POLISH STUDIES ON SATURATION DIVING AND PRACTICAL APPLICATION OF THEIR FINDINGS. PART III B
TECHNICAL AND ORGANISATIONAL ISSUES OF THE IMPLEMENTATION OF SATURATION DIVING IN POLAND FROM THE 1990S ONWARDS. PART 2

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ABSTRACT

This article is another in a series of articles on the research and implementation of saturation diving technology in Poland. It discusses the specificities related to the implementation of this technology against the background of economic and historical conditions in our country. In Poland, the issue of saturation diving for the needs of the emerging offshore mining industry has been for over a dozen years dealt with by the Department of Diving Equipment and Technology of Underwater Works (Polish abbr. ZSNiTPP). In parallel, deep diving technologies were developed, in the first stage, as a basic diving technology and, since 1994, as complementary to ensure the full backup for saturation diving. Since 1995, saturation diving has become an everyday occurrence in the Polish economic zone of the Baltic Sea. This article shows the difficult path that the implementation of saturation diving took during a period of economic instability when the scale of the domestic offshore industry's facilities was small compared to global companies. Selected animators and participants in the implementation are recalled for two periods: one marked with the cooperation with the Italian underwater services company RANA and the other one, a period of implementation of long-term underwater works based on national capabilities. The article also considers the technical and organisational conditions for the implementation of saturation diving for the Polish mining industry. In 1990, the Oil and Gas Exploration and Production Company Petrobaltic (today LOTOS) played one of the key roles in the implementation of saturation diving in our country. The implementation of saturation diving in Poland was linked to the only operational diving system of Italian production, the Af-2, which enabled scientific research related to the application of new technical solutions and testing under operational conditions, as well as contributed to the development of scientific, engineering, and medical staff for the Polish offshore industry. The company played one of the main roles in the implementation of saturation diving in our country The 1995 became a landmark year in the history of saturation diving in Poland, as well as in the Baltic Sea. Through this technology, the process of installing the first two underwater exploitation heads on production wells B3-7 and B3-10 was initiated. The saturation diving was possible thanks to the leasing of the Af-2 diving system by Petrobaltic and its subsequent purchase by the Naval Academy in 1998.This system, after a series of upgrades, is still in service today.
Keywords: saturation diving technology, decompression tables, saturation diving parameters, long-term underwater work, diving system, emergencies, technical and organisational backup for diving, medical issues of operational saturation diving, mobile diving system, saturation diving base, breathing mixtures.

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INTRODUCTION

CONDITIONS FOR UNDERWATER WORK AT PP PETROBALTIC

The hydrometeorological conditions of oilfield work are characterised by a high degree of weather variability, which makes it difficult if not impossible to plan underwater work and, therefore, the exact date of transport of the diving system to the platform. On the other hand, if the diving system is installed on the ship according to the regulations in force in the country, it is possible to dive up to sea state 3o.This regulation also applies when diving from the platform. This results in non-rhythmic underwater work. A short deep dive may be interrupted due to weather conditions. In contrast, a saturation dive that has started cannot be abruptly interrupted, which is related to the high cost and indefiniteness of the task, as the duration of a saturation dive is strictly limited to 23 days, excluding decompression for a saturation plateau of 70m.

Underwater work for Petrobaltic was accompanied by extensive use of diving support equipment. These included underwater TV equipment and ROVs. Unfortunately, none of the ROVs used at Petrobaltic had manipulators for the simple operations required to operate the underwater installation equipment, e.g., valve rotation or cable mooring.

Petrobaltic employees used underwater TV extensively for many operations, positioning the camera or ROV at the desired location using the TV camera's drop-down guides. This made it possible to dispense with the use of divers for field work if only observation was needed. The use of flexible pipelines eliminated the need for underwater welding work and, when installing the tension plugs, the divers' work was reduced to connecting the pipe flanges to the distribution equipment. In contrast, underwater metal cutting technologies were used for emergency procedures when other methods without divers failed. The joining of pipelines was based on manual bolting of flanges and, where possible, hydraulic spanners were used. Feeding a hydraulic spanner or other tools together with supply hoses to depths of 70.5-80m requires additional lifts. Improper handling of the hydraulic spanner by the diver can cause injury to the diver, which, in deep dives and especially saturation dives, greatly complicates the rescue.

In specific cases, underwater work is characterised by a high degree of indeterminacy in the scope of the diver's tasks, as only the underwater on-site check can determine the specific details of the actual operation. This is the case, for example, with underwater work related to dismantling.

