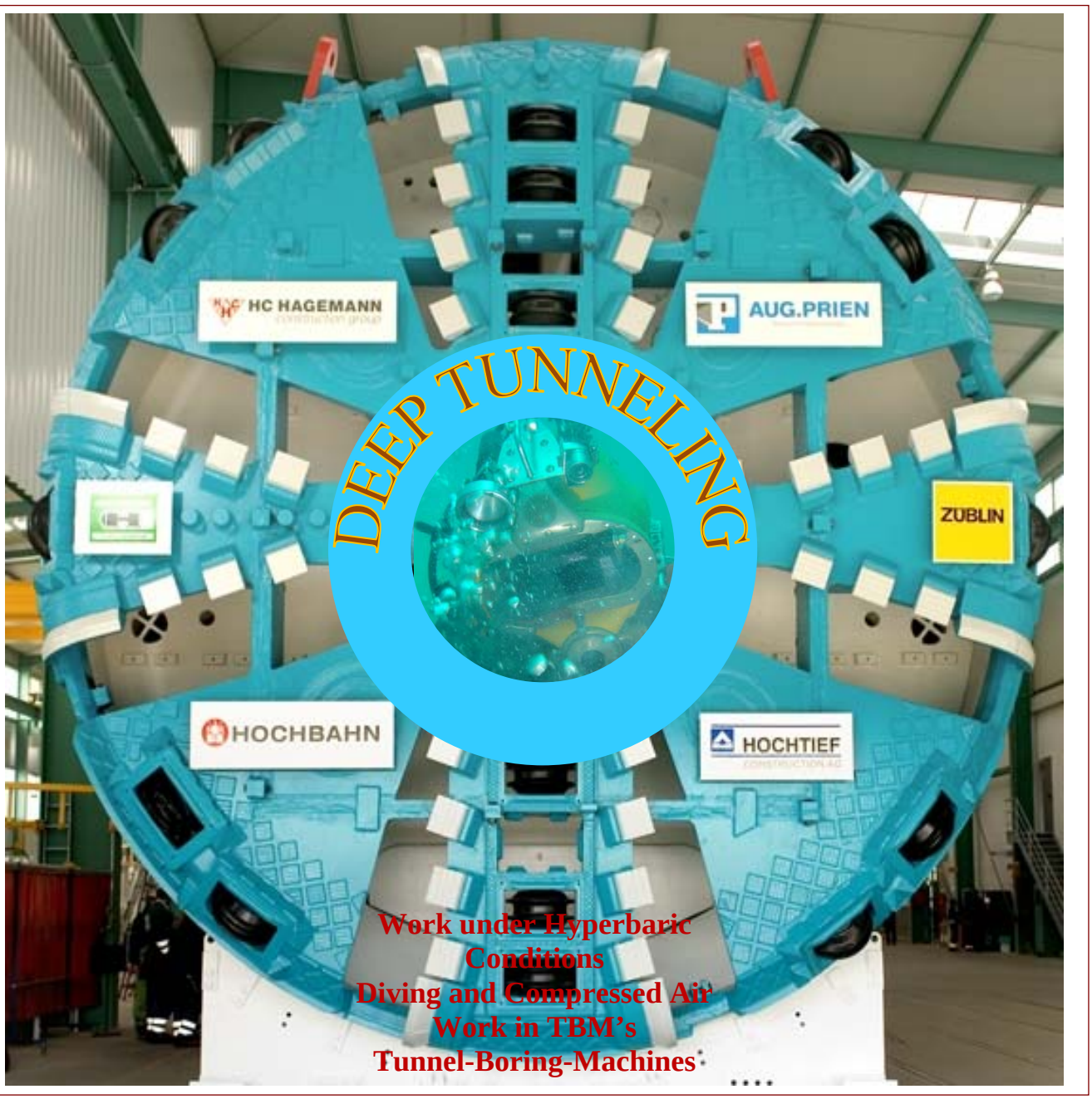
NORDSEETAUCHER GmbH

Hyperbaric Tunnel Construction and Diving®

and

HERRENKNECHT Tunnelling Systems



Work under Hyperbaric Conditions
Diving and Compressed Air
Work in TBM's
Tunnel-Boring-Machines

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Work under Hyperbaric Conditions
Diving and Compressed Air Work in Tunnel-Boring-Machines (TBM's)

