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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

Submarine Storage Batteries:

Methods of Increasing the Specific Gravity of the Electrolyte to 1.280.

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ABSTRACT

This report describes experiments to devise means for rapidly raising the specific gravity of the cells of submarine main storage batteries from the peace-time to the war-time gravity of 1.280. Of the methods employed, the old M.E.I. method proved the slowest, the Naval Research Laboratory method (requiring special equipment) the fastest, while the new Bureau method (discharges omitted) proved nearly as fast as the latter. The report recommends that the new Bureau method be used.

AUTHORIZATION

1. This problem was authorized by Bureau of Engineering letters, references (a) and (b). Reference (c) is also pertinent to this report.

Reference: (a) BuEng let.SS/S62(8-23-D1) of 24 August 1934.
(b) BuEng let.A2-2/EN8(3-22-Y1) of 20 December 1934.
(c) G. W. Vinal, "Storage Batteries".

STATEMENT OF PROBLEM

2. Submarine storage cells are engineered with sufficient active material so that their capacity is limited, not by the active material, but by the electrolyte at 1.280 specific gravity. For reasons of economic long life and operating convenience, electrolyte of 1.210 specific gravity is used during peace-time. To obtain the greatest available capacity for war operations, 1.280 gravity is used in war-time. The problem is to devise a convenient method for rapidly increasing the specific gravity of the electrolyte in submarine storage cells for war to 1.280 specific gravity. Stated otherwise, the problem is to take a submarine with its 120 or 240 cells at 1.210 specific gravity and to increase that gravity by the most rapid and convenient feasible method such that all cells in the submarine will, at the end of the procedure, have the same 1.280 specific gravity and all be fully charged.

KNOWN FACTS BEARING ON THE PROBLEM

3. Electrolyte of 1.210 specific gravity contains 28% H_2SO_4 by weight, 1.280 electrolyte 37% H_2SO_4 (ref.(c)). The problem, then, becomes one of increasing the percentage of sulphuric acid in the electrolyte by the addition of H_2SO_4, either pure or in solution. The practical operating experience of the Electric Storage Battery Company has proved that it is dangerous to the health of the cell to add sulphuric acid solutions of greater specific gravity than 1.350; war stocks of sulphuric acid are of 1.840 specific gravity containing 95% H_2SO_4. Increasing the specific gravity of submarine storage batteries therefore requires, first, the dilution of the war-time stock acid to 1.350 specific gravity and, second, the addition of this acid to the storage cells to raise their gravity to 1.280

THEORETICAL CONSIDERATIONS

4. When sulphuric acid solutions are diluted, or when dilute solutions are concentrated by the addition of stronger acid, heat is generated. It is important that this heat generation be considered in studying any method of increasing the gravity of submarine storage batteries in order that the resulting temperature does not exceed the limits found by experience to be injurious.

NARRATIVE OF ORIGINAL WORK DONE AT THIS LABORATORY

5. The experimental studies of methods of raising gravity were made on a single submarine storage cell, a U.S.S. CUTTLEFISH WLH-29 Ironclad cell. The gravity of this cell was adjusted to 1.210 and then raised by one of four suggested methods, careful account being taken of the amount of acid used and of the time required. The gravity was then lowered to 1.210 and again raised, using another method, etc. By so doing, a comparison of the time required for the several methods was obtained.

METHODS

(a) Preparation of Material

6. The cell used in these experiments was a typical small Ironclad submarine cell - a WLH-29. Sulphuric acid of 1.350 specific gravity was prepared from the 1.840 and used in all but one of these methods (the one making use of the pure 1.840 acid). No special study was made of the apparatus and methods for preparing the 1.350 acid on the scale necessary in raising the gravity of all the cells on a large submarine.

(b) Description of Experiments

7. Four different methods of raising the gravity were tried. These are given below in the form of specific directions for carrying out the methods.

Method I. Proposed Article 28-240, revised Chapter 28.

(1) To raise the specific gravity of a battery from 1.210 to 1.280, proceed as follows:

(a) With the cells filled to normal level, discharge the battery at the 6 hour or longer rate until the gravity reaches 1.110.

