TECHNOLOGY OF CREW SURVIVAL IN A DISAIBLED SUBMARINE: LIQUID BREATING + URGENT FREE ESCAPE

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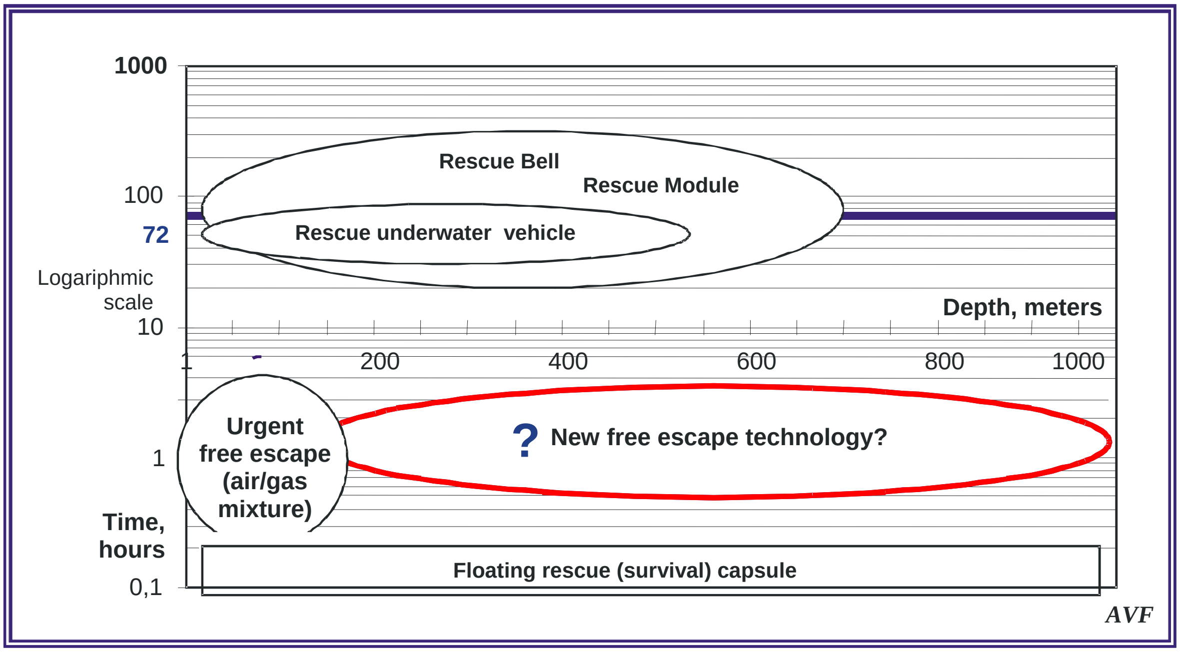
ABSTRACT

The conception named "First aid to submariners" is offered in case of emergency at a depth from 200 to 1000meters.Pilot tests of liquid breathing with volunteers simulating submariner's escape is planned for the year 2007.
The new technology of liquid breathing when a submariner free escape, which has been worked up by author for more than 20 years, rules out the ability of death from decompression disease, without dependence on depth. It was offered to use divers-rescuers, who will be delivered with the pickup-group on the sea surface by aircraft. In case of emergency they will reach the sunken submarine in two hours. An original 5 tons deep-sea rescue vehicle was offered to deliver divers-rescuers in a special "wet" compartment to the place of accident.
According to this conception, the requirements for volunteers tests are worked out - the next step in submarine crew survival problem solution. Another, financial aspect - is the large expenses on submariner's life and health insurance, which can increase interest of insurance companies and business in new safe technologies.

INTODUCTION

In classical book "Subsunk : the story of submarine escape" by English author W.O. Shelford (1963) it was noted, that if a submarine sunk on the depth of 60 meters, it's crew will run the danger of supercooling because of flooding the compartments with sea water and fast growing of pressure above 6 Bars witch is life-threatening. A half a century later the situation hasn't changed, so the only way to prevent the imminent danger of staying under the growing pressure, is to escape from the sunk submarine in the first two hours after an accident.
An existing project in RF Navy is a "Rescue Floating Module" (RFM). Submariners were trying to use it on NS "Komsomoletc" in 1989 when an accident happened and found it very complicated in case of emergency. When an accident occurred on NS "Kursk" in 1998, it was impossible to use RFM because of the damage after an explosion. That's why the result of resent accidents – only one saved submariner, doesn't give much home using RFM. Of cause it's not time now to refuse to use RFM. German engineers, in addition to escape towers, have developed escape "spheres". But it's impossible to use them in small submarines and underwater vehicles.
If a SOS signal from a submarine is received, the coordinates off accident are known on the land, it's possible to use well knows from early 60's method– urgent free escape, making allowance for the help from the surface. Taking an account of today satellite navigation progress, the main thing to think about is air delivery of rescue team who will pickup the freely escaped submariners before navy forces come (normally up to 72 hours).
Rescue boat named "Gagara" which is used in FR Navy was designed to use together with IL–76 MDPS in a aeronavy complex. On RF Navy maneuvers the rescue boat was dropped from a height of 600 – 1500 meters (with a rescue team onboard and roughness up to 5 degrees). The rescue team pickup escaped submariners putting them on inflatable rafts.
NATO uses a similar technique, following example of British rescue team (Subsank Parachute Assistance Group - SPAG), which is dropped prom aircrafts with the inflatable boats (**2**)
Thus the main problem left is how submariners can safely escape from depth of an accident site.

