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TECHNICAL REPORT
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COMPARISON OF THE OCCURRENCE OF HIGH TEMPERATURES IN AIR AND FOOD IN BOXCARS IN DESERT AND HUMID SUBTROPICAL CLIMATES -- YUMA, ARIZONA AND CAMERON STATION, VIRGINIA

by

William L Porter

and

Aubrey Greenwald

January 1971

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Food Laboratory
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Food Laboratory
U.S. ARMY NATICK LABORATORIES
Natick, Massachusetts

Foreword

The quality and acceptance of stored food is strongly affected by its temperature history in storage and transit

Between 1952 and 1958 the Environmental Protection Division, predecessor of the present Earth Science Laboratory, studied such temperatures in warehouses, boxcars, and storage dumps Comparative food storage temperatures in boxcars were studied at Yuma, Arizona, and Cameron Station, Virginia, and a preliminary report of extremes was submitted on the Yuma data

The present report is the result of a steady demand for more detailed storage temperature data, the need to analyze the Cameron Station data, and the availability of computer facilities and programming at US Army Natick Laboratories

The observations were made in 1953 and the data reduction and analysis during 1963 and 1964

The work was done under Project 1K0-14501-A71C, Food Research, and 7-83-005-004A, Environmental Requirements for Design of Military Items

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Abstract

This report contains the detailed computer analysis of the frequencies, means and standard deviations of temperature observations made at 18 positions located in empty and loaded boxcars (two at each location) at both Yuma, Arizona and Cameron Station, Virginia (Washington, DC).

It is a comparative study of storage temperature distribution in storage air and in food in storage cartons in a desert subtropical versus a humid subtropical climate

Detailed analysis of outer and inner wall surface temperatures is also reported.

The effect of both radiation and heat barrier insulation is a reduction of maximum temperatures by 10-15°F and mean temperatures by 5 F° in the more severe Yuma storage Foil-faced kraft paper is as effective as more expensive types of insulation

The temperature distribution data are reported both graphically and in tables for each position for the total period and for separate weeks

Storage temperature weekly means are shown to be highly correlated with outside air temperature means.

It is shown that if an empirical food degradation-temperature relationship is known, storage life in boxcars may be predicted.

Since the predictive relation between mean storage air temperature and outside air temperature appears similar at Yuma and Cameron, one may make moderately dependable predictions of food storage life or of effective temperature for laboratory simulation of food storage in boxcars at widely different locations and exposures

Introduction

A Purpose of the Study

During the summer of 1953, comparative studies of high storage temperatures in boxcars were carried out from April through September by the Environmental Protection Division[1] at Yuma, Arizona - a desert subtropical station - and from June through August at Cameron Station[2], Virginia - a humid subtropical station. It was known that Yuma was in an area with conditions favorable to extreme heat accumulation in storage spaces However, it was planned to compare the relations of inside to outside conditions found at Yuma with those at a more moderate site, and one with higher water vapor content in the lower atmosphere Thus, if the relations developed at Yuma were similar to those found at Cameron, their generality would be much increased

A short preliminary report of the extremes found in the Yuma portion of the boxcar study was made at the time of the study (1) The present extensive analysis is the result of a continued demand for more detailed temperature data in food storage and transit and of the present availability of large scale computer analysis at US Army Natick Laboratories. Similar detailed computer studies of warehouse and dump storage data were also prepared (2, 3).

B. Scope of the Study

At both stations, it was planned to expose identical types of boxcars, with identical loads of packaged food. It was also planned to expose identical empty cars, and, in addition, to make measurements of car wall surface temperatures and of the effect of reflective insulation placed over the load This plan was carried out with one exception, i.e., at Cameron, a wooden instead of a steel empty car was exposed The loaded cars and radiation blanket experiments were identical at both locations.

Since the study originated in an interest in degradation of packaged food in cartons, the cars were loaded with food (canned string beans and C-rations) and the results have been analyzed with respect to the position giving maximum storage temperature stress to the packaged food - the Top Center Carton.[3] However, the temperatures at seventeen other positions were sampled every hour and the summarized data are presented in tables and graphs in the appendix for the interested reader, although little detailed written comment is made on them.

The results and conclusions are presented in comparative form, since thereby it is possible to distinguish purely local effects from more general rules. Maximum use has been made of tables and graphs Written analysis has been kept to a minimum, since it is impossible to define in advance the needs of the reader.

---

[1]Predecessor of the present Earth Sciences Laboratory

[2]Referred to hereafter as Cameron

[3]For better recognition, specific measurement positions are capitalized throughout the report.

Research Methods and Materials

A. Choice of Sites

The climatic and logistic factors on which the choice of the Yuma site was based have been reviewed in the abbreviated preliminary report on the Yuma research (1), to which the reader will be frequently referred for details of materials and methods which were similar in both studies.

Cameron was chosen because it afforded a site in a humid, subtropical area geographically convenient to the home office of the Environmental Protection Division. Climatically, the area is in sharp contrast to the desert subtropical area at Yuma, although strong heat accumulation occurs in storage spaces here also Ideally, a tropical rain-forest site like the Canal Zone would be preferable, but the problems of supply and maintenance were deemed prohibitive at the time.

B. Climatic Summary

Since it was found that mean weekly or monthly air temperature in storage spaces is highly correlated with mean weekly or monthly outside air temperature, there is shown below a comparative summary of mean weekly temperatures at Yuma and Cameron in 1953 (Table I), together with the departure of these values from the 30 year normals During the period of the Yuma studies, 13 April to 20 September 1953, the outside air mean temperature was 0.3 F^{o} below normal. During the period 1 June to 7 September, however, which corresponded to the period of study at Cameron Station, it was 0 9 F^{o} above normal, while Cameron outside air mean temperature was 1.9 F^{o} above normal during the same period.

In Table II are shown comparative figures for other climatic statistics less relevant to prediction of storage temperatures.

The Table shows that for both stations, the extremes and means were sufficiently close to the normals to give representative conditions for study. Judging by these monthly values, Yuma was somewhat cooler than normal from May through September 1953 while Cameron was considerably warmer than normal from June through August.

C. Characteristics of the Research Sites and Situations

The site at Yuma County Air Base (Figures 1, 3, and 5) was light desert sand plain with numerous small rock fragments, and has been amply described (1). Prevailing winds in the study period were from the southwest and south.

At Cameron, the study site (Figures 2, 4, and 6) was at an elevation of 75 feet, eight miles southwest of the center of Washington, DC, 4 5 miles due west of the Potomac River, and 150 feet north of the main line of the Southern Railway. The boxcars were placed on a spur track raised 1.5 feet above ground elevation on a gray crushed limestone roadbed, about 40 feet wide. South of this were, successively, a grass strip 40 feet wide, a concrete-lined canal 50 feet wide, another grass strip 50 feet wide and the Southern railroad right-of-way. Six hundred feet to the south lay wooded hilly country which stretched with little settlement 8 miles to the Potomac River. To the southwest and west, similar terrain extends uninterrupted to the mountains. Prevailing winds are from the south

North of the boxcars at Cameron lay an area of gravel frequently filled with parked cars, a grove of trees, a concrete loading apron and a warehouse, and one quarter mile north a 200 foot hill under cultivation. Northeast lay a concrete area with eight large warehouses.

Table I

Weekly Mean Outside Air Temperatures and Departure from Normal (1931-1960)[a]

Week Ending	Study in Progress: Yuma	Study in Progress: Cameron	Weekly Mean Temperature (°F): Yuma Mean	Yuma Departure	Cameron Mean	Cameron Departure
19 April	Y		73	1	49	-6
26 April	Y		74	0	61	4
3 May	Y		69	-6	64	4
10 May	Y		74	-2	71	9
17 May	Y		71	-7	75	10
24 May	Y		79	-1	70	3
31 May	Y		72	-10	64	-5
7 June	Y	C	79	-4	74	3
14 June	Y	C	88	3	71	-2
21 June	Y	C	85	-2	75	1
28 June	Y	C	91	2	79	3
5 July	Y	C	95	4	82	5
12 July	Y	C	96	3	75	-2
19 July	Y	C	95	1	82	4
26 July	Y	C	96	2	78	0
4 August	Y	C	95	0	81	3
10 August	Y	C	94	0	76	-2
17 August	Y	C	96	4	77	1
24 August	Y	C	96	5	72	-3
31 August	Y	C	88	-2	83	9
7 September	Y	C	88	-4	79	6
14 September	Y		93	3	66	-5
20 September	Y		89	3	70	0
Mean 13 April to 20 Sep			85.9	-0.3	72.8	1.7
1 June to 7 Sep			91.6	0 9	77.4	1 9
Highest normal weekly mean						
Week ending 4 August			95	4 August	78	

[a] Reference 4.

Table II

Temperature, Wind Speed, and Radiation Extremes and Means at Yuma and Cameron During Study Period and Period of U.S.W.B. Record

	Temperature (°F)					Wind Speed	Radiation (Lys.)	
	Absolute		Mean Daily			Mean (MPH)	Max	Mean
	Max	Min	Max	Min	Mean		Daily	Daily
Yuma[a] Present Study	114[b]	51[c]	102.3	72.1	87.3	8.6	849[d]	706
Yuma Overall Record	123[e]	39[f]	102.8	75 1	89 0	9 1	867	699[w]
Cameron[m] Present Study	103[n]	49[p]	87 8	67.8	78 8[s]	5 8	713[t]	512[u]
Cameron Overall Record	106[q]	43[r]	85.2	66.4	75.9[s]	5 9	Missing	511[v]

[a]Data for present study cover period May through September 1953. Data for "normal" period (overall record) are based on a 70-year record for temperature, 3-year record for wind speed, and radiation observations for 1952. Radiation is expressed in langleys Reference 5

[b]17 August

[c]1 May

[d]27 May

[e]September

[f]May

[m]Data for present study at Cameron cover period June, July, August 1953. Data for overall record are based on a 29-year record for temperature, a 22-year record for wind speed, and a 12-year record for radiation. Reference 5

[n]31 August

[p]18 August

[q]August

[r]June

[s]Does not agree with Table I, since one week in September has been omitted from data used for Table II.

[t]2 June

[u]Reference 6

[v]Reference 7

[w]Reference 8

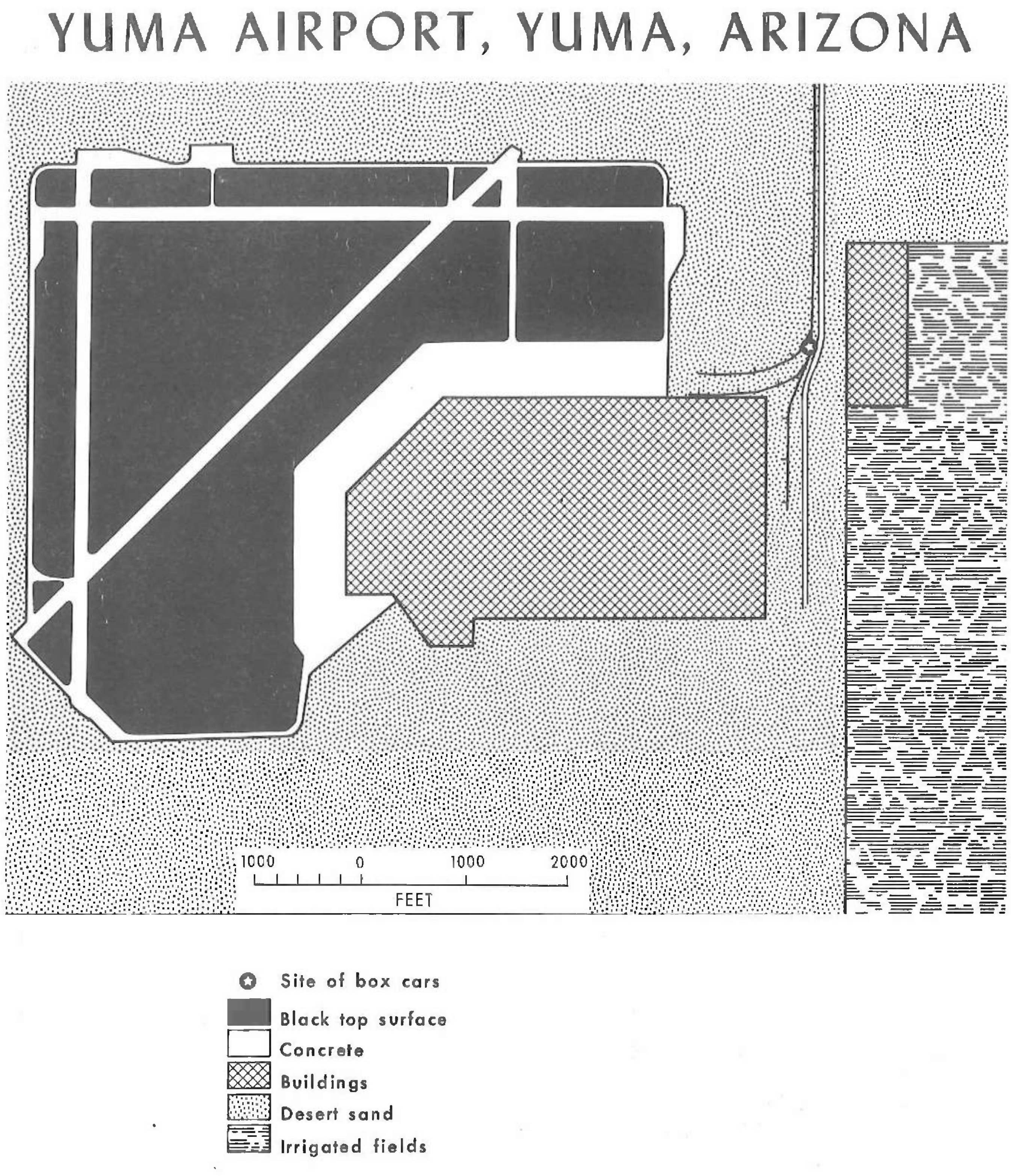

Figure 1. Map of study location - Yuma.

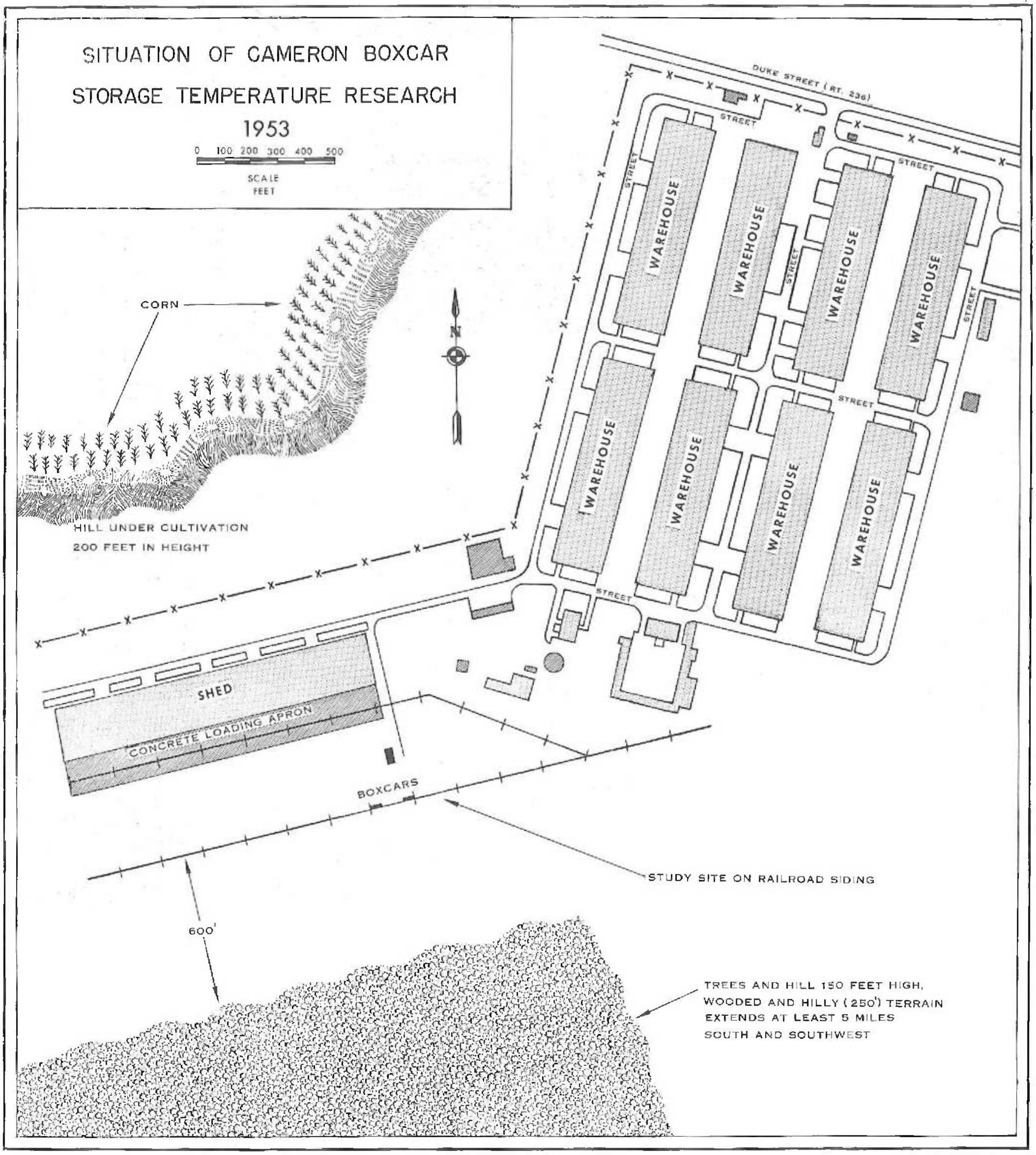

Figure 2. Map of study location - Cameron.

