AD-A037 722   DEFENCE RESEARCH ESTABLISHMENT OTTAWA (ONTARIO)   F/G 10/3

NICKEL/CADMIUM AIRCRAFT BATTERIES: SINGLE SENSOR TEMPERATURE MO--ETC(U)

MAR 77 K FELDMAN, R HAYASHI

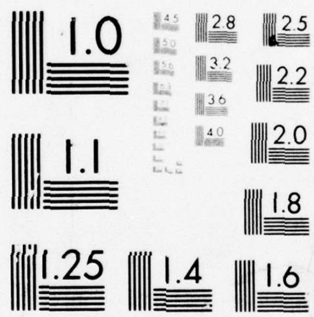
UNCLASSIFIED   DREO-TN-77-3   NL

| OF |

AD
A037722

END

DATE
FILMED
4-77



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

RESEARCH AND DEVELOPMENT BRANCH
DEPARTMENT OF NATIONAL DEFENCE
CANADA

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

DREO TECHNICAL NOTE NO. 77-3
DREO TN 77-3

NICKEL/CADMIUM AIRCRAFT BATTERIES: SINGLE SENSOR TEMPERATURE MONITORING

by

K. Feldman and R. Hayashi

PROJECT NO.
54-03-07

MARCH 1977
OTTAWA

CAUTION

This information is furnished with the express understanding that proprietary and patent rights will be protected.

RESEARCH AND DEVELOPMENT BRANCH

DEPARTMENT OF NATIONAL DEFENCE
CANADA

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL NOTE NO. 77-3

DREO-TN-77-3

NICKEL/CADMIUM AIRCRAFT BATTERIES: SINGLE SENSOR TEMPERATURE MONITORING

by

K. Feldman* and R. Hayashi
Rechargeable Systems Section
Electrical Power Sources Division

RECEIVED FEBRUARY 1977
PUBLISHED MARCH 1977
OTTAWA

PROJECT NO.
54-03-07

13p.

* On contract from Computing Devices Company

77-062

ABSTRACT

Most of the failures of nickel/cadmium batteries in aircraft are triggered by the development of a short circuit in a single cell in the battery. An experiment was conducted to determine whether the use of a single temperature sensor on an intercell link would be adequate to warn of a short circuit in a cell located elsewhere in the battery. The results indicate that this would not be adequate.

RÉSUMÉ

La plupart des défaillances des batteries d'avion au nickel-cadmium se produisent à la suite d'un court-circuit dans un accumulateur de la batterie. Actuellement, les batteries sont munies d'un thermocouple qui mesure la température d'un pontet reliant deux accumulateurs, de sorte que les courts-circuits soient détectés. Nous avons voulu nous assurer que le thermocouple pourrait détecter un court-circuit si ce dernier se produisait dans un accumulateur éloigné du thermocouple. Les résultats nous portent à croire que le thermocouple serait alors inefficace.

INTRODUCTION

Temperatures in nickel/cadmium aircraft batteries are of interest from the safety standpoint in two situations. One relates to the general temperature of the battery when high rate discharges are contemplated. If the initial temperature of the battery is too high, say as a result of previous use or lengthy exposure to very high ambient temperatures, then it may be inadvisable to carry out high rate discharges, such as one or more inboard engine starts. The heat generated by the discharge raises the battery temperature considerably and if the original battery temperature is already high the final temperature may be sufficient to damage the battery. The second situation is one in which battery failure is taking place and dangerous temperatures may be reached. In this case an early indication of above normal temperatures is desired to enable suitable measure to be taken.

Since the first of the above two cases concerns the general temperature of the battery prior to the initiation of a particular high rate use, if cell to cell variations in temperatures are not excessive, then temperature measurement at a single suitable location may be adequate. The study reported here investigated the suitability of such a measurement for the second case where a failure warning is needed. In this case the temperature may not be uniform throughout the battery since frequently the failure of a single cell triggers the failure of others. The question then arises as to whether a measurement at a single location is necessarily adequate for the needed warning.

