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Classification of the underwater diving equipment

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ABSTRACT

In this paper was presented, innovative in preparation of the diving apparatuses classification method, depend on three criteria: the kind of the breathing gas, the operational depth range of the diving apparatus, and the principle of operation. The breathing gas used is the most important criterion. The other basic classification criteria follow from the first one; therefore it should be treated as the one criterion. Such approach to the problem has never been presented before, however it seems to be correct method of the diving apparatuses division.

Keywords: diving apparatus, classification, underwater diving equipment

INTRODUCTION - CHARACTERISTICS OF THE DIVING EQUIPMENT

Traditionally the diving equipment can be divided into the heavy (classic) and light-weight equipment. [2, 3, 6, 7, 8, 9, 10, 11, 12].Classification of the diving equipment according to this criterion is the diving technique based.

The similar to August Siebe's construction, that has been patented in 1836, can be recognised as the heavy diving equipment. The diving equipment has been still developed and improved. However, simultaneously to the new types of the diving equipment the traditional Siebe's constructions are being used in actual diving operations. For these reasons sometimes it seems that the Siebe's constructions were not improved (**Photo 1**). Of course, this diving equipment evolved towards the helmet systems equipped with the diving regulators, however there are also the improved diving equipment with the free flow of the breathing gas. The improved diving systems DM 200/2 (**Photo 2**) and AH-3 are presented below (**Photo 3**).

The features of the heavy diving equipment are presented in Table 1. At assumption that classification criteria, presented

Photo 1a. *The present diving helmet Siebe-Gorman (an advertising materials)*

Photo 1b. *The diving equipment with helmet UWS-50m (the own photography)*

Photo 1c. *The diving helmet UWS-50m (the own photography)*

Photo 2. *The diving equipment type DM 200/2 (the own photography)*

Photo 3. *The diver in the diving equipment type AH-3 (the own photography)*

in Table 1, distinguishing the heavy diving equipment are sufficient it should be recognised that the Henry Fleuss's oxygen diving apparatus (1879) was the independent version of the heavy diving equipment as dive consisted in displacement on the bottom of the especially loaded diver (**Photo 4**). Change in diving methods has led to further development of the oxygen apparatuses and their transformation into light diving equipment.

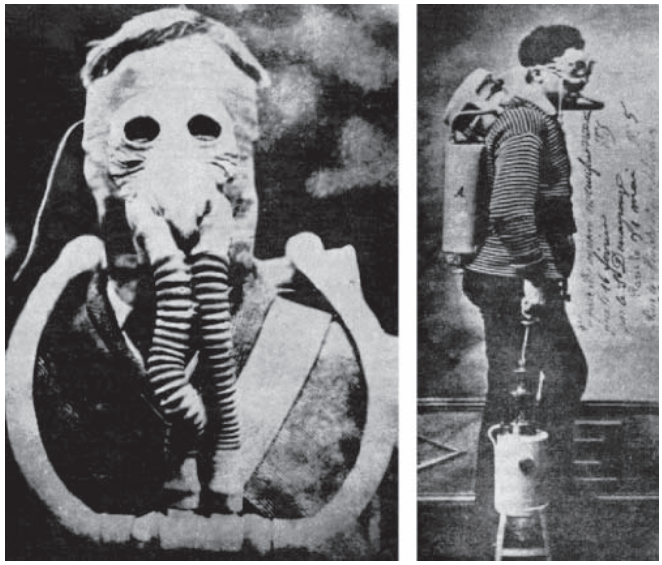

Photo 4. *Henry Fleuss apparatus [4]*

It is generally considered that commander Jaques Ive Cousteau is inventor of the diving apparatus used for free diving (air open-circuit self-contained underwater diving apparatus SCUBA) called Aqua-Lung (1940) – **Photo 5**. It is well known that the prototype such apparatus has been designed earlier. In 1860 Benoit Rouquayrol and August Denayroze have constructed similar apparatus

(**Photo 6**). However, Coustau's gear has caused real landmark and has led to development of free diving. [11, 8].

