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Occurrence and Effects of High Temperature Stress in Rations Stored in Container Vans: A Comparison with Storage Studies in the 1950s

By

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April 1993

Final Report

June 1992 - September 1992

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13. ABSTRACT *(Maximum 200 words)*

Three container vans (CVs) used to transport and store rations in Operation Desert Shield/Storm (ODS) in 1991 were obtained and located at the Yuma Proving Ground (YPG), Yuma, AZ to monitor heat stress occurring in mililtary rations in a desert climate. One of the vans contained Meal-Ready-To-Eat (MRE) rations, one B Rations, and one Tray Rations. A total of 64 thermocouples were attached throughout the vans and temperatures were recorded hourly. Time-temperature indicators (TTI) were also attached to some cartons, and samples of MREs inserted for sensory evaluations after the summer of storage. Temperatures were analyzed for the summer period from 18 June to 14 September 1992 and compared to similar studies conducted in the 1950s in railroad boxcars. Results show that, despite a smaller headspace in the CVs, the maximum temperatures reached in the top cartons of rations, as in the boxcars, rarely exceeded 120 °F, although temperatures four inches below the roof reached 142-151 °F. Mean temperatures of the top ration cartons in CVs were five degrees higher than in boxcars and were five to seven degrees higher than the outside ambient mean. Similar to the situation in boxcars and storage dumps, there appears to be a strong linear correlation between mean weekly ambient air temperature and top carton air temperature. The heat stress in the vans caused appropriate decreases in reflectance with certain TTIs. Significant decreases in sensory qualities of color and other attributes in rations were noted after the summer of storage in the hot desert.

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PREFACE

This effort was compiled under Task No. 1791, entitled Quantification/Reduction of Heat Stress, with funds available for Operation Desert Shield/Storm (ODS) related research. The study was incorporated into the program entitled Food Stabilization and Shelf Life Indices for Military Feeding in Environmental Extremes. The effort was conducted during the period from 1 June to 30 September 1992.

The authors would like to express their appreciation to the personnel at Yuma Proving Grounds (YPG), Yuma AZ for their diligent effort in instrumenting the container vans under harsh environmental conditions, and their very cooperative effort throughout the program. It has been both a very pleasant and productive joint cooperative effort. The personnel assisting throughout this study from the U.S. Army Test and Evaluation Command, YPG, include Project Officer Ms. Etta Starbuck, and Ms. Dianna Quintana, Equipment Specialists, and Mr. Graham Stullenbarger, Chief, Automotive Division. Those who instrumented the container vans included Mr. Richard Bolin, Mr. Mike Neketin, and Mr. David Meade, Range Support Division, Material Test Directorate. Mr. Dean Weingarten, Chief, Yuma Meteorological Team, provided assistance with climatic data and also provided the Monthly Climatological Summaries (Appendix B).

At Natick, the authors would especially like to thank Ms. Mary Friel for her assistance with this project and Ms. Marcia Lightbody, Information Management Directorate, for her assistance in improving and editing this report.

OCCURRENCE AND EFFECTS OF HIGH TEMPERATURE STRESS IN RATIONS STORED IN CONTAINER VANS: A COMPARISON WITH STORAGE STUDIES IN THE 1950S

I. Introduction

a. Objective: This report summarizes the results of a study of high temperature stress in military rations stored at Yuma Proving Grounds (YPG), Yuma, Arizona during the summer of 1992, in so-called Container Vans (CVs), currently used as the major mode of ration transport and field storage in the military.

b. Purpose of Study: Currently prescribed high-temperature testing regimes for military rations were developed 40 years ago, based on dump, boxcar and warehouse storage studies conducted by Porter and Greenwald (1,2,3). During Operation Desert Storm/Shield (ODS) in 1991, it became apparent that rations were not usually transported or stored in these modes, but in somewhat standardized commercial CVs, adaptable for ready transfer to truck, rail, shipboard and desert field storage locations. The boxcars studied earlier can be loaded with rations only to a height five feet below the roof and have wooden sidewall insulation between the metal outer surface and the ration pallets. In contrast, due to the configuration of the door, the newer CVs can be loaded within one foot of the uninsulated steel roof. They also have no wooden side wall insulation. Since temperatures had reached 151^{o}F six inches from the roof in boxcars, the new CVs appeared to pose a much greater potential thermal stress. In addition, because the CVs are used on truck, rail, shipboard, and often at site, rations may be stored in the CVs for relatively long periods of time, i.e., six months or longer. Therefore, this study of detailed observation of the temperatures in container vans would refine current ration testing regimes (4).

c. Yuma Climate: It is useful to discuss the Yuma climate and its analogy to areas of worldwide extreme high temperature stress. The Yuma Proving Ground is a very large area of hot desert, at 32^{o}40′ north latitude and an altitude of 206 feet Mean Sea Level (at headquarters). Earlier studies (5) showed that the Yuma climate is closely analogous to that of other extreme hot-dry areas worldwide (Figures 1-6), particularly the Middle East, northern Africa and northern India. Yuma has a latitude, Mediterranean winter cloudiness, and wind speed regime similar to the Middle East and northern Africa, so that the solar radiation load is very similar. The diurnal cycle of insolation and hence soil and ambient air temperature are very similar from day to day in hot-dry areas, and the daily and yearly temperature marches are regular and repetitious. Therefore, knowledge of storage temperature regimes permits prediction and generalization to many hot-dry areas of the world, providing the induced temperature response of the storage mode is known.

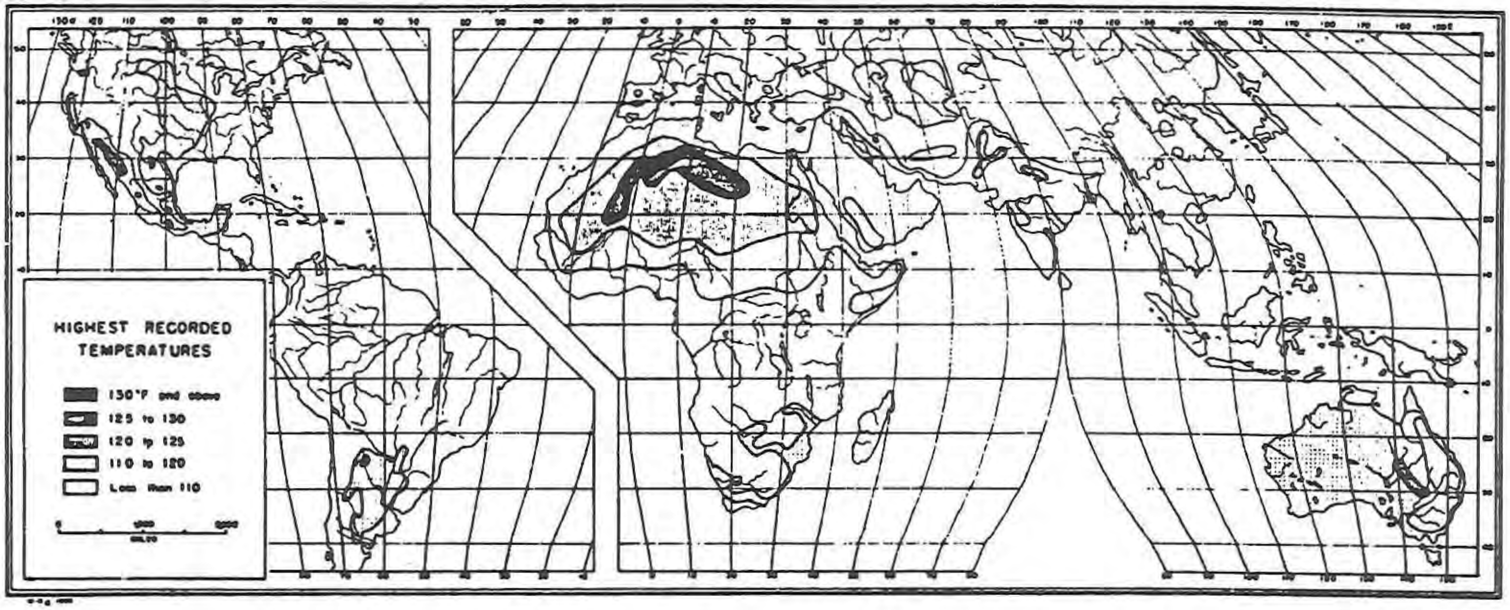


Figure 1. World's highest recorded temperatures

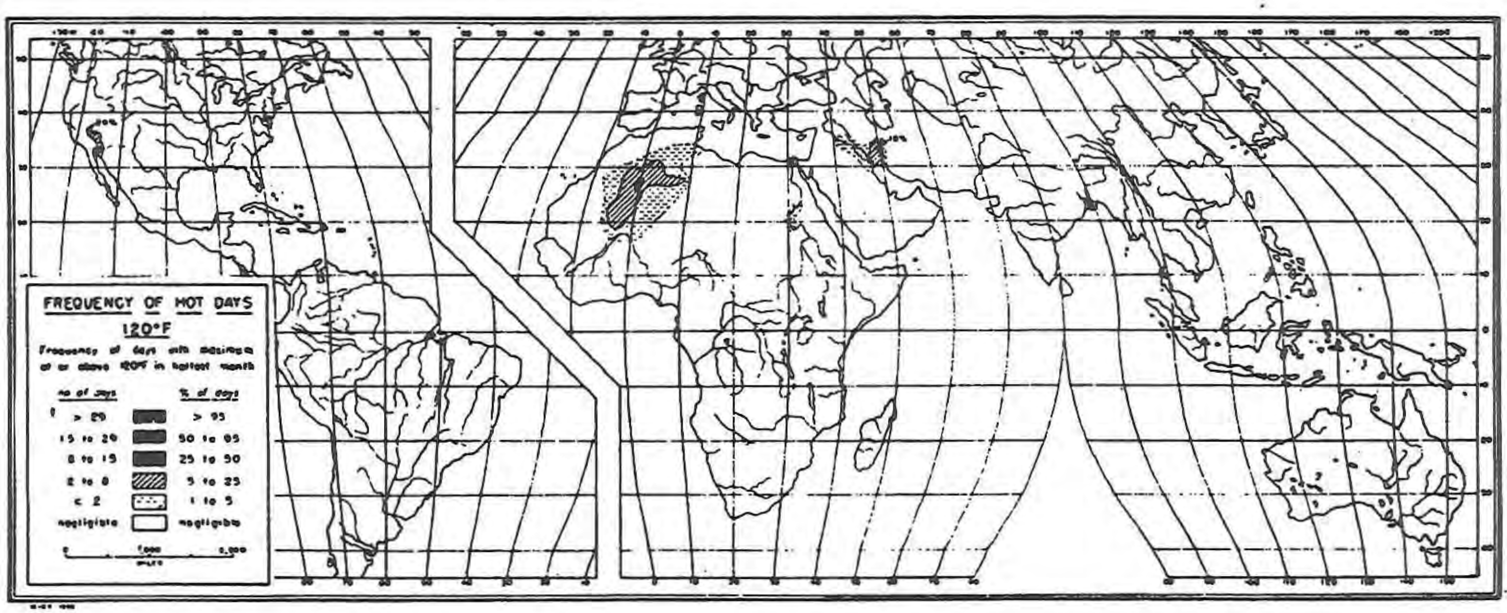


Figure 2. World's frequency of hot days

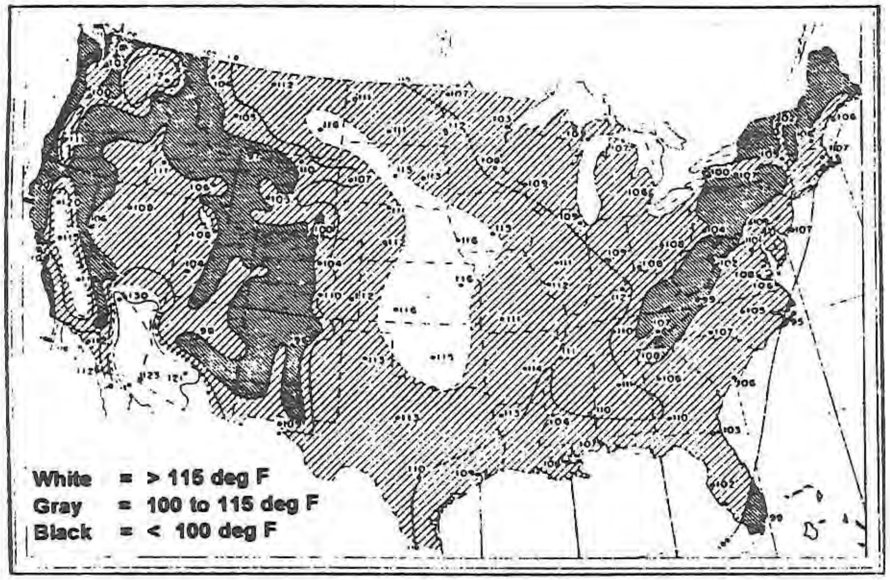


Figure 3. Highest temperature expected in 100 years, U.S.A.
(Based on analysis of highest temperatures in each year 1901–1930, at 100 places listed in "Climatic Summary of the United States" U.S. Weather Bureau Bulletin W, 1930.)

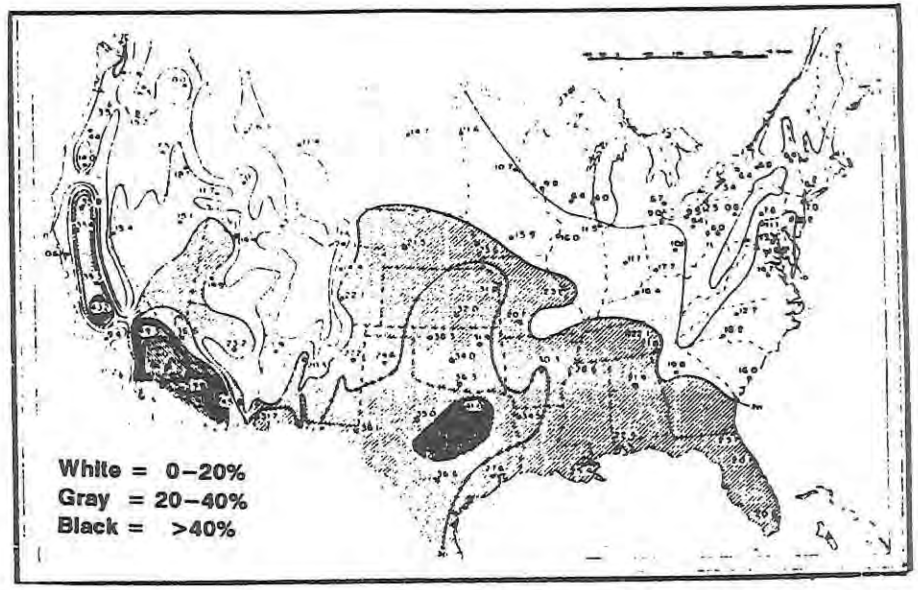


Figure 4. Percent of hourly temperatures above 85F, June, July, August
(Based on summary of observations at 102 places 1935–1939. Compiled from microfilm tabulation of U.S. Weather Bureau, Environmental Protection Section, Research & Development Branch, Military Planning Division, Office of the Quartermaster General, Washington, D.C., June 1951.)