BATTERY FAILURES

Nickel/cadmium aircraft battery failures which are associated with excessive temperatures of the batteries are popularly referred to as "thermal runaways". Unfortunately, this term tends to obscure the actual details of the failures. Under some conditions it is possible for the temperature to rise more or less uniformly throughout a battery. With voltage controlled charging systems this may result in increased charging current, which in turn may result in further elevation of the battery temperature and hence lead to true thermal runaway. However, it seems likely that most failures do not initiate in this manner.

Cells can develop internal short circuit paths either as a result of punctures through the separator materials by sharp particles or edges of plates, tabs, etc., or by the formation of conductive bridges resulting from the deposition of metal particles through openings in the barrier component in the separator materials (1). Such short circuit paths frequently develop slowly at the start and become more conductive at increasing rates as the short circuit current builds up. As the short circuit current becomes sufficiently high, the voltage across the terminals of the cell starts to drop slightly. Consequently, in constant voltage charging systems, the current increases slightly to raise the rest of the battery voltage enough to compensate for this drop. However, the short circuit current must become very large before a significant increase in charging current occurs. Consequently, little direct increase in general battery temperature results during the early stages of the cell failure. Meanwhile the energy in the short circuit current in the failing cell is completely converted into heat and raises the temperature of that cell rapidly.

The pertinent question in the above situation is, therefore, whether sufficient heat is transmitted by thermal conduction from a failing cell to a sensor which may be located elsewhere on the battery. The present experiment was conducted to answer this question.

THE EXPERIMENT

A battery was made up of deteriorated cells to give a high probability of failure. A data logger was used to periodically scan all cell voltages, the total battery voltage, and the temperature of ten intercell current conducting links. The temperature sensors were thermocouples taped to the midpoints of the links with Mylar tape. The locations of these sensors are indicated in Figure 1.

Due to the large number of leads needed to make the above measurements, no cover was placed on the battery. Also, to avoid danger of explosion in the event that failing cells overheated beyond the boiling point of the electrolyte, the cell vent caps were put into place but not tightened.

The battery was cycled daily on a PCA 130 Charger Analyzer until a cell failed. The failure occurred near the end of a charge cycle and involved the development of a short circuit in cell 13. The results of the experiment are discussed in the next section.

