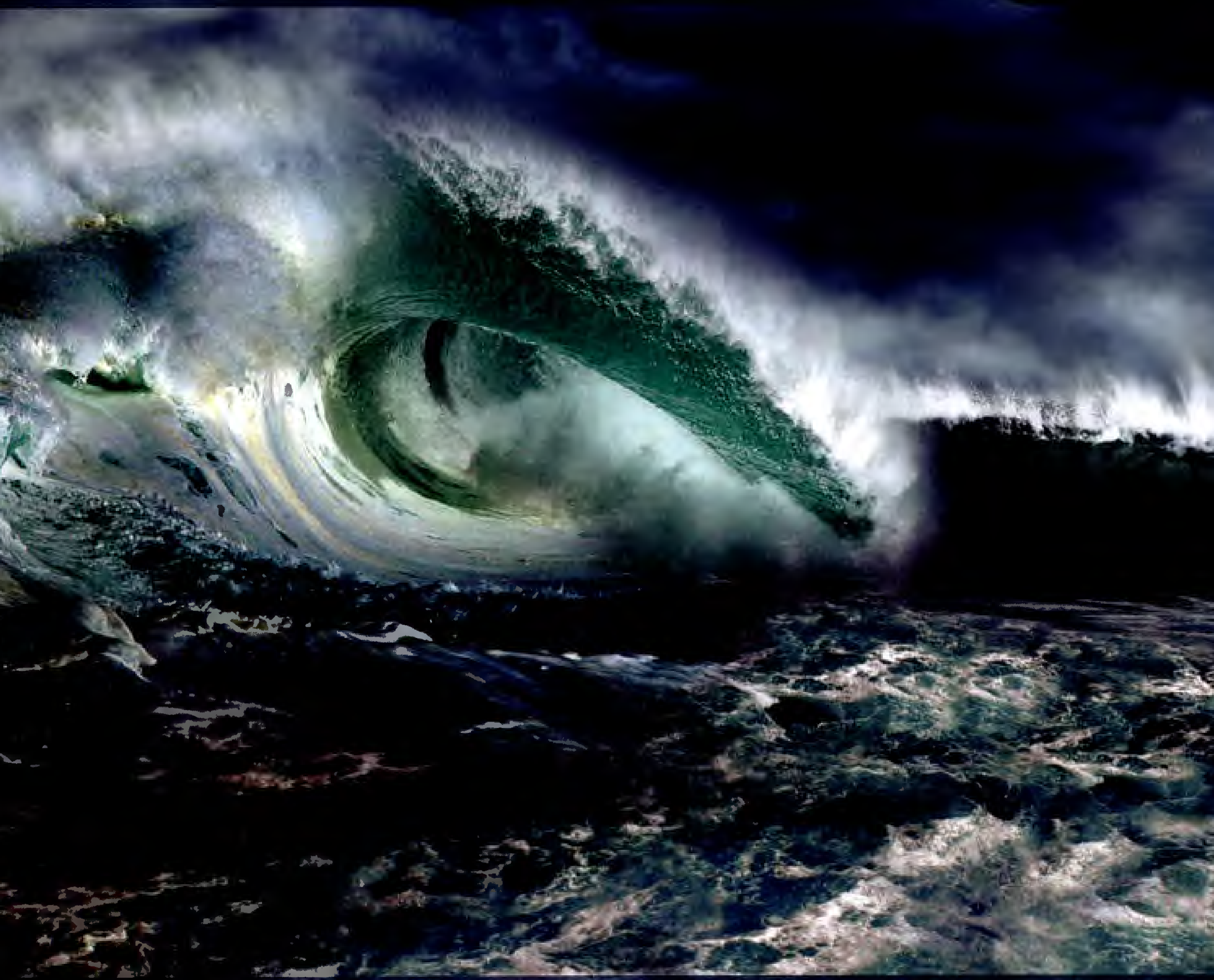
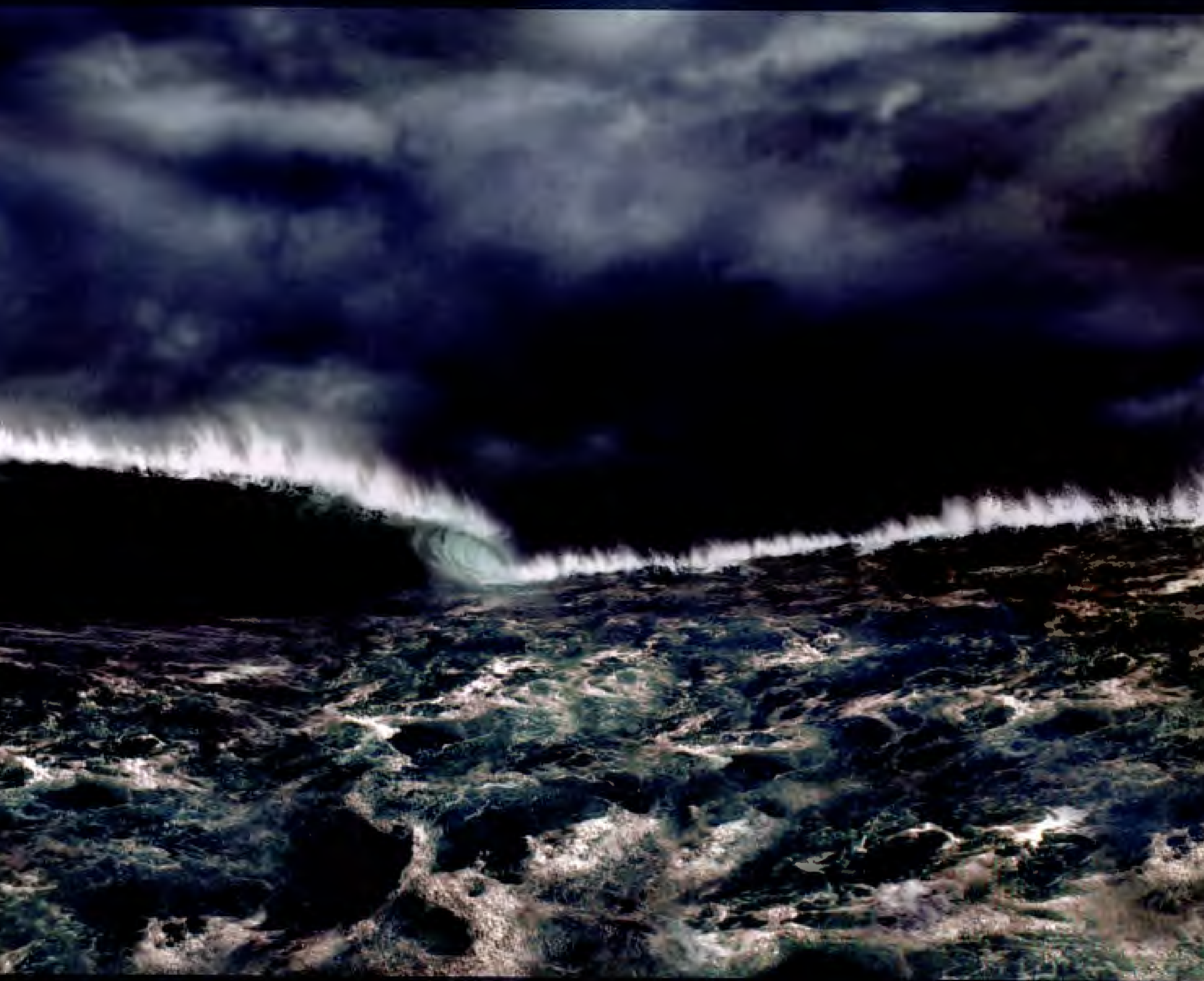
Michael Magerstaedt and Gunther Blitz, ROPLAST, Germany, describe how the construction of the Baltic Sea Pipeline has overcome enormous logistical challenges with a novel pipe protection and security system.