(b) Withdraw electrolyte to the top of separators, or to the glass plate, if installed.

(c) Fill the 1.350 specific gravity electrolyte to the normal level.

(d) Give battery an equalizing charge.

(e) Discharge the battery at the 6 hour or longer rate until the gravity has fallen 100 points from that obtained on the equalizing charge of (d).

(f) Withdraw electrolyte to the top of separators, or to the glass plate, if installed.

(g) Fill with 1.350 specific gravity electrolyte to the normal level.

(h) Give battery an equalizing charge.

(i) Repeat steps (e) to (h) until the desired gravity of 1.280 is reached.

NOTE: When the last adjustment is reached (this can be determined by the readings obtained on the preceding charges), the full amount of electrolyte down to the tops of separators or to the glass plates should not be taken out, but, as estimated, part of this amount should be removed and replaced with a like amount of 1.350 electrolyte in order that the final adjustment will not bring the gravity above 1.280.

Method II. Bureau's Suggested Modification of Method I.

(a) With the cells filled to normal level and fully charged, draw off the electrolyte to the top of the separators, or to the glass plate, if installed.

(b) Fill with 1.350 specific gravity electrolyte to the normal level.

(c) Charge at the equalizing rate until the electrolyte is thoroughly mixed and the gravity becomes a maximum.

(d) Secure the equalizing charge.

(e) Repeat (a), (b), (c), and (d) until full-charge gravity is 1.280.

Method III. Rapid Method Requiring Special Equipment.

In this, a special mixing reservoir (Plate 1) is provided, electrolyte from the cell is pumped into this reservoir, and there 1.840 acid is added with constant stirring until its specific gravity reaches 1.350. This electrolyte is allowed to flow back into the cell while it is charging at the equalizing rate. After a few minutes, some more electrolyte is pumped into the mixing reservoir, 1.840 acid again added to it, until it reaches 1.350, this electrolyte being then permitted to flow back into the cell. The cycle is repeated as often as necessary until 1.280 gravity is reached.

Method IV. Same as Method II, except with a higher equalizing rate.

DATA OBTAINED

8. Logs of the gravity changes by the respective methods are given in Tables 1 to 4 inclusive. These tables give the elapsed time for increasing the gravity without account being taken of the time actually neces-

sary to remove electrolyte and replace it by stronger acid. These data are summarized below:

	Number of Changes of Electrolyte	Elapsed Time (Neglecting time for changing Electrolyte)	Total Electrolyte Removed
Method I	5	76-1/2 hours	15,000 m.l.
Method II	9	9-1/2	50,000
Method III	-	1-3/4	-
Method IV	8	7-1/2	48,000

CONCLUSIONS AND RECOMMENDATIONS

(a) Facts Established.

9. These experiments show that of the four suggested methods of increasing the specific gravity of submarine main storage cells from the peace-time to the war-time gravity, the old M.E.I. method (I) is the slowest, the Naval Research Laboratory method (III, necessitating special apparatus) the fastest, while the new Bureau method (II and IV) would in practice be nearly as rapid as the latter.

(b) Opinions

10. The actual time required for gravity increase by either of Methods I, II, or IV would be greater than shown in the tables by the time necessary to remove the weaker electrolyte and replace it by the stronger. In the actual procedure on a submarine, this would be a time-consuming process. For this reason, Method I, requiring less electrolyte changes, is not quite so slow, relatively, as the tables would indicate. It is believed, nevertheless, that it would be much slower than the new Bureau method.

11. In the above experiments, the temperature rise could be determined only with Method III. With the extreme rapidity with which this experiment was made, the temperature rise was necessarily great. (This method has the disadvantage that the great heat of solution of sulphuric acid in dilute solutions goes to increasing the cell temperature.)

12. The above experiments were, of course, carried out on one cell; it is believed, however, that the method which proves fastest in one cell would prove fastest for a battery of 60 or 120 cells in a submarine.

