JETTISON EMERGENCY CAPSULE

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The jettison emergency capsule is a special device designed for rescuing life under the most difficult weather conditions. The use of slinging pyrotechnic agents makes the launching of the capsule extremely fast, also ensuring that it lands at a considerable distance from the object in danger. The designs brought into practical use enable the capsule to be ejected with 16 persons inside from a height of up to 30 m. The personnel inside' is protected from environmental conditions and such agents as fire and poisonous gases.

The construction utilizes many original technical devices, among those an inner pressure hull, anchors and an automatic system for the regeneration of the atmosphere, which is effective for up to 48 hours. They sustain the life of the rescuees even if the capsule is submerged at the depth of 50m. The capsule's descent is arrested at a safe depth by a special automatic mechanical winch. For communication between the capsule and the outside world, communication and signal devices are used. They can be utilized both on the surface, and under water.

INTRODUCTION

The subject of life protection and saving during marine operations is well understood and appreciated. It is so in the case of the Ship Research Institute at the Technical University of Gdansk. Our scientific and technical staff have been heavily involved in the design and development of life boats for a number of years. Many types of open and closed boats, particulauly those made of fiberglass composites were successfuly introduced and installed onboard hundreds of ships.

Experience of the team involved is significant. Since the boats and other life saving appliances were constructed and applied according to corresponding codes and rules, many people used to think that they are reliable and totally sufficient in every possible condition. However, close analysis of the latest fatal accidents on several ships and offshore units, shows that their capabilities are limited to say the least. The principles of their design and application, established initially for wooden sail ships, are not adequate now, particularly for structures similar to offshore platforms. For this reason, most of the accumulated knowledge, regarding life saving systems can be questioned. A totally new approach is very much required.

The project described below started at the end of 1983, when we first became aquainted with publications concerning the Ocean Ranger disaster. The solution to the problem of personnel evacuation from an offshore object in an emergency provides the use of a hermetically sealed pressure resistant capsule. The capsule with occupants inside is ejected from the object and remains submerged underwater for several hours. This time should be long enough to allow a rescue operation to be organized. Since the position of the anchored capsule is well known, this removes the need for an extensive search of the rescuees. The capsule being a kind of "flying submersible" was designed using the experience gained during the design and construction of a manned submersible. A pressure hull structure was verified in several tests and service under pressure. However, I must stress it is still a proposition to be considered and discussed. The problems, of which we are aware ourselves, are listed at the end of this paper.

1. The technical task

The problem was defined as follows:

1. The device with rescuees is to be ejected from the platform.
2. The device with rescuees is to be safely put down on the water surface.

The above requirements are principal for every life saving system operating in difficult conditions. The best solution seems to be the application of rocket technology. A kind of compartment with personnel inside would be ejected into the air from an arbitrary point on the platform, eg. a roof of accomodation blocks, by means of rockets. The landing at the required distance could then be accomplished using deccelerating rockets. Contact with the surface, which could even be covered with ice, should be smooth and safe for the occupants of the compartment. Later on, it could act as a conventional life boat. The ammount ofpropeilant required is low. Rocket engines are also very reliable and easily available. The principal serious disadvantage of the idea is the open fire which is generated. One can easily imagine the side effects of the launch of the device in an atmosphere enriched with a combustible gas.

The next step in the definition of the technical task is a decision what to do with the life saving device after it is safely floating on the water. According to most of the existing codes, the life boat is to be equipped with an engine allowing fast withdrawl from the area of danger. Flames of burning oil are the principal threat. This is perhaps a proper scenario for a blow up accident at calm sea. In heavy weather, with strong wind, high waves, at remote areas, it is however not so. Boats or rafts can easily be dispersed on large areas. Problems with stability are also known. All this makes a rescue operation difficult, time and equipment consuming. The conditions at the surface are not pleasant for the rescuees. For this reason, two further assumptions were added to those listed previously:

3. To fix the device with the rescuees in proximity of the well known point of accident.

4. To submerge the device below the level of wave action.

Furthermore, to allow rescue crafts (ships, helicopters) direct recovery of the device with rescuees on board, the device should also be as light as possible.

