NORDSEETAUCHER GmbH

(N-Sea-Divers)

Hyperbaric Tunnel Construction and Diving®

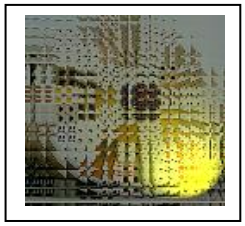
and

HERRENKNECHT Tunnelling Systems

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

NORDSEETAUCHER GmbH

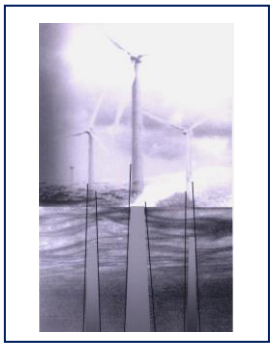
Hyperbaric Tunnel Construction and Diving®



Int. Diving Contractor

OffshoreWind Inwater Service®

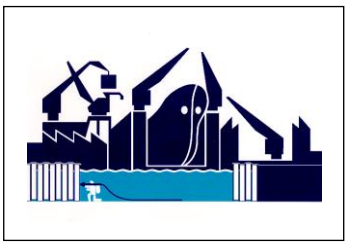
Hyperbaric Tunnel Construction and Diving®



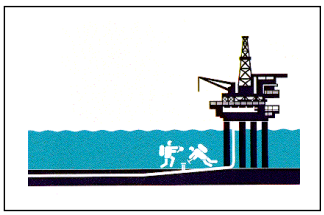
Bramkampweg 9
22949 Ammersbek
Germany

Tel.: +49 4102 23180
Fax: + 49 4102 231820
Mobile: +49 172 4300598

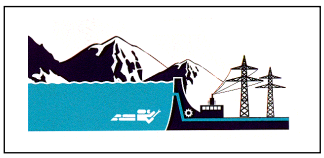
E-mail: info@nordseetaucher.de
Internet: www.nordseetaucher.de



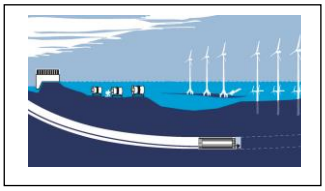
Inshore / Inland



Offshore Oil and Gas



Water Power Plants and Reservoirs



Renewable Energies
Hyperbaric Tunnel Constructions

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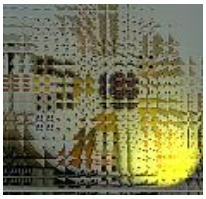

Arbeiten in Überdruck
Taucher- und Druckluftarbeiten im maschinellen Tunnelvortrieb

Ab einer Tiefe von 40 Metern (4,0bar Überdruck) kommt der Druckluftarbeiter in Bereiche wo es von der Zeit her nicht mehr interessant ist Druckluftarbeiten auf herkömmliche Art auszuführen. Da aber die nächste Generation von Tunnelprojekten immer länger und immer tiefer gebaut wird war es nur eine Frage der Zeit und Gelegenheit den Einsatz von Tauchern für die Arbeiten in Überdruck mit einzubeziehen.

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

Below a depth of 40 metres (which equals 4.0bar 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.

Trabajos en ambientes hiperbáricos
Trabajos de buceo bajo aire comprimido para la construcción mecánica de túneles

Por debajo de una profundidad de 40 metros (equivalente a una sobrepresión de 4,0 bar) los buzos entran en una zona donde ya no resulta efectivo llevar a cabo trabajos en ambientes hiperbáricos bajo las condiciones tradicionales. Dado que la próxima generación de túneles se proyectarán cada vez más largos y a mayor profundidad, era sólo cuestión de tiempo y ocasión el destinar buceadores a los trabajos hiperbáricos.

高压氧环境下作业
在隧道掘进机内进行潜水和压气作业

在 40 米水深下（相当于 4bar 的超压），按照常规进行压气作业已不再有效。但是今后的隧道的发展趋势是更深，更长，那么潜水员在压气作业中开始扮演重要角色就只是时间和机会的问题了。

Работы на глубине под давлением

Проведение строительных работ по прокладке тоннелей начиная с глубины 40 метров и при давлении 4,0 бар становится сложным. Это та граница, когда вести строительство тоннеля традиционным способом становится трудно. Однако, как показывает жизнь, большинство новых тоннелей будет прокладываться на все большей глубине и они будут еще длиннее. Это только дело времени, когда к этим работам будут привлекаться специалисты - водолазы.

Nordseetaucher GmbH, Bramkampweg 9, D-22949 Ammersbek, Germany; Tel. +49 4102 23180, Fax +49 4102 231820, Mobile +49 172 4300598
E-mail: info@nordseetaucher.de; Internet: www.nordseetaucher.de

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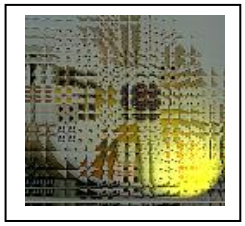

Reference List for Hyperbaric Work
Diving, Compressed Air, Mixed-Gas Maintenance and Repair Work on Tunnel-Boring-Machines (TBM's)

1994

Europipe I and II, North Sea-Germany

1997

Bewagtunnel, Berlin-Germany

1997 - 2000

S-108 4th tube River Elbe Crossing, Hamburg-Germany

1998 - 2002

S-137/38 Westerschelde Tunnel, Zeeland-The Netherlands

1999

M-498 Mompas, San Sebastian-Spain

2000 - 2001

S-152 Wesertunnel, Nordenham-Germany
S-149 Airporttunnel, Zürich-Switzerland
S-140 Bahn 2000-Thalwil, Zürich-Switzerland

2000

S-127 Socatop, Paris-France
M-532 Crosswaytunnel-4th tube of River Elbe, Hamburg-Germany
S-110 Fernbahntunnel, Berlin-Germany

2001

M-611 Neva-Crossing, St. Petersburg-Russia

2001 - 2002

S-164 Lefortovo Tunnel, Moscow-Russia
S-150 Sophiaspoortunnel, Rotterdam-The Netherlands
S-168 Pannerdenschkanaal, Arnhem-The Netherlands

2002

S-205 Peristeri Metro, Athens-Greece
M-518 TENP Los 4/5, Lörrach-Germany
S-170 Deep Sewerage, Singapore

2002 - 2003

S-192 CTRL-Thames Tunnel, London-England
S-175 Oenzbergtunnel, Switzerland
S-200 Herrentunnel, Lübeck-Germany

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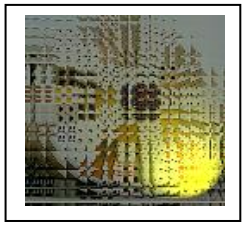


2003

S-209	Aanlegspoortunnel, Antwerpen-Belgium
S-185	Heathrow Airport Tunnel, London-England
S-187	Metrotunnel, Caracas-Venezuela

2003 - 2007

S-250	Silberwald, Moscow-Russia
S-290	Silberwald, Moscow-Russia

2004

S-127	Socatop, Paris-France
S-242	Metro Line 3, Guangzhou-China

2004 - 2005

S-252/53	Smart Tunnel, Kuala Lumpur-Malaysia
S-238	Metro Line 1, Napoli-Italy
M-929	Kura West River Crossing, Azerbaijan

2004 - 2007

S-221	Metro Line 9, Barcelona-Spain

2004 - 2006

S-255	Metrotren, Gijon-Spain

2005

M-000	Medientunnel Leipzig-Germany

2005 - 2006

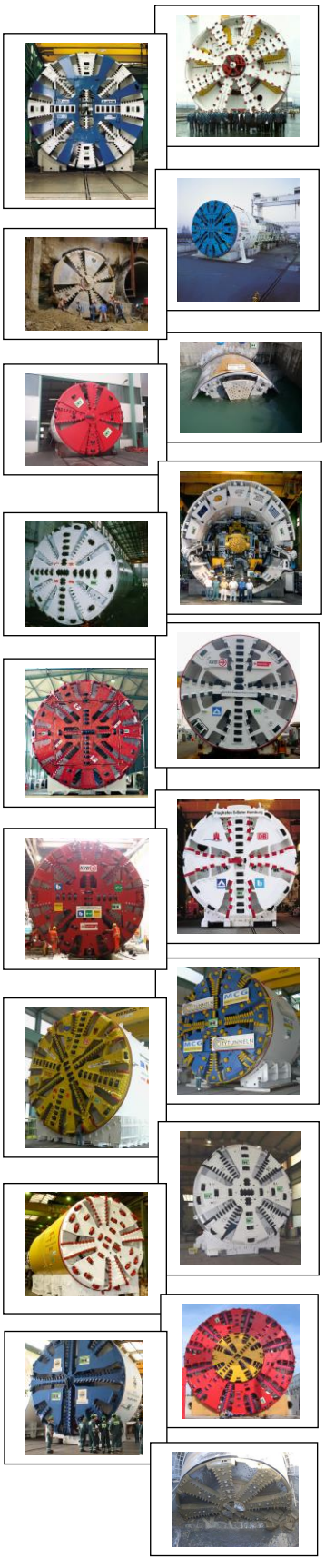
S-258	Flughafen S-Bahn Hamburg-Germany
S-302	Metro de Madrid-Spain

2006

M-675	La Malata, A Coruña-Spain
S-327	Harbour Tunnel, Durban-South Africa
S-320	Almatymetrohurylys, Alma Ata-Kasachstan
M-614	Chateau d'Olonne, France
S-324	Metrotunnel, Ankara-Turkey
S-325	Metrotunnel, Istanbul-Turkey

2006 – 2007

S-331	Fernwärmetunnel, Copenhagen-Denmark
S-314	Stadtbahn Köln Los Nord, Cologne-Germany
S-321/22	Stadtbahn Köln Los Süd, Cologne- Germany
S-127	Socatop, Paris-France
S-328	Metro Strogino, Moskau



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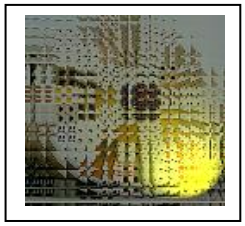


