UNDERWATER CABLE

WHAT MAKES AN UNDERWATER CABLE?
UT2 SPEAKS WITH SANDER VAN LEEUWEN OF DEREGT CABLES.

Subsea cables are instrumental in supplying underwater systems with electrical, hydraulic or pneumatic power and two-way communications.

Applications can range from connecting remote sensors in very deep waters to carrying large amounts of electricity when connecting wind farms, powering offshore installations from shore or connecting islands or other countries to a central grid.

Complex seismic streamers have to withstand large modulus loads while cables used to lower and retrieve ROVs or ploughs to the seabed must also be strong enough endure significant physical mass.

In general, underwater cables broadly resemble their terrestrial counterparts, but have to confront far more challenging conditions.

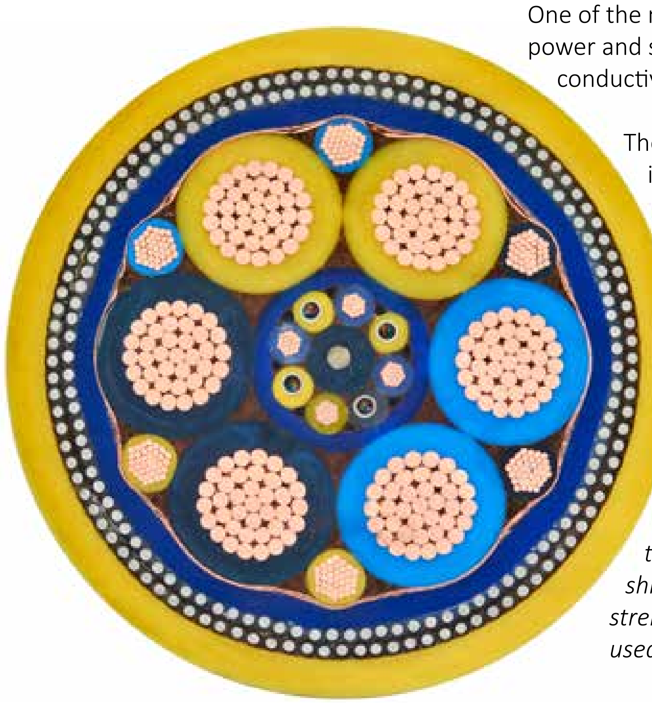
While the design factors of the two remain similar, the potential repair costs are significantly higher in submerged cables. This means having to develop a design that can reliably withstand harsh marine environments, temperature variations, extreme pressures and exposure to salt water, chemicals and marine life over the cable's operational lifespan.

“Although cheaper, off-the-shelf items do exist for simple applications, underwater cables are normally purpose-engineered around a specialist intended function and this typically results in a sophisticated multiple component design," said Sander van Leeuwen, Technical Director at DeRegt Cables

WIRE

One of the most basic units of both power and signal transmission is conductive wire.

The diameter of this wire is proportional to the electric load it can carry. It comes in two variations– a single thicker wire or a number of multi-strand filaments. “Solid wires are the most efficient way of conducting power and signals and these may be particularly useful static applications,” van Leeuwen



Cross section of a typical cable. The foil shield under the outer strengthening cables are used as a Faraday cage.

“If dynamic applications require the cable to flex, then everything above the neutral bending axis stretches while conversely, everything below this accordingly compresses. Cyclical movement will eventually cause a solid metal line to fail due to fatigue stress.

“A common solution is to build up a conductor from numerous wire yarns twisted in a helix. The helix arrangement gives the cable freedom to both bend and elongate without breaking. The bigger the helix angle, the more flexible and stretchier cable becomes.

"For for data transmission, however, excessive strands may pose issues due to the skin effect, where data travels along the outside of the conductor. This can lead to signal distortion in multi-stranded wires, making a solid conductor a better choice for data transfer."

The material of choice for conductor wires is copper. Its inherent advantage is low resistance coupled with good fatigue properties and all for a relatively low price due to the relative abundance of the material. Silver and gold are better conductors but considerably more expensive.

