BROWNFIELD SITE CHALLENGES

HV WET-MATE CONNECTORS AND PENETRATORS HELP ENABLE SUBSEA PROCESSING

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While offshore drilling activity continues to migrate into deeper waters, oil and gas producers are also looking to extend the life of existing brownfield sites. As these sites mature, the challenges of maintaining a profitable flow of hydrocarbons is leading producers to use innovative methods to ensure unobstructed flows. A variety of approaches allow subsea processing to keep brownfields operating efficiently and profitably. Subsea systems must be modular to allow practical deployment; wet-mate connectors are important enablers in allowing modules to be connected.

In brownfields, as pressure drops, the water cut increases. As the flow rate decreases, the hydrocarbons are cooled faster by the low seabed temperatures. This can lead to the formation of hydrates on the pipe walls or the mixed water cut freezing. Either can restrict flow and potentially clog the pipe entirely. Hydrate formation is combated by adding inhibitors such as MEG (mono ethylene glycol) in the pipes, heating the pipes to maintain sufficiently high temperatures, and maintaining a sufficient flow pressure. A large quantity of MEG inhibitors are required, which must then be removed topside and recycled for re-injection.

Pipeline heating can be achieved by direct electrical heating (DEH) or pipe-in-pipe heating (PiP). In DEH, a cable laid alongside the pipeline heats the pipe by either conduction or electromagnetic coupling. PiP uses two concentric pipes. The inner pipe carries the hydrocarbons; the annulus (between pipes) contains the heating cable and fiber-based temperature monitor sensors. To maximize the thermal insulation, the annulus is either held at vacuum or filled with an insulating material.

The third way to achieve flow assurance is to separate the different phases and types of flow—gas, oil, water, or solids (sand). Typically, this involves subsea boosting, either through gas compression or subsea pumping. Subsea boosting increases the flow rate of the oil or gas to the surface by reducing the back pressure on the well, and therefore increases the recovery factor of the reservoir. For oil, pumping can be used, while natural gases are boosted by compression. Another technique, which can be used in combination with pumping, is to separate the water and oil/gas, injecting the water back into the reservoir to limit pressure drops in the well. This saves energy (potential energy of getting the water to the topside facility and down again into the well), and it saves a significant amount of space and weight on the heavily crowded topside facilities. Figure 1 shows examples of types of subsea processing.

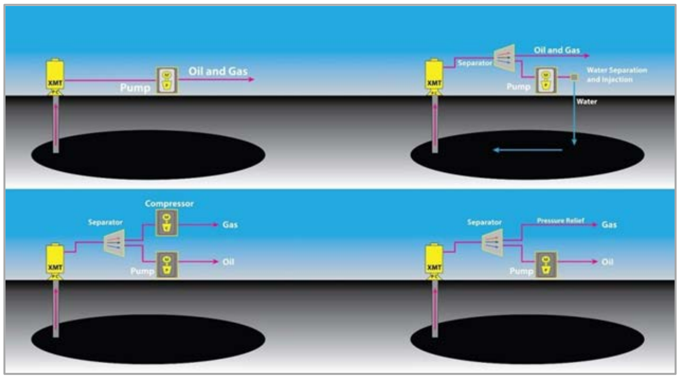

Figure 1. Subsea processing helps maintain flow rates and keep brownfield wells operating efficiently (Source: TE Connectivity)

Modularity Is Key to Deploying Subsea Processing

Moving processing from the platform or shorelines to the seabed creates challenges in the design and deployment of the processing equipment. A limiting factor is the weight of such equipment, especially in deep waters. Weight and size issues require that the equipment is designed in a modular fashion, with modules connected together on the sea floor. For example, transformers, circuit breakers, variable-frequency drives, and the final consumers (pump or compressor) all need to be interconnected. Modularity also presents advantages in retrieving, repairing, or upgrading equipment because it is more economical to replace a module than the entire system.

Where several trains of pumps or compressors are in parallel, modularity allows selective shutdown and retrieval of a module, while the other trains continue to boost hydrocarbon production, increasing the overall availability factor of the subsea station. This also eases maintenance by allowing smaller intervention vessels, which are more readily available than high-payload deployment vessels and less costly to operate.