2007

- **S-317/18 Traffic Tunnel Shanghai-China**
- **M-971 Wuhan, China**
- **M-1016 Santander, Spain**
- **S-264/65 Katzenbergtunnel, Germany**

2006 -2008

- **S-260 Metrobus, Brescia-Italy**
- **S-326 City Tunnel Leipzig-Germany**
- **S-340/41 Citytunnel, Malmö-Sweden**

2007 -2008

- **S-334 U-Bahn Linie 3, Munich-Germany**
- **S-389 Thun, Switzerland**
- **S-227/28 Metro Esfahan-Iran**

2008

- **M-1198 Doha-Qatar, Persian Gulf**
- **S-407 Water Tunnel Shanghai-China**
- **M-518M Pescanova Fishfarm, Mira-Portugal**
- **S-358 Yellow River Tunnel, China**

2007-2009

- **S-352 H3-4 Münster / Wiesing-Austria**
- **S-381 H8 Jenbach-Austria**

2008-2009

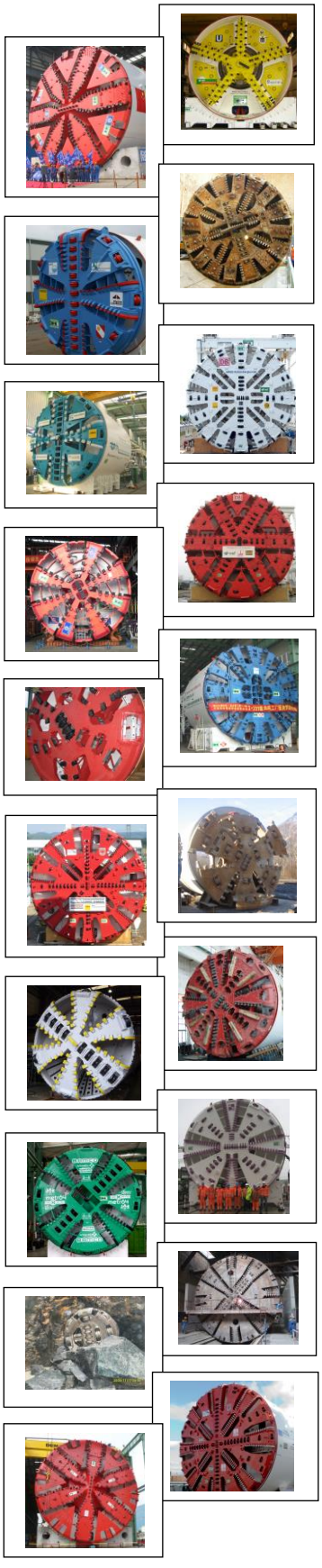
- **S-349/50 Nanjing Yangtze River Crossing-China**
- **M-1193 RS1 H8 Jenbach-Austria**
  RS2 H8 Jenbach-Austria
- **S-419/20 Finnetunnel, Erfurt-Germany**
- **M-254M Sammler Ost, Hamburg-Germany**

2009

- **S-307/08 Metro Tunnel Singapore**
- **S-408 Water Tunnel Shanghai-China**
  Emstunnel, Emden-Germany
- **NFM Railway Tunnel Schlüchtern-Germany**
  RS3 H8 Jenbach-Austria; RS4 H8 Jenbach-Austria
  RS5 H8 Jenbach-Austria; RS6 H8 Jenbach-Austria
  RS16 H8 Jenbach-Austria; RS18 H8 Jenbach-Austria
- **S-477 CREC Tunnel Foshan-China**
- **S-464 Diabolo Tunnel Brussels-Belgium**
- **S-354 Metro Line 4 Budapest-Hungary**

2008-2010

- **S-440 U4 HafenCity, Hamburg-Germany**



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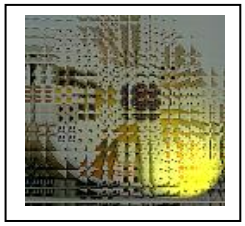


2009-2010

S-227/28	Metro Esfahan-Iran
S-423	Metro Line 3, Cairo-Egypt
M-1061	Sea Outfall, Salvador de Bahia-Brasil
M-907M	Großrohrschirm Zürich-Schweiz
S-221	Ute Gorg, Barcelona-Spain
S-444	Ute Trinidad, Barcelona-Spain

2010

S-246	Hallandsås, Förslöv-Sweden
S-532	LocoBouw, Antwerpen-Belgium
M-1317	Sammlers Ost 2.BA, Hamburg-Germany
M-0000	Düker Brunsbüttel-Germany
M-518M	Großrohrschirm Zürich-Switzerland
S-362	Ute Ave Girona, Girona-Spain
M-1419	Opal Peene Querung Anklam-Germany
M-0000	Maindüker Schweinfurt-Germany
S-509	Metro Tunnel Wuhan-China
S-525	Metro Tunnel Sofia-Bulgaria

2009-2011

S-227/28	Metro Esfahan-Iran

2010-2011

S-491	Wehrhahn-Linie, Düsseldorf-Germany
S-451	Tunnel Weinberg, Zürich-Schweiz
S-547	Kaiser-Wilhelm-Tunnel, Cochem-Germany
M-1186	Sanitary Drainage Networks, Jeddah-Saudi Arabia
S-452	ATUBO Biel-Schweiz
S-551	Nuclear Tunnel Project Taishan-China

2011

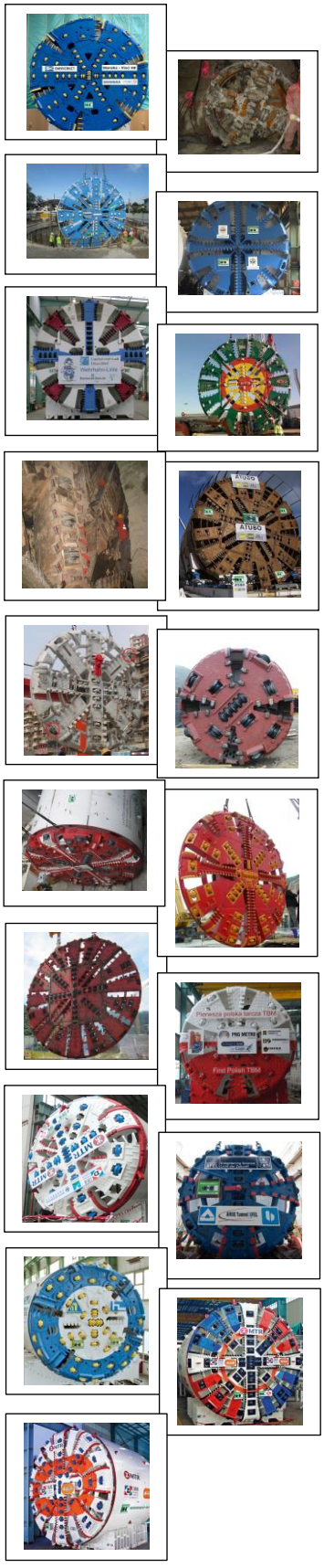
S-546	Metro B Lyon-France
M-1455	CFPP Kraftwerkstunnel W.-haven-Germany
S-642	Wisla River Crossing, Warsaw-Poland
S-550	Railway Tunnel Shenzhen-China
S-554	Metro B Rom-Italy
M1096	Zürich-Oerlikon-Schweiz
S-618	West Island Tunnel-Hong Kong
S-502	Lake Mead, Las Vegas-USA

2010-2012

S-544/45	XFEL Tunnel, Hamburg-Germany
NFM	Railway Tunnel, Beijing-China

2011-2012

S-630/31	Mei Lai Road to Hoi Ting Road Tunnel-Hong Kong
S-597/98	Metro Hangzhou-China



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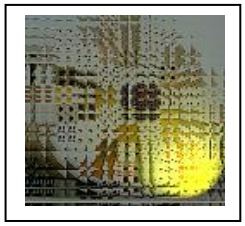


2011-2014

- **S-550 Railway Tunnel Shenzhen-China**
- **S-630/31 Mei Lai Road to Hoi Ting Road Tunnel-Hong Kong**

2012

- **S-644 Metro Warsaw-Poland**
- **S-636 Metro Hangzhou-China**
- **S-668 Road Tunnel Nanjing-China**
- **S-324 Metrotunnel, Ankara-Turkey**
- **S-666 Traffic Tunnel Shanghai**
- **M-663M Drainage Tunnel Catania-Sicilia**

2012-2014

- **CCCC Nanjing Weisan Tunnel-China**
- **S-623/24 Railway Tunnel Shenzhen-Hong Kong**
- **S-731 Crossrail Tunnel London-UK**
- **S-683 Railway Tunnel Nanjing-China**

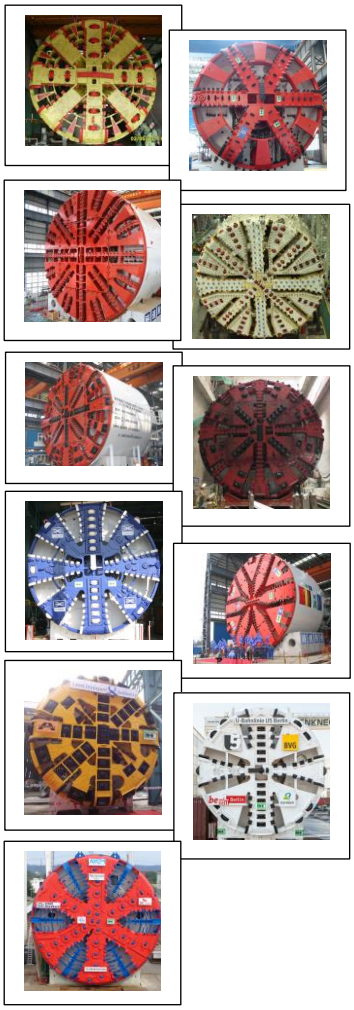
2013

- **S-605 Metro Singapore**
- **S-569 Changjiang Xi Road Tunnel Shanghai**

2013-2014

- **M-1535 Corrib Pipeline Tunnel Ireland**
- **Emscher Tunnel Germany**
- **M-1186 Sanitary Drainage Networks, Jeddah-Saudi Arabia**
- **S-788 Metro Tunnel U5 Berlin-Germany**
- **S-762 Eurasia Tunnel Istanbul-Turkei**

2014



DEEP SEA Tunnel Diving Helmet

Nordseetaucher GmbH, Bramkampweg 9, D-22949 Ammersbek, Germany; Tel. +49 4102 23180, Fax +49 4102 231820, Mobile +49 172 4300598
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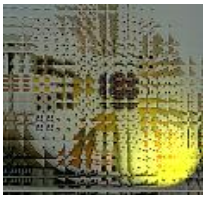
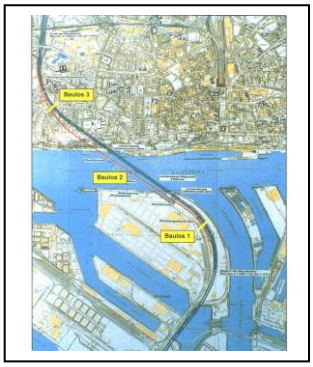


Work under Hyperbaric Conditions
Diving and Compressed Air Work in Tunnel-Boring-Machines

Below a depth of 40 metres (which equals 4.0bar over pressure) compressed air technicians 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 and compressed air technicians start playing a key role in hyperbaric work.