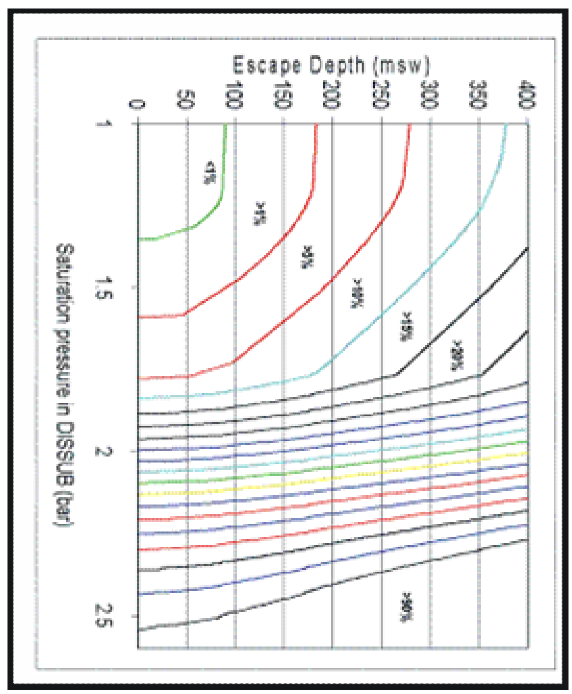


Graph 1. *Submariners rescue technology based on operation time and accident depth*

As shown on a diagram (**graph 1)**, surface rescue vessels can operate on a wide range of depths, but reach the accident site too late – after 3-4 days. Another quick way to reach the surface, besides using RFM, is urgent free escape with air or gas mixture respiration, as it's used in RF Navy when escaping through torpedo tube.

It's possible to rescue submariners from the depth more then 200 meters using urgent free escape technique (when air breathing), but without regard for common safety regulations of urgent free escape.

Thus, symptomatic decompression disease occurs in 1% of cases when escaping from 100 meters, and less than 5 % when escaping from 100 - 180 meters (air respiration). The rate of increase of decompression disease on big depths is theoretically proved in G. Loveman et al. works (**3, 4**). If it would be possible to optimize the compression speed in a escape tower, then decompression disease rate would be 5 – 10 % when escaping from 180-300 metes, and 10-15% when escaping from 300-400 meters (if compartment pressure is about 1-1,6 Bar). As it shown on diagrams «iso-risk» for different depths (**graph 2**). German engineers based their work on these calculations .



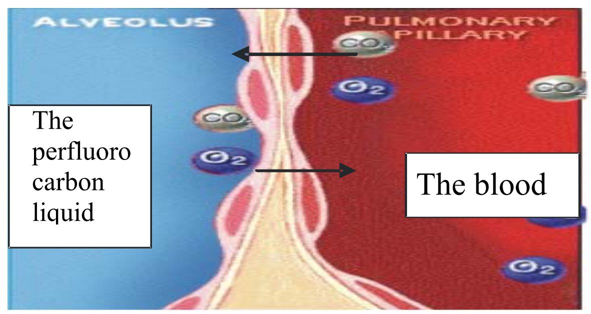
Graph 2. *Decompression disease rate increase:*

- *free escape from up to 400 meters*
- *compartment pressure 1- 2,5 Bar*

By C.Loveman, «QinetiQ» company **(3)**.

HABETaS consortium of German and British companies bfa and HDW worked out a R&D to develop technical and engineering solutions allowing to use free escape from an escape tower of a sunk submarine on the ultimate depths (up to 550 meters).
The objectives of R&D were (**5**):
- decrease required gas amount to minimum (per person) when airlocking to increase possible saved people using limited volume gas;
- use only sea water and compressed air without using any other power supply;
- exclude any devices with electronic and hydraulic components in airlocking construction;
- decrease flooding and blowing time of escape tower to minimum, which a submariner can stand;
- guarantee the floating characteristics of a new escape diving-suit after compression to minimize the surfacing time (while safe decompression).

HABETaS system, developed in R&D, was tested in Institute of Naval Medicine (Alverstone), where rescue simulation from depths from 30 to 550 meters had been worked out. Construction included: modification of a rescue module, new algorithm and stage control system (flooding, compressing and dewatering of the escape tower), exit modification using new escape diving-suit.
The developers consider, that HABETaS system could be installed on any submarine which has an escape tower, or even a submarine which is in service. There are supporters of buying this system in Russia also.
Probably, offered system echoes the resent accident with NS "Kursk", is a English old free escape development of 50-60's (using more advance technology of air and sea-water utilization). But the way human body react to "bubbles" while surfacing.
Another issue, is that HABETaS system is a modification for large and middle class submarine escape towers. It's not designed to use in submarines without escape towers and underwater vehicles.
The number of small class underwater vehicles increases from year to year, now there are two-seater underwater vehicles used to submerge up to 800 meters, and also submarines «for the rich». The main problem of crew survival in this case – is to avoid decompression disease while free escape. The problem how to influence to the underlying cause of the decompression disease – nitrogen supersaturating while compression and decompression – becomes more and more actual.
About sixty years ago when Jak Iv Kusto designed aqualung, he used two words in it's name: "aqua" and "lung". But the technology of filling lungs with water (water-salt solution) became known only after publication of J.A. Kylstra «Of mice as fish» - the first publication on liquid breathing where is told about an ability to use this technology in submariners life-saving (**6**). And he was the first who has worked out experiments on land mammals (mice) showing that liquid breathing completely prevents death from decompression gasification while free escape from the depth up to 1000 meters. It was proved in experimrnt with immobilized dogs artificial lung ventilation with liquid imitating diving up to 1000 meters (**7**).
More than, later works of Sweden researchers C. Lundgren & H. Ornhagen shown that mice immersed in liquid and liquid ventilating are resistant to pressure level imitating diving up to 2500 meters (**8**).
The cause of effect is in gas diffusion through the alveoli membrane according to partial pressure.