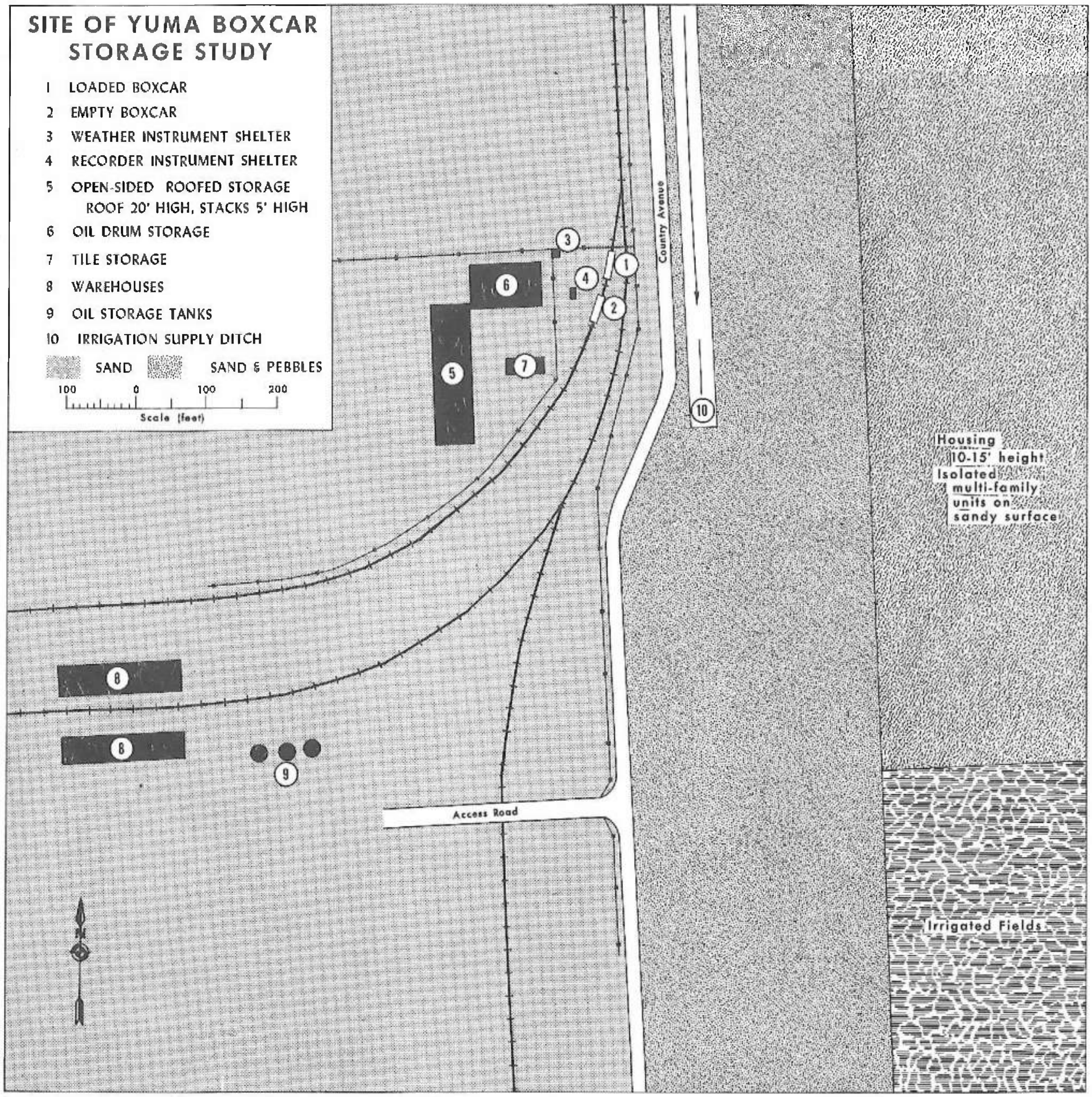

Figure 3. Map of study site - Yuma.

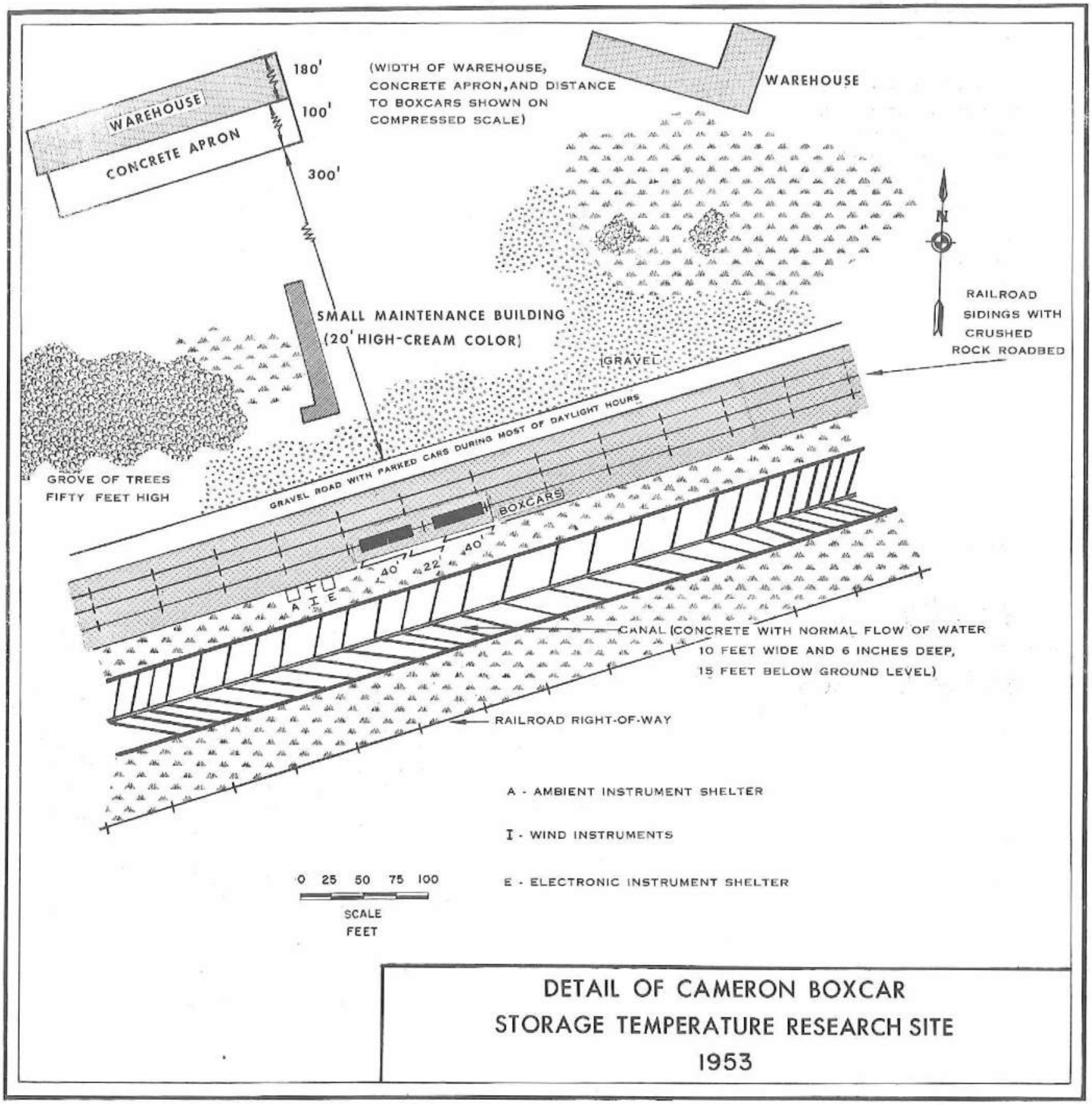

Figure 4. Map of study site - Cameron.

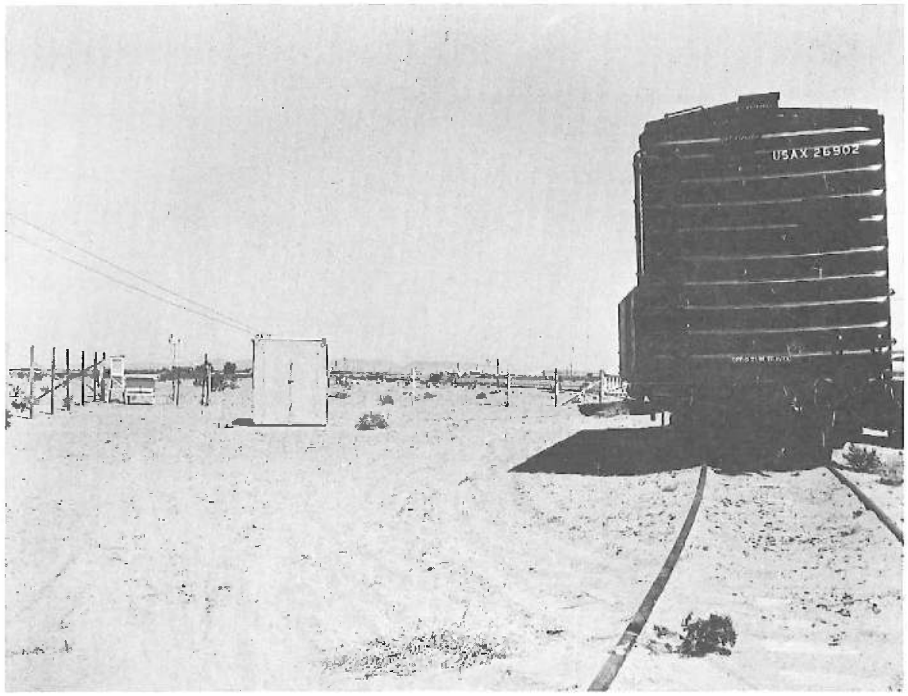

Figure 5a. View of Yuma Boxcar Study Site Facing North - Empty Car and Instrument Shelter in Foreground; Weather Bureau Instrument Shelter in Background.

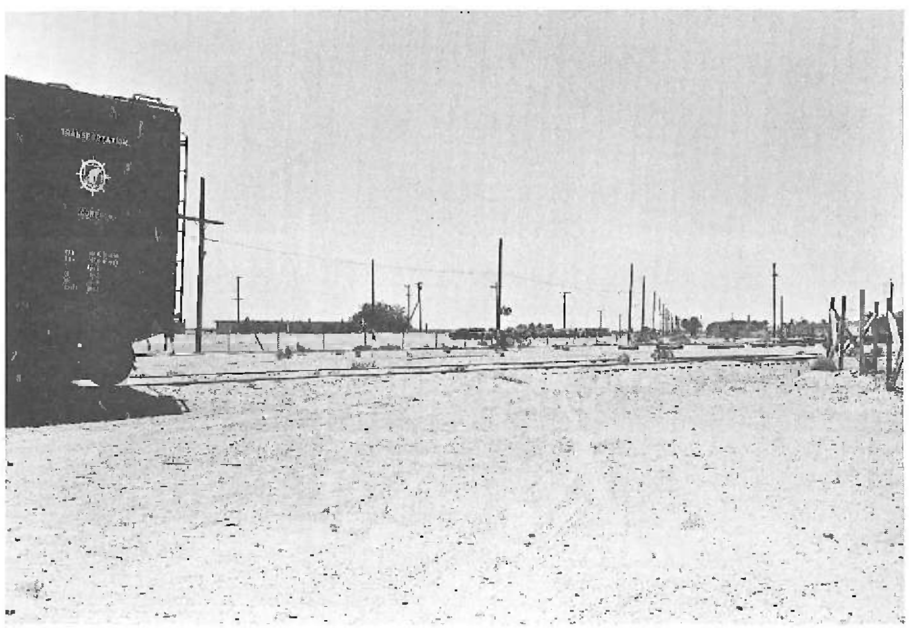

Figure 5b. View of Yuma Boxcar Study Site - Facing South.

Figure 6. View of Cameron Boxcar Study Site Facing East - Empty Car in Foreground

At Yuma, the loaded car was oriented at a heading of 205° true, the empty car being south of it at 211° true. At Cameron, both cars were oriented at a heading of 255° true, the empty car being west of the loaded car.

The Yuma site, because of the sparsity of vegetation in all but the limited irrigated areas[1] near it, was inherently a hotter site than that at Cameron, where the extensive vegetation and the neighboring reaches of the very wide Potomac River gave much cooling by transpiration and evaporation However, the mean wind speed at Cameron was reduced by the wooded hills in the area (cf. Figures 15, 16).

D. Measurement Materials and Methods

A loaded and an empty steel car were observed at Yuma. A similarly loaded and instrumented steel car was observed at Cameron, but the empty car observed had a wooden body. Details of the construction of the cars are shown in Table III The cars were of standard construction, except for the Army olive drab color It is doubtful if other colors conventionally used have much lower albedo

Table III

Characteristics of Cars

Loaded Cars at Yuma and Cameron and Empty Cars at Yuma

Inner Length	40' 6"	Capacity	100,000 lbs
Inner Width	9' 2"	Load Limit	124,200 lbs.
Inner Height	10' 6"	Lt. Wt	44,800 lbs
External Height	14' 5", rails to top of car		
Cu Ft.	3903		

Car was new February 1953 Color - dull olive drab
Wooden sheathing inside of car walls from floor to roof height. Wooden floor
Roof - dull asphalt black on top, at Cameron galvanized within, except at edges of car and ends (over air thermocouples) At these points, asphalt black in color At Yuma, black on upper and lower surface throughout.

Empty Car at Cameron

Inner Length	40' 6"	Capacity	100,000 lbs
Inner Width	9' 2"	Load Limit	123,800 lbs.
Inner Height	8' 10"	Lt. Wt	45,200 lbs
External Height	13' 6", rails to top of car		
Cu. Ft	3364		

Car built January 1924 Color - dull olive drab.
Roof - top - steel painted olive drab. Inside - dark wood.
Walls - dull olive drab outside (wood). Dark wood inside.
Ends - dull olive drab outside - corrugated steel. Light wood inside

[1]Ohman has shown that the cooling effect of irrigated areas of Yuma extends less than 100 feet on the downwind side (9). As Figure 3 shows, the boxcars studied were much farther than this from any irrigated area.

The load was identical at each location (Figure 9, 10), as were the positions of load temperature measurement in the loaded cars, with the exception of Positions XII, XIII, XV, XVI, XVII, XVIII. Table IV and Figures 7 and 8 show the position number and location of the positions listed in the graphs and tables. The wall and surface temperatures (VIII-XI) and the Northeast Corner Carton Air temperatures (XII and XIII) were measured in the loaded car at Yuma, while the Southeast and Southwest Corner Bean Carton Air temperature (XVI and XVII) and a Top Center Bean Carton Air temperature (XVIII) were measured at Cameron.

Table IV

Location of Temperature Measurement Positions in Boxcars

I	Top Center Carton
II.	Load Center Carton
III.	Bottom Center Carton
IV.	Middle Layer Outer Carton Facing West Door (Yuma) or South Door (Cameron)
V.	Middle Layer Outer Carton Facing Center South End (Yuma) or East End (Cameron)
VI.	Air Temperature Six Inches Below Roof and Eighteen Inches From Walls· Loaded Car
VII.	Air Temperature Six Inches Above Load and Eighteen Inches From Walls: Loaded Car
VIII.	East Door (Yuma). Inside Surface Temperature
IX.	West Door (Yuma): Inside Surface Temperature
X.	Roof Center (Yuma). Inside Surface Temperature
XI.	South End (Yuma) Outside Surface Temperature
XII.	Northeast Corner Top Carton (Yuma)
XIII.	Northeast Corner Second Layer Carton (Yuma)
XIV.	South Half (Yuma) or East Half (Cameron) Top Carton
XV.	West Half Top Carton (Cameron)
XVI.	Southeast Corner Bean Carton (Cameron)
XVII.	Southwest Corner Bean Carton (Cameron)
XVIII.	Top Center Bean Carton (Cameron)

At both locations, as described in detail in the preliminary report (1), the load matrix was approximately 1700 cases of string beans, packed in No. 10 cans, 6 cans to a case. Food and carton air temperatures, however, were usually measured in 8 specially prepared cartons of Ration, Individual, Combat-C at each location (Figures 11, 12), with the exception of positions XVI-XVIII, at Cameron, which were located in the carton air of cases of beans, near the top of the cartons.

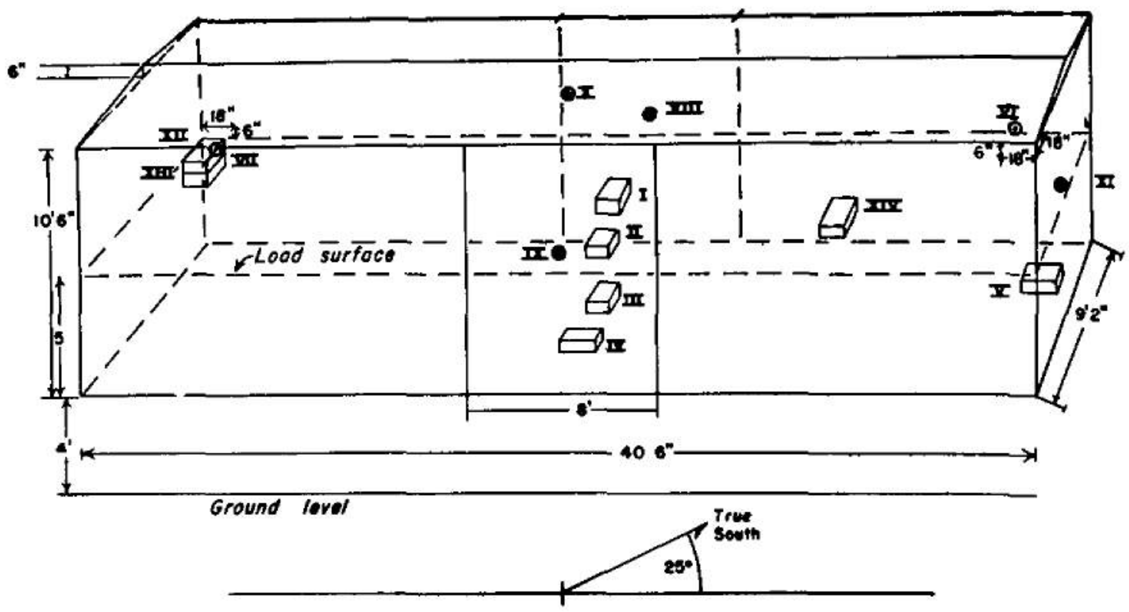

Figure 7. Location of temperature measurement positions in boxcar - Yuma.

