Field-Measured Temperature Profiles of Truck-Carried Materiel in Desert, Tropic, Mountainous Temperate, and Arctic Locations

by
H. C. Schafer
Range Department

APRIL 1983

NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

FOREWORD

This report covers field measurement of the thermal response of ordnance materiel during truck transport. This task was a portion of an ongoing program covering the measurement of thermal response of ordnance and military materiel under a variety of environmental conditions. This program is being supported by the Naval Air Systems Command under the Missile Propulsion Technology Block Program. Mr. Lee N. Gilbert is the NWC technology administrator for this program.

This report was reviewed for technical accuracy by W. W. Parmenter.

Approved by
R. V. Boyd, *Head*
Range Department
16 March 1983

Under authority of
J. J. LAHR
Capt., U.S. Navy
Commander

Released for publication by
B. W. HAYS
Technical Director

NWC Technical Publication 6387

Published by..........................Technical Information Department
Collation..Cover, 38 leaves
First printing.................................. 450 unnumbered copies

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NWC TP 6387	2. GOVT ACCESSION NO. AD-A128 147	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FIELD-MEASURED TEMPERATURE PROFILES OF TRUCK-CARRIED MATERIEL IN DESERT, TROPIC, MOUNTAINOUS TEMPERATE, AND ARCTIC LOCATIONS		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) H. C. Schafer		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Weapons Center China Lake, Calif., 93555		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AirTask A03W3300/008B/F31300000
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Weapons Center China Lake, Calif., 93555		12. REPORT DATE April 1983 13. NUMBER OF PAGES 74
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Temperature profiles
Thermal response of ordnance
Truck transport

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse of form.

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(U) *Field-Measured Temperature Profiles of Truck-Carried Materiel in Desert, Tropic, Mountainous Temperate, and Arctic Locations*, by H. C. Schafer. China Lake, Calif., Naval Weapons Center, April 1983. 74 pp. (NWC TP 6387, publication UNCLASSIFIED.)

(U) Field measurements of the temperature regime of ordnance carried inside a truck bed are presented. Data from desert, tropic, temperate sierra, marine-influenced arctic, and hard arctic are presented for a period of 15 consecutive years. A method is given for combining all these data into a single combined cumulative probability for any given weapon or item of materiel.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

CONTENTS

INTRODUCTION

Environmental temperature criteria are a major controlling factor in the design of all types of ordnance and other military materiel. However, the accepted temperature design criteria in evidence in the various military design specifications and contracts may be such that good designs are being compromised by overly strenuous design and test temperatures. Accurate knowledge of the thermal response of ordnance and materiel during exposure in each stage of the factory-to-target sequence will allow the designer of military materiel to "engineer" the thermal design as he does the other technology areas. It is to provide these data that this report is written. Though a relatively minor event in the overall factory-to-target sequence, truck transportation is almost universal in its application to most military items. Therefore, if there is a chance that the thermal extreme situation may happen during the transport of the item in or on a truck, it should be known, and in sufficient detail to guide the designer.

Any item that is carried by truck will experience heat transfer to or from its mass by differing methods, depending on whether the truck is moving or standing still. If the truck is moving, then its passage through the air tends to insure that the parts in contact with the air will take on the temperature of the air. If the truck is standing still, then the sun's rays tend to heat up the exposed surfaces, usually in excess of the air temperature; conversely, in the arctic, the exposed surfaces of the truck will lose heat by radiation out to the arctic sky. This radiation can (and usually does, given enough time) lower the exposed surfaces between 2 and 12°F below the temperature of the air when no sunshine or clouds are present.

The envelope values of ordnance thermal exposure can be derived from measurements taken on stationary truck-enclosed materiel. All temperature data derived in or on a moving truck will be less severe for a given level of exposure. An adequate indication of the extreme thermal exposures both in the Canadian Rockies during the winter and in Death Valley during August has been previously published.[1] As noted in the referenced report, ordnance being carried in an official U.S. Navy ordnance truck, when traveling by special permission of Canadian and U.S. highway patrol organizations during "the worst storm in the preceding 25 years," experienced temperatures of -3°F or higher. During summer runs through Death Valley (see Figure 1), the most extreme ordnance temperatures measured were 116°F or less. As noted in the referenced report, there were not enough data for statistical analysis, but a concerted effort was made

[1] Naval Weapons Center. *Temperature Profiles of Truck Transported Ordnance*, by B. D. Martin and H. C. Schafer. China Lake, Calif., NWC, June 1970. (NWC TP 4822, AD 871595, publication UNCLASSIFIED.)

to expose the truck to conditions reflecting weather extremes during the portion of the year conducive to the most extreme thermal responses. The severity of the results can be established when they are compared with the statistical data given in this report.

The effort reported herein is only a minor portion of an ongoing larger program: to field-measure the thermal response of ordnance and military materiel.[2] The program, which was started in 1959, has been progressing at a low level.

TEST METHODS

PROCEDURES

Measurements were taken on ordnance contained in stationary trucks located at various sites representing a variety of temperature conditions. Ordnance used in this program included:

105-mm projectile (howitzer)
120-mm projectile (antiaircraft round)
5-inch Zuni rocket
Mk 82 500-pound bomb

Various orientations and palletizations of this ordnance were examined. An effort was made to load the trucks at the different sites as identically as possible so that direct comparison of results could be made from one area to another.

The choice of placement of the truck-borne ordnance was based on two distinct needs: Navy and Air Force situations, which generally require access to deep water anchorage, and Army and Marine Corps situations, which are well removed from deep water anchorage. Sites were carefully chosen to provide the most extreme data that might apply.

The need for Navy and Air Force locations that are near deep water anchorage was determined through experience. It was noted during the Viet Nam action that all airfields servicing tactical aircraft were located well within reach of deep water anchorage, except for three: Taklee, Udorn, and Nakornpanom (NKP). Of these, Udorn and NKP were used for fighters or for search and rescue only, and Taklee was eventually closed because of logistic problems even though an all-weather highway

---

[2] Naval Weapons Center. *Environmental Criteria Determination Program, an Overview*, by H. C. Schafer. China Lake, Calif., NWC, April 1981. (NWC TP 6121, publication UNCLASSIFIED.)

and large convoys of 5-ton fifth-wheel trucks tried to supply it (see Figure 2).

Even so, some of the locations selected for the present study were well removed from deep water anchorage. These were established because the combat arms units of the Army and Marine Corps must still use truck transport, and their needs also were of importance to this subject.

SITE LOCATIONS

Five sites were chosen to reflect five different areas of interest: hot desert, tropics, cold mountainous temperate, marine-influenced arctic, and inland arctic. These are described in detail in the following paragraphs.

The most massive set of measurements was done at China Lake, which is pure hot desert. Because it is home base, more effort could be funneled into work at this site than at the other sites. Experimental measurement techniques were proven here before their use at other sites. Both open and closed trucks were used at the China Lake site, which is shown in Figure 3. Data for the other events of the stockpile-to-target environmental sequence of rail transportation, field (dump) storage, and airfield ready service were also derived at this site.

The data indicative of tropical truck transport were taken at the U.S. Army's Fort Clayton in the Panama Canal Zone (Figure 4). Only the van type truck was used. (Field storage was also measured at this site.) The van truck was complete and in running condition, except that Army Southern Command regulations required the removal of the wheels so that it would not be counted against their truck allotment.

A site indicative of the more severe cold areas of the temperate zone was located at the Marine Corp Mountain Warfare Training Center, Bridgeport, California. This installation adjoins the north boundary of Yosemite National Park. The "bowl" in which the main camp is located is at an elevation of 7,500 feet in the Sierra Nevada mountain range, at about the 38th parallel. This location was chosen because of its similarity to the mountainous regions in Europe and Asia in the temperate zone. The measurement matrix installed at that site is shown in Figure 5. The exposed hardware at this site is less than that at the other sites. This is not to imply that this site is of lesser interest, nor that the data are to be ignored. The site was left "small" because it was not expected that "extremes" of temperature response would be measured there, as they were at other sites.

The "arctic" for the Navy is different from the "arctic" for the Army. Therefore, measurement sites were selected so that data useful to both needs could be separately derived. The arctic for Naval and Air Force tactical use is the marine-influenced all-year region typified by Fort Richardson, at Anchorage Alaska, of which Elmundorf AFB is an extension. For the hard inland arctic representative of Army needs, Fort Greely was chosen. This was the home of the Arctic Test Board after its move from Fort Wainwright, about 90 miles west at Fairbanks, Alaska. It is very important to realize the distinction between the arctic ground potential land use of the three services. The resulting design and logistic temperature regimes can mean the difference between an efficient weapon and a mediocre one. Figure 6 shows the Fort Richardson measurement site, and Figure 7 shows Fort Greely. A more extensive measurement matrix was placed at Fort Richardson.

PERCENTAGE DETERMINATION

In the overall project, environmental criteria determination for any weapon system or component, the event of truck transportation is a minor item. Its percentage of the stockpile-to-target sequence is small (see Appendix A). The complete life cycle of any air-launched weapon is divided approximately as follows:

Truck transport	2%
Rail transport	1%
Ship transport	5%
Air transport	less than 1%
Covered storage	85%
Dump storage	less than 1%
At-sea transfer	less than 1%
Combatant ship/aircraft use	5%

These percentages are approximations. The real percentages depend on the item and its military end use. The point, however, is that truck transportation is in most cases not a very long term event in the life of most military materiel.

INSTRUMENTATION

Recorders

The mainstay of this measurement series was the Honeywell Model 15 Universal 24-point stripchart recorder. The state-of-the-art of this instrumentation stretches through at least 25 years. The manufacturer's advertised accuracy for this model is 0.25% of the full scale measurement range (-100 to +250°F). For this measurement series, this accuracy represented an error margin of less than 1°F. None of the more than 30 instruments used in this measurement series exceeded this overall error band.

Some problems resulted because the Honeywell recorders are essentially laboratory instruments and not intended for field use. They were, for all intents and purposes, abandoned on-site for months at a time. Since these instruments were not serviced for periods of 3 months to 1 year, failures had to be kept to a minimum through preventive maintenance. Data were recorded for 60 or 90 days with the recorder unattended before personnel were required to change the stripchart roll.

In May 1970, a 200-channel data logger was installed at the China Lake site. This digital tape instrument is more accurate as well as vastly more complicated and sensitive to the environment than the Honeywell recorder. The data logger can run up to 5 or 6 months on a single tape at an hourly sampling rate, and the tape can be input directly to the computer for quick data reduction. Reduction of the more reliable Honeywell charts, on the other hand, is a strictly manual operation.

After five winter months of data were lost one year due to a malfunction of the data logger's rewind mechanism, it was decided that paralleling important data channels with the cumbersome Honeywell recorder would be a worthwhile precaution. This did, indeed, prove worthwhile and allowed the data for January-March 1971 to be salvaged. In short, the more sophisticated instrumentation proved superior in a situation where a "babysitter" was constantly available, but for off-Center primitive conditions, sample speed, some accuracy, and ease of data reduction must be sacrificed in exchange for usable data.

Because of the relatively slow sample rates necessary, the slow temperature changes encountered, and the low narrow band of temperature sampled in this type of sequence, the normal thermocouple and instrument errors either were not encountered or were classified as "in the noise."

Thermocouple Construction

All thermocouples were copper-constantan (Type T). The hot junction for internal measurements was a welded or silver-soldered 1/16- to 1/18-inch-diameter ball. Two types of surface thermocouples were used for shipping container or motor skin. The most universal and easiest to install is the area averaging type which consists of a 0.005-inch-thick, 1/4-inch-square copper plate. The constantan wire is silver-soldered to one corner, the copper wire to another corner, and the assembly attached to the area of interest with epoxy. Early in the program these units were simply taped to the surface of interest. This attachment method was satisfactory for short times at locations where the installation was regularly inspected for thermocouple lift off. However, for long term, "abandoned" site measurement jobs, this attachment method did not prove satisfactory. Another, more time consuming method was to

1. Drill two small holes about 1/8- to 1/4-inch apart in the surface to be measured.

2. From the underside, place the copper wire in one hole and the constantan wire in the other.

3. Silver-solder the wires in place.

4. Grind down the solder joints so the surfa e was again smooth.

5. Repaint.

Comparative data from both types of installation indicated no significant measurement difference for either application method.

DATA REDUCTION

During the first few years, a complete program of data reduction was followed. But costs were prohibitive and the number of data channels being reduced had to be decreased; only daily maximum and minimum temperatures were considered. This method then indicated the "extreme" days so that complete data for any of those days could be obtained when desired. However, since this method left much to be desired for any type of statistical treatment, it was subsequently decided to revert to reduction of every data point on the Honeywell chart, but only for selected channels. Many of the cumulative probability displays presented herein were derived in this way. Appendix B describes the procedure for statistical handling of data.

This program points up the obvious need for a balance between the quantity of data available and the funding available to reduce these data and thereby give them meaning. The data logger at the China Lake site seems to be one solution to this problem. It skips the costly hand reduction steps and feeds data directly into a computer in a compatible language. This method was used almost exclusively for reduction of the desert storage data.

RESULTS

In a new program, the high-temperature regime during truck transportation usually receives the most attention when environmental criteria are being considered. Therefore, the hot effects of truck transportation are discussed first in the following sections.

HOT DESERT

China Lake, California, was the site of the hot desert measurements. In the following discussion, the differences between a closed van and an open bed cargo truck are discussed separately and compared. The van truck data are more indicative of the logistic sequence of truck transport. However, the situation during combat use tends to require the open bed cargo truck. A good case can be made that truck transportation time for any expendable materiel (i.e., ammunition and supplies) will be primarily during the logistic sequence.

Van Truck

The thermal forcing function to which van truck enclosed materiel responds thermally is shown for the hot desert in Figure 8a. Data for 1970-1974 are shown; no differences were seen for 1970 through 1981. During this multiyear measurement program, the air inside the van was, in fact, "cool." On the whole, during a complete 8760-hour year, less than 10% of the hours exhibited a temperature over 100°F. Figure 8b contains a more detailed look at the various data years. When the 1970 summer data are compared with the lines for 1971, 1972, and 1973, it may be noted that if data for only part of a cycle are used (1970), then all the cumulative probabilities are more "extreme" than if data for a complete cycle (1 year) are used. In fact, the 90% points on the two data bases show a difference of about 5 to 10°F, depending on how one reads Figure 8b.

Another experiment whose result is shown in Figure 8b was to open the south-facing rear doors of the van truck and let the sunshine in onto the enclosed load. This was done during the 1974 measurement year. Differences in enclosed air temperature of up to about 20°F are indicated. This fact indicates that, although the thin skin van has a relatively small thermal mass, the effect of shielding the load from direct solar radiation is important.*

Figures 9 through 12 give an idea of how various sized and palletized ordnance responded to the thermal forcing function. These figures indicate that the projectiles that sat on their base ends (Figures 9 and 10) responded about the same as the bombs lying on their sides (Figure 12). The interesting item is the Zuni rocket (Figure 11). It sat on top of the projectiles, close to the south facing door. The extreme temperature tail shown in Figure 11 is about 5°F more severe than for the other ordnance. This is due to at least three circumstances. First, the projectiles and the pallet of bombs each weigh thousands of pounds, whereas the single Zuni rocket motor weighs about 100 pounds. Second, the Zuni was placed above the normal weight-limited load height for a truck, whereas the other ordnance was placed on the floor where it belongs. Third, the

---

*When an enclosed air temperature commensurate with truck transportation is needed, reference to the data of Figure 8a or to the 1971, 1972, and 1973 data lines of Figure 8b is recommended. The use of the 1970 and 1974 data of Figure 8b requires considerable expertise.

Zuni was close to the hottest side of the van (the rear, south-facing doors). Even so, the four figures indicate not much difference between these representative temperature regimes. In any case, the 3σ hot temperatures are shown to be 120°F or below.

Figures 13 through 16 provide detail commensurate to that of Figure 8b. The 1970 and 1974 data lines in these figures are not representative of a normal-exposure, 1-year measurement cycle. In fact, the open door exposure line for 1974 is indicative of the data for the open bed cargo truck, as shown below*

Open Bed Cargo Truck

During the combat phase of ammunition and supply handling, an item of materiel will be transported by an open bed cargo truck. Though this situation is probably of short duration compared to the life events of the weapon or supply, it will occur. Therefore, during the multiyear temperature measurement program, open bed cargo truck loads were instrumented. Figures 17 through 24 show the data for cargo trucks.

The curve shape of Figure 17 for 105-mm projectiles in the open bed may be compared with that of Figure 9 for the closed van. Notice that the cold ends of the curve bands are about the same, but the hot ends of these same bands differ by up to 15°F. The difference is in the added energy of solar radiation directly striking the 105-mm rounds in the open bed cargo truck. It is conjectured that the reason for this small difference has to do with the density of palletization and the orientation of the projectile (nose up). The sun could not severely affect any one round during a 14-hour maximum exposure day. Therefore, the heating of each exposed round was a function of surface area variation and of different individual rounds shading each other. At any rate, the 3σ temperature for this palletized unit was about 125°F.

The results shown in Figure 18 for the larger 120-mm projectile are similar. Of interest is the softening of the curves shown in Figure 18 when compared with those of Figure 17. The hot end tail is not as pronounced nor as indefinite in Figure 18. The cold end, which is a function of nighttime winter exposure, is almost identical. As a rule, the data displayed in any curve of cumulative probability versus ordnance response temperature from about 0.0 to 0.65 for any single location will be a function of the night, because it is the daytime sun that raises any temperature above that of the ambient air.

---

*The statement must again be made that these data are presented for the reader's use. The 1971, 1972, and 1973 data are preferred for normal use. An expert who understands the ramifications for so doing may find the 1970 and 1974 data useful.

The display of data in Figure 19 for the Zuni rocket motor and in Figure 20 for the Mk 82 500-lb bomb also seems to follow the pattern. One item of interest is the hot tail of the Figure 20 curve. When the hot tails of Figures 17 and 18 are compared with that of Figure 20, it may be noted that the tail of the Figure 20 curve is slightly more pronounced than that shown even in Figure 17. This difference might be ascribed to the palletization mode of the Mk 82 bomb, which lies on its side instead of standing on its base as the projectile does. Hence, even though it has more mass, the bomb exhibits a slightly higher surface temperature than the 105-mm or 120-mm projectiles in this experiment.

The detailed yearly (or summer display) data for the ordnance shown in the last four figures are presented in Figures 21 through 24. The data identified as 1970 are for the summer months in the pure desert only. Data based on a short time of measurement can be converted into a more representative yearly cycle cumulative prediction. For example, compare the curve shapes of the 1970 data with the 1971, 1972, 1973, and 1974 data for a given item. The hot extreme point is about the same each year. The rest of the 1970 curve leads the others down the chart. The difference is the effect that the missing data for the year have on the more complete curve.*

TROPICAL

Tropical measurements were made at Fort Clayton in the Panama Canal Zone. Measurements inside a van truck painted Navy haze gray were taken between 1969 and 1972. The truck was painted Army olive drab some time in 1973, and the measurements were continued through 1975. The physical setup is shown in Figure 4. There was a question as to whether this change in paint color would negate the measurement series. However, a check of the air temperature inside the van truck from 1969 through 1975, as shown in Figure 25, reveals that the detail cumulative probability versus temperature lines for the various years virtually overlap. Hence, there apparently was little difference in thermal response inside the truck due to the change in color from Navy haze gray to Army olive drab.

Another observation concerning the thermal response of ordnance inside a closed container, box, or building is that the item will get no hotter or colder than the contained air. (This assumes no major radiation source is interacting, such as sunshine through a window, etc.) Therefore, a fairly accurate thermal response probability temperature curve for any ordnance or materiel can be derived if the curve of enclosed air is known. For example, consider Figures 26 through 29. (Notice in these figures that the same types of ordnance reported in the previous section are again in evidence.) The plots of Figures 26 and 27 cover the

---

*As previously mentioned, the 1970 data are incomplete.

Army 105-mm howitzer and 120-mm antiaircraft rounds. The thermal responses of this ordnance fall well within that shown in Figure 25 for the entrapped air in the van. The 120-mm rounds experienced higher temperatures than the 105-mm rounds even though they are heavier. This again was caused by their position close to the back door, which faced south. Other than that, these two figures are virtually interchangeable. A check of Figure 28, for the Zuni rocket motor, which was set on top of the 120-mm rounds, shows that the "southern exposure" in the Northern Hemisphere is conducive to slightly hotter temperatures. The Mk 82 500-lb bombs (Figure 29) which again were forward in the truck bed (north end) did not respond as much thermally as the other ordnance.

Even with all the minute differences indicated, the plots of Figures 26 through 29 are virtually identical. As long as a truck is loaded to the weight-limited condition, all materiel will thermally respond about the same, especially in the somewhat thermally stable tropics.

