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APEX, ACTIVELY POSITIONED EXPLORATION SYSTEM

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Abstract

A conceptually new, modularly designed exploration system for the deep sea (600 m) has been constructed and tested. In its base unit, different soil sampling tools can be integrated. These are for the time being a drill core barrel with Ø 48 mm iD and a length of 500 mm for rocky basements as a box corer for softer soils as well as an orange peel grab. Towed along via a coaxial cable from a research vessel, the system is TV-guided and can be actively positioned by means of 2 thrusters in order to be lowered precisely and horizontally levelled on the seafloor. The total system is operated by the help of an onboard computer and may be controlled by sensor displays and operation messages. Microprocessors control the underwater unit which is partially automated. Possibilities for further potential developments are presented. The system yields prospective new exploration methods.

Introduction

Detailed small scale investigations of the seafloor require tools that facilitate perfect observation with simultaneous (soil) sampling possibilities on the one hand and precise positioning on the sea bottom on the other one. This is true in particular for the recent exploration of ocean minerals of small deposits but also for general examinations of partially restricted phenomina. Up to now, these demands could only be accomplished by submarines that are extremely costly and need extensive infrastructural support. The current trend in the development of new exploration tools therefore aims at substituting the performance of some of these specific tasks of submarines by remote-controlled devices that are less costly and more comfortabely to handle.

In 1987, the German Ministry of Research and Technology (BMFT) therefore placed an developmental program of 3 years in order to design, to construct and to test a prototype for geological deep sea work that realised those recent demands of potential users.

Experience and selected components were derived from 2 devices already existing in Germany that had turned out to be rather useful in deep sea exploration in the past. One was the Ocean Floor Observation System (OFOS) for visual sea bottom inspection, the other was an electro-hydraulically activated grab (clamshell or orange peel type) equipped with an underwater TV-camera. The intensive extension of their capacities, as well as the addition of thrusters for active positioning resulted in the conceptual layout of the new exploration system, called APEX.

Systems design

1 Mechanical concept

The system was modularly designed, i.e. it is composed of an underwater base unit that incorporates all facilities for control, bidirectional data transfer and power supply as well as "plug-in" facilities for different soil sampling tools, so-called modules. The structual element of the base unit is some 3 m high and encloses three adjustable legs for levelling, two reversable thrusters, continuously adjustable and an internal tool rack with module suspension that may be vertically transversed for 950 mm. Six spherically shaped shells mounted on shock absorbers surround the whole base unit for reasons of protection (fig.1,2).

2 Power supply and driving

As a combined data link and power supply for deep sea systems via a conventional coaxial cable turns out to be problematic, the totally necessary energy of the underwater unit is supplied by four pressure compensated zinc-lead batteries, each with a capacity of 230 Ah. Most of the energy is then transferred into oil hydraulical energy by two redundantly working driving units and subsequently branched within a second hydraulic aggregate with valves in order to activate all components of the base unit as well as to drive soil sampling modules which all have identical interfaces.

3 Subsea Electronics

The total electronic system, contained in various pressure tight boxes, is integral part of the base unit and thus serves any module (fig.5).

The main electronic unit organizes the communication through the single conductor tow cable to the control post on board the supply vessel. It synchronizes video pictures, transmits sensor data and status indications to the surface using the blanking intervall of the video signal, distributes arriving control commands to further units and it also continuously checks the reliability of the data link by comparing test bits.

Further units perform the data acquisition of sensors as well as the steering of all hydraulic valves. Using microprocessors, automatic control and cycling of command sequences without any necessary intervention from the surface are accomplished. Emergency conditions can independently be recognized and emergency procedures are then initiated self-acting to achieve safe conditions of the system for salvage.

An additional unit serves for power control to economise energy and to protect electric main drives.