For pipeline heating, wet-mate connectors allow the pipeline to be deployed with its heating elements. The umbilical cable is separately deployed and used to power the system. The umbilical and heating cables can then be connected on the seabed via ROV (remotely operated vehicles). This makes a more efficient and cost-effective approach. Without the ability to make wet-mate connections, the two cable ends need to be “fished up” to the surface–requiring an extra length of cable–so that splicing can be performed topside. This operation takes a long time, is costly, and depends on adequate weather conditions. Poor weather can disrupt deployment schedules.

Wet-Mate Connectors Enable Modularity

A wet-mate connector is a device that allows connection of electrical conductors. Connectors are designed for a certain current and voltage, frequency, and water depth. Their materials are corrosion resistant and designed to withstand the harsh conditions of subsea environments for their design life, typically up to 25 to 30 years.

For modularity to be achieved, power distribution must rely on wet-mate high-voltage connectors that can be mated or unmated in an unprotected underwater environment. Figure 2 shows a typical wet-mate connector pair. In offshore applications, we distinguish between dry-mate and wet-mate connectors. Dry-mate connectors are mated topside in dry circumstances and then submerged to their rated depth. They cannot be interconnected on the sea floor. A subsea processing system will involve both dry-mate connectors within a module and wet-mate connectors for intermodule connectivity.

Figure 2. Wet-mate power connectors (Source: TE Connectivity)

Application of subsea wet-mate connectors is similar to other connector applications—they are used to directly connect two modules or to connect a cable to a module.

A special type of connector is the penetrator, an example of which is shown in Figure 3. The penetrator is a feed-through connector used to separate chambers from each other or separate a chamber from the outside world. It is basically a bushing designed to accommodate pressure differentials. The inside of a sealed piece of equipment, for example, may be at a significantly different pressure than the surrounding seabed. When possible, subsea modules are pressure balanced—i.e., fluid filled—with the fluid being adjusted at the same sea pressure as outside the module. This allows for thinner walls, reduced weight, and higher reliability as seals are not required to withstand differential pressures. Some modules, such as those containing electronics or other devices such as circuit breakers, cannot withstand pressure higher than atmospheric. Therefore, a penetrator is used to prevent the seawater from leaking into them. On other devices, such as pumps and compressors, which are potentially exposed to the reservoir shut-in pressures, pressure ratings can get up to 15 kpsi/1034 bars.

Penetrators are rated for withstanding pressures—such as 5 kpsi, 10 kpsi and 15 kpsi—which are linked to the reservoir pressure. Required withstanding pressures are related to the fact that the boosting unit is in contact with the hydrocarbons. In case of a shutdown, the whole reservoir pressure may apply to the penetrator. The penetrator serves an environmentally important function: an electrical failure would mean a loss of production, but a mechanical failure would release hydrocarbons into the environment.

Figure 3. Penetrator (Source: TE Connectivity)

On other modules not linked to the oil flow, the penetrators are the barrier ensuring the electrical integrity of the module, preventing the modules from being flooded with water.

Wet-mate connectors, then, are key elements allowing cost-effective and technically feasible deployment, while penetrators are essential to preserve the integrity of the complete electrical power supply and to prevent hydrocarbon release into the environment.

Specifying Wet-Mate Connectors

A high-voltage wet-mate connector is usually specified by the following criteria:

Voltage/Current Rating: Voltage and current handling capabilities are the basic metrics in choosing any power connector. Since power in subsea systems is usually three-phase, a connector is specified through three values, such as 18/30 (36) kV. The first number, 18 kV, is the phase-to-ground rating. The second, 30 kV, is the phase-to-phase rating. The final, 36 kV, is the maximum system voltage.

Some operational philosophies require the connectors to still operate when there is a ground fault on one of the three phases. In that case, the connector needs to withstand the second value (30kV in our example) and is selected accordingly.

Frequency: Depending on the connectors and the application, the frequency can be low (50 or 60 Hz) for transmission. Higher frequencies—up to 200 Hz—are found downstream of a variable-speed drive. For some long, step-out applications, low-frequency AC transmission or DC can come into play.

