

PREVENTION OF COMPRESSED AIR ILLNESS<sup>1</sup>OBSOLETE STATUTORY REGULATIONS AS AN  
OBSTACLE TO PROGRESS

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ABOUT 25 years ago Dr J. S. Haldane, Dr A. E. Boycott and Capt. Damant, R.N., in the course of investigations for the British Admiralty, worked out a system of decompression for divers and compressed air workers. This system was adopted by the Admiralty, and by its use compressed air sickness has been practically eliminated entirely amongst naval divers. The system has become known as stage decompression, although in fact stages are not an essential feature of it, though a convenience in practical working. The system has been frequently and fully described. The latest explanation will be found in the last edition, 1935, revised by Haldane and Priestly, of *Respiration*, by J. S. Haldane (Clarendon Press). Its most essential feature is that the pressure is lowered quickly to approximately half the absolute pressure during decompression, and one of the most important assumptions for working out the decompression tables is that different parts of the body saturate and desaturate at different rates. Enquiries sent out by me during 1934 to the United States, the principal countries of Europe and to Japan indicate, so far as definite information has been received in reply, that stage decompression has been universally adopted for divers, but in no case has it been adopted for caisson and tunnel workers in countries where State regulations already existed, except in a modified form, and I conclude that the reason for this failure to adopt stage decompression is the existence of statutory regulations, either still in force, or only partly modified in accordance with new ideas.

## GERMANY

For the German regulations, which are dated June 28th, 1920, and were still in force in 1934, a modified form of stage decompression has been adopted, but although a first rapid drop in pressure is laid down, this is to half the gauge pressure, instead of to half the absolute pressure, thus considerably increasing the time required for decompression, especially at the lowest pressures. The length of time for decompression is a minimum, but is the same for a short as for a long shift, being in this respect quite contrary to the principles of stage decompression. The daily working hours are limited, and must not exceed

<sup>1</sup> In this connexion the following papers which appeared in this *Journal* may be consulted: Boycott, Damant and Haldane (1908), 8, 342-443; Boycott and Damant, *ibid.* 445-456; Damant (1926), 25, 26-49. EDITOR.

8 hours at 29 lb. per sq. in. above atmosphere, or 2 hours at a pressure of 50 lb. above atmosphere. The time required for shifts of various duration for a working pressure of 29 lb. per sq. in. is given in Table I. It will be noted

Table I

Working pressure = 29 lb. per sq. in. above atmosphere.

Length of shift hours	Total time for decompression, German regulations min.	Equivalent time to German using stage min.	Strict stage method min.
1	42	28	15
2	42	28	22
3	42	28	30
8	42	28	48

that for a 3-hour shift the German rule gives practically equal immunity with the stage method, *i.e.* the equivalent to 28 min. as compared with 30 min., but that for shorter shifts the time of decompression is too long, and for longer shifts too short. The 42 min. is divided up to allow 7 min. for the first rapid drop of pressure down to  $14\frac{1}{2}$  lb. above atmosphere, and the balance of 35 min. for the lowering from  $14\frac{1}{2}$  lb. to atmosphere. In Table II will be found the same comparison for decompression from 50 lb. working pressure. At this

Table II

Working pressure = 50 lb. per sq. in. above atmosphere.

Length of shift hours	Total time for decompression, German regulations min.	Equivalent time to German using stage min.	Strict stage method min.
1	90	68	52
2	90	68	90
3	90	68	114
4	90	68	130

pressure the length of shift is limited to 4 hours. The times of locking in and locking out are not included in the length of shift. The first rapid drop is about 2 lb. per min. (0.15 kg. per sq. cm. per min.) and therefore takes 12 min. The remaining decompression from 25 lb. gauge to atmosphere takes 78 min. Using the stage method the first rapid drop would be to an absolute pressure of  $\frac{50+15}{2} = 32\frac{1}{2}$  lb. or to a gauge pressure of  $32\frac{1}{2} - 15 = 17\frac{1}{2}$  lb. per sq. in., and the first rapid drop from 50 to  $17\frac{1}{2}$  lb. would take 3 min. only.