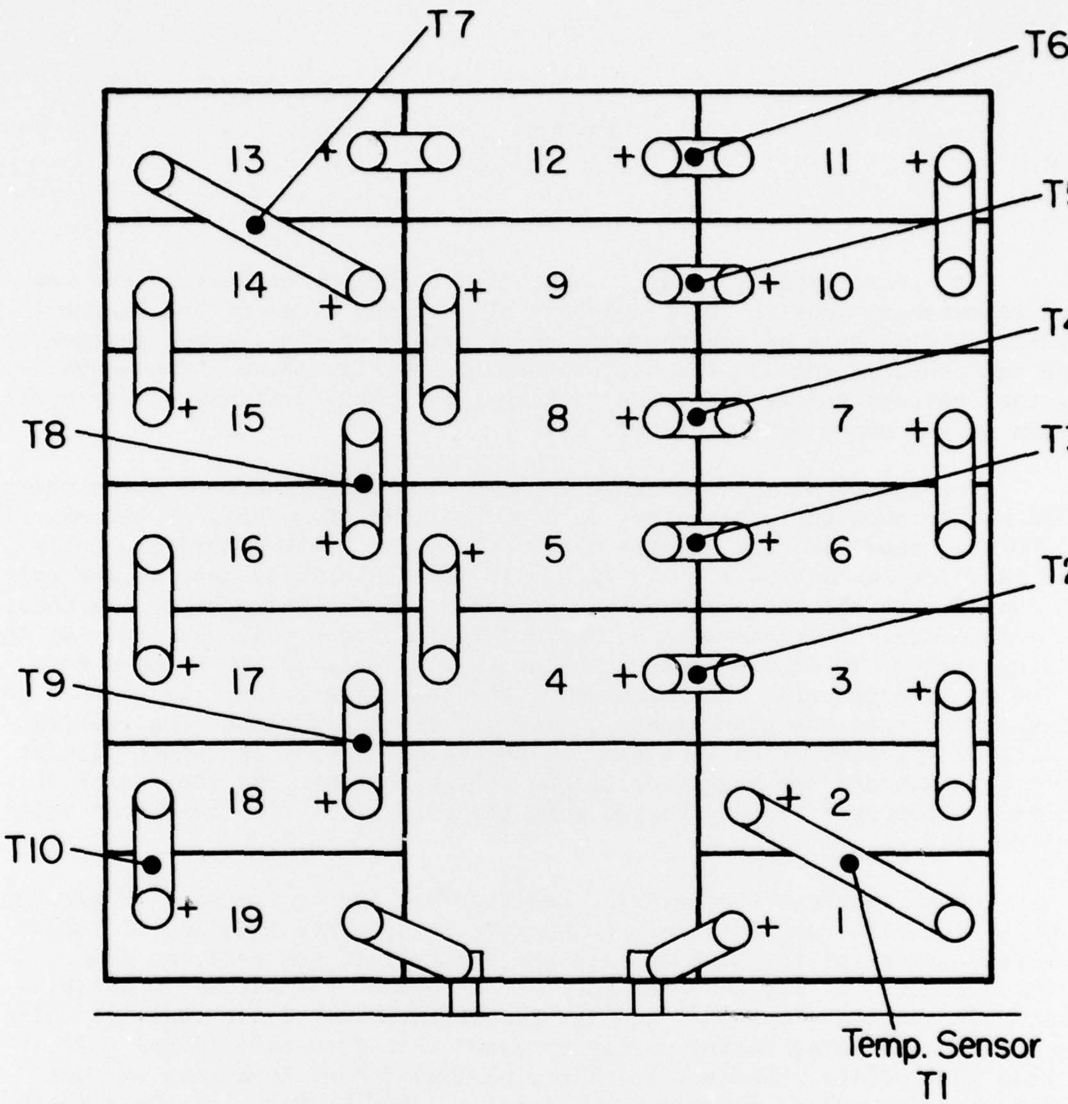


Fig. 1: Cell and Temperature Sensor Locations.

RESULTS

The short circuit in cell 13 started to become evident in the recorded measurements during the final hour of a charge cycle of the Charger-Analyzer. During this period the mode of operation of the charger changes to reduce the charging rate as the battery nears its full charge. Consequently, the actual battery voltage decreases during these final portions of the cycle, as shown in the upper part of Figure 2.

The lower portion of Figure 2 shows the voltages across three cells singled out to show their behaviour during the final 50 minutes of the experiment. One of these is cell 13, the one which failed. The others are cells 12 and 14 which, as may be seen in Figure 1, were physically near to the cell which failed. At the beginning of the period shown the voltages of the three cells were nearly identical with no obvious indication of malfunction. By the next scan period, 10 minutes later, the voltage of cell 13 had dropped more than 160 millivolts below the voltages of the other two cells. In another 10 minutes its voltage was approximately 1.4V. This is lower than the initial open circuit voltages of the other cells so indicates that the short circuit current now exceeded the magnitude of the charge current. By the end of the 50 minute period cell 13 had dropped more than 300 millivolts below the voltage of cell 12.

Figure 3 shows the temperatures recorded during the same 50 minutes period on four different intercell connectors. The curve labelled T7 refers to the temperature of the link between the short circuited cell and the adjacent cell 14. It may be noted that at the end of the period in question the link had reached about 60°C and its temperature was rising rapidly. Also, since cell 14 was being heated mainly by conduction from cell 13 and must have been much cooler than cell 13, the link itself must have been at some temperature intermediate between the two cells. Furthermore, at the time the experiment was terminated (cell 13 was disconnected, removed from the battery and immersed in cold water) steam-like vapour was issuing from the vent of the failed cell and presumably the electrolyte was close to its boiling temperature.

