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SUBJECT

Submarine Storage Batteries: Charging Procedure for Wartime.

by

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ABSTRACT

This report comprises a discussion of the factors affecting the choice of a charging procedure for use in charging submarine storage batteries in wartime. The charging procedure which is considered best is the present standard Bureau charge. The principal recommendation in this report is that some designated submarine, such as one about to be decommissioned, be used to study in detail wartime charging procedure by raising the gravity of its main storage battery and operating it under conditions simulating those anticipated in time of war.

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AUTHORIZATION

1. This report was authorized by reference (a); other pertinent references are given from (b) to (e).

Reference: (a) Bu.Eng.ltr.SS/S62(7-30-D1) of 7 August 1935.
(b) NRL Report on Problem P-12 of 30 December 1932.
(c) NRL Report No. P-1243 of 4 March 1936.
(d) Bu.M&S ltr.S38/SS(071) of 10 July 1935 forwarding report "Submarine Patrols in Tropical Waters -- Effects of high temperature and humidity on personnel; USS CUTTLEFISH".
(e) Material Laboratory, Navy Yard, N.Y., Test No. 2527-A of 2 July 1934.

STATEMENT OF PROBLEM

2. Submarine main storage batteries are engineered with sufficient active material and current-carrying capacity so that sulphuric acid of specific gravity of 1280 or greater would be required to use up that active material. Experience shows that it is inadvisable ever to use sulphuric acid of specific gravity greater than 1280. In order to insure economic long life and to have a reserve of life still left in a battery in the event of national emergency, submarine batteries during peacetime are operated with 1210 specific gravity electrolyte. Upon the outbreak of war, the gravity is immediately raised to 1280 in accordance with war plans. The problem, then, is to study the charging procedures best adapted to use with this gravity under wartime conditions of operation.

KNOWN FACTS BEARING ON THE PROBLEM

3. Actual operating experience with wartime specific gravity dates back to the World War under conditions so different from those anticipated in the future as to make that experience of little value.

4. A suitable wartime charging procedure for submarines must

(a) Charge the battery under the most favorable military conditions.
(b) Make the procedure as convenient as possible to the operating personnel.
(c) Be as economical as possible of time, fuel and battery water.
(d) Be safe.

The procedures for peacetime should attempt to insure long life of the batteries for reasons of economy, but this is not so important in time of war. The criterion as to life in wartime is that the battery should last at least one year and, if possible, last as long as any anticipated war.

5. Two possible basic methods of operation suggest themselves: (a) to use an operating procedure which will insure that the battery be kept healthy at all times, and (b) to use a procedure which will be somewhat detrimental to the health of the battery and then periodically to restore the battery to health by the use of appropriate known methods. As will be seen later, conditions may require that the second of these be used.

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6. One important factor in discussing the wartime charging procedure is that a principal effect of raising the gravity of the storage battery is to increase the capacity of that battery. For example, in the battery of the USS CUTTLEFISH, the wartime capacity is 35 percent greater than the peacetime. This means that the heat effects of the discharge and charging processes are that much greater and, since this heat is confined within the same battery space as before, the temperature rise is considerably increased.

7. An important consideration in discussing wartime charging procedures is the anticipated effect of newer developments such as airplane scouting on the tactical operations of submarines. For example, it is visualized that a submarine in the war area may have to operate submerged all day long, surface and charge its batteries during the hours of darkness while, possibly, underway at high speed, again submerge throughout the following day, and so on. This type of operation may obtain either in the high latitudes of the Northern Pacific where the nights are very short, or in the tropical waters where the battery temperatures are initially high. Inevitably, the effect of such extreme operation is rapidly to increase the temperature of the battery until it approaches the limiting temperatures set by the manufacturer or until the living spaces become so hot that the limit of human endurance is reached. It is believed that temperature conditions will prove to be one of the chief factors in limiting the efficiency of submarine wartime operation.