TEMPERATE SIERRA

Data for a mountainous temperate area were taken at Bridgeport, California, which is located at 7,500 feet in altitude. The data were taken from the truck shown in Figures 5a and 5b. A difference not noticeable in Figure 5, when compared with Figure 3 or 4, is that only projectiles were used as measurement matrices inside the van truck. At the time of installation, data were urgently needed to support the Navy's 5-inch guided projectile program. Therefore, no other ordnance was integrated into this exposure sequence. However, the 105-mm and 120-mm projectiles were thermocoupled quite extensively.

Data on the temperature of the air inside the van during the 4 years of measurement are shown in Figure 30. The minimum air temperature inside the van truck during this time was about 0°F, even though the outside air temperature during the winter was recorded at -15°F or lower at times. The reason for this discrepancy is illustrated in Figure 5b. When a cold front goes through the area, the air-held moisture is precipitated as snow, which covers and insulates the truck. Outside air is no longer the prime thermal forcing function for the enclosed materiel. Geological heat from the earth also seems to cause moderation of the ordnance temperature. (This phenomenon was seen in measurements from all cold climates, not just temperate sierra. The writer feels that this fact should be given credit any time the environmental criteria for weapons are being determined with respect to cold climates. In other words, the cold air temperature is not necessarily the ordnance temperature, even though the cold snap may last for 3 to 8 days.)

The rest of the curve of Figure 30 is quite undistinguished. The spread, or lack thereof, from year to year indicates that the exposure of ordnance or materiel in such a situation might be quite predictable.

In any case, covered storage of any type should fall between the temperatures of 0 and 120°F.

As can be seen in Figure 31, the projectiles reflected the cold air temperature of the van truck. However, the van acted as a thermal shield during the summer season and the projectiles reported temperatures less than 100°F, no matter where the thermocouple was placed.

The temperature regime that 500-lb bombs or a Zuni rocket motor would have experienced if they had been included in the measurement sequence can be inferred from the tropical data. For all intents and purposes, Figure 31 can be used for the missing ordnance also.

MARINE-INFLUENCED ARCTIC

The arctic exposure for Air Force and Naval truck-transported materiel is in reality close to deep water, semi or true all-weather anchorage. Anchorage, Alaska is representative of that type of arctic port. Any further north and the sea transport conditions become seasonal. For example, resupply barges were frozen in while returning from the Alaska north slope oilfields in early fall. Therefore, it can realistically be reasoned that no Air Force or Naval major supply base or airfield will be established in an arctic area much different in climate from Fort Richardson or Elmundorf Air Force Base, Alaska. That was the reasoning for choosing Fort Richardson as the marine-influenced arctic measurement site. Ladd Air Force Base had been decommissioned at Fairbanks (it became Fort Wainwright); Eielson Air Force Base was relegated to the status of an emergency and refueling base, and Elmundorf Air Force Base remained the only real combat air base in Alaska as far as tactical weapons were concerned. (It must be stated that Army and Marine aviation materiel may not be constrained to marine-influenced airfields.)

The van truck is shown in Figure 6; much ordnance was installed and instrumented during September 1968. Data were taken for the 7 years from 1969 through 1975.

The temperature of the air inside the van truck is displayed in Figure 32. The temperature envelope extends from about -35 to +100°F. Therefore, from the correlations so far seen in this report, it might be projected that any ordnance that is transported in a van truck in the marine-influenced arctic will probably also experience temperatures between these envelope bounds. The displays of Figures 33, 34, 35, and 36 seem to verify this projection. The 105-mm and 120-mm projectiles, 5-inch Zuni rocket motor, and Mk 82 500-lb bomb were used as measurement matrices. Also, the cold exposures of this ordnance are largely the same. The only marked difference in exposure can be seen at the hot end of Figures 33 through 36. Usually, there is not much interest in how hot something will get in the arctic, however. The thing to remember is that no item experienced a temperature as low as -40°F during the 7-year exposure period.

HARD ARCTIC

Because the Army and Marine Corps need interior continental arctic information on the thermal regime during truck transport, this section is included. It is in no way to be construed to mean that Navy or Air Force air-launched tactical weapons or shipborne equipment will be subjected to such a domain.

In this domain, air temperatures of -60°F will be found. Figure 37 shows that, for a very few hours during one out of the eight reported years, the AIR INSIDE THE VAN reached a temperature of -60°F. During the rest of that 8 years of measurement, the temperature was less extreme. It should be noted that the ordnance enclosed inside a van truck will respond in a time-phase-shifted manner to the air temperature inside the van. Figures 38 through 41 show that the extreme temperatures inside the van were less than -50°F during that same time. (During any event of the factory-to-target sequence, the meteorology of interest will not necessarily be a good predictor for the design value. The physics of the particular unit should be taken into account. In this case, these data indicate at least a 10°F break from van air temperature for all ordnance shown. The van air temperature was responding to the meteorology during that time, with a time phase lag of its own.*)

The differences between Figures 38, 39, 40, and 41 are so small that the generalization can be made that most materiel, had it been in that van truck during the 8 years of measurement, would have responded thermally in a like manner. Therefore, one might assume that these data are quite universal.

COMBINED PROBABILITIES

In an effort to aid the user of these thermal response data, the author has devised a method for compressing the cumulative probability data shown in Figures 8 through 41 into a single figure containing a single line of data. It is felt that the user basically needs only a pair of temperatures as design criteria or for information on the advisability of granting a waiver, and that this method, though somewhat questionable, will serve this purpose.

---

*A more detailed discussion on this topic is included in a previously published report: Naval Ordnance Test Station. *Temperature Environments of Jet Fighter and Attack Bomber Aircraft Instrumentation*, by Howard C. Schafer. China Lake, Calif., NOTS, August 1962. (NOTS TP 2910, AD283805, publication UNCLASSIFIED.) In that report, Figures 41 through 44 show a correlation of outside meteorological air temperature and the response of military materiel. Also, in Appendix B of that report, Major E. H. Picket, U.S. Army, discusses in detail the engineering aspects of arctic meteorology.

This method is based on two assumptions:

1. That the air-launched rocket motor, or weapon, is intended for use on a "worldwide" basis. That is, the weapon must be capable of functioning as designed anywhere on the surface of the earth that treaty does not exclude. However, this does not mean that the unit will be exposed to any thermal forcing function outside of its use patterns. Thus, although a weapon may be intended for a target in an area of extreme heat or cold, it would not be located in such an environment long enough to be soaked thermally. Its normal use patterns would comprise only environments to which it would be exposed long enough to be thermally conditioned. Therefore, other situations of environmental concern are of no interest.

2. That midrange temperature data are of minor interest in the design community. The extreme temperatures cause most of the problems and thus engender the most attention.

Building on these two assumptions, the author arbitrarily chose a Gaussian statistical distribution for the example described below, although any other distribution might do as well. The method used was to select two points from each relevant figure, combine these into two single points, plot these last two points on Gaussian paper, and draw a straight line that then becomes a single display for the various candidate thermal data.

As the example, Figure 42 was prepared. It represents the cumulative probable thermal response of an air-launched weapon during truck transport at a continental United States, temperate European, tropical, or marine-influenced arctic airfield or storage depot. Data from Figures 11, 28, 31, and 35 were used. (The fact that an air-launched weapon might not be based under the circumstances of all four of these figures was ignored.) Two values (a hot and a cold extreme--0.0015 and 0.9985) were chosen from each envelope response, as follows:

Climate	Figure	Temperature, °F	
		Hot	Cold
Desert	11	120	20
Tropic	28	117	65
Temperate sierra	31	117	10
Marine arctic	35	95	-20

If the values for hot temperature are simply averaged, a high temperature 3σ value of 112.25°F results. Since the 0.25°F is of no worth in a calculation of this gross degree, it may be ignored. It is also not meaningful to use a number ending in anything other than zero or five.

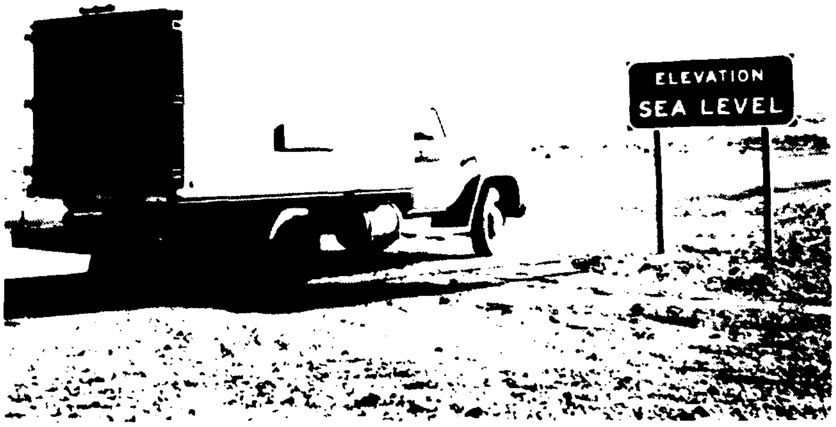
Therefore, a hot value of 115°F and a cold value of 15°F were chosen. For this example, these values were plotted in Figure 42.

A check on the "believability" of Figure 42 was made using the 50 percentile value from Figures 11, 28, 33, and 35. The mean comes out between 50 and 55°F. The mean in Figure 42 is about 50°F. Because it is not desired to give the impression that Figure 42 is exact, the line is purposefully plotted very wide. Also, the line does not stop with the bounds of the figure, because any distribution should be bounded by infinity, not 99.99% or any other "assurance" value.

The author grants that there are inaccuracies in logic as pertains to Figure 42. For instance, not as much of the earth's surface is conducive to arctic conditions as to temperate, tropic, or desert conditions. Yet, Figure 42 is plotted as if they were equal. Distributions other than Gaussian may be used, and other weapons or ordnance items may be selected. The end use should be the deciding factor as to how much accuracy is needed for any given job.

CONCLUSIONS

This report exhibits the thermal response of ordnance during 31 measurement site-years of gathering field data on the truck transportation temperature regime. It encompasses the calendar years 1967 through 1981, for a combined total of 15 consecutive years. It can be concluded that there are few meaningful differences from year to year at any one of the various measurement sites for truck-borne cargo. Also, it can be concluded that the contribution of truck transportation to the overall thermal response of materiel during its logistic cycle is, in fact, minor and moderate. There is no indication that temperatures of -65°F or 160°F have much meaning during this part of the factory-to-target logistic sequence.



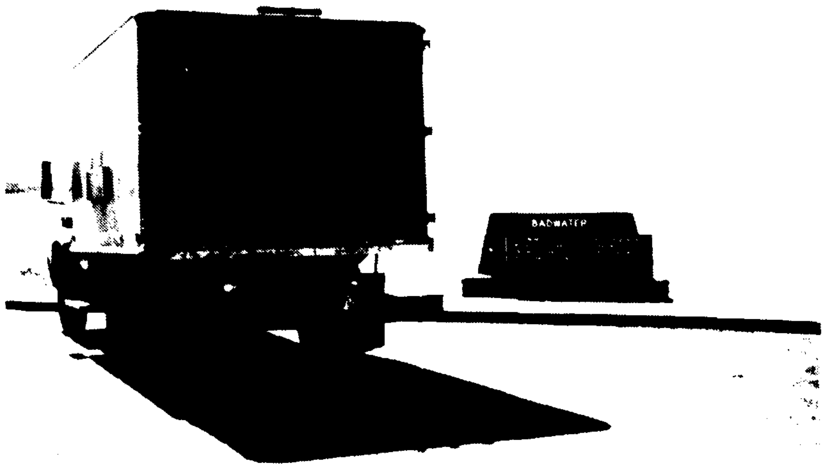


FIGURE 1. Ordnance Truck Used for Summer Measurements in Death Valley.

FIGURE 2. Ordnance Convoy From Bangkok/Sattahup to Taklu/Udorn/Korat.

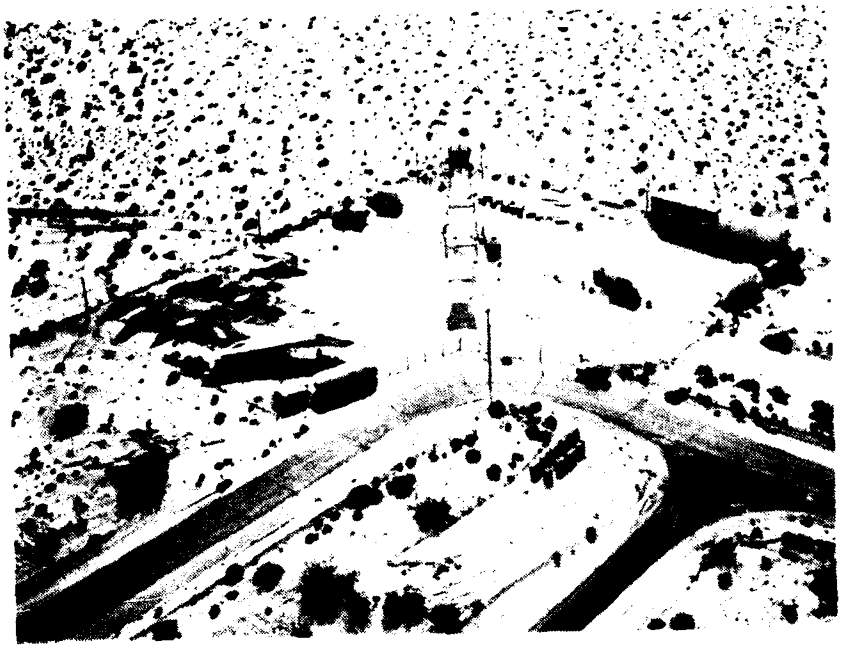


FIGURE 3. China Lake Measurement Site.

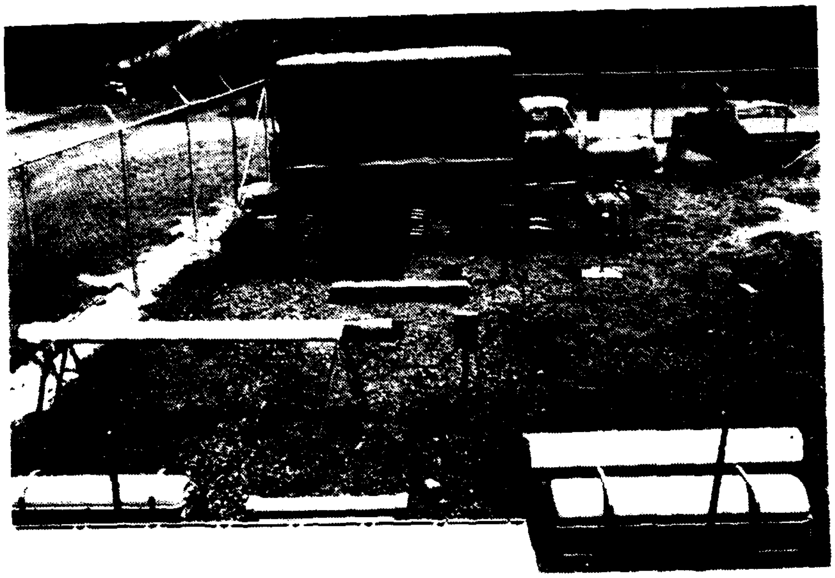
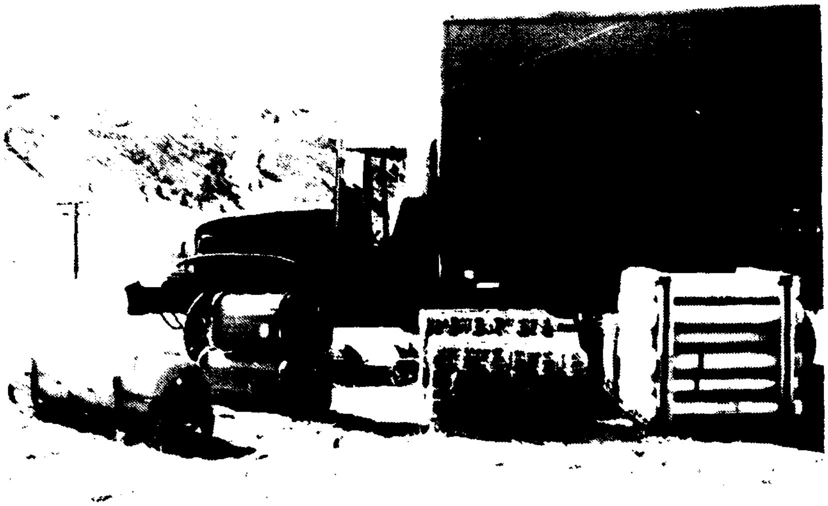
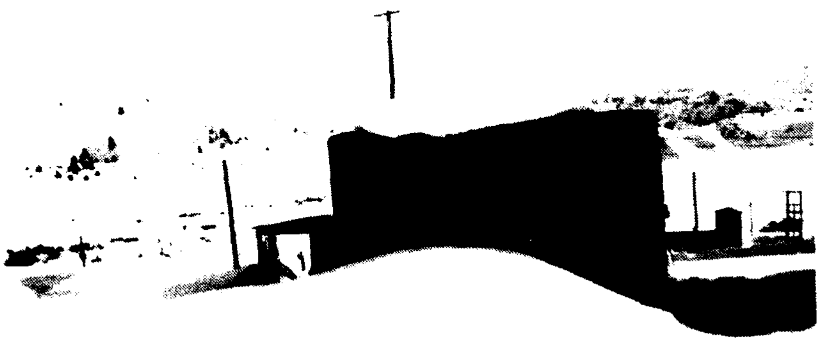


FIGURE 4. Fort Clayton Measurement Site.



a. Summer.



b. Winter.

FIGURE 5. Bridgeport, California, Measurement Site.

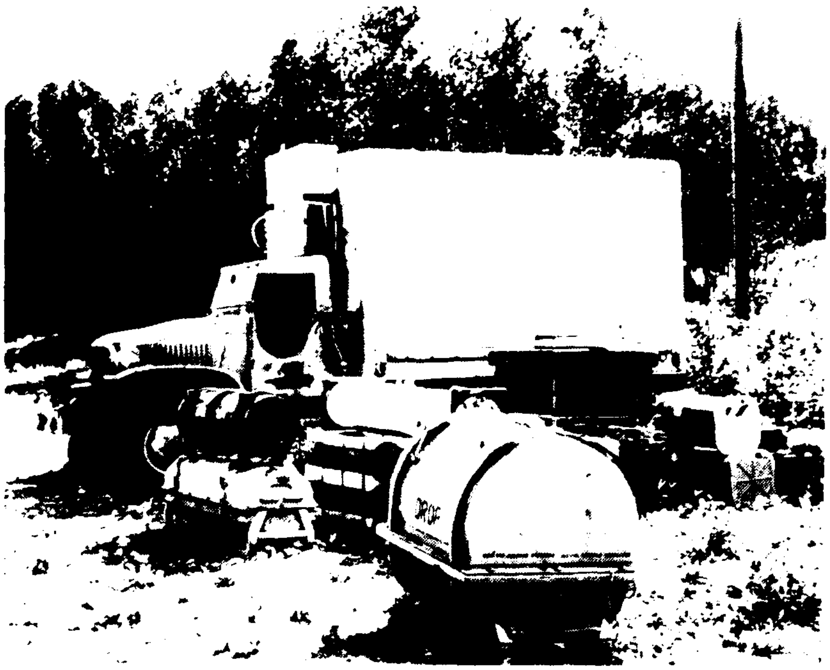
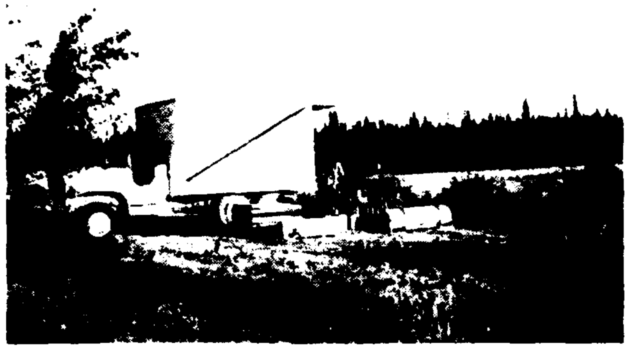
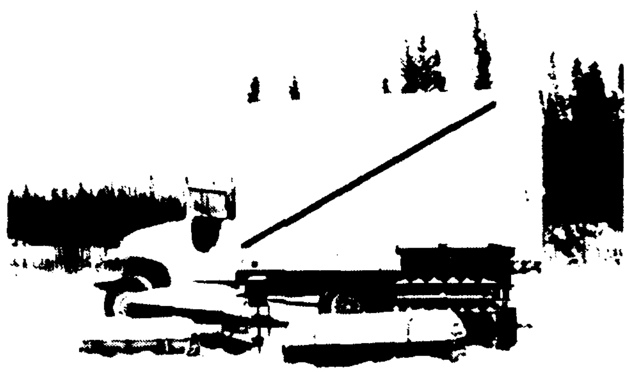


FIGURE 6. Fort Richardson Measurement Site.



a. Summer.



b. Winter.

FIGURE 7. Fort Greely Measurement Site.