The organisation of underwater work requires a high degree of availability on the part of the diving team, as underwater work is part of the overall work being carried out, and as a rule divers work after a specific drilling operation has been completed. This is why the team may start working at any time of the day, and night work is not unusual. In the organisation of diving work carried out from the deck of the platform, it should be taken into account that the safety and dive management takes place from a height of about 20m. from the water surface. In this case it is critical to ensure that the back-up diver is quickly brought into action. The qualifications of divers carrying out tasks should also include a good technical background, as sometimes a diver when on site underwater has to assess the condition of the equipment or the extent of the work himself. The diver should also have the spatial imagination to ensure that with his equipment when moving on an underwater head structure he does not get caught or entangled underwater, and be able to correctly assess the correct alignment of flexible hoses, pipes etc.

An essential skill for divers is the operation of an underwater TV camera, as this skill determines the assessment of the correctness of the execution of underwater operations. Divers and support staff must optimally prepare the diver's workstation, which involves setting up the lighting, selecting the right tools, adjusting the equipment and supplies for the work, choosing the route to the work area and the place where the tools are handed out. These operations are carried out in parallel, while ensuring the divers stay on the plateau and the diver exit from the diving bell. Underwater strapping is a particularly important element of underwater operations and should be considered as early as the design stage of the components to be assembled underwater[7, 8].

The boundary between short deep dives and saturation dives is very difficult to grasp. Only economic factors speak in favour of short standard deep dives. In contrast, saturated dives have all but the economic factor.

This principle applies to large production platforms. Petrobaltic has platforms of relatively small dimensions, on which there is no space to set up diving systems of the typical dimensions envisaged for typical stationary diving systems. To be installed, the configuration of a small-scale mobile diving system must be specially prepared. For most of the diving systems in use, it is not possible to set them up on Petrobaltic platforms. Therefore, most of the saturation and deep dives were and are performed from the deck of a service vessel capable of securing the diving system's operation. Such a vessel at Petrobaltic was the vessel 'Bazalt'.

The installation of a mobile diving system on a service vessel makes the work dependent on the weather. In prevailing storm conditions, the vessel protects itself in the harbour. This dramatically increases the cost of saturation diving due to interruptions caused by weather conditions. It is therefore very important to monitor the weather so that a vessel with a diving system can find a safe place of refuge at the right moment, and so that pressurised divers are not subjected to additional stress due to seasickness, hull vibration or noise. These impacts are not experienced on the platforms. Added to these impacts is the factor of the difficulty of operation, as the Af-2 diving system that has been operating in the Polish offshore for 27 years is an open-deck system. On top of that, if we bear in mind that underwater work is carried out all year round with the majority of the work performed in winter conditions, which require additional equipment and protection against freezing of gas and water system components of the diving system and ice on the deck and components, it is clear that it requires highly qualified personnel capable of working in these conditions. Ensuring operational capacity in these difficult conditions is possible because the technical team of the AMW Underwater Work Technology Department has got the required construction, technical, and organizational experience, gained during the implementation of the

DGKN-120, and GWK-200 systems. Equally important was the transfer of experience by the diving team of the RANA company, which conducted the first dives from the Af-2 diving system on the Polish coastal waters. The trials of the new installation site on the Beta platform were not without mistakes, where, disregarding the .technical analysis and the comments of experienced dive managers, an attempt was made to install the dive system by force, fitting it to the requirements of the drillers, rather than to the technical capabilities of the Af-2. A year earlier, such an installation took place after the removal of many onboard devices which interfered with the structure of the platform. As a result, the Af-2 dive system was dismantled and placed on the service vessel the following year, which turned out to be a very good decision and for several years it was the most commonly used solution for saturation and deep dives, and is still used today.

THE CHOICE OF THE DIVING SYSTEM FOR UNDERWATER WORK AT PETROBALTIC

By 1994 it was already known that for the installation of the heads it was necessary to use saturation dives. As mentioned above, at that time Poland did not have an operational saturation diving system, and the attempt to use the remnants of the Szczecin Shipyard systems was abandoned after the first technical analysis, due to the costs and dimensions that did not allow these systems to be installed on the drilling platform.

From the beginning of 1994, work was carried out to procure a diving system for the works on the Petrobaltic oilfield. RANA company was chosen because of its head installation work practice, cost and ownership of a mobile diving system that had been operated for 18 years by this company. The decisive factor in these negotiations was RANA's reduction in the cost of the underwater service and Naval Academy participation in part of the work to secure the saturation dives. Following difficult negotiations, in which the participation of the Naval Academy in this work was approved, we focused on the 'gaps' that the RANA company could not secure. In 1994, after an audit, the Italian company RANA decided to co-operate and, in order to secure the work at Petrobaltic, was preparing a back-up Af-2 diving system for shipment to the country, which was in storage and acted as a supplement to the work of the company's other diving systems. The diving system was leased with an option to buy it back after the last instalment was paid in September 1998. In view of the company's capabilities, with a heavy workload in the Mediterranean, it was agreed that the work will be supported from the Polish side; a decision was taken to cooperate with a team from the Polish Navy. In this team, the leading role was played by the Department of Diving Equipment and Underwater Work Technology of the Polish Naval Academy which secured 90% of the Polish watch staff and provided technical and medical security for the 1995 saturation dives, as well as a team of back-up divers [1].