13. There is still a further method which has been suggested for increasing the gravity, this one requiring a slight change in the original design of submarine cells. In this, one of the Ironclad tubes in the element would be left out and in its place would be put a long hard rubber

tube reaching to the bottom of the element (Plate 2). With cells of this design, the process of gravity increase would be as follows: by use of an acid pump connected to this rubber tube, enough 1.210 gravity electrolyte would be pumped out of the cell so that when the cell was filled up to its normal electrolyte level with 1.350 electrolyte and given an equalizing charge, the gravity would come up to 1.280. This method would be the most rapid and convenient of any, and it is believed that the Bureau should consider embodying this slight change in future designs.

(c) Recommendations

14. It is recommended that the tentative M.E.I. 28-240 be changed so that the several discharges specified are omitted, the gravity change being made by Method II above.

15. It is recommended that the Bureau consider modifying future designs to include a tube in the element by which electrolyte can be pumped out.

TABLE 1

Log of Gravity Increase, Method I.
(Proposed M.E.I. Article 28 - 240)

Elapsed Time (Hours)	Amperes Charge	Amperes Discharge	Electrolyte Change Added	Electrolyte Change Removed	Specific Gravity (Corrected) Top	Specific Gravity (Corrected) Bottom	Volts
0	Cell fully charged.				1210	1210	2.21
0		700			1210	1210	1.94
1/2		"			1208	1207	1.94
1		"			1202	1202	1.93
1-1/2		"			1193	1193	1.92
2		"			1186	1186	1.92
2-1/2		"			1179	1179	1.91
3		"			1166	1166	1.89
3-1/2		"			1158	1157	1.88
4		"			1148	1148	1.87
4-1/2		"			1140	1140	1.86
5		"			1131	1131	1.84
5-1/2		"			1122	1122	1.82
6		"			1112	1112	1.81
6-1/2		"			1102	1103	1.79
7		"			1094	1095	1.76
				3000 ml.	1077	1080	
			3000 ml.				
7	1300				1096	1098	2.17
7-1/2	"				1096	1113	2.19
8	"				1097	1125	2.22
8-1/2	"				1099	1144	2.23
9	"				1104	1162	2.26
9-1/2	"				1108	1178	2.29
10	1300				1122	1201	2.36-
	1050						2.32
10-1/2-	1050						2.36
	800						2.31
10-1/2					1139	1211	2.33
10-1/2+	800						2.35-
	550						2.28
11-	550-						2.35
	330						2.26
11	330				1155	1222	2.28
11-1/2	"				1176	1224	2.36
12	"				1210	1210	2.44
12-1/2	"				1218	1218	2.46
13	"				1221	1221	2.47
13-1/2	"				1221	1221	2.47
14	"				1222	1222	2.47
14-1/2	"				1222	1222	2.47
15	"				1222	1222	2.47
15		700			1223	1223	2.27-
							1.95

Table 1 (Continued)

Elapsed Time (Hours)	Amperes Charge	Amperes Discharge	Electrolyte Change Added	Electrolyte Change Removed	Specific Gravity (Corrected) Top	Specific Gravity (Corrected) Bottom	Volts
15-1/2		700			1220	1220	1.95
16		"			1212	1215	1.95
16-1/2		"			1204	1208	1.94
17		"			1195	1199	1.93
17-1/2		"			1188	1193	1.92
18		"			1176	1183	1.90
18-1/2		"			1166	1172	1.89
19		"			1156	1162	1.88
19-1/2		"			1146	1153	1.87
20		"			1138	1144	1.85
20-1/2		"			1132	1137	1.84
21		"			1122	1127	1.82
21-1/2		"			1112	1115	1.79
22		"			1102	1105	1.77
				3000 ml.	1084	1061	
			4400 ml.				
22	1300				1114	1128	1.94-2.19
22-1/2	"				1112	1127	2.20
23	"				1113	1145	2.23
23-1/2	"				1116	1159	2.26
24	"				1120	1174	2.28
24-1/2					1125	1191	2.31
25	1300				1137	1210	2.37-
	1050						2.33
25-1/3	1050						2.36-
	800						2.33
25-1/2	800				1152	1222	2.35
25-3/4	800						2.37-
	550						2.32
26					1170	1230	2.35
26+	550						2.37-
	330						2.31
26-1/2	330				1185	1235	2.35
27	"				1220	1235	2.44
27-1/2	"				1227	1229	2.47
28	"				1234	1234	2.49
28-1/2	"				1236	1235	2.49
29	"				1236	1235	2.48
29-1/2	"				1236	1236	2.48
30	"				1236	1236	2.48
30		700			1239	1239	2.19-
							1.95
30-1/2		"			1237	1238	1.95
31		"			1229	1232	1.94