## FRANCE

The French regulations date back to October 1913, but were still in force in September 1934. In these regulations there are no restrictions as to length of shift, but a decree of 1903 states that it is imprudent to work more than 8 hours at the lower pressures, or more than 4 hours at the higher pressures. The total time of decompression only is specified, but as a sudden lowering of the pressure when workers are inside the working chamber is prohibited it must be assumed that the lowering of the pressure must be at a uniform rate. Table III shows the time lengths of decompression required from a 50 lb.

per sq. in. working pressure. One French contractor writes that for working pressures of 29 lb. per sq. in. and over he makes his men enter the medical recompression chamber after locking out from the working chamber at the regulation rate and remain there for a period equal to twice that of the original decompression. The length of shift worked when this system is in use was not

Table III

Length of shift hours	Working pressure = 50 lb. per sq. in. above atmosphere.			
	Total time for decompression, French regulations min.	Equivalent time to French using stage min.	Time in medical recompression chamber, one French contractor min.	Strict stage method min.
1	70	35	(140?)	52
2	70	35	(140?)	90
3	70	35	(140?)	114
Maximum	70	35	140	140

stated, and therefore the time to be spent in the decompression chamber is entered only against a maximum shift, and elsewhere with a question mark. It will be noted, however, even when making a comparison most favourable to the French method, that it takes  $70 + 140 = 210$  min. to attain results which can be attained in 140 min. by using the stage method.

## BELGIUM

The Belgian rules somewhat resemble the German, inasmuch that a preliminary drop to half the gauge pressure is made use of. These regulations date from January 1914, but were still in force in 1934. For shifts of 1 hour and upwards the time of decompression is the same, but for shifts of less than 1 hour the time of decompression is reduced (consult Table IV). From a working pressure of 50 lb., after a length of exposure of 1 hour and upwards, the total time of decompression is 65 min. The first quick drop of pressure is to 27 lb., or to just slightly over half the gauge pressure, and takes 6 min. The lowering of the remaining 23 lb. to atmosphere takes up the balance of 59 min. and is at an approximately uniform rate, but slowing down as the pressure is reduced in accordance with the principles of stage decompression.

Table IV

Length of shift hours	Working pressure = 50 lb. per sq. in. above atmosphere.		
	Total time for decompression, Belgian regulations min.	Equivalent time to Belgian using stage min.	Strict stage method min.
$\frac{1}{2}$	35	27	25
1	65	48	52
2	65	48	90
3	65	48	114
4	65	48	130
8	65	48	140

## THE STATE OF NEW YORK

Broadly speaking three different methods for the prevention of compressed air sickness belong to three different periods. A first period when the method was to reduce the period of the shift so as to give a reasonable amount of immunity; a second period when decompression at a uniform rate, and without any first quick lowering of the pressure, was in use; and a third period when stage decompression has, at any rate for divers, superseded earlier methods. In the State of New York Regulation, effective early in 1935, we find a survival of the first method of the first period in combination with a modified form of

Table V

Length of shift hours	Total time for decompression, State of New York min.	Equivalent time to State of New York using stage method min.	Strict stage method min.
Working pressure = 29 lb. per sq. in. above atmosphere.			
1	20	14	15
2	20	14	22
Working pressure = 50 lb. per sq. in. above atmosphere.			
$\frac{1}{2}$	50	40	25

the third method of the last period. In the State regulations (Table V), at a working pressure of 29 lb. by gauge, or above atmosphere, the working day consists of two shifts of 2 hours each, with an interval of not less than 2 hours to be spent at atmosphere. With this interval any cumulative effect due to the two shifts may be neglected. The total time of decompression is 20 min. The first quick drop is to half the gauge pressure and takes 3 min. The last  $14\frac{1}{2}$  lb. to atmosphere takes 17 min. From 50 lb. gauge pressure the first rapid drop to 25 lb. gauge pressure takes 5 min., and from 25 lb. to atmosphere takes 45 min., giving a total time for decompression of 50 min.

## CONCLUSION

The fact that strict stage decompression has been adopted for divers in the navies of both the United States and of France, examples of whose rules for decompression for caisson and tunnel workers have been given, seems sufficient proof that the stage method is the method most approved by physiologists in these two countries. There remains, therefore, only the existence of obsolete State regulations to account for the fact that stage decompression has not been adopted for caisson and tunnel workers in France, and in only a modified form in the State of New York. It is not suggested that the time devoted to decompression should always be in accordance with that given in the last column of the tables. With small airlocks compromise methods may be necessary or even desirable. But it seems clear that, in the sphere of compressed air work, State regulations have proved to be more of a hindrance to health than a help to those for whose benefit they were intended.

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