The AF-2 diving system comes from the 1970s and was built under Italian regulations, very different from those binding in the North Sea countries, considered the standard at the time. For the Polish team that built and carried out remote tests of the stationary GWK-200 system, the proposed design solutions came as a 'technical shock' that were difficult to accept. The Af-2 system was a "composite" of a hyperbaric chamber and a diving bell made by the Italian company Drass, to which other components necessary for saturation diving were added. Unlike the GWK-200 stationary system, built to the requirements of the Norwegian classification society DNV, which implied expenses and a certain degree of functional and structural redundancy from a safety point of view, the Af-2 system was built to the requirements of the Italian society RINA. Their requirements were more 'flexible' in terms of the equipment, installation, and measurement base. The systems differed in practically everything, from dimensions, measurement base to emergency equipment. With its minimal dimensions and minimal equipment, the basic elements of the Af-2 saturation diving safety system could be used on virtually any vessel with 150m2 of deck. The most important advantage of this system was (and still is) the possibility to install it on Petrobaltic platforms of the time. The Af-2 diving system was captivating in its simplicity of technical solutions and operation. As the Italians put it, the system was built by divers and for divers. It was built with the least possible expense and observed technical safety requirements. The system did not fully comply with the construction regulations of leading diving countries such as Norway, the UK, France or even Russia. The Af-2 had no parameter maintenance automation, no life support installation and its gas installation was very simplistic. However, this was its advantage in terms of maintenance and repairs.

The Af-2 diving system had an up-to-date maintenance certificate (authorisation to operate) by the Italian classification society RINA with a maximum operating depth of 200m for the bell and chamber, while life support systems from the technical parameters could be used up to 160m (operating pressure 16 bar).

RESEARCH AND IMPLEMENTATION CHALLENGES POSED BY DIVING SYSTEM MOBILITY

The research activities of the ZSNiTPP team were directed towards the implementation of a stationary diving system for saturation diving. Being stationary has one undeniable advantage; the permanent link to its site. All its equipment is permanently installed. The linking of the operational diving system with the object on which it is installed, which may be mining platforms, specialised vessels or other floating objects, dictates how these systems are used and operated. It should be noted that the regulations of the classification societies are generally concerned with the construction and design of stationary diving systems. In these regulations of the leading countries in the last two decades, contain definitions of '*mobile*' or '*transferable*' diving systems. Generally, they are only defined and implicitly must be functionally and technically equivalent to stationary systems.

For example, current DNV regulations [9,10] define a mobile diving system as "A diving system designed to be easily transportable in one or more units and which can be installed on board a vessel, barge or offshore platform for a short period of time, not exceeding one year". They explain that a mobile diving system can be assembled from different components into a specific configuration, suitable for a specific task. For mobile systems, there is a wide variety of potential pressure objects and assembly options. In contrast, the Polish PRS regulations [11] of 2020 define a diving nurkowych „mobile” względnie system as not permanently integrated into a craft (mobile) in paragraph 8.26.1. A diving system installed for a specified period of time on board and temporarily integrated with the systems and equipment of a vessel engaged in underwater work is to comply with the requirements of PRS, including the surveys and tests specified in Chapter 2, each time it is re-installed on board a vessel or other facility. Other class-related additional requirements for the vessel and the diving system temporarily integrated on board the vessel, such as, e.g., depth or weather restrictions beyond those associated with the additional marks, shall be entered in the Class Certificate/Temporary Class Certificate.

I would like to mention that the AF-2 diving system was the only system on offer that could be installed on the platform (on the Beta platform, bulkheads and structural load-bearing were cut to install it). In our case, the mobility of the diving system forced us to solve a number of problems that are not defined in the case of diving from a stationary system, or not addressed at all in the regulations of the classification societies. In the period under consideration, there were no regulations and norms for saturation diving in our country, both on the technical and on the organisational side. On the medical side, the situation was similar, except that the regulations in use in the Western countries did not provide for such extensive medical cover as the current Polish provisions, modelled on the Soviet ones. Mobility was therefore defined for local needs by adopting national conditions and the very valid point of view of the Italian specialists from RANA. Important were the launch conditions, i.e., the requirements of the owner of the Af-2 system, the requirements of the Petrobaltic company, and the potential of the Navy, including the ZSNiTPP.

In view of the 5-year loan of the Af-2 system, teams at the ZSNiTPP were being prepared to operate and exploit the system. The technical and operational documentation provided for the AF-2 diving system was, to put it mildly, 'incomplete'. We did not obtain from RANA the data of the equipment under the supervision of the classification society, such as, drawings and installation diagrams, not to mention the technical description of the chamber, diving bell, manoeuvring control panel, life support systems, compressors and filters. We only obtained drawings of the chamber shell and bell and documentation of the pressure vessels. Also missing was documentation of the bell's lowering and lifting equipment, the bell and chamber's gas and electrical distribution panels. During the first installation on the Beta platform, for assembly and maintenance purposes, the Polish team made their own diagrams of the bell and chamber gas panels, the bell gas and electrical systems of the chamber and diving bell, the life support system No. 1, the air charging station, the shunting control panel system, the hydraulic system of the bell lowering and lifting system, the heating equipment of the bell and the diver's suit.