4 Sensoring

The base unit incorporates a set of various sensors, to keep the user informed about the operational conditions of the system, in order to allow a steady supervision and - if necessary to allow - precise interference in case of any trouble. This was considered to be essential for a reliable operation in unknown, sometimes hazardous areas. The base unit mainly comprises:

- two low light level video cameras for soil and module observation,one of the SIT-type, the other one of the CCD-type

- four flood lights, each of them individually to be dimmed from 0-100%,

- an altitude sonar to detect the distance between the seafloor and base frame,

- sensors for the water depth and the oil hydraulic pressure

- a flux gate compass

- a pitch and roll measurement of the base frame inclination and an

- indication of the leaving battery capacity

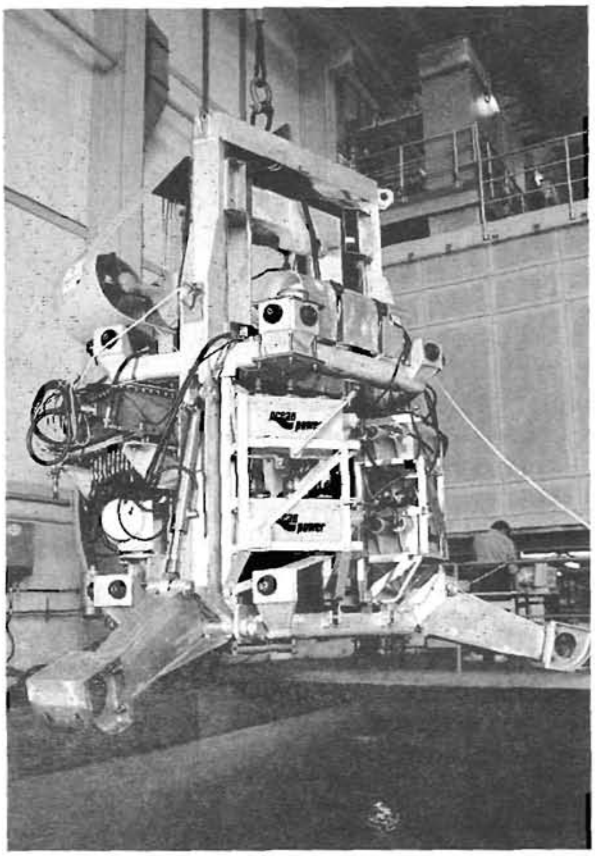
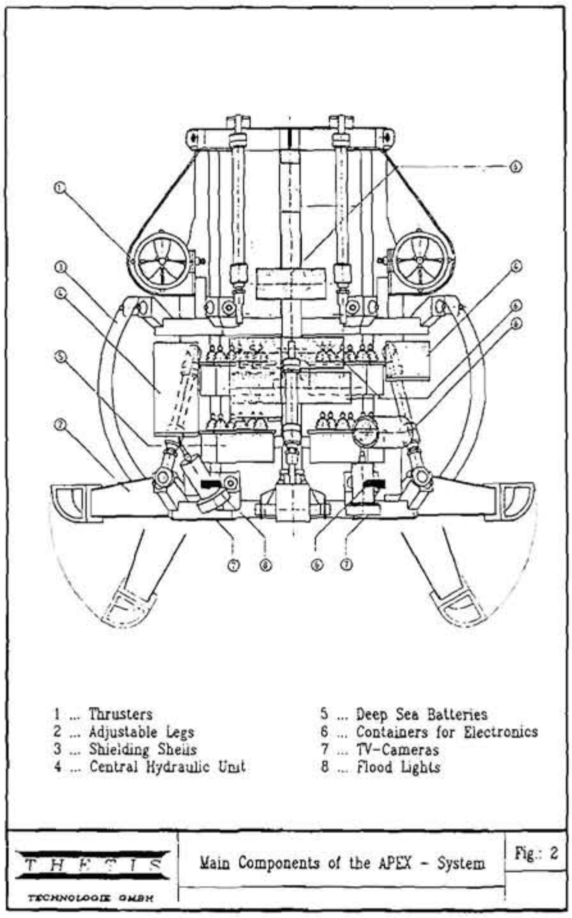