One drawback with pure copper is that it has a maximum operating temperature of only 100ºC, above which it starts blackening and gradually losing its conductivity.

"Another reason copper is a good material is that it can be alloyed with other materials,” van Leeuwen. "By adding Tin, the operating temperature increases to 150ºC while applying a silver coating can be even more successful.

"Magnesium also improves its strength and fatigue life. Alloying the copper with Cadmium results in considerably greater strength and fatigued life for a little less conductivity, however, while still in common use, the heavy metal is very pollutive and is likely to be banned by the community.

"A good alternative material Aluminium. It has a low density of only 2.7kg /Lit (compared with nearly 9 kg /Lit for copper) but has poor fatigue characteristics.

Its low mass makes it ideal for overhead high voltage lines, particularly when combined with steel wires for strengthening, but subsea companies are also looking at this cheap material for long-distance subsea power transmission applications.

"In the far future, Graphene, with its quantum effects of superconducting, promises great conductivity. At present, however,it is still confined to the laboratory, but if cost decreases and availability increases, it may conceivably become common."

At certain voltages, the electrical field can become so strong, that the electrons will effectively jump into adjacent conductors resulting in a short circuit, and generating sparks between the lines.

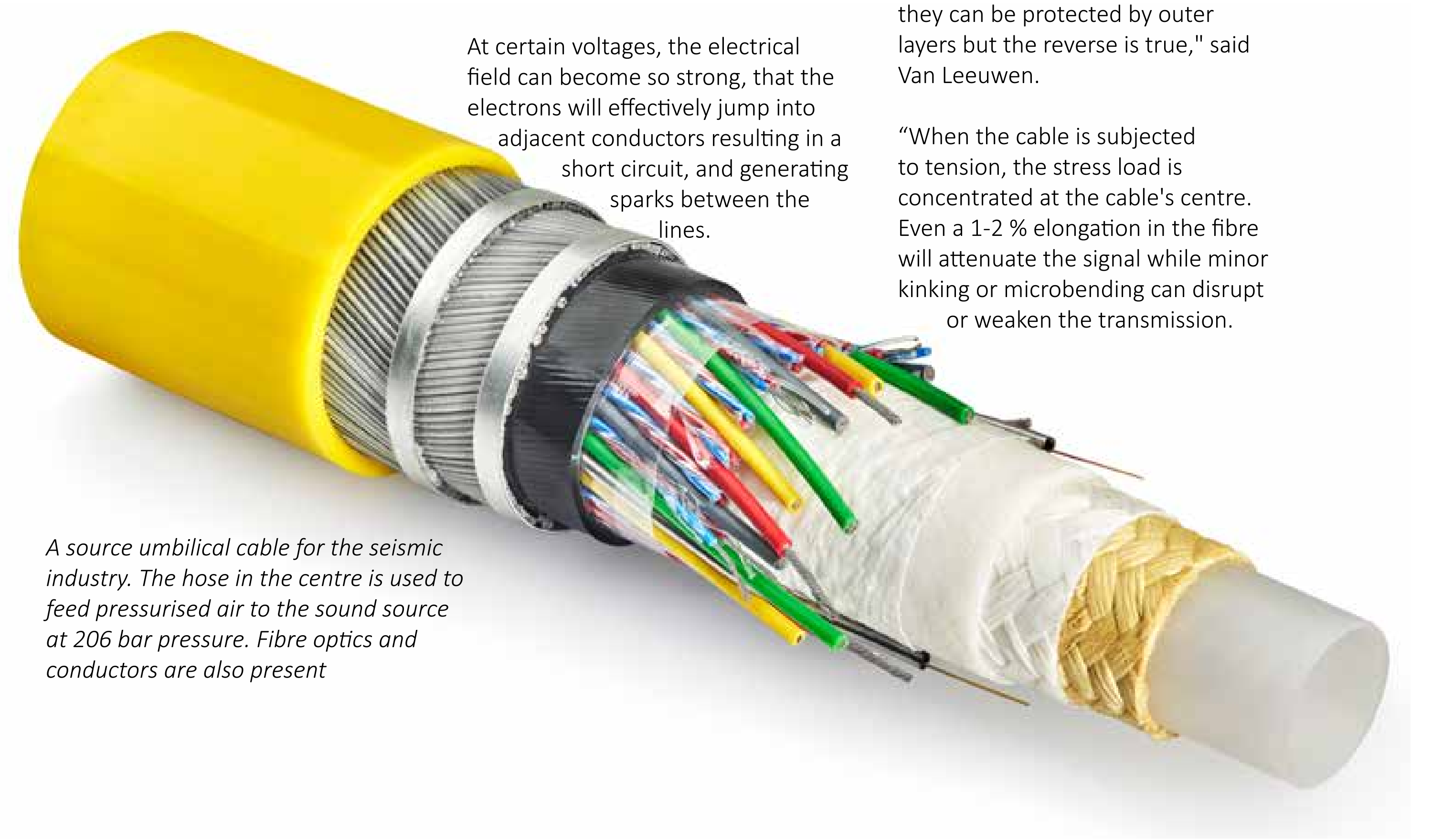
The bare copper wires are therefore normally clad with an insulation material with a higher dielectric strength. This cladding helps shield power conductors from induced electromagnetic frequencies. Similarly, in communications cables, crosstalk or signal interference can be introduced from neighbouring wires.