The assembly of the system involves reliably setting up in a configuration that allows the bell to be lowered and 14 components to be set up for operation. The Af-2 system was delivered to Gdańsk by road, which forced the hyperbaric chamber to be adapted and partly dismantled. Damage to valves and installations was not avoided during transport. For example, the lowering and lifting device had a bent support frame, the bell cable harness wheel had to be replaced with a larger one (on average by 600 - 700 mm.) so that it would not bend the harness, i.e., the bell's hydraulic system needed adjusting, the hydraulic installation leaked. Several hydraulic couplings also had to be replaced.

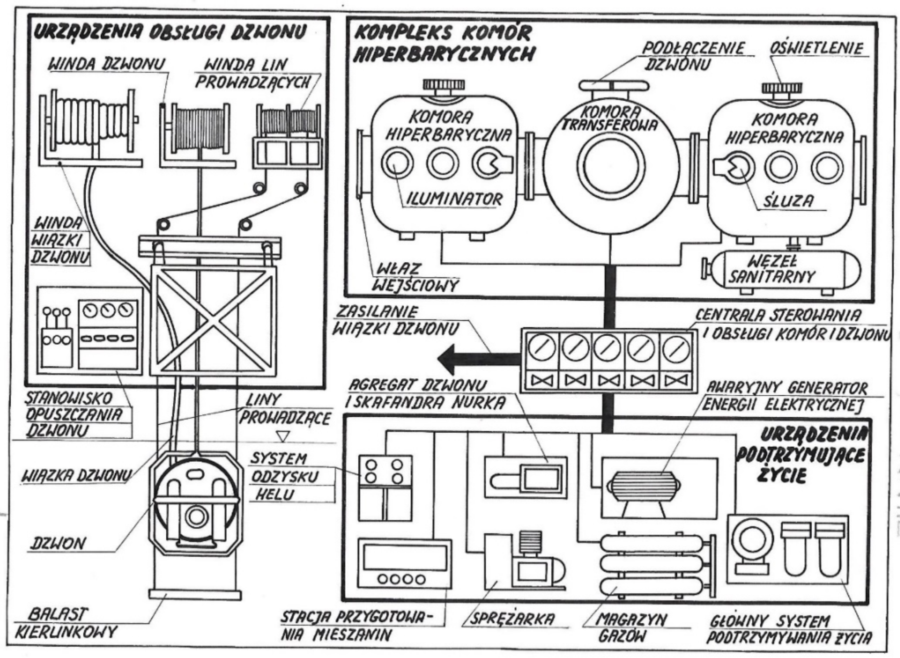

Fig. 1 Structural layout of the diving system for saturation diving without relief devices that ensure a certain degree of safety.

The above-mentioned equipment had to be connected into a functional whole during installation with gas hoses, hydraulic hoses, cooling and heating water hoses, fresh water, salt water and chamber heating glycol, electrical cables supplying the power network for the lift equipment, life support heater, electric bell heating water heater, control, measurement, communication and lighting cables. The installation of the Af-2 system required the connection of more than two hundred hoses and pressure pipes of various diameters and more than a hundred cables and electrical wires. Gas installations had to be connected to more than 400 connections of various threads and diameters depending on the purpose; high, medium and low pressure to supply the Af-2 system's essential equipment. The use of flexible connections requires that the system configuration is tailored to the site, taking into account the following hose routes:

- gas with mixtures, oxygen, and low, medium and high pressure diving air,
- water for fresh water, sanitary water, overboard heating of the diver and cooling of the equipment,
- hydraulic for supplying power to lifts and control of the lowering and lifting system,
- glycol for heating the chamber and heaters for life-support systems,
- technical air for supplying the primary and emergency equipment of the diving bell lowering and lifting system and the bell's ballast.

