Introduction to Subsea Production System

04 Xmas Tree Systems

Bjørn Søgård
May 19th 2008
Xmas Tree Systems

This module will cover:

- Main codes for XT equipment
- XT Principles and functions
- Typical schematic
- Main types
- Building Blocks
  - Valves, Main principles
  - Chokes, Main principles
  - Tree Connector
  - Tubing Hanger
- Control System and Monitoring
Goals

- Know purpose and basic function of a XT
- Understand the main concept types of XT
Xmas Tree Systems

This module will cover:

- Main codes for XT equipment
- XT Principles and functions
- Typical schematic
- Main types
- Building Blocks
  - Valves, Main principles
  - Chokes, Main principles
  - Tree Connector
- Control System and Monitoring
Applicable codes and standards

Main codes for XT Equipment:

- API 6A/ISO 10423 Specification for Wellhead and Christmas Tree Equipment
- API 17D/ISO 13628-4 Subsea wellhead and tree equipment
- ISO 13628-1 General Requirements and recommendations
- ISO 13628-6 Subsea Production control System
- API 16A / ISO 13533 Specification for Drill-through Equipment
- + ASME, ISO, BS
Xmas Tree Systems

This module will cover:

- Main codes for XT equipment
- XT Principles and functions
- Typical schematic
- Main types
- Building Blocks
  - Valves, Main principles
  - Chokes, Main principles
  - Tree Connector
  - Tubing Hanger
- Control System and Monitoring
Xmas Tree Systems

- The purpose of a **production** Xmas Tree is to control the flow of hydrocarbons from its respective well via various control valves and choke, to receiving unit. This can be a fixed or floating vessel or produced via pipeline to shore.

- The purpose of an **injection** Xmas Tree is to control the flow of water or gas into its respective well via various control valves and choke, from a process installation off- or on-shore.
Xmas Tree Systems

Xmas Tree Functions:

- Safety barrier
- Safely stop produced or injected fluid
- Injection of chemicals to well or flowline
- Allow for control of downhole valves
- Allow for electrical signals to downhole gauges
- To bleed of excessive pressure from annulus
- Regulate fluid flow through a choke (not mandatory)
- Allow for well intervention

Xmas Tree (FMC, Girassol):
Xmas Tree Systems

This module will cover:

- Main codes for XT equipment
- XT Principles and functions
  - Typical schematic
- Main types
- Building Blocks
  - Valves, Main principles
  - Chokes, Main principles
  - Tree Connector
  - Tubing Hanger
- Control System and Monitoring
X-Mas Tree

XT Schematic

PMV  Production Master Valve
PWV  Production Wing Valve
AMV  Annulus Master Valve
AWV  Annulus Wing Valve
ACV  Annulus Circulation Valve
XOV  Cross Over Valve
SCSSV Surface Controlled Subsurface Safety Valve
PTT  Pressure/Temperature Transmitter
Xmas Tree Systems

This module will cover:

- Main codes for XT equipment
- XT Principles and functions
- Typical schematic
  - Main types
    - Building Blocks
      - Valves, Main principles
      - Chokes, Main principles
      - Tree Connector
      - Tubing Hanger
    - Control System and Monitoring
**X-Mas Tree**

Two main types of subsea trees are used in modern offshore technology:

1. Horizontal XT

2. Conventional or Dual Bore tree
X-Mas Tree

It is not the intention to advocate the other concept compared to the other here.

Horizontal trees have gained popularity in Norwegian waters for the past 10 years. This is mainly due to the complex reservoir structure, which promote a solution for easy access to heavy work over and subsequent production tubing retrieval.

Probably the most important selection criteria is the HXT possibility to accommodate 7” production tubing, whilst the conventional tree hardly accommodate larger than nominal 5”.

Recent field developments where simultaneously gas injection/oilproduction are required have been with conventional trees.
X-Mas Tree

Other concepts may be introduced in order to meet new requirements, e.g. when going to large bore > 7” through bore, or light weight trees.

See ISO 13628-4 for other concepts.
Xmas Tree Systems

This module will cover:

- Main codes for XT equipment
- XT Principles and functions
- Typical schematic
- Main types
  - Building Blocks
    - Valves, Main principles
    - Chokes, Main principles
    - Tree Connector
    - Tubing Hanger
- Control System and Monitoring
Xmas Tree Valves

The Xmas Tree assembly contains the following valves:

- Production (or Injection) valves (typ. 5-7” gate valves) for controlling the process medium
- Annulus (or Injection) valves (typ. 2” gate valves) for annulus access.
- Service valves (typ. 3/8” to 1”) for chemical injection.
- Isolation valves (typ. 3/8” to 1”) for pressure test and downhole lines
- Check Valves (typ. ½-1”) for preventing back-flow of well fluid to service lines
Xmas Tree Gate Valves
Xmas Tree Gate Valves

Valve principles

- Valve Product Verification testing in principle described in API 6A with additions in API 17D. Pay attention to pressure classification and verification to max/min pressures at rated sea water depth.

- According to standards, valve and actuators can be qualified separately. However, the simplest way of actuating the valve in the test is often by using the dedicated actuator.

- Principles, pressures, force balance, seawater depth effects, see previous slide.

- Do not forget that Subsea Production Control Codes may influence your valve/actuator design parameters.
Xmas Tree Systems

This module will cover:

- Main codes for XT equipment
- XT Principles and functions
- Typical schematic
- Main types
- Building Blocks
  - Valves, Main principles
  - Chokes, Main principles
  - Tree Connector
  - Tubing Hanger
- Control System and Monitoring
Subsea Production Choke

- The choke is used to control the production rate and downstream pressure from the well. The subsea choke is located on the XT, or as with recent projects, on a ‘choke bridge’ on the template.