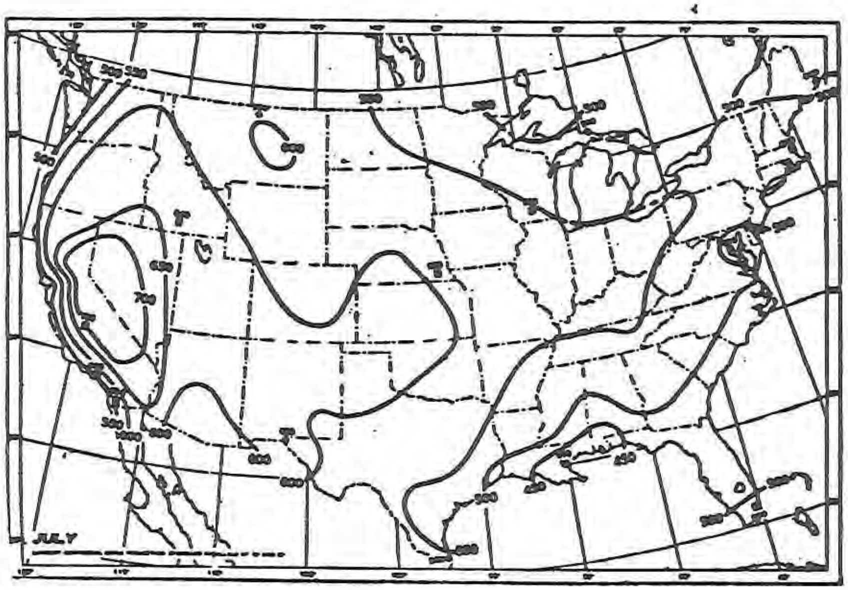


Figure 5. Average daily solar radiation for July, in langleys per day

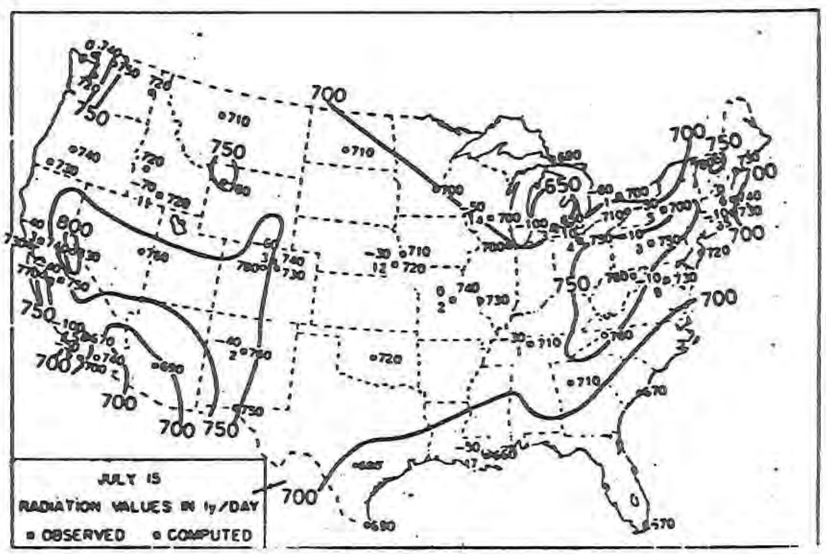


Figure 6. Average cloudless day solar radiation for July 15 in langleys per day

d. Procurement of CVs: Excess commercial CVs used in ODS became available to valid consumers and users in late 1991. Through the Troop Support Division, Office of the Deputy Chief of Staff for Logistics, three commercial CVs containing, respectively, B Rations, Meal-Ready-to-Eat (MRE), and Tray Pack (T) rations were procured. The vans were shipped to Yuma from Oakland Depot, California, where they had been stored after return from Saudi Arabia. Funding for installing temperature recording equipment, downloading of data, and data analyses was obtained from research funds available for ODS-related issues.

e. History of CVs: The history of the CVs and their contents during 1991 is largely unknown. It is known that the rations were shipped from the U.S. by sea (approximately one month) to Saudi Arabia soon after January or February 1991 when the rations were produced. During the conflict they were stored in an unknown manner, but presumably in CVs on desert sand, either alone or as part of a vertical stack of vans, which was customary (and which is a much cooler environment for the vans below the topmost one). The vans were shipped back by sea by November 1991, having endured a desert summer. After extensive negotiation by Natick, the vans containing the rations were transported to YPG, where they remain as an available heat stress laboratory for ration storage.

f. Findings: The results in this report concern the thermal stress on rations stored at YPG beginning in the summer of 1992. YPG is continuing to download temperature recordings at least through June FY93 and a later report will discuss the findings over a one-year period.

II. Research Methods

a. Site and Situation: The three CVs are sited (Figure 7) at the Material Test Area of YPG, at an elevation of 350 feet on a large alluvial fan sloping from Castle Dome Mountain about 25 miles north of Yuma, AZ and three miles east of the extensive spillways and impounded water areas of the Imperial and Laguna Dams. The site is in the southwest corner of the U.S. and has one of its most extreme hot-dry conditions.

b. Location and Orientation of Vans: The vans are placed 20 feet apart in a lengthwise line oriented 120^{o}-300^{o} from true north, and 500 feet from any large building (Figure 8). They are set with their bottom steel members flush with the desert surface, and from west to east are: B Ration van, MRE van and T Ration van (Figure 9). Doors of the vans are on the west end. There is a line of parked, camouflaged vehicles 60 feet south. The surface is light

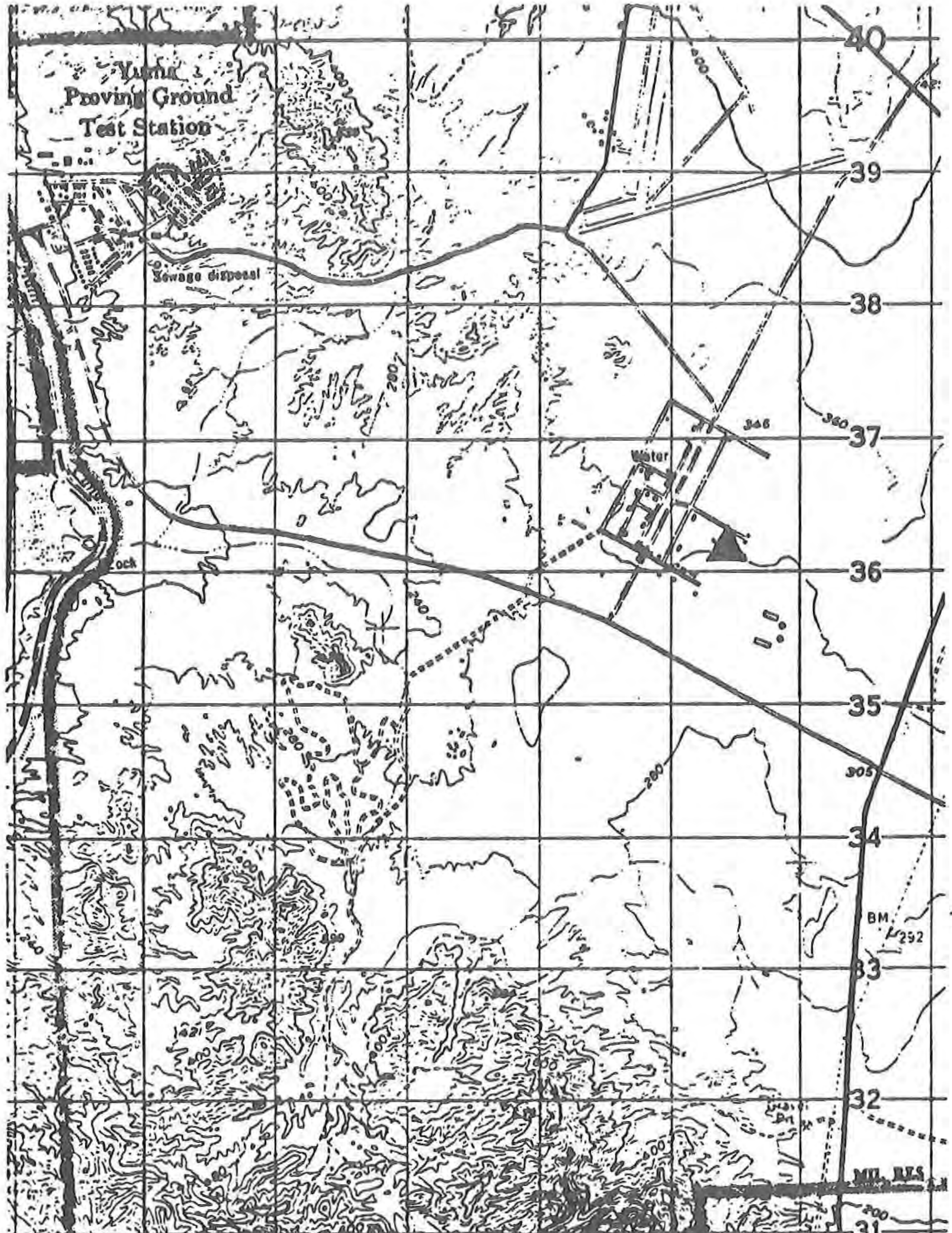


Figure 7. U.S. Army Yuma Proving Ground, Mobility Test Area

▲ = Location of container vans

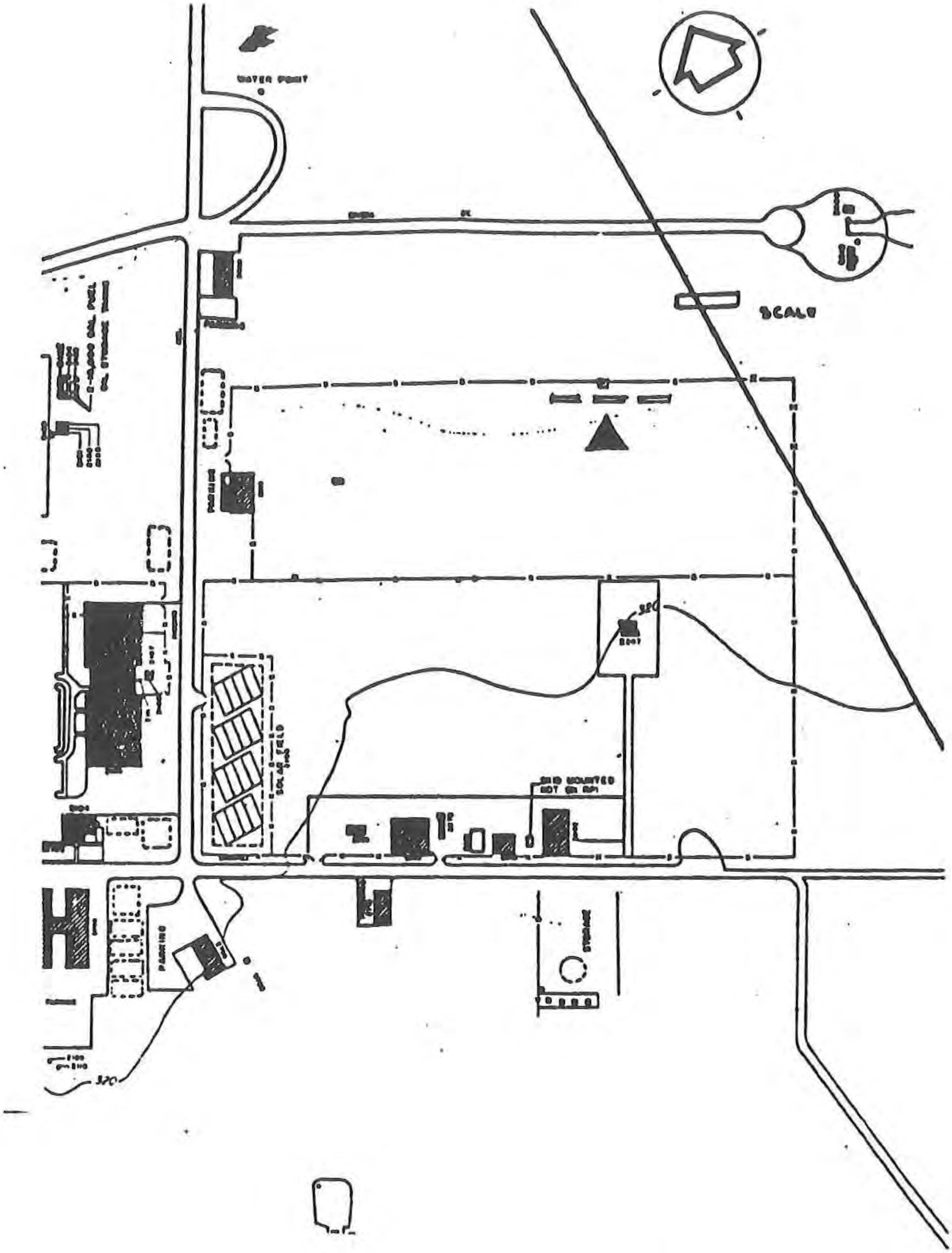


Figure 8. U.S. Army Yuma Proving Ground, Mobility Test Area Headquarters/Materiel Test Area

▲ = Location of container vans

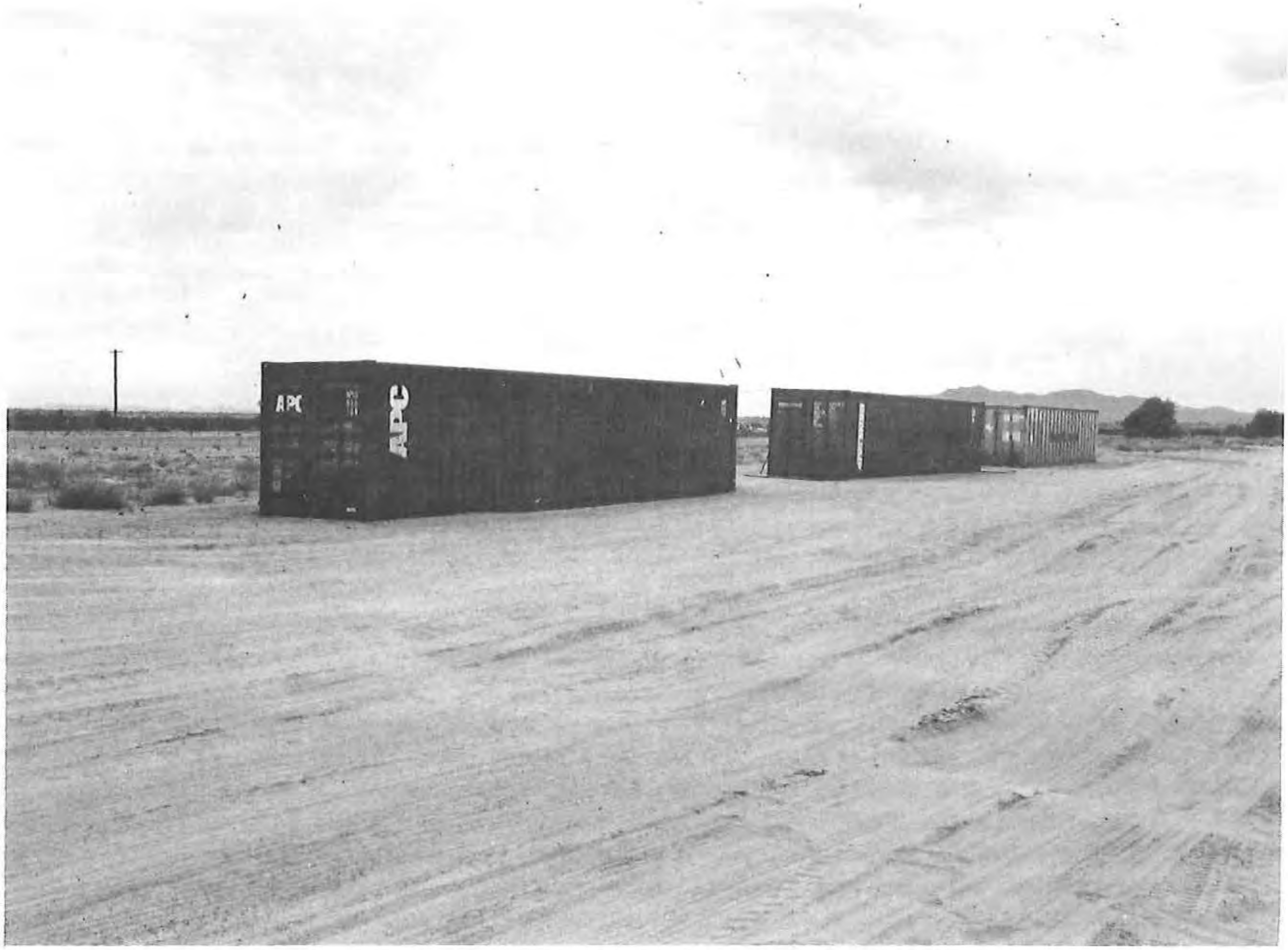


Figure 9. Container Vans for Ration Storage Test at Yuma Proving Ground. There is a twenty foot distance between vans for (left to right) Ration, MRE, and T Ration storage.