The same is true of the cable routes, the cables varying in cross-section from very large ones for the collective power supply of the power loads and the heating water heater for the bell and the diver, to thin cables for communications, TV, measurement and IT networks. When planning the routing of cable and hose lines supplying or connecting components of the Af-2 diving system, the specifics of the facility on which they were installed had to be taken into account, and everything had to comply with the requirements of ensuring reliable operation, crew safety, fire protection, emergency escape and rescue routes, and access to rescue resources. In general, consideration had to be given to the sequence of regulations of maritime conventions, oil mining, crane operations, fire regulations (including oil and gas extraction zone hazards), pressure vessel operations, and occupational and leisure hygiene. These problems are not encountered with fixed systems as they are dealt with during the construction phase of the vessel or facility having a diving system. For instance, no crane operations are allowed over the chamber and bell and over gas and electrical transmission lines, oxygen cylinders must be in a specific location in relation to the storage of flammable materials, i.e., oils and lubricants, no other noise-producing extraction activities should be carried out while the bell is submerged, escape routes should not be obstructed during loading and unloading operations, the diving system should be separated from the vessel's or platform's crew, divers' hygiene requires that they should have a separate washing and drying machine and eating utensils during saturation. The problem where all the problems started was ensuring the functional configuration of the diving system. The starting point was to be able to lower the diving bell into the water at a specific point; as close as possible to the work area after the dive (maximum 15m), and to locate the back-up diver station as close to the bell as possible. The first saturation dive in 1995 on the Beta platform required the removal of several on-board devices so that the system could be functionally set up.

In the case of the Af-2 system, we were generally dealing with two objects, i.e. platforms and a service vessel. The only thing they had in common was the diving system. The Af-2 was an open-air mounted system, which was both an advantage and a disadvantage for year-round operation. The platform gave a stable deck regardless of the weather and access to heat sources in winter, better accommodation conditions and virtually unlimited access to crane services, which was very important for the logistical support of the dive. The vessel did not provide these conditions, but it had the indisputable advantage of being operated close to the water (about 2m), which, compared to the platform (more than 20m from the water surface), offered a greater possibility to respond in emergency cases and the ability to carry out work at any point in the deposit.

It should be noted that the installation site also contributed to the professional development of the crew's personnel, not only of the ZSNiTPP. Only 4-5 members of the Naval Academy team, which organised and carried out deep dives from the rescue ships on which the diving system was built and the outings at sea were relatively short (up to 10 days), had experience in this type of activity. For most, this type of task and its execution was new. Stays of several months on a ship or platform were a test of people's resilience to stress and difficult conditions. People with isolation syndrome, fear of heights and fear of helicopter flight could not stay at the platform. In contrast, working on the service ship was not appropriate for people with constant motion sickness and a lack of resilience to the harsh social conditions. For many members of the team, those who took part in the decompression table tests, working in real conditions was a shock, but one that most of the team endured without problems. In addition to working in real life conditions, there were stress factors caused by the real danger facing divers underwater, the pressure of the underwater works contractor to complete the task quickly (irrespective of the time of day) and the requirement to be available for underwater work. The mental strain of succeeding in underwater work was shared by all, both contractors and executors, and began at the stage of preparing and installing the diving system on the designated site.

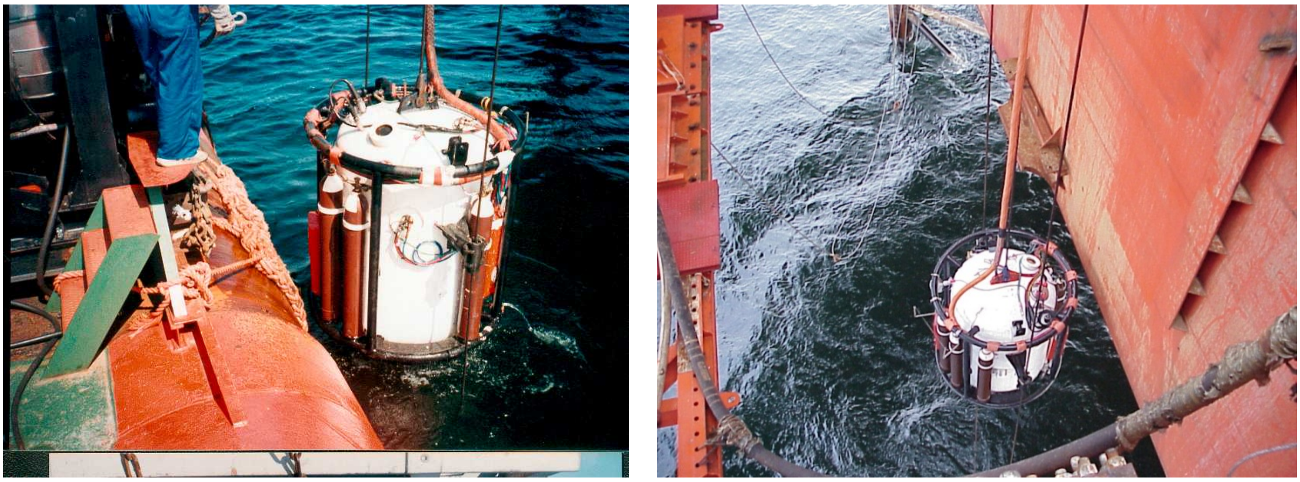

Fig. 2 Submersion of the bell of the Af-2 diving system from the Bazalt ship (1997) and from Petrobaltic platform (2000).