TABLE 1 (Continued)

Elapsed Time (Hours)	Amperes Charge	Amperes Discharge	Electrolyte Change Added	Electrolyte Change Removed	Specific Gravity (Corrected) Top	Specific Gravity (Corrected) Bottom	Volts
31-1/2		700			1219	1225	1.94
32		"			1206	1217	1.93
32-1/2		"			1204	1210	1.92
33		"			1194	1201	1.91
33-1/2		"			1187	1194	1.90
34		"			1177	1186	1.89
34-1/2		"			1166	1175	1.88
35		"			1157	1166	1.87
35-1/2		"			1152	1157	1.85
36		"			1139	1148	1.83
36-1/2		"			1131	1139	1.81
37		"			1122	1128	1.78
				2400 ml.	1103	1111	
			5000 ml.				
37	1300				1139	1139	1.96-2.20
37-1/2	"				1137	1150	2.22
38	"				1137	1165	2.25
38-1/2	"				1139	1180	2.28
39	"				1143	1196	2.30
39-1/2	"				1147	1213	2.34
39-3/4	1300						2.37-
	1050						2.32
40					1157	1228	2.34
40+	1050						2.37-
	800						2.32
40-1/2	800				1172	1239	2.36
40-1/2+	800						2.36-
	550						2.31
41	550				1187	1248	2.36-
	330						2.29
41-1/2	330				1199	1253	2.34
42	"				1222	1254	2.42
42-1/2	"				1240	1240	2.47
43	"				1246	1246	2.49
43-1/2	"				1250	1249	2.49
44	"				1250	1250	2.49
44-1/2	"				1252	1251	2.48
45	"				1252	1251	2.48
45		700			1252	1252	2.29-
							1.98
45-1/2		"			1248	1248	1.98
46		"			1241	1244	1.98
46-1/2		"			1232	1234	1.96
47		"			1223	1228	1.96
47-1/2		"			1214	1219	1.95

TABLE 1 (Continued)

Elapsed Time (Hours)	Amperes Charge	Amperes Discharge	Electrolyte Change Added	Electrolyte Change Removed	Specific Gravity (Corrected) Top	Specific Gravity (Corrected) Bottom	Volts
48		700			1206	1211	1.94
48-1/2		"			1199	1204	1.93
49		"			1191	1195	1.92
49-1/2		"			1183	1187	1.91
50		"			1173	1176	1.90
50-1/2		"			1162	1167	1.88
51		"			1154	1158	1.86
51-1/2		"			1145	1149	1.84
52		"			1137	1141	1.81
				3600 ml.	1124	1129	
			4000 ml.				
52					1147	1158	1.97-2.20
52-1/2					1145	1160	2.23
53					1147	1174	2.26
53-1/2					1149	1190	2.28
54					1155	1211	2.31
54-1/2					1161	1223	2.34
54-3/4	1300						2.36-
	1050						2.30
55					1172	1239	2.35
55-1/4	1050						2.36-
	800						2.31
55-1/2					1185	1249	2.35
55-1/2+	800						2.36-
	550						2.31
56					1202	1258	2.34
56-1/4	550						2.36-
	330						2.30
56-1/2					1218	1263	2.32
57					1236	1265	2.39
57-1/2					1249	1260	2.43
58					1261	1261	2.47
58-1/2					1263	1262	2.48
59					1264	1264	2.48
59-1/2					1265	1264	2.48
60					1265	1265	2.48
60		700			1265	1264	2.36-
							2.20
60-1/2		"			1262	1264	1.98
61		"			1256	1259	1.98
61-1/2		"			1249	1252	1.97
62		"			1239	1244	1.96
62-1/2		"			1231	1237	1.95
63		"			1220	1227	1.94
63-1/2		"			1211	1221	1.93
64		"			1202	1209	1.92