High groundwater head is a major challenge for tunneling in soft ground and weak rock. It has a strong impact on design and operation of Tunnel Boring Machines (TBMs) in order to prevent excessive groundwater inflow, to ensure face stability and to enable access to the cutterhead for maintenance, which can lead to an increase of the required construction period and budget. Designers should keep this in their mind when planning a tunnel alignment.

The 4th River Elbe Tunnel was a milestone in Slurry-TBM tunneling due to the large TBM diameter of 14.2 m, low cover of as small as 7 m and high groundwater pressure of up to 4.5bar.



The southern section of the 2.561 km long tunnel was excavated in glacial deposits consisting of sand, marl and boulders, while more cohesive ground such as marl and clay with sand lenses and boulders was present on the northern tunnel section.

Frequent interventions for cutterhead maintenance were necessary due to presence of abrasive soils. Severe wear was observed on excavation tools and on the backside of the cutterhead which had to plough through accumulated spoil at the bottom of the excavation chamber. Thus intensive and time consuming repair works (6 weeks) were required under compressed air.

At the deepest point of the river crossing, the crew had to enter the excavation chamber and work under compressed air up to 4.5bar.

In total 10,920 work hours were spent under regular compressed air at pressures up to 4.5bar by the engineers, diver and technicians during the 4th River Elbe Construction In total 2,738 man interventions were performed, 237 of them at pressures >3.6bar.

In total 21 cases of decompression illness were reported, all of them occurred at pressures < 3.6bar.

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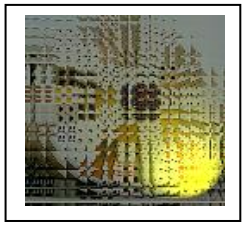
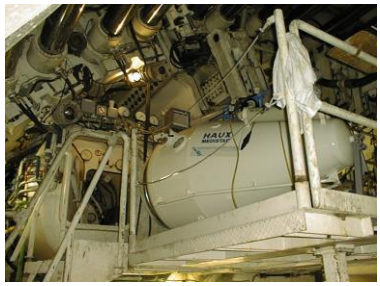
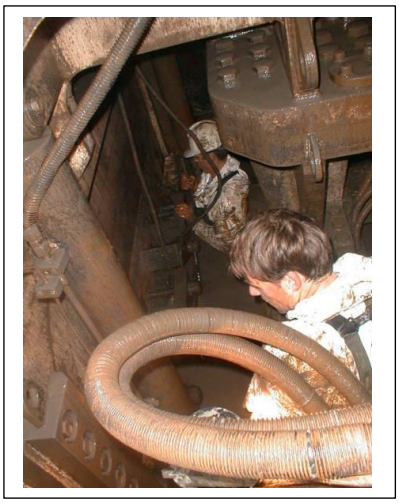




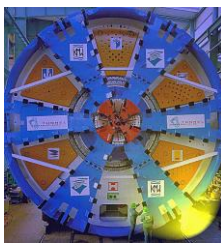
The 4th River Elbe tunnel was the first project where a rescue could be completed by connecting a NATO flange to the compressed air lock on the TBM to enable transport of injured personnel under compressed air pressure to a shuttle for pressurized transport the surface. Fortunately it was not necessary to use it.

The 1.640 km long twin tube **Wesertunnel** crosses the river Weser north of Bremen, Germany. A Slurry-TBM (∅ 11.71 m) was used to excavate the tunnel in glacial deposits. The glacial soil consists of poorly graded and partly very loose cohesion, less sand with hard granite boulders, and very soft to soft clay and peat in shallow areas. Below the river, plastic clays were found to have mainly stiff to hard consistency reaching shear strength values of weak rock.



The tunnel invert's deepest point was 40 m below sea level. Due to tidal influence of the North Sea the water level of the river was typically between +/-2 m above/below sea level and reached in maximum +5.2 m above sea level. Along the tunnel route, groundwater head encountered at tunnel invert was typically in a range of 2.5 to 4.0 bar and reached a maximum of 4.5 bar at storm tide.

Maintenance under compressed air was performed at up to 4.5 bar air pressure for works at the cutterhead and up to 5 bar for works at the stone crusher. Additionally divers were used to work within the bentonite slurry under pressure of up to 5 bar. Regular compressed air (no mixed gases) and oxygen decompression were successfully used. In total 5.000 h of compressed air works and a total of 1.400 man interventions were performed while 600 of them were under pressures exceeding 3.6 bar. Only 15 minor cases of decompression illness were reported, all of them under pressures less than 3.6bar.



The 6.6 km long **Westerschelde Tunnel** is the first tunnel project where saturation diving technique was used for excavation chamber interventions. The twin tube tunnel was excavated by two Slurry-TBMs (Ø 11.33 m). Ground conditions consist of medium to fine quaternary sands within shallow sections and a massive formation of tertiary stiff clay on a length of approx. 2 km. Dense tertiary sands are found below the clay within the deepest tunnel section.

At the deepest point the tunnel invert is at a depth of 60 m below sea level. The water level was typically within a range of +/- 2.5 m above/below sea level and reached about +4.0 m in maximum. The tunnel cover was in a range of 28 m to 40 m.

Nordseetaucher GmbH, Bramkampweg 9, D-22949 Ammersbek, Germany; Tel. +49 4102 23180, Fax +49 4102 231820, Mobile +49 172 4300598
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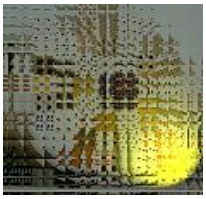
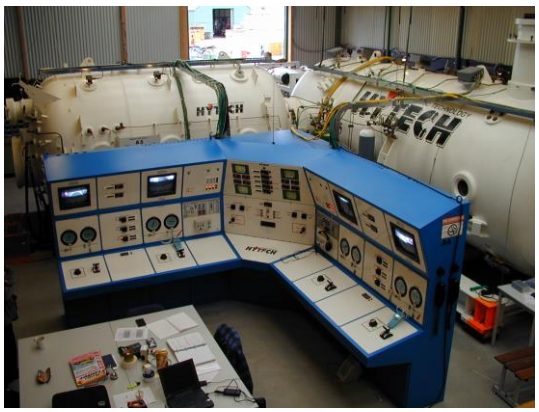
Hyperbaric Tunnel Construction and Diving®



When Nordseetaucher GmbH was asked to cooperate on this 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 Crossing and the Wesertunnel, Germany contracts.



However, the problems we could expect to face were on a slightly different scale. In the 4th Tube of the River Elbe Tunnel we were working under pressures of up to 4.5 bar, while work in the Wesertunnel was carried out at 5.0 bar. The brief for the two tunnels of the Westerschelde Tunnel Project called for us to work at pressures of up to 8.5bar.

It is impossible to work at 8.5bar pressure with compressed air, because the nitrogen contained in breath causes narcosis. Accordingly, from the very start we planned to work using mixed gases.

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 5.0bar.

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 bar 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.

Due to the relatively thin clearance above the tunnel it would have been dangerous to lower the bentonite level in the cutterhead chamber, the excavation chamber. Accordingly, specially trained diving personnel were on hand to carry out inspections and tool changes in the event of repair and maintenance work becoming necessary.

In total, 6 excursions in saturation were performed with a total saturation time of 40 days. The decompression time was 4 days each time. 10 inspection excursions with mixed gas were performed, in addition to 1.652 hours with compressed air involving 546 man interventions. 5 cases of decompression sickness occurred, all of which were successfully treated in the onsite treatment chamber.

Nordseetaucher GmbH, Bramkampweg 9, D-22949 Ammersbek, Germany; Tel. +49 4102 23180, Fax +49 4102 231820, Mobile +49 172 4300598
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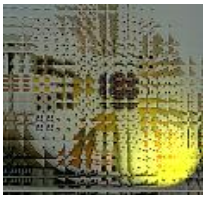

Diving in Bentonite

Preparation

To allow manned interventions to be carried out in the bentonite, special flanged connections were installed in the pressure 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. Those flange connections are also perfect for the new overpressure work helmet.

The Diving Helmet

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 Compressed Air Work 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.