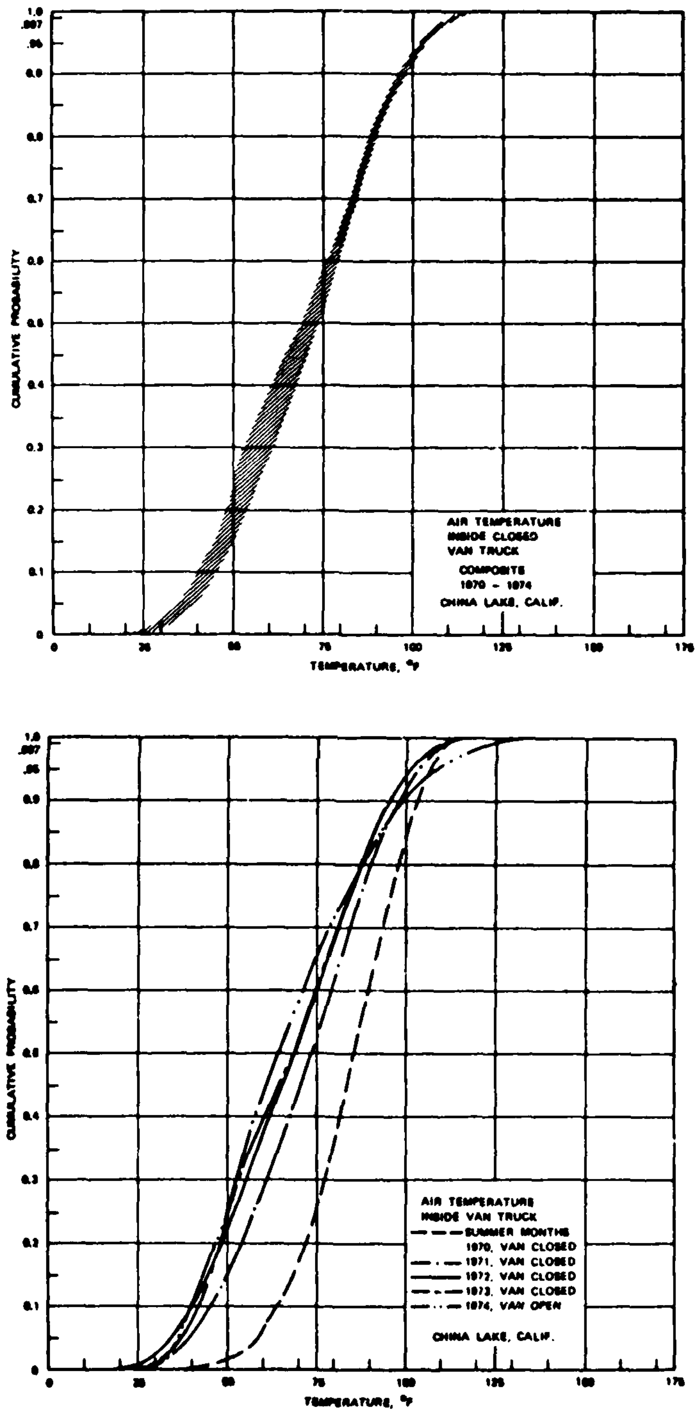


FIGURE 8. Air Temperature Inside Van Truck, Desert Area.

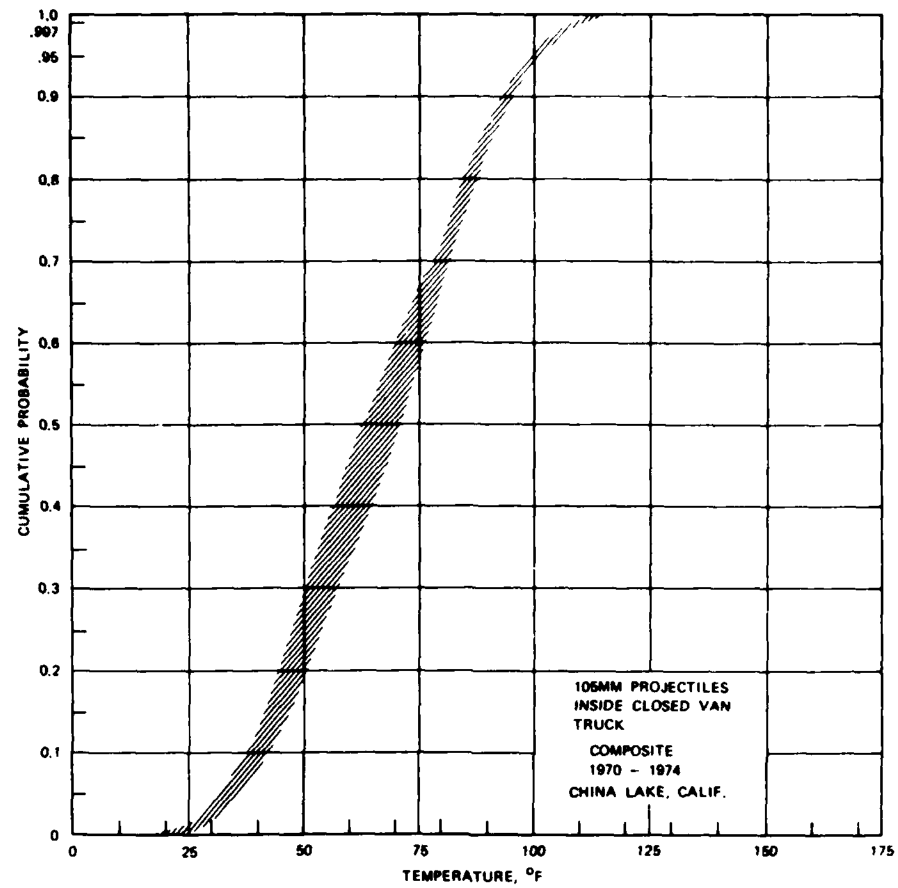


FIGURE 9. Temperature of 105-mm Projectile Inside Van, Desert Area.

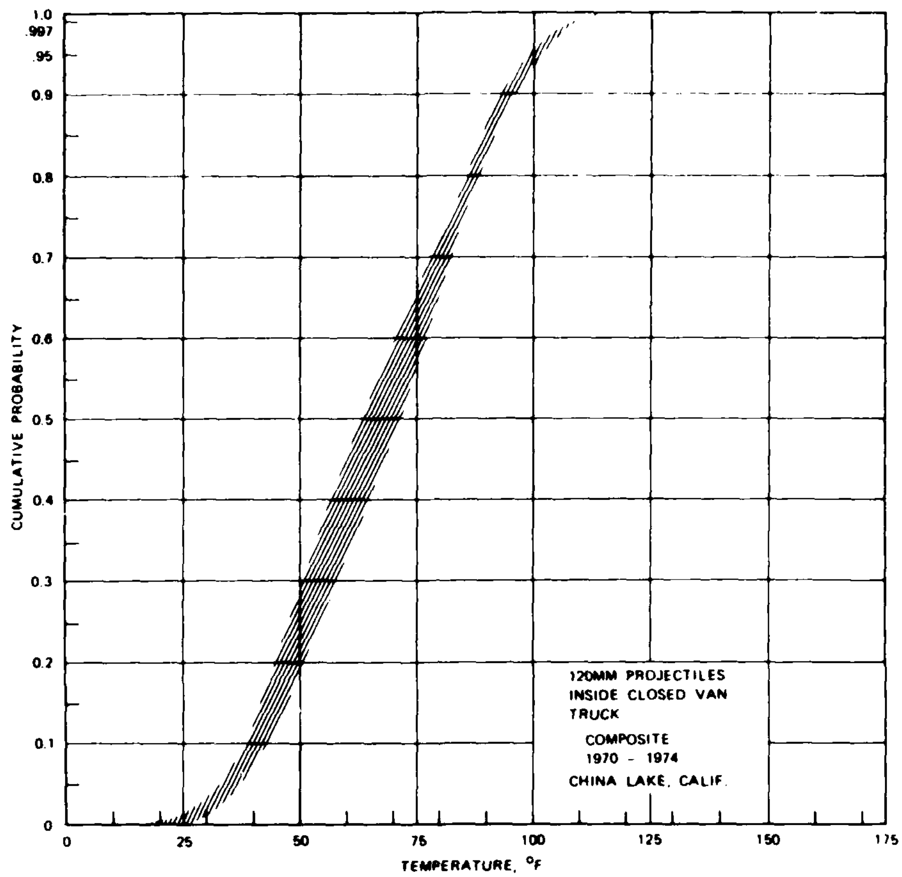


FIGURE 10. Temperature of 120-mm Projectile Inside Van, Desert Area.

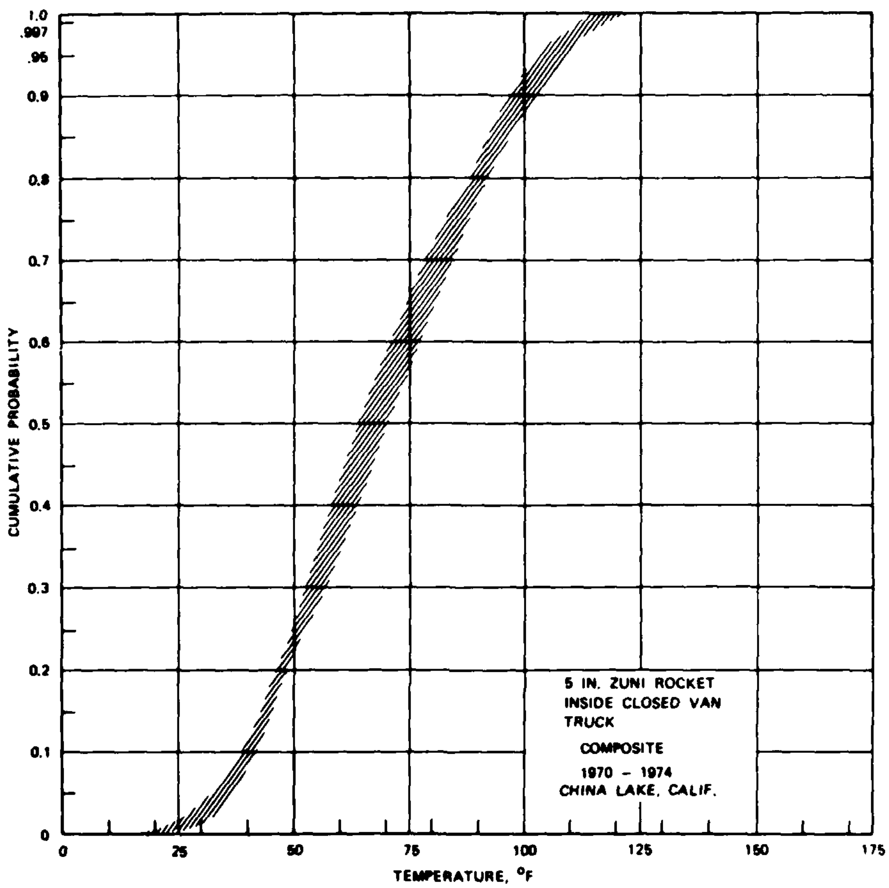


FIGURE 11. Temperature of 5-Inch Zuni Rocket Inside Van, Desert Area.

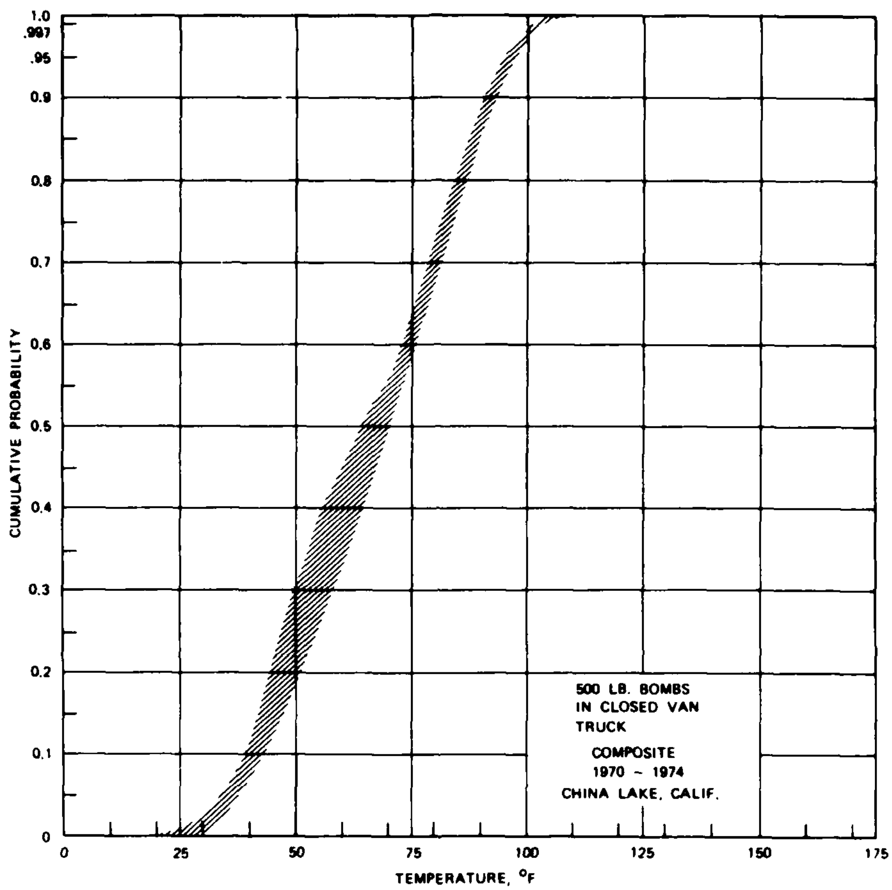


FIGURE 12. Temperature of 500-Pound Bombs Inside Van, Desert Area.

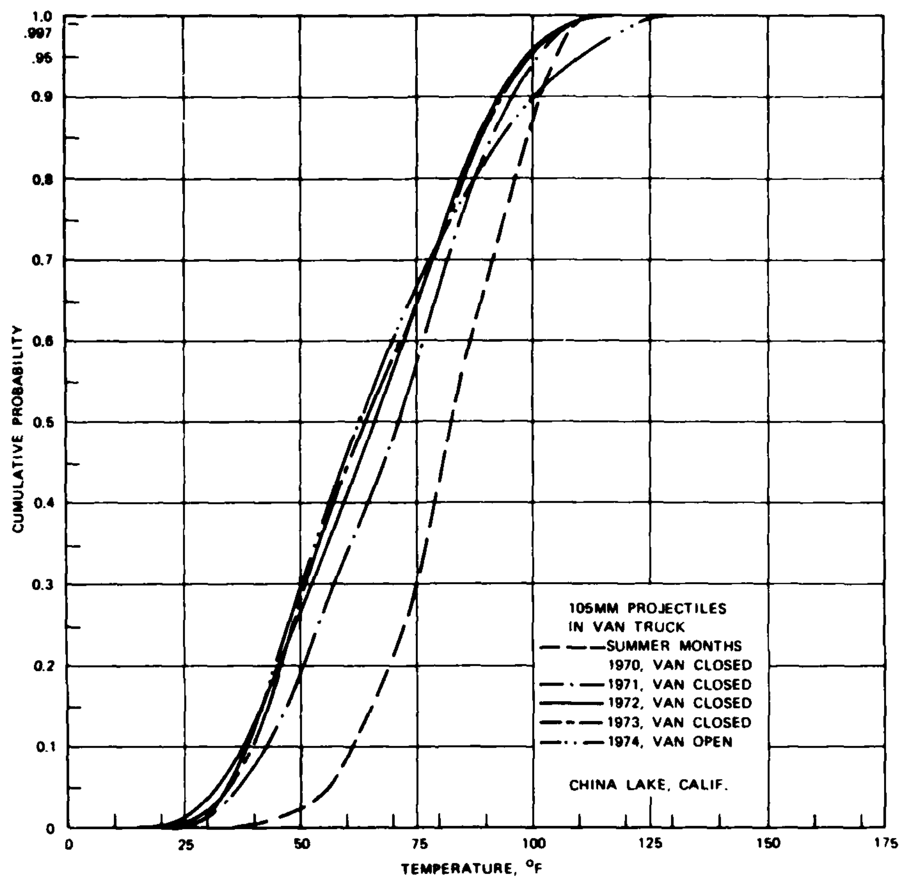


FIGURE 13. Temperature of 105-mm Projectiles Inside Van, Desert Area (Detail).

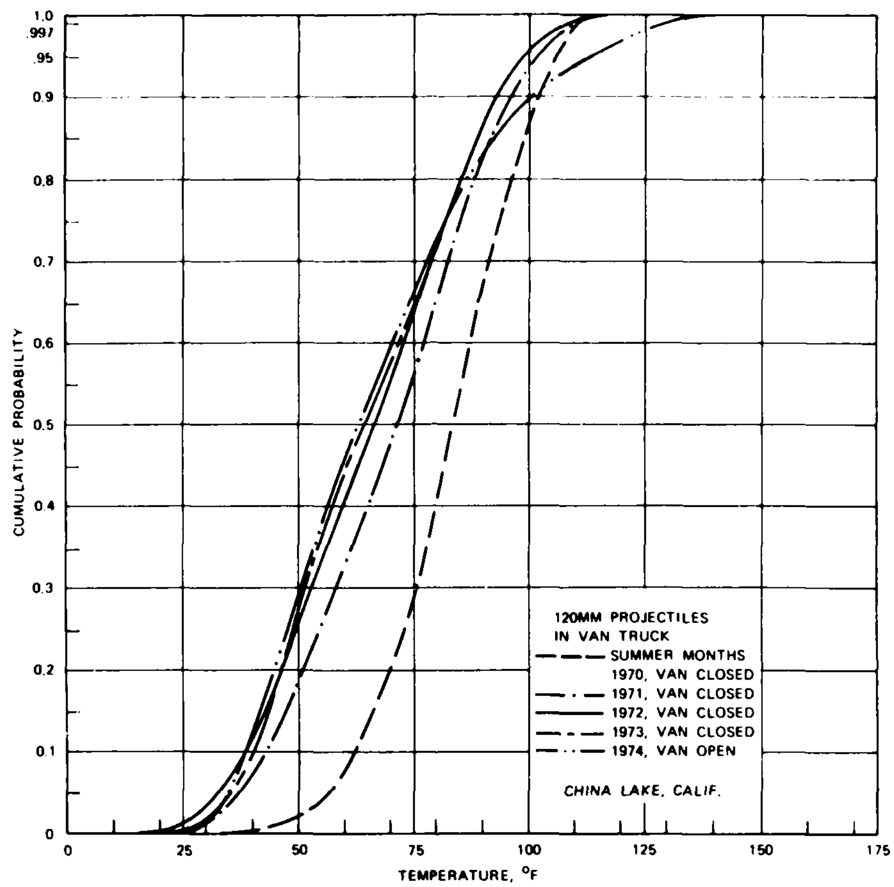


FIGURE 14. Temperature of 120-mm Projectiles Inside Van, Desert Area (Detail).

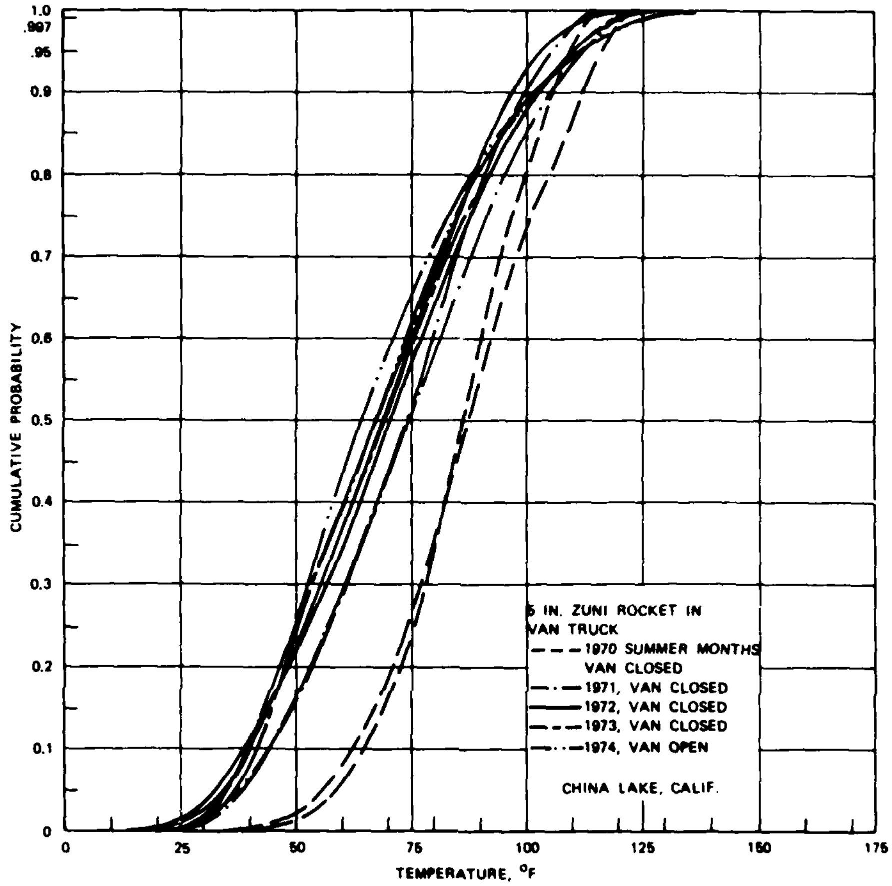


FIGURE 15. Temperature of 5-Inch Zuni Rocket Motor Inside Van, Desert Area (Detail).