TABLE 1 (Continued)

Elapsed Time (Hours)	Amperes Charge	Amperes Discharge	Electrolyte Change Added	Electrolyte Change Removed	Specific Gravity (Corrected) Top	Specific Gravity (Corrected) Bottom	Volts
64-1/2		700			1194	1201	1.91
65		"			1187	1193	1.90
65-1/2		"			1179	1185	1.88
66		"			1171	1174	1.88
66-1/2		"			1159	1165	1.84
67		"			1151	1152	1.82
				2600 ml.	1135	1143	
			5000 ml.				
67	1300				1167	1175	1.98-2.23
67-1/2	"				1163	1177	2.25
68	"				1164	1195	2.29
68-1/2	"				1169	1207	2.30
69	"				1171	1225	2.33
69-1/2	1300				1179	1239	2.36-
	1050						2.33
70	1050				1168	1253	2.36-
	800						2.33
70-1/2	800				1199	1262	2.36-
	550						2.32
71	550				1212	1267	2.34
71-1/4	550						2.36-
	330						2.32
71-1/2	330				1223	1273	2.32
72	"				1234	1278	2.34
72-1/2	"				1255	1276	2.39
73	"				1269	1269	2.45
73-1/2	"				1273	1273	2.47
74	"				1276	1276	2.48
74-1/2	"				1277	1277	2.48
75	"				1278	1277	2.48
75-1/2	"				1279	1279	2.48
76	"				1280	1280	2.48
76-1/2	"				1280	1280	2.48
		Total -	21400 ml.	14600 ml.			

TABLE 2

Log of Gravity Increase, Method II.
(Bureau Modification of Method I.)

Elapsed Time Hrs.	Min.	Amperes Charge	Electrolyte Change Added	Removed	Specific Gravity Top	Bottom	Volts
0		Cell fully charged.			1210	1210	
0		165		5000 ml.	1210	1225	
0		0	5500 ml.				
0		165			1226	1230	2.21-2.36
	10				1226	1226	2.46
	20				1224	1224	2.48
	30				1224	1224	2.49-2.21
	30			5300 ml.			
	30	0	5700 ml.				
	30	165			1238	1241	2.21-2.40
	40	"			1236	1236	2.48
	50	"			1235	1235	2.48
1	0				1234	1234	2.48
	10				1233	1233	2.48
	20				1233	1233	2.49
	30				1232	1232	2.49
	40				1232	1232	2.49-2.22
	40	0		6000 ml.			
	40	0	6000 ml.				
	40	165			1248	1251	2.22-2.44
	50				1247	1247	2.48
2	0				1246	1245	2.48
	10				1244	1244	2.48
	20				1244	1244	2.48
	30				1243	1243	2.48
	40				1243	1243	2.48-2.22
	50	0		6000 ml.			
	50	0	6700 ml.				
	50	165			1253	1255	2.22-2.40
3	0	"			1253	1253	2.48
	10	"			1252	1251	2.48
	20	"			1251	1251	2.48
	30	"			1250	1250	2.48
	40	"			1250	1250	2.48
	50	"			1250	1250	2.48-2.22

TABLE 2 (Continued)