Water Depth/Pressure: Connectors must withstand not only the pressures of deepwater applications, but also other harsh conditions. Today, subsea processing must withstand depths of up to 3000 meters, and, in the next decade, will need to withstand even deeper depths.

Temperature Rating: Seabed temperatures are usually rather low and very stable, but the connectors and penetrators need to withstand storage temperatures that may be in direct sunlight in places like the hot climate of the Gulf of Mexico or may be in the cold climate of the Norwegian continental shelf. Penetrators must also be able to withstand the high temperatures generated by the modules (up to 90°C) or the hydrocarbons, which may be up to 200°C.

A Typical Interconnection System

Figure 4 shows a typical power-cabling system. An umbilical cable is terminated to a SUTA (subsea umbilical termination assembly), which is roughly equivalent to the wall socket in your home. From the SUTA, electrical flying leads (EFLs) bring power to the pump or other modules. To continue the home analogy, EFLs are like extension cords. A secondary jumper harness ensures connection from the EFL to the penetrator that serves as a transition at the pressurized motor enclosure.

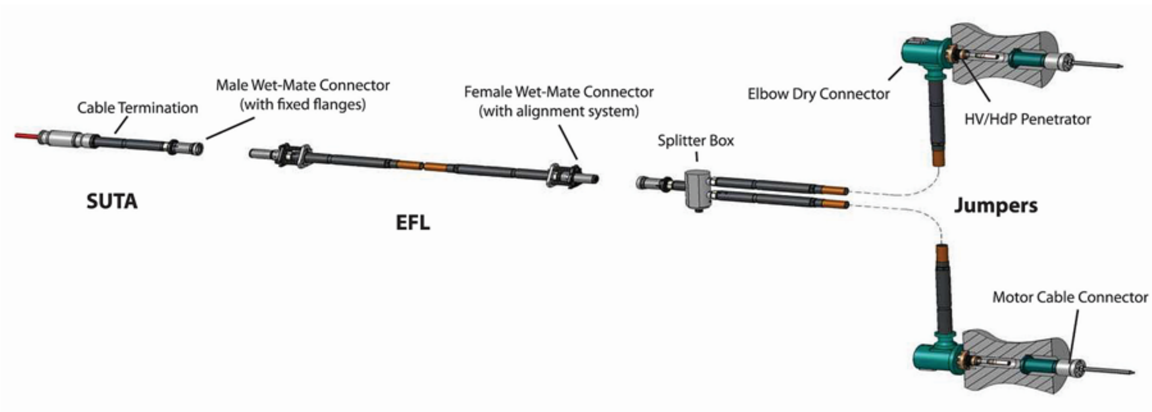

Figure 4. Power-cabling system diagram (Source: TE Connectivity)

Signal and Optical Connectors

Wet-mate connectors also provide a means of communications between the control room and the subsea equipment. They enable information retrieval from the sensors located in the well and related subsea equipment to assess the integrity of the well and related equipment, optimizing reservoir production. Available for both copper and fiber-optic cables, signal-level connectors serve telemetry and control needs.

Conclusion

Wet-mate connectors are highly engineered devices suitable for harsh marine environments. They are a key element of subsea equipment used in the subsea factory processing for oil and gas extraction. They are more complex than standard electrical connectors because of the need to provide a sealed interface that can be maintained at subsea water pressures, carry high voltages and currents, and deliver very long operating lives. Products such as TE's DEUTSCH line of subsea wet-mate connectors and penetrators are the result of years of offshore experience, both topside and undersea. Our product development advantage includes a close working relationship with designers and users of deepwater equipment to best match the connector to application needs, providing for subsea power distribution and subsea processing in a safe, reliable and economical manner.

Author's Bio

Josselin Legeay is Product Manager for High Power Systems within TE Connectivity, Global Aerospace, Defense & Marine. Josselin has more than 10 years' experience with subsea electrical connecters. His areas of expertise include high voltage connectors, connection systems and subsea distribution/collection systems.