desert sand plain with numerous small rock fragments having a dark wind-derived patina characteristic of the desert. Albedo of such a surface at Blythe, CA has been determined to be 25%, as compared to 6% for black tarpaulin material. The Yuma Meteorological Team main observing station is less than 1000 feet southwest, affording abundant confirmatory observations of ambient air temperature as well as soil surface temperature, 45^{o} and horizontal surface solar radiation, dewpoint, windspeed and direction.

c. Characteristics of Vans: Tables 1 and 2 show salient features of the vans.

d. Characteristics of Loads: The MRE and T vans were delivered from Oakland, CA on 21 February 1992, while the B van was delayed until 17 March 1992. For all three, however, it is clear that they were exposed to the Yuma thermal stress since early spring, a sufficient period to attain thermal equilibrium for entering the critical summer season. Measurements commenced on 18 June at 1400 hours, Julian calendar 92170. Characteristics of the load are shown in Table 3.

e. Insulation: In each van, rations were stacked, as received, two pallets high. One-half of the pallets were left uncovered, as received, except for the installation of thermocouples. Over one-fourth of the pallets, one layer of empty ration cases (closed) was placed on top for insulation. In the remaining fourth of the van, one inch of rigid foam insulation, foil faced on both sides, was placed on top of the pallets for insulating purposes.

f. Measurement Procedures: Thermocouples were placed in a total of 64 locations in the three CVs and outside air. Temperatures were measured and recorded on an hourly basis using the T-type thermocouples, 2 in a shelter in the outside air, 38 in the MRE van (Figure 10), and 12 in each of the T ration (Figure 11) and B ration (Figure 12) vans. All temperatures in this report are stated in degrees Fahrenheit.

g. Ambient Air Measurement: Ambient air temperature was recorded by two thermocouples 4" apart suspended 9" above the bottom of a white wooden shelter 9" wide, 6 1/2" deep and 16" high (Figure 13). There was a 4" hole in the floor of the shelter, the bottom of which was 4' above the desert surface, 23' north of the center of the MRE van and 18'8" east of the northward projection of its west end. There were also about 10 small (1/4") holes in the east and west faces of the shelter. A black solar energy collector panel (13"X13") was located on the roof of the shelter, in order to recharge the Campbell Micrologger data recorder. This seems like an unwarranted

TABLE 1. EXTERIOR PHYSICAL CHARACTERISTICS OF VANS

RATION TYPE	DIMENSIONS	EXTERIOR COLOR	COMPOSITION ROOF	COMPOSITION WALLS	COMPOSITION DOOR	CONFIGURATION ROOF	CONFIGURATION WALLS	CONFIGURATION DOOR
B RATION	8'X8'X40'	DARK BROWN RUSTOLEUM	STEEL SINGLE SHEET	STEEL SINGLE SHEET	STEEL SINGLE SHEET	FLUTED 9"-4" TRANSVERSE	FLUTED 9"-4" VERTICALLY, EAST END HORIZONTALLY	FLAT
MRE	8'X8'X40'	LIGHTER RUSTOLEUM	STEEL SINGLE SHEET	STEEL SINGLE SHEET	STEEL SINGLE SHEET	FLUTED 9"-4" TRANSVERSE	FLUTED 9"-4" VERTICALLY, EAST END HORIZONTALLY	FLAT
T RATION	8'X8'X40'	DIRTY LIGHT GREY	STEEL SINGLE SHEET	STEEL SINGLE SHEET	STEEL DOUBLE SHEET	FLAT	RIBBED EVERY 2' VERTICALLY	FLAT

TABLE 2. INTERIOR PHYSICAL CHARACTERISTICS OF VANS

RATION TYPE	FLOOR	SHEATHING	HEAD SPACE	FROM WALLS OR OTHER PALLETS	DOOR TO PALLETS
B RATION	WOOD OVER STEEL	NONE	13"	FLUSH WITH WALLS 2-3" BETWEEN NORTH AND SOUTH PALLETS	2.5 FEET
MRE	WOOD OVER STEEL	NONE	18"	4-5" WALLS TO PALLETS	8"
T RATION	WOOD OVER STEEL	1/4" PLYWOOD FLOOR TO 4'	11"	2" LEFT, 1" RIGHT WALLS TO PALLETS	2 FEET

TABLE 3. CHARACTERISTICS OF CONTAINER VAN LOADS

RATION TYPE	WEIGHT (LB) GROSS	WEIGHT (LB) TARE	WEIGHT (LB) NET	STACKING (PALLETS) ROWS (SIDE)	STACKING (PALLETS) HIGH	STACKING (PALLETS) ROWS (LENGTH)	DATE OF PACK	RATION CONTENTS
B RATION	67200	7520	59680	2	2	10	14 FEB 91	UNITIZED B RATIONS 100 MAN MODULES
MRE	67120	8500	58620	2	2	9	22 JAN 91	MEAL, READY-TO-EAT INDIVIDUAL 12 MEALS/CASE
T RATION	67200	6000	61200	2	2	10	JAN 91	UNITIZED TRAY PACKS 36 PERSON MODULES

Figure 10. MRE Container Van with Doors Open and Ration Cartons Visible. Dr. and Mrs. Porter Inspect Rations in the 1990's Follow-up of 1950's Study.

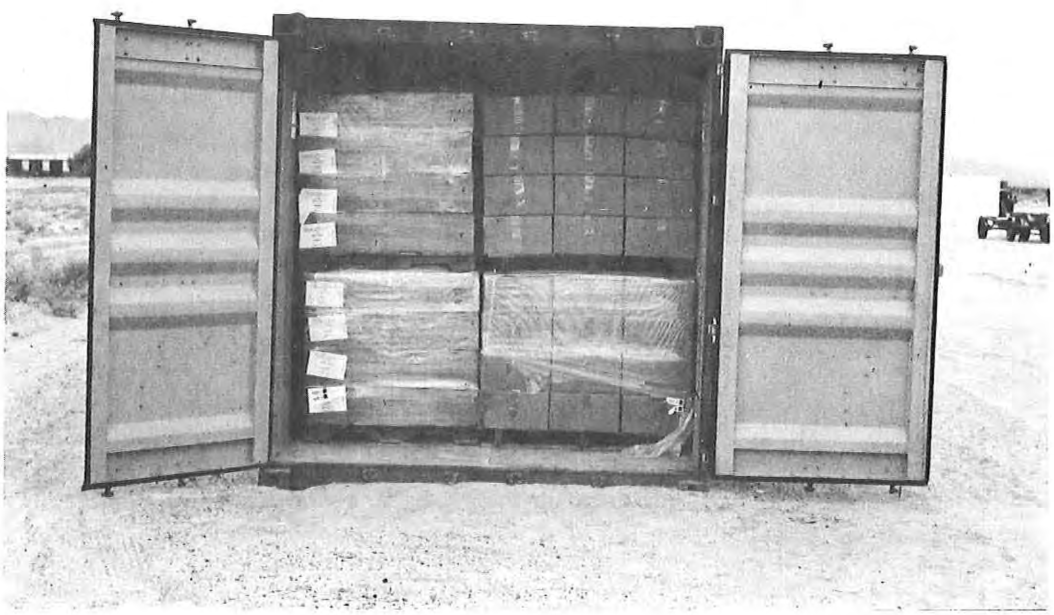


Figure 11. T Ration Container Van with Doors Open and Ration Cartons Visible.

Figure 12. B Ration Container Van with Doors Open and Ration Cartons Visible.

Figure 13. Shelter with Thermocouples for Measuring Outside Ambient Temperature. Door is closed during use.

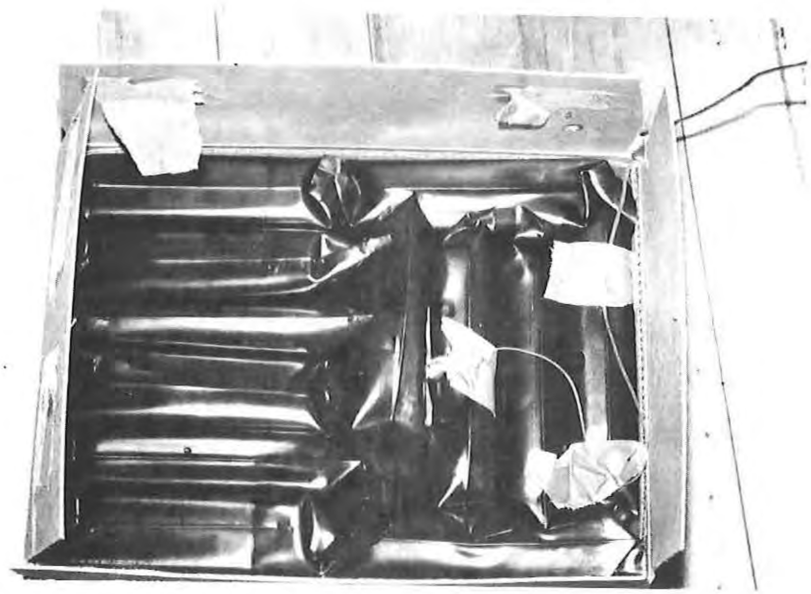


Figure 14. Open Case of MRE Rations with Thermocouples Attached

heat source for the shelter. The two thermocouples gave very similar readings throughout the summer, but it was felt that the setup was not a perfect replica of a standard instrument shelter, as evidenced by the fact that ambient temperature in the shelter was three degrees higher at maximum than that measured at the Yuma Meteorological Team standard shelter 1000' southwest. For this reason, a standardized thermocouple probe in an approved reflective metal (nested hemispheres) shield is being installed to check the current installation. If readings are discordant, the Yuma Meteorological Team readings for the entire summer will be used.

h. Carton Temperature Measurements: Thermocouples for measuring carton temperatures were attached to the inside of the carton, on the top surface of the rations as shown in Figure 14.

i. Data Recording: Reading and storage of the data is by a Campbell Micrologger located next to the north face of the MRE van 9' east of its west end. Temperature calibration is by isopoint reference and time is checked periodically for any drift occasioned by the heat. Data was downloaded weekly onto disk and forwarded to Natick for analyses.

j. Data Analyzed: The configuration of the ration pallets, with insulation, is shown in Figures 15 and 16. For the purposes of this report, only six temperatures in each van will be reported, and only for the most extreme day of the summer. Due to the repetitious nature of the daily cycle, and the correlation of its mean with the ambient temperature mean for weekly periods, the hottest day can be very informative about the relative storage temperature stresses in the various vans and under two different protective measures. A list of the reported positions is shown in Table 4, together with their thermocouple number, by which they are reported in later graphs.

k. Time-Temperature Integration: Time-temperature indicator (TTI) labels are also being used in the study as integrators to measure the heat stress that rations are subjected to in a desert environment. The TTI labels used were manufactured by LifeLines Technologies and contain a substituted diacetylene monomer that initially is white and eventually becomes bluish and purplish upon polymerization (6). The label is self-adhering with a bar code section for identification and a temperature sensitive patch section where the thermal integration and heat-induced polymerization occur.

For a given food quality loss reaction, rate generally increases with temperature. Thus, to replicate at a constant temperature the effects of a series of varying storage temperatures, more weight must

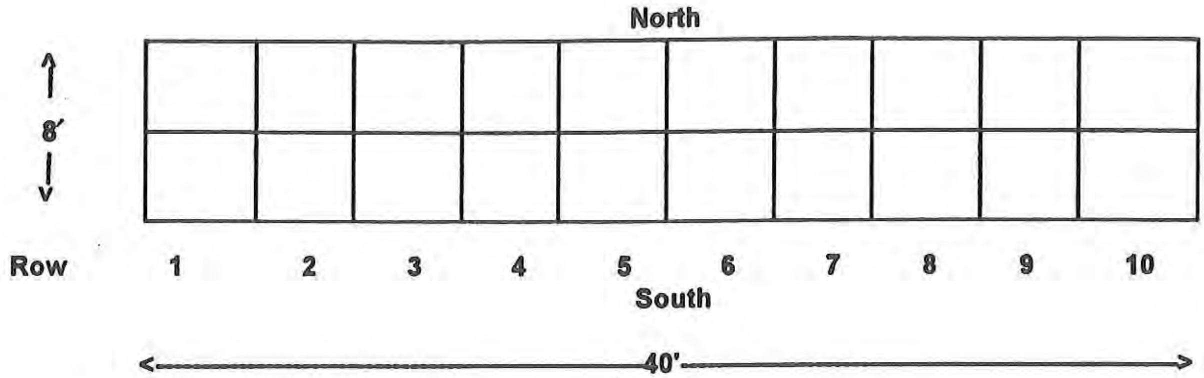


Figure 15. View from top showing container van with paired rows. Insulation on top(not shown)was cardboard cartons(Rows 6, 7, 1/2 of 8) and rigid foam with foil top and bottom (1/2 of 8, Rows 9, 10). *Not to scale*