The curves labelled T3, T6 and T8 in Figure 3 indicate temperatures of various other links (see Figure 1). All show a slight rise in temperature. This rise is typical of the behaviour observed during earlier cycles before the short circuit developed. Furthermore, there is little temperature difference between T3 and T6 or T8. It may be noted that the T6 link is connected to cell 12 whose end wall contacts the end wall of the short circuited cell, while T3 is remote from that cell. Thus during the critical period,

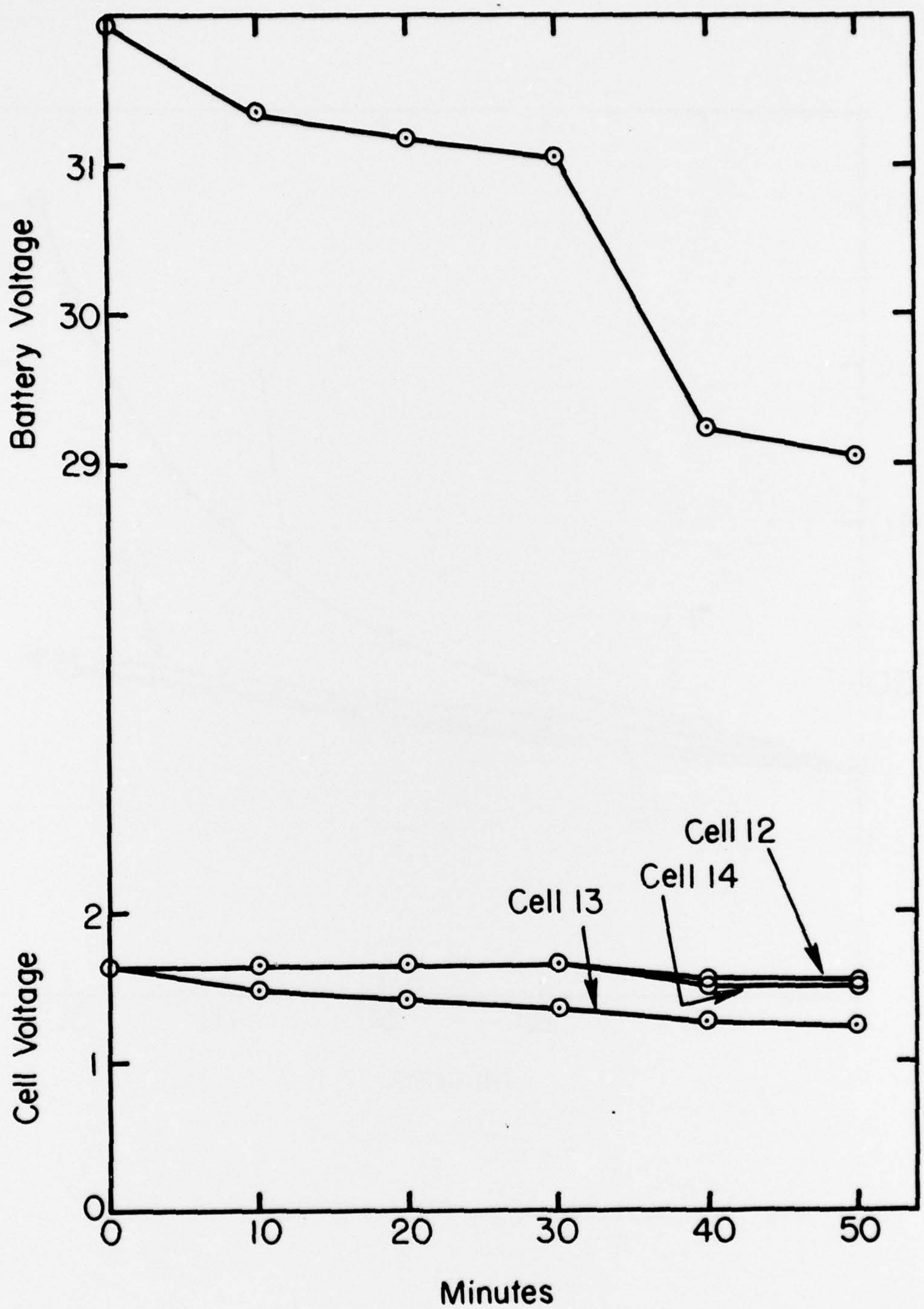


Fig. 2: Voltages During the Final 50 Minutes.