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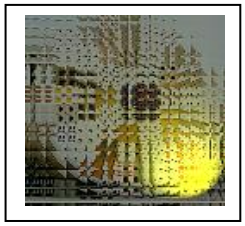


The Transport Shuttle

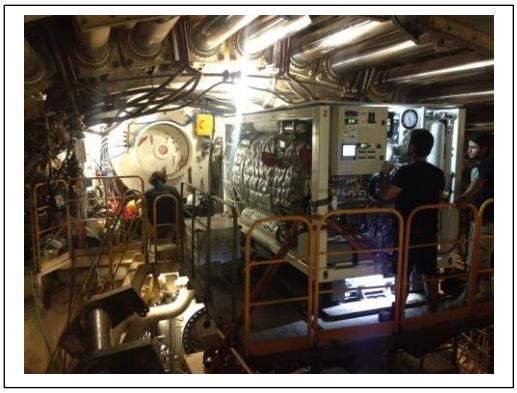
Due to technical and hygienic reasons, it is not as a rule feasible to locate the saturation habitat in the tunnel zone and link it to the tunnel machine. This makes it necessary to use a mobile transportation system – a shuttle. The shuttle collects the divers from the habitat outside the tunnel zone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

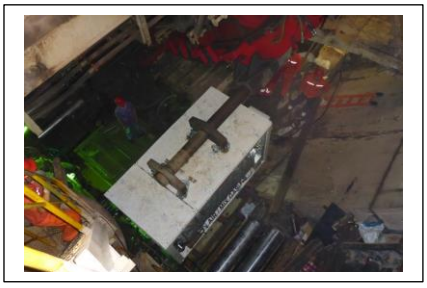
The NEW Technology 2012/2013

Lake Mead (USA) and
Nanjing Weisan Tunnel Project (China)

The new Mixed-Gas-Saturation Generation is designed and manufactured by IHC Hytech from the Netherlands in co-operation with Nordseetaucher GmbH. Those mobile Systems are for overpressure up to 20bar. The containerised System can be installed on the TBM in the shaft and/or on the surface.

The diver/technicians will be transported from the Living Chamber into the tunnel and on the TBM with a special designed Shuttle and Lifting System.





Since September 2013 the designed new Mixed-Gas-Saturation System is busy in Nanjing-China on the TBM of CCCC-China Communication Construction Company.

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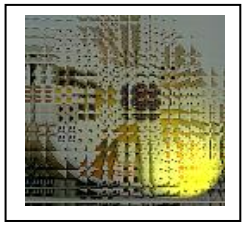

The Hyperbaric Helmet

Unlike in the 4th Tube of the River Elbe Tunnel and Wesertunnel projects, where the pressure was in excess of 4.5 and 5.0bar, 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° Celsius.

The NEW Technology 2012/2013

This new helmet design of Composite Beat Engel, Switzerland is the construction of an overpressure helmet. It has been realized in close co-operation with Nordseetaucher GmbH. This type of helmet - that with an additional kit can be transformed within one hour into a breathing controlled helmet - is now operational in extreme hazardous environment like tunnel machines and gives full satisfaction to the user. Every helmet is provided with connections for surface air/gas supply, an independent emergency air/gas connection and communications equipment.

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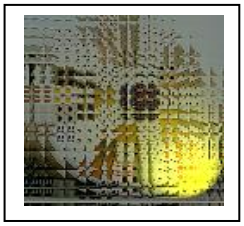

The **Nanjing Yangtze River Crossing Tunnel** is a 2.990 km long twin tube crosses the river Yangtze in Nanjing, China. Two Slurry-TBMs (∅ 14.96 m) are in use to excavate the tunnel in soft alluvium strata. The strata are mainly silt and fine sand.

The tunnel invert's deepest point is 65 m below sea level. Due to tidal influence the water level of the river is typically between +/-1.5 m above/below sea level.

On this project, welding in compressed air was the major task to carry out. From our experience and research of welding in compressed air and under water we knew that it is not a real problem. But this time it was very extreme. The buckets of 6 arms of the TBM had to be renewed. Therefore we welded new supports on the side arms of the cutterhead. The total time of this work took more than 12 weeks, day and night. The pressure was up to 5.4 bar overpressure in air. To keep the support pressure stable we used bentonite with a special mixture of high density and viscosity.

Maintenance and repair under compressed air was performed at up to 5.4 bar air pressure for works at the cutterhead and up to 6.5 bar for works at the stone crusher. Regular compressed air (no mixed gases) and oxygen decompression is successfully in use. In total more than 4.000 h of compressed air works and more than 945 total man interventions are performed. Only 3 minor cases of decompression illness are reported.

For the welding operation we used the first time a new special designed compressed air helmet with triple air supply, two regulators and one free flow, communication and an integrated welding shield with sensors.

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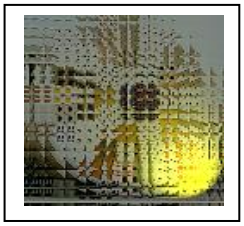
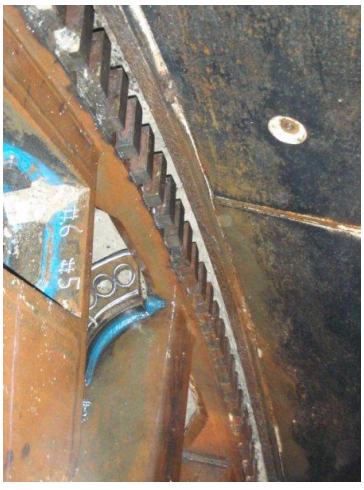


The **Esfahan Metro Tunnel** is a 4.550 km long twin tube between Shohada Aquare and Azadi Aquare. The west and the east tunnel crosses the river Zayandehrood in the south of Esfahan, Iran. The two EPB TBM's (∅ 6.96 m) are in use to excavate the tunnel in soft alluvium strata. The strata are mainly silt, fine sand and gravel.
The tunnel invert's deepest point is 20 m below street level and river.

Welding in compressed air is the major task to carry out. But this time the job is more extreme. The 8 cutterhead arms of the TBM had to be renewed more or less completely from the front side and the cutterhead edge of both machines from the back side. Therefore we welded new vertical side plates and new cover plates on the arms of the cutterhead and new hardox plates on the cutterhead edge. The total time of this work will take more than 6 month, day and night. The pressure is up to 2.0 bar overpressure in air. To keep the support pressure stable we used bentonite with a special mixture of high density and viscosity.



Maintenance and repair under compressed air is performed at up to 2.0 bar air pressure for works at the cutterhead. Regular compressed air and oxygen decompression is successfully in use. In total more than 2.000 h of compressed air works and more than 375 man interventions until 31.03.2010 are performed. No minor case of decompression illness is reported.

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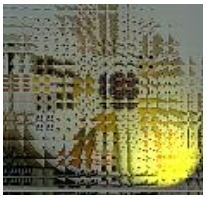

Beijing Railway Tunnel ZJX – 2 Project

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WELDING PROCEDURE SPECIFICATION

WPS No. 004/2011 **Beijing Railway Tunnel ZJX – 2 Project** Job No.: 1-1410

Joint Description: Qualified Professional Hyperbaric Cutterhead Welding accor. EN ISO 15618-1 / EN 287-1 /AWS 3.6D

111/ Rev.: Shielded Metal Arc-Welding Joint No.: 01/Fillet Weld a 25mm
02/2011 Retzlaff Rev.: PA, PB, PC, PD, PE, PF

W01

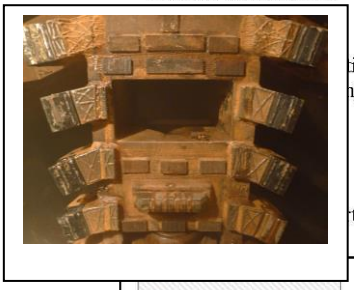
2.8 bar
30-40° C Compressed Air

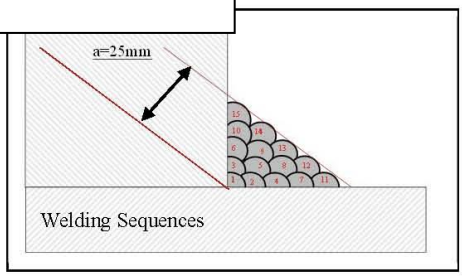
	approved by:	date:
Project Mgr.	Claus Mayer (NST)	2011.04.08
QC Supv.	Martin Wenning (GL)	2009.11.06
Client*	CRTG China Railway Tunnel Group	
ANI*		

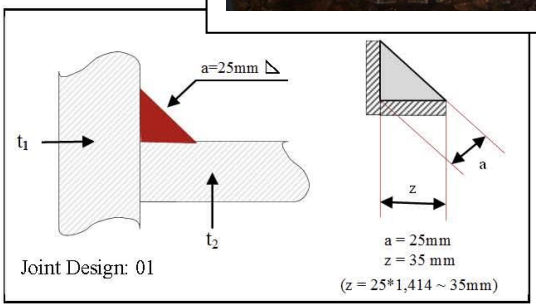
*if required

amrau date of birth: 1969.02.09
Frank Jans date of birth: 1959.10.14

Specification of Base Material	:	S355J2+N
Welding Method	:	Compressed Air -Shielded Metal Arc-Welding (SMAW)
Form of Welded Joint	:	multi –run fillet weld
	:	DIN EN 287-1 / PD, PB, PF
	:	DIN EN ISO 5817:C
ion	:	Fillet Joint
n)	:	1) t1=60mm / =30mm 2) t2=60mm / =35mm / =50mm
	:	NFM / Nordseetaucher GmbH
	:	CREC
tificate	:	GL DIN 18800-7, Class C/D







Name of Filler Material: ESAB OK 53.16 special
Filler Metal: E 38 2 B 3 2 H10 (EN ISO 2560-A)
Details for Welding

Preheating Temperature: 50 – 80°C
Interpass Temperature: max. 200°C

Bead of weld	Process	Size of er metal	Current Intens. A	Voltage V	Kind of polarity	Wire Feed	Travelspeed cm / min
		.50 Ø	ca.80		= -	/	/
		.25 Ø	ca.130		= +	/	/
		.00 Ø	ca.180		= +	/	/
		.00 Ø	ca.180		= +	/	/

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Nordseetaucher GmbH, Bramkampweg 9, D-22949 Ammersbek, Germany; Tel. +49 4102 23180, Fax +49 4102 231820, Mobile +49 172 4300598
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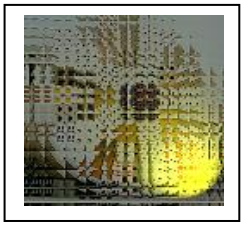
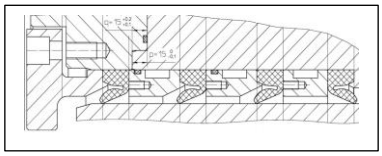


Project: S-636 Metro Hangzhou

Change of the Main Drive Sealing System
at 2.1bar overpressure.



