A subsea separation system is designed to separate the multiphase fluids on the seabed and then send the oil and gas streams with a minimum amount of water either together or using separate lines to the surface for further treatment. Separated water may be re-injected back to formation either for disposal or for pressure maintenance. There are two main subsea separation types - gravity based three phase subsea separation systems and cyclone based two phase subsea separation systems.

**GRAVITY BASED**

The basic gravity based subsea separation system design will include the following:

- a gravity (horizontal or vertical) separator;
- water injection facilities such as injection pump and injection Xmas tree;
- a chemical injection system for treatment of emulsion, foam and corrosion etc.;
- a system for sand separation and removal;
- a system for power transmission and distribution;
- instruments for injection water quality monitoring, detection of separator interface levels and emulsion composition monitoring, and of course measurement of pressure and temperature.

One of the most significant steps taken recently has been the installation and successful running of the Subsea Separation and Injection System (SUBSIS) in Norsk Hydro’s Troll C field. The system was installed in October 1999. However it was not brought on-stream until August 2001. Since then the system has been performing to its specifications with nearly 100% availability. Both water-in-oil and oil-in-water levels have met the key performance requirements. In fact oil-in-water as low as 15 ppm was recently reported when the system was still running at its 100% design liquid flow.

Some of the key design parameters of the SUBSIS system are given below:

- Total liquid capacity: 10,000 m³/d (~ 63,000 b/d)
- Water capacity: 6,000 m³/d (~ 38,000 b/d)
- Oil capacity: 4,000 m³/d (~ 25,000 b/d)
- Gas capacity: 800,000 m³/d (28 MMcf/d)
- Maximum water cut: 90%

Two key performance requirements, which have been met include:

- Maximum oil-in-water: 1000 ppm
- Maximum water-in-oil: 10%
For the Troll C pilot project an article given by Rick von Flatern on "Troll pilot sheds light on seabed separation" should provide some further interesting reading.

Following on the success of the Troll C pilot, a full scale subsea separation and produced water re-injection system was deployed at the Statoil’s Todis field in the North Sea.

CYCLONE BASED

Gas Liquid Cylindrical Cyclones (GLCC) have become well established in the past decade for separation of gas and liquid for the oil and gas industry. Cyclone based subsea separation systems use the same principle. One such system called VASPS (Vertical Annular Separation and Pumping System) was developed in the 1990's. This system enables high capacity integrated separation and pumping equipment to be installed in a 30 to 36 inches conductor in a dummy well. In 2001 the world’s first VASPS system was installed by Petrobras in Campos Basin.

In a VASPS system a multiphase stream from one or more well enters at the top of the pressure housing with a tangential path into the spiral formed by the pressure housing and the helix. The fluid is then directed down to the bottom of the separator guided by spiral conduit. Due to the centrifugal force, gas and liquid are separated. Gas flows upward through the gas holes into the annulus then the expansion chamber before exiting the separator unit while liquid flows to the bottom into the sump where it enters the discharge tubing before flowing out of the separator. An electrical submersible pump is installed at the bottom of the discharge tubing. Both gas and liquid phases are then sent to surface for further treatments.

Further information on the installation, commissioning and start up of the VASPS in the Campos Basin can be seen from the paper by O. R. do Vale et al on “VASPS Installation and Operation at Campos Basin", a paper presented at the 2002 Offshore Technology Conference, Houston, 6-9 May 2002.

FUTURE SEABED PROCESSING SOLUTIONS

Seabed processing is considered as one of the main game changes in the future for improved oil recovery in the offshore oil and gas productions. Two major oil operators joined forces with two subsea equipment designers to create the Seafloor Processing Collaboration (SPC). SPC aims to identify the technology gaps that must be closed for subsea processing to become a reality, also to assist in closing those gaps and to culminate in a pilot test of a fully integrated system in an operating offshore field.

In the proposed configuration well fluids enter the system first through a low-pressure drop cyclone-based gas/liquid separator which separates most of the gas from the liquid and solid. The separated liquid phase then goes to a three-phase separator where oil, water and solids are separated. Separated oil is then combined with the gas, which is separated from the gas/liquid separator, and then sent to surface. Water containing sand will then pass through a cyclone based desander. For the proposed pilot trial, sand is pulled through a water driven eductor and then join the main oil and gas stream, the bulk water is then deoiled using a hydrocyclone. Oil
separated from the deoiler hydrocyclone goes to the main oil and gas stream and water is then re-injected.

Further details of the SPC can be seen from an article by Terry Knott *Shifting to the Seabed* published in BP’s Frontiers, August 2002.

For gas production an innovative technology called Twister Supersonic Separator has been under development for subsea processing and gas conditioning. The technology helps dehydrate and dewpointing and enables dry, single phase export that would eliminate many flow assurance risks and limitations associated with wet, multiphase export systems. Specifically for subsea application of the technology there is a brochure entitled *Twister the missing link for Subsea Processing* from Twister B.V.