Graph 3. *O_2 molecules diffusion, from alveoli to pulmonary capillary, CO_2 – back.*

When nitrogen, helium or any other inert gas (oxygen diluent) is replaced to liquid, oxygen diffusion stays the same: it goes according to partial pressure gradient (**graph 3**). In the total, the liquid providing the diffusion of oxygen into blood, makes the diluent – inert gas – needless, excepting the initial cause of supersaturation with this gas.
When changing the breathing environment, the main thing is to chose the liquid with high solubility of O_2 and CO_2. Water and water-saline solutions dissolve well gas only under high pressure. Under atmospheric pressue thes dissolve oxygen very poor (only 0,004 % of mass at 20 ^oC.). More than, they damage alveoli, washing surfactant from them, preventing them from sticking together, there by extremely complicates the return to air ventilation. For water replacement Russian and foreign resechers started to use chemically pure fluorocarbon (Teflon). Для замены воды и у нас и за рубежом стали, which has no such defects. They are highly chemically inert, have no taste or smell, transparent **(graph 4)**, dissolve up to 40-50 volume % of O_2 and for times more CO_2.
The are very few manufacturers of these liquids, because they are produced as by-product of "atomic projects". Thee a few world known manufactures:

DuPont (USA), ICI and F2 (UK), Elf-Atochem (France). Fluorocarbon liquids produced in institute of «Applied Chemistry» in St.-Petersburg (Russia), now lead in medicine and cosmetology.

Graph 4. *Fluorocarbon liquids in ampoules.*

Lung lavage with water-saline solutions has benn studied in experimental department of institute of Pulmonology of 1 St.-Petersburg State Medical University named after I.P. Pavlov (1 S.-Pb SMU). Author of the research started to work out with samples of medical fluorocarbon liquids in 1983 on animals. Starting as a senior staff scientist, Navy SSS agent, than a research supervisor of a problem set by R&D «Olifa M3» in 1986-89.

1. OBJECTIVES

First own results confirmed known data of foreign researchers about an possibility of hours-long liquid ventilation (unassisted, spontaneous, total) of dog's puppies as well as other small laboratory animals: rats and mice. However with bigger animas, which have similar to human trachea diameter and lung organization spontaneous liquid breathing without a help of artificial lung ventilation device did not occur. Os it was shown in J. Kylstra experiments, adult dogs were not able to hours-long spontaneous liquid ventilation. They rarely sustained more then 10-20 minutes and then died from lung failure. When artificial lung ventilation vas performed it improved clinical results, but to use this technique when surfacing from depth it was decided to design the respiration equipment which does not use electricity.
To bring the ideas of new technique of submariners life-safe to life it was necessary to develop a new method, new equipment and new respiration liquids.
Then conduct new experiments on bigger animals-dogs, and then on volunteers imitating the variants of free escape of submariners according to the new technique of their life-saving.

1.1 Main objectives:

1. Biological tests of fluorocarbon liquids produced in institute of «Applied Chemistry» and giving recommendations to manufactures to enhance their products.
2. Work out the technique of dogs liquid breathing (unassisted, spontaneous) imitating submariner's free escape. The technique and equipment must work:
    - when being under normal and slightly raised pressure in compartment up to 5 minutes;
    - when compression and decompression.
3. Liquid ventilation technique development (artifishial). Methods and equipment (individual respiration device for dogs, compressed gas powered) must work wen imitating free escame from flooded compartment with 5-30 minutes stay at depth.
4. Develop conception of liquid breathing and liquid ventilation while submariners free escape.
    - Prepare volunteer tests in clinic and hyperbaric chamber.

2. MATERIALS AND METHODS

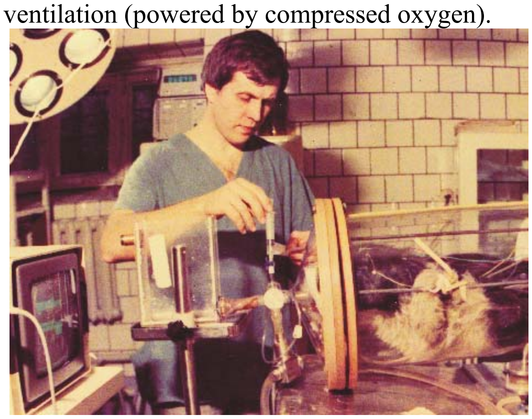
Experiments with normal pressure were worked out in laboratories of institute of Pulmonology of 1 St.-Petersburg State Medical University named after I.P. Pavlov. Hyperbaric experiments on dogs imitating free escape were help in state institute of search and rescue affairs and deep-water works of Department of Defense of FR (Lomonosov), financed and conducted by R&D «Olifa M3».
After reforms in 1991 all works on developing method of liquid breathing and submariners life-saving, as well as preparation of volunteer tests planned on 2007 (Objective 4) were performed and perform without any material assistance at the expenses of "AVF" co-working with 1 St.-Petersburg State Medical University named after I.P. Pavlov and some other organizations.