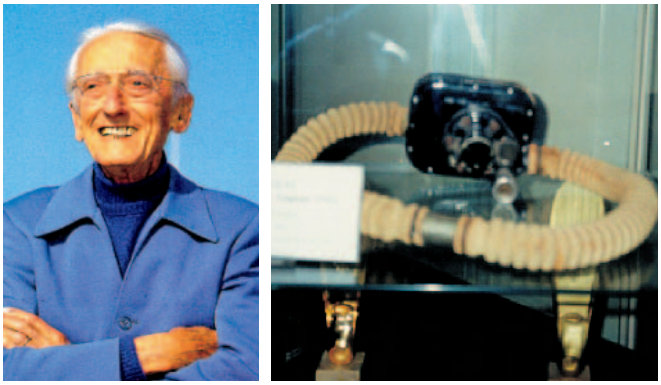

Photo 5. *Jaques Ive Cousteau (left) [5]. Cousteau's diving reulator (right) (the own photography, courtesy La Spirotechnique I.C. Nicea)*

Table 1. *Characteristics of the heavy-weight diving equipment*

The heavy-weight (classic) diving equipment	
During normal work the equipped diver has high negative buoyancy. It is possible to change buoyancy, however it is only used to change the diver's work plane or while descending (ascending).	
Disadvantages:	-The diver can perform work only at the fixed plane such as the trap, the diving platform, the bottom, decks of the sunken vessel etc. -The diver's mobility is limited. Moving of the diver according to the work planes needs to employ a large force.
Advantages:	-The diver's position is stabile. It gives the possibility to perform the heavy work without large effort to keep the diver's position.

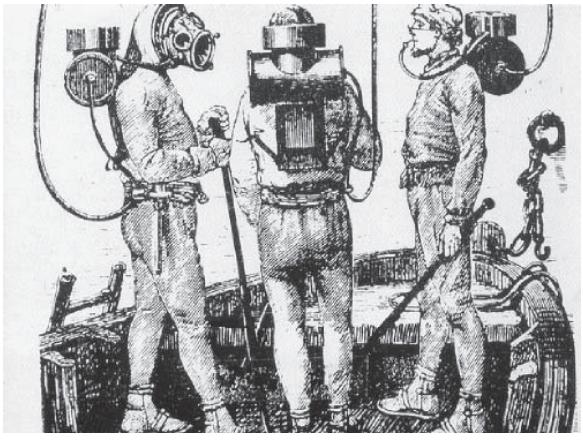

Photo. 6. *Rouquayrol's apparatus [1]*

Paul Bert's physiological research (**Photo 7**) and Elihu Thomson's theoretical works have contributed to the first experimental mixed-gas diving performed in 1924. In 1940 experiments resulted in development of the independent oxygen-nitrogen (nitrox) diving apparatus (**Photo 8**) proposed by Lambertsen.

Photo 7. *Paul BERT [4]*

Photo 8. *Lambertsen diving apparatus [11]*

However, the first diving apparatus type DM 40 (**Photo 9**) was elaborated and manufactured by Dräger in 1915. However, many historians accept that Lambertsen's gear [11] has begun real development of the diving apparatuses. Despite of the breathing gas used, the characteristic features of the diving apparatuses are as follows (**Table 2**).

Photo 9. *The diving apparatus DM 40 manufactured by Dräger 1915 (the own photography, courtesy Dräger AG Lübeck)*

At present, the differences between the heavy and light-weight diving equipment are covered up as dependently upon the additional equipment chosen, the basic equipment can function as the classic or light-weight diving equipment.