2. The life saving system

To meet the above requirements, a device described shortly as an ejectib-le and submersible life saving capsule is proposed. The complete system consists of the capsule and a launcher. the capsule itself is shown on Fig 1. and Fig 2, while the capsule on the launcher is shown on Fig 3 and 4.

The principal component of the capsule is a spherical, pressure resistant fiberglass composite shell. It is equipped with five entry hatches acting simultaneously as view ports. The interior of the shell is a personnel compartment. It contains seats for fourteen to sixteen rescuees, a life support system, depth control mechanisms, and communication components. The shell playing the role of a pressure hull, is contained within an outer structure. There are no stiff mechanical connections between these two elements. The spherical shell is suspended on elastomeric pads. The external shell, also built of a fiberglass-polyester composite, protects the pressure hull and externally placed components. It has to resist thermal and mechanical shocks, particularly fire and loads generated when the capsule penetrates the water surface. It is structurally connected with a large size lifting frame at the top. It is also a base for a telescopic mast, pinger and marking buoy.

The spherical pressure shell with a diameter of 3 metres has a very high displacement, when compared to an assumed maximum mass of the capsule. Even with internal and external equipment and fully manned, the total capsule mass should not exceed 5 Mg. To submerge it underwater, even with a single human being inside, 13 Mg of ballast is required. This mass is divided into a 3 Mg anchor, 2 Mg anchor winch with 200 to 300 m steel rope, 7 Mg ballast and approximately 1 Mg of auxilliary equipment. During the launch operation, the anchor is released by the anchor winch controlled by external pressure. It keeps the capsule submerged at the depth between 30 and 60 m. In the case of the winch mechanism failure, ten soft buoyancy tanks are provided. They are supplied with gas from a pyrotechnic generator and are contained between the pressure spherical shell and external protection. Their volume is sufficient to make the fully ballasted capsule positively buoyant. The gas generators are activated automatically when the depth limit of 60 m is exceeded. Manual activation is provided also. In this mode, buoyancy tanks can give additional buoyancy and stability at the surface.

3. Seats and life support

The exact number, form and arrangement of the seats have not been decided upon yet. We need more information regarding the capsule behaviour. They will however be shaped according to the principles established for free fall systems and aircraft seats. As an alternative for safety belts, a kind of stiff cover, with pneumatic pillows are considered seriously. We expect they will provide a human body better protection from accelerations along directions other than vertical and horizontal.

The life support system operating in the submerged position uses dual role chemical composed mainly of potassium superoxide. It is stored in hermetically soldered metal cans in the form of plates or pellets. In an emergency, the cans are opened and chemical placed in a scrubber. Carbexhaled by humans is absorbed in a chemical reaction and the ammount of oxygen released is almost equal to the ammount of carbon dioxide absorbed. The difference is to be balanced by means of soda lime or other scrubbing material. An electrically driven fan is provided to circulate air through the scrubber and air cooler-dehumidi-fier. The ammount of chemicals provided for the air revitilization is sufficient for 48 h with a 30 % safety' margin. When surfaced, the capsule interior will be ventilated by means of a snorkel.

Food and water are stored in quantities required for 14 days. Drinking water is contained in tanks placed inside a foundation structure supporting the seats, while the cans with chemicals and food are placed under the seats.

The toilet is arranged under one of the seats. It is connected with an excrement and urine collecting tank below. Its contents can be pumped out of the personnel compartment by means of a hand pump. The pump is also utilized for condensating and leaking water removal

4. Source of energy

Communication and signalling equipment as well as fans, interior lights and pyrotechnic devices are supplied from a nickel-cadmium accumulator battery. For reliability, the battery is divided into four parallely connected sections, with a nominal voltage of 24 V each. The nickel-cadmium cells were selected for their long operational life and good performance while permanently charged. The latter is provided to have a fully charged source of energy at every moment of the capsule's operational life. The battery charger is placed inside the launcher, and is supplied from an offshore platform's electrical system. The sections of the battery are placed outside the pressure shell in pressure compensated compartments. This prevents hydrogen gas buildup in the personnel compartment, during long term, low maintenance service.

