MASTER

LOFT TECHNICAL REPORT LTR 1310-8 Rev. B

NOVEMBER 14, 1978

CAPABILITY OF LOFT VITAL BATTERIES TO SUPPLY
EMERGENCY POWER DEMANDS DURING SEVERE COLD
WEATHER CONDITIONS

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THIS REVISION COMPLETELY SUPERSEDES ALL PREVIOUS ISSUES OF LTR 1310-8.

EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

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1.0 INTRODUCTION

The LOFT vital batteries "A" & "B" each consists of 129 submarine cells and are housed in Building TAN 629. These batteries provide redundant sources of electrical power for vital MG sets A & B which in turn power the 480 volt AC class IE, PPS loads. The building is unheated* and the batteries may be subject to very cold temperatures during winter conditions resulting in a reduction in their output capability. This report presents evidence of the temperatures to which the batteries may be subjected and evaluates the derating factors which are applicable to this installation. The report compares the expected electrical load with the battery capacity and evaluates the time interval during which the batteries can supply the required vital loads at a temperature of 5 F.

2.0 NECESSITY FOR A COLD TEMPERATURE ANALYSIS

In order to determine the cold temperature to which the batteries might be subjected, special data was recorded during the period Jan. 1 to Jan. 14, 1974. This data consisted of readings of air temperatures adjacent to the batteries recorded at 0830 hrs. and 1600 hrs. each day. It was noted that the lower temperatures occurred at 0830 hrs. In Fig. 1 these temperatures are plotted together with a companion plot of the official outside minimum temperatures for the TAN area.

The minimum inside air temperature observed was -30°F. It is presumed credible that with longer sustained periods of -30°F. outside temperature the inside air temperatures and the electrolyte temperatures in turn could lower to the range of -5°F to -10°F. Such possibilities dictate a need to analyze the limits of the battery capability in the event such temperature conditions are approached.

3.0 ELECTRICAL LOAD DATA

From LTR 1310-13 two electrical AC load conditions are noted as being applicable to the vital MG-Battery power sources.

- a. The initial load is the load which would be automatically assumed by the MGs immediately following loss of commercial power and which could continue up to 30 minutes. The load analysis in the LTR 1310-13 shows this load could reach 293 kw. This load is considered the MG load which must be used for this temperature analysis. Allowance for MG losses (15%) increases this value to 34 5kw load on the battery.
- b. Following the initial 30 minute period, trimming of non PPS loads from the vital 480 V-bus will reduce the MG loading to 135 KW. No analysis is made using this value.

*Office trailers have been installed in Bldg TAN 629 and will furnish incidental heat. The amount of heat is not considered significant compared to the heat dissipation through the large roof.

4.0 BATTERY DERATING FACTORS

The analysis considers three derating factors which can affect the batteries during cold temperature emergency use.

- a. A derating to 80 percent of nominal capacity (5016 Ampere Hours) is used for allowable deterioration due to age and usage. This is the maximum permissible deterioration of capacity as indicated in Section 4.7 of the LOFT Technical Specifications. This 80% factor appears in Column 10 of Table I.
- b. A derating equal to 1000 ampere hours of discharge is considered here to show the effects of a trickle discharge during normal operation. In percentage of rated capacity this derating factor varies from 13 to 18 percent depending on the discharge time for which the capacity rating is selected. The battery capacity is computed with and without this derating and is shown in Column 5 of Tab. I.

It is the recommendation of the Gould Battery Company that the batteries be operated at a slight trickle or float charge, with that company's assurance that the thick plate construction of this model cell prevents it from loss of capacity resulting from such operation. Thus, except for some unforeseen loss of capacity during plant operation, the 13 to 18 percent derating is ~~app~~ applicable and its inclusion in this analysis is provided only for information purposes.

- c. The percent temperature derating of the battery operating time at 50°F is shown in Fig. 2 for discharge at the 3 hr. rate (418kw) and the 8 hr. rate (200kw).

Fig 2 is the key figure and basis for the conclusions of this report. It is redrawn from Curve EB 6792 furnished by Gould, Inc. This curve was derived from tests of Exide Co. stationary storage batteries and is included as Appendix A of this LTR. It is important to note that the test batteries used to derive curve EB 6792 had a specific gravity of 1.210, whereas submarine type batteries have specific gravities in excess of 1.265 thus greatly improving the cold temperature capacity. Curve EB 6792 was chosen for this analysis because it is noted that the cold temperature derating for batteries is more severe for conditions where load is held constant effecting a reduced operating time than conditions where load (discharge amps), are reduced to permit the rated operating time. EB 6792 reflects the first condition.