The quality of liquids was tested in dozens of experiments on small laboratory animals – rats and mice. When it was noticed that micro admixtures in them could significantly affect to pharmacokinetics of anesthetics and other drugs, after our request, chemists improved the quality of fluorocarbon liquids.
After developed new technologies they improved world's best results, achieved the isomer separation and 95-99% main product outcome (for example perftordecalin. It reduced reciprocal potentiation of anesthetics and reduced co-effects while liquid breathing.

More than a hundred dogs with weight from 6 to 25 kg participated in experiments to work off the techniques of liquid breathing (unassisted, spontaneous). Experiments were help on operating table in lying on the back position and in transparent capsule in common to dogs position - lying on abdomen (**graph 5**).

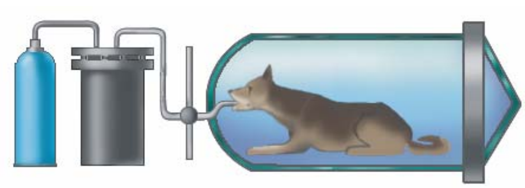
Dog's nasopharynx and upper airways were anaesthetized to prevent cough reflex impeding filling lungs with liquid. When using intubating catheter, the anesthesia level was higher. When not using intubating catheter, they breathed when swimming in fluorocarbon liquid aerated with oxygen (liquid breathing and immersion at the same time). Respiratory metabolism rates and essential function indicators were recorded before, during and after liquid breathing in different periods (up to 3 years).

Liquid breathing was supplemented with newly developed respiration devices for artificial lung ventilation (powered by compressed oxygen).



Graph 5. *Dog in a transparent capsule. Respiration liquid sampling for O_2 and CO_2 level examination. Inspiration and Expiration liquid pressure and main essential function indicators are monitored.*

For testing them a "dry" transparent or fulfilled with water capsule with a dog inside was placed in pressure chamber. Dog's airways were filled with fluorocarbon liquid and dog was switched to forced liquid ventilation using different modifications of the specified device (**graph 6**), in some cases in hyperbaric conditions.



Graph 6. *Model of portable liquid ventilation device connected to transparent capsule filled with water.*

10 experiments were worked out to learn the imitation of compartment flooding wile staying under maximum pressure level from 5 to 30 minutes and than free escape from 300, 500, 700 and 1000 meters.

Because of high intensity of noise when compression and decompression in pressure chamber, dogs started to breath spontaneously and tried to get free from the stand, that didn't allow staying them on ground for more then 30 minutes.

When fast compression, air in the chamber shortly warmed up to +100 ^{o}C, and cooled up to -100 ^{o}C when decompression. Such temperature gradient effected significantly to experimental redactor of pressure of portable device. When technical tests of the device a «cramping» occurred to the oxygen deliver device that limited free escape depth to 700 meters. More than, if the O_2 consumption for self needs is equal on any depth, supporting forced ventilation on big depths is problematical because of always left small amount of compressed gas in individual respiration device.

Physical state and anesthesia level of dogs in the chamber filled with water (worked also as a temperature buffer) was monitored on ECG, EEG pressure level in airways.

Is some cases the anesthesia level was minimal and dog had some freedom of movements and breathed with the liquid around it without any intubation (liquid breathing and immersion).

In other cases the anesthesia level was selected in such way that dog only started spontaneous breathing after get out the chamber.

But exactly spontaneous breathing with full consciousness was put by author in the conception of submariners life-saving and volunteer tests. Many chemical, technological, biomedical and construction details on this project will be missed in this publication. Not them, as it turned out, determine the fate of domestic means of life-saving. The political-economic does it. And for now it's not time to develop new variants of anesthesia or new oxygen metering device construction. At least we have to try to try to "interline" a new technique to the existing technology of submariners life-saving.

3. RESULTS

3.1. The way fluorocarbons interact with.

In the liquid breathing experiments on dogs 60-75% of liquid flew out from lungs with a help of low negative pressure, performed with a help op a pump, or even simply after body inclined. The rest part of the liquid vaporized in 3-4 day by it's self.

Chromatographic tests shown that only minute amounts of fluorocarbon liquid was grabbed by alveoli macrophages, then thy were transported with the blood flow to liver and spleen and then extracted from lungs, as it happens when potential using of fluorocarmons as a blood substitute. No pathology occurred during experiments.
The high quality fluorocarbon liquids, elaborated during the work, significantly decreased suppression of the respiratory center spontaneous activity – the co-effect performed by ad-mixtures, which increased the anesthetics effect. Externally it manifested as normal spontaneous respiration activity, dogs “switched to liquid” , that opened new opportunities in developing a new type of breathing.

3.2. Liquid breathing. A new technique.

The new technique of liqid breathing included three main components:

- highly purified fluorocarbon liquids,
- new method of anesthesia,
- a “soft switch” from air breathing to liquid breathing.