8. There is a compromise which must be made between the effect of battery temperature on the charge and its effect upon the discharge of the cell. Low temperatures enable the charge to be put in rapidly and effectively, but low temperatures diminish the capacity of the battery on discharge; high temperatures are best to get high capacity in a military submarine battery, but are worst in their effects upon the charge. It is considered that the best compromise for most submarine wartime operations is to accept the high temperatures which will prevail on present type submarines and to insure the comfort and efficiency of the personnel by air conditioning the living spaces. Some foreign navies, however, attempt to cool the batteries in submarines operating in tropical waters.

9. The probable need for the completion of charge during the dark hours of night, a need which was so strongly felt by the German submarines during the World War, requires that wartime charging procedure be such as to complete the charge in as short a time as possible.

10. The charge of a submarine battery involves two distinct processes: (a) the reconversion of the active material in the discharged cells, and (b) the mixing up of the stratified electrolyte. As battery operation on the submarines fitted with Battmeters so clearly indicates, it is possible almost completely to reconvert the active material before the electrolyte is completely mixed up. (The basic principles of military submarine battery operation have been given in detail in reference (b).)

11. To hasten the completion of a charge, the following expedients may be employed:

(a) Increase the starting rate.
(b) Use a strictly constant potential charge during the initial part of the charge.

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(c) Raise the cutting voltage on the temperature-voltage-gassing curve.
(d) Increase the finishing rate.

The objections to these are, however:

(a) A higher starting rate would increase the heating effects which are so pronounced during this stage of the charge; this would increase the temperature of the battery abnormally. (Ref.(c))
(b) A strictly constant-potential charge is difficult to control with the Diesel-engine charging system.
(c) Experiments on single cells seem to indicate that the voltages on the TVG curve could be slightly raised, but with the battery of a large number of cells it is considered that the gassing voltage could not be raised very much with safety.
(d) Increasing the finishing rate of the charge hastens the mixing of the electrolyte and therefore the completion of the charge; but a high finishing rate increases the heating effects and the water loss from gassing, in addition to its other detrimental effects. (Ref.(c))

12. A condition must also be visualized under which a submarine charging its batteries is forced by an airplane patrol to secure the charge at once, submerge, and remain submerged for a long period of time. This might occur just as the gassing phase of the charge was being approached, at which time the active material would be practically all reconverted but the deleterious effects resulting from stratification would be at their greatest. Sufficient of the battery's capacity would be available so that the commanding officer could make an attack or escape, but the possible effects of this type of use on the health of the battery must be considered.

13. Another governing factor in the choice of methods of charge is that a submarine may be away from its base for long periods. Hence fuel and battery water must be conserved. This Laboratory is now determining the water loss from a submarine cell during charge with the wartime gravity. Owing to the lower water vapor pressure of the 1280 specific gravity electrolyte as compared with the 1210, the water loss in time of war is not as great under the same temperature conditions as with the peacetime gravity. Indeed, under some conditions of humidity and temperature the cells actually water themselves from the humid air.

14. In analyzing wartime charging methods the discharge of the cells by the heavy auxiliary load of present submarines and by self-discharge must be considered. The self-discharge of a submarine battery with 1280 gravity is greater than with 1210 and is greater under the high temperature conditions which would usually prevail under wartime operations. The auxiliary load for the large amount of new equipment on the newer submarines is a serious drain on the capacity of the battery for propulsion purposes. Presumably the commanding officer of a submarine will attempt always to keep a battery fully charged as by floating the battery on the engines or using, as in the newer submarines, the small charging engines while underway on the surface and by charging immediately when conditions permit after having operated submerged. It is considered that the reduction in the auxiliary load to the minimum possible would be desirable.