- In both scenarios, downstream the PWV.
Subsea Production Choke

Different concepts exist:

See ISO 13628-4 for main principles

- **3 Major suppliers**
  - Cameron Willis
  - Master Flo
  - Kent Introll (Vetco gray)

- **Other suppliers of similar equipment not currently serving the subsea business area:**
  - Mokveld
  - Hydril
  - Wood Group Pressure Control
  - N-Line
Subsea Production Choke
Subsea Production Choke

- In addition to the different concepts shown on previous slide can following classification be given
  - Positive chokes
  - Adjustable chokes
  - Subsea retrieval chokes
  - Non retrievable chokes

- The trend in choke industry have changed from having focus on erosive wear resistant design to be more robust for vibration and foreign objects.
Selection Criterion for Subsea Choke are:

- Upstream and downstream pressure, flow rates, (gas, oil/water), molecular weight or density to the components and temperature.
- This will predict the capacity of the unit, CV capacity according to ISA S75.01 - Choke flow capacity. ISA give firm recommendations to test fixture for CV classification and CV testing.
- ANSI/FCI also give criterion for Seat pressure test. This test is normally conducted at relatively low pressure.
Subsea Production Choke
Xmas Tree Systems

This module will cover:

- Main codes for XT equipment
- XT Principles and functions
- Typical schematic
- Main types
- Building Blocks
  - Valves, Main principles
  - Chokes, Main principles
  - Tree Connector
  - Tubing Hanger
- Control System and Monitoring
X-Mas Tree connector

Tree connector are the element that allows the tree to be installed and securely connected to the wellhead.

Normal requirements are:

- 25 % increased capacity to unlock compared to lock

- Mechanical lockdown function, (both on hydraulic and mechanical connectors)

The hydraulic connector are getting its hydraulic pressure from WOCS through the TRT.

The mechanical connector are mechanically functioned through the TRT.
X-Mas Tree connector

The connector used for latching and lock tree onto wellhead or test stump.

- Classification of subsea connectors can be done according to:
  - Hydraulic activated connector
  - Mechanical connector (remote operated or diver operated)
  - Collet Connector
  - H4 connector

- The connector requirements are relatively detailed described by the code ISO 13628-4.

- See ISO 13628-7 for requirements to components which is in the riser string.
X-Mas Tree connector

The connector capacity are often described with following load chart

The manufacturer shall state whether the basis of the graphs is stress limits or gasket separation limits
Tree connector analysis, Connector Mechanics

The tree connector forms a bolt diagram.

External load, FL does not transfer in its whole to increased bolt forces, which is $F_s$. 

$$D_1/D_2 = A_2/A_1 \text{ if } E_1 = E_2$$
Fastener/Connector analysis, Connector Mechanics

\[ F_{d} = F_{i}/(1 + \partial_{1}/\partial_{2}) \]

Safety Margin for Separation

\[ N_{k} = F_{i}/(F_{i} - F_{k}) \]

\[ \partial_{n} = (F_{l})/(E_{n}A_{n}) \]
Stresses in bolts

![Graph showing stresses in bolts]

- **Expected Bolt Stress**
- **Allowable Bolt Stress (API)**
Separation/leakage

![Graph showing Hub face Preload vs Load Step with expected values indicated.](image)

Load Step

Hub face Preload [MN]

Millions
Xmas Tree Systems

This module will cover:

- Main codes for XT equipment
- XT Principles and functions
- Typical schematic
- Main types
- Building Blocks
  - Valves, Main principles
  - Chokes, Main principles
  - Tree Connector
  - Tubing Hanger
- Control System and Monitoring
Tubing Hanger

- The TH have its own lockdown mechanism, with additional mechanical lockdown functions.
- To save one trip and therefore also rig time is to days trees often equipped with a combined Tree Cap / Tubing Hanger. The TH then provides two set of lockdown profiles internally for plugs.
- Safe setting of ITC have been troublesome
- Normally a pup pieces is installed onto Tubing Hanger. This pup is normally CPI and the threaded connector type are controlled through contract or project interface.
Tubing Hanger

- From ISO 13628-4
Tubing Hanger

- From ISO 13628-4
Xmas Tree Systems

This module will cover:

- Main codes for XT equipment
- XT Principles and functions
- Typical schematic
- Main types
- Building Blocks
  - Valves, Main principles
  - Chokes, Main principles
  - Tree Connector
  - Tubing Hanger
- Control System and Monitoring
X-Mas Tree

- Controlsystem and monitoring
  - In modern offshore technology, the XT is remotely operated through a multiplex system. This means, through modern power and signal technology the production is continuously monitored with pressure and temperature as well as valve actuation and status are given/monitored by the PCS

  - Pressure and temperature sensors are installed in production flow, upstream and downstream choke and on the annulus. XT also provides possibilities to monitor pressure and temperature down in the production tubing.
  - Pressure and temperature sensors are often duplicated for redundancy
  - Modern fields are often designed with sand and/or erosion probes to detect sand production or erosion in system
  - Multiphase flow meters are getting more common in the industry.
Buzz group

Two by two:

- Use drawing of XT and describe the functionality using the terminology just presented… (10 min)

- Do you have any questions? Clarify in plenary!
X-Mas Tree

Control Module

Umbilical / Manifold I/F

HP Supply

LP Supply

Return

Workover interface
Safeguarding life, property and the environment

www.dnv.com