Fig. 1 : The APEX Base Unit with Removed Shielding Shells



Main Components of the APEX - System Fig.: 2

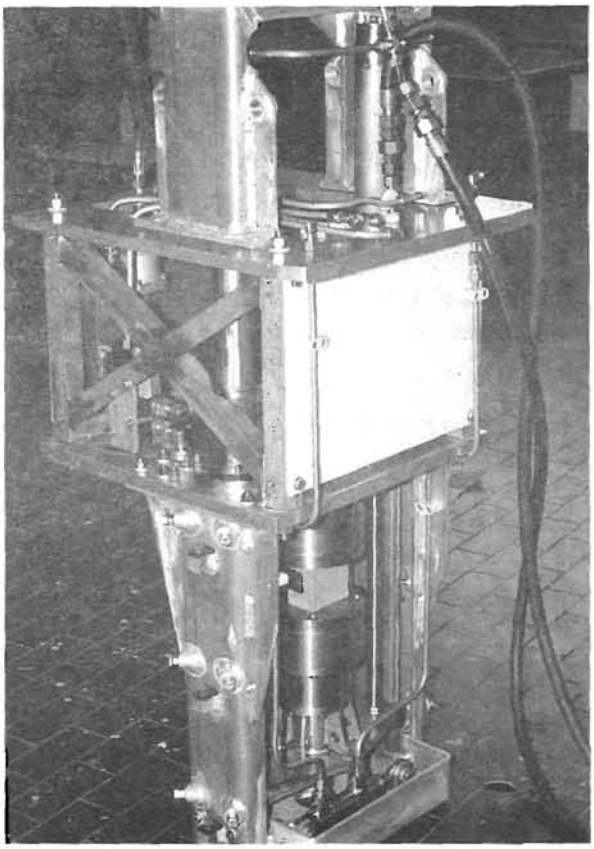


Fig. 3 : The Apex Drilling Module for Hard Rock Coring

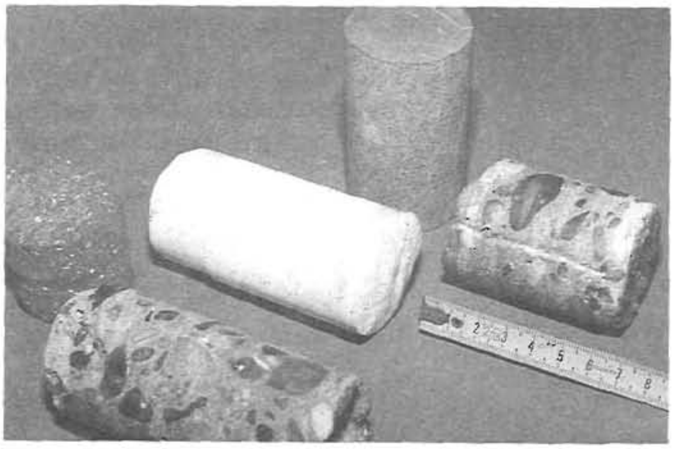
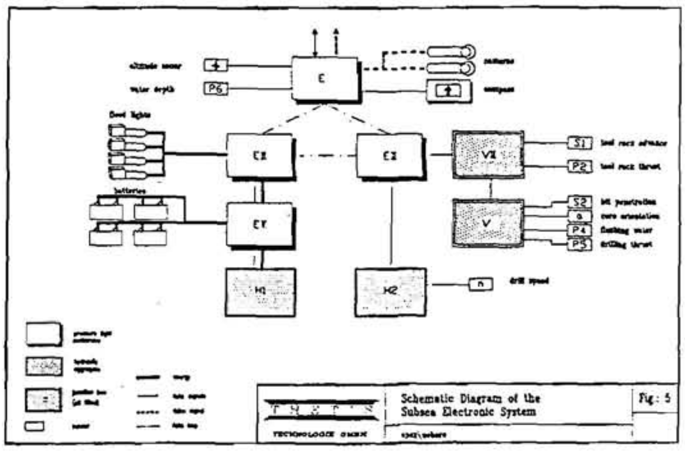