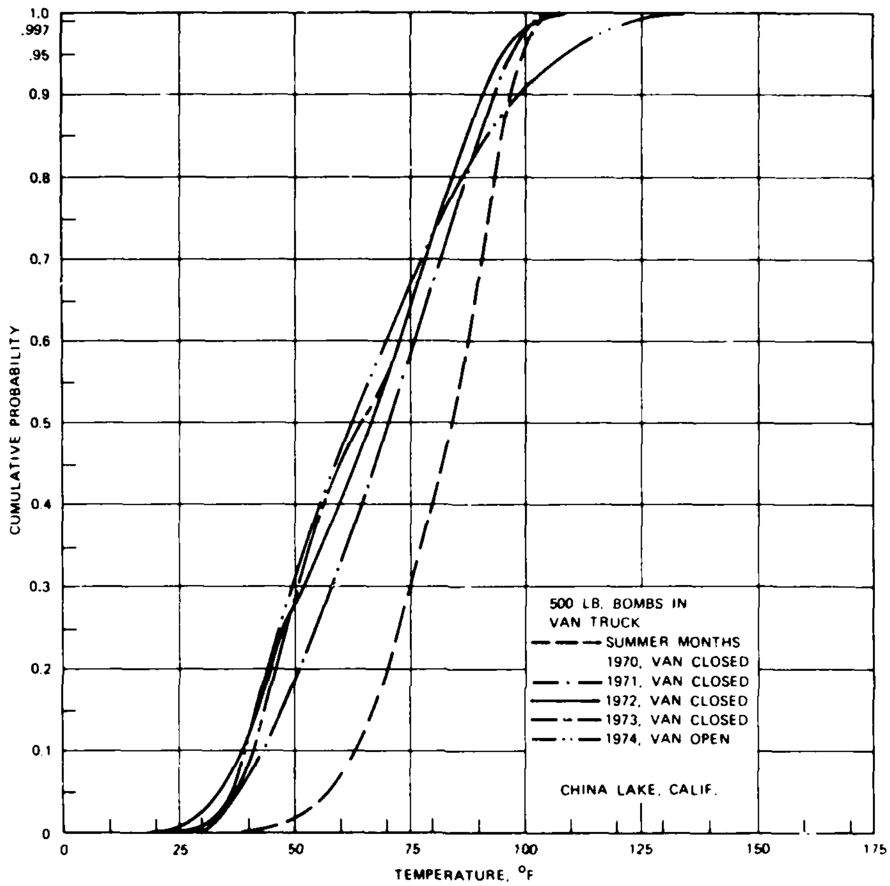


FIGURE 16. Temperature of 500-Pound Bombs Inside Van, Desert Area (Detail).

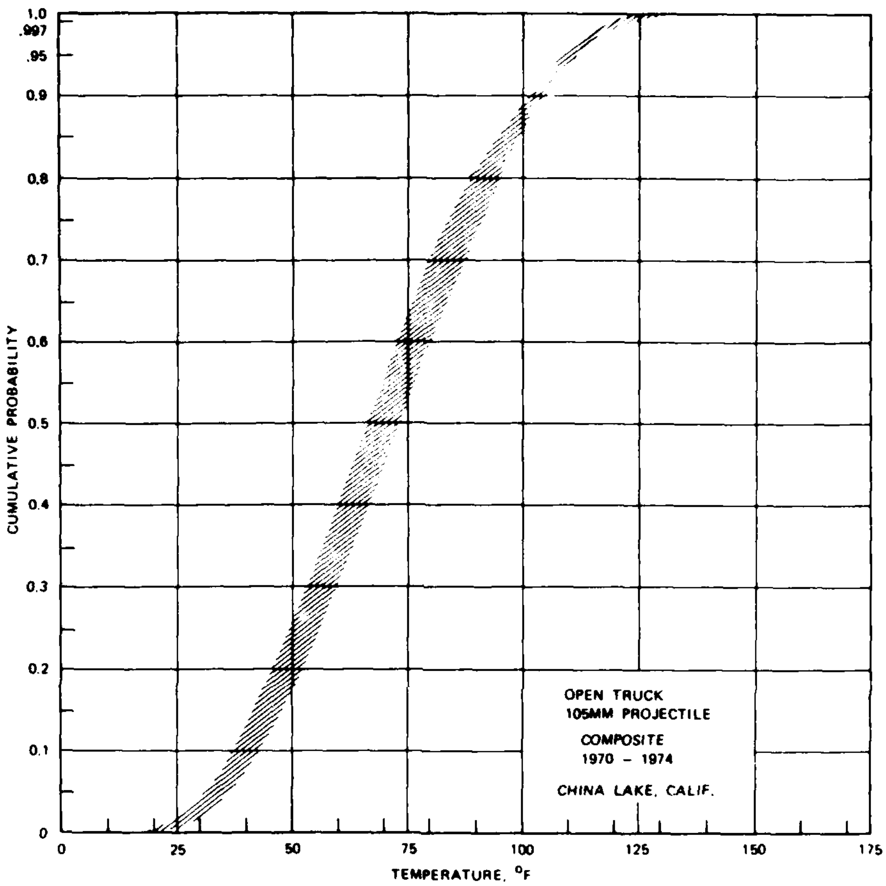


FIGURE 17. Temperature of 105-mm Projectile, Open Bed Truck, Desert Area.

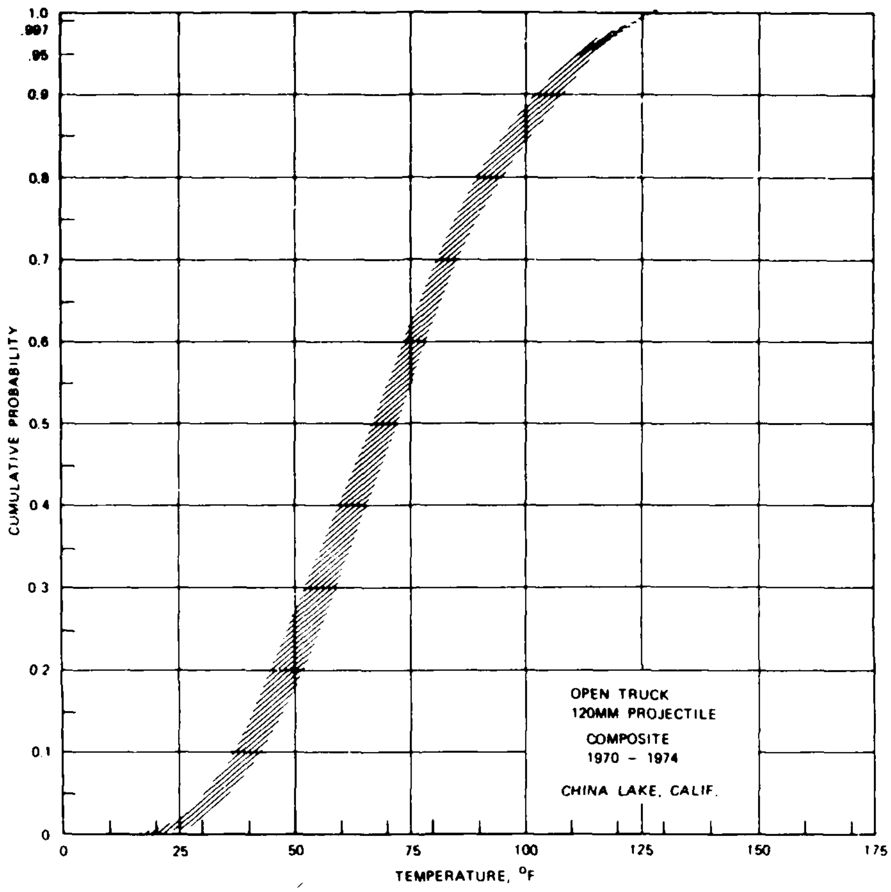


FIGURE 18. Temperature of 120-mm Projectile, Open Bed Truck, Desert Area.

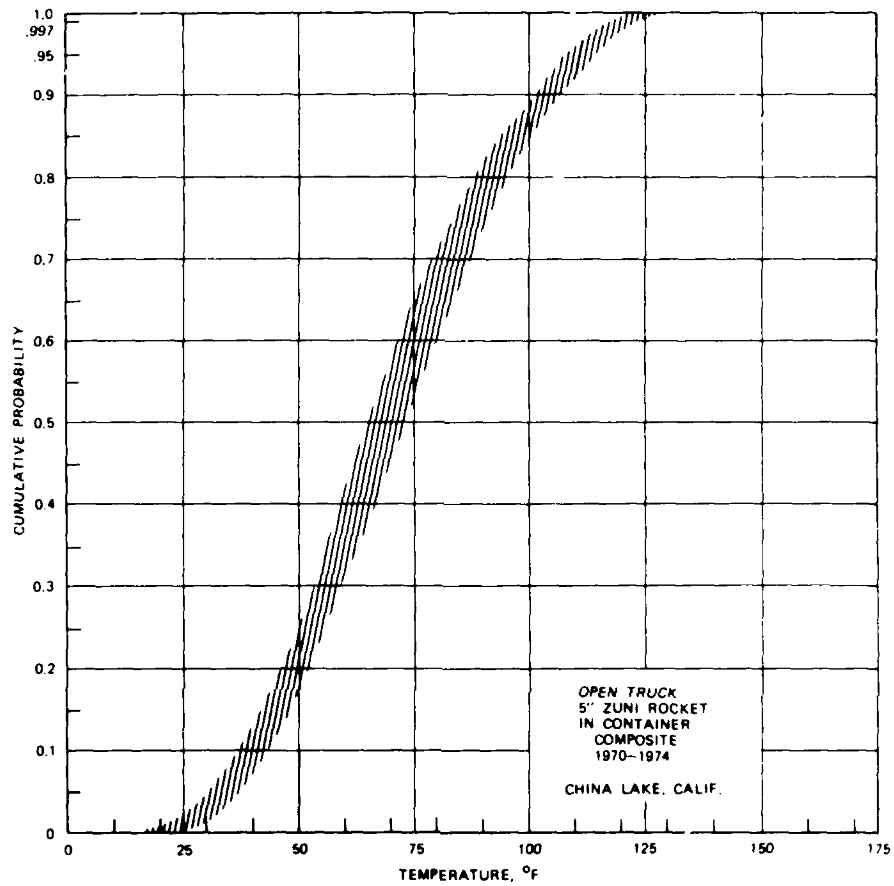


FIGURE 19. Temperature of 5-Inch Zuni Rocket, Open Bed Truck, Desert Area.

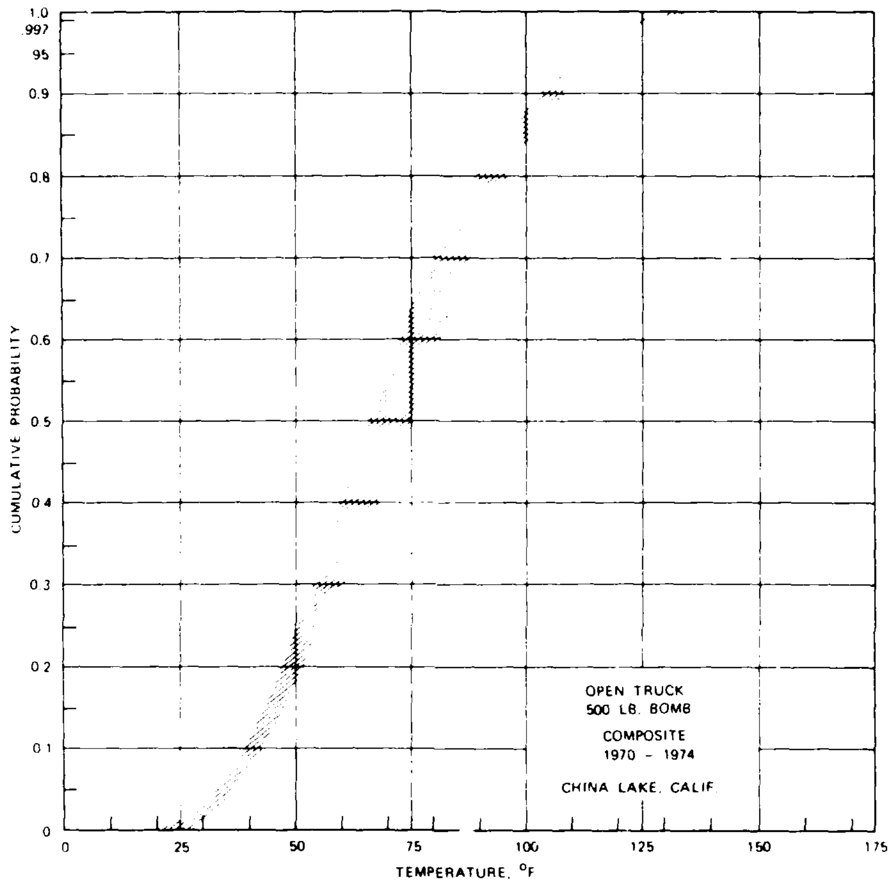


FIGURE 20. Temperature of 500-Pound Bombs, Open Bed Truck, Desert Area.

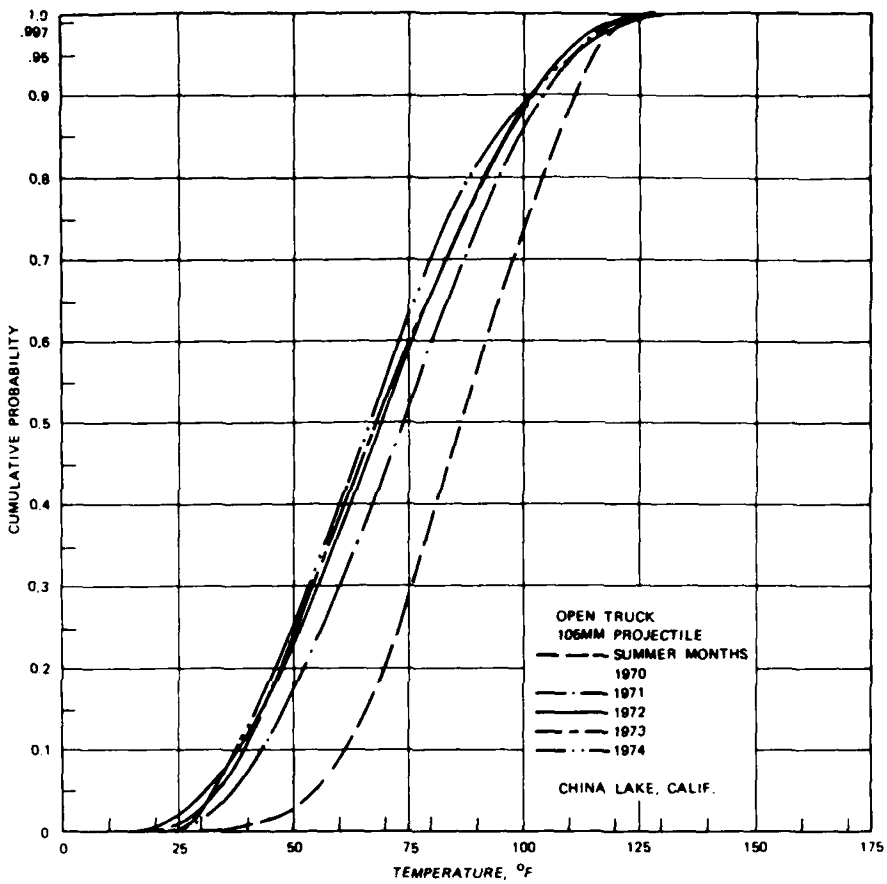


FIGURE 21. Temperature of 105-mm Projectile, Open Bed Truck, Desert Area (Detail).

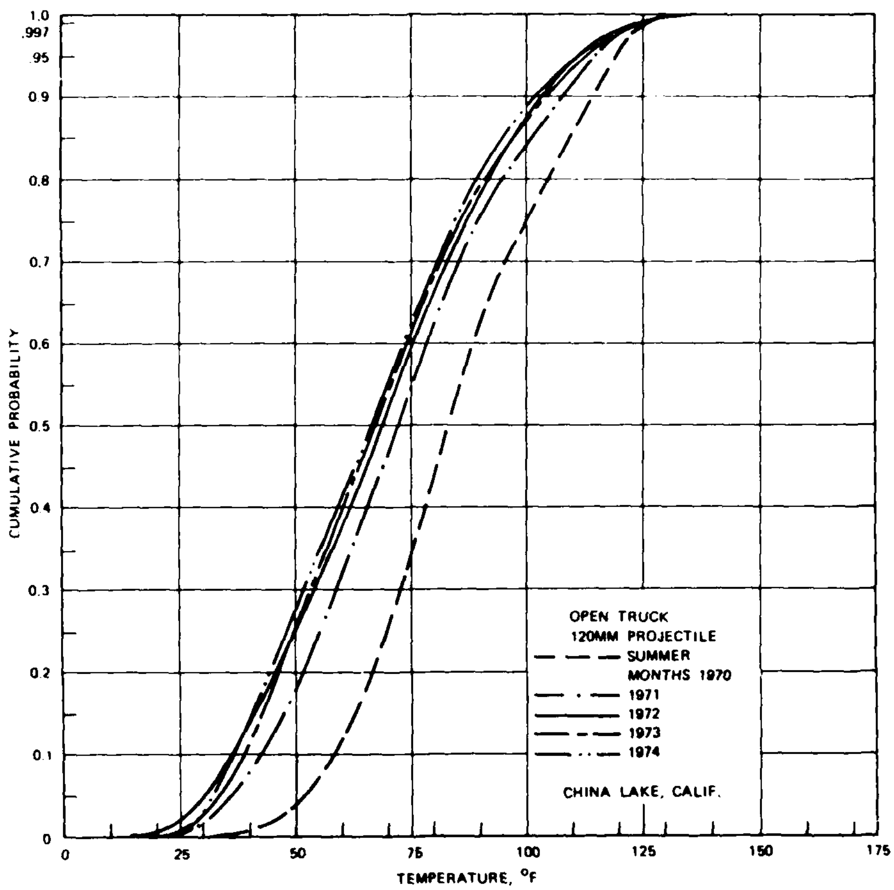


FIGURE 22. Temperature of 102-mm Projectile, Open Bed Truck, Desert Area (Detail).

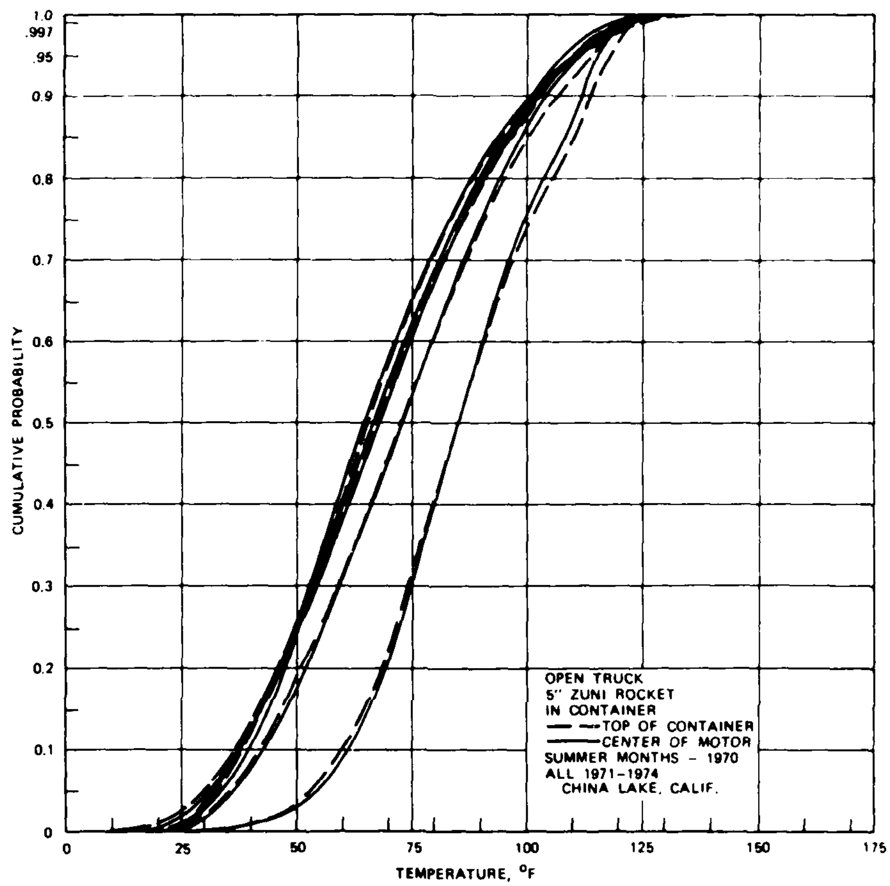


FIGURE 23. Temperature of 5-Inch Zuni Rocket, Open Bed Truck, Desert Area (Detail).