Table 2. *The features of the light-weight diving equipment*

The light-weight diving equipment	
During normal work the equipped diver has neutral buoyancy that can be adjusted within the certain range.	
Disadvantages:	The diver under water is almost weightless. Even if the diver is supported under water by the immovable elements, weightless makes the diver's work (drilling the holes, surface cleaning, shooting pegs, welding etc.) difficult.
Advantages:	Compared to heavy-weight diving equipment, the light-weight one enables relatively long distance diving without the significant effort and free displacement in all directions at depth or reminding at the given place at the depth. This feature enables to make underwater inspection of the technical state of the large underwater objects, sweeping at the depth etc.

METHODS

Generally (here) the diving equipment is defined as follows: it is the technical equipment that enables the man safety descent, staying at the depth and ascent. There are some tendencies to extend the above definition by normobaric dives (see further). In the definition accepted it is essential that the diving equipment enable the man to perform the direct work at the depth. As it follows from above the water environment exerts the pressure on the diver's equipment that is directly transferred on the man.

This feature distinguishes the diving equipment from among the other kinds of the submersibles, for example: atmosphering diving suits (normobaric diving suits, one atmosphere diving suits – **Photo 10**), or manned underwater vehicles (**Photo 11**) that enable normobaric dives. Descent and ascend to water environment should be safety, therefore the diving equipment requires from the diver except operating skills, special health qualifications and training.

Photo 10. *Armored suits:* ***a)*** *Newsuit (the own photography, courtesy Drägerwerk AG Germany)*

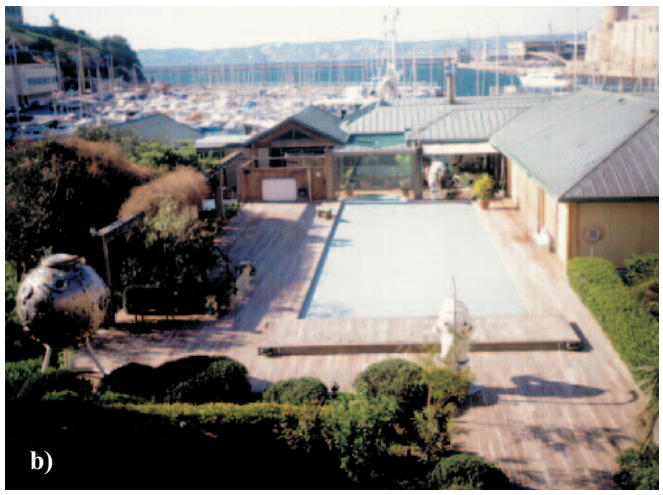

Photo 10. *Armored suits:* ***b)*** *Russian armored suits in the villa of COMEX-President, Marsylia (the own photography, courtesy H. Delauze)*

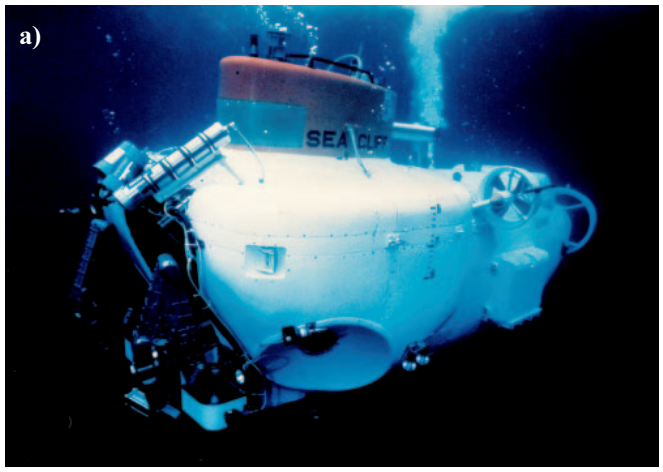

Photo 11. *The underwater vessels - scientific vessels:* ***a)*** *the general view of the underwater vessel SeaCliff,* ***b)*** *the historical underwater vessel of Comex*

THE DIVING APPARATUSES AND THEIR CLASSIFICATION

Except the traditional classification for the heavy and light-weight diving equipment there are many other classification criteria. Most divisions that have been presented in the literature are based on the diving apparatus constructional criteria [for example [2, 7, 9]. In this paper the new classification will be presented that seems to be more accurate and useful. Further,