Elapsed Time Hrs.	Min.	Amperes Charge	Electrolyte Change Added	Removed	Specific Gravity Top	Bottom	Volts
3	50	0		5500 ml.			
	50	0	5600 ml.				
	50	165			1260	1262	2.22-2.39
4	0				1260	1260	2.45
	10				1258	1258	2.48
	20				1258	1258	2.48
	30				1257	1257	2.48
	40				1256	1256	2.48
	50				1256	1256	2.47
5	0				1256	1255	2.47
	10				1256	1255	2.47
	20				1256	1255	2.47-2.22
	20	0		5000 ml.			
	20	0	6000 ml.				
	20	165			1256	1269	2.10-2.45
	30	"			1267	1266	2.45
	40	"			1266	1265	2.47
	50	"			1265	1264	2.48
6	0				1265	1264	2.48
	10				1264	1264	2.48
	20				1264	1264	2.49-2.23
	20	0		5800 ml.			
	20	0	6000 ml.				
	20	165			1274	1276	2.23-2.45
	30				1274	1274	2.48
	40				1273	1273	2.49
	50				1272	1272	2.49
7	0				1272	1272	2.49
	10				1271	1271	2.49
	20				1271	1271	2.49-2.23
	20	0		6000 ml.			
	20		6000 ml.				
	20	165			1278	1281	2.23-2.38
	30				1279	1279	2.48
	40				1278	1278	2.48
	50				1278	1278	2.48
8	0				1277	1277	2.48
	10				1277	1277	2.48
	20				1277	1277	2.48-2.23

TABLE 2 (Continued)

Elapsed Time Hrs.	Min.	Amperes Charge	Electrolyte Change Added	Removed	Specific Gravity Top	Bottom	Volts
8	20	0		5000 ml.			
	20		5000 ml.				
	20	165			1283	1283	2.23-2.48
	30	"			1282	1282	2.48
	40	"			1282	1282	2.48
	50				1281	1281	2.48
9	0				1281	1281	2.48
	10				1281	1281	2.48
	20				1280	1280	2.48
	30				1280	1280	2.48-2.21
		Total -	53500 ml.	49600 ml.			

TABLE 3

Log of Gravity Increase, Method III.
(NRL Method Requiring Special Apparatus.)

NOTE: The rapidity of this method is dependent upon the size of the mixing apparatus. The data below were obtained using a small mixer; hence, the method is even faster than indicated.

Elapsed Time Hrs.	Min.	Amperes Charge	Temperature	Specific Gravity Top
0	0	0 - 330	70°	1210
	15	330	72°	1215
	25		74°	1220
	28		76°	1230
	37		77°	1235
	42		81°	1235+
	47		84°	1245
	52		83°	1245
	57		86°	1252
1	0		88°	1263
	5		90°	1277
	10		93°	1274
	15		94°	1280
	25		93°	1280
	30		96°	1280
	35		96°	1280
	45		97°	1280

TABLE 4

Log of Gravity Increase, Method IV.
(Modification of Method II,
Higher **Charging Rate.**)

Elapsed Time Hrs.	Min.	Amperes Charge	Electrolyte Change Added	Removed	Specific Gravity Top	Bottom	Volts
0		Cell fully charged.			1210	1210	
0				6600 ml.			
0			6600 ml.				
0		330			1228	1231	2.21-2.53
	10	"			1228	1227	2.56
	20	"			1226	1225	2.56
	30				1225	1224	2.56
	40				1224	1222	2.56
	50				1224	1223	2.56
1	0				1224	1223	2.56-2.20
	0	0		6600 ml.			
	0	0	6000 ml.				
	0	330			1239	1241	2.20-2.50
	10	"			1237	1236	2.55
	20	"			1236	1235	2.55
	30	"			1235	1235	2.55
	40	"			1235	1235	2.55
	50	"			1234	1234	2.55
2	0	"			1234	1234	2.54-2.20
	0	0		6700 ml.			
	0		6700 ml.				
	0	330			1249	1249	2.20-2.54
	10				1248	1248	2.54
	20				1247	1247	2.54
	30				1246	1246	2.54
	40				1246	1246	2.54
	50				1245	1245	2.53
3	0				1245	1245	2.53-2.20
	0	0		6600 ml.			
	0		6600 ml.				
	0	330			1256	1258	2.20-2.51
	10	"			1256	1256	2.53
	20	"			1254	1254	2.53
	30	"			1254	1254	2.53
	40	"			1254	1254	2.53