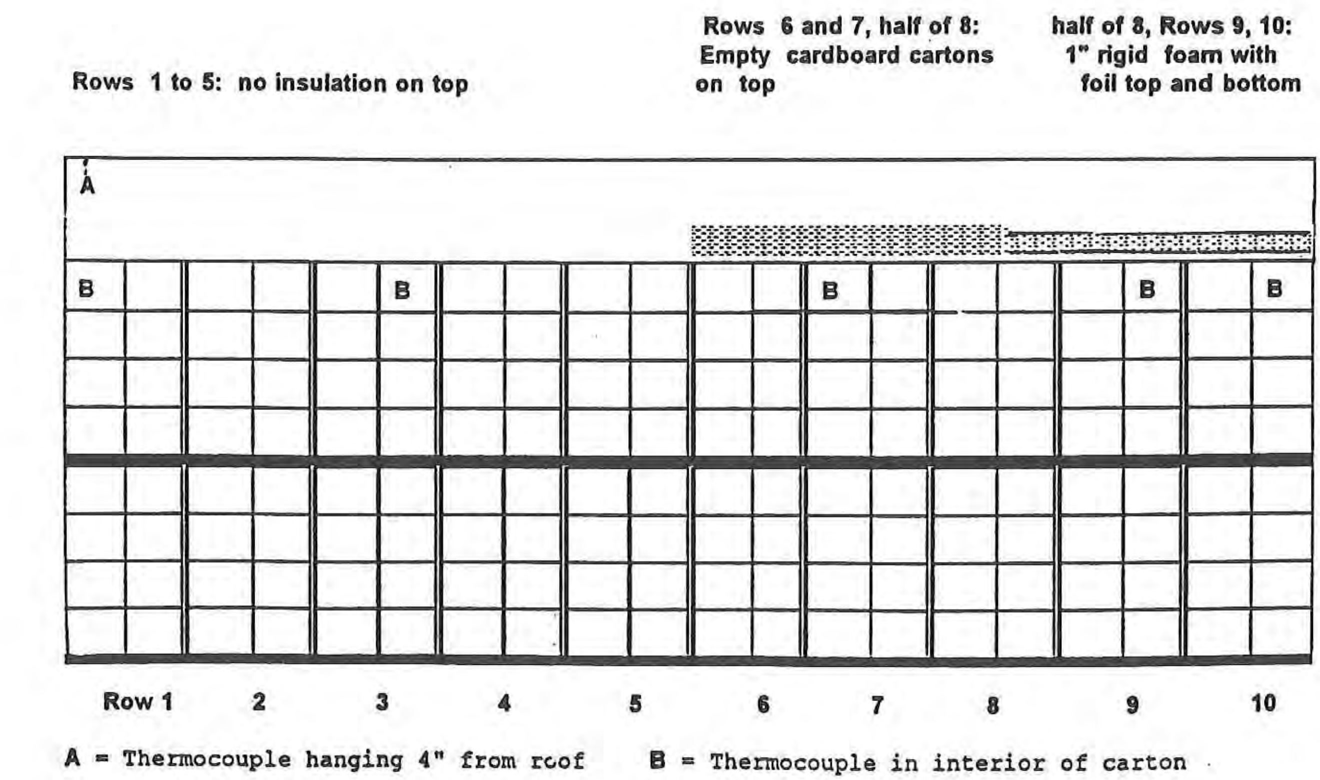


Figure 16. Side view of T Ration storage in 10 (paired) rows of four tiers per pallet. MRE Ration had 9 (paired) rows of six tiers per pallet. B Ration had 10 (paired) rows with cases of varying size depending on the content. *Not to scale*

TABLE 4. LOCATION OF CONTAINER VAN THERMOCOUPLES USED IN DATA ANALYSES

B RATION		T RATION		MRE		
THERMO-COUPLE NUMBER	CODE	THERMO-COUPLE NUMBER	CODE	THERMO-COUPLE NUMBER	CODE	LOCATION
1	AA1					Ambient Air (Outside)
4	B1RTA	16	T1RTA	28	MIRTA	Roof Air (hanging 4" below roof)
5	B1ST	17	T1ST	29	M1ST	SW corner, on top of carton, uncovered
7	B3ST	19	T3ST	31	M3ST	Row 3 south, inside top carton
9	B6ST	21	T6ST	33	M6ST	Row 6 south top, inside top carton covered with empty cartons
11	B8ST	23	T8ST	35	M8ST	Row 8 south, inside top carton covered with 1" double foil-faced styrofoam insulation
13	B9ST	25	T9ST	37	M9ST	SE corner, inside top carton covered with 1" double foil-faced styrofoam insulation

NOTES:

1. MRE, T Ration and B Ration thermocouples were placed inside cartons on second layer from bottom of top pallet and bottom layer of bottom pallet.

2. Additional placements of thermocouples were made on all three rations as shown in Appendix B. Findings will be described in a forthcoming report.

be given to the higher temperatures. In other words, the effective mean temperature will always be higher than the arithmetic mean. The weighting constant is the activation energy (or in a more approximate form, the Q_{10}). This constant will vary depending on the food reaction, be it Maillard browning, ca. 26 kcal/mole, or lipid oxidation, ca. 13 kcal/mole. The reaction used for the TTI has an activation energy of about 28 kcal/mole, but the TTI computer program can resolve any measured series of varying storage temperatures into an effective mean temperature, adjusted for the appropriate food reaction activation energy. Thus, the decreasing reflectance readings integrate the varying time-temperature exposure, based on an activation energy of 28 kcal/mole, but they can be used to compute the integrated effect for any food reaction whose activation energy is known. The ability to correlate the reflectance with the food quality loss makes the direct measurement of temperature unnecessary.

Two different labels were used in the application, Models 11 and 30. Model 11 has an indicator patch of MC (Material Code) 11. Model 30 has two patches, MC11 and 18 which change at different rates. For the purposes of this report, only data from some of the Model 30 labels will be presented. TTI labels were applied to selected cartons in the vans so that most of the labels would be adjacent to a thermocouple for comparison and in locations that would be accessible for scanning without moving pallets or otherwise disturbing the integrity of the total load (Figure 17). Appendix B lists the serial numbers of the time-temperature indicators and the corresponding thermocouple code numbers.

1. <u>Effects of High Temperature Storage on Ration Components</u>: As discussed earlier, the rations contained in the vans upon receipt are being used only to represent the thermal mass of food, rather than for food quality evaluations, due to the lack of exact history. However one case of the MRE Rations was opened and evaluated informally at the time thermocouples were installed (June 1992). Three cases of MRE Rations (Procurement X) were then substituted in the MRE van to replace three cases of rations that came with the van. The substitute rations were removed from the van and returned to Natick after storage for a summer at YPG. Additional cases of MRE XII Rations were put into the van for evaluation of sensory quality after one year of storage at YPG.

Rations placed in storage for the summer in the CVs at YPG were removed on 18 September 1992 and returned to Natick where they were evaluated along with samples stored at Natick at 40^{o}F. Sensory evaluations were conducted on five shelf-stable MRE items, applesauce, cheese spread, grape jelly, peanut butter, and escalloped potatoes with ham. These products are being studied in an on-going

Figure 17. Time-Temperature Indicator Labels on Outside of Ration Cartons.

research effort that evaluates items in long-term storage (three years) at 40°F and 80°F with items stored at higher temperatures (100°F, 120°F, and 140°F) for as long as the quality permits. The evaluations were conducted by a panel of food technologists who used quality rating questionnaires developed for those products. Color readings to measure L*a*b* values were taken prior to sensory evaluations using a portable colorimeter (Hunter MiniScan Model MS/S).

III. Results

a. <u>Comparison of Yuma Climatic Record with Summer 1992</u>: Recent climatological data have changed little from a summary by Porter et al. (5) of the 1950s. The absolute maximum temperature is now considered to be 121°F (June 1990). Not mentioned in the quote below is the striking rise in dewpoint temperature which often occurs at about the second week in July and persists into mid-September. This is the so-called "Arizona monsoon", which is caused by the appearance of moisture at high levels advected from the Gulf of Mexico. Its effects are felt in a sharp rise in nighttime soil and ambient temperature minima stemming from the back infrared radiation to the ground by water molecules. Daytime maxima are much less affected, but both ambient and induced storage temperature means are elevated substantially in July and August.

The following summary is quoted from Porter, et al.(5).

> Yuma Test Station experiences a hot desert climate with no distinct season of rainfall. There are long, hot summers and cool winters, a large daily range of temperature, generally low humidities, and deficient rainfall. Skies are usually clear and percent of possible sunshine in winter and summer is at the maximum for the United States. Yuma is near the center of an area having the greatest frequency of hourly temperatures over 85°F in the United States (over 60%). The combination of the high temperatures possible at low elevations and the relatively high radiation load produces a heat stress on and within objects at the surface which is comparable to the extremes to be found anywhere in the world. The hottest month, July, has a mean temperature of 91°F, and a mean maximum of 106°F. The absolute maximum, 123°F, occurred in September 1950. The mean monthly dewpoint of 59°F for July was used in comparing

humidities, though August, with a value of 64°F, is more humid. In January the mean temperature is 55°F and the mean minimum 42°F. Of the scanty annual rainfall, two-thirds of the total, 3.4 inches falls in the winter months. However, occasional thundershowers give August the heaviest mean monthly rainfall. Rainfall from one year to another is highly variable, ranging from a record low of 0.31 to a high of 11.41 inches. Wind speeds are light throughout the year, and consequently visibility restriction by blowing dust is not critical. In July the mean wind velocity is 6.1 miles per hour. The prevailing wind direction is southwest in the warmest month and north in the coldest month. Mean cloud cover, sunrise to sunset, is 1.6 tenths in July, and skies are clear 80 percent of the time in this month.

Tables A-1, A-2, and A-3 in Appendix A show the monthly climatological summaries for YPG during June, July and August 1992. The tables show the appearance of the dewpoint rise on 6 July. Table 5 is a brief comparison of 1992 climatological data with the long-term record norms.

b. <u>Storage and Ambient Temperatures on the Most Critical Day</u>: On August 16 the YPG weather station experienced a maximum ambient temperature of 114°F, a minimum of 90°F, and a mean of 103°F, making it the most thermally stressful day of the summer. Table 6 shows for each of the three vans the ambient and selected induced storage temperature means, standard deviation and maxima. Included are the air 4" from the roof, and air in the top southernmost cartons

TABLE 5. CLIMATOLOGICAL CONDITIONS: COMPARISON OF TEST PERIOD (1992) WITH LONG-TERM CLIMATOLOGICAL NORMS, YUMA PROVING GROUNDS

	TEMPERATURE (F) MEAN		TEMPERATURE (F) MEAN MAX		DEWPOINT (F) MEAN		WINDSPEED (MPH) MEAN		DAILY RADIATION (LANGLEYS) MEAN	
	1992	NORM	1992	NORM	1992	NORM	1992	NORM	1992	NORM
JULY	94	91	105	106	53	59	4	6	665	620
AUGUST	94	90	105	104	65	64	5	6	606	575

TABLE 6. TEMPERATURES (F) OF HOTTEST DAY: RATION CONTAINER VANS

MRE VAN

	OUTSIDE AMBIENT	INSIDE ROOF AIR	TOP CASES				
			CORNER		MIDDLE		EMPTY BOXES
			NO INSUL	INSUL	NO INSUL	INSUL	
THERMOCOUPLE NO.	1	28	29	37	31	35	33
MEAN (F)	104	113	109	109	110	108	108
S.D.	9.2	17.8	3.8	2.6	4.3	2.4	2.3
MAX. (F)	117	144	115	114	116	111	112

B RATION VAN

	OUTSIDE AMBIENT	INSIDE ROOF AIR	TOP CASES				
			CORNER		MIDDLE		EMPTY BOXES
			NO INSUL	INSUL	NO INSUL	INSUL	
THERMOCOUPLE NO.	1	4	5	13	7	11	9
MEAN (F)	104	115	111	114	111	112	110
S.D.	9.2	20.3	5.2	5.3	3.2	3.1	1.2
MAX. (F)	117	151	119	122	116	117	112

TRAY RATION VAN

	OUTSIDE AMBIENT	INSIDE ROOF AIR	TOP CASES				
			CORNER		MIDDLE		EMPTY BOXES
			NO INSUL	INSUL	NO INSUL	INSUL	
THERMOCOUPLE NO.	1	16	17	25	19	23	21
MEAN (F)	104	112	109	111	111	102	109
S.D.	9.2	16.5	5.7	2.6	7.0*	12.5*	2.2
MAX. (F)	117	142	118	114	122*	117*	113

* BELIEVED TO BE DEFECTIVE POSITIONING OF THERMOCOUPLES

of rows 1, 3, 6 or 7, 8 or 9, and 9 or 10, embracing unprotected (rows 1, 3), empty carton-covered (row 6) and insulation-covered (rows 8,9, or 10) cartons. Figures 18, 19 and 20 show these data graphically.

In contrast to the extreme temperatures reached in the roof air (142°F-151°F), maximum temperature in the air in the unprotected top cartons, little more than one foot distant, rarely exceeded 120°F in any of the vans. Indeed, it tended to cluster around 116°F-118°F, comparable to the ambient air maximum. Protection measures reduced this only 4-5 degrees, empty cartons being as effective as, and in some cases more effective than, commercial insulation. On the other hand, mean daily storage temperatures in the unprotected top cartons were 5-7 degrees higher than ambient mean. Protection measures reduced these only 1-2 degrees. This is substantially less than reductions observed in boxcars (10-15 degrees maximum and 4-5 degrees mean) when foil shielding with foil-faced kraft paper was used (2).

The smaller effect in the present study is probably related to the fact that cartons in this study were located against the south wall as opposed to the top center and that the walls were unsheathed, unlike the wooden-sheathed walls of boxcars. Table 7 shows the contrasting temperatures in boxcars and CVs. This shows that the hottest day for the CV test was substantially warmer than for the boxcar test carried out nearly 40 years before, but that induced interior temperatures differed significantly only in the top carton mean air temperature.