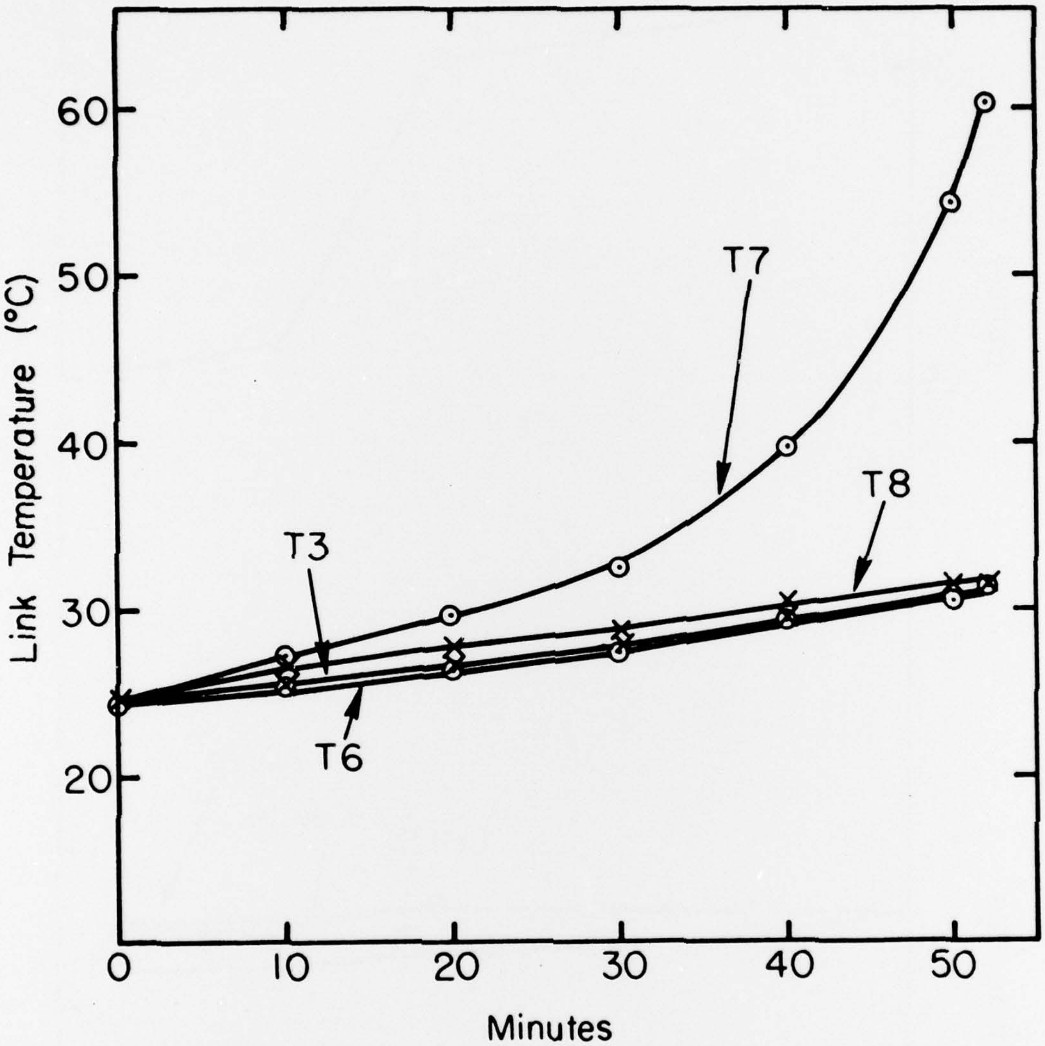


Fig. 3: Temperatures During the Final 50 Minutes.

insufficient heat was transmitted to the adjacent cells to raise their temperature significantly.

CONCLUSION

It is obvious from the above experiment that the temperature of a link does not rise significantly in a moderately short time as a result of internal heating of a remote cell. A single temperature sensor system is therefore not a suitable device with which to warn of a rapidly developing internal short circuit. An effective warning system based on temperature measurement would require temperature sensors on alternate links or in some other series of locations to enable temperatures of all cells to be monitored more or less directly.