Photo 11. *The underwater vessels - the rescue vessels:* ***c)*** *the view of DSRV Mystic cockpit (the own photography, courtesy Deep Submergence Unit San Diego),* ***d)*** *the general view of DSRV Mystic (the advertising photography, courtesy Deep Submergence Unit San Diego),* ***e)*** *the general view of the underwater vessel for rescue of the submersible crews (the own photography, courtesy HMS Belos Sweden), f) manned underwater robot produced in UK (the own photography, courtesy HMS Belos Sweden)*

Table 3. *Classification of the underwater diving apparatuses*

Specification		**Classification of the underwater diving apparatuses**									
1.breathing species		air		oxygen	mixed gases (most often: nitrox, helioks, trimix ,hydrox, hydreliox, neox)						
2.depth range		0÷50 mH_2O		up to 6 mH_2O	0÷200 mH_2O				most often deeper than 200 mH_2O		
3. Principle of work	a) group	of the open gas circuit		closed gas circuit	semi-closed gas circuit				closed gas circuit		
	b) sub-group				premix		preparing the breathing gas during diving process				
	c)type	self-contained	hose supply	self-contained	self-contained	hose supply	self-contained	hose supply	small circulation	increased circulation	high circulation
4. Examples	Haux [**1968, 1982**]	PA-38/3600	PL-70	LAR V	-	FGG III	SM III	SM III-S	Elektrolung	-	GAK-600
	Polish construc-tions	PR-27	UAN-82	-	APW-6M	GAN-87	APW-3	-	-	-	-
	the other examples	AGA MkII	KMB-10	COBRA	ACSC	Sealab III (Fink Rig)	SIVA+	-	Mk-15/16	DOLPHIN 7	CCBS
5. Remarks		not recommended to the underwater works	recommended to the underwater works at the shallow and mean depths	military diving	mostly used for the diving works performed beyond the saturation zone (or the bail-out apparatuses during saturation) and for the operational diving at the large depths (standard approximately 150m H_2O)				military diving at the large depths	apparatuses used to underwater works during saturation diving	
WARNING! The diving apparatuses with the chemical preparing and complementation of the breathing gas are not taken into account here											

we will deal with the diving apparatuses as the part of the diving equipment.

The diving apparatuses are defined as the part of the diving equipment that is responsible for supplying the diver the compressed breathing gas. The gas pressure is adequate to the diving depth. The breathing medium can be stored outside the apparatus and supplied by the suitable hose, the gasholders containing the breathing medium can be the integrate part of the diving apparatus or it can be obtained (or complemented) in chemical reaction.

To classify the diving apparatuses for the tasks assumed, the following criteria are the most convenient:

- ⇨ the kind of the breathing gas,
- ⇨ the operational depth range of the diving apparatus,
- ⇨ principle of operation.

The diving apparatus with chemical preparation or complementation of the breathing gas are not discussed here. Classification of the diving apparatuses according to the above criteria is presented in Table 3. The presented here classification of the diving apparatuses used for underwater work enables gathering, systematising and analysing of those construction development trends.

Although the presented here classification is not excellent, it is the most complete classification that has been met in the professional literature. It has practically confirmed it usability at the diving apparatuses' data systemising and analysis.

DISCUSSION AND CONCLUSIONS

- ❍ Development trends of the diving apparatuses and analysis of the development directions have shown in Europe and in the world the great interest in the semi - closed circuit diving apparatuses. It was several years before the great marked for these products has been opened (recreational diving use and beginning of the technical diving).
- ❍ It was innovative in preparation of the diving apparatuses classification to use three criteria: the kind of the breathing gas, the operational depth range of the diving apparatus, and the principle of operation. The breathing gas used is the most important criterion. The other basic classification criteria follow from the first one; therefore it should be treated as the one criterion. Such approach to the problem has never been presented before, however it seems to be the most correct method of the diving apparatuses division.

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