TABLE 4 (Continued)

Elapsed Time Hrs.	Min.	Amperes Charge	Electrolyte Change Added	Removed	Specific Gravity Top	Bottom	Volts
3	50	330			1254	1254	2.52
4	0	"			1254	1254	2.52-2.20
	0	0		6400 ml.			
	0	0	6600 ml.				
	0	330			1264	1266	2.20-2.52
	10	"			1263	1263	2.52
	20				1263	1263	2.52
	30				1262	1262	2.52
	40				1263	1263	2.52
	50				1262	1262	2.51
5	0				1262	1262	2.51-2.20
	0	0		5800 ml.			
	0	0	6800 ml.				
	0	330			1272	1274	2.23-2.51
	10				1272	1272	2.54
	20				1271	1271	2.55
	30				1271	1271	2.55
	40				1271	1271	2.55
	50				1271	1271	2.55
6	0				1271	1271	2.55-2.24
	0	0		6600 ml.			
	0	0	6600 ml.				
	0	330			1279	1281	2.22-2.51
	10	"			1279	1279	2.55
	20	"			1278	1278	2.55
	30				1278	1278	2.55
	40				1278	1278	2.54
	50				1278	1278	2.54
7	0				1278	1278	2.54-2.23
	0	0		2400 ml.			
	0	0	2400 ml.				
	0	330			1280	1280	2.22 2.53
	10				1280	1280	2.53
	20				1280	1280	2.54
	30				1280	1280	2.54-2.23
Total		-	48300 ml.	47700 ml.			