FEATURES OF THE AF-2 DIVING SYSTEM (1995-1997)

The operating conditions of this system were not specified in the documentation. According to the RANA specialists, it was prepared for the conditions of the Mediterranean Sea. The national underwater working conditions, as defined in the then civilian national underwater working regulations and the Navy's diving regulations, were adopted as acceptable.

Operating conditions for the AF-2 complex:

- ambient temperature (according to DNV -10°C) 0°C to 40°C,
- sea state up to 3°,
- wind force up to 5°Beaufort.

Based on the components and equipment of the Af-2 diving system supplied in 1995 by the owner, it was determined that it could be installed on any floating or fixed facility with a free surface area of approximately 150 - 180m^2. The "carrier" facility to secure the operation of the complex must provide an adequate supply of electricity, fresh and salt water, and have lifting equipment to secure the loading of the complex, the supply of gases and the ability to evacuate divers working under pressure.

The facility should have a social base to provide food for the divers and the service team for a minimum of 16 people, and a base to provide for the rest and living needs of the team with laundry facilities and hygiene procedures for the complex (laundry, disinfection, food preparation, etc.).

The AF-2 diving complex required to supply the ship's power systems with 3 x 440V or 3 x 380V electricity, which should secure an uninterrupted power supply as follows:

- primary power supply ~ 200kW (maximum power for lowering and raising of the bell),
- emergency power supply ~ 60kW (during the saturation plateau),
- emergency power ~ 170kW (while divers are underwater),
- outboard water: p= 6 bar min $V = 3m^3/h$,
- fresh water: - intermittent intake min ~ 1m^3/day,
- technical air: p=6 bar, $V = 20m^3/h$. (intermittent intake - during bell submersion – raising operations and emergency bell raising drive and optionally from compressed air system of the complex**)**.