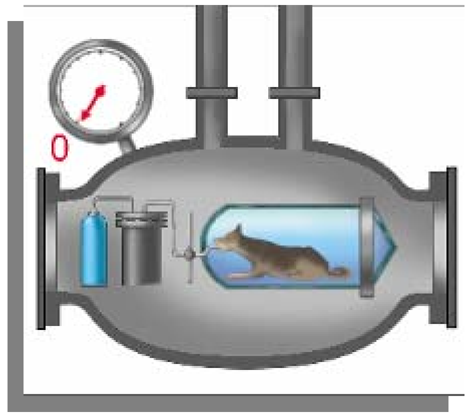
That’s why already in the experiments in R&D «Olifa M3» the dogs could breath not 15-20, but 60, 120, 200 minutes (it was of great importance to the work), then they returned to air breathing and had no symptoms of pathology.
Some dogs were brought into experiments for the second time, in these cases after the first experiment learning effect was mentioned: dogs started to breath faster, then the previous time.

3.3. Liquid ventilation.

After several tests of different variants of individual respiration device when normal and increased pressure, the devive powered by compressed gas was chosen, which worked during imitation of free escape from a flooded compartment which could work from 5 up to 30 minutes (**Graph 7**).

Graph 7. *An individual device of liquid ventilation to imitate free escape from 350-700 meters on a dog.*

This portable device included:
combined into stand-alone block CO_2-adsorber and pump, a balloon with compressed air and a reducer, some pneumoloqic elements and additional reservoir, a block with valves of in- and expiration, an intubation tube.



Graph 8. *Experimental model on dogs in hyperbaric chamber .*

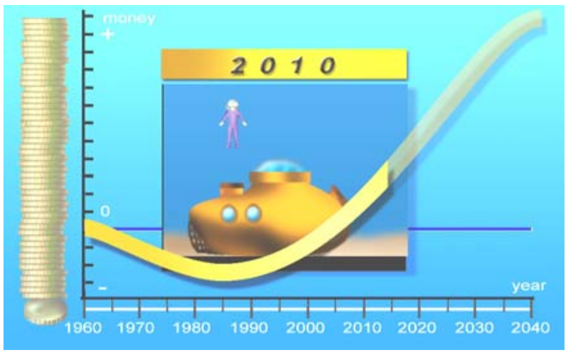
Using this device, a hour-long liquid ventilation with normal pressure experiment was worked out in 1988. Then a 5 to 30 minutes experiment imitating staying under high pressure when escaping from flooded compartment at 300 -700 meters depth (**Graph 8, 9**).

Graph 9. *A dog eats chocolate after 30 minutes imitating free escape from 700 meters depth.*

3.4. Individual respiratory devices.

Individual respiratory devices for liquid berathing (spontaneous) and liquid ventilation (not spontaneous, forced ventilation) complicate by including O_2, CO_2 sensors, high-precision metering devices etc…

On this stage, subject to respiration time the 3 types of respiration devices are known.
First type is allows to perform liquid breathing up to 10-15 minutes is the most simple.
Issue from the demands of simplicity and reliability of individual respiration device, it required that respiration time in the compartment where accident occurred lasted not more than 5 minutes before the submariner leave it. And as soon as he reaches surface he will switch to air breathing. According to calculations, if the surfacing speed is 2-3 m/s (using special suit with air space) this "first type" ventilation device could be used when escaping from depth of 600-1000 meters (**Graph 10**).



Graph 10. *A business plan illustration. Escaping from a private submarine with a suit with air space.*
When reaching the surface, the submariner will be picked up with a helicopter. It's hardly probable that
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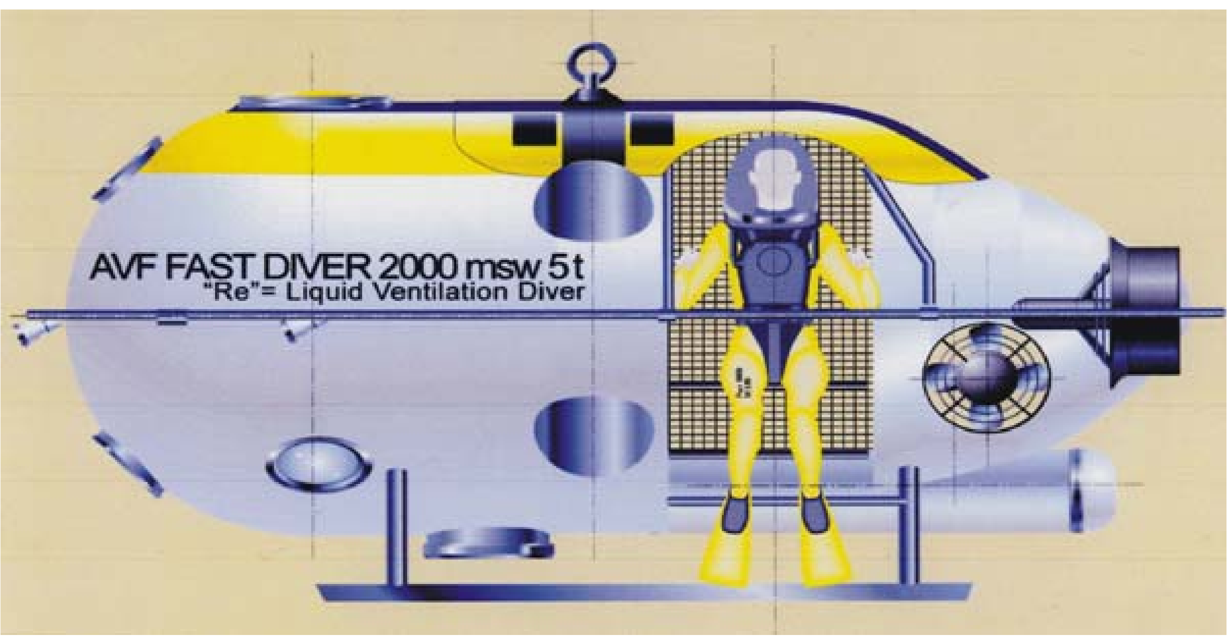
a full-scale rescue operation will be performed in this case.