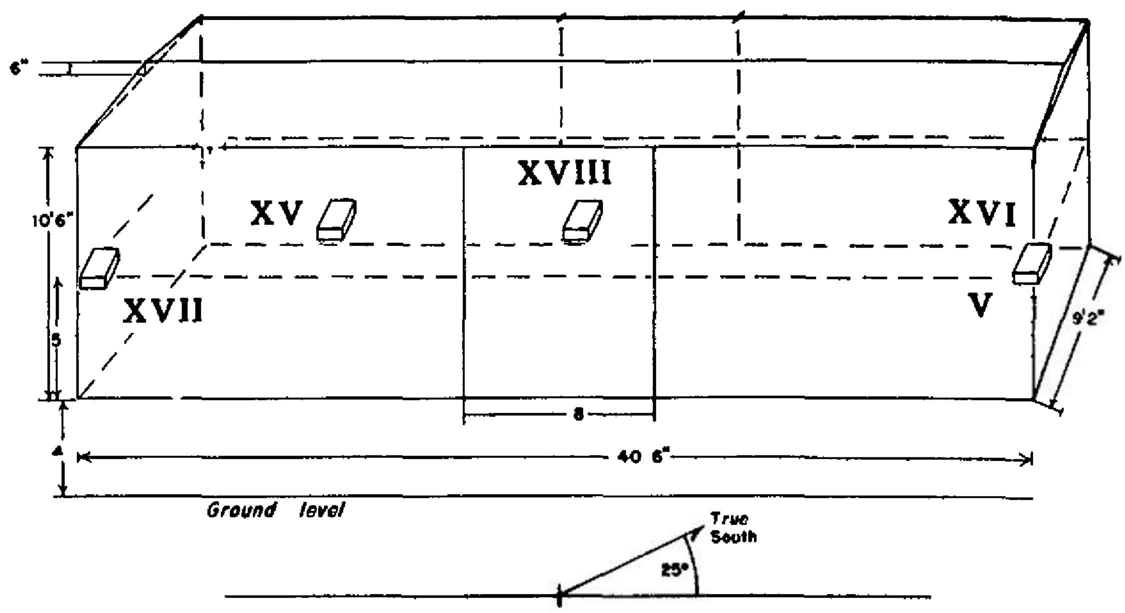

Figure 8. Location of temperature measurement positions in boxcar - Cameron

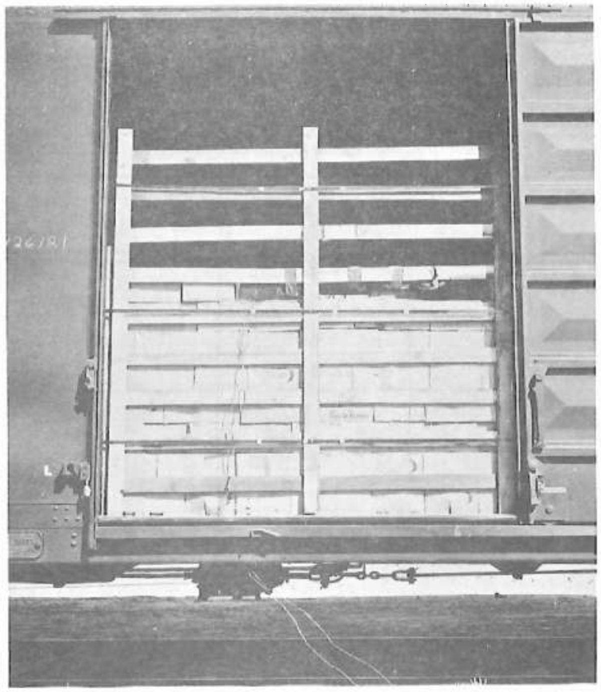

Figure 9. View of Side of Boxcar and Load

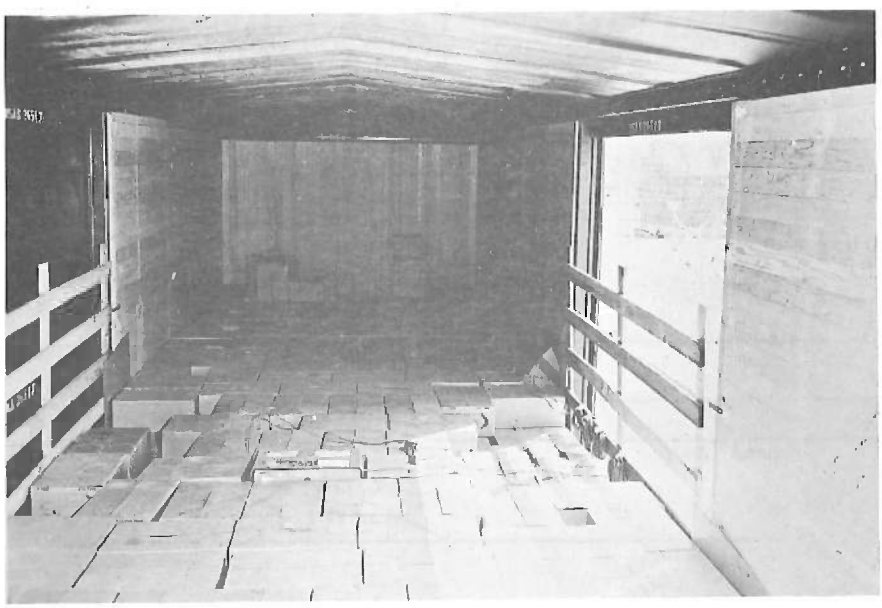

Figure 10. View of Interior of Boxcar

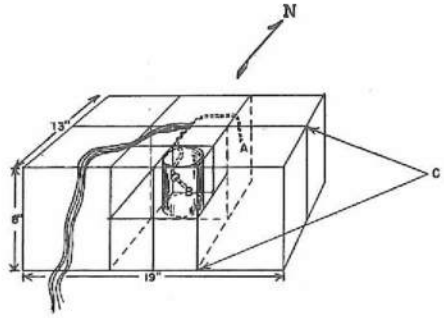

Figure 11. View of Thermocouples in C Ration Cartons

Figure 12. Diagram of Location of Thermocouples in C Ration Cartons

In all other cartons, the air temperature was sampled by means of a thermocouple suspended between two central or side packages and 2 1/2" below carton top[1]. The food temperature was sampled by a thermocouple inserted under sterile and gas-tight conditions in the luncheon meat can of the lower layer of cans, in a central ration package, at all food temperature positions except Top Center Carton at Yuma, where a top layer can was used. In all cartons touching walls (IV and V), the air and food thermocouples were on or in a ration package removed from the one nearest the wall.

Instrumentation at Yuma was described in the preliminary report (1). Measurement of temperature at Cameron was carried out with copper constantan thermocouples, recording on continuous strip charts of two electronic recorders, a Leeds and Northrup Micromax Recording Potentiometer and a Brown Electronik Recorder. The specifications of each are shown below:

Type of Instrument	Model	No. Points	Time Per Point (secs.)	Range (F°)
Leeds and Northrup	S 40000	16	60	-20 - 180
Brown	141648	6	30	0 - 300

Ambient (Outside Air) temperature was measured at Cameron by a thermocouple suspended at standard height in a standard U.S.W.B. instrument shelter located 15 feet south of the track and 38 feet west of the cars, oriented north-south as shown in Figure 4. Wind speed and direction (the latter was not analyzed) were measured by a Beckman-Whitley wind vane and anemometer located six feet from the ground and positioned as in Figure 4, 18 feet west of the cars and 15 feet south of the track. The values were recorded on an Esterline-Angus Recorder.

All electronic equipment was given servicing at least once weekly, with balancing, standardization, and an ice-bath and ambient temperature check. Temperature checks revealed that the instruments were usually correct within ± 1 F°, and no error was greater than 2 F°. All errors were included as correction factors in data reduction.

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[1]Between 16 July and 6 August at Cameron, Top Carton Air temperatures (I) was measured within the air of a ration package and not between ration packages, as was the location of Position I at all other times here and at Yuma.

Total solar and sky radiation data were obtained from the U.S. Weather Bureau. They were collected at American University until August 5, and thereafter at Silver Hill, Maryland, both stations being less than 10 miles northeast of the site.

Data reduction was performed on a Telecomputer Corporation system composed of a Telereader, Teleducer, Program Unit, IBM Electric Typewriter, and IBM Key Punch (procured from the then Telecomputer Corporation, Burbank, Cal.). Data analysis was performed on a G.E. 225 Computer.

Three types of reflective insulation blankets were tested for their radiation shielding effect in reducing storage temperature extremes. The characteristics of these are shown in Table V.

Table V

Characteristics of Insulation Blankets

Label	Manufacturer and Trade Name	Type	Thickness (in.)	Density (lbs/sq. ft.)
Foil-faced[1] Kraft Paper	Reynolds Metals Co. "Type C"	Sheet of reflective aluminum bonded to one side of heavy, dark-brown kraft paper	Negligible	0.05
Foil-faced[2] "Fiberglas" Blanket No. 1	Owens-Corning Fiberglas Corp. "Aerocor"	Sheet of reflective aluminum bonded to "fiberglas" blanket	1	0 75
Foil-faced[2] Glass fiber Blanket No. 2	Gustin-Bacon Manufacturing Co. "Ultralite"	Sheet of reflective aluminum bonded to insulating fiber blanket	1	0 75

[1] Purchased at wholesale market prices after receiving bids

[2] Furnished at nominal cost for study by one of the three major suppliers of this item who were contacted.

The blankets were tested simultaneously at Yuma and Cameron, after a control period of one week, 5 through 10 August, during which Positions XII through XV were connected to the recorder and allowed to record without radiation blanket protection Thereafter, for periods of one or two weeks, interspersed occasionally with control days (25 August and 1 September, Figures 56, 57), the various blankets were tested separately at the two locations, until the close of the study.

One or two Top Carton Air positions were always left uncovered as control on the blanket tests, the position being occasionally altered to avoid a consistent bias. The control position will be obvious on the graphs and tables, since blanket-covered positions are always so labeled.

E. Limitations of the Comparative Study

The study, of necessity, had limitations of precision and scope, most of which are detailed in the preliminary report (1). It would now appear, after detailed computer analysis, that such of these limitations as applied both to the precision and to the generality of the study results are less restrictive than was supposed at the time of the field work First, computer analysis revealed high consistency of means and extremes at comparably located positions, supporting the accuracy of the data. Second, the predictive relations derived from the Cameron study are very similar to those for Yuma, and thus serve to support the latter study in both a different location and a different and less severe climate.

Possibly the greatest limitation to the generality of the study lies in the large effect of height (within the storage space) and degree of protection on extreme temperatures in storage. Temperatures were measured, for the most part, in C-Ration cartons protected by an Overseas Sleeve of so-called "V-Board" in addition to the corrugated board of the carton. In addition, the food temperatures were measured within a can contained in yet another cardboard layer, that of the ration package. Judging from the large effects of such layers in suppressing daily temperature extremes, which are reported below, it would now appear to have been advisable to sample more air temperatures in less protected cartons, like that at the very top of one of the matrix cases of canned string beans. A limited amount of such observation was performed in July at Cameron, but with a different recorder, the results from which are not as reliable as those from the Leeds and Northrup instrument, because of uncertainties in the balancing and standardization process.

Research Results at Cameron Compared to Yuma

A. The Hottest Day

Absolute extremes for the period of study at Yuma were shown in detail in the preliminary report (1). As in that study, the targets of analysis in this comparative report are the Critical Top Center Carton Air and Food temperatures since, as noted above, the study originated in an interest in the worst conditions for packaged food degradation. The most extreme day with reference to this position at Cameron was 30 July (Figure 14), whereas at Yuma it was 13 August (Figure 13). Comparative temperatures at various positions for these two days are shown below in Table VI, derived from Figures 13 and 14.

Table VI

Comparative Hottest Day Temperatures at Yuma and Cameron

Position	Temperature[a] (°F) Maximum	Minimum	Mean[b]
Yuma - 13 August			
Roof Air	149	76	112
Ambient Air	110	82	96
Top Center Carton Air	117	94	106
Top Center Carton Food	112	97	104
Buried Load Food[c]	98	97	98
Cameron - 30 July			
Roof Air	139	76	108
Ambient Air	100	70	85
Top Center Carton Air	101	82	91
Top Center Carton Food	91	85	88
Load Center Carton Food	81	79	80

[a]Derived from hourly observations Inter-hourly values may differ slightly. See (1).

[b]Derived from (Maximum -- Minimum)/2.

[c]Derived from Middle Layer Outer Carton Food Temperatures at West Door and South End, both of which showed the same values.

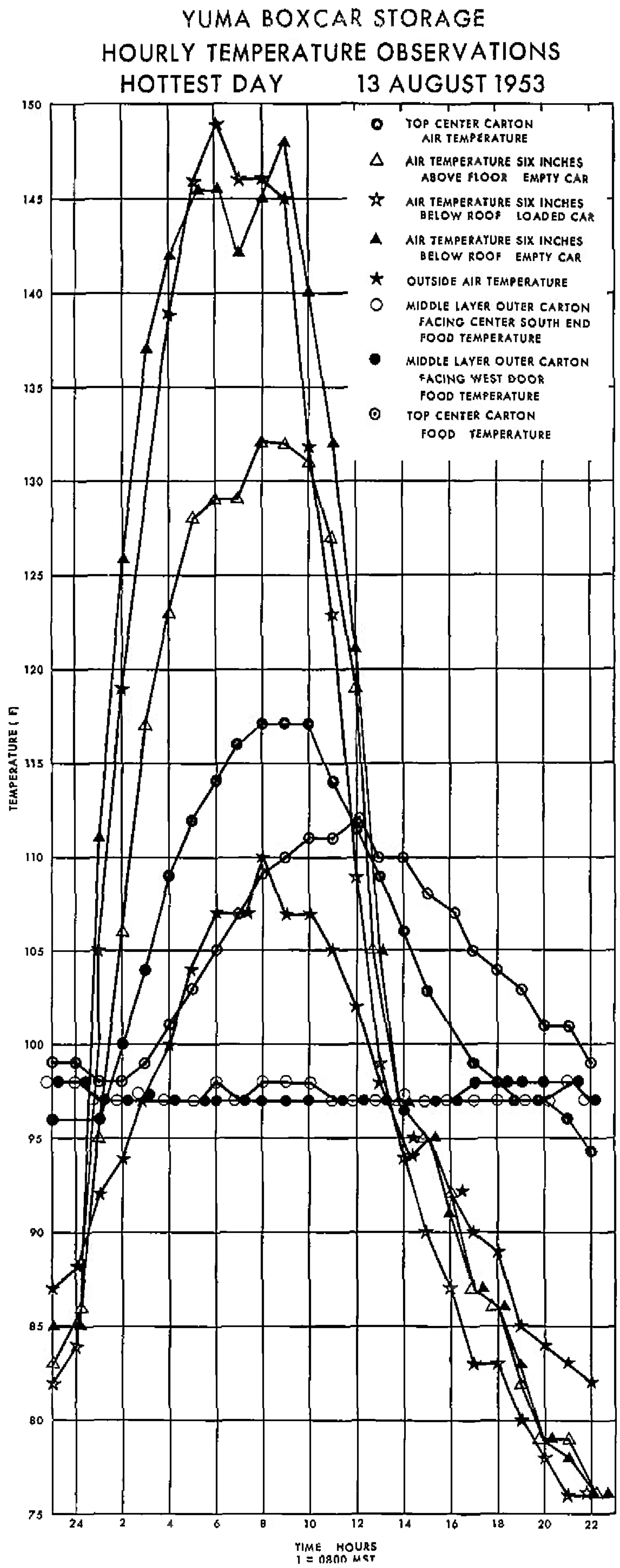

Figure 13 Storage temperatures for hottest day - Yuma

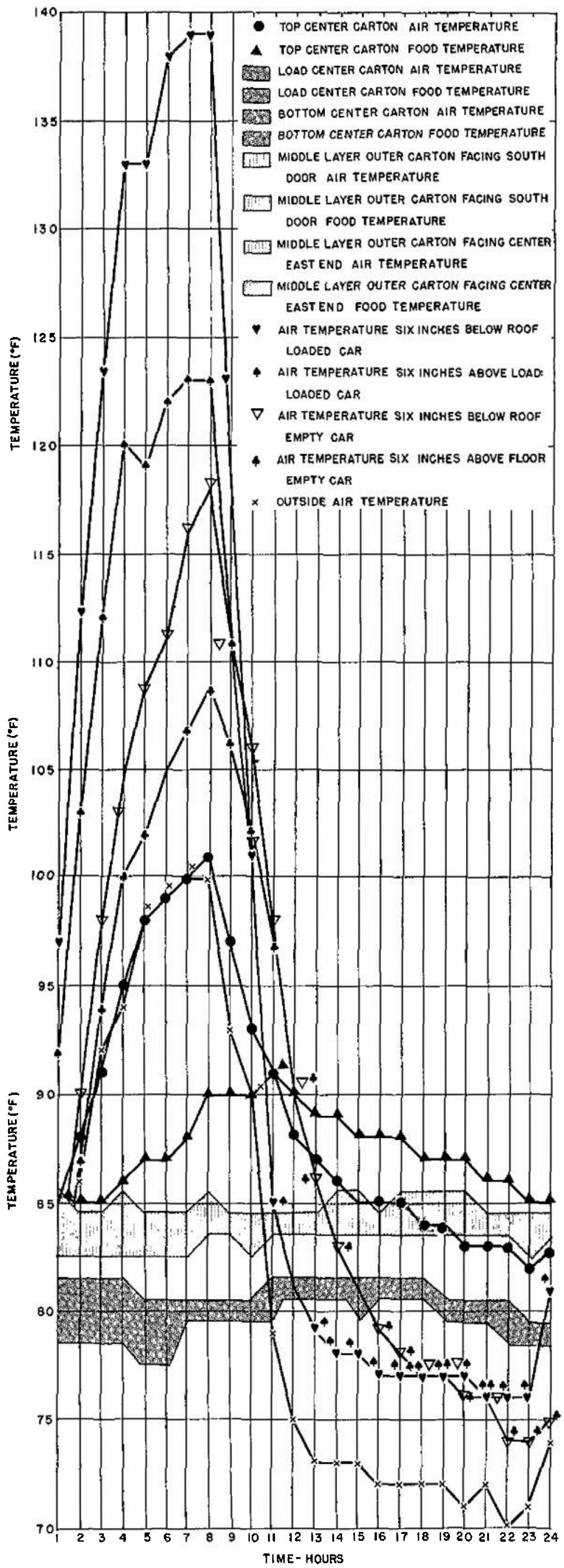

Figure 14 Storage temperatures for hottest day - Cameron

Top Center Carton Air temperature maximum was 16 F° less at Cameron than at Yuma, whereas Roof Air temperature was only 10 F° less. Indeed, on 31 August at Cameron, another extremely hot day, when Roof Air temperature reached its all-summer maximum of 145°F (interhourly), Top Carton Air temperature only reached 97°F Thus, although all-summer maximum and mean Roof Air temperature were within 5-6 F° at the two locations, the difference between the corresponding Top Carton Air Temperatures at the two locations is considerably greater, 15-18 F°. This is probably the most pronounced difference in temperature behavior between the boxcars at the two locations, which in other statistics, show a similar response to external heat stress