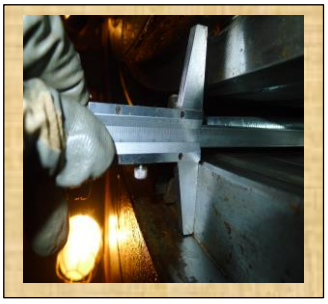
All 4 seals of the Main Drive Sealing System of a TBM were worldwide changed in overpressure in June 2012 for the first time. The unusual feature of this repair primarily consisted that the seals had to be changed, not like in the manufactory in a horizontal layer, in a vertical layer.

To make the dismantling and assembly work easier some grits were mounted in the excavation chamber, so that each place of the Main Drive Sealing System was attainable without problems. The dismantling of the faulty seals and the Chamber Rings was carried out by means of pulling-off devices made especially for it.

Before the opening of the Main Drive Sealing System it was needed to clean the cutterhead and excavation chamber and suck out all material to make sure that no pollutions be able to hinder the seal replacement.
All chamber rings and the seal housing were cleaned from any dirt and grease with high pressure water and cold-cleaner.

The new seals were volcanized with a special bonding device of Nordseetaucher. To ensure a one hundred per cent connection, the device has been heated up to approximately 70 - 80 ° degrees Celsius for three hours.

The correct situation of the single seals and chamber rings were measured before and after the mounting. The measurements record was made according the design plans, delivered by Herrenknecht AG.



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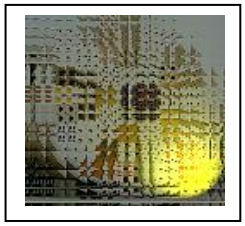

Summary

High groundwater pressure (above 4 bar) makes tunneling much more difficult and requires special knowledge of cutting edge technologies during design and construction. TBM, tunnel equipment and tunneling procedures should be designed to enable reliable application of adequate support pressures at all times during excavation and hyperbaric interventions to counterbalance the acting groundwater head.

If adequate primary components and backup systems are not installed on the TBM, major problems including cost overruns and time delays can occur.

Tunnel excavation in strong, fine grained cohesive soils and rock under high groundwater pressure is generally not problematic for Slurry- and EPB-TBMs, as typically the face is stable and the amount of inflowing water is low due to low permeability of the ground. In coarse-grained soil or unstable rock, tunnel excavation requires a reliable active face support to provide face stability and prevent excessive lost ground during tunneling and interventions. Suitable active face support is easier to achieve with Slurry-TBMs.

Depending on the level of the groundwater pressure, abrasiveness of the ground and the length of the corresponding tunnel sections, the TBM should include provisions for hyperbaric interventions using regular compressed air, mixed gases or saturation diving, depending on pressure level and duration of intervention time expected.

Only in very strong, low permeability soils or in competent rock are risks of attempting cutterhead interventions under free air reasonable (if not otherwise restricted), but there should always be provisions available to apply adequate compressed air support or ground treatment if needed.

The experience gained in the projects proves that the saturation method is a very successful approach to hyperbaric tunnel constructions. It also shows us that work in compressed air is possible up to 6.5 bar overpressure, but not very efficient.

The cooperation between the tunnel construction companies, the manufacturer of the TBM's, the Herrenknecht AG, the Hyperbaric Medic Dr. Faesecke, the Hyperbaric Training Center, Germany, the Classification Company Germanischer Lloyd, the Design and Manufacture Company Composite Beat Engel and the Nordseetaucher GmbH is very rewarding and productive, and we hope that it can be intensified in future co-operations. The excellent training of the diving personnel, engineers and hyperbaric construction technicians involved in this ground-breaking projects, the continual training and the adaptation of the tunnelling machines to the existing conditions open up a highly promising perspective on the future of tunnel construction:
deeper, larger and longer.

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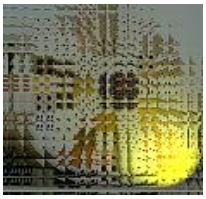

Requirements for Work in Compressed Air and Mixed Gas

Operation Pressure 0.7 – 3.0 bar

Intervention Method	Required Equipment on the TBM	Required Equipment for Hyperbaric Works	Required Personal	Requirement at the Excavation Chamber
Breathing Gas: Compressed Air **Work Method:** Technician in Compressed Air Divers in Bentonite	**Minimum** 1 Air Lock equipped according to Compressed Air Regulation device with O_2 Decompression Excavation Chamber with double compressed air supply lines for safety reasons Compressed Air Breathing System for welding and cutting DN 300 mm Penetration Flanges for diver/technician breathing gas, monitoring, HP-Water and Hydraulic supply	**On the TBM:** Front Gate & independent regulation tank to regulate the excavation chamber pressure during compressed air work Video Monitoring System **At the Surface:** Compressed Air Station inclusive air cooler and air filter	**Compressed Air Supervisor** **Compressed Air Team:** 1 Shift Supervisor 2 trained Technicians changing the tools 1 trained Technician in charge of material handling and service **Surface Team:** 1 Lock Attendant (chamber operator) 2 Service Technicians Max. working time in compressed air 0,7 bar = > 4:00 hrs to 3,0 bar = 2:45 hrs _____ **Hyperbaric Doctor** **Medical Advisor**	Necessary to lower the level of Bentonite under the location of the tools to be changed, to have free access to the excavation chamber

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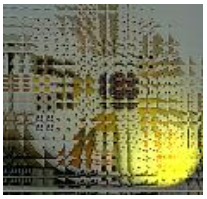

Operation Pressure 3.1 – 5.0 bar

Intervention Method	Required Equipment on the TBM	Required Equipment for Hyperbaric Works	Required Personal	Requirement at the Excavation Chamber
Breathing Gas: Compressed Air or Mixed Gas **Work Method:** Technician in Compressed Air Divers in Bentonite	**Minimum** 2 Air Locks equipped according to Compressed Air and Mixed Gas Regulations with O_2 Decompression Excavation Chamber with double compressed air supply lines for safety reasons Compressed Air / Mixed Gas Breathing System for welding and cutting DN 300 mm Penetration Flanges for diver/technician breathing gas, monitoring, HP-Water and Hydraulic Supply	**On the TBM:** Front Gate & independent regulation tank to regulate the excavation chamber pressure during compressed air work Gas bottles for Mixed Gases Operations, specific Hyperbaric Helmets for the workers (see Nordseetaucher document) Video Monitoring System **At the Surface:** Compressed Air station inclusive air cooler and air filter	**Compressed Air Mixed Gas Supervisor** **Compressed Air Team:** minimum 2 shifts 1 Shift Supervisor 2 trained Technicians changing the tools 1 trained Technician in charge of material handling and service **Surface Team:** 2 Lock Attendant (chamber operator) 2 Service Technicians Max. working time in Compressed Air 3,1 bar = >2:50 hrs to 5,0 bar = 1:00 hrs Mixed Gas 5,0 bar = 2:15 _____ **Hyperbaric Doctor** **Medical Advisor**	Necessary to lower the level of Bentonite under the location of the tools to be changed, to have free access to the excavation chamber For diving in Bentonite extra entrance door below the centre in the lower area. Not necessary to lower the level of Bentonite

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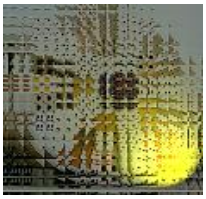
Hyperbaric Tunnel Construction and Diving®



Operation Pressure > 5.0 bar

Intervention Method	Required Equipment on the TBM	Required Equipment for Hyperbaric Works	Required Personal	Requirement at the Excavation Chamber
Breathing Gas: Mixed Gas **Work Method:** Technician and Divers in Mixed Gas Divers in Bentonite Entering in Semi-Sat and Saturation Method	**Minimum** 2 Personnel Locks equipped according to Sat-Diving Regulations Excavation Chamber with double compressed air supply lines for safety reasons Due to the long decompression time, specific equipment at the surface (see Nordseetaucher report) are necessary Mixed Gas Breathing System for welding and cutting DN 300 mm Penetration Flanges for diver/technician breathing gas, monitoring, HP-Water and Hydraulic Supply	**On the TBM:** Front Gate & independent regulation tank to regulate the excavation chamber pressure during compressed air work Gas bottles for Mixed Gases operations, specific Hyperbaric Helmets for the workers (see Nordseetaucher report) Video Monitoring System **At the Surface:** Compressed Air station inclusive air cooler and air filter Saturation Living System 2x Transport Shuttle (see Nordseetaucher report)	**Saturation Mixed Gas Supervisor** **Team:** minimum 2 shifts 1 Shift Supervisor 2 trained Technicians changing the tools 1 trained Technician in charge of material handling and service **Surface Team TBM:** 2 Lock Attendant (chamber operator) 2 Service Technicians Sat.-System Team 24 h Service on request Max. working time in Semi-Sat or Saturation: on request _____ **Hyperbaric Doctor** **Medical Advisor**	Necessary to lower the level of Bentonite under the location of the tools to be changed, to have free access to the excavation chamber For diving in Bentonite extra entrance door below the centre in the lower area. Not necessary to lower the level of Bentonite