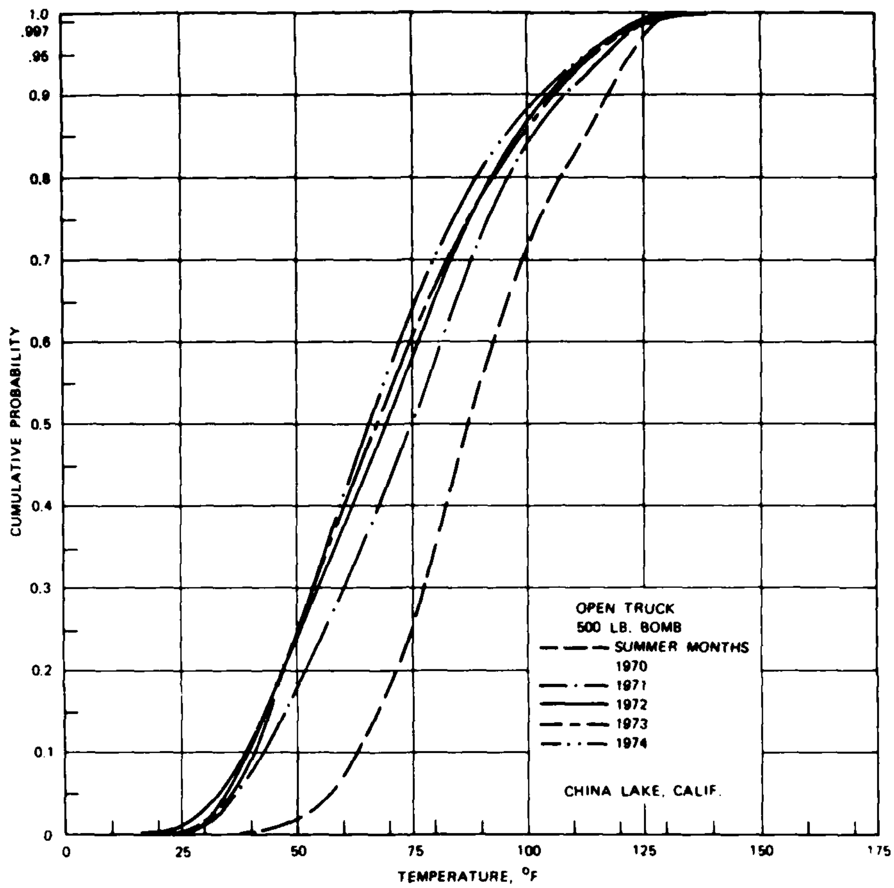


FIGURE 24. Temperature of 500-Pound Bomb, Open Bed Truck, Desert Area (Detail).

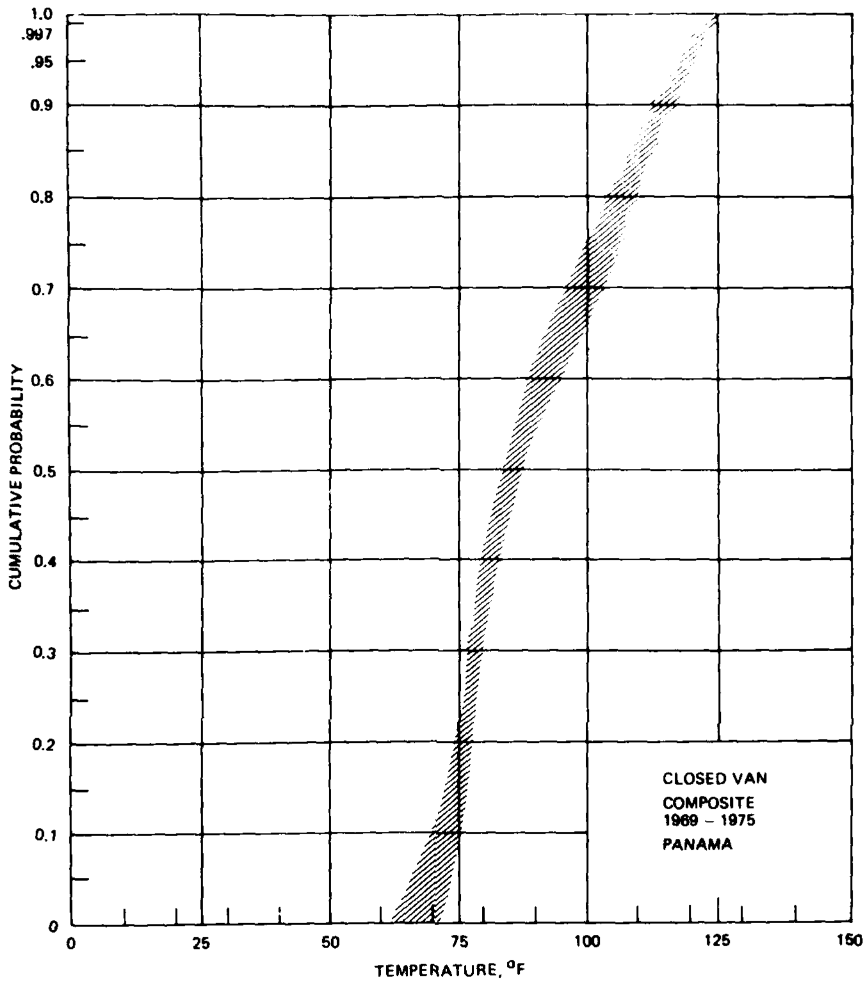


FIGURE 25. Temperature of Air Inside Van Truck, Tropic Area.

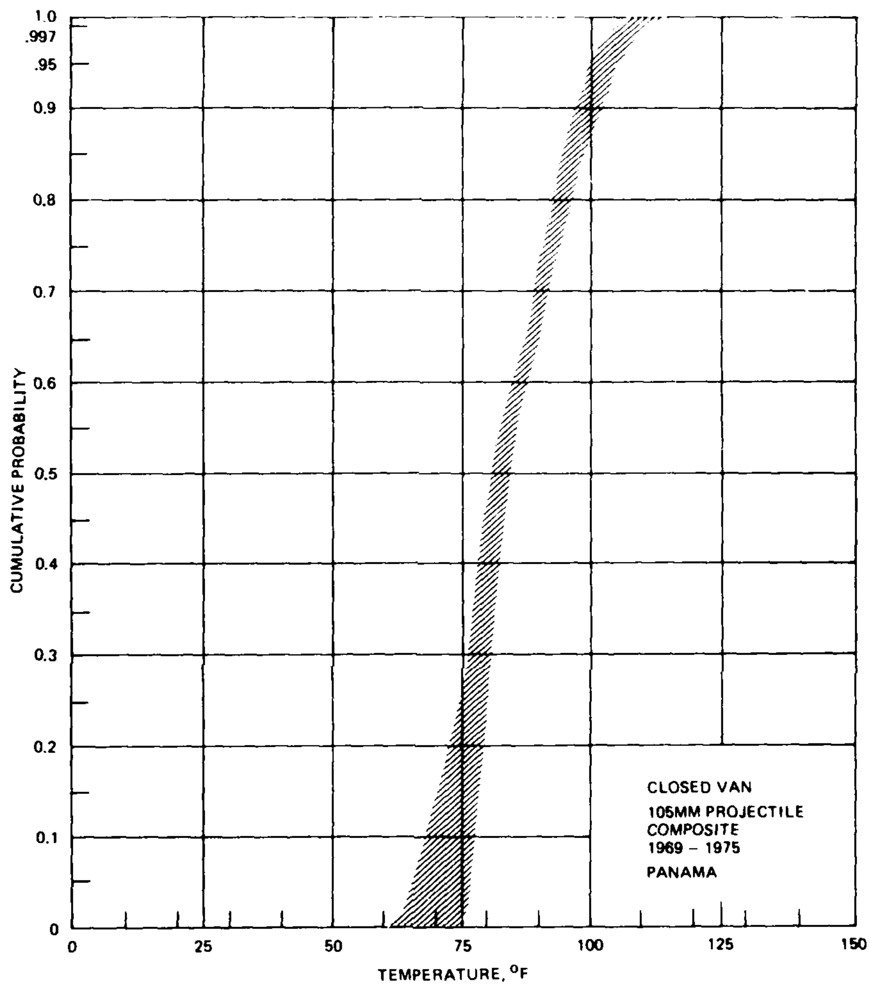


FIGURE 26. Temperature of 105-mm Projectile Inside Van Truck, Tropic Area.

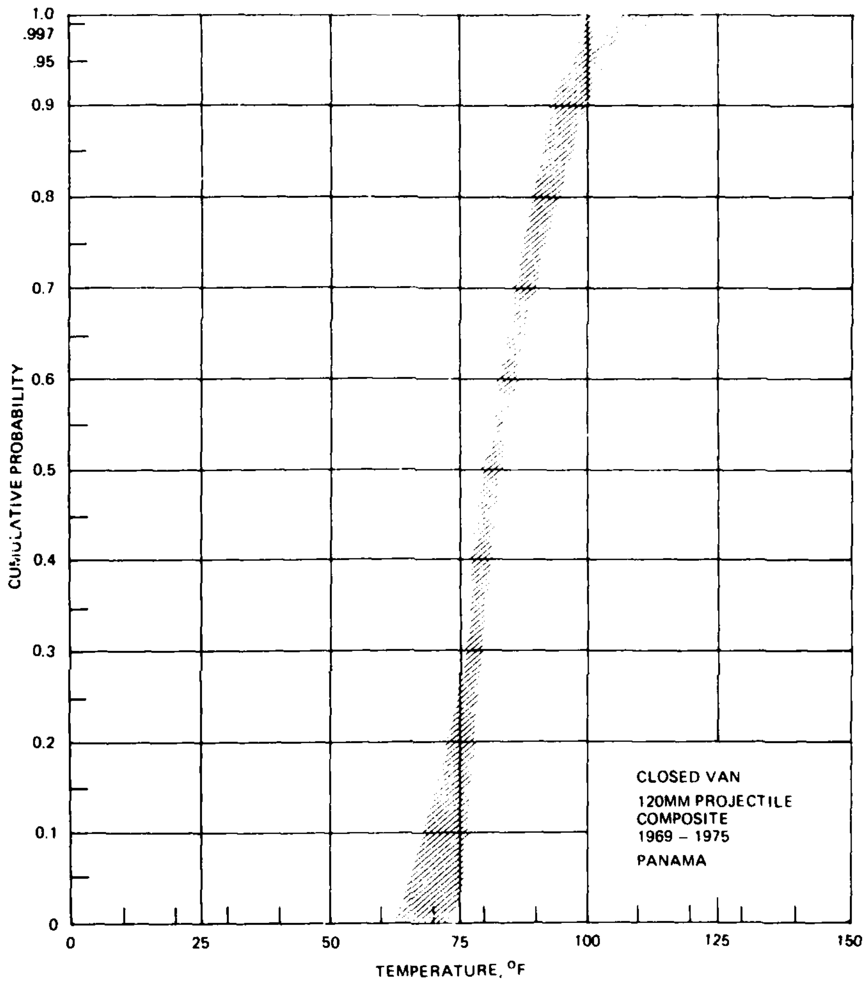


FIGURE 27. Temperature of 120-mm Projectile Inside Van Truck, Tropic Area.

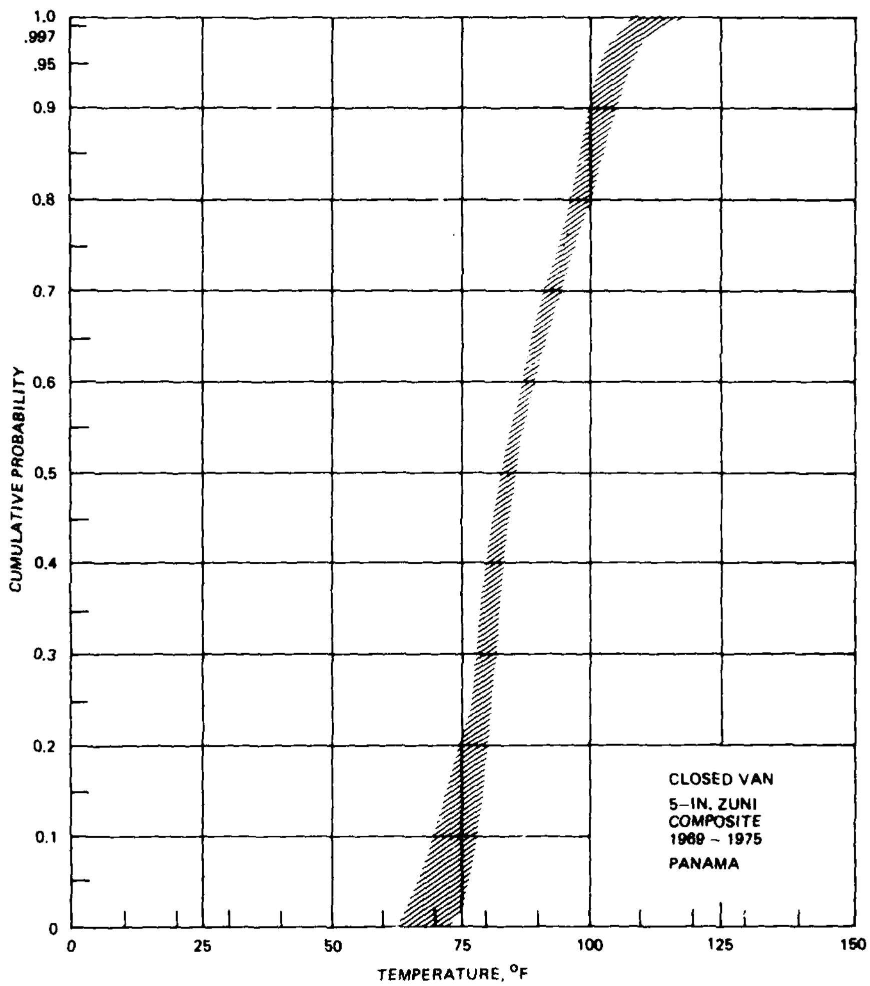


FIGURE 28. Temperature of Zuni Rocket Inside Van Truck, Tropic Area.

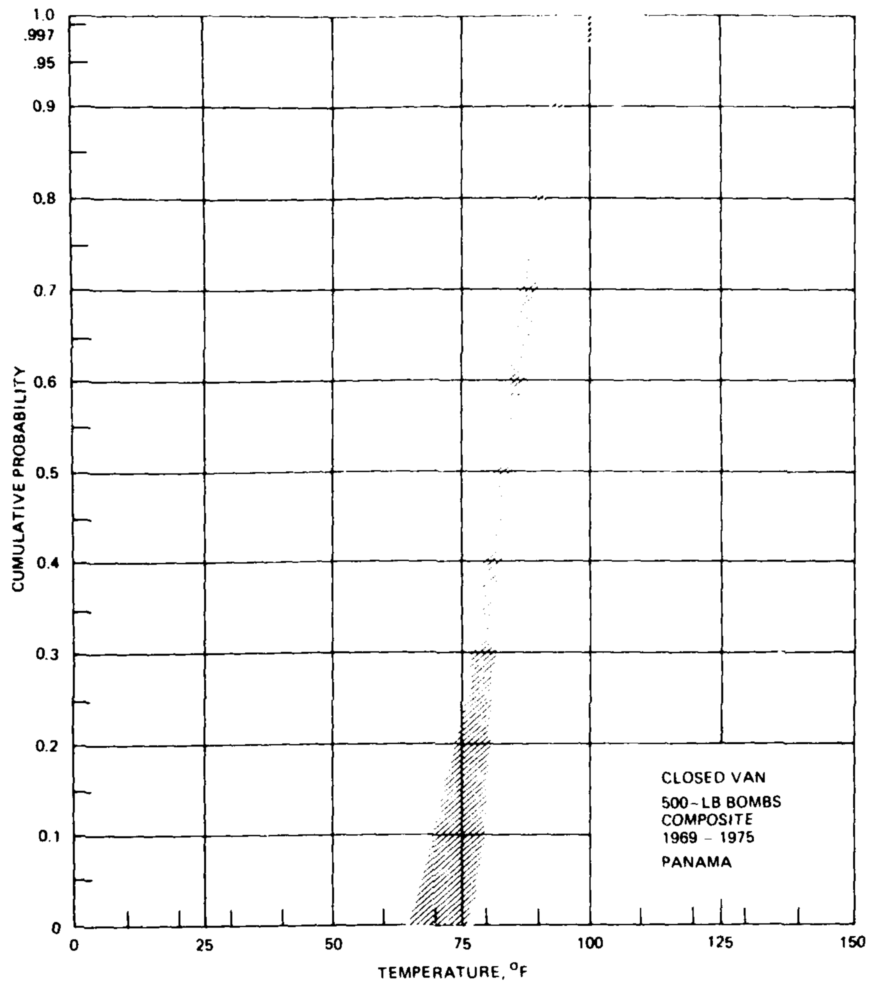


FIGURE 29. Temperature of 500-Pound Bombs Inside Van Truck, Tropic Area.

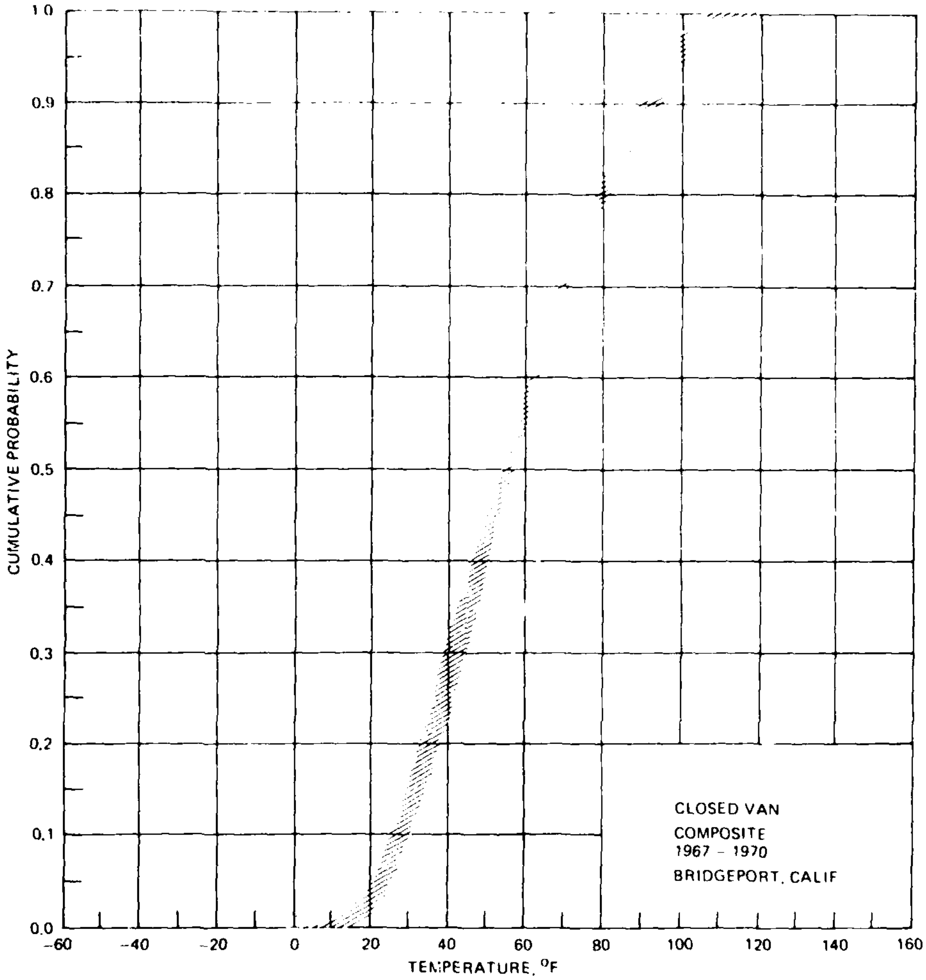


FIGURE 30. Air Temperature Inside Van Truck, Mountainous Temperate Area.