TABLE 7. COMPARISON OF EXTREME DAY TEMPERATURES IN BOXCARS AND STORAGE DUMPS IN 1950'S AND CONTAINER VANS IN 1992 (F)

LOCATION	1950'S BOXCARS		1950'S STORAGE DUMP		1992 CONTAINER VAN (B RATION)	
	MAXIMUM	MEAN	MAXIMUM	MEAN	MAXIMUM	MEAN
AMBIENT AIR	112	95	112	100	117	104
ROOF AIR	151	114	159 **	119 **	151	115
TOP CENTER CARTON (INTERIOR) *	118	106	118	108	119	111

* CENTER IN BOXCAR AND STORAGE DUMP, SOUTH WALL IN CONTAINER VAN

** POSITION WAS ON UNDER SURFACE OF DARK, OLIVE-DRAB 8 OZ DUCK TARPAULIN COVER

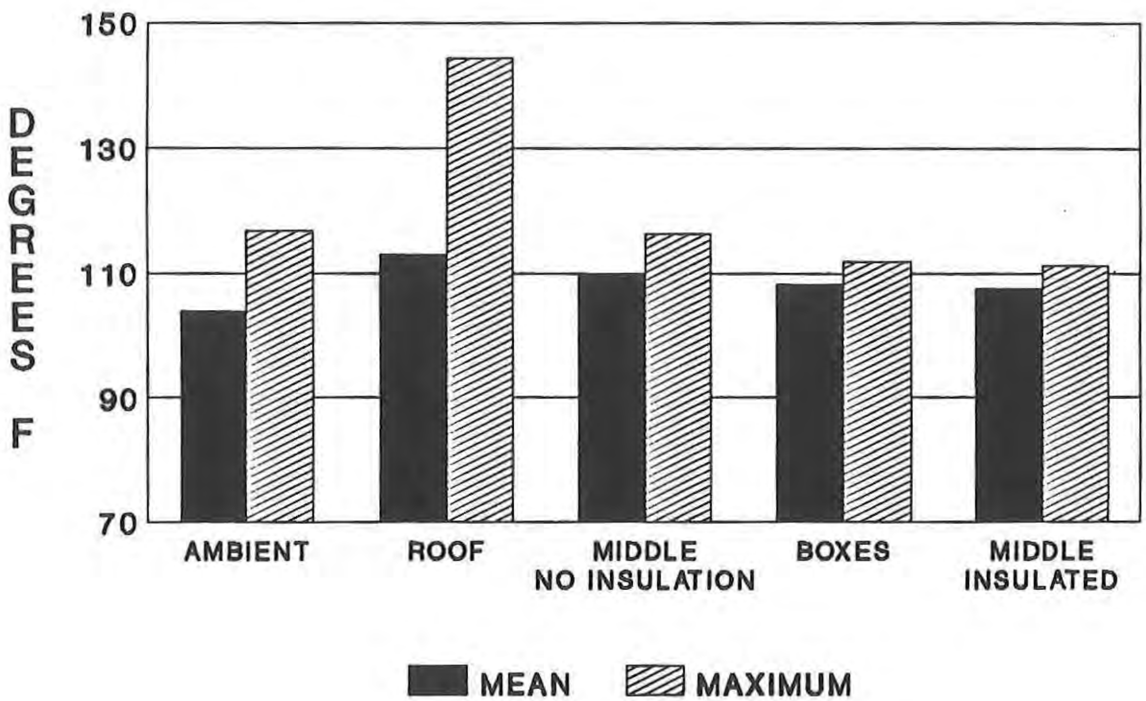


FIGURE 18. MEAN AND MAXIMUM TEMPERATURES
MRE VAN, HOTTEST SUMMER DAY

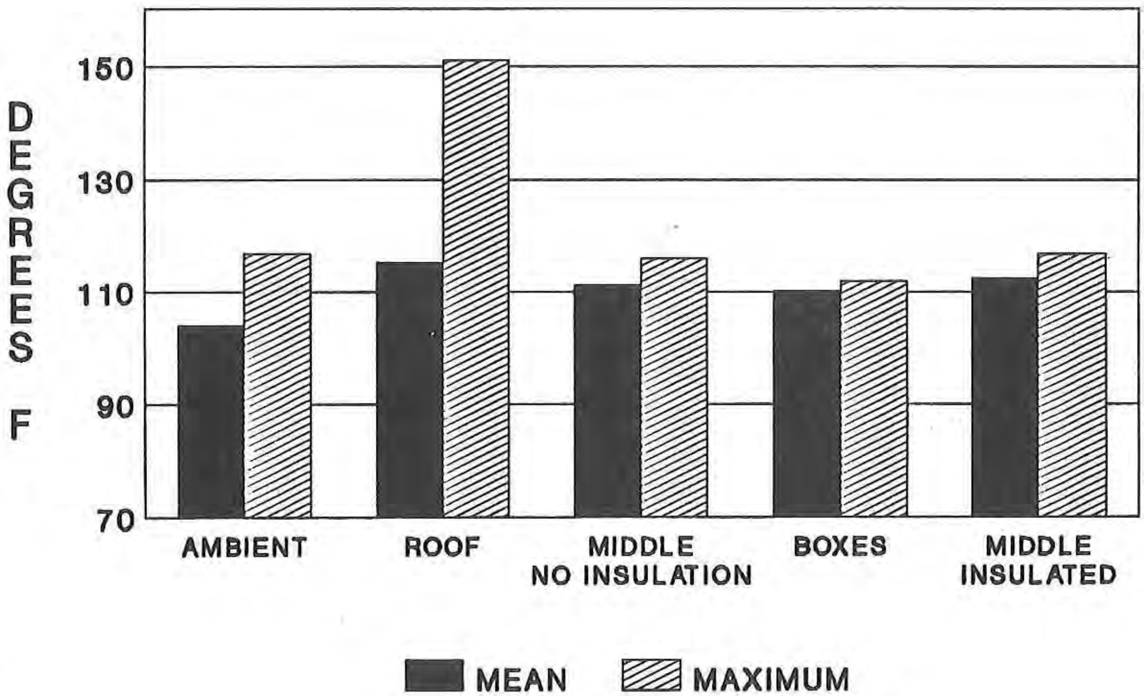


FIGURE 19. MEAN AND MAXIMUM TEMPERATURES
B RATION VAN, HOTTEST SUMMER DAY

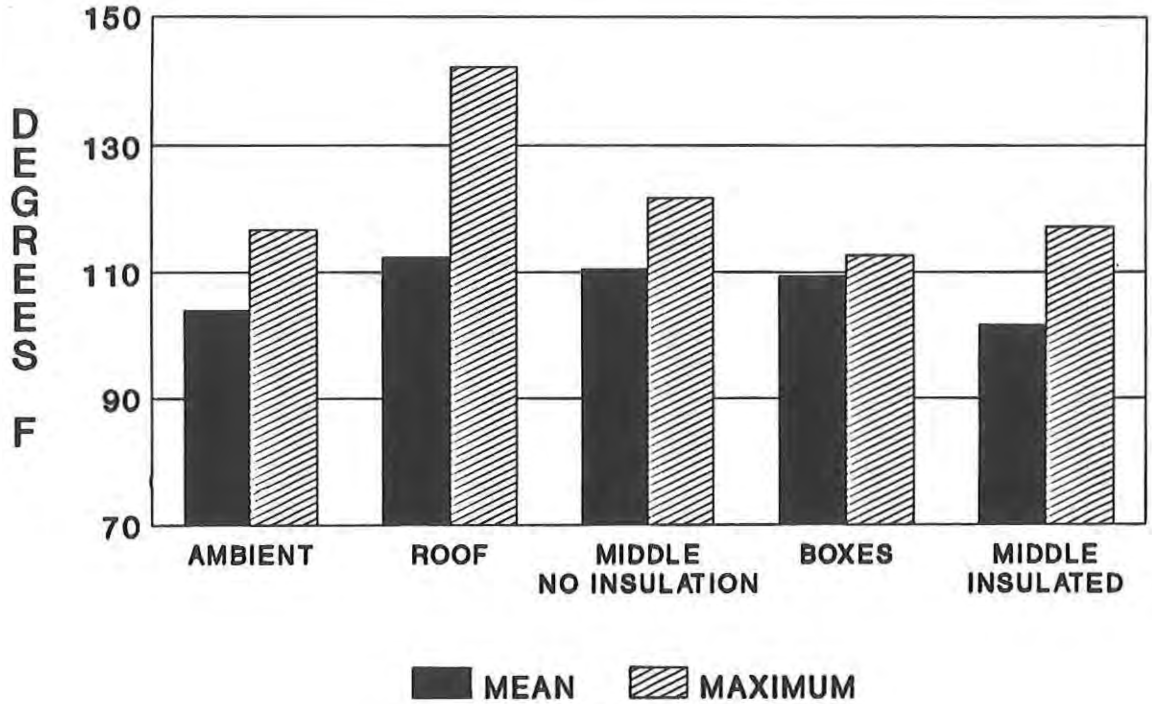


FIGURE 20. MEAN AND MAXIMUM TEMPERATURES TRAY RATION VAN, HOTTEST SUMMER DAY

Experience gained in the boxcar test with measurement of food temperature in relation to carton air temperature suggests that food temperature maximum would be about five degrees lower and the mean about two degrees lower. The B Ration CV was chosen because of the presence of canned items to be comparable, since the boxcar test had mostly string beans in No. 10 cans. Reasons are not clear for the similar maximum but higher mean carton air temperatures in the B Ration CV compared with the boxcar. The volumes of the loads are quite comparable (ca. 1800 cu ft, boxcar to 2250 cu ft, CV), but the CV load is only one foot from the roof compared to five and one-half feet in the boxcar. In addition, the top carton is located on the south wall in the CV compared to the center for the boxcar. Whatever the reason for the higher top carton air mean, it is similar in all three CV types, with different construction, different colors and hence, albedos, and different loads.

This similarity of extreme maximum and mean temperatures in all three vans and the similarity in maximum to the older boxcar (and, indeed, dump storage) data give reassurance that these extreme day data are quite generalizable for different van types, loads and reflectances. Because of the analogy of Yuma to other extreme hot-dry climates, one can be reasonably sure that the day temperatures are representative of the worst "normal" storage conditions. These data, of course, do not reflect such abnormal exposures as that of a ration resting on solar-heated surfaces like desert sand, the top of a tank or of a CV, or on the dashboard of a helicopter cockpit, the latter of which may reach temperatures over 200°F.

It is of interest to compare the daily march of temperature at the locations covered in this report for the extreme day. Figures 21, 22 and 23 show these data for the three CVs. Conspicuous for all three vans is the great range of the roof air, the moderate range of the ambient air due to nighttime cooling and the conservative behavior of the induced temperatures in the cartons. The moderate lowering of the maximum in top carton air caused by empty cartons or insulation is also shown, as is the pronounced lag of induced temperatures behind ambient and roof air, which more closely follow the sun. Empty carton protection appears to be as effective or, in the case of the B Ration, more effective than the commercial insulation. Again, it would appear that the lack of sidewall wooden sheathing causes the side walls to be a major heat source, unaffected by stack top surface protection, which, as noted above, is less effective in CVs than in boxcars.

A plot of the weekly mean air temperature for ambient air and top carton air (MRE van) versus time using the period from 18 June to 14