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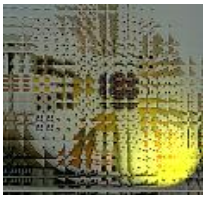
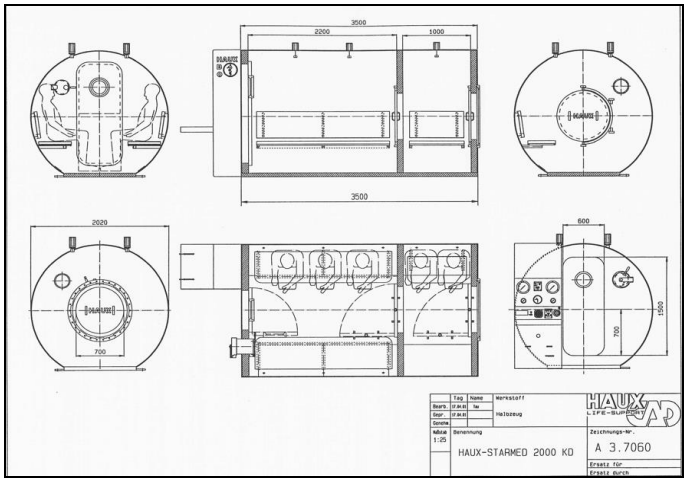


Containerized Hyperbaric- and Diver Treatment Chamber

with Spray Fog Fire Fighting System



Max. Design Pressure	5,5 bar
Max. Working Pressure	5,0 bar
Max. Test Pressure	8,25 bar
Main Chamber Capacity	3 seating or 2 lying persons 2 seating persons
Ante Chamber Capacity	
Chamber Diameter	2000 mm
Length of Main Chamber	2200 mm
Length of Ante Chamber	1000 mm
Length over all, incl. control panel	approx. 4000 mm
Width over all	approx. 2020 mm
Height over all, incl. illumination units	2145 mm

Entrance and Control Panel

HAUX LIFE SUPPORT

Starmed 2000 / 5.5

Treatment Area to the Entrance

Treatment Area to the Ante Chamber

Main Chamber Volume	6.800 l
Ante Chamber Volume	3.100 l
Material	Mild Boiler Steel H II
Number of Doors	3 pieces
Rectangular Door (MC-direct access)	1500 mm x 600 mm
Circular Door, free diameter (AC-direct / MC-AC)	700 mm
Number of Windows in MC (Wall MC/AC and AC/MC door)	3
Window Free Diameter (cylinder wall + doors)	200 mm
Supply Lock (MC-control-panel-side	1
free diameter	200 mm
free length	300 mm
volume	approx. 9 l
NATO/STANAG/DIN-Bayonet-Flange (female) for connection of Rescue Chamber	1 arranged at AC-access
Electrical Connection	230/400 Volt 50 Hz
Electrical Consumtion	approx. 4000 Watt
Certification	German Lloyd
Weight, chamber complete equipped	approx. 14.500 kg

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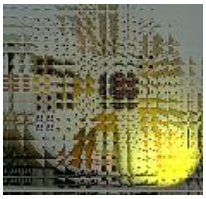


TUNNELDIVING CONTAINER

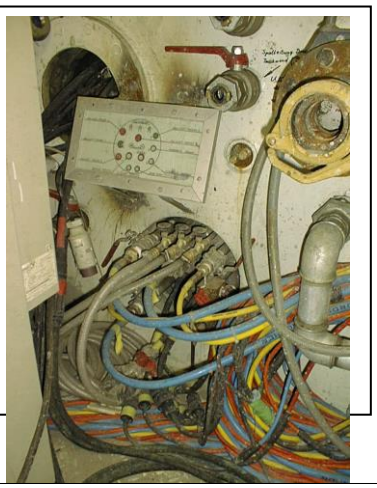
Container Datas:
Length of Container 3,0 m
Length over all 4,7 m
Width over all 2,0 m
Hight of Container 2,0 m
Hight over all 2,25 m

Container Equipment:
1 x 1 Compressor Draeger K 14 200/300 bar
4 x 50 Ltr. HP Air Storage
2 x 50 Ltr. HP Air Reserve
1 x Diver Panel
2 x Communication Round Robin
1 x Video System
1 x Air Test Unit
1 x Office Computer
Spare Parts

Diver Umbilical:
2 x 30 m Container – Flange
3 x 20 m Flange – Diver

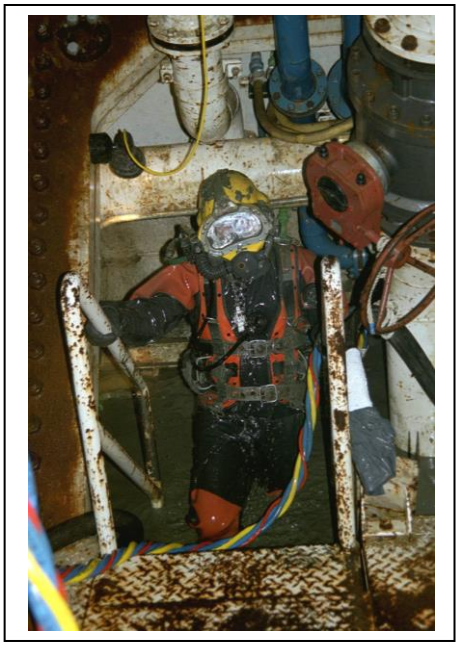
Diver Helmets:
2 x Kirby Morgan 27 / Composite DSL-D1

Diver Suits :
3 x Heavy Duty
3 x Harness + Weight
3 x Gloves



Pressure-Wall Flange:
Flange Diameter NW 300 (460 x 40 mm)

Flange Connection:
3 x 3/8“ LPAir Supply
3 x ¼“ Deapth Measurement
1 x 1” Water Supply
1 x 1” HP Air
3 x Communikation (Round Robin)
3 x Light
2 x Video
2 x Hydraulik Supply (in / out)
2x Power Supply Welding / Cutting



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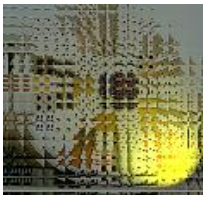

Video Endoscope System
Everest XL G3

A video probe should be always used if the compressed air technicians are unable to inspect the tools at the cutter head in complete safety.

The advanced, proven inspection technology of the XL G3 range of products enables you to inspect and measure the angle, depth and distance of all damage or objects precisely and safely.

Images can be recorded, stored and retrieved for precise, seamless documentation.

References: Herrentunnel Lübeck-Germany; Metro Linie 9 Barcelona-Spain;
Pescanova Fish Farm, Mira-Portugal; CRCC Nanjing Yangtze River Crossing-China

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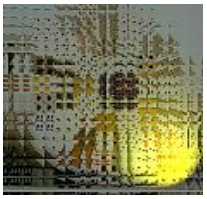


and

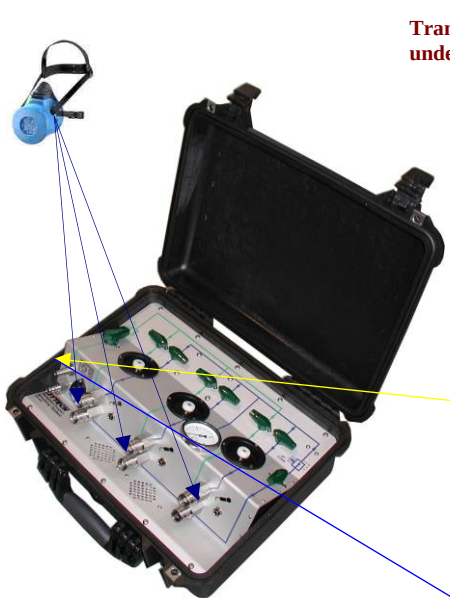
HYPERBARIC TECHNOLOGY HYTECH

presents

POBS - Portable Oxygen Breathing System

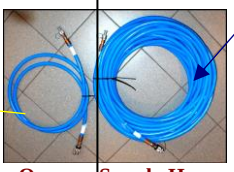
(Utility Model DE 20 2005 014 078)

The portable oxygen breathing system is a solution for pressure chambers where fragile mask and communication connections are not permanently needed. For example locks built into tunnel boring machines, where the lock is mostly used to transfer materials into the head of the machine. The portable oxygen breathing system can easily be taken out of the pressure chamber when it is not in use for decompression. The system can provide up to three masks with oxygen, and has communication connections built in for a 3-channel communication set.



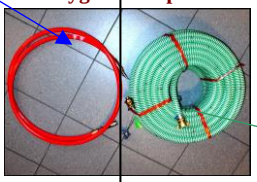
Transfer Lock under Pressure

Med. Oxygen



Oxygen Supply Hoses

Oxygen Dump Hoses



The Oxygen Breathing Unit consists of the following components:

- **A hard case with a built-in mask connection panel**
- **Breathing masks**
- **A frame with a vacuum expiration assistance system**
- **An oxygen pressure reducer**
- **Connection hoses**

To install the system at a pressure chamber, two hull penetrators and a 7-wire electrical connection are needed (minimum 1”)

The Frame can be placed at a safe location to dump the exhaled oxygen. The frame is connected to the pressure chamber with a large diameter exhaust hose.

The frame has an expiration assistance system.

Nordseetaucher GmbH, Bramkampweg 9, D-22949 Ammersbek, Germany; Tel. +49 4102 23180, Fax +49 4102 231820, Mobile +49 172 4300598
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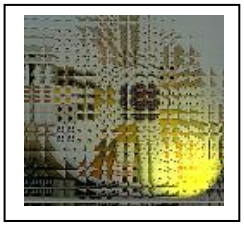

Portable Oxygen distribution system for 3 masks includes:

- Heavy duty transport box, complete with integrated panel, consisting an aluminium anodized control panel, with line diagrams, pictograms, as well as 3 x inhalation and exhalation breathing regulators with a free flow adjustment knob, all with inhalation and exhalation isolation valves.

- The interface hoses between the oxygen inlet and the oxygen outlet system, length each hose 3 meters, and complete with phosphor bronze swaged fittings.

- The chamber wall penetrations with control valves

- Oxygen inhalation and exhalation hoses with a length of 45 meters

- 1 x high pressure oxygen regulator; 1 x oxygen BIBS vacuum controller; 1 x low pressure reducer in the control panel

- Exhaust vacuum system which makes it possible to exhale at shallow depths, and this exhaust vacuum control system will be installed in an ABS heavy duty transport case (identical to the oxygen panel which is used for the portable oxygen control panel)

- All quick connectors on the oxygen control- as well as vacuum panels-, as well as on the hoses-, will be provided with blind caps/protective caps

All fitted together to a full working system.