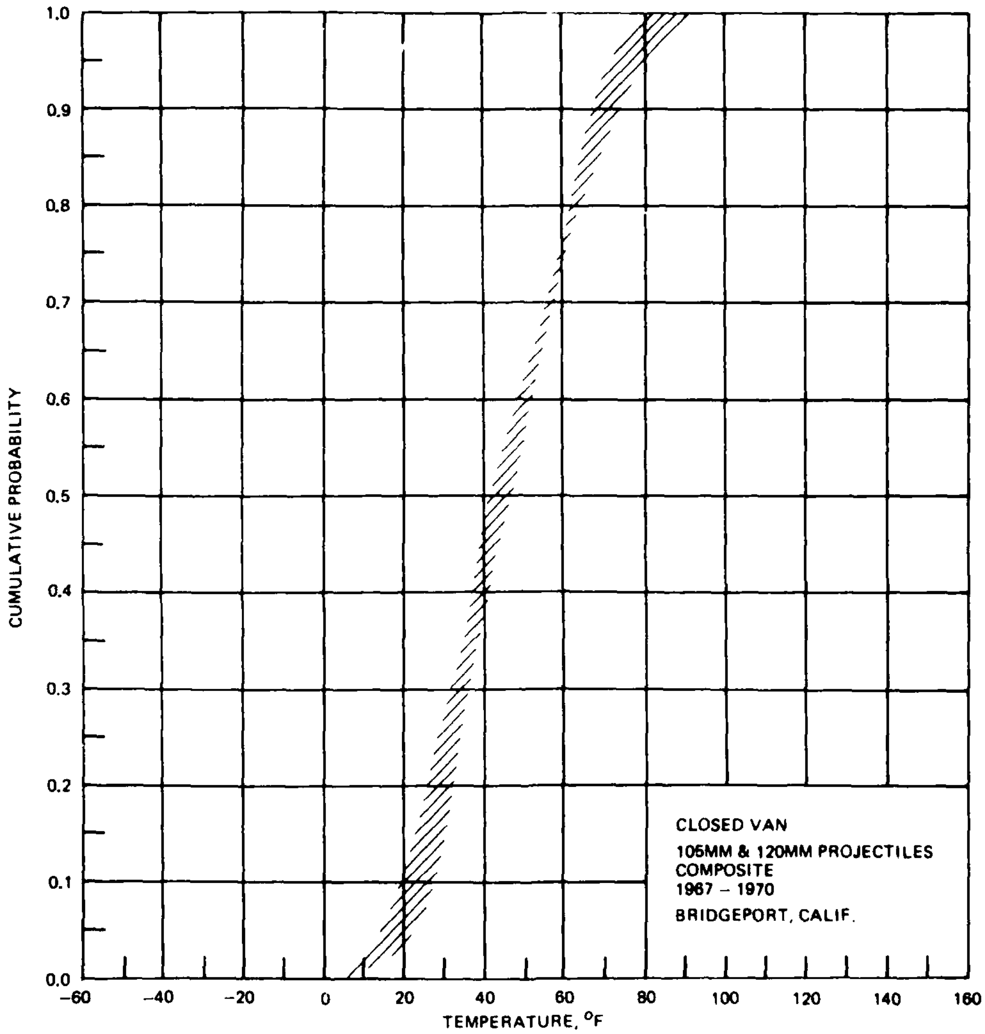


FIGURE 31. Temperature of 105-mm and 120-mm Projectiles Inside Van, Mountainous Temperate Area.

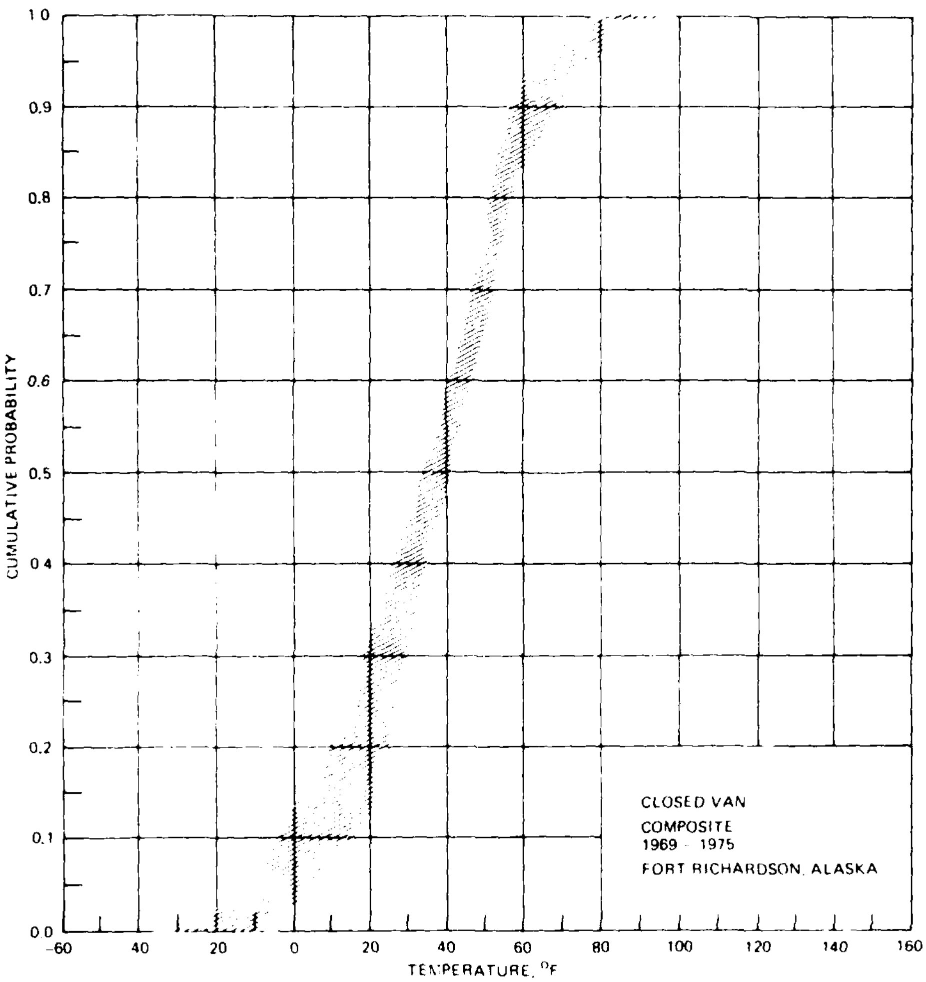


FIGURE 32. Temperature of Air Inside Van, Marine-Influenced Arctic Area.

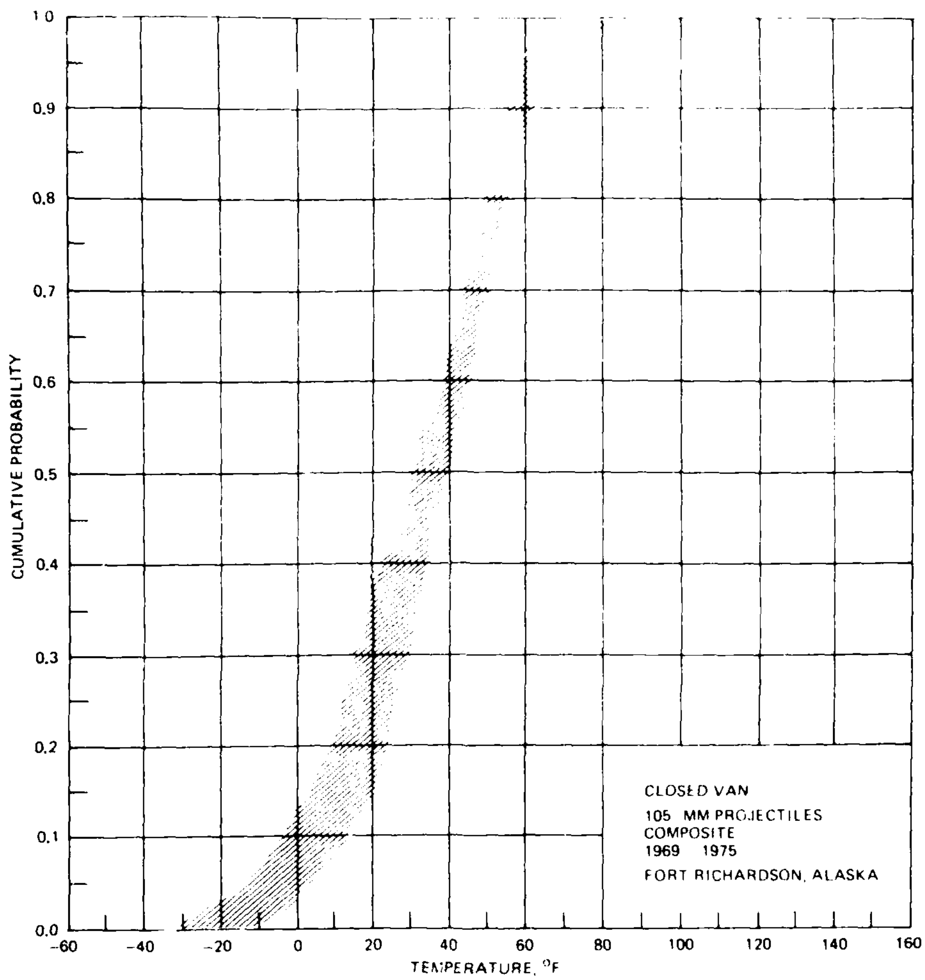


FIGURE 33. Temperature of 105-mm Projectiles Inside Van, Marine-Influenced Arctic Area.

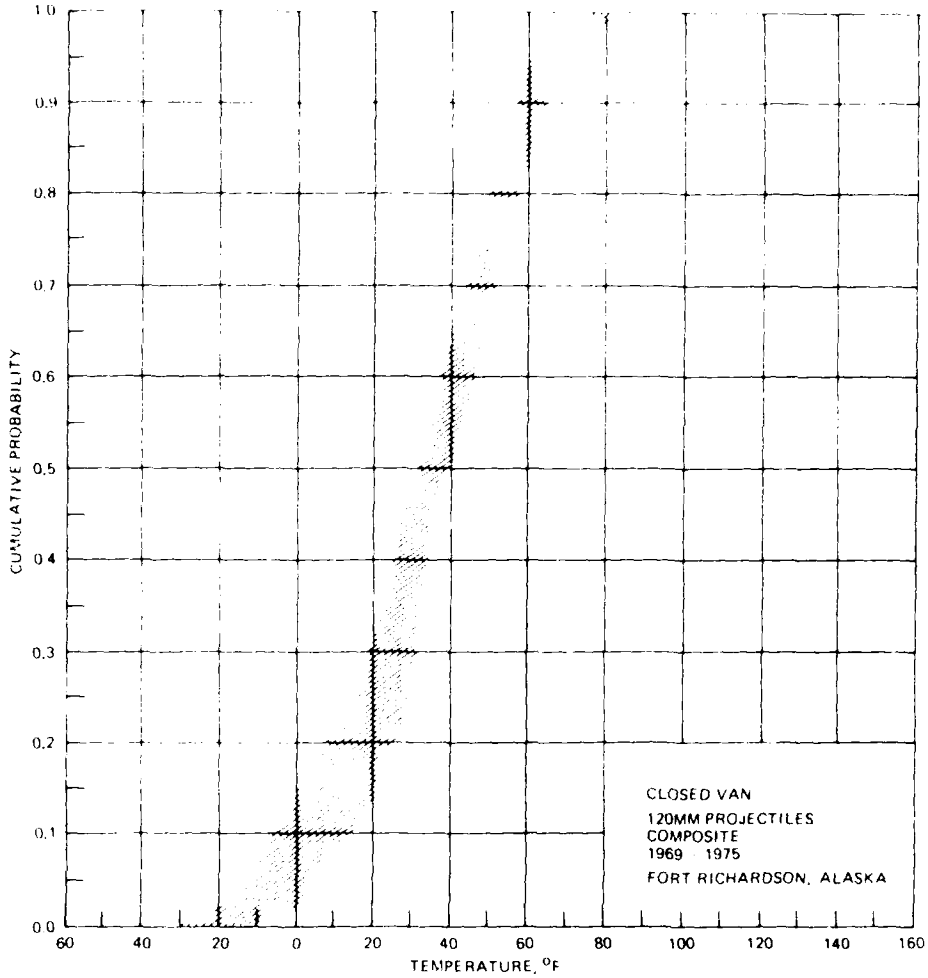


FIGURE 34. Temperature of 120-mm Projectiles Inside Van, Marine-Influenced Arctic Area.

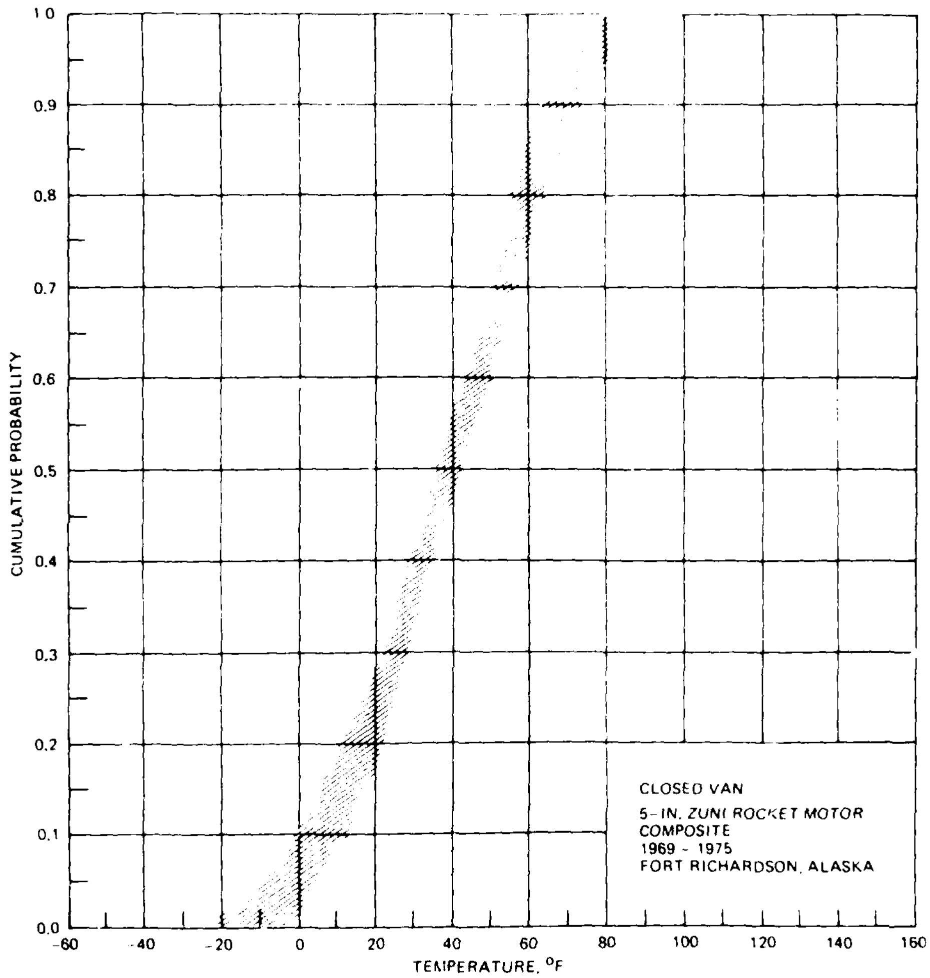


FIGURE 35. Temperature of 5-Inch Zuni Rocket Inside Van, Marine-Influenced Arctic Area.

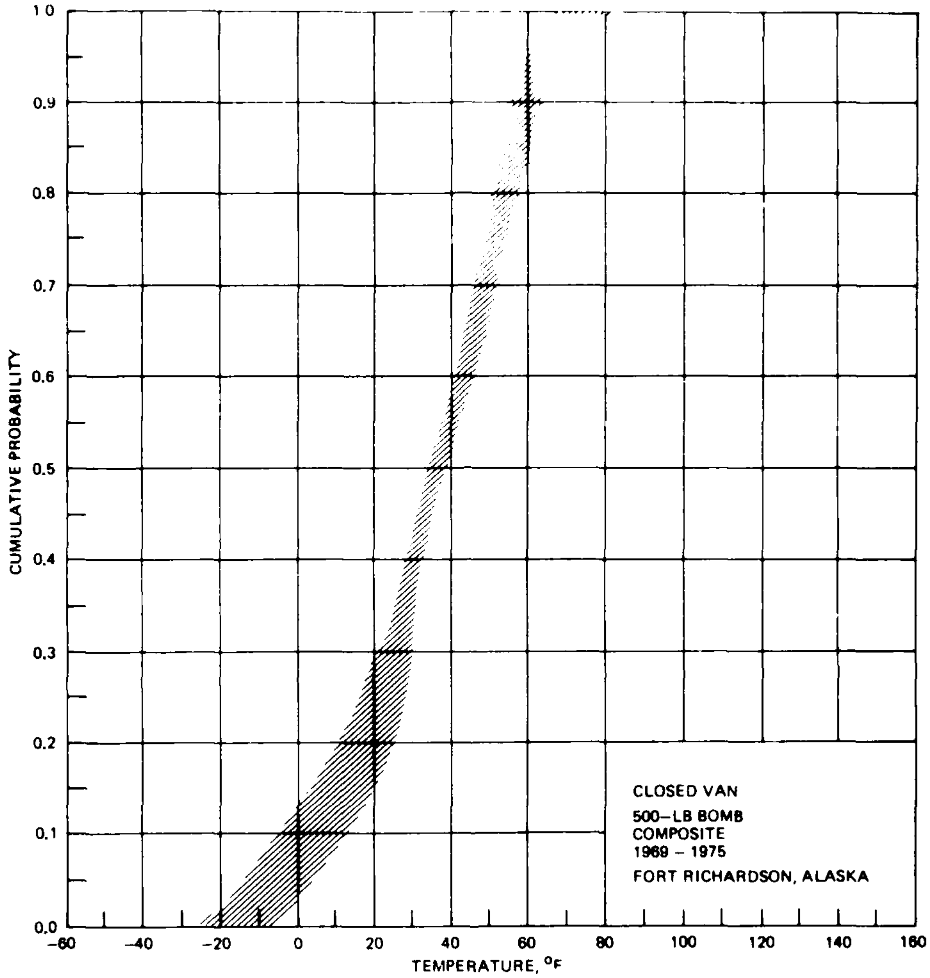


FIGURE 36. Temperature of 500-Pound Bomb in Van, Marine-Influenced Arctic Area.

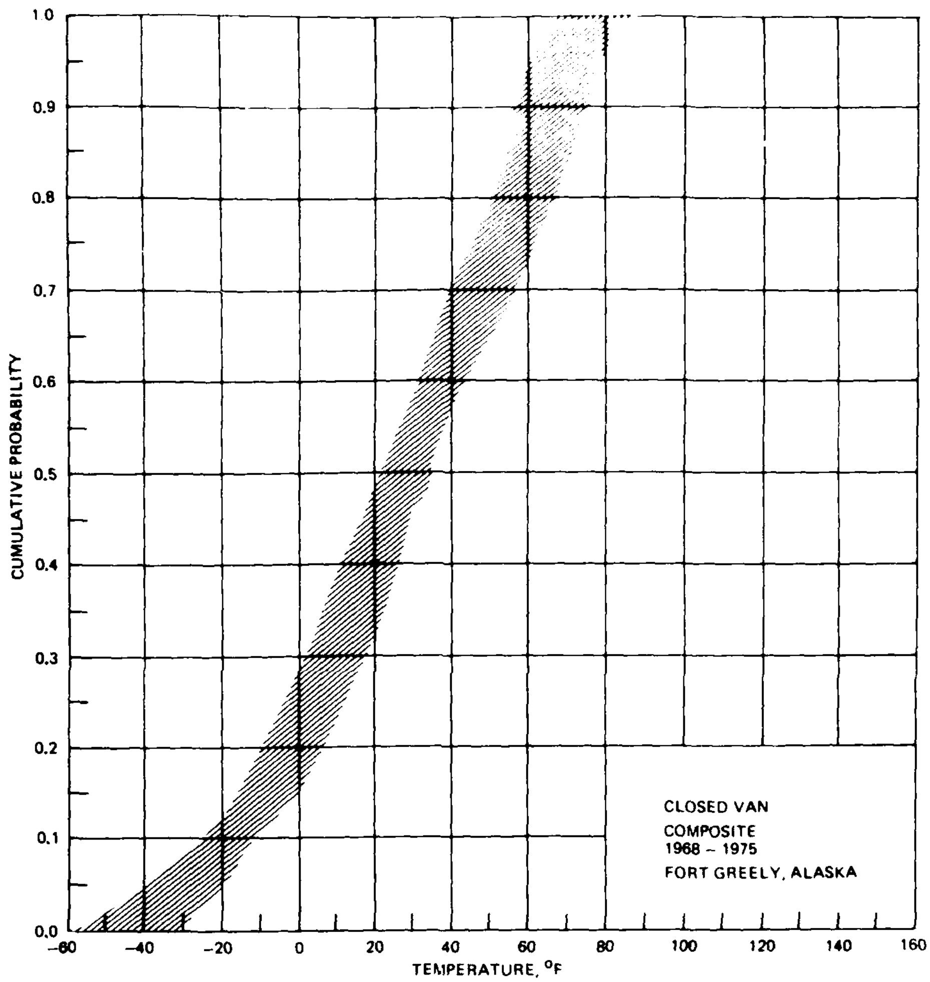


FIGURE 37. Air Temperature Inside Van, Inland Arctic Area.