The use of this Fig. 2 is discussed in Par. 5.0- "Analysis and Application of Derating Factors".

5.0 ANALYSIS AND APPLICATION OF DERATING FACTORS

EMERGENCY LOAD VALUES

LTR 1310-13 projects an AC load of 247 kw for one half hour on Bus A and recommends verification of this amount by actual load test. In response, SO 68.02 Attachment 6 was performed using a load of 250 kw. However, some loads from Vital Bus B were necessarily connected in order to obtain this value and it is believed doubtful if in actual emergency conditions the load value of 250 kw would be reached. LTR 1310-13 also projects that new DAVDS loads will increase the peak loading to 293 kw. This value is used throughout this analysis even though it is considered an extremely unlikely load. With reference to Par. 3, b above the factor of energy conservatism is:

$$\frac{293 \text{ kw} \times 1 \text{ hr}}{293 \text{ kw} \times \frac{1}{2} \text{ hr} + 135 \text{ kw} \times \frac{1}{2} \text{ hr}} = 1.37$$

VITAL MG LOSSES

A recent review of vital MG input and output values indicated the combined losses of the DC and AC machine to be 15% at 75 to 100% of rated load. Thus an AC load of 293 kw AC requires a battery output of 345 kw DC. These conservative values are used as basis of the analysis.

DIESEL GENERATOR STARTING TIME

LOFT Technical Specification Par 4.7.3 (2) (d) states that the time required for diesel generators to start and assume loads shall not exceed one hour. Hence the vital batteries must carry the vital loads for this one hour period following a commercial power outage.

DETERMINATION OF TEMPERATURE DERATING

To allow maximum conservatism a vital bus AC load of 293 kw is assumed which corresponds to 345 kw DC output from the battery. By interpolation, using Fig. 4, this is equivalent to a 4 hr. discharge time rate.

The required energy for 1 hour is then 345 kw hr.

Again using Fig. 4 as an aid for interpolation, the design capacity at the 4 hr. rate is 1380 kw hr. Allowing 80% for deterioration gives 1100 kw hr. present capacity. Permissible combined derating of discharge time is then: $\frac{345 \text{ kw hr.}}{1100 \text{ kw hr.}} = 31.4\%$

From Fig. 2, the minimum temperature for this derate is 20°F.

Calculation of Total Time Derating Factor

In order to develop Table I and Figure 3, showing Battery discharge load vs Discharge time, the value of 50°F is selected as a lower operating temperature limit. Column 9 of Table I shows the temperature derating factors at 50°F for various KW loads determined from Fig. 2. Column 9 shows the total derate factor, and column 11 shows the resulting available hours of operation at 50°F.

Throughout Table I data is shown for a condition in which 1000 ampere hours of prior trickle discharge is considered. This condition is also shown on Fig. 3.

Curve No. 1 of Fig. 3 is noted to show the load point of 293kw AC power and shows capability for operation for 1.2 hours. Because of the high degree of conservatism in selection of electrical loads, duration of loads and derating of the battery, the actual operating time is without doubt greater than this value. Curve No. 2 reflects the prior use of 1000 Ampere hours and is shown for information only.

Recommendations

- a. It is recommended that during cold temperature conditions (electrolyte temperatures less than 20°F) the state of charge of the batteries be observed and maintained at a near full charge condition.

Conclusions

The vital batteries as rated are adequate to sustain all PPS loads for a period of more than one hour.

SUBJECT TEMP DATA TAN 629 DATE _____
 PREPARED BY W. Peates CHECKED _____
 WORK REQUEST _____

FIG. 1.

TEMPERATURE DATA
AT TAN.

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Note: This is a reproduction of Curve EB-6792
Furnished by Gould Co. It illustrates
how the time period of discharge to
1.75 volts per cell is reduced by cold Temp.
while the battery ampere discharge
rate remains as rated.