The breathing masks to be connected to the portable oxygen system

- We supply “Sea Long” resuscitation masks with a soft wearing comfort, better than the most other masks on the market.

- The mask comes complete with a 90 degrees hose adaptor, and the headgear.

- Also masks are designed for long term use, and can be disinfected easily.

The communication system for the oxygen breathing masks:

- The technician wearing a throat microphone, which has to be mounted around the neck / throat, by means of a small rubber strap

The communication box:

- The communication box is a transportable box with handgrip, and front lid to be installed at the position of the lock attendant or supervisor.

- The communication box is provided with a 220 volt power supply, as well as a rechargeable battery.

- Further the system is provided with volume controls, electrical connectors for the power leads running from the chamber to the diver communication box.

- The length of the connection cable between the man lock and the communication system is up to 45 meters, and will delivered complete with a electrical through hull penetrator, which has to be installed in the chamber wall.

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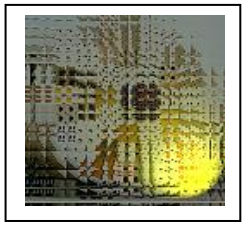

Abrasive Cutting
Underwater and in Tunnel Boring Machines

in co-opearation with

cutting of concrete in a tunnel boring machine

WASS - System
(**W**asser**A**brasiv**S**uspensions **S**chneidverfahren)
is an abrasive cutting system for cutting of concrete and steel, above and underwater as well as for cutting in nuclear power plants and tunnel boring machines.

Technical Datas
cutting pressure up to 1500 bar
water flow 8-10 ltr./min
abrasive (grit) consumption 1,3 kg/min
cutting speed in steel is approx.:
50 mm thickness = 40 mm/min
180 mm thickness = 15 mm/min

The length to be cut was from 250° till 110°.
The height to be cut was approx. 5 cm
The depth to be cut was approx. 110 cm

The nozzles were mounted on top of the cutter head. The hose were connected to the tunnel pressure wall.

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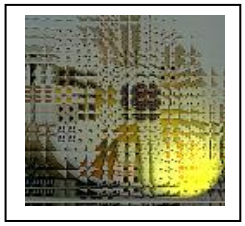
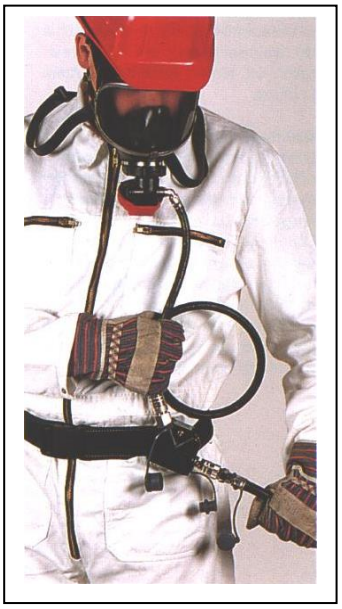


Air supply

Breathing protection equipment

The compressed air filter unit AF 1400 produces breathing air in compliance with international standards from every compressed air source. The unit is fully compatible with all breathing protection devices that run with compressed air. The device can supply breathing air for up to four persons. No electrical socket is required. Its weather-proof, shockresistant and conductive casing makes the AF 1400 ideal for all kinds of on-site applications.



AEROTEST Simultan LP

The Aerotest LP and HP are the standard low and high pressure Aerotest simultaneous kits.

Technical Data

Transport case
Weight approx 4.4 Ibs (2 kg)
Supply Pressure
Maximum 150 psi (10 bar)
Flow
0.2 L/min and 4.0 L/min
Detects Four Contaminants
Oil, CO2, CO, H2O Vapor
For use by
Military, Chemical Industry, Pharmaceutical Industry, Medical Industry and Hospitals, Food Industry, Power Plants, Consultants and Contractors, Offshore Industries, Hyperbaric Tunnel Constructions

AEROTEST Simultan HP

Technical Data

Transport case
Weight approx 6.6 Ibs (3 kg)
Supply Pressure
Maximum 4500 psi (300 bar)
Adapters
CGA 347 (female) connection to cylinder valve
CGA 347 (male) connection to compressor/filling station (G 5/8" or INT)
Flow
0.2 L/min and 4.0 L/min
Detects Four Contaminants
Oil, CO2, CO, H2O Vapor
For Use By
Petro-Chemical Industry, Power Plants, Ship Industry, Gas Industry, Utilities, Fire Brigades, Industrial Hygienists, Manufacturing, Pharmaceutical Industry, Diving Industry

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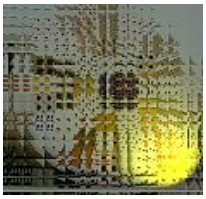

AMT Maschinen- und Gerätetechnik GmbH

Hybrid 600 UW - Hyperbaric

600 A electronically regulated welding power source for welding and cutting in wet and dry hyperbaric environment.

The system concept consists of: power source, wire feeder, cooling unit, remote control, heating mats, welding torches and accessories.

The units are built to EN 60974-1 and meet the additional requirements of welding power sources for underwater wet welding. They may be used during intended use and in compliance with applicable regulations and rules for welding under water and under excess pressure !

System advantages

- emergency shutdown
- low open circuit voltage
- User friendly
- Multifunctional by GMA, MMA, Heating
- compact design
- high process stability
- adjustable Arc-Force
- adjustable Hot-Start
- 100% generator-compatible
- high efficiency
- high reliability

Technical Data

Type	Hybrid 600 UW - Hyperbaric
Mains voltage	3 x 400V, 50 Hz
Mains voltage fluctuation	max. +/- 10%
Power consumption	max. 27 KVA
Power factor cos. phi	ca. 0.99
Efficiency	> 85 %
Open circuit voltage	max. 60 V
Welding current range	20 A – 600 A
Welding voltage range	10 V - 50 V
Duty cycle (no filter mat)	60 % (25 °C)
Dimensions Power source (h-w-d)	400 x 400 x 700 mm
Weight power source (no. periphery)	95 Kg

Our power sources are labeled with CE- and S-Symbol according to EN 60974-1. They are made in Germany.

Nordseetaucher GmbH, Bramkampweg 9, D-22949 Ammersbek, Germany; Tel. +49 4102 23180, Fax +49 4102 231820, Mobile +49 172 4300598
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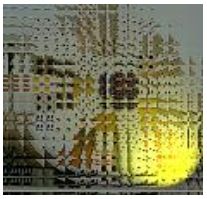


Hybrid 600 UW - Hyperbaric

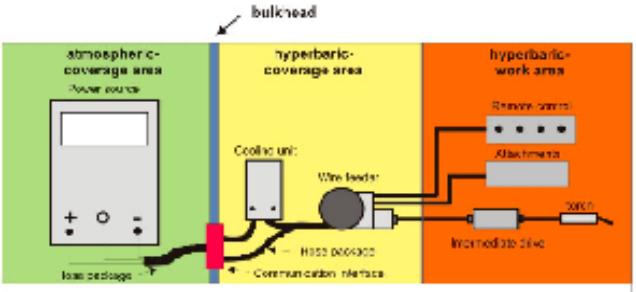
Elektronically regulated GMA / MMA welding power source for welding and cutting under excess pressure in dry and wet conditions.

AMT Maschinen- und Gerätetechnik GmbH

Device concept

The ***Hybrid 600 UW - Hyperbaric*** was developed specifically for welding and repair work in hyperbaric and wet environment. (eg. tunnel boring machine). In developing the system, the valid rules and regulations and the AMT safety concept for under water welding machines have been applied.

In conjunction with the associated welding peripherals which was exactly matched to the increased requirements of the welding personnel to the hyperbaric welding and wet underwater welding, the ***Hybrid 600 UW - Hyperbaric*** represent with their newly developed control concept the optimal system technology for over pressure welders.
That from AMT developed and since years approved AMT safety concept for UW devices provides a maximum protection for the welder (divers) against electrical hazards.



Block diagram welding concept

For safety, the power source must never be used in direct over pressure range. All for the process necessary interconnections are routed through a panel mounting in the hyperbaric workspace and distributed to the peripherals. In hyperbaric work area as the wire system are composed of wire drive and push-pull unit, cooling unit, remote control and auxiliary equipment.

By integrating the different methods (GMA welding, MMA welding, electrode cutting, gouging, and heating) in a facility, allows the user to perform all the work by preheating about cutting up to welding in a single dive (pressure) operation.
The operation of the control system is done by the welder or his assistant over a remote control locally in the hyperbaric range.

GMA welding sample, weld with the new AMT control concept under 5 bar pressure!

Fields of application

- **MIG/MAG:** New developed GMA control concept for short-, normal- and spray arc welding with low spattering under pressure with solid wires of 0.8 to 1.6 mm and flux cored wires from 1.0 to 2.4 mm diameter. Highest process stability by AMT - HYBRID technology.
- **MMA:** Optimal properties with high precision direct current for all types of electrodes from acid to basic. Integrated hot-start and arc-force function ensured best welding results in all welding positions. Large power reserves for special electrodes with more than 100 % deposition rate.
- **Gouging:** Due to the high energy levels and the associated high short-circuit currents of about 1000 A very good properties in arc cutting and gouging.
- **Heating:** Using the integrated heat program and associated heating mats, can be to prevent stress cracking of the weld area preheat partially.