Fig. 4 : Test Cores of various Materials : Concrete, Brick, Marbel and Basalt



Schematic Diagram of the Subsea Electronic System

Fig: 5

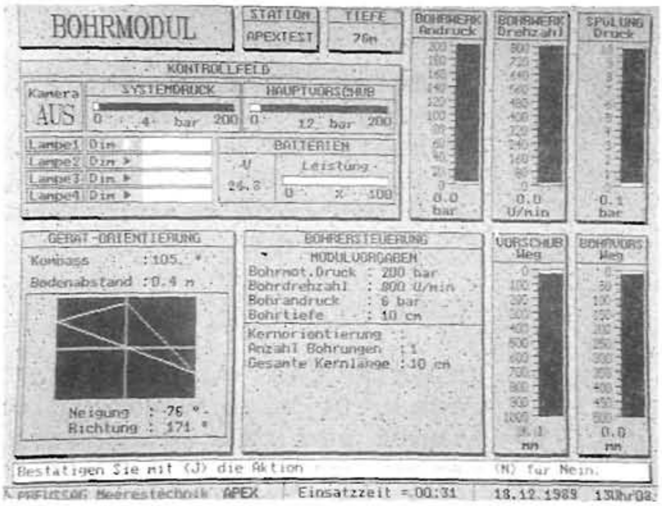
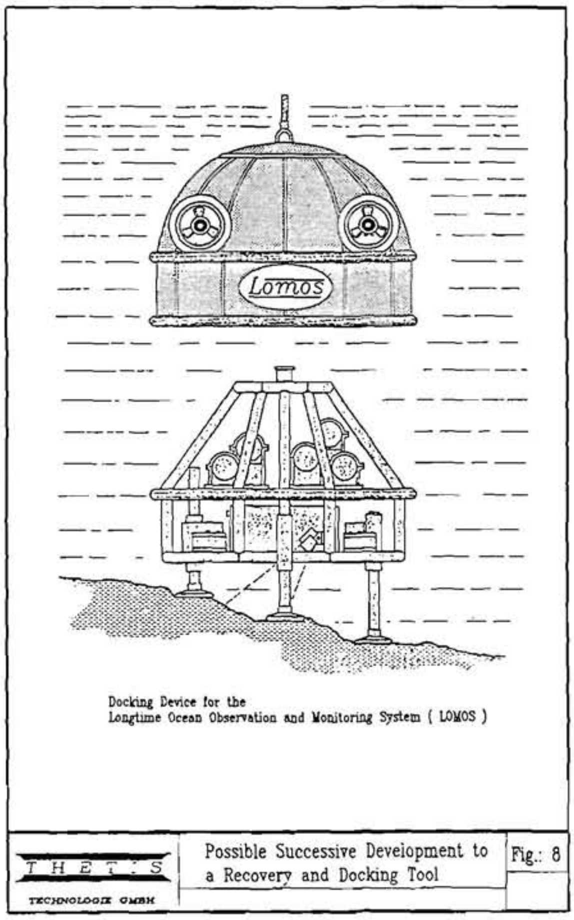
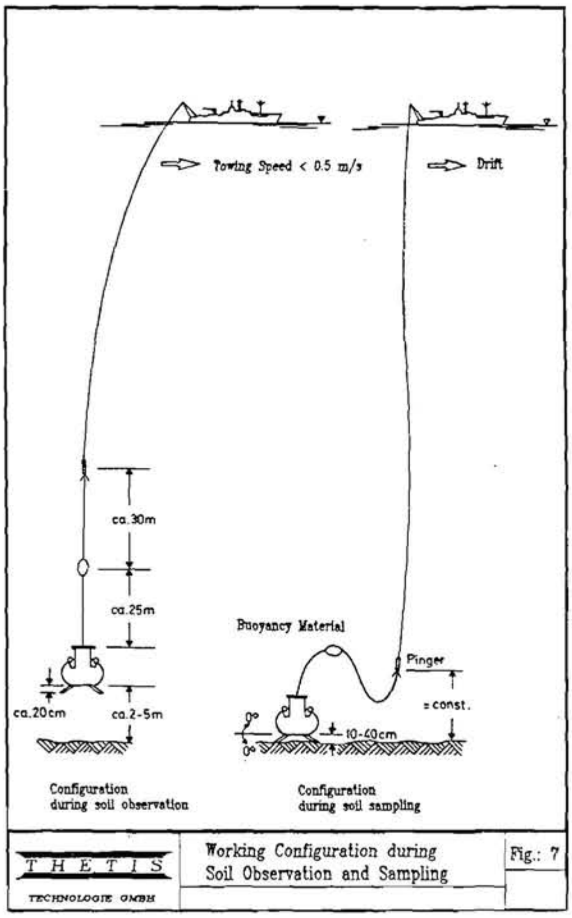


Fig. 6 : Controll Display during Soil Observation



Possible Successive Development to a Recovery and Docking Tool

Fig.: 8



Working Configuration during Soil Observation and Sampling

Fig.: 7

Modules possess their own, additional sensors for operation control. For the drill corer, there are sensors to display drill speed, penetration depth, drill torque, drill bit thrust, head of flushing water and the core orientation as well as coring success.