# EXTREME CHALLENGES IN HARSH CONDITIONS



Eventually connecting the European Union to the world's largest gas reserves in Russia, the Baltic Sea Pipeline project is set to make an important contribution to the energy partnership between the EU and Russia and hence to the long-term energy security of Europe. Consisting of two parallel 1220 km long pipelines, the first of which will become operational in 2011, the new connection will have a total capacity of 55 billion $m^3$/yr. Due to its sheer magnitude, the project posed major logistical challenges, which were overcome by means of a sophisticated and innovative concept. Amongst a number of very innovative concepts employed by Nord Stream, a novel pipe cap system for corrosion protection and a pipe tracking method for asset security were instrumental in both the conception and implementation of this award-winning logistics strategy.

## Ingenious solutions to complex logistical challenges

It was clear from the outset that the construction of two 1220 km gas pipelines in the Baltic Sea would pose major logistical challenges. Since the most expensive part of the construction process is laying the pipes, this meant that for each pipe, the entire process from the beginning


Figure 1. Right-of-way and logistics sites (© Nord Stream AG).

to the end of load-out had to take no more than a few minutes. Given the large numbers of pipe joints required, these could be neither manufactured nor labouriously prepared (e.g. concrete weight-coated) within the short time frame of the pipelaying operation. As a result, huge quantities of pipes had to be manufactured well in advance of pipe installation and stored in various locations for lengthy periods of time. Obviously, long storage and complex handling procedures can easily lead to pipe damage.

Due to the time-critical nature of laying the pipes, there were two ultimate logistical challenges. The first one consisted in providing a steady supply of pipes, even in to the most remote parts of the Baltic Sea, to ensure that the costly installation process was completely uninterrupted. The second one was that the condition of every single pipe had to be impeccable at the time of installation. Only by overcoming these two challenges was it possible to meet the project schedule and to stay within the allocated budget. The Swiss company Nord Stream AG tackled the challenges by placing concrete coating hubs near the beginning and end of the gigantic building site to minimise material flow. Also, Nord Stream optimised the use of available means of transport to reduce building site traffic and emissions. This resulted in an error rate of zero in the material supply and hence in an uninterrupted construction process. Moreover, new employment opportunities were created in regions with a weak economic structure. In recognition of these achievements, the German Logistics Association (BVL) chose Nord Stream for the prestigious German Logistics Award in 2010.

## The ROPLAST pipe cap system for corrosion protection

The logistic concept implemented by Nord Stream AG not only meant that large quantities of pipes had to be stored for long periods of time, but the entire project cycle involved up to 20 handling operations. This is due to the fact that five distribution ports with various stock yards each were involved to reduce transport distances A final pipe inspection before load-out to the pipe laying vessels was first considered to ensure that all pipes were completely free of any type of damage and contamination associated with storage and handling as well as other types of adverse effects. These notably include corrosion and contamination resulting from condensation, weather, and environmental conditions, and even third-party interference. Given the tight time constraints of approximately three to four minutes for laying each pipe, a solution involving individual inspection and subsequent cleaning was soon discarded as impracticable. A commonly applied system for the protection of pipes involves caps made from relatively cheap plastic to prevent damage and contamination of the pipes in the first place. In this solution, desiccant bags inside the pipe joints are indispensable to prevent damage from condensation. However, since the bags need to be removed again before load-out and may even spill their contents inside the pipe joints occasionally, this approach too also was ultimately rejected because of the time factor.

Figure 2. Inner cap.

Figure 3. Membrane in inner cap.

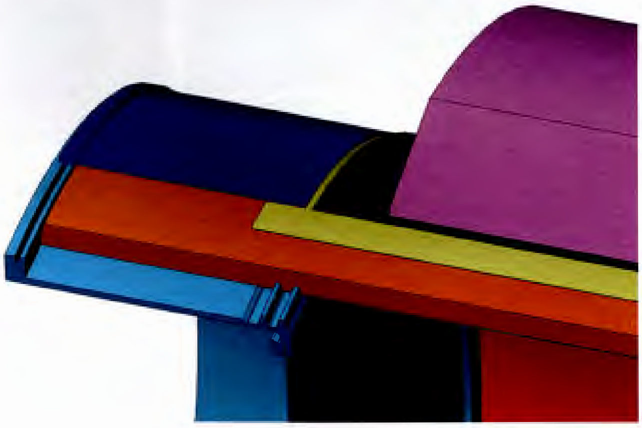


Figure 4. Outer cap with inner cap zip-lock system.