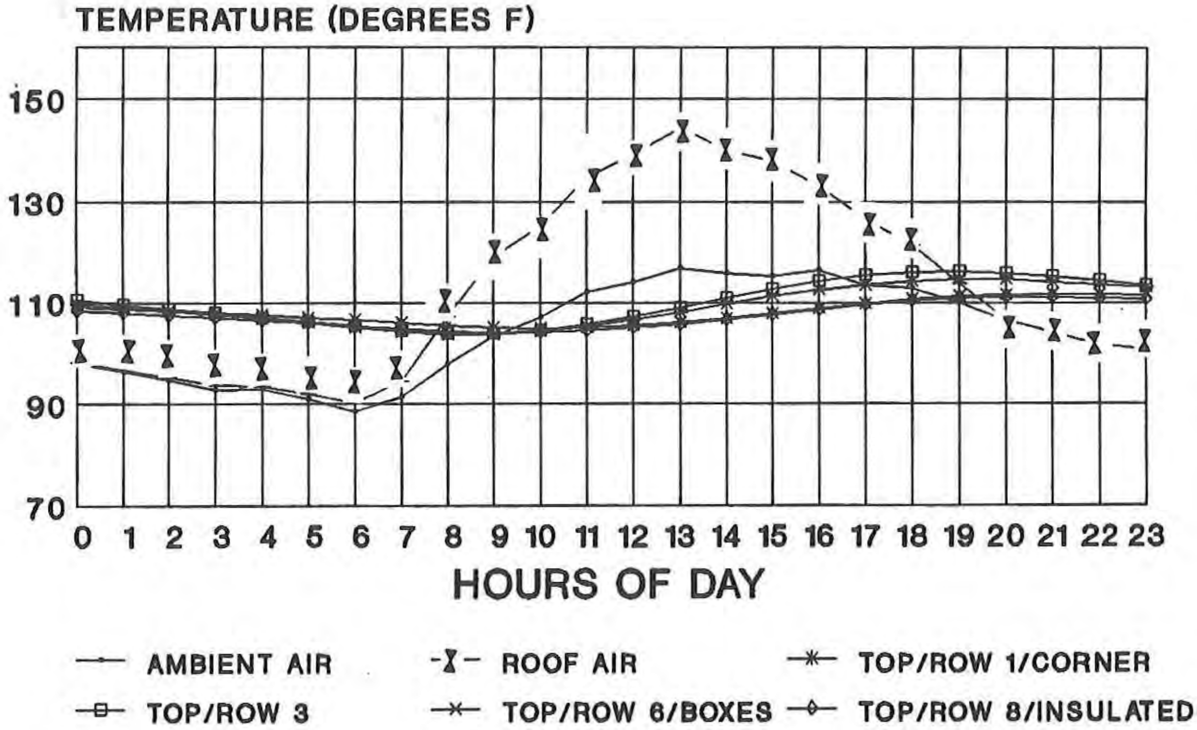


FIG 21. MRE VAN, TEMPERATURES HOTTEST DAY, AMBIENT, ROOF, & TOP CARTON AIR

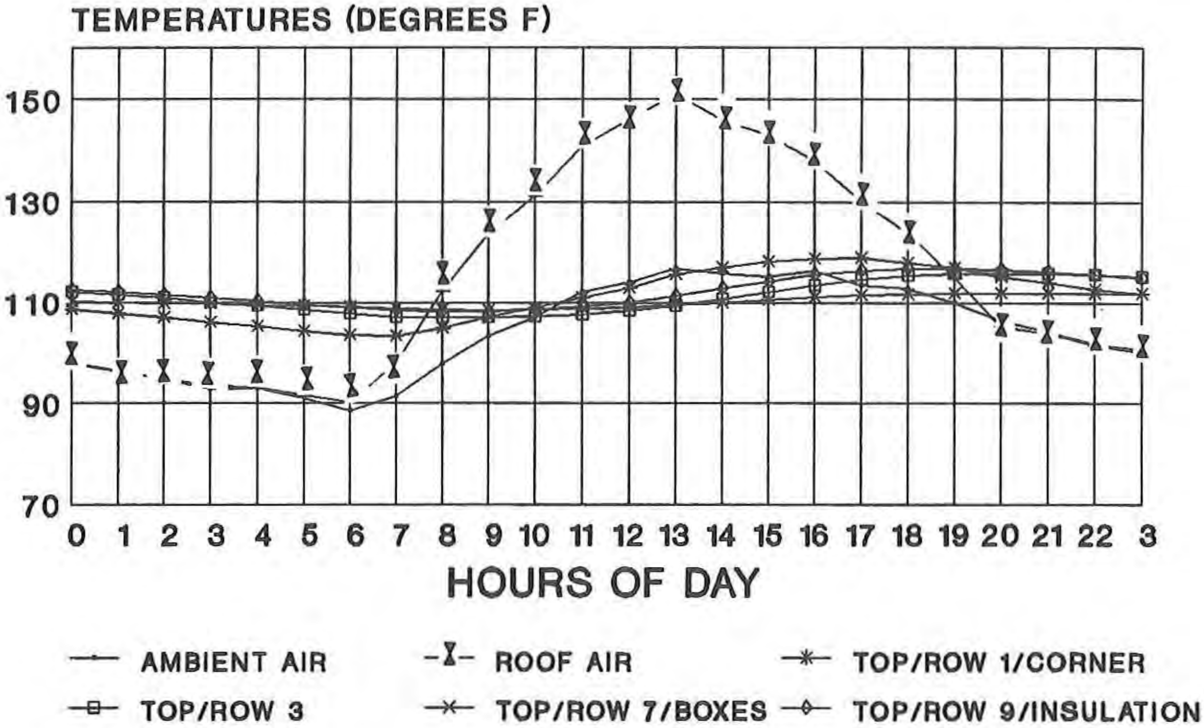


FIG 22. B RATION VAN, TEMPERATURES
HOTTEST DAY, AMBIENT, ROOF, & TOP CARTON AIR

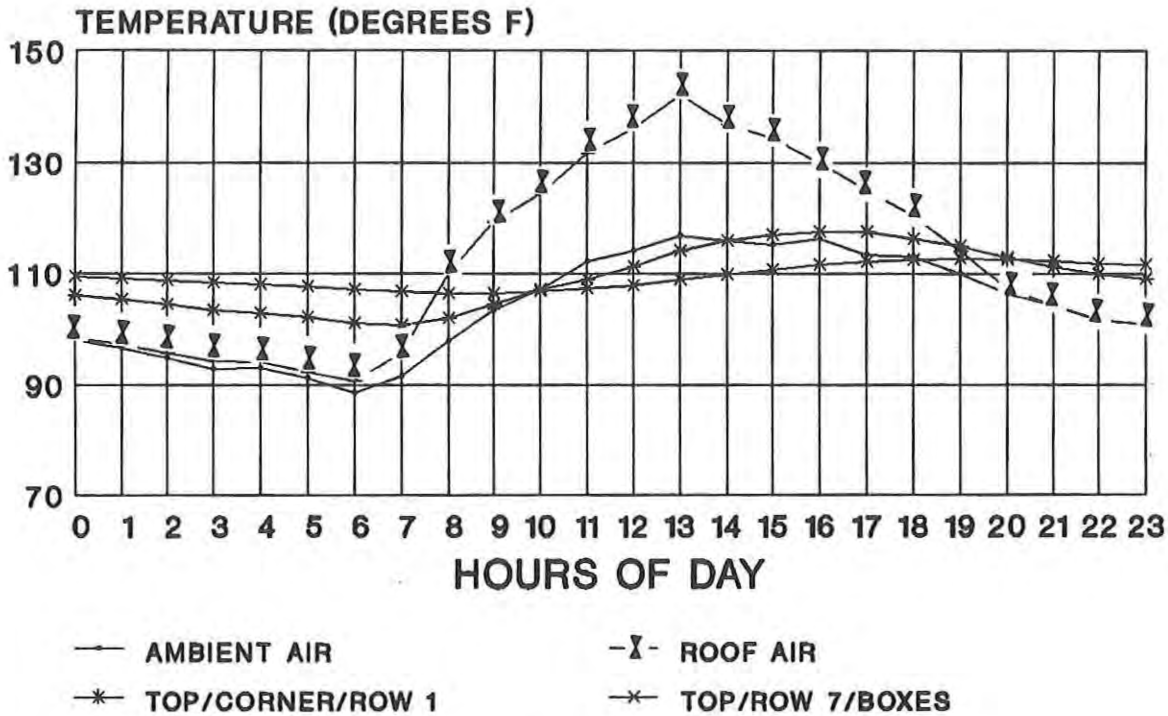


FIG 23. T RATION VAN, TEMPERATURES
HOTTEST DAY, AMBIENT, ROOF, & TOP CARTON AIR

September 1992 is shown in Figure 24. This depicts the close correlation of ambient temperature with the top carton temperature. Figure 25 is a preliminary graph of weekly mean ambient air versus top carton air temperature. In both these figures, week 5 is omitted because of missing data. However, it is clear from this preliminary plot that, except for week 1, which was only three days long, the top carton weekly mean air temperatures show a moderate linear correlation with ambient air weekly mean. Since the range of the data is small (essentially, the three hottest months), it is anticipated that the previous strong positive correlation of the mean induced (interior) storage temperatures and mean outside ambient temperatures for boxcars and storage dumps will prevail in CVs both for weekly and monthly mean temperatures.

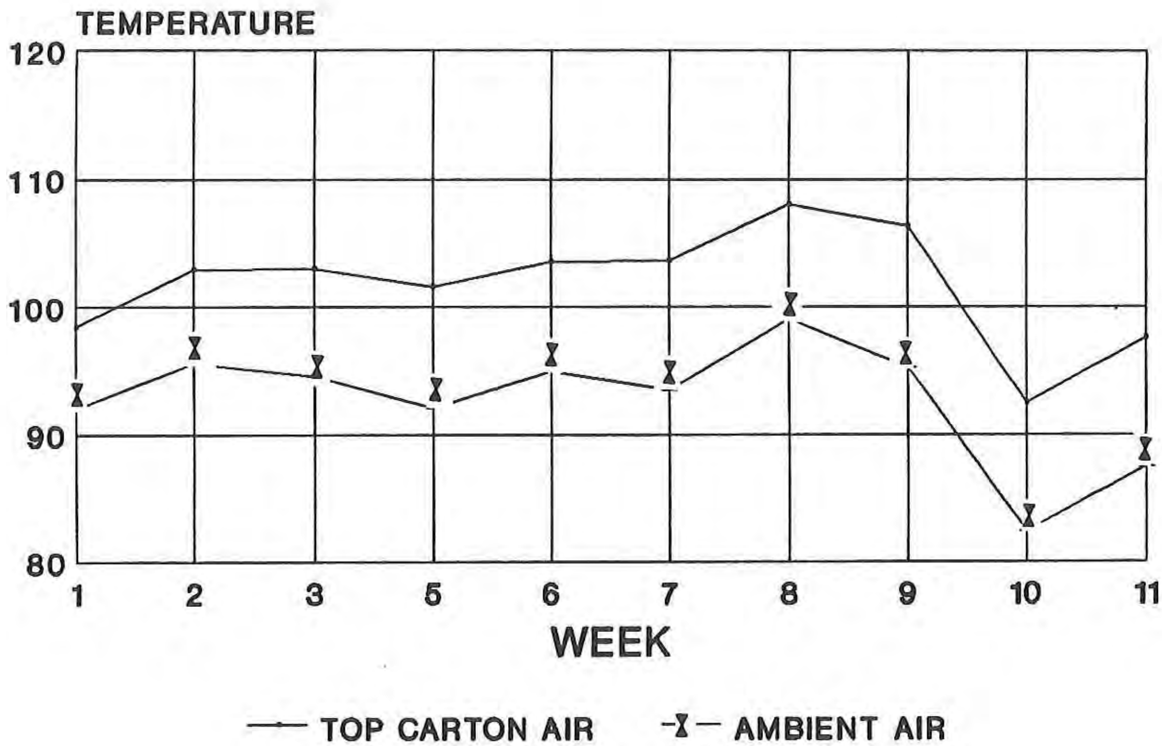
c. Time-Temperature Integration: TTI labels were scanned four times over the summer of 1992 at approximately one-month intervals, including the initial scans made in June 1992. The average reflectance readings from six out of the 56 labels applied to the outside of cartons are listed in Table 8. The two types of indicators, MC18 and MC11, are listed separately because they each have different rates of change at a given temperature. The rate of change is faster for the MC18 than the MC11. The indicators are in the same relative locations in each of the three vans; the top surface of the carton in the first row on the south side at the corner. Locations of the labels and the associated thermocouples are provided in Appendix B.

TABLE 8. COMPARISON OF MEAN REFLECTANCE READINGS BETWEEN VANS IN SUMMER MONTHS

% REFLECTANCE (MODEL 30)

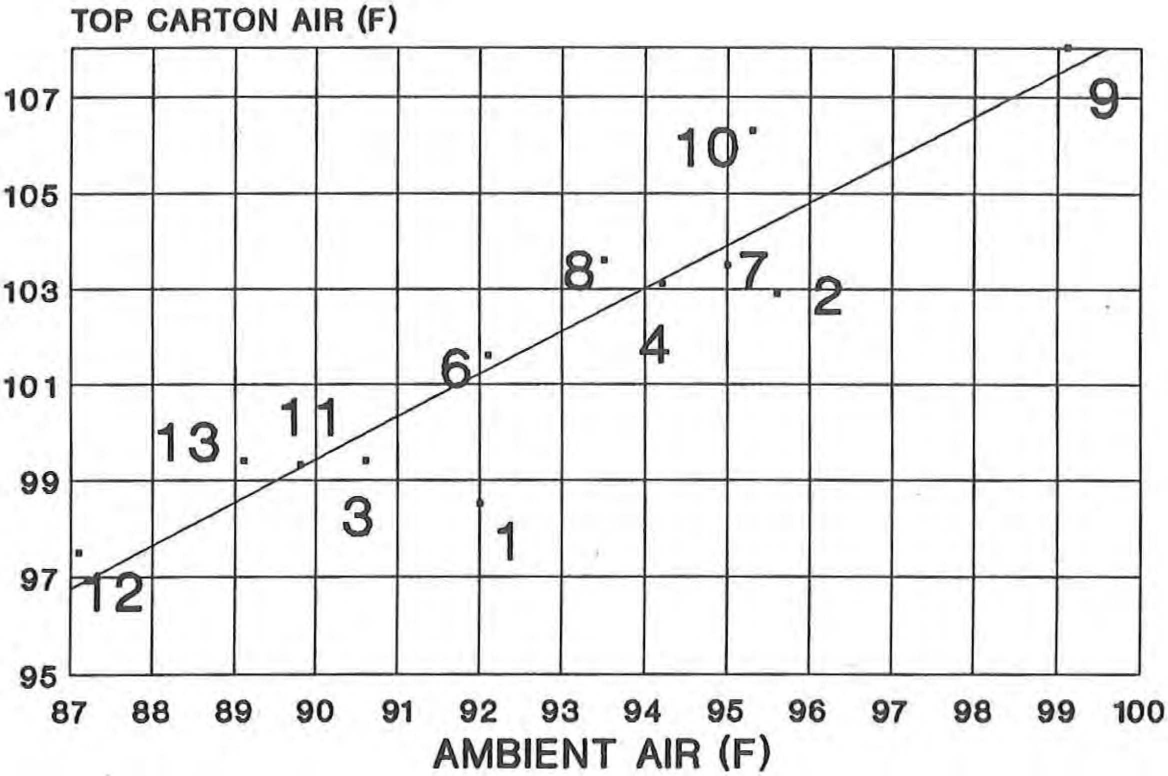
RATION VAN	B RATION		T RATION		MRE	
THERMOCOUPLE	3		15		27	
LOCATION	B1A		T1A		M1A	
INDICATOR	MC18	MC11	MC18	MC11	MC18	MC11
JUNE (INITIAL)	94	95	96	94	95	95
JULY	5	40	19	54	9	52
AUGUST	1	38	NA*	NA*	NA*	NA*
SEPTEMBER	3	12	3	24	5	31

* NOT AVAILABLE, DATA MISSING



WEEK 5 DATA NOT AVAILABLE

FIGURE 24. TOP CARTON AND AMBIENT AIR WEEKLY MEAN TEMPERATURES (F)



WEEK 5 DATA NOT AVAILABLE

FIGURE 25. TOP CARTON VS AMBIENT AIR WEEKLY MEAN TEMPERATURES (F)

Readings show that the MC18 reflectance labels reached their expiration point by September in the described location in all three vans and probably by July in the B Ration van. The initial readings went from about 95% in all three vans to 3, 3, and 5% for the B, T, and M vans, respectively, in relatively short time periods.

The MC11 indicators changed from about 95% to 12, 24, and 31% for the B, T, and M vans, respectively. As expected, this is a similar pattern to the MC18 indicators but at a slower rate. Over the whole summer the MC11 readings show more pronounced differences between the vans than the MC18 indicators. The monthly scanning interval, although appropriate for the MC11 indicators, was probably not frequent enough to validate the more rapid changes in the MC18 indicators. A more significant reason for the differences between vans is probably the albedo of the vans. As shown in Table 1, the B van was brown in color, the T a light grey color, and the MRE van light rust in color. Therefore the brown B van could be expected to absorb more energy and cause a faster rate of decrease in reflectance. The MC18 appears to be a useful indicator for detecting changes in the vans during transport and/or short term storage periods at high temperatures and also could be useful for products with a short shelf life.

d. Evaluation of Rations:

Samples of MRE ration components that arrived in the van were evaluated informally at YPG at the time of installation of thermocouples. Although the components showed evidence of high temperature storage (principally Maillard browning reactions), only the chocolate covered cookie, which had melting of the chocolate coating, was obviously not acceptable.

Objective color measurements on the MRE samples, placed in the CVs in June and stored at YPG over the summer, were made on a portable Hunter colorimeter (Hunter MiniScan, Model MS/S). Results in L*a*b* numbers are shown graphically in Figure 26. For the L* values, 100 equals pure white and 0 is totally black. Thus the decrease in L* values for the cheese spread, applesauce, and grape jelly show darkening in color for the samples stored at Yuma compared to those stored at 40^{o}F. For a* values, a positive number indicates red, and a negative number indicates green. The cheese spread, applesauce, and grape jelly values increased in redness when stored at Yuma. In b* values, positive indicates yellow and negative blue. The cheese spread and applesauce increased slightly in yellow, but the grape jelly showed a dramatic switch to blue when stored at the higher temperatures. The peanut butter showed very little color difference from the higher storage temperatures. In the grape jelly the slight darkening together with the increase in red (a* values) and a shift from yellow towards blue (b* values), created a darker, more purple colored product. When comparing the data in Figure 26, one should note the differences in the y axes scaling. For example, the grape jelly values are very low in each of the L*a*b* values.

The color ratings of the sensory panels are depicted in Figure 27 with the following data adjustments. The applesauce rating scale, unlike the others was not dark to light, but extremely poor to excellent. It was obvious, however, from the panelists' comments that poor correlated with dark and excellent with light. The data from the peanut butter were inverted to correspond with the dark to light, rather than light to dark scale. The data show a significant deterioration of color in the applesauce, cheese spread, and grape jelly. The peanut butter, as shown in the instrumental data, showed relatively little difference in color score and that difference was not toward a darkening in color.

As shown in Table 9, the applesauce stored at YPG showed a significant decrease in apple flavor and increases in fermented and caramelized flavors. Viscosity in the Yuma samples was decreased (thinner) and the overall quality was significantly lower than the nonheat stressed products. The peanut butter showed less significant differences than the applesauce, cheese spread and grape jelly. The peanut butter's appearance seemed less viscous and there were slight decreases in the perception of stickiness and mouth coating. The overall quality was not decreased by summer storage in the heat. Grape jelly showed significantly more syneresis as well as an increased fermented flavor with a lower intensity of grape flavor and a decrease in overall quality. The ratings for the escalloped potatoes with ham were not significantly lower in the heat-stressed samples. The cheese spread had significant decreases in all qualities rated, including scorched/cooked milk flavor, off flavors, and overall quality.

Overall, the applesauce and the cheese spread had the most changes. The potatoes had no significant changes and the peanut butter very few. Parallel studies comparing these products stored for various lengths of time at $40^{\circ}F$, $80^{\circ}F$, $100^{\circ}F$, $120^{\circ}F$ and $140^{\circ}F$ will determine when quality changes, seen in this study, become unacceptable.

IV. Conclusions

From the preliminary analysis presented here, the following conclusions can be drawn:

a. Induced maximum and mean storage space air temperatures for the hottest day show surprising similarity in all three CVs, differing in van type (T), color, and load.