For example, the conservatism of the Load Center temperature daily cycle is similar at both stations, as is the reduction in temperature at this position in contrast to the Top Center Carton

This exemplified the pronounced effect of position of measurement and degree of protection, which is one of the salient results of these studies There is, thus, 45-60 F° difference between the maxima at different positions within the same car, and indeed, within 7 1/2 feet in actual distance Indeed, in the summer, there is often more range of temperature within the air of one boxcar than in the ambient temperatures throughout the United States at a given time

B. Regression of Weekly Mean Top Carton Air Temperature and Roof Air Temperature on Weekly Mean Outside Air Temperature

As found in pilot analyses of mean storage temperatures derived from maxima and minima in the Yuma boxcar and Yuma Dump Storage Studies (1, 10), it was found in the detailed computer analysis of the Cameron and Yuma data reported herein that there was a high degree of correlation between weekly mean Top Carton Air and Roof Air temperatures and weekly mean Outside (Ambient) Air temperatures at both locations, and that the linear regression equations developed had similar constants

A plot of the weekly mean temperatures for Yuma and Cameron used in this regression analysis versus time is shown in Figures 15 and 16 Values are shown in Tables VII and VIII. Similar means for windspeed and total weekly solar and sky radiation are shown, since multiple regression equations were computed using them, although the correlation coefficients were found to be low for these latter two parameters

A prominent feature of Figure 15 is the arrival of the Continental Tropical - Maritime Tropical dewpoint "front" at Yuma on 29 June. This is the intermittent arrival of air of higher dewpoint which has moved from the Gulf of Mexico at high levels It is discussed at length elsewhere (9, 10, 11). The effect, plainly seen in Figure 15, is a drop in weekly total radiation, a pronounced rise in ambient and storage night-time minimum temperatures, and a corresponding rise in mean ambient and storage temperatures, since the maxima are little affected (11). Thus the highest ambient and storage mean temperatures occur under conditions of reduced total incoming as well as outgoing radiation It is the reduction of the amount of outgoing long wave radiation, especially at night, which causes the large excess of sensible heat after the arrival of the moister air

This effect is not found at Cameron, as Figure 16 shows However, at both locations, the close relation of storage and ambient mean temperatures is plain, the relation holding both before and after the "front" at Yuma with equal validity

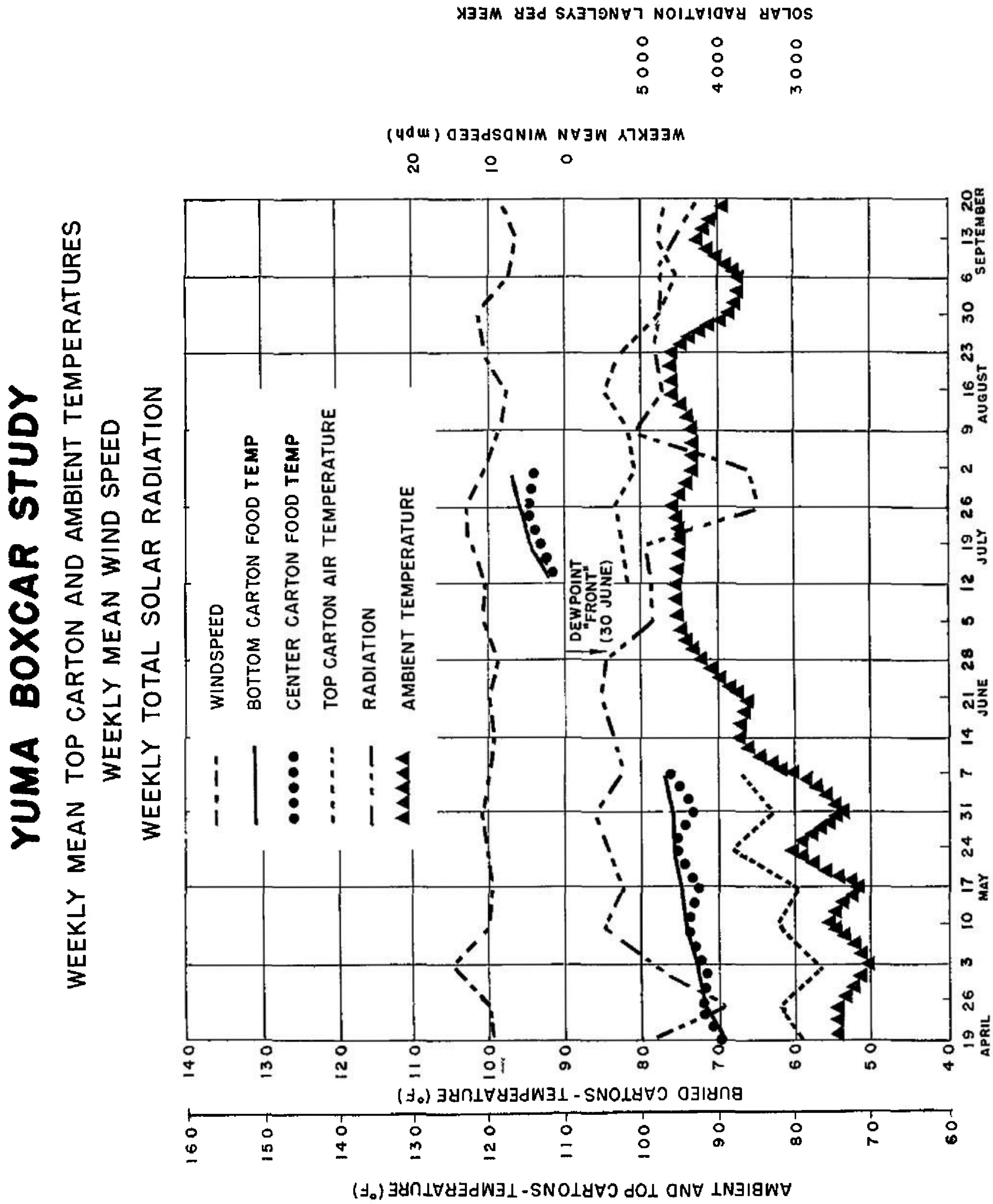

Figure 15. Weekly means of temperature, wind speed, and radiation - Yuma

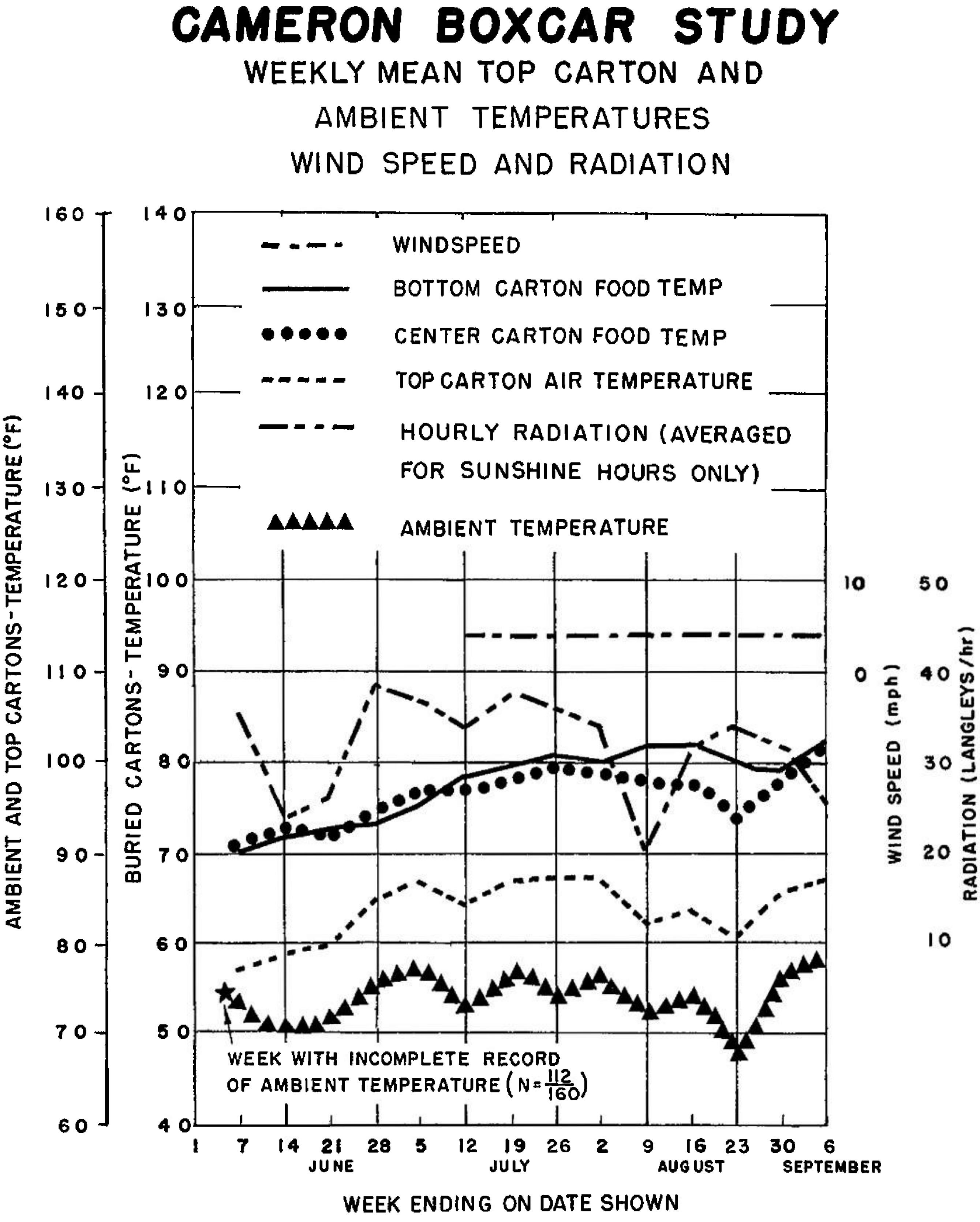

Figure 16 Weekly means of temperature, wind speed, and radiation - Cameron

Table VII

Weekly Mean Storage and Ambient Temperatures,
Wind Speeds, and Total Weekly Radiation

Yuma

No. of Period	Week[c] Ending	Top Carton Air (°F)	Roof Air (°F)	Ambient Air (°F)	Wind Speed (mph)	Radiation (langleys)
1	19 Apr	78.8	83.3	73.6	9 3	4924.1
2	26	81.6	85.5	73.3	9.9	3902.4
3	3 May	76.9	76.9	68.9	14.8	4827 6
4	10	82.0	86.1	75.2	10.0	5445.3
5	17	79 9	82.1	70.7	9.6	5226.9
6	24	88.0	92.6	79.6	10 0	5432.0
7	31	82.7	85.0	72.2	10.9	5551.5
8	7 Jun	86.9	89.9	78 1	9 8	5210.0
9[a]	14	90.1	98 4	87.6	9 3	5321 3
10	21	93 7	98.0	85 2	9 7	5507 3
11[a]	28	105 0	130.8	91 8	8 8	5452.0
12[a]	5 July	99.8	102.0	94.8	10.5	4804.5
13	12	101.7	104.9	94.7	10 4	4831.4
14	19	102.1	104.6	94.1	12 1	4949.8
15	26	103 2	104.4	95 5	13 0	3400 0
16	2 Aug	100 8	101.8	92.6	10.4	3590.5
17	9	101.6	103.5	92.5	8.5	5057.5
18	16	104 4	106.4	95.4	7.6	4714.4
19	23	102.8	103.8	95.6	10 6	4803.5
20	30	97 3	95.5	87.6	11.4	4740.9
21[b]	6 Sept	95.3	97.6	86.7	7.1	4748.1
22[b]	13	97.9	101.3	92.5	6.7	4549.5
23[b]	20	96.7	96.6	88.5	8 1	4273.2

Number of Hourly Observations

No. of Period	Top Carton Air	Roof Air	Ambient Air	Wind Speed
1	158	128	168	141
2	158	158	168	155
3	168	168	168	165
4	168	168	168	156
5	168	168	168	155
6	168	168	168	147
7	167	167	168	149
8	168	168	168	152
9[a]	33	33	168	148
10	129	129	168	148
11[a]	6	6	168	139
12[a]	95	95	168	158
13	166	166	168	160
14	168	168	168	163
15	168	168	168	161
16	168	168	168	160
17	168	167	168	158
18	168	168	168	149
19	168	168	168	167

(cont'd)

Table VII (cont'd)

Number of Hourly Observations

No. of Period	Top Carton Air	Roof Air	Ambient Air	Wind Speed
20	168	167	168	160
21[b]	168	165	168	138
22[b]	168	168	168	131
23[b]	168	168	168	130

[a]Not used in correlation because of incomplete number of observations. (See lower table).

[b]Not used in correlation since Top Carton Air position covered by aluminum foil

[c]Dates of periods used in correlation do not coincide with periods used in frequency distributions, since the latter were adjusted to coincide with changes in the program of insulating blanket testing.

Figures 17 and 18 are plots of ambient versus storage temperature weekly means to show more plainly the degree of correlation. The linear regression lines and the mean point used for each line are also shown. On Figure 17 for Yuma, the regression lines for Cameron have been superimposed on the plots, together with a few of the points at the extremes of the distribution. The relatively good agreement of the relations at the two locations, particularly in Top Carton Air temperature, is clear. Since in Figure 17 there is a thirty degree range of mean weekly Top Carton Air temperature, the agreement lends much support to the generality of the relationships.

Table IX shows the linear regression equations and multiple linear regression correlation coefficients developed in this study. The high correlation with mean ambient weekly temperature and low negative correlation with wind speed is plain at both locations. However, the low negative correlation with total weekly radiation at Yuma is replaced by a moderately high positive correlation at Cameron. This is a direct and somewhat misleading result of the dewpoint "front" at Yuma mentioned above, which temporarily reduces total daily radiation, but increases mean storage and ambient temperature. This does not occur at Cameron, at least within the period studied, since the general summer southwesterly flow of Maritime Tropical moist air begins quite early there. Therefore, the positive correlation with radiation appears, which would show up at Yuma, were the study period twice as long.

In any case, it is clear that the multiple linear correlation coefficients are relatively little increased by the addition of radiation or wind speed (except, perhaps, for Roof Air temperature in the loaded car at Cameron). Period means of storage temperature correlate most closely with ambient temperature means in their complex response to radiation, advected heat, and wind. Therefore, while certainly not the causative agent, mean ambient temperature is an effective predictor of mean storage temperature.

C. Means and Frequency Distributions of Hourly Temperature

Percentage frequency distributions of hourly temperatures, means, standard deviations, some extremes, and numbers of observations at the eighteen positions observed in this study are shown in Tables X-LV and Figures 19-55 for the total period and each week of the research period at Yuma and Cameron. The weeks used in these tables do not necessarily coincide with those for the regression line computations, since the periods used in the frequency distributions have been adjusted to coincide with times of insulation blanket changes.

In both maximum and mean temperature, the Top Center Carton is by far the most critical carton studied (Tables VII, VIII, X-XIII, XXXVII, XXXVIII and Figures 13, 14, 19, and 20). In fact, although their maximum temperatures were greatly different, the mean temperature of Top Center Carton Air for the total period was only 2 F° less than that of Roof Air at Yuma and 5 F° at Cameron (Figure 17, 18). This was caused by the nightly cooling of Roof Air to temperatures 5-7 F° below Top Carton Air for 12-14 hours per day (Figure 13).

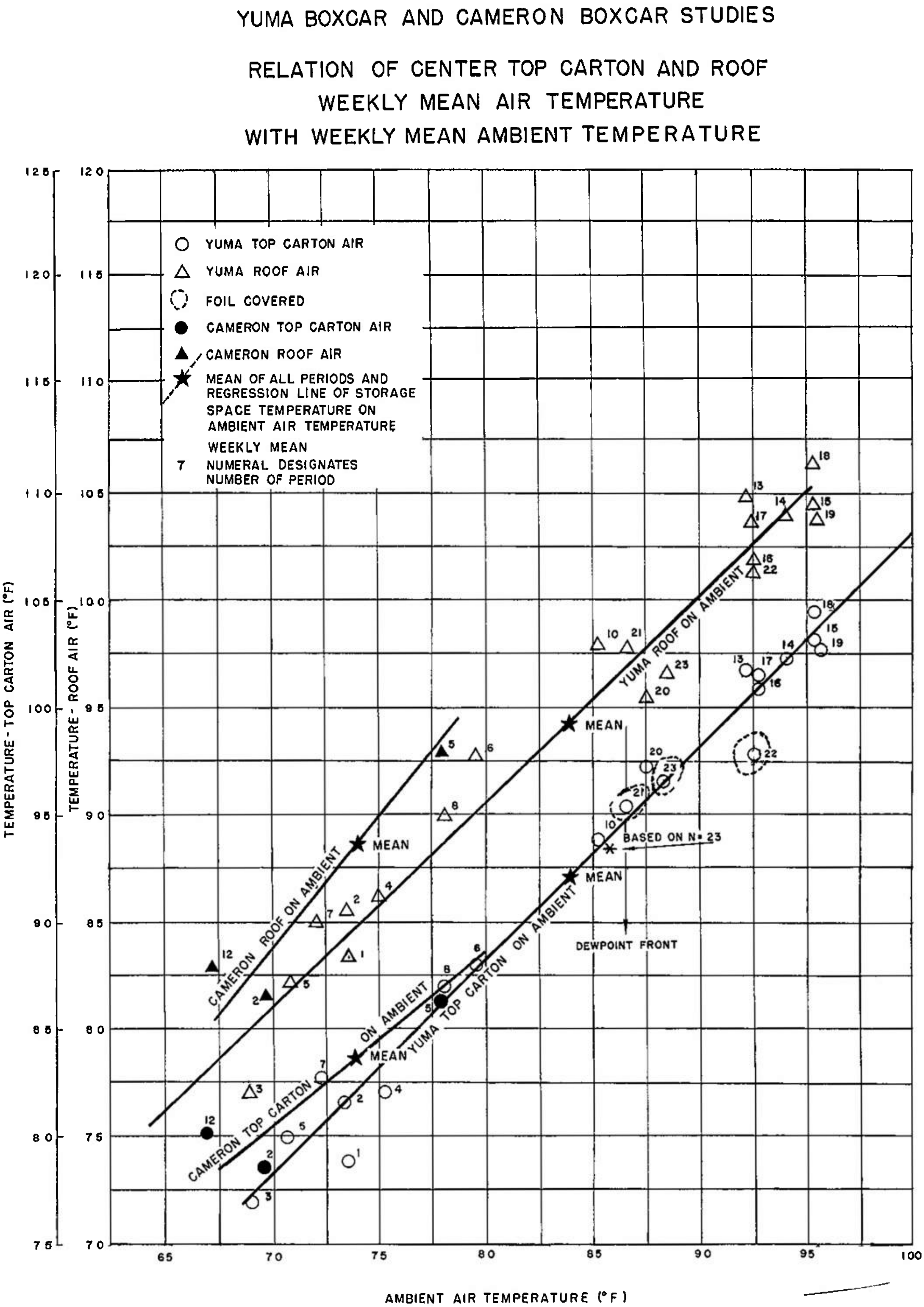

Figure 17 Regression of weekly mean storage temperatures on weekly mean ambient air temperature - Yuma.