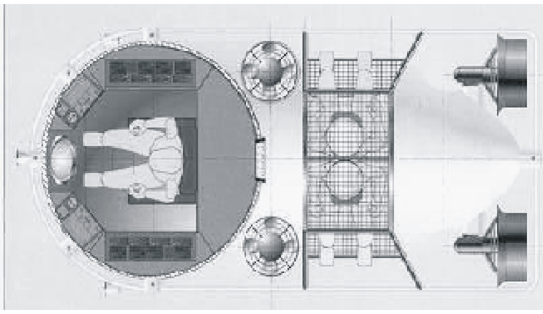
Second type – is a liquid ventilation device – it's used when air breathing is is impossible accordin to the difficult situation for up to 60 minutes: airlock failure, escaping the last part of the crew through the torpedo tube. In other words when the flooding of compartment is unavoidable and it's necessary to stay some time in the flooded compartment.
The third type are devices for 2-4 hours work – for professional diving works. For example, divers-rescues, helping the crew to leave the flooded submarine. To deliver them to the place a special underwater vehicle with a "wet" compartment could be used, which is driven by a pilot in a norm baric compartment. It guarantees the reliability and short time of delivery and makes possible to easily deliver such vehicles by aircraft.

3.5. Underwater vehicle delivered by aircraft

For now this type of underwater vehicles exist as a part of author's conception of fast submariners life-safe project (**9**, **10**). It's based on unique features of steady fast divers-rescuers when liquid breathing.
("Fast divers" – the term fully reflects their abilities and qualities). It could be compared to "ER" vehicles which aim is not to treat a patient, but to save him and deliver rapidly to a doctor **(Graph 11, 12)**.



Graph 11. *Fast delivery of divers-rescues underwater vehicle project named "Fast Diver"*



Graph 12. *A view from top of «Fast Diver». A pilot in a durable compartment with normal pressure. Two divers-rescues in a " wet" compartment (using liquid ventilation devices). They can go up and down fast (together with escaping submariners).*

Performance characteristics:

- height 2 m, width 2 m, length up to 4,5 m;
- crew: 1 pilot in a «sphere» of durable material, up to 2000 meters diving + 2 divers with liquid ventilation (operating depth up to 700 meters) in the «wet» compartment of "light" part;
- autonomy: without divers - 8 h (72 h in case of emergency), with divers - 4 h;
- horizontal speed up to 2 knots, vertical – up to 3;
- durable body designed up to 1000-2000 m: sphere 1,65 m (steel/titan);
- illuminators: 7 pieces, diameter 400 mm;
- exit hatch 450 mm;
- accumulator battery "4PzV 168", 168 A/h;
- hydraulic engines 3 kW with screws 400 mm (два - up/down, two - fw/bw one – for maneuvering);
- onboard network to control and divers hurting;
- underwater towing devices (two) to lighten the exit place from hatch and escorting divers who free escape.
- hydro locator of all-around looking, photo-video cameras, underwater sound devices etc.

3.6. Variants of landing with aircraft

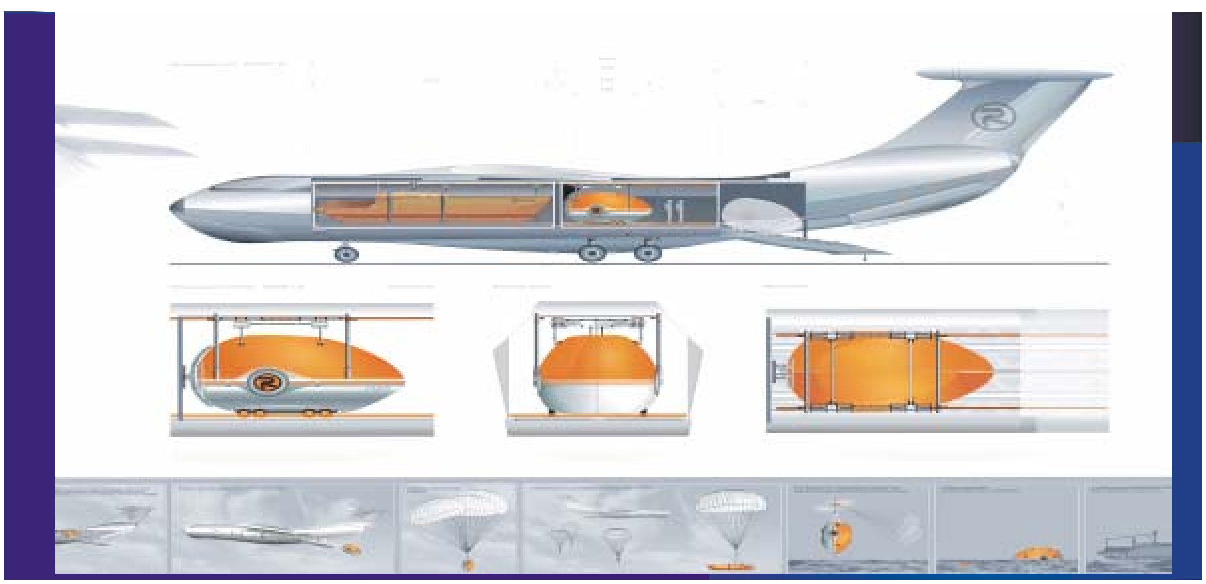
Variants of landing and reaching the rescues to the accident place:

- self-landing of rescues from a S&S helicopter or airplane, than diving with a underwater towing device to the accident place,
- landing of crew inside the underwater vehicle an then diving,
- landing of the crew and a vehicle separately, than reaching it and diving.