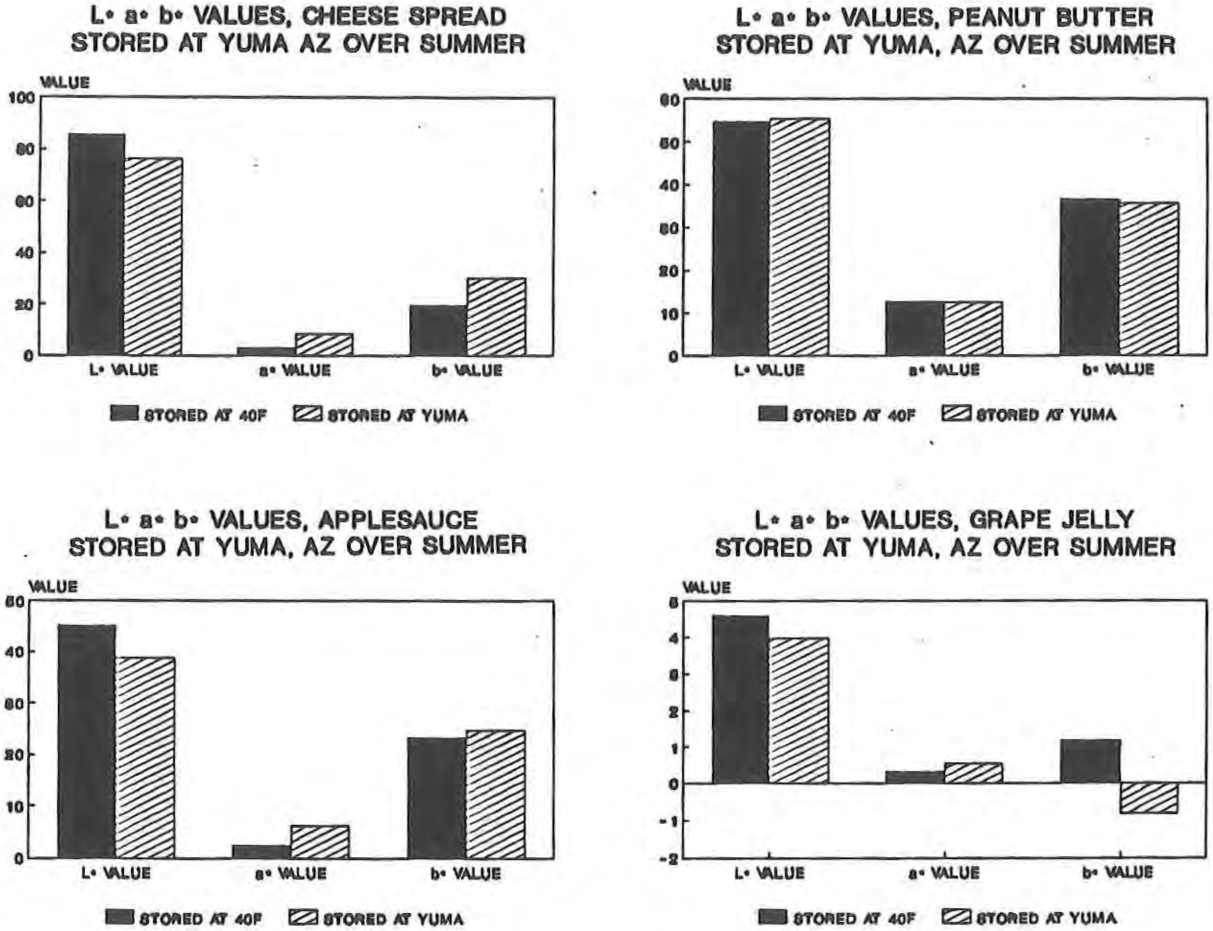
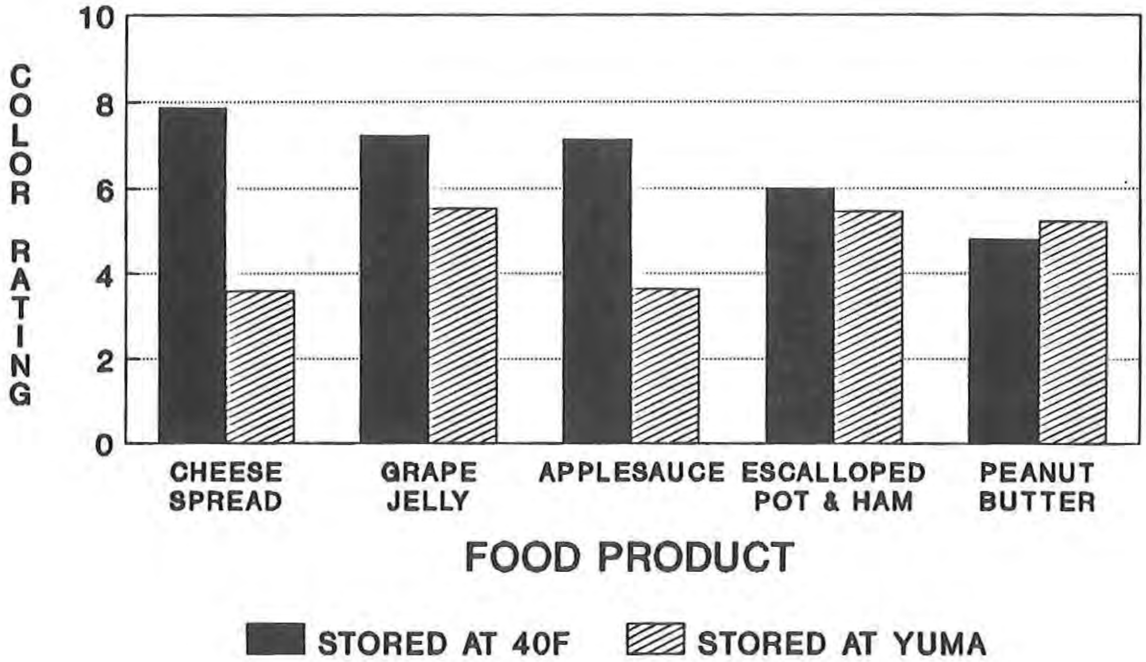


FIGURE 26. COLOR VALUES OF RATION COMPONENTS STORED ONE SUMMER IN CONTAINER VAN AT YUMA PROVING GROUND AND AT 40 DEGREES F



STORED FOR ONE SUMMER (JUNE-SEPTEMBER)

FIGURE 27. FOODS STORED AT YUMA OR AT 40F
COLOR RATINGS, SENSORY PANEL
1 = DARK, 9 = LIGHT

TABLE 9. RESULTS OF SENSORY EVALUATIONS, ITEMS STORED AT YUMA, AZ AND AT 40F FOR SUMMER

APPLESAUCE

	40F	YPG		
COLOR	7.1	3.6	**	1=POOR, 9=EXCELLENT
SYNERESIS	4.0	5.1		1=NO FREE LIQUID, 9=V HIGH
APPLE FLAVOR INTENSITY	6.3	4.7	**	1=V LOW, 9=V HIGH
SWEETNESS	4.7	4.1		1=V LOW, 9=V HIGH
SOURNESS	5.6	5.7		1=V LOW, 9=V HIGH
FERMENTED FLAVOR	2.4	4.5	**	1=NONE, TRACE, 9=V HIGH
CARAMELIZED FLAVOR	2.0	4.3	**	1=NONE, TRACE, 9=V HIGH
VISCOSITY	5.2	4.2	**	1=V THIN, 9=V THICK
OVERALL QUALITY	6.6	4.0	**	1=EXTR POOR, 9=EXCELLENT

PEANUT BUTTER

	40F	YPG		
COLOR	4.2	3.8		1=LT BROWN, 9=DK BROWN
VISUAL VISCOSITY	7.5	6.6	**	1=V THIN, 9=V THICK
SURFACE SMOOTHNESS	6.9	7.3		1=V GRAINY, V SMOOTH
PEANUT FLAVOR	6.6	7.1		1=V STALE, 9=V FRESH
OIL FLAVOR	6.3	6.9		1=V RANCID, 9=V FRESH
PEANUT FLAVOR INTENSITY	6.7	6.7		1=V LOW, 9=V HIGH
MOUTHFEEL	6.9	6.9		1=V GRAINY, 9=V SMOOTH
STICKINESS	6.9	6.1	*	1= V LOW, 9=V HIGH
MOUTHCOATING	7.0	6.1	**	1=V LOW, 9=V HIGH
OVERALL QUALITY	6.6	6.8		1=EXTR POOR, 9=EXCELLENT

GRAPE JELLY

	40F	YPG		
COLOR	6.2	5.5	*	1=V BROWN, 9=V RED
SYNERESIS	1.5	2.6	**	1=TRACE/NONE, 9=V HIGH
GRAPE FLAVOR INTENSITY	6.2	5.4	*	1=V LOW, 9=V HIGH
SWEETNESS	6.1	6.1		1=V LOW, 9=V HIGH
FERMENTED FLAVOR	2.4	3.5	*	1=TRACE/NONE, 9=V HIGH
MOUTHFEEL	6.7	6.2		1=V GRAINY, 9=V SMOOTH
OVERALL QUALITY	6.9	5.8	**	1=EXTR POOR, 9=EXCELLENT

* STATISTICALLY DIFFERENT AT 0.05%

** STATISTICALLY DIFFERENT AT 0.01%

TABLE 9 (CONT). RESULTS OF SENSORY EVALUATIONS, ITEMS STORED AT YUMA, AZ AND AT 40F FOR SUMMER

ESCALLOPED POTATOES WITH HAM

	40F	YPG	
COLOR	6.0	5.5	1=YELLOW/BROWN (DARK), 9=TAN/CREAM (LIGHT)
HAM DICE COLOR	4.1	4.3	1=PINK/RED (LIGHT), 9=REDDISH/BROWN (DARK)
INTENSITY OF SCORCHED/ COOKED MILK FLAVOR	3.0	3.1	1=TRACE/NONE, 9=V HIGH
OVERALL FLAVOR INTENSITY	6.5	6.3	1=V LOW, 9=V HIGH
HAM FLAVOR INTENSITY	6.1	5.9	1=V LOW, 9=V HIGH
OFF FLAVOR INTENSITY	2.1	2.6	1=V LOW, 9=V HIGH
OVERALL QUALITY	6.7	6.3	1=EXTR POOR, 9=EXCELLENT

CHEESE SPREAD

	40F	YPG	
COLOR	7.9	3.6 **	1=YELLOW/BROWN (DARK), 9=TAN/CREAM (LIGHT)
CHEESE FLAVOR INTENSITY	7.3	6.1 **	1=TRACE/NONE, 9=V HIGH
INTENSITY OF SCORCHED/ COOKED MILK FLAVOR	2.9	5.2 **	1=TRACE/NONE, 9=V HIGH
INTENSITY OF OFF FLAVOR	2.5	4.8 **	1=TRACE/NONE, 9=V HIGH
MOISTNESS	5.6	4.6 **	1=TRACE/NONE, 9=V HIGH
MOUTHFEEL	7.5	6.6 *	1=V GRAINY, 9=V SMOOTH
OVERALL QUALITY	7.1	4.9 **	1=EXTR POOR, 9=EXCELLENT

* STATISTICALLY DIFFERENT AT 0.05%

** STATISTICALLY DIFFERENT AT 0.01%

b. These temperatures also show a similarity in maximum temperature to those measured in boxcars and tightly covered storage dumps, nearly 40 years ago. Mean temperature, however, is three to five degrees higher in the CVs.

c. Extreme day maximum unprotected top carton air temperature is, with few exceptions, below 120^{O}F in all CVs and in storage dumps and boxcars.

d. Greatest extreme day mean unprotected top carton air temperature in the CVs is about 111^{O}F while the mean roof air is 115^{O}F. However the greatest range in unprotected carton air is 16^{O}F (103^{O}F to 119^{O}F) whereas the range in roof air is 61^{O}F (90^{O}F to 151^{O}F), just eighteen inches away.

e. Although the data are incomplete, there appears to be a strong linear correlation between mean weekly ambient air temperature and top carton air temperature, the latter ranging from 7 to 10F^{O} higher. Coupled with the low daily range of the carton temperature and the repetitious nature of solar-controlled climatic cycles, there appears to be a good potential of prediction of the monthly and yearly distribution of storage temperatures from ambient means. With logarithmic weighting corresponding to the appropriate activation energy, the effective mean monthly or yearly temperature for isothermal duplication of a degradation process like Maillard browning should readily be accessible.

f. Protective measures lowered maximum temperature in storage about five degrees, but gave little lowering of the mean. In general, the measures were less effective than in boxcars.

g. The vans and the rations contained therein offer a semipermanent testing laboratory for rations and possibly more effective protective measures.

h. TTI labels appear to provide an alternative approach to temperature readings for the measurement of thermal stress in subsistence management.

i. Ration components stored for a summer at high temperatures can be expected to show obvious color degradation. Other attributes of sensory quality and overall quality of some items will decrease.

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in the series of reports approved for publication.