FIBRE

For communication systems, optical fibres can carry a tremendous amount of traffic- magnitudes than copper conductors. The disadvantage is that they can be very fragile

“One may imagine that these delicate fibres might be positioned at the centre of the cable so that they can be protected by outer layers but the reverse is true," said Van Leeuwen.

“When the cable is subjected to tension, the stress load is concentrated at the cable's centre. Even a 1-2 % elongation in the fibre will attenuate the signal while minor kinking or microbending can disrupt or weaken the transmission.



A source umbilical cable for the seismic industry. The hose in the centre is used to feed pressurised air to the sound source at 206 bar pressure. Fibre optics and conductors are also present

"Instead, the fibres are typically positioned between larger wires nearer the periphery and housed in a steel tubes that offer high crush resistance under pressure.

"Known as STFO (Steel Tube Fibre Optics), FIMT (Fibre in Metal Tube) or FIST (Fibre in Steel Tube), this consists of a small-diameter steel tube containing oxygen-scavenging silicone gel. The fibre can move freely inside the tube.

"The size of the tube may vary from containing just a few fibres to maybe a bundle of 50. The diameter of the protective steel tube depends on the expected water depth and the hydrostatic pressure that it has to withstand. Wall thickness of 6-7mm are not uncommon.

"Sometimes, large export cables such as those in North Sea wind farms incorporate thick power conductors with steel tube fibre optics.

"It is not possible to induce signal interference into the fibre but the power cables may transfer heat into the steel tube, causing damage to the line. One solution may necessitate running the conductor and optical fibre as separate lines.

TAPES

It is common for subcomponent bundles to be bound together with tape. Polyester tape is commonly used because it is very slippery.

"If a tightly-bound dynamic cable moves, the bending moment may cause the one part to compress and the opposite side to stretch," said Van Leeuwen. "Wrapping polyester tape causes the layers to slide past each other and reduce stress.

"Sometimes, a metallic foil tape is used which can also form a Faraday cage to keep all the electromagnetic disturbance on the outside from being induced into the line. Copper or aluminium foil excels in screening against high-frequency noises but are less effective against low-frequency interference."

STRENGTH

Most cable designs require some sort of strength member to limit distortion and provide protection.

A steel armour wire wrapped helically around the cable body is a good way of providing radial strength, but it doesn't prevent elongation. In the same way that a classic land telephone handset cable works, the helix simply extends.