Instead, a pipe cap system was then devised that would guarantee the perfect condition of each type without any desiccant bags, despite long storage and extensive handling, thus making inspection and cleaning redundant and permitting highly time-efficient installation. Pipe caps offering maximum protection were developed and manufactured by ROPLAST, a subsidiary of the ROSEN Group specialising in high-performance elastomers, which are exceptionally resilient to a wide range of adverse influences such as temperature changes and physical impact, etc. These excellent protective properties of the caps are important, because the pipe joints feature inner cutbacks made from blank steel without epoxy coating and outer cutback of blank steel with no PE undercoat and no concrete coating to enable welding together the pipe ends during the installation. Given the northern maritime environment of the operation, it was vitally important to cover these unprotected areas to prevent rust formation. The task in hand then was to ensure full protection of the inner and outer cutbacks, to prevent accumulation of condensate forming in the pipe joint interior, and more generally to provide a physical barrier against dirt and debris as well as insects and small animals. A specially developed two-part cap system consisting of inner and outer high-performance polyurethane elastomer caps provided the answer.

The inner cap reaches far enough into the pipe to prevent the arms of the hydraulic spreader from damaging the pipe as the spreader bar reaches into the inner cap during the handling process. In addition, the cap material has very high compressive strength to avoid damage to the extremely heavy pipe joints (up to 30 t each). On the outside, a collar (outer cap), which is smaller than the outside diameter of the pipe, is mounted to ensure the structural stability of the cap and to protect the bevel. Its profile at the outer boundary provides adequate sealing of the outer cap. On the inside of the pipe is a second collar with sealing lips. When the cap is pushed into the pipe, the sealing lips will bend, thereby creating contact pressure. Providing the necessary grip of the cap on the pipe interior, the sealing lips compensate for shrinkage and expansion resulting from changes in temperature to which the pipes are exposed. Additionally, the sealing lips also accommodate ovality and differences in internal pipe diameter.

The inside of the cap is equipped with a membrane which is molded into the elastomer very firmly and therefore cannot come loose, due to strong winds for example. Made of breathable material, the membrane allows moisture to escape through the cap surface. Despite being moisture-permeable, the membrane has high tear strength and is UV-resistant. The width of the outer cap is determined at one end by the FBE cutback and at the other end by the outer collar of the inner cap. Since the outer FBE coating is very smooth and thin, a good sealing effect is achieved. Once installed, the even and very tight fit of the outer cap eliminates any air entrapments, thereby effectively protecting the outer

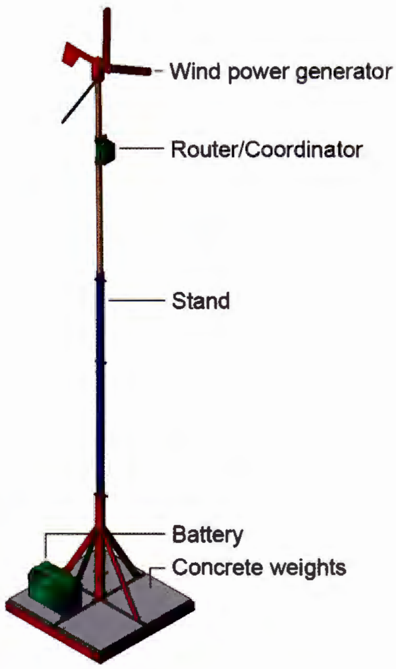



Figure 5. Self-sufficient router/repeater system.

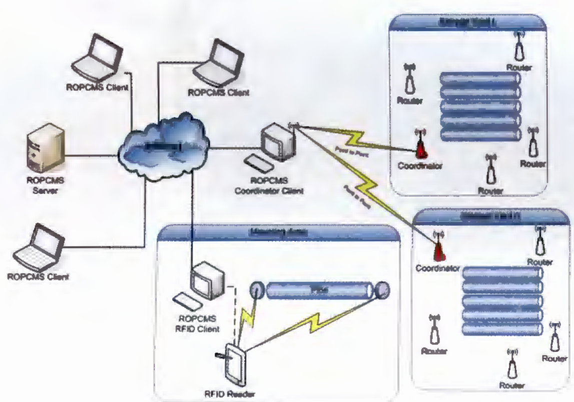



Figure 6. Central control system.