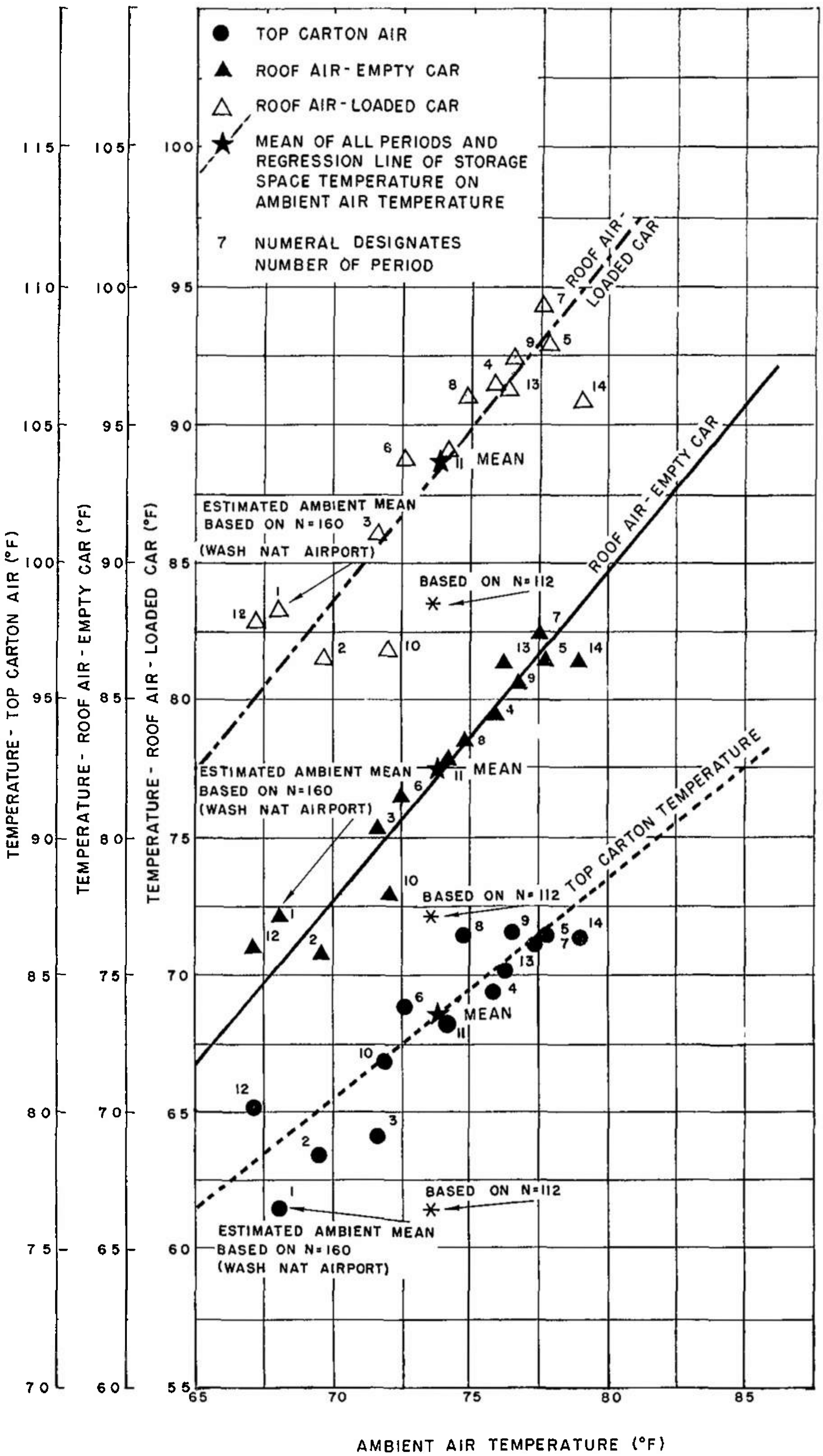

Figure 18. Regression of weekly mean storage temperatures on weekly mean ambient air temperature - Cameron

Table VIII

Weekly Mean Storage and Ambient Temperatures, Wind Speeds and Mean Hourly and Total Weekly Radiation

Cameron

Number of Period	Week Ending	Top Carton Air (°F)	Roof Air Loaded Car (°F)	Roof Air Empty Car (°F)	Ambient Air (°F)	Wind Speed (mph)	Mean Hourly Radiation for Hours of Recorded Radiation[d] (langleys)	Total Weekly Radiation (langleys)
1[b]	7 Jun	76 5	83 6	77 1	73 7	Misg	34 8	3911
2	14	78 4	81 6	75 9	69 7	Misg	23 3	2568
3	21	79 1	86 0	80 4	71 7	Misg	25 5	2811
4	28	84 5	91 4	84 6	75 8	Misg	38 1	4249
5	5 July	86 5	93 0	86 6	77 9	Misg	36 6	4101
6	12	84 0	88 9	81.6	72 7	3 8	33 4	3779
7	19	86 4	94 4	87 6	77 7	3 4	36 9	4128
8	26	86 6	91 2	83 6	74 9	3 4	35 5	3984
9	2 Aug	86 7	92 5	85 7	76 7	3 4	33 2	3735
10	9	81 8	81 9	78 0	72.1	3 7	19 1	1532[e]
11	16	83 3	88 7	82 7	74.1	3 7	31 0	3471
12	23	80 2	82 9	76 1	67 2	3 2	33 7	2579[e]
13	30	85.1	91 3	86 4	76 3	3 3	31 3	3587
14[c]	6 Sept	86.5	90 9	86 6	79 1	3 6	25 5	2842

Number of Hourly Observations

No of Period	Top Carton Air	Roof Air Loaded Car	Roof Air Empty Car	Ambient Air	Wind Speed
1[b]	160	160	160	112	
2	167	167	167	167	
3	164	164	164	164	
4	167	167	167	167	
5	166	166	166	166	
6	168	168	168	168	168
7	168	168	168	168	165

(cont'd)

Table VIII (cont'd)

Number of Hourly Observations

No. of Period	Top Carton Air	Roof Air Loaded Car	Roof Air Empty Car	Ambient Air	Wind Speed
8	168	168	168	168	168
9	164	164	164	164	113
10	147	147	147	147	92
11	167	167	167	167	60
12	168	168	168	168	68
13	159	159	159	159	75
14[c]	168	168	168	168	54

[a]See footnote c on Table VII.

[b]Not used in correlation because of incomplete number of observations. (See lower table).

[c]Not used in correlation since Top Carton Air position covered by aluminum foil.

[d]Used in correlation in place of total weekly radiation, since four days of record were missing from the latter

[e]Missing record for 8, 9, 22, and 23 August.

Table IX

Linear Regression Equations of Storage Temperatures on Ambient Variables

Dependent Variable	Independent Variable	Mean Dep. Var.	Mean Ind. Var.	Y Intercept	Slope	Standard Error of Estimate	Linear[a] Correlation Coefficient	Multiple[b] Correlation Coefficient		N
				Yuma						
Top Carton Air	Ambient Air	92.0	83.8	8.55	0.996	1.17	0.993	T on A	0.993	17
	Radiation		4830.3	120.0	-0.006	9.26	-0.363	T on A, R, WS	0.993	
	Wind Speed		10.5	100.2	-0.779	9.86	-0.127	T on A, R	0.993	
Roof Air	Ambient Air	94.3	83.8	15.2	0.944	1.54	0.987	T on A	0.987	17
	Radiation		4830.3	117.8	-0.005	8.99	-0.319	T on A, R, WS	0.992	
	Wind Speed		10.5	107.7	-1.282	9.25	-0.220	T on A, R	0.988	
				Cameron						
Top Carton Air	Ambient Air	83.6	73.9	24.3	0.802	1.39	0.877	T on A	0.906	12
	Radiation		31 5	72.3	0.359		0.701	T on A, R, WS	0.947	12

(cont'd)

Table IX (cont'd)

Linear Regression Equations of Storage Temperatures on Ambient Variables

Dependent Variable	Independent Variable	Mean Dep. Car.	Mean Ind. Var.	Y Intercept	Slope	Standard Error of Estimate	Linear[a] Correlation Coefficient	Multiple[b] Correlation Coefficient	N
	Wind Speed		3.5	90.3	-1 714		-0.149	T on A, R 0.947	8
Roof Air Loaded	Ambient Air	88 6	73.9	-3.4	1 246	1.77	0 912	T on A 0.873	12
	Radiation		31.5	69.5	0.609		0 797	T on A, R, WS 0.998	12
	Wind Speed		3.5	105.4	-4 681		-0.219	T on A, R 0.998	8
Roof Air Empty	Ambient Air	82 4	73.9	-5.9	1.196	0.28	0 964	T on A 0.958	12
	Radiation		31.5	67.8	0.465		0.671	T on A, R, WS 0.991	12
	Wind Speed		3.5	94.5	-3.369		-0 174	T on A, R 0 990	8

[a] See last column for N.

[b] For Cameron, N = 8 throughout.

Table X

Percentage Frequencies, Means and Standard Deviations of Hourly Observations for Total Period
April 13 to August 31, 1953 - Yuma

Temperature (^{o}F)

Position	30-9	40-9	50-9	60-9	70-9	80-9	90-9	100-9	110-9	120-9	130-9	140-9	$\overline{x}$	S_x	N
Top Center Carton Air Temperature			1	16	20	31	20	12	0.03				92.4	12.3	2952
Top Center Carton· Food Temperature			0.25	13	26	24	32	4					92.2	10.8	2952
Middle Layer Outer Carton Facing West Door: Air Temperature			1	35	13	30	19	2					87.5	12.0	2952
Middle Layer Outer Carton Facing West Door: Food Temperature			1	33	14	33	19						87.5	10.8	2952
Middle Layer Outer Carton Facing Center South End: Air Temperature			0.39	27	23	28	21	0.37					88.6	10.7	2952
Middle Layer Outer Carton Facing Center South End: Food Temperature			0.39	36	14	41	9						87.4	9 9	2952
Load Center Carton: Food Temperature			2	44	5	33	16						84.7	11.7	2952
Bottom Center Carton· Air Temperature			1	44	5	33	15						85.5	11.6	2952
Bottom Center Carton: Food Temperature			1	44	6	37	12						85.2	11 4	2952
Air Temperature Six Inches Below Roof: Loaded Car		4	12	12	20	10	9	10	12	7	3	0 03	94.8	24.3	2919

(cont'd)

Table X (cont'd)

Position	30-9	40-9	50-9	60-9	70-9	80-9	90-9	100-9	110-9	120-9	130-9	140-9	150-9	$\bar{x}$	S_x	N
Air Temperature Six Inches Above Load· Loaded Car		2	14	10	14	20	19	11	7	3				92 3	19.4	2944
Air Temperature Six Inches Below Roof Empty Car			2	12	25	10	7	9	14	13	7	0.08		103 6	23 4	1118
East Door: Inside Surface Temperature			2	11	26	9	9	13	13	8	4	3	0 17	103.0	23.0	1118
Roof Center: Inside Surface Temperature				2	21	23	7	11	19	14	2	0.08		106.4	18 9	1118
Air Temperature Six Inches Above Floor: Empty Car			2	13	26	12	13	16	14	3				97.5	18.0	1118
South End: Outside Surface Temperature			2	14	30	13	10	9	10	7	4	1		98.1	21.3	1118
West Door: Inside Surface Temperature			2	12	31	13	10	8	9	6	4	3	1	99 9	23 1	1117
Outside Air Temperature	0.02	3	12	17	27	24	15	2						84.9	13.6	3385

Table XI

Percentage Frequencies, Means and Standard Deviations of Hourly Observations for Total Period
June 1 to September 1, 1953 - Cameron

Temperature (^{o}F)

Position	66-7	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	86-7	88-9	90-1	92-3	94-5	96-7	98-9	$\bar{x}$	S_x	N
Top Center Carton: Air Temperature	1	1	2	4	4	6	11	14	11	10	7	7	6	6	4	3	1	83 2	7.2	2180
Top Center Carton: Food Temperature			1	2	2	4	7	13	19	18	17	9	3	1				82 7	4.9	2180
Load Center Carton: Food Temperature	1	1	10	16	5	5	26	28	5									76 8	4 0	2180
Bottom Center Carton: Air Temperature	1	2	6	16	17	23	22	10	1									75 7	3.3	2161
Middle Layer Outer Carton Facing South Door: Food Temperature		1	1	3	9	11	6	19	30	17	1	1						80 3	3.9	2161
Middle Layer Outer Carton Facing Center East End: Food Temperature		1	1	2	5	12	7	16	33	20	2							80.8	3.6	2161

Temperature (^{o}F)

Position	50-9	60-9	70-9	80-9	90-9	100-9	110-9	120-9	130-9	140-9	150-9	160-9	$\bar{x}$	S_x	N
Air Temperature Six Inches Below Roof. Loaded Car	3	19	27	9	7	8	9	9	4				88 5	23.2	2180
Air Temperature Six Inches Above Load. Loaded Car	3	20	27	10	10	14	10	2					84.7	18.6	2180
Air Temperature Six Inches Below Roof. Empty Car	4	18	26	15	16	14	3						82.3	15.6	2180

(cont'd)

Table XI (cont'd)

Temperature (^{o}F)

Position	50-9	60-9	70-9	80-9	90-9	100-8	110-9	120-9	130-9	140-9	150-9	160-9	$\bar{x}$	s_x	N
Air Temperature Six Inches Above Floor: Empty Car	4	19	28	20	19	7							79.8	13.0	2181
Outside Air Temperature	8	29	30	21	9	1							74.1	11 0	2133

YUMA BOXCAR STORAGE
13 APRIL-31 AUGUST 1953
FREQUENCIES, MEANS, AND
STANDARD DEVIATIONS OF
HOURLY TEMP. OBSERVATIONS

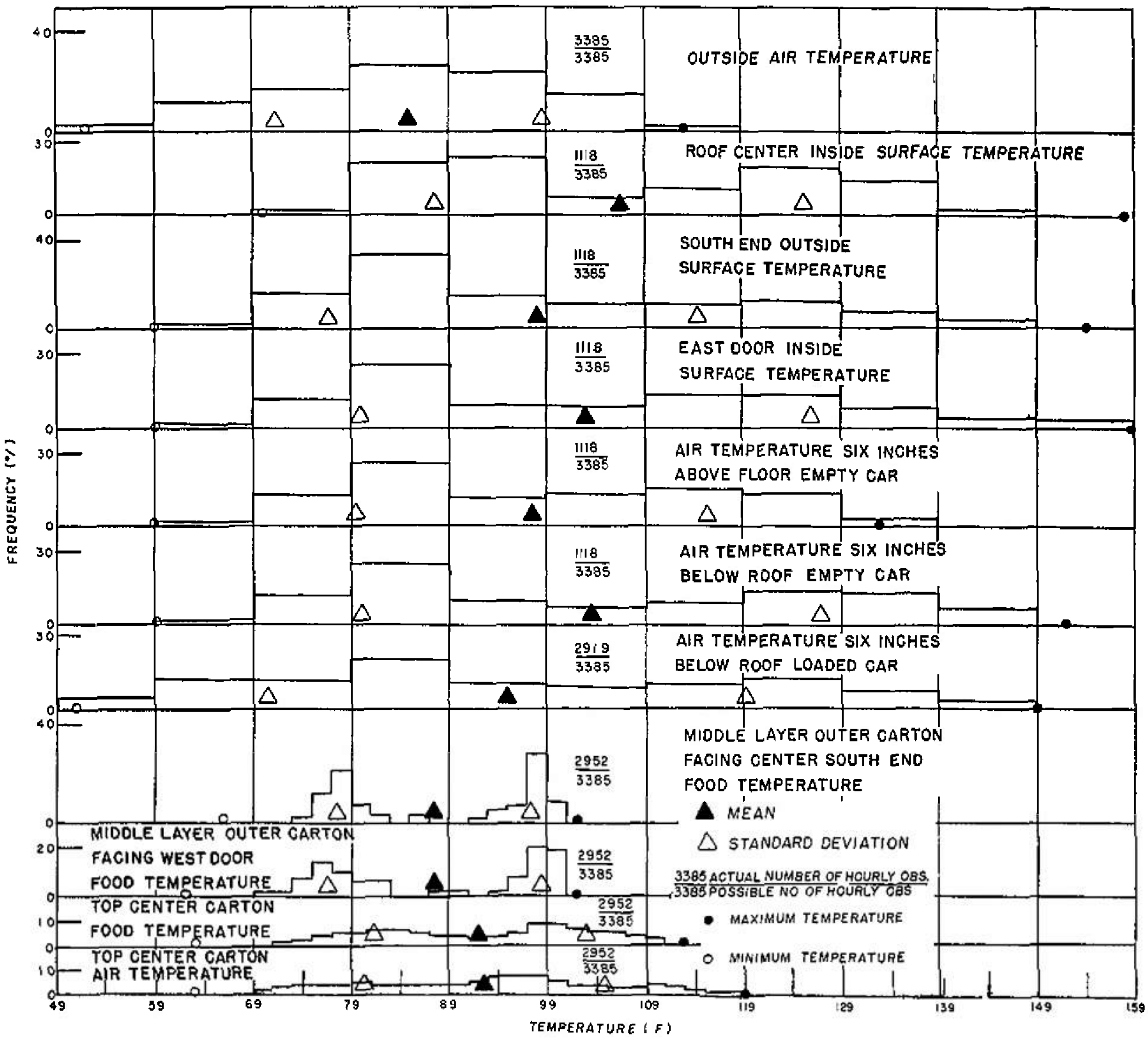

Figure 19. Means, frequencies, and standard deviations of temperature observations for total period - Yuma.