Below a depth of 40 metres (which equals 4.0 bars over pressure) workers enter a zone where it is no longer effective to carry out compressed air work under conventional conditions. However, because the next generation of tunnels will be longer and deeper than anything we have at present, it can only be a matter of time and opportunity before divers start playing a key role in hyperbaric work.
When Nordseetaucher GmbH was asked to cooperate on a project to build two tunnels under the Westerschelde in the Netherlands, we didn't hesitate a moment, knowing that it would be an ideal opportunity to put to use the skills and expertise we had gained during our 4th Tube of the River Elbe Tunnel and Wesertunnel contracts. However, the problems we could expect to face were on a slightly different scale. In the Elbe Tunnel we were working under pressures of up to 4.5 bars, while work in the Wesertunnel was carried out at 5.0 bars. The brief for the two tunnels of the Westerschelde Tunnel Project called for us to work at pressures of up to 8.5 bars.
For several decades, a number of methods and procedures have been tested and applied in international commercial offshore diving which can also be used in machine-driven tunnel construction projects carried out in hyperbaric pressure in excess of 5.0 bars. For instance the use of mixed gas. These gases are a mixture of oxygen and various inert gases, blended according to the specific pressure spectrum to allow the divers to work for days and weeks under pressurised conditions (saturation method). At hyperbaric pressures of between 3.0 and 6.0 bars compressed air can be used as working gas with the saturation method, and may indeed be the method of preference in future. In order to use mixed gases safely and successfully, meticulous preparations to the tunnel boring machine and logistical processes are necessary.

Diving in Bentonite

Preparations
To allow manned interventions to be carried out in the bentonite, special flanged connections were installed in the fore walls of the tunnel boring machines. These lines supplied the divers with breathing air, reserve air, communication lines, lighting, video and data transmission, and water to flush the breathing regulators in the diving helmets.

The Diving Helmets
Diving helmets normally used for offshore diving were specially modified to allow them to be used for diving in Bentonite. To make it easier for the divers to breathe in the Bentonite, which is a clay suspension, and to reduce breathing resistance, the helmets were fitted with a water flushing system for the air regulator. The constant supply of fresh water also prevents the breathing membranes from sticking together.

The Umbilical
As the name indicates, the umbilical is the diver's lifeline. The umbilical consists of a variety of differently coloured tubes and cables, which pipe in air, reserve air and fresh water, and also contain communication lines, light, video and data transmission lines.

Diving and Working in Saturation Conditions

The Living Chamber
Saturation diving means living and working under hyperbaric conditions for long periods of time, i.e. anything up to 28 days, although the limits have never been fully tested. To enable divers and engineers to survive and work under these conditions requires a pressurised living chamber consisting of a number of rooms outside of the tunnel zone. Up to 9 divers and engineers can live in this system, and it contains all the necessary facilities, from berths to showers and toilets.

The Transport Shuttle
Due to technical and hygienic reasons, it is not as a rule feasible to locate the saturation habitat in the tunnel zone and link it to the tunnel machine. This makes it necessary to use a mobile transportation system – a shuttle. The shuttle collects the divers from the habitat outside the tunnel zone and takes them to the tunnel, where they dock on to the tunnel machine. Each pressurised shuttle can take up to 4 divers and engineers. Once it docks on to the tunnel machine, the passengers disembark and go to their stations in the control room and the cutter head chamber to carry out all necessary repair and maintenance work to the cutter head.

Hyperbaric Helmets
Unlike in the 4th Tube of the River Elbe Tunnel and Wesertunnel projects, where the pressure was in excess of 4.5 and 5.0 bars, we were unable to work with compressed air under the Westerschelde. Instead, we used mixed gases, consisting of helium, nitrogen and oxygen. The equipment used by the divers was identical to that used in the other tunnel projects. Partially submerged work under the Westerschelde was carried out with the aid of a new, lightweight type of helmet used in the chemical industry. These helmets, which are not available on the free market, were specially refitted and adapted for the task. All tests and trial runs prior to the start of the project were carried out at the Belgian Navy's Hyperbaric Centre in Zeebrugge. This special helmet has two breathing regulators and a controllable cooling system, the latter being essential, as temperatures in front of the tunnel face can reach up to 50°C.