It may be noted that in this experiment the voltage of the shorting cell had already dropped by 160 millivolts relative to the other cells, about 40 minutes before termination of the experiment. This drop is far more than is necessary to trigger the battery alarm unit recently developed at DREO (2).

REFERENCES

1. J.J. Lander, Separator Testing in Nickel/Cadmium Batteries, Fall Meeting of the Electrochemical Society (1971).
2. DREO Invention No. 100/74.

DOCUMENT CONTROL DATA – R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATING ACTIVITY Defence Research Establishment Ottawa National Defence Headquarters Ottawa, Ontario, Canada K1A 0Z4	2a. DOCUMENT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. DOCUMENT TITLE

NICKEL/CADMIUM AIRCRAFT BATTERIES: SINGLE SENSOR TEMPERATURE MONITORING (U)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
TECHNICAL NOTE

5. AUTHOR(S) (Last name, first name, middle initial)

FELDMAN, Keiva and HAYASHI, Robert

6. DOCUMENT DATE JANUARY 1977	7a. TOTAL NO. OF PAGES 7	7b. NO. OF REFS 2
8a. PROJECT OR GRANT NO. 54-03-07	9a. ORIGINATOR'S DOCUMENT NUMBER(S) DREO TECHNICAL NOTE NO. 77-3	
8b. CONTRACT NO.	9b. OTHER DOCUMENT NO.(S) (Any other numbers that may be assigned this document)	

10. DISTRIBUTION STATEMENT

UNLIMITED DISTRIBUTION

11. SUPPLEMENTARY NOTES	12. SPONSORING ACTIVITY DREC

13. ABSTRACT

Most of the failures of nickel/cadmium batteries in aircraft are triggered by the development of a short circuit in a single cell in the battery. An experiment was conducted to determine whether the use of a single temperature sensor on an intercell link would be adequate to warn of a short circuit in a cell located elsewhere in the battery. The results indicate that this would not be adequate.

UNCLASSIFIED

Security Classification

KEY WORDS

THERMAL RUNAWAY

AIRCRAFT BATTERIES

BATTERY TEMPERATURE SENSING

BATTERY TEMPERATURE MONITORING

BATTERY LINK TEMPERATURES

SHORT CIRCUITED CELL TEMPERATURE

THERMAL WARNING

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the organization issuing the document.

2a. DOCUMENT SECURITY CLASSIFICATION: Enter the overall security classification of the document including special warning terms whenever applicable.

2b. GROUP: Enter security reclassification group number. The three groups are defined in Appendix 'M' of the DRB Security Regulations.

3. DOCUMENT TITLE: Enter the complete document title in all capital letters. Titles in all cases should be unclassified. If a sufficiently descriptive title cannot be selected without classification, show title classification with the usual one-capital-letter abbreviation in parentheses immediately following the title.

4. DESCRIPTIVE NOTES: Enter the category of document, e.g. technical report, technical note or technical letter. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the document. Enter last name, first name, middle initial. If military, show rank. The name of the principal author is an absolute minimum requirement.

6. DOCUMENT DATE: Enter the date (month, year) of Establishment approval for publication of the document.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the document.

8a. PROJECT OR GRANT NUMBER: If appropriate, enter the applicable research and development project or grant number under which the document was written.

8b. CONTRACT NUMBER: If appropriate, enter the applicable number under which the document was written.

9a. ORIGINATOR'S DOCUMENT NUMBER(S): Enter the official document number by which the document will be identified and controlled by the originating activity. This number must be unique to this document.

9b. OTHER DOCUMENT NUMBER(S): If the document has been assigned any other document numbers (either by the originator or by the sponsor), also enter this number(s).

10. DISTRIBUTION STATEMENT: Enter any limitations on further dissemination of the document, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this document from their defence documentation center."

(2) "Announcement and dissemination of this document is not authorized without prior approval from originating activity."

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document, even though it may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall end with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (TS), (S), (C), (R), or (U).

The length of the abstract should be limited to 20 single-spaced standard typewritten lines, 7½ inches long.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a document and could be helpful in cataloging the document. Key words should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context.