TABLE I
CALCULATION OF VITAL BATTERY OPERATING TIME
FOR VARIOUS DISCHARGE RATES AT 50°F

Line No.	1 Nom. Discharge Time Hrs. (Gould Data)	2 Rated Discharge Amps Gould Data	3 Rated Output Amp Hrs. Gould Data	4 Amp Hrs. Minus 1000 (3)-1000	5 % A.H. Remaining (4) (3)	6 Rated Batty Output KW Gould Data	7 Rated Batty Capcy KWHR (6)x(1)	8 MG AC Load KW (6) x .85	9 Temp Derate Factor for 50°F Fig 2	10 Total Derate Factor .8x(5)x(9)	11 Derated Op. Hrs (10)x(1)	12 Batty Capcy at 50°F KWhr (10)x(7)	13 MG Output KWHR (11)x(8)
1	3	1835	5505	4505	81.8	418	1255	356	.34	.223	.67	280.	238
2	3	1835	5505	—	100	418	1255	356	.34	.272	.815	331	290
3	5	1220	6100	5100	83.6	345* 291	1455	293* 248	.37	.248	1.24	361	307
4	5	1220	6100	—	100	291	1455	248	.37	.295	1.48	430	367
5	6	1045	6270	5270	84	251	1500	213	.38	.255	1.53	382	326
6	6	1045	6270	—	100	251	1500	213	.38	.304	1.82	456	387
7	10	685	6850	5850	85.4	167	1670	142	.42	.29	2.9	484	411
8	10	685	6850	—	100	167	1670	142	.42	.336	3.36	561	476
9	20	370	7400	6400	86.5	91	1820	77.4	.50 (EST)	.346	6.9	626	534
10	20	370	7400	—	100	91	1820	77.4	.50	.4	8.0	727	620

* Predicted Max Vital load during loss of Commercial Power Outage during LOC
(X) = Column No.

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Calc. of Vital Battery Operating Time
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Time of Battery Discharge to Rated Min. Cell Volts
At 5 Deg F

Note: Data points are calculated in Table I, Col. 11.

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SUBJECT Vital Battery Load KW vs Discharge Hrs PAGE OF PAGES
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All data is rated at 77°F

REFERENCES

1. NAVSHIPS 0962-000-4000
Service Manual Type GNX-33
US Submarine Main Storage Battery
Gould National Batteries, Inc.
2. LTR 1310-13
LOFT Vital Bus System Load Study
R. A. Borgen, December 1976
3. LOFT Technical Specifications

APPENDIX A

TECHNICAL ARTICLE "EFFECT OF TEMPERATURE
ON BATTERY CAPACITY"

EFFECT OF TEMPERATURE ON BATTERY CAPACITY

Since the storage battery is an electrochemical device, the capacity to produce electricity is affected by temperature. The battery ratings in Tables I and II are generally expressed as at 1.210 full charge specific gravity and for a temperature 77°F. (25°C). For lower battery temperatures the ratings must be reduced; for higher battery temperatures, additional capacity may be obtained.

The effect of temperature varies with the discharge rate and to some extent with different types and sizes of cells, but for practical purposes the family of curves in Drawings EB-6791 and EB-6792 are considered as typical of the batteries in this Bulletin.

EB-6791 illustrates how the ampere ratings should be corrected, leaving the time periods unchanged. As an example, at 32°F., the rating per positive plate for the one minute period to 1.75 volts per cell, is reduced to 67% of the 77°F. rating.

EB-6792 illustrates how the time period should be corrected with the ampere ratings unchanged. As an example, at 40°F., the 3 hour period would be reduced to 67.5% (or to $67.5 \times 3 = 1.93$ hours), with the ampere rating unchanged. Note that this curve has no information for the one minute period, as the characteristic volt-time curve for a one minute discharge (page 20) does not lend itself to making the correction in the time period. For the one minute correction, EB 6791 should be used.

When determining the size of the battery (page 5), if battery operating temperatures below 77°F., will occur, reductions in the ratings per positive should be employed in the calculations. While some increase in capacity occurs with battery temperatures above 77°F., this is generally too small for consideration in the sizing of the battery.

Edgemoor Generating Station, Delaware Power & Light Co., Wilmington, Del., relies upon Exide-Manchex Batteries for a number of vital services.