Figure 7. Capped pipes in storage yard.

bevel from weathering and corrosion. Also made of high-performance elastomer, the outer cap has a hardness of approximately 65 Shore-A. With an elongation at break of 500%, the material is very flexible and completely resistant to weather conditions. Last but not least, it has a high density and therefore the oxygen-permeation rate is much lower than that of other materials.

Within three months of the conception of the new pipe cap system, the construction of manufacturing equipment (e.g. moulds and casting machinery for polyurethane casting) and mounting devices for the caps was begun. After only five months, fully functional caps were approved by the operator. Because two pipelines will ultimately have to be laid, the cap system was designed in such a way as to be reusable for protection of the second line. Testing subsequently confirmed that the novel pipe cap system effectively protects inner and outer cutbacks from corrosion and pipe joint interiors from contamination and condensation, thereby guaranteeing the full internal cleanliness of some 210 000 pipes.

## A sophisticated pipe tracking system for safety and security

The system, jointly developed by the operator and ROPLAST, went well beyond physical protection by means of polyurethane elastomer caps. Since damage may occur or could even be deliberately caused by third parties, despite the best physical protection systems, it was necessary to conceive a system that would further facilitate the complex logistics of the project and protect system components both during installation and beyond. Inspections that could realistically be carried out on site prior to laying were limited to a visual examination. Hence, a system had to be designed accounting for the condition of pipes up to the point of load-out by creating a traceable storage history for every single pipe joint through constant monitoring for potential damage.

In response to this need to track pipes and provide protection from accidental and deliberate damage, a pipe tracking solution based on near-field communication was developed. To enable real-time monitoring of all pipes at all times and all locations, all pipes are equipped with a barcode number, which is painted onto the interior coating at the time they leave the pipe production plant. The encoded pipe serial number is stored on a Radio Frequency Identification (RFID) chip integrated into the pipe cap system. With this serial number, the pipe cap system allows complete tracking of each pipe joint from concrete coating to load-out. Being able to account for the location of all pipes is indispensable for a constant supply of building materials at the construction site and thus an integral part of the logistics strategy implemented.

To ensure pipe safety and security, the inner pipe cap holds an e-box containing sensors, a battery, the RFID chip and a wireless transmitter. The e-box provides alarm messages by radio frequency (RF) transmission if any sensors are triggered, for example if the membrane described above is ruptured or in case of third-party interference. Whenever the sensors detect an anomaly, the pipe number is transferred together with the type of alarm, the date and the time of day. In addition, the e-box sends 'alive' signals at regular intervals to communicate that the e-box itself is functioning correctly.

Special central control software receives all communication from e-boxes and analyses the incoming messages. Events that clearly do not pose a threat are excluded before the alarm is triggered. Once an alarm message does reach the operator, security personnel is automatically dispatched to physically check the specific pipe joint in question. The beauty of this system is that the operator is able to track back all potential incidents on the basis of an analysis of all types of alarms, thereby preventing quarantined pipe joints from being loaded out. This pipe tracking system not only makes current construction and subsequent operation of the pipe system much more safe and secure, it is also extremely cost-efficient compared to a conventional guarding system involving fences, cameras, watchdogs and trained security guards.

## Conclusion

Despite the fact that the new pipe cap and pipe tracking systems were developed over a very short period of time, they have already proven their viability. The construction of the first pipeline, which has been in progress for some time has now shown the following: the automated mounting and demounting equipment works well, making for a smooth load-out of pipe joints, and the alarm system has reliably indicated precarious situations. Most importantly, repeated audits have revealed that the pipes being installed meet all cleanliness and integrity requirements. This was achieved by the protection from corrosion and contamination provided by the high-performance elastomers and by e-box monitoring. The Baltic Sea Pipeline project is thus a prime example of how even extreme challenges in harsh climatic conditions can be overcome by close cooperation between innovative companies specialising in different fields. **WP**

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