CAMERON STATION BOXCAR STORAGE
1 JUNE-1 SEPTEMBER 1953
FREQUENCIES, MEANS AND STANDARD DEVIATIONS OF HOURLY OBSERVATIONS

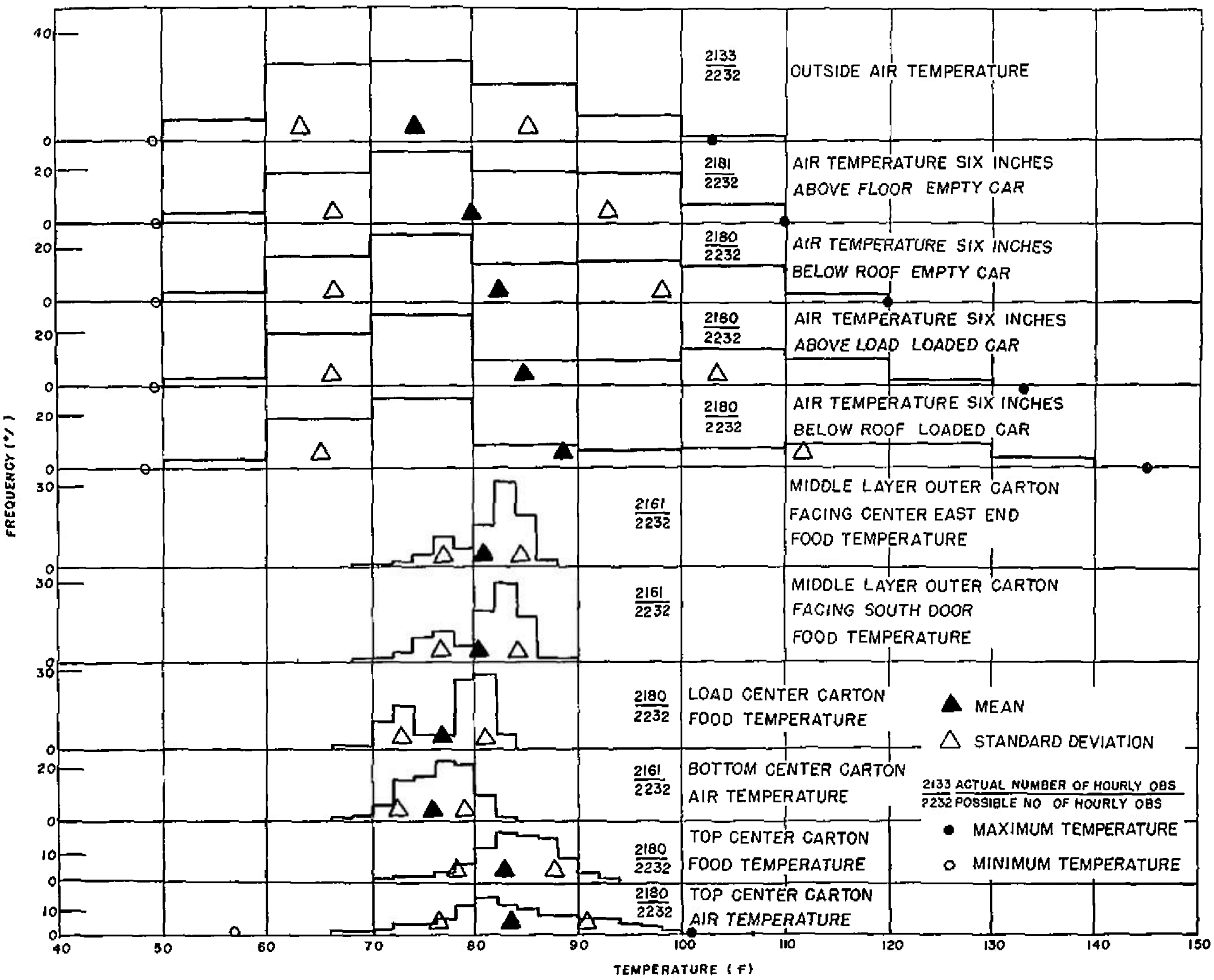

Figure 20 Means, frequencies, and standard deviations of temperature observations for total period - Cameron

The variability of hourly Top Carton Air temperatures around the mean for the week is shown in the following summary:

	Number of Weekly Periods as Fraction of Total Number for which Two Standard Deviations Added to Mean Gives Maximum:			Number of Degrees Required to be Added to Mean to Include Maximum for all Periods (F°)
	Within 1 F°	Within 2 F°	Greater Than 2 F°	
Yuma	15/21	21/21	--------	18
Cameron	12/14	13/14	14/14	15

The similarity of the figures for Yuma and Cameron in the last column of the summary, i.e., the greatest number of degrees which must be added to the mean of each period to include the maximum for that period, suggest that the use of 20 F° added to the predicted storage air temperature mean for a period is a safe figure in the divergent locations studied to predict the maximum for that period

The consistency of the frequency distributions is shown in Figures 58 and 59, in which weekly standard deviation of Top Center Carton Air is plotted against the corresponding Ambient Air standard deviation. For Yuma, 15 out of 18 carton temperature standard deviations are between 6 and 8 F°, while for Cameron, essentially 10 out of 13 are between 5 and 7 F°. In both figures, the hotter weeks have been shown by open circles, which at Yuma occur after the dewpoint "front". The standard deviations of these hot weeks tend to be lower and less variable than for other weeks at Yuma. At Cameron, standard deviations of hot weeks are intermediate but also less variable than for cool weeks Thus, the temperature frequency distributions of critical hot weeks are more predictable

For a given week the mean temperature of all cartons are within 10 F°, in general, but, as noted for the hottest day, above, the load center cartons are very conservative in the weekly temperature cycle, as compared to the large range of the top layer cartons Thus, the same effect of position and degree of protection operates on the weekly maximum carton air temperatures which are 20 F° higher in the top layer than within the buried load It would seem advisable for shippers to give serious thought to the possibilities of loading dummy cartons protected by reflective insulation above the actual load for items sensitive to temporary excesses of temperature over certain discrete limits. Indeed, the brevity of the mid-day pulse of strong incoming solar radiation, as it is transmitted to the load, and the long night-time period available for recovery by emission of radiation, place a premium on all forms of protection which smooth the mid-day peaks of the cycle.

D. Prediction of Actual and Effective Mean Carton Air Temperatures with Respect to Sterile Food Degradation

Weekly mean air temperature in storage can be predicted with a high confidence level from ambient mean temperatures by use of the appropriate relation from Table IX or Figures 17 and 18, part III-2 above. Also, because of the consistency of frequency distribution, quite reliable predicted frequency distributions of hourly Top Carton Air temperatures with reference to each predicted mean may be constructed, by the judicious use of the appropriate data from Tables XII-LV. Total predicted storage temperature frequency distribution for a period comprising a number of weeks may then be obtained by addition of the component frequency distributions

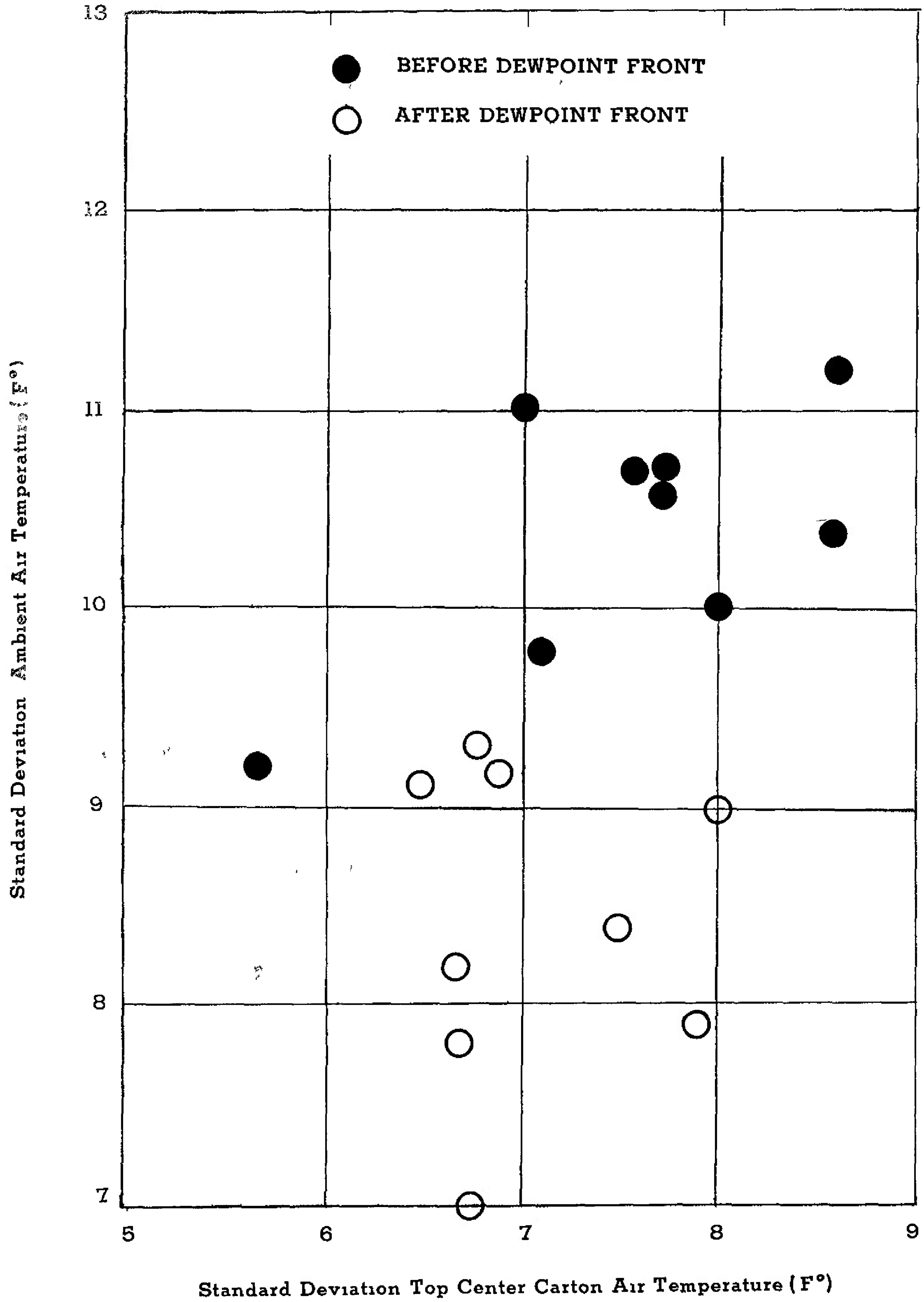

Figure 58. Variability of storage and ambient air temperatures - Yuma.

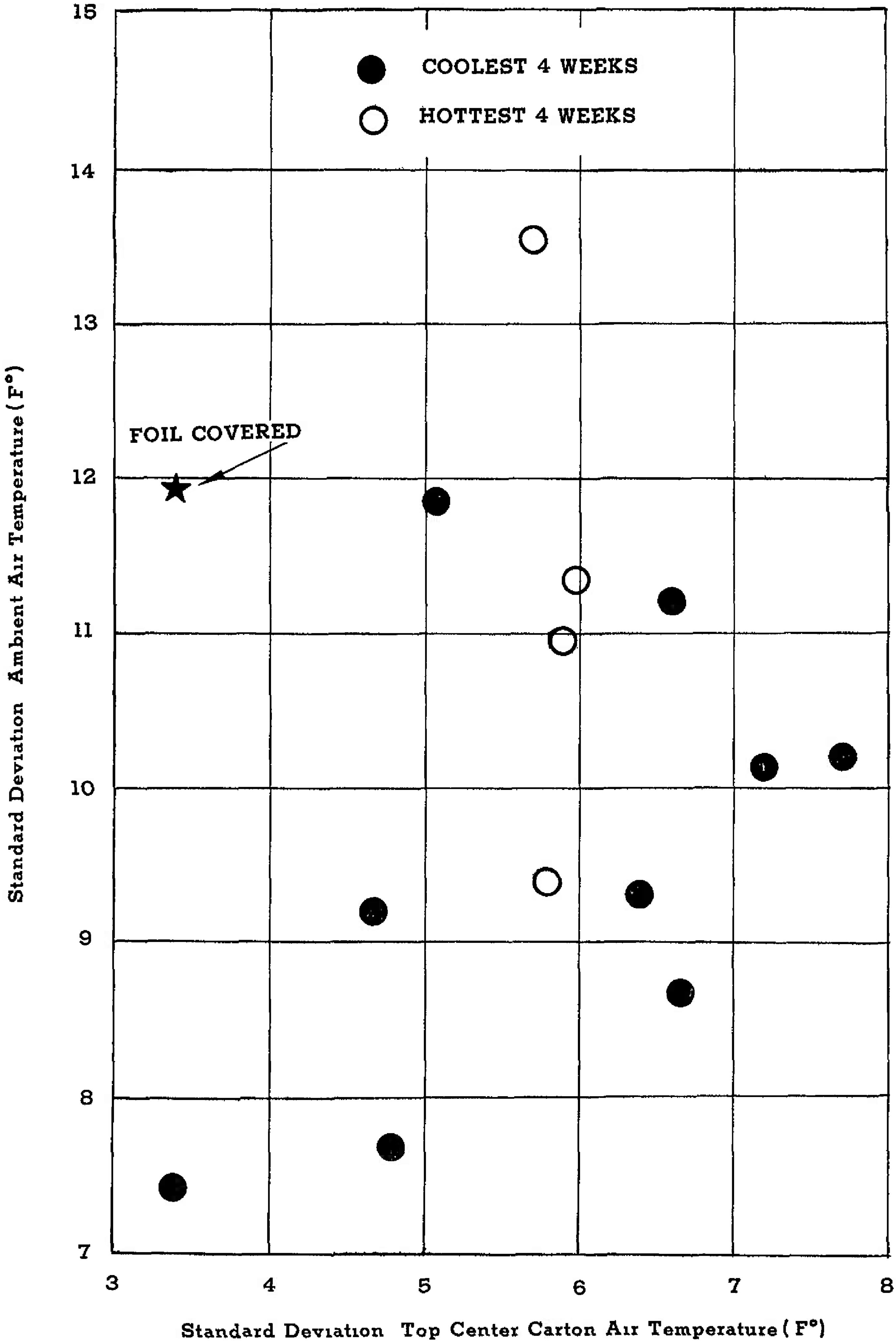

Figure 59. Variability of storage and ambient air temperatures - Cameron.

The method of computing an effective mean storage temperature for use in laboratory simulation of predicted storage stress under variable temperature conditions has been extensively discussed elsewhere (10). This, of course, presupposes a known relationship of relative rate of degradation and temperature. Such a relation often approximates an exponential function with so-called Q_{10} of 2 (i.e., doubling of reaction rate with every 10°C or 18°F rise in temperature).

If such a relationship is known, one may compute the total relative degradation corresponding to the time spend at each temperature of the frequency distribution for the total period concerned. From this, a mean relative degradation rate for the period may be computed, which corresponds to one temperature, the effective mean temperature for storage. Such computations based on Q_{10} of 2 are shown in Tables LVI-LVIII for both the Top Center Carton Air and Food temperature frequency distributions at Yuma and Cameron. The difference between effective mean and arithmetic mean is 3 F° or less in all cases. Table LIX shows the relative degradation rates corresponding to Q_{10} of 2 at various temperatures of storage.

Alternatively, one may compute the effective temperature increment representing the weekly fluctuation by using frequency data for the weekly period with the greatest storage temperature range, as in Tables LX and LXI, and add this to the effective mean temperature obtained by computation from the predicted mean storage temperatures for the several weeks of the period, as in Table LXII. The results usually differ from those by the first method by one degree or less, and the method had the advantage of greater simplicity. For example, the increment due to the fluctuation within the week is approximately 1.5 F°, while the effective mean of all the weekly mean Top carton air temperatures at Yuma happens to be also 1.5 F° higher than the arithmetic mean (93.9-92.4). Thus, the total increment is 3.0 F°, in this case, exactly the same figure as that obtained by the first method

E. Effect of Reflective Insulation in Radiation Shielding

Three types of reflective insulation (Part II-4, above) were tested as means of reducing daily maximum Top Carton Air temperatures. Tables LXIII-LXVI show the effects of these tests on mean and maximum temperatures, together with the same data for the control week ending 10 August at both locations, when the newly located positions were left uncovered The same results are covered in more extended form in Tables XI, XIII, XXII, XXIX, XXXVII-XLII and Figures 35-41 and 51-57.

One may conclude from the data of Tables LXIII-LXVI that, both at Yuma and Cameron, the effect of these coverings on the mean Top Carton Air temperature was not pronounced, resulting in a lowering of less than 5 F° in all cases.