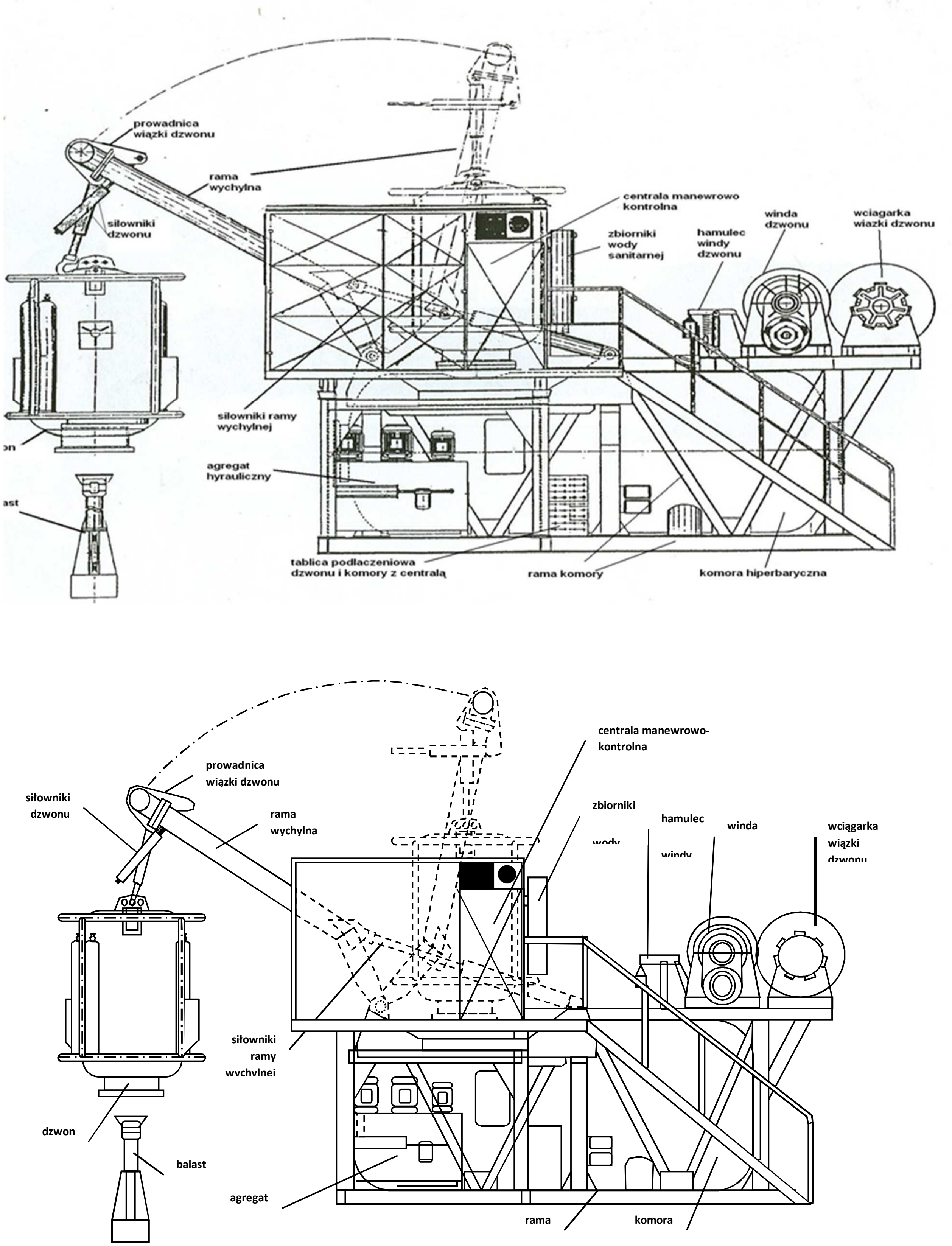

Fig. 3 Basic Af-2. diving system assembly (bell, ballast, swing frame, bell and ballast lifts, cable/hose harness winch mounted on the chamber frame, and manoeuvring control panel set on the hydraulic power unit frame).

The Af-2 complex consisted of 14 separate, independent, custom-configurable units, with the exception of the basic chamber-diving bell assembly - a lowering and lifting device, hydraulic power unit and manoeuvring control panel (see Fig. 3) as required.The delivered set of the complex included:

1. a two-compartment hyperbaric chamber with an operating pressure of p=.20 bar (200mH_2O), with an internal diameter of 1900mm and an overall length of 4700mm, with five hatches which allowed these compartments to be operated independently and the divers' passage to the bell to be performed. A living compartment with a volume of 7.5 m^3 prepared for the stay of four divers. The compartment had a small sluice box for serving meals and consumables. The volume of the transfer compartment was 3.8 m^3. It was prepared for the following functions:

- TUP-transfer under pressure to the bell, shaft with a manhole controlled by the pressure of the working mixture,
- personal hygiene and toilet facilities,
- divers' dressing in wetsuits and equipment before entering the diving bell,
- storage of suits heated with water,
- evacuation compartment for two divers.

The chamber had an installation for the external fire extinguishing system, but no serving the purpose was provides. Fire protection relied on individual fire extinguishers and water from the sanitary system.

For example, the volume of the living chamber of the GWK-200 diving system was 18 m^3.

2. closed diving bell - designed for 2 people, operating as a team of a working diver - bell operator (volume V=3.4m^3 weight G=5.1kN, working pressure pr=20bar). It was equipped with devices required by the classification regulations for saturation diving, with the exception of securing the required autonomy of 24 hours, i.e., the ability to maintain the operation of the basic equipment when the power from the surface is cut. This was compensated for by rescue procedures.

According to DNV's classification regulations at the time, the diving bell was to have a separate stand-alone mixture supply with a minimum capacity sufficient to provide 1 Nm^3 of oxygen for each diver and suitable breathing mixtures. The bell's supply of mixtures should provide a volume sufficient to displace water from a bell filled with 40% water at maximum operating depth or sufficient to provide each diver inside the bell with adequate breathing gas for 15 minutes. Accustomed to the infallibility of DNV regulations, the ambitious team members immediately pointed out these shortcomings. In their interpretation, RANA specialists referred to their own regulations. Assuming a saturation plateau of 65m, a stock of 30 m^3 of mixture in the bell was supposed to meet all conditions. At 15% oxygen content in the heliox, the amount of oxygen exceeds 2 m^3

Fig. 4 Example of a diving bell equipment as recommended by IMCA and selected binding classification regulations.

Fig. 5 Af-2 diving bell equipment seen from the entry (photo taken in 2016). We can see hoses and the bottom of the diving helmet used by the working diver.

3. Lowering and lifting device - a bell hoist mounted on the chamber's supporting frame with a 240m rope, a ballast hoist with a 380m rope and a bell cable harness winch; the length of the harness is 140m (umbilical according to PRS). The kinematic system of the unit consists of frame swinging cylinders, bell hoisting hooks and horizontal cylinders to control the hooks. The lifts do not have rope lay-up and therefore during the operations of raising and lowering the bell and ballast, as well as the operations of setting on the chamber shaft, the operation of four persons is required. Operations are particularly difficult when the system is mounted on a vessel in inclement weather. Operating this equipment requires close manning and increased operator attention in the manoeuvring control room, where the control panel is located. The system provides a maximum lowering speed for the bell (average 18m/min and ballast 9m/min).

4. Bell stabilisation ballast - weight G=1.2 kN, lowered at twice the speed of the bell lowering on a double rope, as this is required to stabilise the bell against rotation. This arrangement also allows the diving bell to be pulled to the surface in an emergency situation.