5. Automatic anchor winch

A critical factor in every thrown or free fall manned system is the acceleration or decceleration involved, while the water surface is penetrated. To decrease its value, the capsule has been designed with a conical bottom. Furthermore, it is assumed that the dive begins dynamically. The very short time of the whole launch operation (2.5 seconds in the air and fractions of a second in the water) gives the personnel no chance to control the process. Therefore the equipment is designed to operate automatically. To release the anchor at 20 m and to stop the capsule at the depth between 30 m and 60 m, a mechanical automatic winch of special design has been constructed. It contains a rope drum, the rotational speed of which is controlled by means of hydraulic and friction brakes. The control loops in the winch mechanism, are shown of Fig 5. It is worth noting that all the control functions are performed by means of simple and very reliable mechanical components. These include a multi disc, steel-cast iron brake, radial water pump acting as a brake and simple gears, some of them with epicyclic gearing. The gear wheels are utilized for multiplying the drum rotational speed, the friction brake moment control and all the functional component coupling. In spite of its simplicity, the winch performs very complex functions.

The capsule penetrating the water surface after launch, deccelerates rapidly. At a short distance, its movement becomes steady. When the depth of 20 m is reached, a pressure operated hold releases the conical anchor weight. A Fl force appears in the anchor line. Its value depends on a braking moment developed by hydraulic and friction brakes. It can not be lower than the actual capsule buoyancy when the anchor is released. Sim ulta-neously it can not exceed a value for which a difference between the anchor and the capsule speed is not high enough. For an area depth of 200 m and assumed submergence depth range of 20 m to 60 m, the following relation is to be observed:

$$Va / Vc > (200-20) / (60-20) = 4.5$$

where:

Va - Anchor vertical speed

Vc - Capsule vertical speed

To give the system some margin of safety, the above value should be greater than 5. Otherwise the capsule would not stop and would exceed the 60 m depth limit. To make the problem more complex, the above statement must be observed for different capsule mass, because of a varying number of rescuees on board. With a maximum capsule mass difference of 1200 kg this can not be accomplished by means of a constant moment brake. Its cha racteristic is to be selected to reduce the line force to a value of the capsule force of buoyancy. To reach the required depth range, the force is to be corrected bymeans of a pressure sensitive device. In the design adopted it is performed by a hydraulic cylinder. The external pressure acts on the cylinder piston and by this means decreases spring force loading friction disks in the friction brake. The expected capsule and anchor velocities which are a result of the winch action in this phase of the launch operation, are shown on Fig 6. After the capsule is anchored and stopped, the line force is to be increased above the value most adequate in dynamic conditions. This is important in order to prevent a horizontal drift caused even by small side forces from currents or residual wave action. This means that the static braking moment must exceed the value developed while the anchor speeds to the bottom. The latter requirement is corn paratively easy to fulfil while it is in accordance with principles of the steel-cast iron friction phenomenon.

After the anchored capsule is stopped automatically, it can be moved in the vertical direction according to the will of the personnel. To move it upwards, the friction brake is to be used. The friction force is decreased by a manually operated hydraulic system (a pump) contained within the pressure hull. The force of approximately 30 kN in the anchor rope is more than sufficient for this manoeuvre. Unfortunately, to move the capsule downwards, the same force must be overcome. Manual activation of the winch is provided by means of a crank placed within the personnel compartment. Adequate gear with total reduction of 1:357 decreases the force to an acceptable level. However a moment of 17 MN is required. The 50 m displacement of the capsule in the downward direction in such conditions takes hours.