EB-6791

The preceding correction curves are to a final voltage of 1.75 vpc (volts per cell). For the 8 hours discharge rate, this is a point of its volt time curve where the voltage begins to fall rather quickly. This is called the "knee of the curve." However when discharging at higher rates, the "knee of the curve" is at an inherent lower voltage. For the one hour rate, it is 1.60 vpc. From the practical or user viewpoint, this means that at the higher rates as 1 min., 1 or 3 hour, that there is no abrupt exhaustion of battery capacity at 1.75 vpc, but rather a slow tapering off of the voltage.

The preferred battery room temperature is in the range 60 to 90°F., for the benefit of the battery, the maintenance personnel, and the charger performance. Where battery room temperatures would average above 90° more than thirty days in the year, and a few days when the average temperature is below 40°F., one should consider using the battery with a full charge gravity of 1.170 (1.160-1.180). Ratings for this gravity are available at both 77°F. and 100°F. Longer battery life will be obtained with 1.170 full charge gravity at these "tropical" temperatures. The floating voltage suggested for 1.170 cells is 2.12 volts instead of the higher voltage values for 1.210 batteries shown on page 17.

Slush ice will begin to form in the electrolyte, depending on its specific gravity, as shown below.

Specific Gravity	Freezing Point (Slush)
1.200	-16°F.
1.175	- 4°F.
1.150	+ 5°F.

E8-6792

It is the water in the electrolyte that freezes first, leaving the remaining electrolyte with a higher acid content or gravity, and thereby adding a plus factor of safety in this low temperature analysis. Consider further that the specific gravity in a cell lowers during discharge, how much it lowers or the "points drop" for the ampere hours of the 8 hour rating is shown in the instruction book for each cell type. The specific gravity rises again on charge, but in engineering low temperature jobs, if a battery is

A portion of a 60-cell Type E-7 Exide Battery installed in the Lesperance Street Substation of the Union Electric Co., St. Louis, Mo., in November 1926.

to stand discharged, with no charging current, in a low temperature situation, the possibility of freezing at lower gravity values should be recognized in sizing the battery. Where charging current is available, this has a small heating effect, and freezing of batteries in switchgear applications is a rarity.

Batteries could be produced with a higher full charge gravity than 1.210 in order to meet a low temperature condition, but it is recommended that heating of the battery compartment or room be done instead. Batteries located in wells below the ground surface have successfully operated in very low ambient temperatures without heating equipment.

Very low temperatures may also affect the amount of power required to operate out-door switching equipment. Such installations require special consideration.

HOW TO SELECT BATTERY RACKS

Good maintenance, so important to a storage battery's welfare, is encouraged by the ease with which the periodic voltage tests, the specific gravity tests, and the cell temperature readings can be taken. Cells mounted on racks are easier to maintain and keep clean. The periodic adding of water can be done quickly and easily when all cells are located within reach at a convenient height.

Exide four basic type steel racks as shown in tables IV and V are extremely adaptable. They fit into almost any size or shape of floor space. The racks are shipped unassembled, with complete instructions for easy installation. Racks especially designed for earthquake protection are available upon request.

In 1957, after 31 years of dependable service, Exide Battery Type E-7 (above) was replaced by 60 cells of this modern trim-looking Exide Battery Type EMP-7.

LOFT TECHNICAL REPORT
LOFT PROGRAM

FORM EG&G-229
(Rev 12-76)

TITLE		REPORT NO.
Capability of LOFT Vital Batteries to Supply Emergency		LTR 1310-8 Rev. B
Power Demands During Severe Cold Weather Conditions		
AUTHOR	GWA NO.	
J. A. Yeates <i>J. A. Yeates 11/9/78</i>		
PERFORMING ORGANIZATION	DATE	
Electrical Design <i>W. Banister</i>		
LOFT APPROVAL	November 14, 1978 <i>[Signature]</i>	
<i>P&CSB</i> Mgr.	<i>RSB</i> Mgr.	<i>PSB</i> Mgr.

See incorporated DRR-L-2555.

ABSTRACT

This study evaluates the capability of the vital batteries (PPS) to provide electrical power via the vital DC-AC motor generator sets to the LOFT PPS loads during severe cold weather conditions. It is concluded that these batteries while at a temperature of 5°F will supply the necessary PPS electrical loads for a time in excess of the one hour permitted to start the diesel generators and are, therefore, adequate at this temperature.

This Revision B of the LTR includes revised, more recent, and complete technical data relating to MG set efficiency, battery operating procedures and cold temperature derating. Revision B supersedes and replaces all previous issues.

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