There was, however, a much more pronounced effect on the <u>maximum</u> temperatures, a reduction of 6-10 F° at Cameron and 10-15 F° at Yuma being common, in contrast with the control positions Since the controls were both concurrent (one top layer position covered, the other simultaneously bare) and successive (the same top layer position first covered, then bare), and since the effects are demonstrated at both Yuma and Cameron, one may conclude that maximum temperatures are markedly lowered by these measures However, the graphs reveal that minimum temperatures are raised somewhat, accounting for the much smaller effect on the mean

Table LVI

Computation of Effective Mean Temperature from Percentage Frequency of Temperature[a]

Yuma - Total Period - 13 April to 1 September

Top Center Carton - Air Temperature

	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	99-0	101-2	103-4	105-6	107-8	109-0	111-2	113-4	115-6	117-8
Degradation Rate at T	1 00	1 08	1 17	1 26	1 36	1 47	1 59	1 71	1 85	2 00	2 16	2 33	2 52	2 72	2 94	3 17	3 42	3 70	4 00	4 32	4 67	5 04	5 44	5 88	6 35
Percentage Frequency (%)	2	3	4	4	4	5	4	4	4	4	4	5	8	8	8	6	4	4	3	3	4	3	2	1	1
Total Degradation at T	2 00	3 24	4 67	5 04	5 44	7 35	6 35	6 86	7 41	8 00	8 64	11 66	20 16	21 77	23 52	19 02	13 68	14 80	12 00	12 96	18 67	15 12	10 89	5 88	6 35

Mean Degradation Rate	2 662
Effective Mean Temperature	95 4
Arithmetic Mean Temperature	92 4
Difference	3 0

Top Center Carton - Food Temperature

	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	99-0	101-2	103-4	105-6	107-8	109-0	111-2	113-4	115-6	117-8
Percentage Frequency (%)		1	2	4	5	5	6	6	5	4	3	4	5	9	9	7	6	6	4	3	1				
Total Degradation at T		1 08	2 33	5 04	6 80	7 35	9 53	10 29	9 26	8 00	6 48	9 33	12 60	24 49	26 46	22 19	20 53	22 21	16 00	12 96	4 67				

Mean Degradation Rate	2 501
Effective Mean Temperature	93 8
Arithmetic Mean Temperature	92 2
Difference	1 6

[a] Method of Computation (1) Relative degradation rate corresponding to the higher temperature of each class is obtained from Table LIX, (2) Total degradation for each temperature class is obtained by multiplying frequency times degradation, (3) Mean degradation rate is obtained by dividing total degradation by total frequency, and (4) Effective temperature corresponding to mean rate is obtained from Table LIX

Table LVII

Computation of Effective Mean Temperature from Percentage Frequency of Temperature[a]

Cameron - Total Period - 1 June to 1 September

Top Center Carton - Air Temperature

Temperature (°F)

	66-7	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	86-7	88-9	90-1	92-3	94-5	96-7	98-9	100-1	Totals
Degradation Rate at T	0 89	0.96	1.04	1.12	1.21	1.31	1 41	1.53	1.65	1 78	1.92	2 08	2.24	2.42	2.67	2 83	3.05	3 29	
Percentage Frequency (%)	1	1	2	4	4	6	11	14	11	10	7	7	6	6	4	3	1	0 2	98 2
Total Degradation at T	0.89	0.96	2.08	4 49	4 85	7.85	15.55	21.39	18.15	17.82	13.47	14.55	13.47	14.54	10.46	8 48	3.05	0.66	172 73
Mean Degradation Rate	1.759																		
Effective Mean Temperature	84.7																		
Arithmetic Mean Temperature	83.5																		
Difference	1.2																		

[a]See Table LVI for computation method. Degradation rate based on lower temperature of each class.

Table LVIII

Computation of Effective Mean Temperature from Percentage Frequency of Temperature[a]

Cameron - Total Period - 1 June to 1 September

Top Center Carton - Food Temperature

Temperature (°F)

	70 -1	72 -3	74 -5	76 -7	78 -9	80 -1	82 -3	84 -5	86 -7	88 -9	90 -1	92 -3	Totals
Degradate Rate at T	1.04	1.12	1 21	1.31	1.41	1 53	1.65	1 78	1 92	2 08	2 24	2.42	
Percentage Frequency (%)	1	2	2	4	7	13	19	18	17	9	3	1	96 0
Total Degradation at T	1.04	2.25	2.42	5.24	9.90	19 86	31.35	32.08	32 71	18.71	6 73	2 42	164.71
Mean Degradation Rate	1.716												
Effective Mean Temperature	84 2												
Arithmetic Mean Temperature	82.7												
Difference	1.5												

[a]See Table LVI for computation method Degradation rate based on lower temperature of each class

Table LIX

Theoretical Relative Degradation Rates at Q_{10} of 2^{a}

Temp (°F)	Rate	Temp (°F)	Rate	Temp (°F)	Rate	Temp (°F)	Rate	Temp (°F)	Rate
57	0.606	77	1.31	97	2.83	117	6.11	120	6.86
56	0.583	76	1.26	96	2.72	116	5.88	119	6.60
55	0.561	75	1.21	95	2.61	115	5.65	118	6.35
54	0.540	74	1.17	94	2.52	114	5.44		
53	0.520	73	1.12	93	2.42	113	5.24		
52	0.500	72	1.08	92	2.33	112	5.04		
51	0.480	71	1.04	91	2.24	111	4.85		
50	0.463	70	1.00	90	2.16	110	4.67		
49	0.445	69	0.962	89	2.08	109	4.49		
48	0.429	68	0.926	88	2.00	108	4.32		
47	0.412	67	0.890	87	1.92	107	4.16		
46	0.397	66	0.857	86	1.85	106	4.00		
45	0.382	65	0.824	85	1.78	105	3.84		
44	0.367	64	0.794	84	1.71	104	3.70		
43	0.354	63	0.764	83	1.65	103	3.56		
42	0.340	62	0.735	82	1.59	102	3.42		
41	0.328	61	0.707	81	1.53	101	3.29		
40	0.315	60	0.680	80	1.47	100	3.17		
39	0.304	59	0.654	79	1.41	99	3.05		
38	0.292	58	0.630	78	1.36	98	2.94		

[a] See text, p. 41 , for meaning and method of derivation.

Table LX

Computation of Effective Mean Temperature from Percentage Frequency of Temperature[a]

Cameron - Week of 17 to 23 June

Top Center Carton Air Temperature

Temperature (°F)

	68 -9	70 -1	72 -3	74 -5	76 -7	78 -9	80 -1	82 -3	84 -5	86 -7	88 -9	90 -1	92 -3	94 -5	96 -7	Totals
Degradation Rate at T	0.96	1.04	1.12	1.21	1 31	1 41	1 53	1.65	1.78	1.92	2.08	2.24	2 42	2.62	2.83	
Percentage Frequency (%)	2	6	10	12	8	9	8	7	7	3	6	4	9	4	3	
Total Degradation at T	1 92	6.23	11 23	14.54	10.47	12.73	12.22	11 55	12.47	5.77	12 47	8.98	21.82	10.46	8.48	161.36
Mean Degradation	1.647															
Effective Mean Temperature	82.9															
Arithmetic Mean Temperature	81 4															
Difference	1 5															

[a]See Table LVI for computation method.

Table LXI

Computation of Effective Mean Temperature from Percentage Frequency of Temperature[a]

Cameron - Week of 17 to 23 June

Top Center Carton Food Temperature

Temperature (°F)

	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	86-7	88-9	90-1	Totals
Degradation Rate at T	0.96	1.04	1.12	1.21	1.31	1.41	1.53	1.65	1.78	1.92	2.08	2.24	
Percentage Frequency (%)	1	0	12	6	12	12	13	11	10	11	8	2	98
Total Degradation at T	0.96	0	13.48	7.27	15.71	16.97	19 86	18 15	17.82	21 16	16.63	4.49	152.51
Mean Degradation	1.556												
Effective Mean Temperature	81.5												
Arithmetic Mean Temperature	80.5												
Difference	1.0												

[a] See Table LVI for computation method.

Table LXII

Computation of Effective Mean Temperature from Weekly Mean Storage Temperatures

Cameron - Weeks Ending 7 June through 30 August
Top Center Carton Food Temperature

Week Ending	Mean Top Carton Food Temperature	Relative Degradation Rate[a]
6/7	75.3	1.23
6/14	78.5	1 39
6/21	78.1	1 37
6/28	83.6	1.69
7/5	85.5	1 82
7/12	84.1	1 72
7/19	85.3	1.80
7/26	86.6	1.89
8/2	86.1	1 86
8/9	82.6	1 62
8/16	83.2	1 66
8/23	80.8	1 52
8/30	84 3	1.74
Total		21 24
Mean Degradation Rate		1 64
Effective Mean Temperature		82 8
Arithmetic Mean Temperature		82 6
Difference		0 2

[a] Derived from values in Table LIX

Table LXIII

Effect of Reflective Insulation - Yuma

Figures for Covered Positions are Underlined

Mean Temperature for Week Ending on Date Shown (^{o}F)

	10 Aug	17 Aug	24 Aug	31 Aug	7 Sept	14 Sept	20 Sept
Outside Air	93 7	95 8	95.2	86.0	88 2	92.3	88 0
Top Center Carton Air	102 0	104 8	102.1	96.5	<u>95.8</u>[a]	<u>98 0</u>[a]	<u>96 5</u>[a]
Northeast Corner Top Carton Air	101.3	105.2	102.6	95.7	95.3	99 0	95 4
South Half Top Carton Air	100.3	<u>99.6</u>[a]	<u>98.5</u>[b]	<u>97.6</u>[c]	97.2	99.0	96.3

[a] Foil Covered.

[b] Covered with foil-faced No 1 blanket

[c] Covered with foil-faced No. 2 blanket.

Table LXIV

Effect of Reflective Insulation - Yuma

Figures for Covered Positions are Underlined

Maximum Temperature for Week Ending on Date Shown (°F)

	10 Aug	17 Aug	24 Aug	31 Aug	7 Sept	14 Sept	20 Sept
Outside Air	111	112	111	103	109	110	106
Top Center Carton Air	116	119	117	108	<u>101</u>[a]	<u>102</u>[a]	<u>101</u>[a]
Northeast Corner Top Carton Air	108	112	109	101	103	105	102
South Half Top Carton Air	106	<u>102</u>[a]	<u>101</u>[b]	<u>100</u>[c]	103	104	102

[a] Foil Covered.

[b] Covered with foil-faced No 1 blanket

[c] Covered with foil-faced No 2 blanket.

Table LXV

Effect of Reflective Insulation - Cameron

Figures for Covered Positions are Underlined

Mean Temperature for Week Ending on Date Shown (^{o}F)

	10 Aug	17 Aug	24 Aug	31 Aug	7 Sept
Outside Air	72.4	73.5	67.5	78.4	76 5
Top Center Carton Air	81.8	83.0	80.4	86.4	84.8[a]
West Half Top Carton Air	82.9	81.8[a]	78.8[a]	81.2[a]	84 4[b]
East Half Top Carton Air	82.5	81.7[c]	81.0[c]	81.9[b]	86.1

[a]Foil Covered.

[b]Covered with foil-faced No. 1 blanket.

[c]Covered with foil-faced No. 2 blanket

Table LXVI

Effect of Reflective Insulation - Cameron

Figures for Covered Positions are Underlined

Maximum Temperature for Week Ending on Date Shown (°F)

	10 Aug	17 Aug	24 Aug	31 Aug	7 Sept
Outside Air	94	93	89	103	101
Top Center Carton Air	93	93	90	97	91[a]
West Half Top Carton Air	91	85[a]	84[a]	85[a]	88[b]
East Half Top Carton Air	90	85[c]	85[c]	84[b]	95

[a]Foil Covered.

[b]Covered with foil-faced No. 1 blanket

[c]Covered with foil-faced No. 2 blanket

It would appear that the much less expensive foil-faced kraft paper is just as effective for this purpose as the other blankets, which are four to five times as expensive per square foot This suggests that the principle source of heat is not conduction or convection but radiation from the inner surfaces of the steel roof and the doors, the remainder of the car having an interior wooden sheathing.

F Condition of Subsistence at End of Research Period

Special inspection of the subsistence was carried out by a surveillance inspector of Food Service Division, Office of the Quartermaster General, 21 September 1953 and by the Mira Loma QM Laboratory The Report of the Mira Loma Quartermaster Depot Laboratory on 6 sample cans of beans (12) stated:

> "Loss of vacuum and some chemical decomposition seems to have taken place in this product in the desert heat. The product is sound, however, and is fit for issue".

Similarly, the report of the Richmond Quartermaster Depot Laboratory (13) stated, in reporting on 3 sample cans of beans·

> "The product examined is 'commercially sterile'. Gas analysis and physical inspection of the sample, compared with normal optimal growth rates and biochemical reactions of organisms isolated, indicate that these organisms are metabolizing very slowly. A decrease in the vacuum of sample cans and corresponding increase in carbon dioxide and bacterial counts reveal that deterioration by bacteria may accelerate with continued storage It is recommended that this product be issued immediately while bacterial counts remain at their present level"

The combat rations did not fare so well. The surveillance inspection report (14) made at Yuma by an inspector from Mira Loma Quartermaster Depot, on two critical cartons of C rations, is quoted:

> "Inspection revealed the following listed ration components to be unfit for issue. These cans are flippers, springers, and/or swells:
>
> 1 can Beans w/franks
> 1 can Ham and Lima Beans
> 1 can Prunes 8 oz.
> 2 cans Grapefruit 8 oz.
> 1 can Beans with Pork
> 1 can Meat and Beans
>
> Due to the extent of deterioration found in these rations, it is recommended that all of the C rations be salvaged".

At the time of the study, Quartermaster Food and Container Institute used oven testing for 6 months at 100°F as a measure of suitability of subsistence items for overseas shipment. In view of the combat ration deterioration noted above, and presuming that the same grades of food as those used at Yuma were so tested, it might seem that the Yuma stress was greater than the effective temperature derived above (less than 100°F) would indicate However, since at Yuma (and also at Cameron) all the matrix load of string beans was pronounced fit for issue after exposure, and since the beans were not protected by either a ration package or an overseas carton sleeve, the presumption is that the combat ration provided for study was not of recent pack or was slightly below standard. It is, of course, probable that brine-packed beans are more heat-tolerant than the C-ration components

G. Temperatures in the Empty Boxcars and Wall Surface Temperatures at Yuma

Air temperatures in the empty boxcars at Yuma and Cameron and interior surface temperatures in the loaded boxcar at Yuma are reported herein for the first time, since the previous pilot study (1) did not concern itself with such detail

Tables LXVII-LXIX summarize these temperatures, but the detailed frequency distributions, means, and standard deviations are found in Tables IX-LV and Figures 19-55 Comparative data on roof air at Yuma and Cameron are shown:

Air Temperatures Six Inches Below Roof (°F)

Location	Period	Loaded Car		Empty Car	
		Mean	Absolute Maximum	Mean	Absolute Maximum
Yuma	19 July - 20 Sep	101 4	149	103.4	152
Cameron[a]	2 June - 7 Sep	88.5	145	82 5	120

[a]Empty car was of wood construction.

The wooden car at Cameron clearly gives a much cooler environment than the loaded steel car both in mean and maximum temperatures, whereas the empty steel car at Yuma was slightly hotter than the loaded car. The reason for the contrast appears to be that at Yuma there is radiation from the steel roof and doors into the steel car. The wooden car, although it has a steel roof like the steel car, has also a wooden ceiling sheathing underneath

Wall temperatures for the loaded steel car at Yuma are shown in Tables LXVIII and LXIX A summary of the data follows:

Position	Wall Surface Temperatures (°F)	
	Mean	Absolute Maximum
Outside Surface of South End	99.0	173
Inside Surface of East Door	103.2	159
Inside Surface of Roof Center	106.3	148

The upper outside surface of the metal corrugations on the south end of the loaded steel car, as might have been expected, reached the highest maximum surface temperature, 173°F, at 1400 on 10 September with a wind speed of 3 mph However, the inside surface of the roof center sustained the highest mean surface temperature for the total period, although its maximum temperature was notably lower. This is probably because the outer surfaces cool strongly by radiation at night, while the interior roof surface is warmed by radiation from the warm load within the car until cooling makes the interior air space isothermal at about the time of sunset.

Limited data obtained in July on the west door interior surface suggest that it is the hottest surface of the car, but the data are not extensive enough to predict what temperature it might have reached on 10 September (the day of hottest observed surface temperature mentioned above) had measurements been available.

If further confirmation were needed for the thesis that boxcar high temperatures are extremely divergent at different points in the air space and load at any given time of intense heat accumulation, these surface temperatures provide it. For example, at the moment (1700, 22 July) that the surface of the West Door was reaching 167°F, its summer maximum, the air in the Top Carton reached 116°F and the Top Carton Food 110°F, the absolute maxima for that day for the two positions. Roof Air reached 145°F and Air Above Load 136°F this day, at 1600. The danger of making inference about food temperatures from haphazard temperature measurements at various points in a storage space is plain from these data

Table LXVII

Roof Air Temperatures - Cameron

Loaded (Steel) Versus Empty (Wooden) Boxcar

Temperature (^{o}F)

Week Ending	Mean			Maximum[a]		
	Loaded	Empty	Difference	Loaded	Empty	Difference
9 June	88 3	82.2	6.1	129	106	23
16 June	80.6	74.0	6.6	127	99	28
23 June	87.9	82.8	5.1	134	111	23
30 June	93.1	85 9	7.2	144	114	30
7 July	92.8	86.6	6.2	133	111	22
15 July	88.5	80.9	7.6	137	113	24
23 July	94.4	88.2	6.2	138	116	22
30 July	92.6	84.4	8.2	139	118	21
4 August	86 0	80.6	5.4	130	108	22
10 August	82.8	78.9	3.9	124	106	18
17 August	87.4	81.8	5.6	143	111	32
24 August	83.8	76 8	7.0	134	109	25
31 August	93 5	88.4	5.1	145	118	27
7 Sept	87.1	82.9	4 2	141	117	24
Mean for Total Period	88.5	82.5	6.0	135.6	111.2	24 4
Absolute Maximum for Period				145	120[b]	32

[a]Absolute Maximum for week.