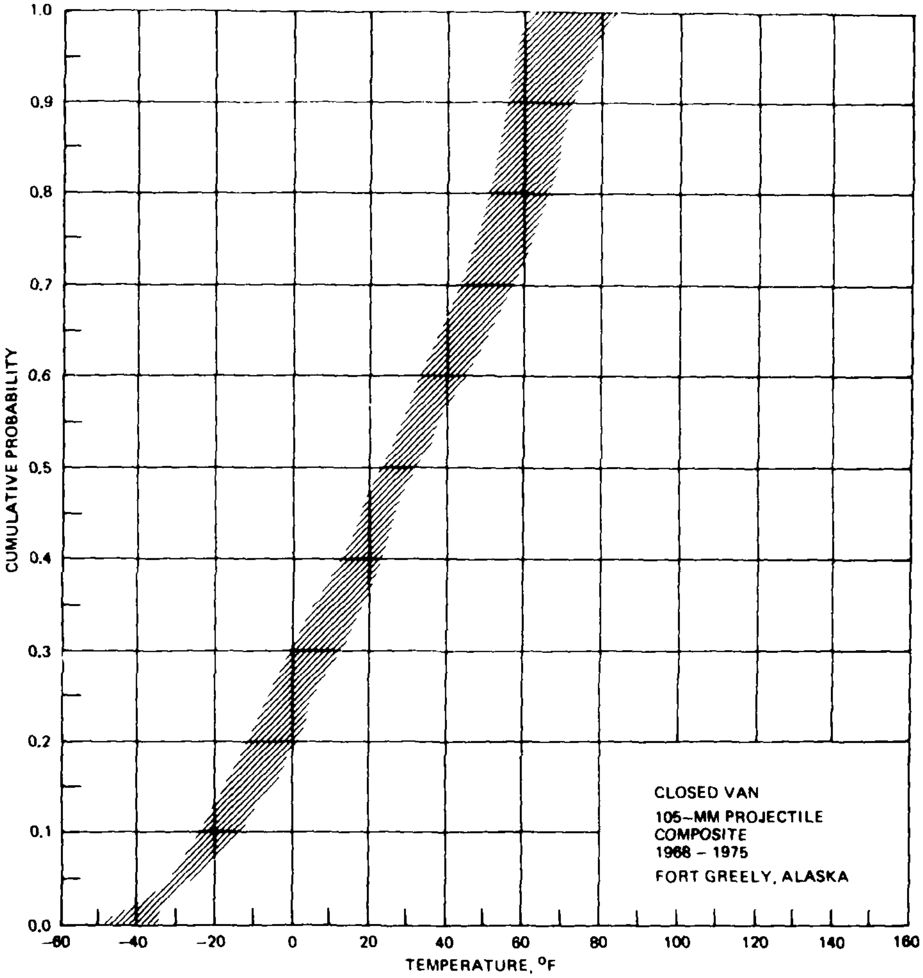


FIGURE 38. Temperature of 105-mm Projectile Inside Van, Inland Arctic Area.

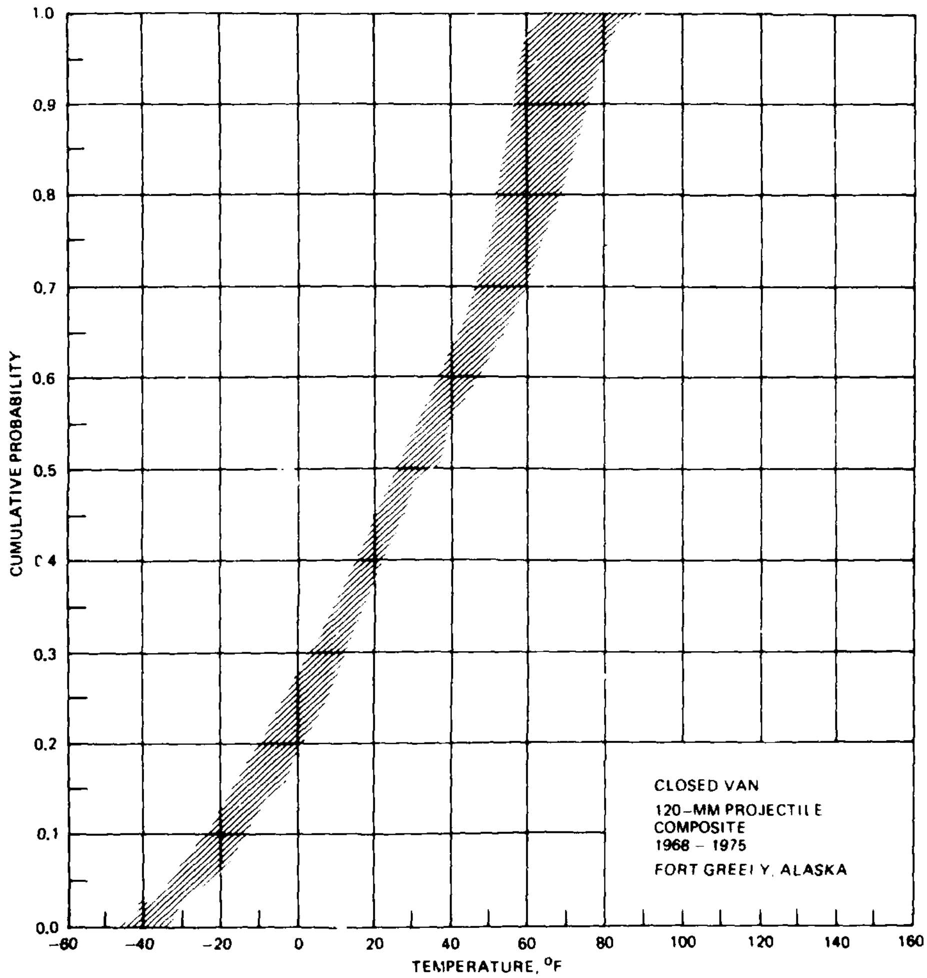


FIGURE 39. Temperature of 120-mm Projectile Inside Van, Inland Arctic Area.

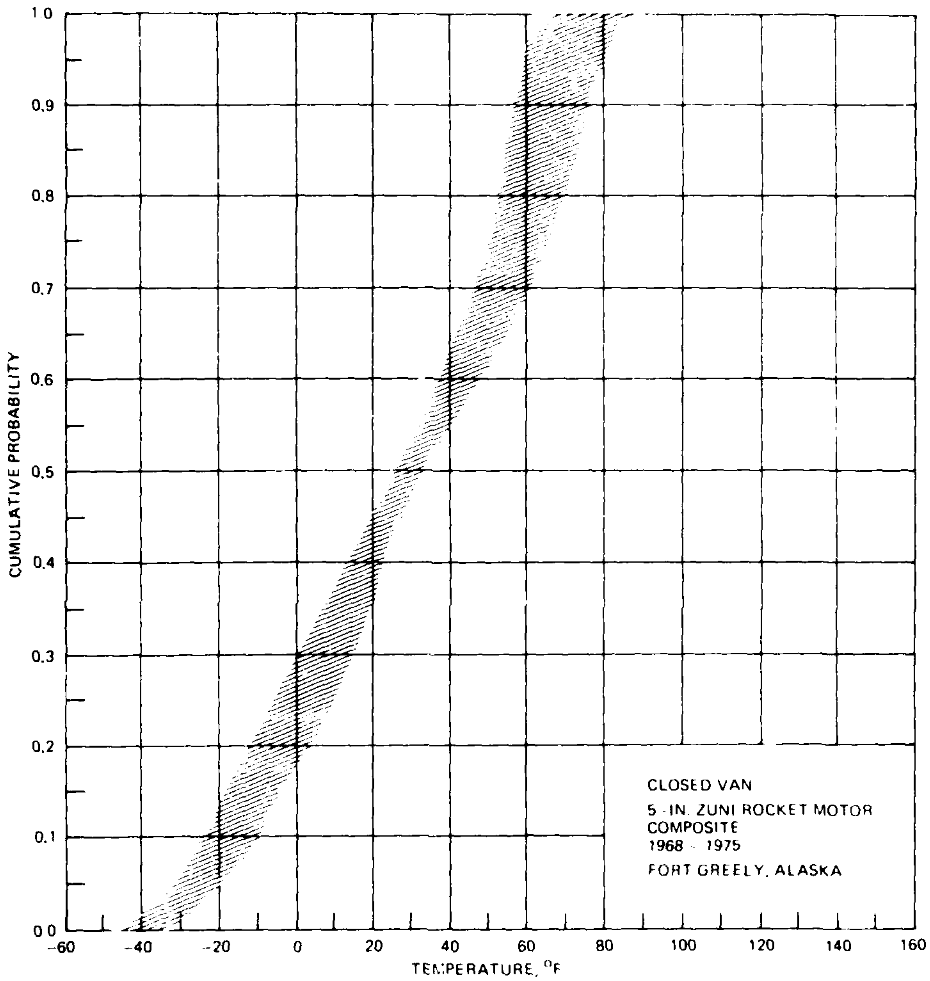


FIGURE 40. Temperature of 5-Inch Zuni Rocket Inside Van, Inland Arctic Area.

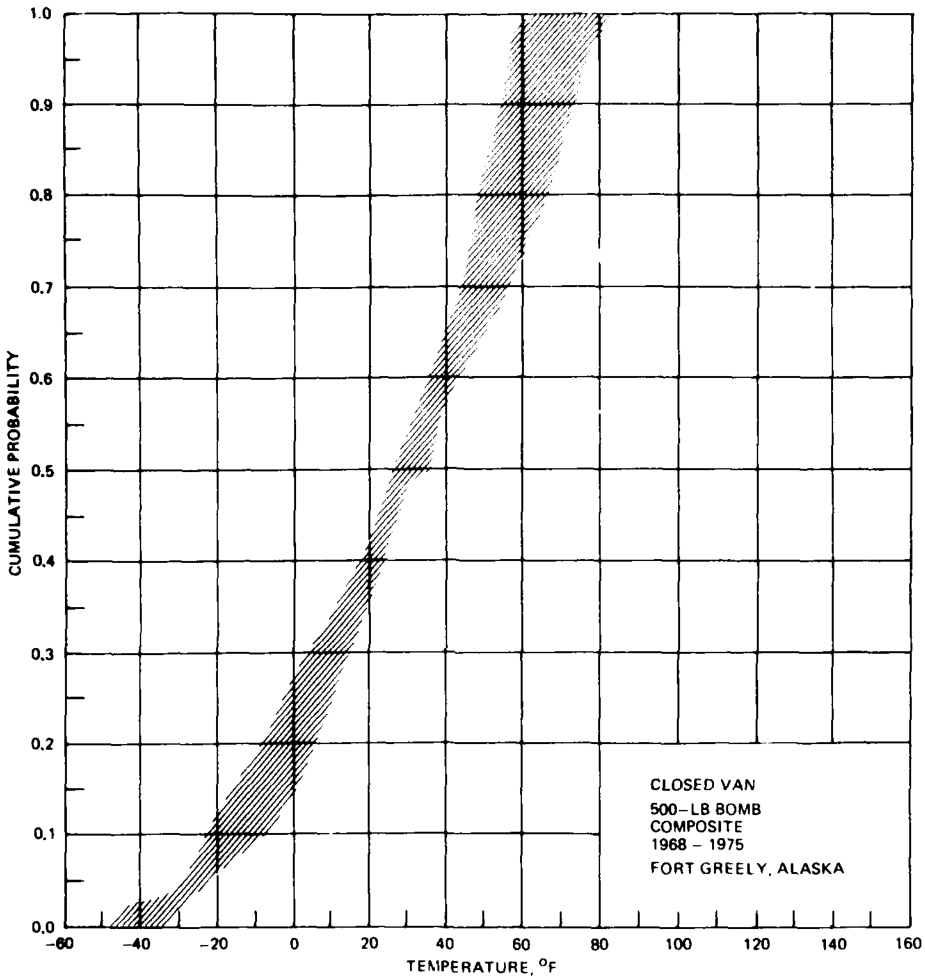


FIGURE 41. Temperature of 500-Pound Bomb Inside Van, Inland Arctic Area.

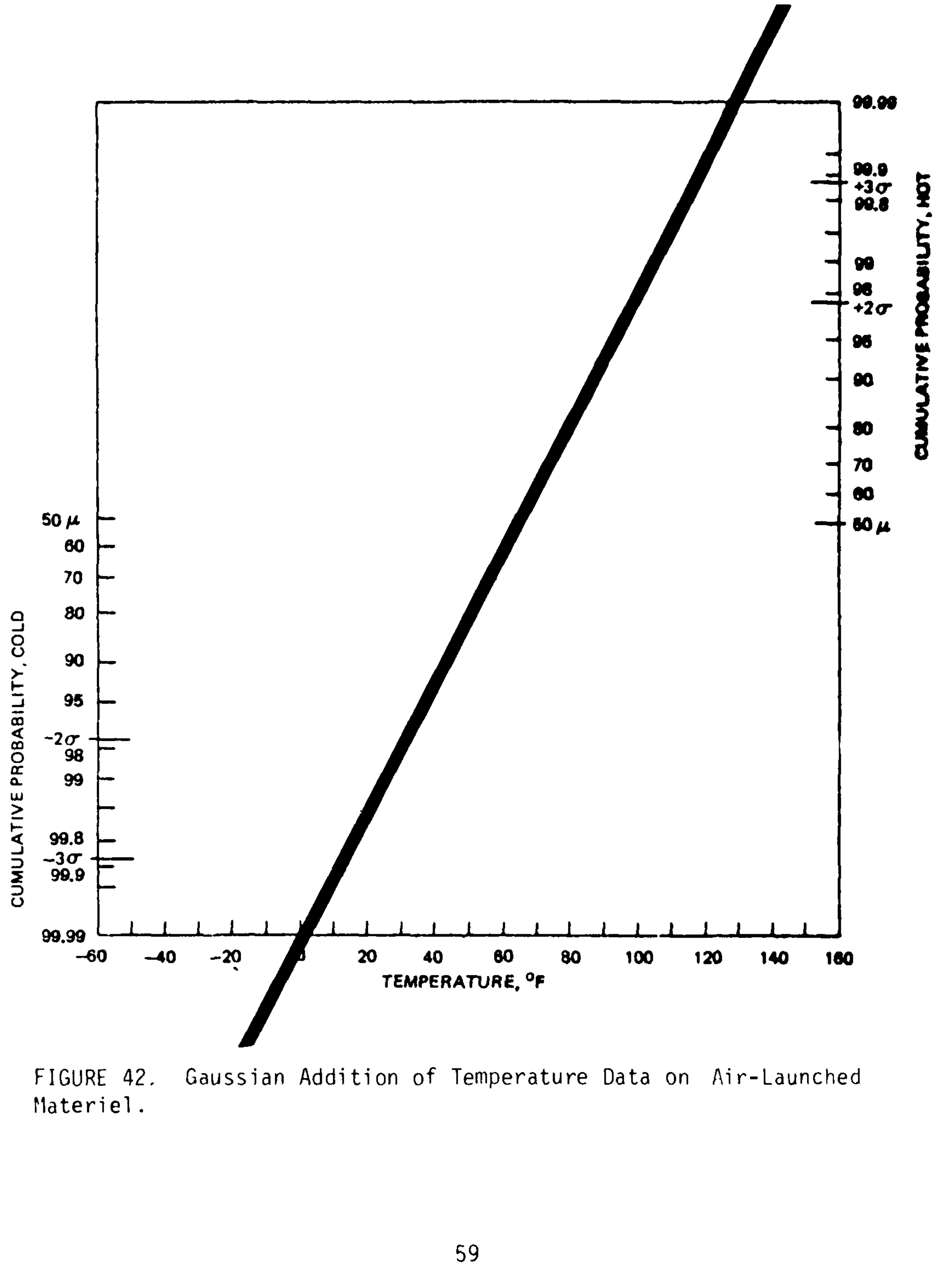


FIGURE 42. Gaussian Addition of Temperature Data on Air-Launched Materiel.

REFERENCES

1. Naval Weapons Center. *Temperature Profiles of Truck Transported Ordnance*, by B. D. Martin and H. C. Schafer. China Lake, Calif., NWC, June 1970. (NWC TP 4822, AD 871595, publication UNCLASSIFIED.)

2. ------. *Environmental Criteria Determination Program, an Overview*, by H. C. Schafer. China Lake, Calif., NWC, April 1981. (NWC TP 6121, publication UNCLASSIFIED.)

3. ------. *Evolution of the NWC Thermal Standard. Part 3. Application and Evaluation of the Thermal Standard in the Field*, by Dr. Richard D. Ulrich and Howard Schafer. China Lake, Calif., NWC, May 1977. (NWC TP 4834, Part 3, publication UNCLASSIFIED.)

Appendix A

STOCKPILE-TO-TARGET SEQUENCE

This appendix presents a method for determining the use life of an air-launched rocket motor and consists of graphically outlining the probable life of an air-launched unit. Figure A-1 indicates that, no matter what the air-launched ordnance item is, during its life span it will follow the events as depicted in the diagram.

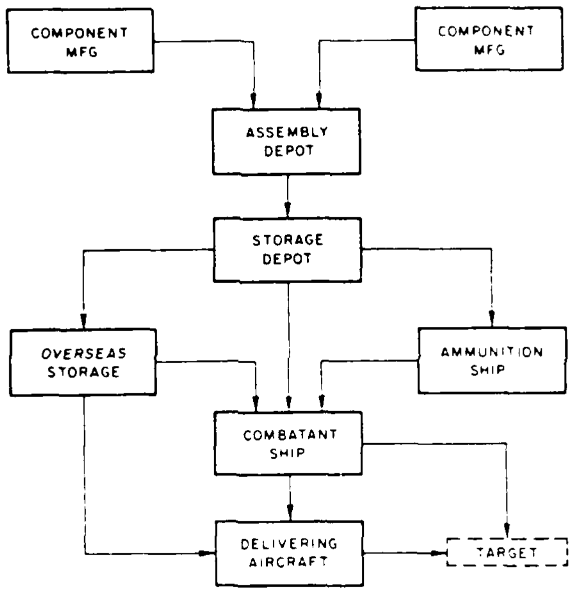


FIGURE A-1. Stockpile-to-Target Sequence.

In general, the sequence starts at the component manufacturer level. It can be assumed that the components will be built in the manufacturing centers of industrialized nations of the world. Therefore, the components will be shipped from the manufacturer to assembly depot by only four different modes of transportation: truck, rail, ship, or air.

The assembly depot can be assumed to be located in a manufacturing complex; or, if in a remote location, it will have the equivalent facilities of a modern manufacturing complex. All subcomponent storage will be in some type of covered area, either above-ground storehouses or earth-covered igloos. Therefore, the component will be protected from the adverse effects of exposure to the weather. On assembly, the units will be packaged and palletized for delivery to the fleet. If manufactured in the United States, the unit is then shipped via truck, rail, or air to one of the established Naval Ammunition Depots (NAD), situated within the continental boundaries. Once at the ammunition depot, the unit will be placed in a standard "explosive hazard magazine" as per instructions delineated in NavWeps OP-5, Volume I. Again, there will be no outside storage and a very small chance of storage in above-ground storehouse facilities.

From the continental United States storage depot, the item will be (1) sent to an aircraft carrier, (2) sent overseas for storage or use, or (3) stored on board an ammunition ship. In the vast preponderance of situations, the unit will be transported via ship to a forward area or loaded on board an aircraft carrier for a tour of duty. During wartime, the use of civilian merchant ships is a good probability. Therefore, the use of non-Navy ships and the inherent chance of cargo mishandling must be recognized. Once at a forward storage area, three storage modes are possible: (1) igloo storage, (2) above-ground storehouse or primitive covered storage, and (3) primitive dump storage. It has been observed that, at the forward storage depots, air-launched rocket motors and components receive preferential treatment. Where there are storage igloos, bombs, gun ammunition, ballistic rockets and some pyrotechnics are dump-stored to provide room for the more sophisticated air-launched guided missile components. This is only an indication, but a strong one, that the air-launched rocket will, whenever possible, receive preferential treatment. However, it was also observed that the Marine Air Wings were forced to dump-store even air-launched rocket components at forward airfields. Later investigations disclosed that even as Butler-type huts became available, the air-launched guided weapons were given preferential treatment. The forward storage situation is the most severe portion of the stockpile-to-target sequence that a weapon can be expected to experience.

Another flow sequence (Figure A-1) shows the unit being loaded onto an ammunition ship for at-sea transfer to an aircraft carrier. This operation has become increasingly popular in the limited war situation where the aircraft carrier is used more as a Naval air station than as a tactical weapon system as in World War II.