15. But there is one drain on the batteries which will probably have to be accepted, namely, that for the air conditioning equipment, for the heating effect on the living spaces and hence on the operating personnel of the high temperature batteries would seriously impair the efficiency of the personnel and hence the military efficiency of the submarine were this air conditioning equipment not employed. In this connection, attention is invited to the report of the Bureau of Medicine and Surgery to the Bureau of Construction and Repair, reference (d), which studies the physiological conditions in a submarine under the high temperature and humidity conditions of a submarine patrol in tropical waters.

16. It is to be expected that after the gravity change from peacetime to wartime specific gravity electrolyte has been effected all the cells in the battery will not be alike in specific gravity unless slight adjustments of the gravity are made. It is important that the operating personnel appreciate this fact, else they conclude that certain of the cells are become unhealthy. If operating circumstances permit, these necessary adjustments should be made.

DESCRIPTION OF EXPERIMENTS

17. The experiments at this Laboratory were made on a WLH-29 Exide Ironclad (USS CUTTLEFISH) cell. Comparative experiments on a high-capacity pasted plate cell, a Tudor Type 20-POR-820, were made at the Material Laboratory, Navy Yard, New York (reference (e)).

CONCLUSIONS AND RECOMMENDATIONS

(a) Facts Established

18. From the above discussion and an analysis of numerous charges put in by this Laboratory and by the Material Laboratory, Navy Yard, New York, the following facts have been established:

(a) When the time factor is the most important of the charge, a submarine battery can be charged in the shortest time by using a true constant-potential charge with the voltage regulated according to temperature and with a constant current finishing rate. The initial rate can be as high as the engines and generators can give.

(b) The time of charge can be somewhat shortened by raising the voltage now used on the voltage-temperature-gassing curve. To give the shortest possible charge, the gassing could be increased to the limits imposed by the battery ventilation system.

(c) The time of charge can be somewhat shortened by increasing the finishing rate. Here, again, the maximum gassing is limited by the battery ventilation system.

(d) The most feasible charging procedure for wartime use is the present standard Bureau step-charge procedure with a constant-current finishing rate, the cutting voltages for the several steps being chosen from the Bureau TVG curve. The steps and cutting voltages used with 1210 specific gravity are suitable.

(e) The increased capacity resulting from the use of 1280 specific gravity electrolyte will increase the temperature of the cells (assuming, of course, that the discharges are carried to the same low gravity).

(f) Under conditions prevailing in a wartime patrol, battery temperatures will tend to become excessive.

(b) Opinions

19. The above discussion has brought out a number of factors which it is considered should be analyzed. Thus the possible effects on the health of a submarine battery of repeated charging under conditions where the gassing phase of the charge is not reached should be determined by the manufacturers. Methods should be considered by which a submarine on an extended patrol could revive the health of a battery which had been impaired by such operation.

20. The new grid alloys now being developed may greatly simplify wartime submarine battery operation. Much of the trouble anticipated in operating with 1280 specific gravity is due to the self-discharge effects of antimony. Moreover, the new grid alloys together with rubber separators may permit higher battery temperatures than those now permitted.

(c) Recommendations

21. It is recommended

(a) That a submarine be designated to study in detail the wartime charging procedure by raising the gravity of its main storage battery to 1280 and operating the submarine under conditions simulating those anticipated in time of war. The experiments of this Laboratory and those of the Material Laboratory, Navy Yard, New York, were made only on single cells. The data therefrom should be checked by full scale experiments.

(b) That the battery manufacturers be requested to consider the possible effects upon the health of the batteries of repeated charging without the charge reaching the gassing phase, a condition which may obtain during wartime operations. It is understood that the Electric Storage Battery Company has already done some work along these lines.

(c) That the manufacturers be asked to recommend methods of restoring wartime batteries to health when their health has been impaired by wartime operations. The Electric Storage Battery Company's experience would be of great value in this connection.

(d) That the attempt be made to develop submarine main storage batteries having higher capacity per unit of weight and space so that the propulsive capacity of submarines may be increased. This is especially necessary in view of the increasing auxiliary load, such as from air conditioning.