6. The launcher

The form of the launcher presented below, is one of many possible. It is designed to be welded to the side of an offshore structure. But a launcher can also be arranged on a horozontally oriented deck or frame structure. The main components of the launcher are the guiding frame and throwing cylinder. The frame is suspended on cantilever supports welded to the platform structure. The rotary suspension allows rotation of the guiding frame in the vertical plane. While the capsule-guiding frame system center of gravity lies far below the point of rotation, the capsule guides are always levelled closely to the horozontal. Hydraulic dampers are used for damping possible oscillating movements. The frame is of an open construction at the end facing the sea, thus allowing the capsule to leave the launcher. Mechanical stoppers are provided to prevent an accidental drop of the capsule from the launcher. The throwing cylinder is placed at the other end of the guiding frame. It is joined to the frame in that manner, so that it can be shifted backwards against the force of a loading spring. The force is delivered by the cylinder itself, when it is activated and presses on the capsule ballast. In the first moment the body of the cylinder moves back. In this position a bolt or coupling pin at the end of the cylinder enters one of the cut-outs of the rocket shown on Fig 3. This protects the guiding frame and the capsule from undesired tilting during the launch. Active length of the guides is only 6 meters. The total stroke of the cylinder is 6.2 metres when fully extended, while its initial length is only 1.2

metres. So a significant extension is possible owing to the telescopic construction of the cylinder. It consists of six movable sections sealed by means of o-rings. The outside diameter is approximately 500 mm. The force exerted by the cylinder can be varied by means of changes of entering gas pressure. To give the capsule the required acceleration equal to 2 to 3 g, its value should be three times the capsule weight (i.e. 450

500 kN). This requires gas pressure of 10 MPa. An optimal source of the gas is a pyrotechnic generator, but compressed air stored in steel bottles is a practical alternative. The storage volume required is 250 - 300 dm^3.

The bottles permanently charged from an offshore rig or gas generator, are placed inside the spacious structure of the supports. It is an adequate compartment for the capsule battery charger and water tanks of the external spray system. An emergency battery, supplying external illumination is placed here also. The upper surfaces of the supprts and guiding frame serve as a gangway. This gives an easy path from a deck of an offshore structure to the capsule entry hatches. The water spray system is provided for protection of the system area against fire. The above mentioned emergency source of energy is used for launcher illumination in case of the rig electrical system failure.

7. The tests

Up to date, launch tests of 1:10 and 1:5 scale models were performed. With 1:10 scale it was possible to model only the general shape of the capsule as well as the idea of horizontal throw. Vertical and horizontalaccelerations were measured during the tests. While the acceleratins measured (see Table I) were not excessive, the construction of 1:5 scale model was decided upon. With this scale of reduction it was possible to obtain a structural similarity between the model and the designed full scale object. The internal pressure shell with transparent hatch covers and external protection with the lifting frame were modelled. Damping elastomeric pads betweert the above components were introduced also. Unfortunately it was not possible to simulate auxilliary equipment and particularly its functions. The phenomena which occur in these componens cannot be scaled properly.

The experiments with the 1:5 scale model were done in two series. Firstly behaviour of the capsule during simple drops from heights ranging from 3m up to 9 m was observed. This corresponds to 15 m to 45 in full scale. The vertical accelerations measured were equal to these from the 1:10 scale tests. The launcher model with tilting guiding frame and air activated teles-copic cylinder was utilized in the second series of tests. The capsule model was thrown from the height of 7 m. Different pressures of air supply were utilized. During these throws, vertical and horizontal accelerations were measured. Again it was found that vertical accelerations do not exceed the value of 12 g. Stability of the capsule during its flight in the air was found to be satisfying. The capsule in different phases of the flight was photographed. One of the records is shown on Fig 7.

8. The future

With financial support from Polish Governmental agencies, the launch tests of a full scale capsule model are prepared. The tests of the principal components and acceleration measurements will be finished hopefully later this year or next spring. For the next year, the construction of a life saving prototype is also scheduled. However, this phase of the project depends very much upon the full scale model test results which will be decisive.

The answers regarding the following problems are to be found during the tests of the full scale model and system prototype:

- The behaviour of the launcher-capsule system under extremely diverse conditions
- Protection of the capsule personnel during decceleration in an inclined orientation.
- Human factors in system design and operation (claustrophobia, locomotion illness)
- Motions of the capsule while anchored in proximity of the water surface.
- Finnancial factors of the system construction and operation for maximum reliability.
- Influence of the system weight on offshore rig design.
- Personnel raining

Fig. 1.