5. Dive control room - connected to all equipment in the system by flexible gas and hydraulic hoses, and electrical cables and wires. The design of the control room must ensure the ability to house the maximum number of equipment. Measuring 2.4m x 3.4m, the room offers working space for underwater work manager and control station for basic diving parameters. It combines giving directions to divers performing underwater work and the service personnel, while controlling the parameters of the atmosphere in the bell and in the chamber and the supply of breathing gases, heating water for the diver and the bell, water for sanitary needs, and the control of the bell lowering and lifting system. The control room houses control panels of the chamber and the diving bell, the main power switchboard, the communications panel and the control panel for the diver/bell lowering and lifting device. In addition, the sanitary hot and cold water tanks are located in the control room, along with their control systems. The working conditions in the control room required a minimum of three people without providing any comfort to them. Managing divers underwater was not separate from the operation of the hyperbaric chamber, as is normally the case in fixed systems. Modern ergonomics and construction regulations do not allow for incompatibilities regarding the obstruction of the work of the diving team, but this solution for the control room was and still is effective. It requires only adequate preparation and high qualifications of the diving staff.

6. Hydraulic power pack, comprising three pumps of the stated working power P=25kW, emergency power 25kW, and service power P=8kW. The frame of the power unit serves as the base of the control room.

7. Life support system - primary, LSS-1 in a 20’ container. Circulation control of the chamber ventilation was manual and was done by throttling the flow of mixtures with a valve. The LSS container was also used as a storage facility for consumables and an overpressure pump.

8. Life support system - emergency, LSS-2 in a 10' container. This system was not prepared for operation (faulty refrigeration unit). Also, it was used as a sorbent storage facility and to supplement the replaceable filter baskets with LSS sorbents.

9. Compressor unit p=200 bar in a 10' container consisting of two Bauer K-1515 compressors and two diver air filter units.

10. Gas storage (12 diving bundles, 10 for the mixture and 2 for control air). Operational storage capacity of 1350m^3 mixture and 180m^3 air.

11. Primary electric diving suit and bell water heater - manufactured by MARA Engineering Mini Electric Heater MHE-01, heating power P= 95kW.

12. Spare combustion heater - by DUI Simple 520 P= 102kW, oil-fired. Virtually unused (faulty burner).

13. Haskel twin air-powered pump

14. Two sets of diving equipment with Superlite 17B helmets and a back-up diver mask in a Heliox 18B bell, prepared to be fed from the bell.

15. workshop – storage – installed in a 20' container.

The job of the Department of Diving Equipment and Underwater Work Technology (ZSNiTPP) was to complete the Af-2 system equipment. Their primary tasks included:

- arranging a spare diving team; 2 divers and an underwater work manager,
- replenishing stocks of breathing gases, sorbents and spare parts of diving and surveying equipment and replacing cylinder bundles with breathing mixtures during the dive,
- supply of helium in cylinder packs and portable cylinders and oxygen in portable cylinders,
- preparation of heliox working mixtures,
- securing and carrying out of repairs and the supply of components for gas and electrical installations,
- provision of a diving support team,
- securing the work of the diving system technicians during assembly and disassembly of the system, and during the dive, as well as in the period before and after the dive,
- equipment replenishment at the request of the Italian team,
- medical assistance in accordance with national regulations,
- provision of water-heated suits (obtained from the Szczecin Shipyard),
- protection for saturation dives from the shore, including evacuation operations of divers under pressure and implementation of possible medical recompression procedures.

The primary research objectives for the ZSNiTPP focused on technical and organizational issues, namely:

- diver safety assessment analysis and emergency operation for diving mobile systems,
- evaluation of measurement methods and technical support in the light of world standards and so-called "good diving practice",
- development of "quick" installation methods for the object on which the system was to be installed and Petrobaltic's technical and organisational requirements, taking into account installation time and minimising the involvement of the company's organisational units,
- updating training programmes for divers and the service personnel taking into account the use of the diving bell in normal working and emergency conditions,
- comparing medical safety procedures binding in Poland and in RANA to meet international standards,
- drafting national procedures for the operation of an operational diving system based on national capabilities,
- development of methods for the evacuation of divers under pressure from offshore to the shore taking into account national considerations.

The above issues should be reflected in the diving documents and procedures that are required in the diving plan, in the medical, technical backup and the organisation of the diving and underwater work. These documents are important from the point of view of the administrative permits, the supervisory requirements of the diving system classifier and the operation of the platform or vessel on which the system is installed, the maritime administration, the insurance of the underwater work with the assurance company, and the financial expenditure on the specific underwater task. In 1995, all stakeholders engaged in performing underwater work were just learning and familiarising themselves with these issues. The experience resulting from research on diver decompression and the construction of diving systems was invaluable. For the ability to grasp the overall problem of interoperability of commercial saturation diving, experience acts only as the basis, the use of which depends on the offshore working environment. Our experience involved only two environments, a ship and a platform, and related to working with one Italian underwater services company and the Polish Petrobaltic company. Research and organisational problems were born 'on the fly' as the work progressed. We were carrying out commercial operational dives for the first time, and this affected everyone involved. The literature and regulations address this subject to a limited extent and generally do not deal with organisational and technical solutions, but only give guidance.

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