The land counterpart of the aircraft carrier is the Marine Corps forward airfield. In a wartime situation, a forward airstrip will be cut from the terrain and any natural hill and valley area used for dump storage of the explosive components. Usually, there will be few or no pieces of elaborate handling gear or specialized tools and equipment to transport or service the ordnance.

Since the unit is to be used in both circumstances, it should be designed so it will be usable and function when air-carried from either situation. Therefore, the more stringent environmental considerations of Marine Corps use should be given recognition. Instead of the "antiseptic" conditions of an aircraft carrier, the unit may sit in the sand, wind, and rain for a period of time before it is manhandled to the "hot line" and installed on the aircraft from which it is later launched.

A study of Figure A-1 will reveal that all variations of paths have not been discussed here. There are many possible combinations of the enumerated stations in the sequence; however, the other combinations would lead to no new environmental criteria that have not already been identified. Therefore, for brevity, they have been omitted.

Appendix B

STATISTICAL SAMPLE

The sheer volume of data available made the data reduction task enormous. Initially, every data point obtained was to be used to develop specific trends and geographic identifiers for at least a single year cycle. However, after each geographic location of interest had been characterized, the search continued for an alternate method, using a data sampling technique, that would reduce the volume of the reduction job, hopefully with negligible induced errors. It must be remembered that each cumulative probability, or chance of occurrence, plot for each thermocouple location is an integration of between 4,380 and 8,760 data points (depending on the recorder speed or return cycle). For example, from only one 24-channel potentiometer stripchart recorder at one location, between 150,000 and 210,000 data points would be accrued. During the majority of the dump storage and thermal environment measurement program, there were between 23 and 31 of these machines running continuously.

The key to reducing the data reduction workload was the fact that only a single data point per channel was taken every so often (i.e., at 1 hour, 1.1 hours, or 2 hours depending on the location). It was reasoned that even "continuous" time-temperature recording is, in actuality, only the codified chance sampling of a possibly noncontinuous time-temperature history. The noncontinuous nature, or nonpredictability, of the next temperature is especially evident in the response to the sun, wind, rain, and air of a thin wall shipping container exposed in the tropics. There are many times when common sense would dictate that the container wall must be hotter than the air inside, since the air inside continues to gain energy. However, at the time the recorder was ready to sample the container wall temperature, a small "buttermilk" cloud could have shielded the container from the sun and a zepher might have cooled the skin temperature below that of the enclosed air. This is exactly the type of phenomenon that makes an hour-to-hour or day-to-day thermal response prediction of ordnance or material from meteorological data next to impossible. (This is one of the factors that leads the author to prefer the statistical rather than specific treatment of the data.)

If, in fact, these continuous measurements are only samples, then it is quite probable that a lesser number of data points would yield the same shape and magnitude of cumulative probability curve for a given thermocouple, location, and time cycle. It was found that the statistician had long ago solved this problem. The theory of random numbers has demonstrated that a certain confidence can be had in the correctness of an approximation of "truth" if a given number of data points is incorporated from the total group (or cycle of interest). If there is only one measurement, one can definitely say that it is possible to experience that measured value. But, it now becomes a problem to indicate how often that value will be valid and how often it will be in error. Of course, the more measured values there are, the more confident one can become as to the correctness of the "truth." The pitfall here is, what if all the measured values of temperature were taken in December on the desert? If the weapon works only during December on the desert, the "truth" should be known to a good certainty. However, if the weapon must function all year in the desert, then the "truth" is not so well known after all. Thus, the cardinal responsibility of each investigator or user of any data is to be certain that he at least understands (1) the use context of the data and (2) hopefully, a bit about the yearly cycle of interest for any weapon, material, or even consumer goods. The yearly cycle is usually in no way tied to a particular geographical area; in most cases, the "extreme" exposures do not impinge on any given item for even a single cycle.

It was seen, from the work done with statistics by the reliability discipline, that good results could be obtained, in this context, with very small samples of data *if they were, in fact, selected at random* from the cycle of interest. Therefore, since the reliability experts consider 300 data points to be sufficient, it was decided that about 1200 would also be adequate or, in statistical terms, "statistically infinite."

The number of data points is, it must be stated, somewhat arbitrary. The author felt that 60 days should be picked from any given year at random. These 60 days would then be used for an accumulation of their integral 24-hour cycle of sampled data points. This arbitrary decision was made in the full knowledge that each daily cycle of temperature responses of ordnance in the tropics is not identical and, in fact, may be only somewhat similar in an overall sense when compared with the nearly sinusoidal precise responses of like units in the pure desert domain. It was also seen, however, that the reduction of 60 days worth of data in 24-hour groups would reduce the work by at least a factor of 6.

Being a novice in the art of statistics, the author then decided that perhaps he should not rely entirely on the above approach. It was reasoned that this approach would give the general shape of the cumulative probability curve, but what were the chances of having the extreme end points for the total data sample included? Therefore, the data were again scanned for the maximum and minimum data points in a cycle. Since there are usually no more than 5-10 of these in the extreme of interest, it didn't consume too much time and gave more assurance that the cumulative probability curves not only had the correct shape but, hopefully, the correct end points for the cycle of interest.

The year was split into its random parts by reference to a "Table of Random Numbers." It was necessary to modify this table for only 366 numbers. The first 60 of the 366 numbers were recognized and referenced to the Julian calendar with its numbered dates. The result is shown below.

Serial	Number	Date	Serial	Number	Date
1	13	13 Jan	33	121	1 May
2	85	26 Mar	34	295	22 Oct
3	365	30 Dec	35	13	~~13 Jan~~
4	34	3 Feb	36	311	7 Nov
5	205	24 Jul	37	293	20 Oct
6	116	26 Apr	38	166	15 Jun
7	157	6 Jun	39	360	26 Dec
8	359	25 Dec	40	247	4 Sep
9	30	30 Jan	41	354	20 Dec
10	226	14 Aug	42	102	12 Apr
11	335	1 Dec	43	232	20 Aug
12	221	9 Aug	44	276	3 Oct
13	117	27 Apr	45	295	~~22 Oct~~
14	184	3 Jul	46	195	14 Jul
15	109	19 Apr	47	269	26 Sep
16	220	8 Aug	48	107	17 Apr
17	152	1 Jun	49	98	8 Apr
18	178	27 Jun	50	178	~~27 Jun~~
19	20	20 Jan	51	88	29 Mar
20	303	30 Oct	52	10	10 Jan
21	49	18 Feb	53	60	1 Mar
22	52	21 Feb	54	76	15 Mar
23	226	~~14 Aug~~	55	204	23 Jul
24	186	5 Jul	56	342	8 Dec
25	198	17 Jul	57	263	20 Sep
26	80	21 Mar	58	159	8 Jun
27	114	24 Apr	59	125	5 May
28	281	8 Oct	60	40	9 Feb
29	110	20 Apr	61	279	6 Oct
30	199	18 Jul	62	41	10 Feb
31	241	29 Aug	63	19	19 Jan
32	95	5 Apr	64	209	28 Jul

Notice that there were four reoccurring dates in the above 60 random selections (serials 23, 35, 45, and 50). These were arbitrarily discarded and the next random dates substituted. This is indicated by the strike-throughs in the table and the addition of serial 61, 62, 63, and 64 to the bottom of the table. When simplified into month-day order, the above listing becomes:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10	3	1	5	1	1	3	8	4	3	7	1
13	9	15	8	5	6	5	9	20	6		8
9	10	21	12		8	14	14	26	8		20
20	18	26	17		15	17	20		20		25
30	21	29	19		27	18	29		22		26
			20			23			30		30
			24			24					
			26			28					
			27								

At first glance, the above table looks a little lopsided. However, if the numbers are regrouped into seasons, then the grouping looks as if if might, in fact, be quite representative of the yearly cycle of exposure. It must be remembered that the summer is extreme only in desert and maybe temperate climate areas; it is of next to academic interest for material used in the arctic, for example. Winter is of importance in cold climates, and spring and fall seem to yield the thermal extremes in the tropics. (This is because the rainy season cancels out "summer.")

The regrouping of number of days per 3-month season of the sample reveals the following:

Spring	Summer	Fall	Winter
16	18	10	16

Notice that if there is any appreciable bias, it is toward summer, with the spring-fall time span very well represented. Therefore, for the author's uses (i.e., tropics and desert exposure predominantly), the sample was a pleasant surprise.

Work done by Brigham Young University for NWC indicates that a fair amount of accuracy can be retained with only a 10% sample of continuously recorded temperature data when placed in a cumulative probability versus temperature format. In fact, it has been shown that the use of only 1% of the data is conducive to only a 5% error when large amounts of cyclic data are available.[3]

With the previously published background, it was deemed reasonable to apply this sampling process in a much modified manner to some of these data. The author somewhat arbitrarily decided to use as many complete years of data from each of the representative depot locations as were available. In this manner the overall job of massive data reduction was reduced to handleable proportions yet the statistical accuracy would not be unduly compromised. Even so, the data necessary to carry out even this much abridged program totaled in excess of 700,000 temperature values.

---

[3] Naval Weapons Center. *Evolution of the NWC Thermal Standard. Part 3. Application and Evaluation of the Thermal Standard in the Field*, by Dr. Richard D. Ulrich and Howard Schafer. China Lake, Calif., NWC, May 1977. (NWC TP 4834, Part 3, publication UNCLASSIFIED.)

INITIAL DISTRIBUTION

64 Naval Air Systems Command
AIR-00 (1)
AIR-00D4 (2)
AIR-00X (1)
AIR-01 (1)
AIR-03 (1)
AIR-03D (1)
AIR-03P23 (1)
AIR-031 (1)
AIR-04 (1)
AIR-05 (1)
AIR-05B (1)
AIR-06 (1)
AIR-12 (1)
AIR-310A (1)
AIR-32 (1)
AIR-32R (1)
AIR-320 (1)
AIR-321A (1)
AIR-323A (1)
AIR-33 (1)
AIR-33R (1)
AIR-330 (4)
AIR-332C (1)
AIR-340 (1)
AIR-340G (1)
AIR-350 (1)
AIR-350B (1)
AIR-5162 (1)
AIR-5162B (1)
AIR-5162B2 (1)
AIR-5162B3 (1)
AIR-5162C (1)
AIR-522 (1)
AIR-53033 (1)
AIR-541 (1)
AIR-5410 (1)
AIR-5410B (1)
AIR-5411 (1)
AIR-5413 (1)
AIR-542 (1)
AIR-542A (1)
AIR-5421B (1)
AIR-5421C (1)
AIR-5421CA (1)
AIR-5422 (1)
AIR-5422A1 (1)
AIR-5422A2 (1)
AIR-5422A3 (1)
AIR-5422A4 (1)
AIR-5422B (1)
AIR-5422B1 (1)
AIR-551 (1)
AIR-552 (1)
PMA-242 (1)
PMA-242A (1)
PMA-257 (1)
PMA-258 (1)
PMA-259 (1)
PMA-262 (1)
PMA-2622 (1)

6 Chief of Naval Operations
OP-009D2 (1)
OP-092E2 (1)
OP-098 (1)
OP-098W (1)
OP-983 (1)
OP-987 (1)

19 Chief of Naval Material
MAT-03 (1)
MAT-04 (1)
MAT-0423 (1)
MAT-08 (1)
MAT-08E (2)
NSP-26 (1)
NSP-43 (2)
JCM-00 (1)
JCM-02 (1)
JCM-06 (1)
JCM-40 (1)
JCM-A-00 (1)
JCM-A-40 (1)
JCM-G-00 (1)
JCM-G-40 (1)
JCM-M-40 (1)
JCM-S-00 (1)

3 Chief of Naval Research, Arlington
ONR-100 (1)
ONR-200 (1)
Technical Library (1)

14 Naval Electronic Systems Command
- NAVELEX-00 (1)
- NAVELEX-00B (1)
- NAVELEX-03 (1)
- NAVELEX-05 (1)
- NAVELEX-470 (1)
- NAVELEX-4702 (1)
- NAVELEX-4703 (1)
- NAVELEX-480 (1)
- NAVELEX-520 (1)
- NAVELEX-540 (1)
- PME-107 (1)
- PME-108 (1)
- PME-117 (1)
- PME-119 (1)

1 Naval Facilities Engineering Command, Alexandria (NFAC-03)

33 Naval Sea Systems Command
- SEA-00 (1)
- SEA-003D5 (1)
- SEA-311 (1)
- SEA-3133 (1)
- SEA-322 (1)
- SEA-61C (1)
- SEA-61R (1)
- SEA-62C (1)
- SEA-62M2, G. Mustin (2)
- SEA-62R (1)
- SEA-62Y (1)
- SEA-62YC (1)
- SEA-62Y1 (1)
- SEA-62Z (1)
- SEA-62Z1 (1)
- SEA-62Z2 (1)
- SEA-62Z3 (1)
- SEA-62Z4 (1)
- SEA-62Z5 (1)
- SEA-63Z (1)
- SEA-64 (1)
- SEA-90 (1)
- SEA-90E (1)
- SEA-90T (1)
- SEA-902 (1)
- SEA-94 (1)
- SEA-99612 (2)
- PMS-402 (1)
- PMS-405 (1)
- PMS-406 (1)
- PMS-407 (1)

1 Deputy Assistant Secretary of the Navy for Research and Advanced Technology

1 Commander in Chief, U.S. Pacific Fleet (Code 325)

1 Commander, Third Fleet, Pearl Harbor

1 Commander, Seventh Fleet, San Francisco

2 Fleet Analysis Center, Naval Weapons Station, Seal Beach, Corona
- Code 862, GIDEP Office (1)
- Technical Library (1)

5 Naval Air Engineering Center, Lakehurst
- Code 93 (1)
- Code 9313
  - D. Broude (1)
  - Cornetz (1)
- Technical Library (2)

2 Naval Air Test Center, Patuxent River (CT-252, Bldg. 405)

2 Naval Avionics Center, Indianapolis
- R. D. Stone (1)
- Technical Library (1)

1 Naval Ocean Systems Center, San Diego (Code 4473)

25 Naval Ordnance Station, Indian Head
- Code 5A (1)
- Code 5011C, A. P. Allen (1)
- Code 5712A (1)
- Code FS11C (1)
- Code FS12A1 (1)
- Code FS12A2 (1)
- Code FS12A6 (1)

Code FS12B (1)
Code FS12D (1)
Code FS13 (1)
Code FS13A (1)
Code FS13C (1)
Code FS14 (1)
Code FS15A (1)
Code FS15B (1)
Code FS42 (1)
Code FS63 (1)
Code FS64 (1)
Code FS72 (1)
Code QA (1)
Code QA3 (1)
Code TDT, A. T. Camp (1)
J. Wiggin (1)
Technical Library (2)
1 Naval Postgraduate School, Monterey (Technical Library)
2 Naval Research Laboratory
Code 2600, Technical Library (1)
Code 5804, R. Volin (1)
3 Naval Ship Weapon Systems Engineering Station, Port Hueneme
Code 5711, Repository (2)
Code 5712 (1)
4 Naval Surface Weapons Center, Dahlgren
Code D (1)
Code T (1)
Code U42, G. W. Allison (1)
Technical Library (1)
7 Naval Surface Weapons Center, White Oak Laboratory
Silver Spring
Code E21
C. V. Vickers (1)
V. Yarow (1)
Code NO, French (1)
Code WE (2)
Code XWF, Parker (1)
Technical Library (1)
1 Naval Underwater Systems Center, Newport
1 Naval War College, Newport
3 Naval Weapons Evaluation Facility, Kirtland Air Force Base
APM-4, G. V. Binns (1)
AT-2, J. L. Abbott (1)
Technical Library (1)
2 Naval Weapons Quality Assurance Office, Washington Navy Yard
Director (1)
Technical Library (1)
4 Naval Weapons Station, Colts Neck
Code 70, C. P. Troutman (1)
Naval Weapons Handling Center
Code 805, R. E. Seely (1)
Technical Library (2)
1 Naval Weapons Station, Concord (Technical Library)
5 Naval Weapons Station, Seal Beach
Code QE (1)
Code QESX (1)
Code QESX-3 (1)
Environmental Test Branch (1)
Technical Library (1)

2 Naval Weapons Station, Yorktown
 Code 3032, Smith (1)
 Technical Library (1)
7 Naval Weapons Support Center, Crane
 Code 30331, Lawson (1)
 Code QETE (1)
 Code RD (1)
 NAPEC, J. R. Stokinger (1)
 S. Strong (2)
 Technical Library (1)
8 Pacific Missile Test Center, Point Mugu
 Code 1141, T. Elliott (1)
 Code 1143, C. V. Ryden (1)
 Code 1202, L. Matthews (1)
 Code 2133, F. J. Brennan (1)
 Code 2143, R. W. Villers (1)
 Code 3322, E. P. Olsen (1)
 Code 6862, Technical Library (1)
 Code 7379, Sparrow Office (1)
1 Theatre Nuclear Warfare Project Office, PM-23 (Code TN-11)
1 Army Armament Research and Development Command, Dover (DRDAR-TSS)
1 Army Training & Doctrine Command, Fort Monroe (ATCD-T)
7 Aberdeen Proving Ground
 AMSTE-TA
  Goddard (1)
  Peterson (1)
 DRSTE-AD-M, H. Eggbert (3)
 STEAP-MT-M, J. A. Feroli (1)
 Technical Library (1)
4 Army Engineer Topographic Laboratories, Fort Belvoir
 ETL-GS-EA (1)
 ETL-GS-EC, T. Neidringhaus (2)
 Technical Library (1)
2 Chemical Systems Laboratory, Aberdeen Proving Ground
 Research and Development Laboratory (1)
 Warfare Laboratory (1)
3 Harry Diamond Laboratories, Adelphi
 Technical Director (1)
 R. Smith (1)
 Technical Library (1)
2 Office Chief of Research and Development
 Dr. Leo Alpert (1)
 Technical Library (1)
15 Headquarters, U.S. Air Force
 AF/CVB(S) (1)
 AF/SA (1)
 AF/SAG (1)
 AF/RD (1)
 AF/RDC (1)
 AF/RDPS, Allen Eaffy (1)
 AF/RST (1)
 AF/XO (1)
 AS/DASJL (1)
 ASCC/MC (1)
 CCN (1)
 RDQF (1)
 SAFAL (1)
 XOORC (1)
 XOORE (1)

1 Air Force Logistics Command, Wright-Patterson Air Force Base (Technical Library)
1 Strategic Air Command, Offutt Air Force Base (Technical Library)
1 Tactical Air Command, Langley Air Force Base (Technical Library)
1 Air Force Acquisition Logistics Division, Wright-Patterson Air Force Base (Technical Library)
10 Air Force Armament Laboratory, Eglin Air Force Base
AFATL/102 (1)
AFATL/AW (1)
AFATL/DL (1)
AFATL/SD (1)
AFATL/SD2 (1)
AFATL/SD3 (1)
AFATL/SD4 (1)
AFATL/SD8 (1)
AFATL/SDL (1)
Technical Library (1)
2 Air Force Cambridge Research Laboratories, Hanscom Air Force Base
Code LKI, P. Tattleman (1)
Technical Library (1)
1 Air Force Office of Scientific Research
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (Technical Director)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (RKMA, L. Meyer)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (Dr. Trout)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (Technical Library)
1 Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base (AFWAL/AA)
1 Air Force Wright Aeronautical Laboratories, Wright-PattersonAir Force Base (AFWAL/FI)
1 Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base (AFWAL/FIE)
1 Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base (Head, Research and Technology Division)
1 Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base (Technial Library)
3 Environmental Technical Applications Center, Scott Air Force Base (CB)
O. E. Richards (1)
Technical Director (1)
Technical Library (1)
1 Nellis Air Force Base (Technical Library)
2 Ogden Air Materiel Area, Hill Air Force Base
Munitions Safety (1)
Technical Library (1)
2 Rome Air Development Center, Griffiss Air Force Base
Code RCRM (1)
Technical Library (1)
1 Sacramento Air Materiel Area, McClellan Air Force Base
1 Warner Robins Air Materiel Area, Robins Air Force Base (Technical Library)
3 Armament/Munitions Requirements and Development (AMRAD) Committee (2C330, Pentagon)
2 DLA Administrative Support Center (Defense Materiel Specifications and Standards Office)
J. Allen (1)
D. Moses (1)
12 Defense Technical Information Center
3 Department of Defense Explosives Safety Board, Alexandria
3 Deputy Under Secretary of Defense, Acquisition Management
Director, Materiel Acquisition Policy, J. A. Mattino, 3E 144 (1)
Deputy Director, Standardization & Support, Col. T. A. Musson, 2A318 (2)
2 Deputy Under Secretary of Defense, Research and Advanced Technology
Director, Engineering Technology (1)
R. Thorkildsen (1)
1 Director, Defense Test & Evaluation (Deputy Director, Test Facilities & Resources, W. A. Richardson, 3D1043A)