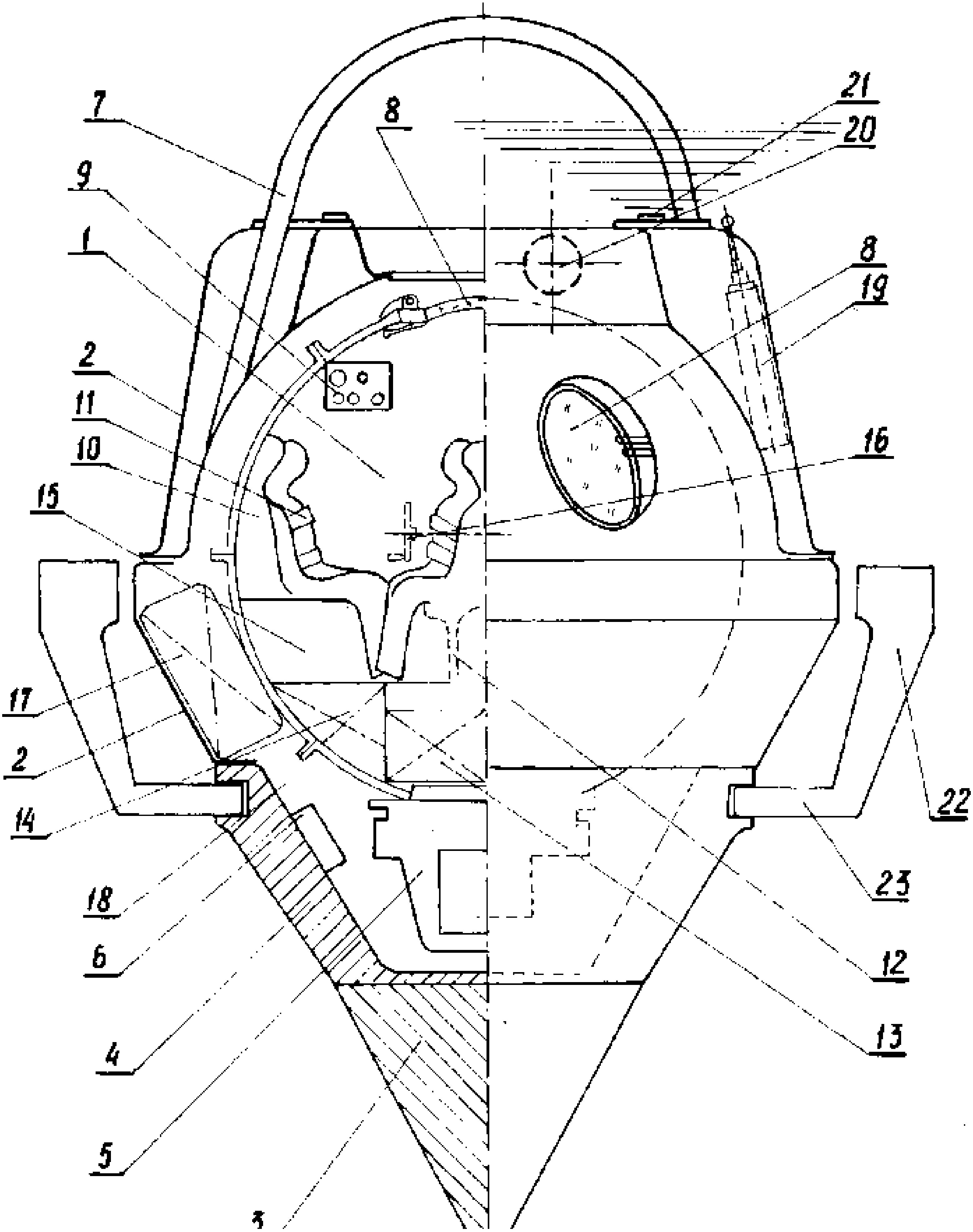
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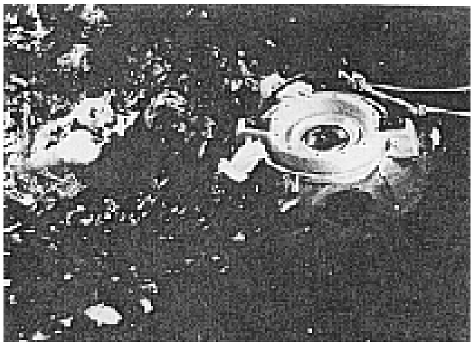
Fig.2 the capsule 1:5 scale model during drop tests