There is certain doubt of an ability to land the crew inside a vehicle on a parachute. But there is a well-tested technology of landing a space multi-tons module in the sea.

More than, it's possible to use other well-tested technologies, for example helicopter KA-27 PS, which is specially developed to deliver space module from sea to the land or a S&S ship. It can carry up to 3, 5 tons of weight. Another, more powerful model KA-32 S can carry up to 4,5 tons, and using new engines – up to 7 tons of weight.

It's also possible to use hydroplanes like "BE-200" or big airfoil boats like "KM", but even now the zone where the S&S party can be delivered is quite wide. For helicopters it's about 200-300 km (at the speed of - 250 km/h), and for Il-76 T, the most common landing force transport which covers up to 1500 km (at the speed of 650 km/h).



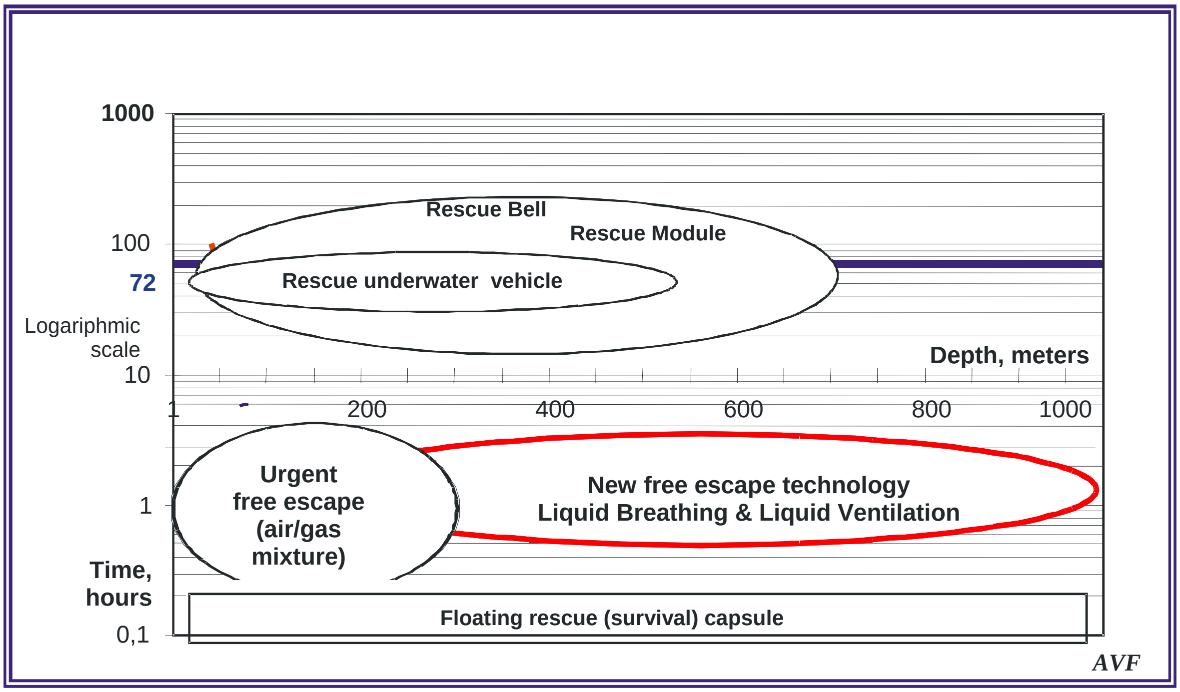
Graph 13. *The underwater vehicle variants of delivery and landing*

Must be mentioned that aircraft delivered underwater vehicle could be, primary, kept for a long time ready to start a rescue operation any time. Secondary, could easily delivered on boards of different aircrafts. Thirdly could be landed as S&S boat "Gagara" at roughness up to 5 degrees, so the can work together. After landing the vehicle must be tested of cause.
The answer to complete all these requests could be found in a "duck, egg and a needle inside" technology, which is used in space industry (**Graph 13**). According to RSTU «Voenmeh», when using Il-76 it's necessary to use a container with a vehicle inside, transported to the load box together with the "Gagara". It's supposed to use both parachute and reactive systems of braking.

3.7. The application area

Certainly it's only the direction how this technology can be brought to life. In all cases 2-3 hours after a special emergency signal is achieved, it's possible to reach the place of accident by plane, helicopter of maybe other means, landing of the underwater vehicle and than diving to a failure submarine. And submariners could be picked up from the surface after they free escape, where they can receive needed help. But divers must be ready to use this technique in a real situation of submarine failure.
Especially if:

- No time. (Waiting for underwater or surface vehicles will occupy more time then it's possible to stay in compartments.)
- No conditions. (No way to link up because of great heel of coming-platform failure.)
- No chance. (For air breathing or getting out with buoy rope.)
- No signal. (Because of electronic failure of safety conditions).