5 Control

Within the control post on board, just a personal computer with keyboard and joystick serves as command input and currently displays sensor data and messages about conditions of the underwater unit. Menue guided, the user operates the system and initates all soil sampling procedures that runs partly automatically although he still keeps the possibility to interrupt and to adjust new parameters or settings. Thus he will be able to adapt the performance of APEX to actual environmental or operational conditions.

6 Modules

Three different soil sampling modules for different soil types to be plugged into the APEX-system are currently tested and ready for application:

- a sediment sampler of 0.5 x 0.5 x 0.7 m size similar to the Kasten-corer type but with sealing plates on the top side to ensure undisturbed sampling even of liquid layers

- an orange peel grab of $0.1 m^3$ of volume and with closing forces of 3.4 kN to facilitate sampling of coarse material such as talus or weathered rock.

- a rock drill to recover drill cores of Ø 50 mm and a maximum length of 500 mm from hard substrates. The system is a double tube core barrel with different diamond bits and separate, independent water flushing. Furthermore, the core barrel allows oriented coring, i.e. the core's orientation to geographic north can be established after salvage. Besides, a so-called core check is automatically performed after each sampling in order to immediately control proper core retaining. Drill speed, drill thrust and drill penetration can continuously be adjusted - and modified during operation- while the complete coring procedure runs automatically (fig.3).

Tests

The construction of APEX and its first functional tests under (dry) workshop-conditions were finalized in January 1990. Since February, APEX was submerged in a test pool of the GKSS Research Center in Geesthacht, in order to prove its capacity under controlled conditions and perfect visual supervision. Additionally, thrust measurements and hydromechanical tests were performed.

In April, APEX was fitted into the 100bar pressure chamber of the GKSS Research Center to test and record all of its functions under a simulated waterdepth of 1000 m. Subsequently APEX was shipped to the Research Platform Nordsee (FPN), 110 miles north-east of Helgoland. Beside (successful) coring tests into reinforced concrete (fig.4), tests along a 50 m long cable within 25m of waterdepth aimed at establishing manouevring facilities in spite of tide currents and low visibility. Results demonstrated that precise positioning of the system was feasable and computer calculations about its motional behaviour could be adjusted.

Deep Sea Operation

With its total weight of 3-3.5 tons depending on its implemented module, the APEX system can be handled from each conventional research vessel that is furnished with a coaxial cable. APEX can be submerged down to 6000m and then used as a soil observation vehicle while it is towed along with approx. 1 kn some meters above the ocean floor, presenting a viewing area of 3-9 m in diameter, depending on soil clearance. Once locations of interest have been visually detected, APEX can be precisely positioned on the spot by means of 2 thrusters that may horizontally shift the cable bound system within an action radius of 5-10 m. After landing, the base unit is horizontally levelled, operational parameters for sampling are preestablished and automatic sampling can be initiated while the user onboard supervises the procedure by a second camera as well as by digital and graphical display of operating conditions. In case of failure, a new approach may be conducted if enough spare energy is left (fig.6).

Using a cable configuration as illustrated, no DP of the vessel is required even for coring that lasts for not more than 10-15 min.(fig.7).

Further Developments

The extension of module capacities, such as the increase of the coring penetration or the number of samples is currently anticipated as well as the implementation of further modules, e.g. a geotechnical soil investigating tool assembly. Besides, positive results with the APEX-positioning capabilities encouraged the conception of a Longtime Ocean Monitoring and Observation System (LOMOS) that is released on the ocean from an actively positioned steering device which is also able to approach the station by automatic sonar control and to remotely dock and retrieve the station after mission. Using similar main components as are already tested within the APEX-system, such a docking system would be one of several consequent continuations that started with the development of the APEX concept (fig.8).

Conclusion

The development of APEX which has now come to an end after successful testing induces a new generation of deep sea exploration tools that meet requirements of future oceanographic work by combining observation, active steering and sampling facilities whereas the hard coring tool appears to be the most valuable one for scientific investigations. Modularity in both, mechanics and electronic as well as an universal hydraulic driving concept make the system easily extendable. The intensive use of micro-electronics and the implementation of a Personal Computer (PC) decisevely influence the system's capabilities and its control possibilities that ultimately improves the quality of obtained samples.

Acknowledgement

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