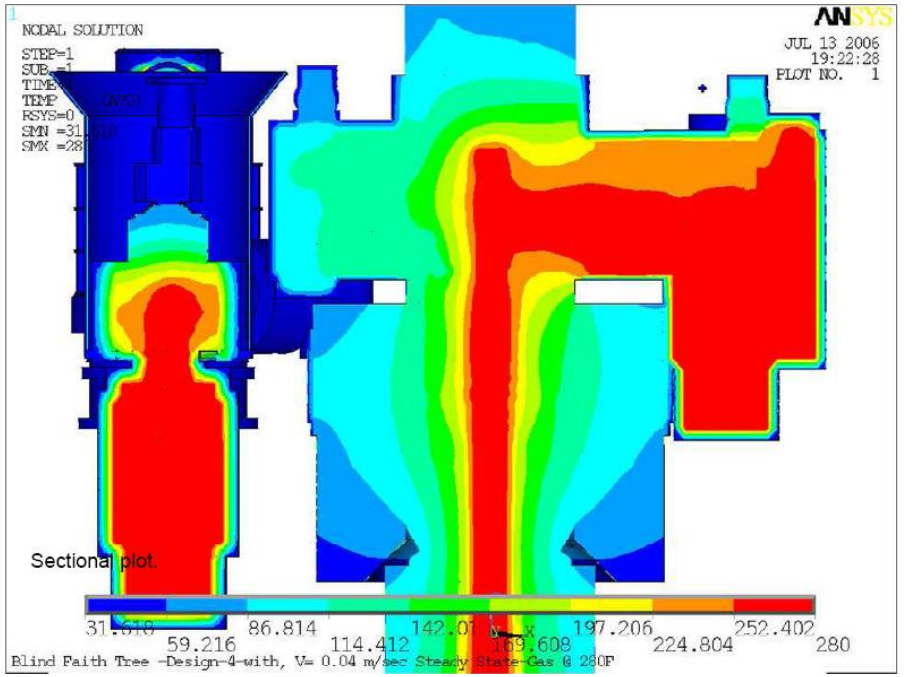


Manifold Piping Dead Legs

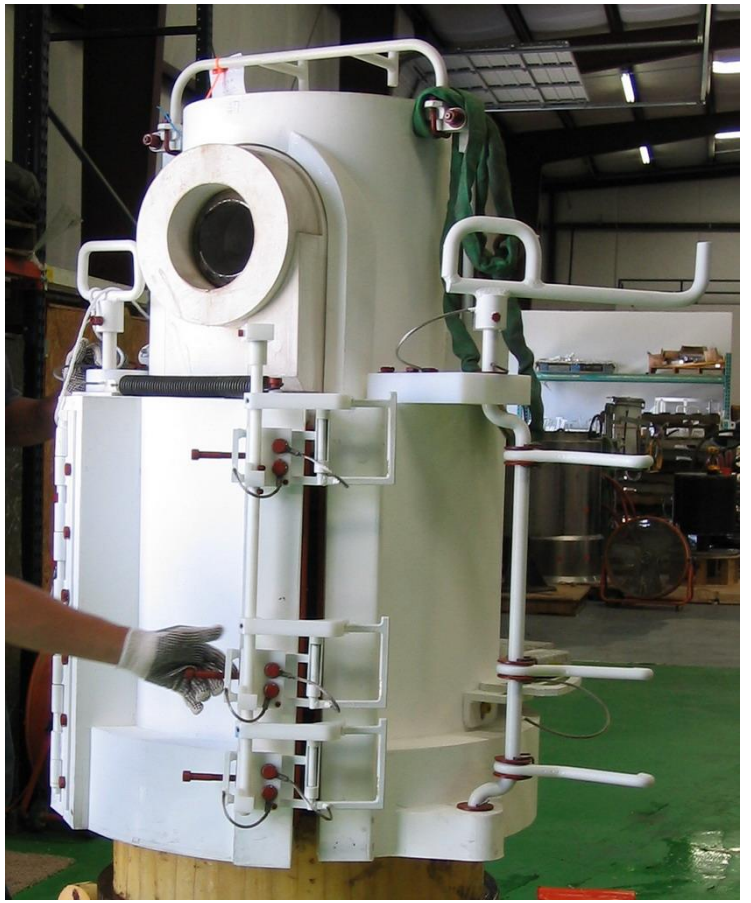
Thermal FEA Example

Figure 61: Iteration 3, Steady state - metal parts.

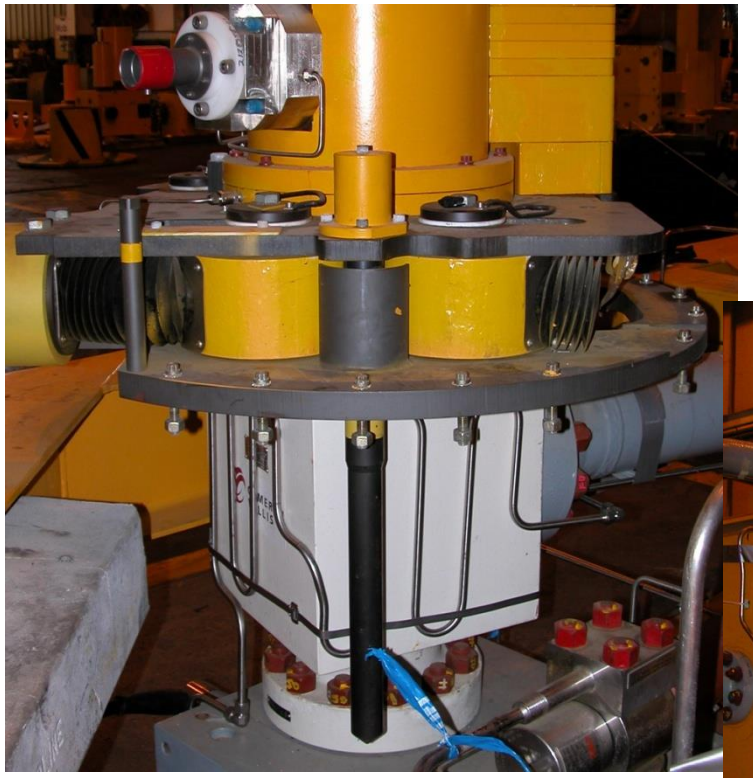




Thermal Insulation Shrouds for Blind Faith/Agbami



Hydrate Remediation – Hot Water heat trace (Tree)



QUESTIONS ???