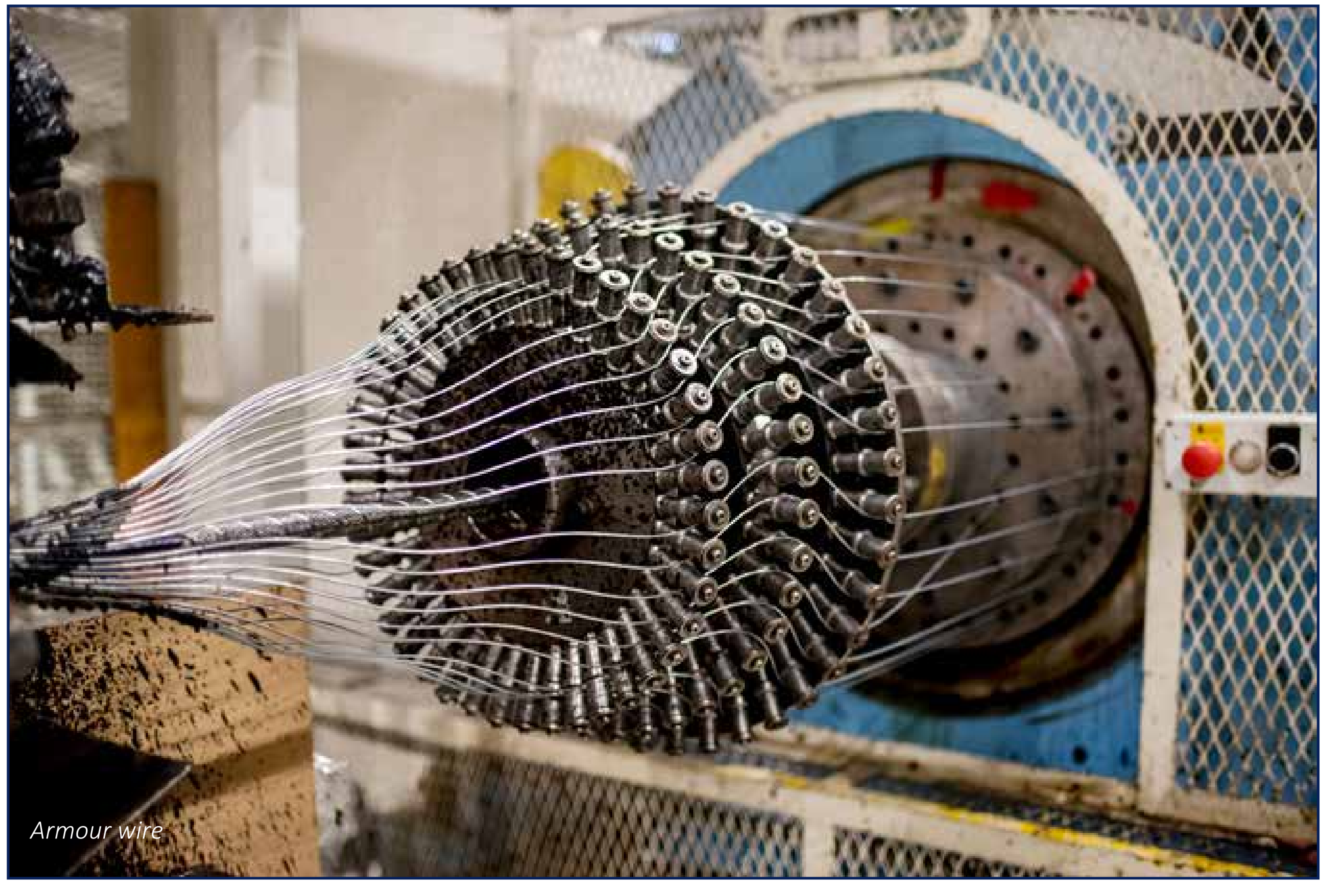
To achieve maximum support It is necessary to apply a second helical armour layer wrapped in the opposite direction of spin to the first, thus balancing the torsion generated. The result is known as being torque balanced.

"In practice, even torque balanced cables have some imbalance because of manufacturing tolerances and material deviations. It is important, therefore, that the cables don't rotate any more than 2deg for every metre," said Van Leeuwen.