APPENDIX A
Table A-1

ASL YUMA METEOROLOGICAL TEAM
YUMA PROVING GROUND, ARIZONA 85365
*** MONTHLY CLIMATOLOGICAL SUMMARY ***

JUNE 1992

DAY	PRE CIP	PRESSURE MAX	PRESSURE MIN	PRESSURE AVG	TEMPERATURE MAX	TEMPERATURE MIN	TEMPERATURE AVG	RELATIVE HUMIDITY AVG	RELATIVE HUMIDITY 0500	RELATIVE HUMIDITY 1100	RELATIVE HUMIDITY 1700	RELATIVE HUMIDITY 2300	AVG DP	WIND DIR	WIND SPD	PEAK DIR	PEAK SPD	TIME	SOIL TEMP MAX	SOIL TEMP MIN	SOIL TEMP AVG	CLD CVR	DEG DAY
1		998.5	993.6	996.5	104	76	91	16	30	14	7	16	36	SSE	5	SSW	19	2137	121	81	99	0	-26
2		997.3	991.6	994.8	106	76	92	19	36	15	8	13	39	ESE	5	ENE	20	1924	125	83	101	1	-27
3		996.7	991.4	994.2	107	76	94	13	22	10	7	9	32	SE	5	SW	22	2206	126	83	102	0	-29
4		995.6	990.7	993.3	108	77	94	10	14	8	6	11	27	SE	5	SE	24	1210	126	84	103	1	-29
5		993.2	988.1	991.0	103	75	90	15	19	10	7	26	34	SSE	5	E	22	1758	124	82	101	0	-25
6		993.4	990.3	991.9	98	72	86	22	40	16	9	22	38	SSE	5	SW	20	1451	124	80	98	0	-21
7		996.8	993.2	994.9	94	73	83	34	49	34	13	45	48	SSE	4	E	24	1628	122	81	97	—	-18
8		1000.0	995.8	998.0	95	69	83	29	48	25	12	15	43	SSE	5	ESE	20	1624	121	78	96	0	-18
9		999.7	995.4	997.5	99	70	86	26	69	16	8	13	38	SE	3	SW	18	1523	123	78	97	0	-21
10		999.2	995.0	997.2	99	69	86	15	25	13	8	12	31	ESE	5	SSW	28	1514	122	77	97	0	-21
11		1000.1	996.9	998.2	98	71	85	20	42	16	8	16	36	ESE	4	SSE	18	1610	123	77	97	0	-20
12		1000.6	996.3	998.4	100	71	86	23	52	15	8	12	38	WSW	4	S	22	1316	121	34	94	0	-21
13		998.3	993.5	996.2	96	67	83	18	41	10	8	12	31	W	5	WSW	20	1449	121	75	95	0	-18
14		995.7	993.0	994.4	92	71	81	12	14	11	10	16	24	W	6	W	22	1543	115	75	92	0	-16
15		997.5	993.6	995.9	91	64	79	23	39	19	12	29	36	W	4	NW	19	2238	118	71	92	0	-14
16		1001.3	996.9	998.8	92	66	80	24	41	23	12	24	38	W	3	N	22	1249	118	72	92	0	-15
17		999.3	995.0	997.2	101	67	86	17	25	12	9	13	33	ESE	3	SW	16	2210	124	73	95	0	-21
18		998.5	994.2	996.4	104	70	89	15	24	12	8	18	33	ESE	3	WSW	15	0000	126	70	98	0	-24
19		996.8	992.5	994.7	104	70	90	17	27	14	8	15	36	E	3	WSW	17	2236	126	77	99	0	-25
20		995.3	992.0	993.8	105	72	90	17	28	12	7	17	36	ESE	3	WSW	17	2051	127	79	100	0	-25
21		997.0	994.0	995.5	107	73	93	17	25	9	7	10	34	ESE	3	S	16	1751	129	79	102	0	-28
22		999.5	995.9	997.6	109	84	97	13	22	9	7	15	36	SSE	4	WNW	25	1938	129	89	105	0	-32
23		998.3	994.0	996.5	107	86	97	14	19	12	10	16	40	S	3	WNW	19	1201	127	90	105	0	-32
24		996.7	991.8	994.4	109	83	98	15	21	12	10	18	41	SE	3	W	20	1532	131	87	107	0	-33
25		997.4	993.7	995.4	104	82	94	13	19	9	8	14	34	S	5	WNW	28	1351	124	87	103	0	-29
26		997.3	993.1	995.3	103	76	92	13	20	11	8	14	33	ESE	4	SSW	21	1624	126	82	101	0	-27
27		997.9	993.9	995.8	107	75	94	14	22	16	8	15	36	SE	4	E	20	1419	129	82	103	0	-29
28		998.0	992.6	995.8	108	75	94	16	23	12	9	17	38	ESE	4	WSW	23	2013	128	83	104	0	-29
29		997.2	993.1	995.2	104	79	92	19	29	20	14	16	43	W	5	W	22	1436	126	85	103	0	-27
30		996.5	992.3	994.7	98	75	86	16	19	16	12	20	35	W	6	W	24	1428	120	80	98	0	-21
TOT	0.00																						-703
AVG		997.6	993.4	995.6	102	73	89	17	29	13	8	16	35	ESE	4				124	78	99	0	

Table A-2

ASL YUMA METEOROLOGICAL TEAM
YUMA PROVING GROUND, ARIZONA 85365
*** MONTHLY CLIMATOLOGICAL SUMMARY ***

JULY 1992

DAY	PRECIP	PRESSURE MAX	PRESSURE MIN	PRESSURE AVG	TEMPERATURE MAX	TEMPERATURE MIN	TEMPERATURE AVG	RELATIVE HUMIDITY AVG	RELATIVE HUMIDITY 0500	RELATIVE HUMIDITY 1100	RELATIVE HUMIDITY 1700	RELATIVE HUMIDITY 2300	AVG DP	WIND DIR	WIND SPD	PEAK DIR	PEAK SPD	PEAK TIME	SOIL TEMP MAX	SOIL TEMP MIN	SOIL TEMP AVG	CLD CVR	DEG DAY
1		997.9	994.5	996.0	93	70	82	24	37	28	11	19	39	W	6	W	25	1426	119	76	95	0	−17
2		998.4	993.8	996.1	102	68	87	16	26	16	8	13	34	E	3	E	15	1330	126	75	98	0	−22
3		996.7	992.5	994.8	105	74	91	15	23	12	9	21	35	E	3	E	14	2108	128	80	100	0	−26
4		997.5	993.4	995.4	108	74	94	13	19	10	6	11	32	E	3	E	21	1523	129	81	103	0	−29
5		997.0	993.1	995.0	112	81	99	14	20	11	8	13	39	SE	4	SSE	20	2136	132	86	107	0	−34
6		1000.1	996.0	998.4	102	83	93	31	31	34	27	39	57	ESE	5	SSW	21	1458	116	88	101	0	−28
7		1002.1	997.9	999.9	105	82	94	40	61	37	26	32	65	E	4	ESE	22	1607	127	87	104	—	−29
8		1004.4	999.0	1001.6	105	84	95	39	48	46	29	35	62	ESE	4	SW	15	2033	127	90	104	0	−30
9		1002.8	996.7	1000.0	106	86	95	38	42	32	31	49	65	SE	4	E	20	1902	132	91	108	0	−30
10		1000.5	994.1	997.7	102	83	93	37	50	35	33	23	63	SE	6	WSW	21	2028	126	63	102	0	−28
11		998.6	993.5	996.5	102	82	92	34	29	34	16	41	57	ESE	4	SE	31	1635	124	88	104	0	−27
12		999.8	995.9	997.8	99	77	89	37	53	39	23	30	58	SSE	4	E	24	1414	125	84	102	0	−24
13		1001.1	997.1	999.0	102	76	91	31	50	35	15	23	53	SSE	3	W	17	1728	128	83	103	0	−26
14		1001.4	997.0	999.3	105	79	93	22	38	23	7	16	44	ESE	3	E	19	1530	124	85	103	—	−28
15		998.9	993.8	996.8	108	79	96	15	28	14	7	15	38	ESE	4	E	18	1656	123	86	103	—	−31
16		997.4	993.6	995.7	112	80	98	16	26	13	7	19	42	SE	3	SE	16	2143	131	87	107	—	−33
17		999.5	995.7	997.4	113	81	99	18	28	14	7	23	44	ESE	4	ESE	20	1518	130	88	107	—	−34
18		1000.5	995.0	998.1	115	81	99	23	40	21	7	22	50	SE	4	SSW	24	2051	132	89	108	—	−34
19		999.6	994.0	997.0	109	84	98	22	20	24	17	23	52	SSE	4	SW	19	1212	129	90	108	—	−33
20		997.6	992.0	995.1	110	82	97	27	40	23	16	32	56	ESE	5	SSW	22	1916	129	89	107	—	−32
21		998.1	993.6	996.0	104	83	93	41	51	42	31	38	65	ESE	5	SW	24	1630	126	90	105	—	−28
22		998.4	993.5	996.0	103	78	92	33	43	34	23	22	57	SE	5	SW	25	1551	123	85	102	—	−27
23		999.0	994.5	996.8	101	75	90	37	38	39	32	42	60	SE	5	SSW	22	1555	122	83	101	—	−25
24		1001.6	997.4	999.6	100	77	89	44	55	47	35	35	63	ESE	5	SW	27	1626	122	83	99	—	−24
25		1005.1	999.9	1002.4	103	75	90	37	55	42	18	27	58	E	4	S	18	1707	124	81	100	—	−25
26		1003.9	998.2	1001.2	108	75	94	23	38	18	10	23	47	ESE	3	E	15	1421	129	82	104	—	−29
27		1001.1	995.7	998.7	113	80	99	18	34	15	8	14	45	ESE	3	SSE	17	1844	133	87	107	—	−34
28		1001.7	996.2	998.9	110	89	98	26	31	28	13	28	57	ESE	5	SW	21	2051	128	93	107	—	−33
29		1000.4	995.6	998.2	103	86	95	38	35	40	33	39	65	ESE	5	SSW	22	1605	117	94	103	—	−30
30		1001.9	997.4	999.7	98	84	92	45	58	43	38	54	67	E	4	ESE	22	0143	112	91	100	—	−27
31		1002.6	997.0	1000.2	107	83	96	47	68	48	31	37	70	E	4	ENE	20	2057	128	89	105	—	−31
TOT	0.00																						−888
AVG		1000.2	995.4	997.9	105	80	94	29	39	29	19	28	53	ESE	4				126	85	103	0	

Table A-3

ASL YUMA METEOROLOGICAL TEAM
YUMA PROVING GROUND, ARIZONA 85365
*** MONTHLY CLIMATOLOGICAL SUMMARY ***

AUGUST 1992

DAY	PRE CIP	PRESSURE MAX	PRESSURE MIN	PRESSURE AVG	TEMPERATURE MAX	TEMPERATURE MIN	TEMPERATURE AVG	RELATIVE HUMIDITY AVG	RELATIVE HUMIDITY 0500	RELATIVE HUMIDITY 1100	RELATIVE HUMIDITY 1700	RELATIVE HUMIDITY 2300	AVG DP	WIND DIR	WIND SPD	PEAK DIR	PEAK SPD	TIME	SOIL TEMP MAX	SOIL TEMP MIN	SOIL TEMP AVG	CLD CVR	DEG DAY
1		1003.8	998.0	1001.0	110	85	97	40	55	37	26	38	67	ESE	5	SSW	26	1915	128	91	108	—	-32
2		1002.6	996.8	1000.0	106	87	96	43	55	43	30	39	69	ESE	5	SW	24	2140	131	93	108	0	-31
3	.08	1002.2	995.6	999.1	107	80	95	45	44	42	32	76	69	E	6	SE	31	2024	129	87	107	0	-30
4	.01	1002.8	998.3	1000.5	97	79	85	71	77	64	56	78	74	ESE	6	ESE	24	2040	115	76	91	0	-20
5		1002.9	997.6	1000.3	101	76	89	64	89	63	40	53	73	E	5	E	15	2101	130	77	98	0	-24
6		1002.0	996.6	999.6	105	81	94	43	60	38	30	36	67	ESE	5	ESE	23	1948	134	83	104	0	-29
7		1002.3	997.0	999.9	106	82	95	40	54	41	28	39	66	E	5	E	19	1648	136	85	104	0	-30
8		1002.7	997.8	1000.2	106	82	95	40	50	37	28	39	66	E	5	E	17	2236	133	85	105	0	-30
9	.29	1002.1	996.6	1000.0	109	79	96	45	53	32	24	88	68	E	4	NE	41	2129	139	83	106	0	-31
10		1002.5	997.2	999.8	108	81	94	53	87	48	30	37	73	E	4	ENE	15	2315	127	82	101	0	-29
11		999.9	994.8	997.7	110	86	100	38	65	34	23	26	67	E	4	E	30	2337	131	87	106	0	-35
12		1000.2	995.2	997.9	110	90	99	34	39	34	24	42	65	E	5	ESE	21	2101	134	92	108	0	-34
13		1003.0	998.7	1001.0	105	88	95	46	49	41	34	57	70	E	3	W	32	1915	128	92	103	0	-30
14		1004.9	999.2	1002.0	107	86	96	45	63	45	31	37	71	E	5	SE	16	1607	130	88	105	0	-31
15		1001.6	995.8	999.2	111	86	100	39	63	40	20	29	68	ESE	5	ESE	16	1639	135	90	108	—	-35
16		998.7	993.6	996.4	114	90	103	29	40	30	15	30	63	ESE	5	ESE	22	2113	138	92	111	—	-38
17		998.9	994.8	996.9	113	91	102	30	36	29	17	39	64	E	6	E	19	2205	137	92	110	0	-37
18		1000.7	996.1	998.4	113	89	101	36	51	34	21	40	67	E	4	E	15	1415	134	90	109	0	-36
19		1002.6	996.4	999.2	111	91	99	37	45	36	29	38	67	E	5	ENE	23	1603	133	91	108	0	-34
20		1000.2	994.0	997.6	110	87	99	32	41	33	22	31	63	E	5	SW	18	1934	137	89	108	0	-34
21		1000.8	996.7	998.9	100	87	92	48	61	46	43	52	69	ESE	7	SSW	25	1313	122	89	100	—	-27
22	.45	998.5	993.8	996.4	101	80	89	64	68	59	41	79	74	E	5	ESE	36	1815	125	83	97	0	-24
23	1.72	997.8	993.9	995.6	88	72	80	82	85	71	94	91	73	E	7	NNE	34	0113	100	71	83	—	-15
24		1001.6	995.8	999.2	96	71	83	70	94	61	45	65	71	E	2	E	24	1717	113	64	86	0	-18
25		1004.4	999.8	1002.0	100	73	86	53	94	54	23	29	63	S	3	SSW	14	2118	120	73	93	0	-21
26		1005.3	1001.3	1003.2	104	74	90	30	62	27	8	36	48	W	2	W	11	1803	125	76	95	0	-25
27		1005.0	999.8	1002.6	109	76	93	26	53	18	10	16	47	W	2	W	12	1446	130	78	99	0	-28
28		1003.1	999.0	1001.2	106	79	94	21	41	16	8	15	43	W	4	W	18	1440	130	82	100	0	-29
29		1003.6	999.5	1001.7	103	79	92	40	45	48	26	48	63	S	6	SSW	34	1448	125	82	99	0	-27
30		1003.0	996.6	1000.3	102	80	90	39	56	50	32	14	60	SSW	5	SW	22	1850	120	80	96	0	-25
31		1000.2	996.3	998.3	97	70	83	24	35	33	9	18	39	WSW	4	S	19	1557	124	70	92	—	-18
TOT	2.46																						-887
AVG		1001.9	996.9	999.6	105	82	94	43	58	41	29	44	65	SW	5				128	84	102	0	

APPENDIX B

TABLE B-1. CONTAINER VAN CODE NUMBERS AND SERIAL NUMBERS OF TIME-TEMPERATURE INDICATOR LABELS

MRE VAN

ASSOCIATED THERMOCOUPLE	LOCATION (CODE)	SERIAL NUMBER 3040010XXX *	SERIAL NUMBER 1140000XXX *
27	M1A	178	477
		179	478
		180	
31	M3ST	169	
		170	
		171	
		172	
33	M6ST	152	
		153	
		155	
		156	
NONE	M6NT	157	
		158	
		159	
		160	
43	M3NT	173	
		174	
		176	
		177	
45	M1RBA	181	
		182	
		183	
46	M4RTA	161	
		162	
		163	
		164	
50	M1LTA	184	
		185	
		186	
51	M1LBA	187	479
		188	480
		189	
52	M4LTA	165	
		166	
		167	
		168	

* LAST THREE NUMBERS OF SERIAL NUMBER LISTED BELOW

TABLE B-2. CONTAINER VAN CODE NUMBERS AND SERIAL NUMBERS OF TIME-TEMPERATURE INDICATOR LABELS

B RATION VAN

ASSOCIATED THERMOCOUPLE	LOCATION (CODE)	SERIAL NUMBER 3040010XXX *
3	B1A	190 191
NONE	B1SB	192 193
NONE	B1NT	194 195
NONE	B1NB	196 197

TABLE B-3. CONTAINER VAN CODE NUMBERS AND SERIAL NUMBERS OF TIME-TEMPERATURE INDICATOR LABELS

T RATION VAN

ASSOCIATED THERMOCOUPLE	LOCATION (CODE)	SERIAL NUMBER 3040010XXX *
15	T1A	198 199
NONE	T1SB	200 201
NONE	T1NT	202 203
NONE	T1NB	204 205

* LAST THREE NUMBERS OF SERIAL NUMBER LISTED BELOW