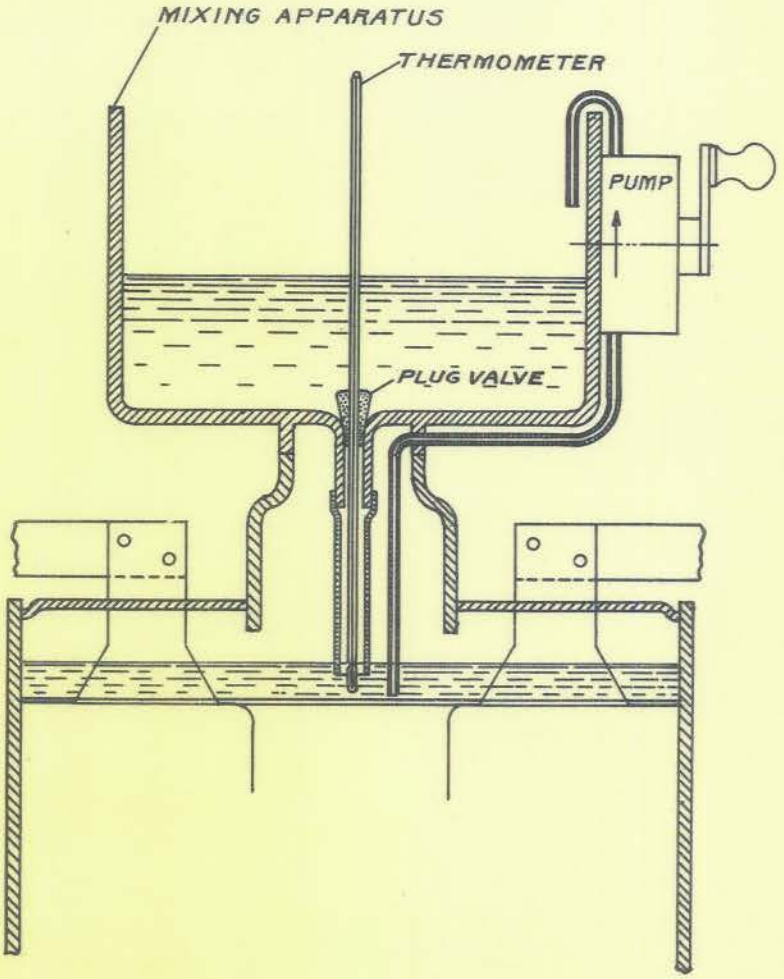

PLATE 1

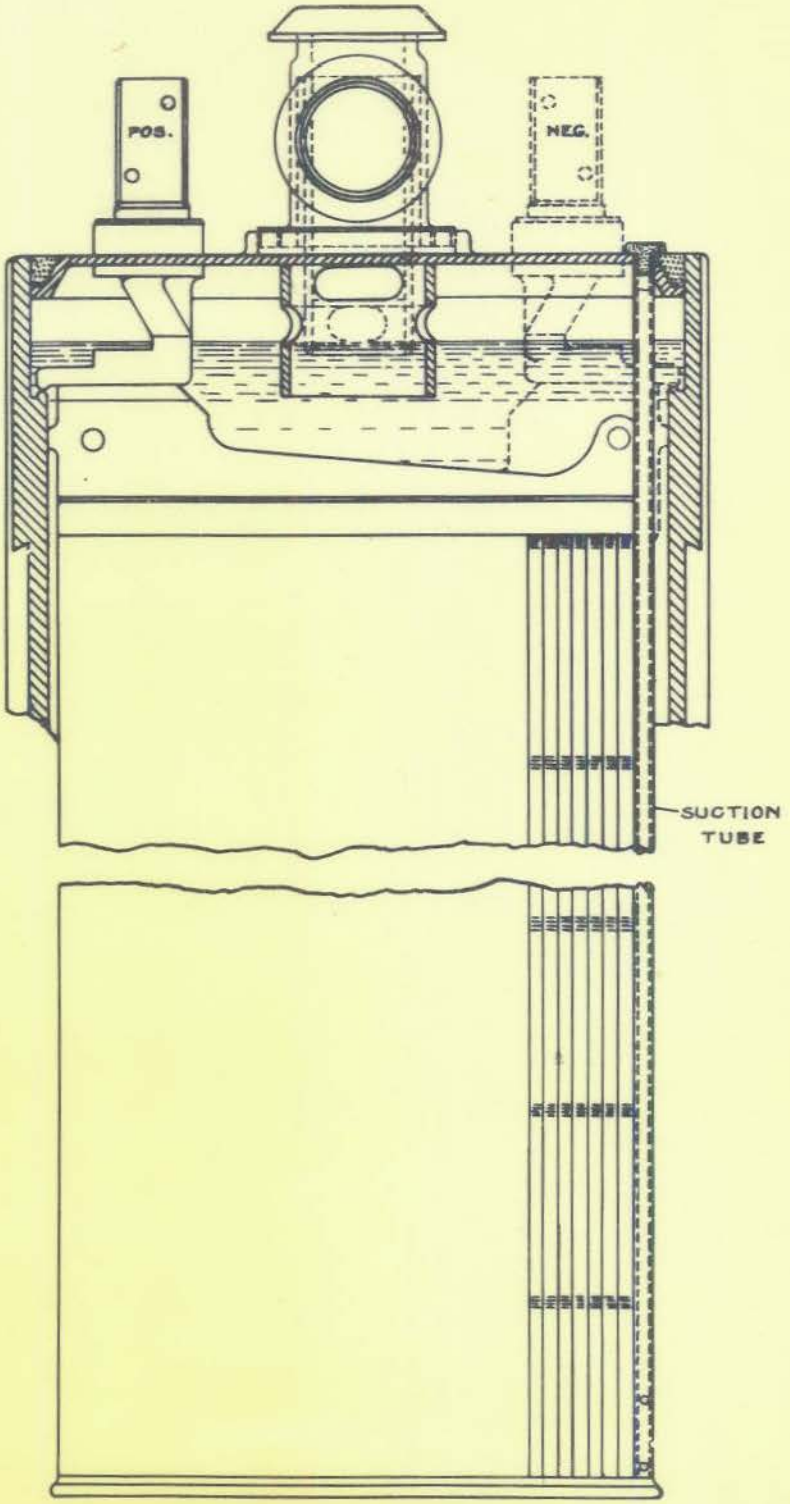

PLATE 2