OUTER COVERING

At the outside of the cable is a waterproof jacket that provides chemical resistance, physical abrasion and protection against sea water. It may also provide protection against ultraviolet radiation from the sunlight which can inflict degradation of the polymer surface over time.

An extrusion line



Armour wire

"Ultraviolet degradation is true of surface cables, but this also applies to underwater cables positioned 3-10m in the water but still in the photic zone," said Van Leeuwen. "Elsewhere, many underwater cables such as seismic cables are stored without cover on the winch on the back deck of a boats.

"In applications where the cables are exposed to UV light for a long time, the industry has devised two main strategies to protect them.

"Many people like prefer bright colours with their inherent ease of visibility. One is to reflect the UV, possibly by adding titanium.

"A more common strategy, however, is to absorb the light and the easiest way to do this is to add carbon black.

"Carbon black has the additional advantage that it consists of very small molecules and it, therefore, act as a lubricant when the external jacket is extruded on the cable.

"The most common coating materials is polyethylene (which comes in high density version, low density version, cross-link polyethylene and semi-conductive polyethylene.

"Thermoplastic elastomers have good properties in terms of very high toughness and a very low creep.

Polypropylene is also commonly used, but if toughness and abrasion resistance is required, nylon is a very good option.

Another alternative is from thermoplastic rubbers which can be extruded in conventional ways and do not need a vulcanisation process.

CABLE MANUFACTURING

The manufacturing process starts with assembling the subcomponents, some purchased while others preassembled on site. These are introduced into the lay-up machine.

These machines can be horizontal or vertical, the former requiring more space but offering the ability to accommodate more components.

Smaller, less complex cable designs can be manufactured by a single run through a lay-up machine. More sophisticated cables, however, either require a larger lay-up machine, or by multiple runs, each pass adding another layer.

"There are two basic systems," said van Leeuwen. "The first is known as a Planetary Strander. Bobbins containing the subcomponents rotate around the core like planets orbiting around the sun. As this central cable passes through the machine, the bobbins wrap around it. This effectively results them being laid in the helix.

"The other method is called a Drum Twister. The planetary Strander has an inherent disadvantage in that the heavier or larger the components and more complex the design, the a larger lay up machine needs to be to produce the finished cable. The drum twister works in the opposite way.

"Instead of the subcomponents rotating around the completed product, it is the drum with the completed product, that rotates. This means that subcomponents are fed onto it from stationary reels. We do have some drum twisters in our factory for small components but we use planetary systems more complex designs."

So, how many individual components go to make up a cable? "We recently fabricated one cable containing 496 different components. Seismic cables tend to particularly complex. They can contain by power quad conductors and multiple fibre optic lines", said van Leeuwen.

Stored bobbins containing individual cable subcomponents waiting to be installed on the lay up machine

ALLEIMA

Alleima recently unveiled a new alloy designed specifically for subsea umbilicals SAF 3007 is the latest addition to the duplex family of Alleima, a super-duplex stainless steel grade developed for subsea umbilicals.

The new tube offers a safe, lighter, stronger and more efficient alternative to SAF 2507, the current standard. With superior strength, fatigue properties and corrosion resistance.

The new tube product represents the next generation of super-duplex seamless tubing developed specifically for the offshore oil and gas industry. It builds on the success of SAF 2507 (UNS S32750), which has become the industry standard, and further advances the duplex revolution that Alleima pioneered decades ago.

STRONG ENERGY DEMAND

"Across the globe, the demand for energy is growing strong. We see a rising tide of activity in the oilfields off the coast of Brazil, in the Gulf of Mexico, North Sea and Southeast Asia. Following a dip during Covid, this new surge comes, underscoring the need for reliable, cost-efficient energy production," says John Tokaruk, Global Product Manager for umbilical tubing at Alleima.

Over the past 30 years, Alleima has supplied more than 160 million meters (525 million feet) to all major fabricators and applications, equal to circling the world three times.