AMT – Safety concept to protect the welder (diver) against electrical accidents

- fulfills the guidelines **„BGV-D1“** and **„Code of Practice for the Safe Use of Electricity under Water“**
- enhanced protection due **maximum open circuit voltage of 60 V-dc** (permissible according to BGV: 65 V-dc)
- external **emergency stop** for fast network-based shutdown in case of danger
- **passive idle voltage limitation** due to secondary switched construction
- **Active idle voltage limitation** at power fluctuations through special electrical suppressor
- **Output voltage limit of 15 V-dc** at inactive welding process or break in the arc
- **external enable switch** for disconnection the power electronics
- **set point dependent enable power part** > 20 A
- **electronic mains over voltage protection**

Freibleibend, technische Änderungen vorbehalten! Stand: 07.2012

AMT GmbH
Jülicher Str. 248
D-52070 Aachen
Tel. +49(0)241/18059-0
Fax. +49(0)241/18059-10
info@amt-aachen.de
www.amt-aachen.de

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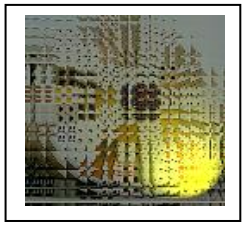
Hyperbaric Tunnel Construction and Diving®



HYPERBARIC TECHNOLOGY HYTECH

Hyfex Fire Extinguishers

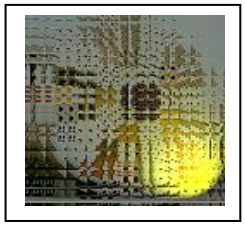
- **DNV Approved**
- **Easily handled**
- **Two sizes available**
- **Instant response**
- **Economica**

HY-FEX Model 7.5 Litre:

Height	600 mm
Diameter	150 mm
Weight charged	12 Kg
Cylinder volume	7,5 liters
Foam discharge	50 liters
Discharge time	50 seconds
Discharge distance	6 m
Effective discharge	99%
Cylinder test pressure	200 bar
Cylinder working pressure	133 bar
Temperature rating	-15° to +55°C
Tested depth	450 MSW
Chamber volume rated	14 m³

Hyfex Hyperbaric Fire Extinguishers are DNV Approved. They are simple, easily handled, and have been designed to be fitted in hyperbaric diving and medical therapy chambers.
They are available in two sizes to facilitate easy mounting and be appropriate in the different compartment sizes found in such hyperbaric systems.
The 3-liter Hy-Fex Extinguisher will probably be found in air dive chambers, entry and transfer compartments and the 7,5-liter Hy-Fex will suit main living chambers and large treatment chambers.
They are foam stored pressure type charged up to 133 bar, with a suitable chamber gas-usually helium. This gas provides plenty of overpressure required to force the water and AFFF mixture through the outlet nozzle, to give a strong jet of foam.
The Hy-Fex units mainly comprise of one robust aluminium cylinder containing the foam mixture and pressurized gas.
This is in contrast to the old fashioned and cumbersome two-cylinder extinguishers used in the past.

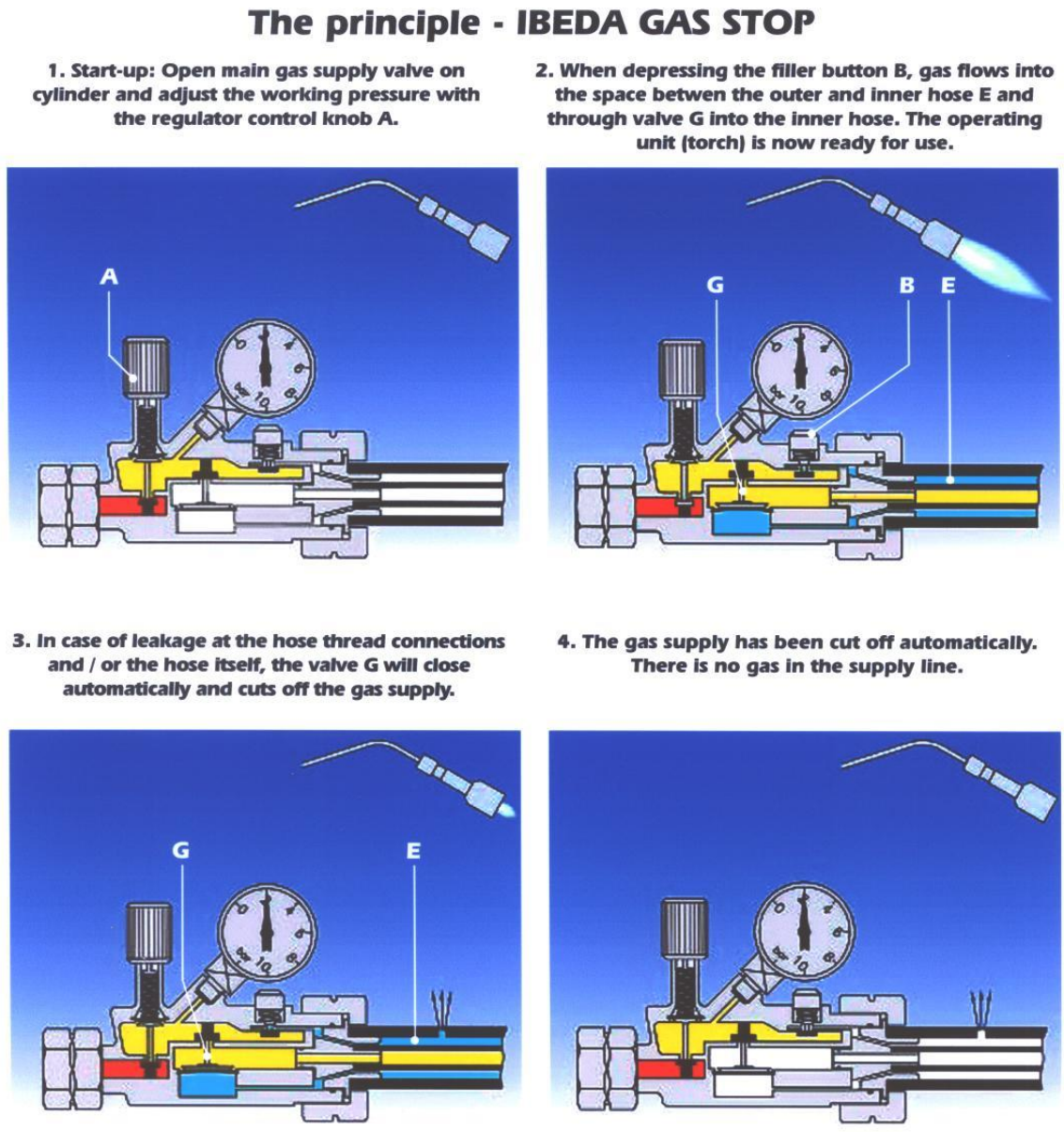
Nordseetaucher GmbH, Bramkampweg 9, D-22949 Ammersbek, Germany; Tel. +49 4102 23180, Fax +49 4102 231820, Mobile +49 172 4300598
E-mail: info@nordseetaucher.de; Internet: www.nordseetaucher.de



Anti leakage and gas delivery line safety

IBEDA – GAS - STOP

The anti leakage and gas delivery line safety is especially constructed for use with gases obtained from either cylinder or mains supply. Through the double hose system, where there is the possibility of hoses damage or loose connections, the gas stop provides absolute safety by preventing unintentional and unnoticed escape of liquid fuel gas.



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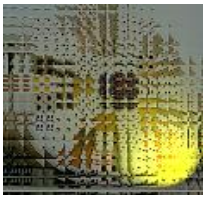
NORDSEETAUCHER GmbH

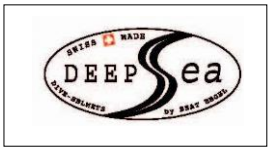
Hyperbaric Tunnel Construction and Diving®

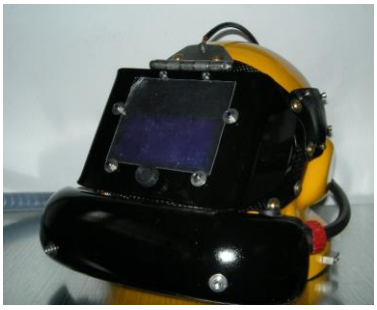


DeepSea Lightweight Model DSL A-2 AIR

d

This new helmet design of Composite Beat Engel, Switzerland is the construction of an overpressure helmet. It has been realized in close cooperation with Nordseetaucher GmbH. This type of helmet - that with an additional kit can be transformed within one hour into a breathing controlled helmet - is now operational in extreme hazardous environment like tunnel machines and gives full satisfaction to the user.





For the welding operation we use the new special designed compressed air helmet with triple air supply, two regulators and one free flow, communication, camera and an integrated welding shield with sensors.

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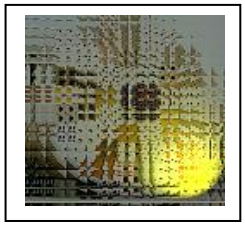
Hyperbaric Tunnel Construction and Diving®



Research and Certification

Because welding in compressed air becomes more and more interest in Caissons and Tunnel Boring Machines, Nordseetaucher GmbH has started in the beginning of the year 2010 a research and training program in co-operation with the Germanischer Lloyd, Germany and some manufacturer for welding electrodes and wires.

The Hyperbaric Chamber for Research and Training

Outside

Inside

Divers and Compressed Air Technicians who has gone through the training program successfully receives a certificate as a Professional Certified Hyperbaric Welder.

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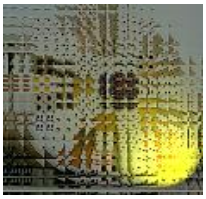

Certificate of Competence

No.77509-12HH

To Whom It May Concern

This is to confirm that

Mr. Claus Mayer
Bramkampweg 9
22949 Ammersbek, Germany
Date of birth: 12.01. 1951

has shown comprehensive experience during several tunnelling and diving projects carried out by Nordseetaucher GmbH, where GL as an recognised classification society was involved for certification purposes.

Mr. Claus Mayer has adequate knowledge in regard to hyperbaric and diving operations under compressed air and mixed gases to verify the scope of equipment and the necessary procedures and to conduct the postulated scope of activities.

This Certificate of Competence is only applicable for operations carried out by Nordseetaucher GmbH in Cooperation with Germanischer Lloyd and may be cancelled at any time.

This certificate is valid until January 2013.

Hamburg, 2012-01-04
Germanischer Lloyd SE

Harald Pauli

Maik Wunsch

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