1. Spherical pressure hull
2. External protection
3. Anchor weight
4. Ballast
5. Anchor winch
6. Ballast release mechanism
7. Lifting frame
8. Entry hatches and windows
9. Control panel
10. Seats
11. Safety seat belts
12. Toilet
13. Waste tank
14. Drinking water tank
15. Food and atmosphere revitalization chemicals
16. Manually operated winch crank
17. Soft buoyancy tanks
18. Suspension pads
19. Aerial/radar reflector telescopic mast
20. Radar reflector
21. Hydroacoustic pinger
22. Guiding frame
23. Guide



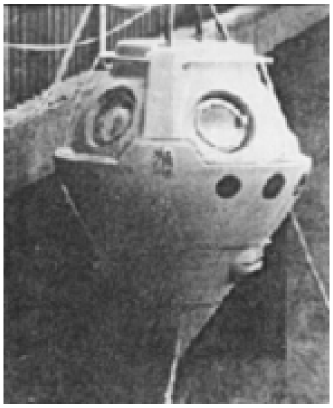


Fig. 3. The Capsule-Launcher arrangement

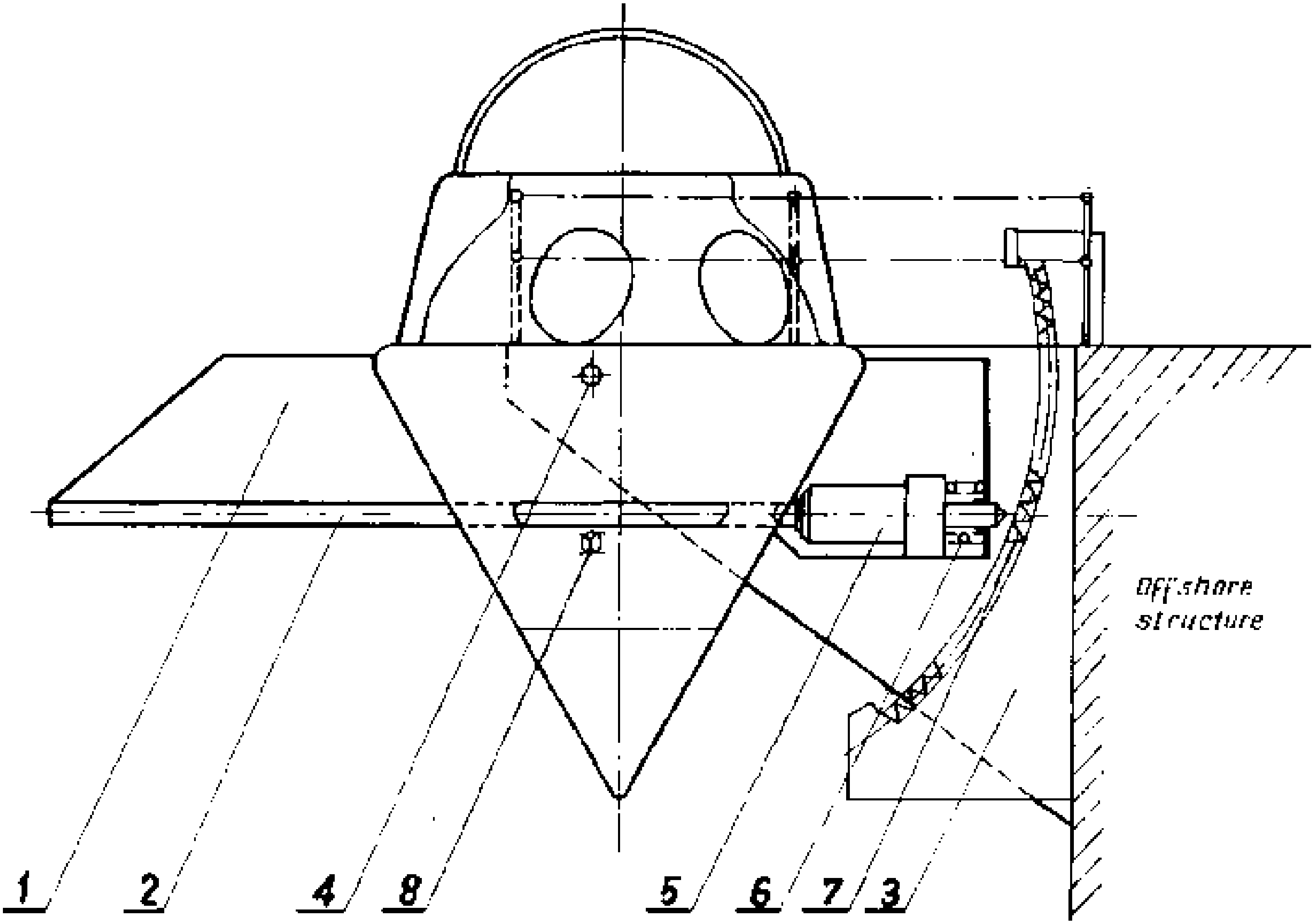
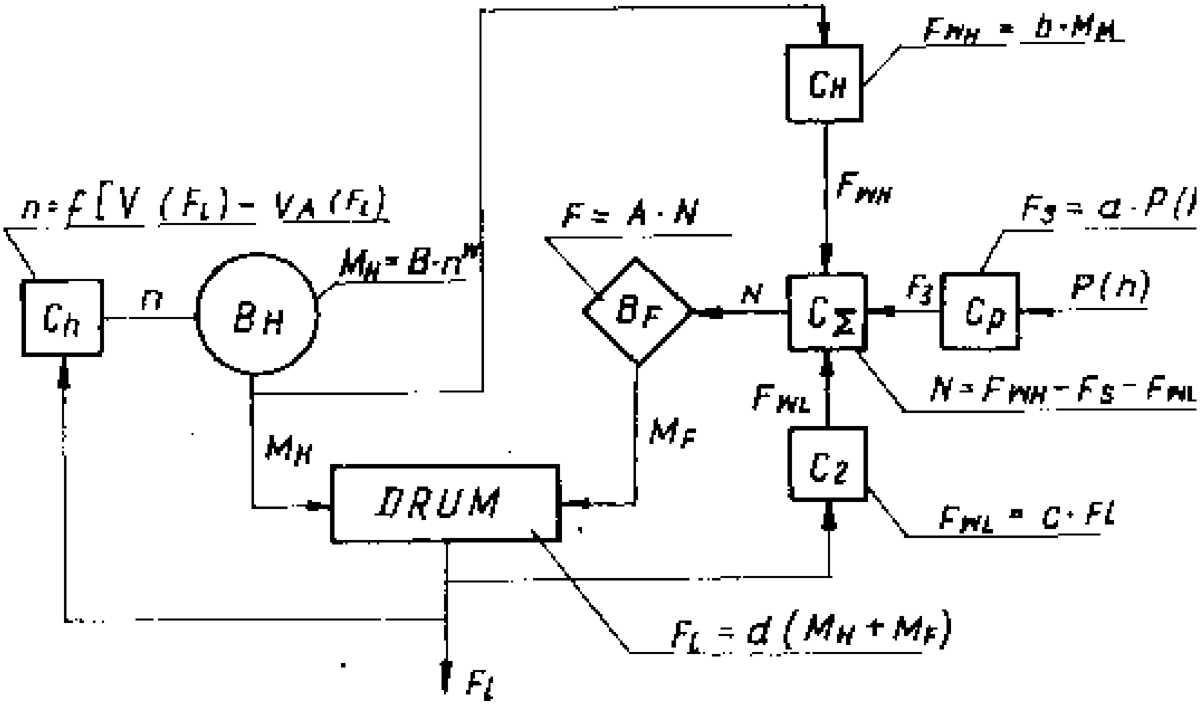