Graph 14. *Prospective technologies of submariners life-saving*

As it could be seen on (**Graph 14**) on a green line of rising pressure in 7,8 and 9 compartments of NS "Kursk", rising pressure has finally led to fire after 6 hours which became fatal. There is a little chance that surface ships with special equipment could reach the accident place in such short time.
The diagram shows that the limit of safe escape (red line – RF Navy normative) dramatically decreases when pressure rising in the compartment because of increasing risk of getting decompression disease. That's why the free escape technique requires a professional training and a will from submariners and probably could be better used with professional submariners (both navy and civil specialists), who can mare a decision in a critical situation.
In this diagram the a raised risk of decompression disease is shown (10%) when free escape and air breathing, the safe zone when this method could be used widened to 300 meters.
Even if it's impossible to calculate risks when escaping with liquid respiration before volunteer tests, expert assessments are already made.
First off all it should be mentioned that the don't change from 700 to 1000 meters (unlike when air breathing). Secondary, they don't exceed 10% risk when escaping from 200 - 300 when air breathing, by the time the risks of staying in a disabled submarine are incomparably higher.

CONCLUSION

The economical key of submariners life-saving - significant expanses on submariners life insurance, which take in interest insurance companies and business to the new safe technologies. There is no such practice in Russian Navy. After recent accident (with NS K-159) in 2003 every widow received only some hundred thousands of rubles. The total sum that all the relations received from a Russian "Military Insurance company" after NS «Kursk» tragedy was about 20 millions of rubles.

In comparison, solders in Iraq - $500 thousand, an economical equivalent of one USA citizen was about $2, 63 millions, in Sweden - $2,48 millions, in UK - $2,32 millions. And this is a strong stimulus.

On the average, in economically developed countries appraisement varies from 1 to $9 millions per person, when actual payments vary from $500 thousand to $100 millions (one case) per one death.

It explains many things: desire for European countries to reduce the number of diving jobs, move more works to unmanned technologies, as Norway does it in gas-extraction works. By the way planning cost of underwater gas-pipeline is higher because of high risk of terrorist attacks and related to it high probability of human works.

New civil market of Russian S&S works is established when new international pipelines projects of "Gasprom" are performed, for example as a North-Europe Project (**11**). There is an experience in RF, though not with domestic companies. When a "Blue Stream" pipeline had been constructed, a deep-water bathyscaphe was used to run the pipeline on a depth about 2000 m on the abyssal plain.

First public presentation of author's conception took place on the congress at 2004 named «Humans in Submarines» in Sweden. Later it was discussed on a special NATO meeting with experts on life-saving (SWERWG 2004, 2005 in St.-Petersburg and Brussels). The symposium named «Fast life-saving. The way to reality» during International Maritime Defense Show - 2005 (St.-Petersburg). Foreign and Russian experts agreed with the main ideas of the conception, the key role of Russian scientists in the development, discussed and suggested the variants and formats of volunteer tests. The questions on the acceptable risks for the submariners and divers during the rescue operation and some financial aspects were put.

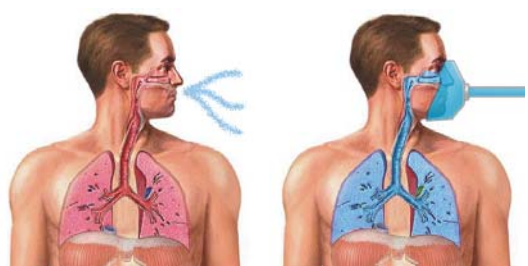
Some specialists St-Peterburg "Rubin" said that the time for liquid breathing goes off. Because of more and more unmanned technologies come to gas and oil production. Because of the appearance of Canadian norm baric suits in the used Russian Navy. But the main thing is that existing high risk technology of free escape (using air) HABETaS is technologically convenient for them.

Another position stand St.-Peterburg "Malachite". The think that escape from a sunk submarine cannot be performed fast, some time is required for the survivability, appraisal of the situation, preparing actions before escaping from submarine etc And the most achievable speed of passing through the torpedo tube is about 10-15 мин minutes per person. That's why they think the most needed can be a respiration device for 60 minutes and more. But it must be mentioned that the customer (RF Navy) traditionally makes a demand to use these devices for crew life-support that is quite complicated with liquid breathing.

In all cases the key questions to specialists are the volunteer tests that can change the priority in organization of crew life-saving on specific submarines and underwater vehicles.

Formulated questions for pilot volunteer tests planned to 2007 are:

- demonstration of the ability for a wakeful man to breath with liquid for 15 minutes and the switch back to air breathing (**Graph 15**);
- testing designed ventilation devices (for mass and dimensions characteristics, ease of use, service and ability to use in extreme situations).



Graph 15. *A model of liquid breathing through mask, then switch back to air breathing.*

To have at least a chance to reach the surface with light and air –this was always a submariner's dream. In the beginning of the 20 century to escape from 20-25 meters was a science fiction. At the end of the century free escape possible depth when air breathing increased by a factor of ten: 183 m in tests, and up to 240 m in an experiment. A real ability to increase this numbers again by a factor of ten, to survive in the conditions of high pressure in a flooded compartment is a deserving task for scientists and researchers nowadays.

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