Fig. 4. The launcher 1:5 scale model with the apsule installed during tests

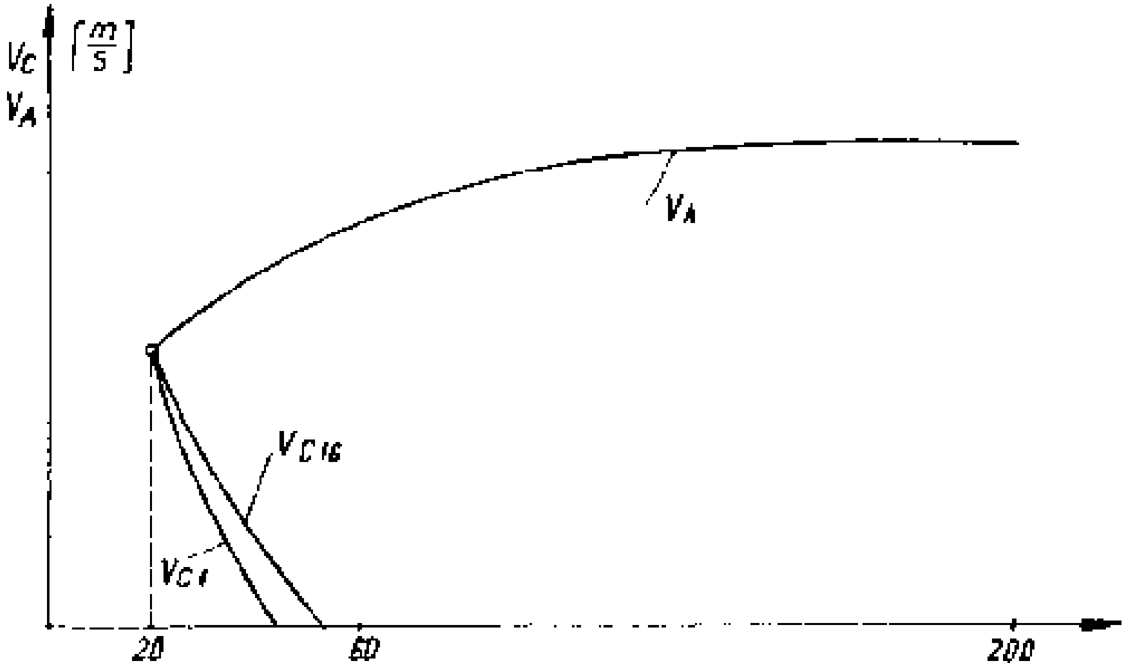
1. Guiding frame
2. Guide
3. Guiding frame support
4. Frame suspension point
5. Telescopic cylinder
6. Spring
7. Ratchet
8. Capsule-guiding frame center of gravity

Fig. 5. Automatic anchor winch control loops



- BH - Hydraulic brake /water pump/
- BF - Friction multi disk brake
- P/h/ - External pressure
- n - Hydraulic brake rotation speed
- MH, MF - Hydraulic and friction braking moment
- N - Resultant force on friction brake discs
- Cp - Pressure transformer
- CL , Cn , CH , C - transformers /epicyclic gears/
- VC, VA, - Capsule and anchor velocities
- A, B, a, b, *c*, d, - Constants

Fig. 6. Expected resultant capsule and anchor velocities vs. depth during anchoring phase



VC1 - Capsule velocity with single person inside

VC16 - Capsule velocity with 16 persons inside

Fig. 7. The 1:5 capsule model during air flight. Some angles of inclination from vertical were observed depending on the capsule's mass arrangement.