[b]Occurred on 1 September, a control day not included in the weekly periods

Table LXVIII

Mean Roof Air and Wall Temperatures - Yuma

Temperature (^{o}F)

Week Ending	Roof Air		Wall Temperatures			
	Loaded Car[a]	Empty Car	West Door[b]	East Door	South End (Outside Surface)	Roof Center
19 April	83 3					
26 April	85.5					
3 May	76.9					
10 May	86 1					
17 May	82.1					
24 May	92.6					
31 May	85.0					
7 June	89.9					
14 June	-----					
21 June	98 0					
28 June	-----					
5 July	102 0					
12 July	104.9					
19 July	104.0	105.1	104.2	104 0	98.6	108.3
26 July	104.4	101 4	100.4	99.9	94.7	104.0
4 August	102.0	103.7	102 6	103 0	97.6	106.9
10 August	103 7	108 3	-----	108.2	102.2	110 4
17 August	106.8	113 0	-----	113 9	106.3	115.7
24 August	102.7	104 4	-----	103.8	101 0	107 0
31 August	94 8	95.8	-----	96.6	92.9	99 6
7 September	98.7	99.5	-----	99.8	96 6	102 5
14 September	101.2	105.9	-----	105.1	103 6	107.5
20 September	96.0	97.1	92 9	97.3	96.6	100 7
Mean for Period (19 Jul - 20 Sept)	101.4	103.4	-----	103.2	99 0	106 3

[a]Data missing for weeks of 14 and 28 June

[b]Data missing for weeks of 10 August through 14 September

Table LXIX

Maximum Roof Air and Wall Temperatures - Yuma

Temperature (^{o}F)

	Roof Air		Wall Temperatures			
Week Ending	Loaded Car	Empty Car	West Door	East Door	South End (Outside Surface)	Roof Center
19 April	132					
26 April	130					
3 May	116					
10 May	136					
17 May	131					
24 May	135					
31 May	132					
7 June	132					
14 June[c]	---					
21 June	146					
28 June[c]	---					
5 July	148					
12 July	148					
19 July	142	145	163	152	139	141
26 July	144	144	167[a]	144	137	137
4 August	142	144	164	159	145	142
10 August	146	146	---	156	151	139
17 August	149	152	---	159	151	148
24 August	147	143	---	150	154	138
31 August	130	133	---	154	149	136
7 September	142	139	---	151	156	136
14 September	150	149	---	158	173[b]	142
20 September	138	142	---	150	159	136
Maximum for Period (19 July - 20 Sept)	150	152	167	159	173	148

[a]1700, 22 July, wind 10 mph.

[b]1400, 10 Sept, wind 3 mph.

[c]Not used because of incomplete data.

Conclusions

The detailed computer analysis of storage temperature data collected in boxcars loaded with typical loads of subsistence at Yuma, Arizona, and Cameron Station, Virginia, desert sub-tropical and humid sub-tropical stations, respectively, permits the following comparative conclusions: Absolute maximum temperatures reached are as shown below:

	Temperature (°F)		
	Yuma	Cameron Station	Difference
Roof Air	150	145	5
Top Center Carton Air	119	101	18
Top Center Carton Food	113	91	22

These values may be taken as realistic upper limits for boxcar maximum storage temperatures, except in such unique environments as Death Valley, a desert station below sea level. Food temperature maxima consistently are 7 to 10 degrees below carton air maxima, although the means of food and carton air temperature are very similar. At Yuma, daily maxima in Top Center Carton Air were 115°F or over on 16% of days of the research period, and 100°F or over on 62% of days. The balance of the load below the Top Center Carton was much more conservative in temperature behavior, daily or weekly maxima being 15-20 F° lower

The observed frequencies of storage temperatures over certain critical values at Yuma and Cameron reveal the much greater prolonged storage stress at Yuma:

Percentage Frequency of Top Center Carton Food Temperatures Over

	90°	99°	109°
Yuma	60	36	4
Cameron	4	0	0

Reflective insulation laid over the upper surface of the load, reduced Top Carton Air maximum temperatures 10-15 F° at Yuma and 6-10 F° at Cameron, when compared either serially or concurrently with controls. The mean was reduced by about 5 F°, at most. The less expensive foil-faced kraft paper was as effective for this purpose as the more bulky insulation.

Mean and maximum air temperatures near the roof of the empty steel boxcar at Yuma were only two degrees higher than those in the loaded car. However, at Cameron, maximum air temperature in the empty wooden car near the roof was 25 F° below that in the loaded steel car, and the mean was 6 F° lower.

The highest temperature on an exterior wall surface at Yuma was 173°F on the corrugated steel surface of the south end of the loaded car. Highest temperature on an interior surface was 159°F, recorded on the east door

Linear regression equations, using the much more refined data of the present computer analysis, confirmed the finding first stated in the preliminary report (1) that period means of temperatures of food in storage spaces have a high degree of correlation with period means of ambient temperature, especially for the week and the month. Degree of correlation was little increased when multiple linear regression was carried out using period mean radiation and wind speed as additional variables The relation appears to be general for both dry and humid sub-tropical climates.

It is possible, therefore, using readily available climatic data, to predict mean temperatures of food in storage spaces for periods short enough so that the figure may be used in computation of an effective mean storage temperature for prediction of food storage life. This can be done if an empirical relation between food storage life and food storage temperature is available. Such an effective mean temperature for the summer five months (Apr-Sept) at Yuma is 94°F, while for the summer three months (Jun-Aug) at Cameron it is 84°F. The storage life of food stored at such a constant effective mean storage temperature will approximate that of food stored under the fluctuating temperatures of the actual environment it is calculated to replicate.

By adding 20 F° to the observed Top Center Carton Air weekly mean temperature, one would exceed the maximum at that position for all weekly periods studied at both stations. For 97% of the weeks studied at Yuma and Cameron, addition of two standard deviations to the weekly mean permits prediction of the weekly maximum with 2 F°, at the Top Center Carton Air position

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Appendix A

Detailed List of Tables Covering Means, Frequencies, and Standard Deviations of Temperature Observations by Weeks

Yuma

Table	
XII	Top Center Carton -- Air Temperature
XIII	Top Center Carton -- Food Temperature
XIV	Load Center Carton -- Air Temperature
XV	Load Center Carton -- Food Temperature
XVI	Bottom Center Carton -- Air
XVII	Bottom Center Carton -- Food
XVIII	Northeast Corner Top Carton -- Air
XIX	Northeast Corner Top Carton -- Food
XX	Northeast Corner Second Layer Carton -- Air
XXI	Northeast Corner Second Layer Carton -- Food
XXII	Middle Layer Outer Carton Facing West Door -- Air
XXIII	Middle Layer Outer Carton Facing West Door -- Food
XXIV	Middle Layer Outer Carton Facing Center South End -- Air
XXV	Middle Layer Outer Carton Facing Center South End -- Food
XXVI	South Half Top Carton -- Air
XXVII	South Half Top Carton -- Food
XXVIII	Air Temperature Six Inches Below Roof in Loaded Car
XXIX	Air Temperature Six Inches Above Load in Loaded Car
XXX	Air Temperature Six Inches Below Roof in Empty Car
XXXI	Air Temperature Six Inches Above Floor in Empty Car
XXXII	East Door - Inside Surface Temperature
XXXIII	West Door - Inside Surface Temperature
XXXIV	South End -- Outside Surface Temperature
XXXV	Roof Center -- Inside Surface Temperature
XXXVI	Outside Air Temperature

Cameron

XXXVII	Top Center Carton -- Air
XXXVIII	Top Center Carton -- Food
XXXIX	West Half Top Carton -- Air
XL	West Half Top Carton -- Food
XLI	East Half Top Carton -- Air
XLII	East Half Top Carton -- Food
XLIII	Load Center Carton -- Air
XLIV	Load Center Carton -- Food
XLV	Bottom Center Carton -- Air
XLVI	Bottom Center Carton -- Food
XLVII	Middle Layer Outer Carton Facing South Door -- Air
XLVIII	Middle Layer Outer Carton Facing South Door -- Food
LXIX	Middle Layer Outer Carton Facing Center East End -- Air
L	Middle Layer Outer Carton Facing Center East End -- Food
LI	Air Temperature Six Inches Below Roof -- Loaded Car
LII	Air Temperature Six Inches Above Load -- Loaded Car
LIII	Air Temperature Six Inches Below Roof -- Empty Car
LIV	Air Temperature Six Inches Above Floor -- Empty Car
LV	Outside Air Temperature

Table XII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Top Center Carton Air Temperature

Temperature (°F)

Period Ending	63 -4	65 -6	67 -8	69 -0	71 -2	73 -4	75 -6	77 -8	79 -0	81 -2	83 -4	85 -6	87 -8	89 -0	91 -2	93 -4	95 -6	97 -8	99 -0	101 -2	103 -4	105 -6	107 -8	109 -0	111 -2	113 -4	115 -6	117 -8	119 -0	$\bar{x}$	s_x	N
Apr 19	2	2	2	5	8	10	13	10	7	11	3	8	5	5	3	3	2													78 8	7 7	158
Apr 26				2	10	10	9	11	10	8	6	4	7	6	4	5	4	2												81 6	7 6	158
May 3			4	14	11	11	10	9	10	9	10	9	3																	76 9	5 7	168
May 10					7	8	12	11	9	8	6	6	11	6	8	2	2	2												82 0	7 0	168
May 17			1	5	9	14	12	7	9	7	6	5	9	4	6	1	2													79 9	7 1	168
May 24							4	8	11	10	7	7	6	8	5	7	6	13	5	3										88 0	7 7	168
May 31				5	8	8	7	10	8	8	8	7	8	2	4	2	5	7	4											82 7	8 6	167
June 7						4	4	9	12	7	8	7	5	6	6	6	6	8	9	1										86 9	8 0	168
June 14[a]																																
June 21									2	5	12	9	7	7	7	3	6	7	8	9	6	2	3	4	1					93 7	8 6	129
June 28[a]																																
July 5														5	6	22	5	9	6	8	7	9	4	7	4	4				99 8	6 9	95
July 12														5	5	11	11	10	10	7	7	6	4	[illegible]	4	5	5	4		101 7	7 9	166
July 19															1	15	13	11	9	6	7	5	8	9	9	4	2	1		102 1	6 8	168
July 26															1	8	14	12	8	8	8	5	9	11	5	7	5			103 2	6 8	168
Aug 4														5	10	12	12	8	6	8	6	4	4	12	7	7				100 8	7 5	216
Aug 10														1	2	12	12	12	10	5	8	6	10	10	7	4	2			102 0	6 7	144
Aug 17																8	12	11	9	6	6	5	4	7	6	6	8	9	1	104 8	8 0	168
Aug 24															1	12	15	12	9	7	6	4	7	10	9	4	2	1		102 1	6 7	168
Aug 31											2	6	5	6	11	11	10	9	6	7	12	8	5							96 5	6 5	168
Sep 7[b]															8	24	27	27	13	1										95 8	2 4	168
Sep 14[b]																3	28	27	26	16										98 0	2 1	168
Sep 20[b]															3	18	31	28	19	1										96 5	2 2	144

[a]Not tabulated because of incomplete data

[b]Position foil-covered

Table XIII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Top Center Carton: Food Temperature

Period Ending	Temperature (°F) 63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	99-0	101-2	103-4	105-6	107-8	109-0	111-2	113-4	$\bar{x}$	S_x	N
Apr 19	1	3	1	3	5	6	13	16	12	13	13	6	4	4													78 8	5.6	158
Apr 26						6	11	14	16	15	13	9	7	4	5												81 4	4 8	158
May 3				1	10	16	15	21	14	15	4	3															77.2	3.6	168
May 10						2	13	14	14	14	16	12	8	5	2												81 8	4.4	168
May 17					2	7	17	16	16	11	14	10	5	2													79.8	4.3	168
May 24							1	1	5	10	14	13	14	11	14	13	3	2									87.6	4.7	168
May 31					1	5	7	13	13	14	14	9	7	5	5	5	1										82 5	5 6	167
Jun 7								2	5	11	18	16	13	12	10	11	2										86.7	4.4	168
Jun 14[a]																													
Jun 21											2	6	14	15	9	12	13	14	8	5	2	1					93 2	4.9	129
Jun 28[a]																													
July 5														1	0	5	15	21	17	18	13	8	2				99.7	3.6	95
July 12															2	5	11	17	15	12	9	9	10	6	4		101 3	5.1	166
July 19																	4	20	18	14	17	14	7	6			101 9	3 8	168
July 26																	3	7	21	16	16	16	11	11			103.1	3.8	168
Aug 4																2	11	20	17	14	13	14	8	2			101.0	3.9	216

(cont'd)

Table XIII (cont'd)

Temperature (^{o}F)

Period Ending	63 -4	65 -6	67 -8	69 -0	71 -2	73 -4	75 -6	77 -8	79 -0	81 -2	83 -4	85 -6	87 -8	89 -0	91 -2	93 -4	95 -6	97 -8	99 -0	101 -2	103 -4	105 -6	107 -8	109 -0	111 -2	113 -4	$\bar{x}$	S_x	N
Aug 10																1	6	20	15	13	14	17	12	3			101.8	3 9	144
Aug 17																		9	17	13	12	11	11	18	10	1	104.6	4 5	168
Aug 24																	5	16	18	14	14	16	11	6			102 3	3.8	168
Aug 31													3	5	8	12	16	22	15	15	4						96 7	3.8	168
Sep 7[b]														1	2	19	38	34	6								95 8	1 9	168
Sep 14[b]																	7	48	45								98 3	1.3	168
Sep 20[b]																6	35	38	22								97 0	1.6	144

[a] Not tabulated because of incomplete data.

[b] Position foil covered.

Table XIV

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Load Center Carton Air

Temperature (^{o}F)

Period Ending	59-0	61-2	63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	$\bar{x}$	S_x	N
Apr 19	1	3	8	6	4	18	40	20							70.0	3.4	158
Apr 26					1	23	37	20	15	4					72.2	2.2	158
May 3					7	43	33	11	7						70.9	1.9	168
May 10						2	20	40	27	11					74.0	1.8	168
May 17					4	16	40	33	7						72.0	1.7	168
May 24						1	3	5	32	40	18	1			76.7	2.0	168
May 31					2	19	28	30	19	2					72.6	2.2	167
Jun 7								17	36	44	4				76.2	1.5	168
June 14[a]																	
June 21											8	43	37	12	82.5	1.5	129

[a]Weeks of June 28 through September 20 not tabulated because of incomplete data

Table XV

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Load Center Carton - Food

Temperature (^{o}F)

Period Ending	61-2	63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	$\bar{x}$	s_x	N
Apr 19	3	8	6	15	29	38	1													69 1	2 8	158
Apr 26					19	61	19	1												71 7	1 3	158
May 3					41	42	17													71 1	1 3	168
May 10						22	58	20												73 5	1 2	168
May 17					6	45	49	1												72 4	1 1	168
May 24						5	11	41	42	2										75 9	1 6	168
May 31					2	41	40	17	1											73 1	1 5	167
June 7							16	45	38	1										75 9	1 3	168
June 14[a]																						
June 21											58	43								82 5	0 8	129
June 28[a]																						

(cont'd)

Table XV (cont'd)

Temperature (^{o}F)

Period Ending	61-2	63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	$\bar{x}$	S_x	N
July 5														8	87	5				89 5	0 7	95
July 12														6	35	48	11			90 8	1 3	166
July 19															1	61	38			92.4	0 7	168
July 26																	60	40	1	94.3	0 8	168
Aug 4																10	90	1		93 3	0.7	216

[a]Not tabulated because of incomplete data.

Table XVI

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Bottom Center Carton Air

Temperature (°F)

Period Ending	63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	$\bar{x}$	S_x	N
Apr 19	6	9	10	73	2														68 6	1 9	158
Apr 26				3	94	3													71 6	0 6	158
May 3					46	54													72 5	0 6	168
May 10					7	79	14												73 7	0.8	168
May 17						49	51												74 4	0 8	168
May 24						9	68	23											75 7	1 0	168
May 31						5	83	13											75 8	0 8	167
Jun 7						1	15	82	2										77 1	0 9	168
June 14[a]																					
Jun 21										31	67	2							82 9	0 8	129
Jun 28[a]																					

(cont'd)

Table XVI (cont'd)

Temperature (^{o}F)

Period Ending	63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	$\bar{x}$	S_x	N
July 5													19	75	6				89 3	0 8	95
July 12														13	76	11			91.6	0.9	166
July 19															4	32	65		94 6	0.9	168
July 26																	76	24	96 0	0 7	168
Aug 4																	28	72	96.8	0.6	216

[a] Not tabulated because of incomplete data

Table XVII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Bottom Center Carton Food

Temperature (°F)

Period Ending	63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	$\bar{x}$	s_x	N
Apr 19	6	9	13	71	1														68 5	1 8	158
Apr 26				8	92														71 4	0 6	158
May 3					54	45													72 3	0 7	168
May 10					11	78	11												73 5	0 8	168
May 17						51	49												74 4	0.7	168
May 24						16	70	14											75 4	1.0	168
May 31						5	83	13											75 7	0 8	167
June 7						2	23	73	1										76 9	0 9	168
June 14[a]																					
June 21										40	60	1							82 8	0 8	129
June 28[a]																					

(cont'd)

Table XVII (cont'd)

Temperature (°F)

Period Ending	63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	$\bar{x}$	S_x	N
July 5													39	60	1				88 9	0 8	95
July 12														19	75	5			91 2	0 9	166
July 19															6	61	34		94.1	0 8	168
July 26																5	92	2	95 4	0 6	168
Aug 4																	52	48	96 4	0 6	216

[a]Not tabulated because of incomplete data

Table XVIII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Northeast Corner Top Carton Air

Temperature (^{o}F)

Period Ending	87-8	89-0	91-2	93-4	95-6	97-8	99-0	101-2	103-4	105-6	107-8	109-0	111-2	$\bar{x}$	S_x	N
Aug 10				3	6	18	17	17	15	16	8			101 3	3 6	144
Aug 17						1	14	15	13	14	17	21	5	105 2	3 8	168
Aug 24						13	18	14	23	16	14	1		102 6	3 3	168
Aug 31	4	7	8	14	20	21	20	5						95 7	3 5	168
Sep 7	2	10	11	18	18	21	13	7	1					95 3	3 6	168
Sep 14			2	7	16	19	27	14	14	2				99 0	3 2	168
Sep 20	1	10	10	19	20	17	15	7						95 4	3 5	144

Table XIX

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Northeast Corner Top Carton Food

Temperature ($^{\circ}F$)

Period Ending	89-0	91-2	93-4	95-6	97-8	99-0	101-2	103-4	105-6	107-8	109-10	$\bar{x}$	s_x	N
Aug 10			4	4	8	26	23	32	3			100 9	2 7	144
Aug 17						2	17	23	22	29	7	105 1	2 5	168
Aug 24					1	20	32	29	17	2		102 5	2 2	168
Aug 31	4	7	15	23	28	23						96 2	2.6	168
Sept 7	4	18	19	26	23	10						95 1	2 7	168
Sept 14			2	13	25	36	22	2				98.8	2 1	168
Sept 20	1	11	21	33	13	21						95 7	2.7	144

Table XX

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Northeast Corner Second Layer Carton Air

Temperature (^{o}F)

Period Ending	87-8	89-0	91-2	93-4	95-6	97-8	99-100	101-2	103-4	$\bar{x}$	S_x	N
Aug 10		4	1	5	13	41	37			99 4	2.4	144
Aug 17						10	27	42	21	103 0	1.7	168
Aug 24					1	28	46	25		101.4	1 4	168
Aug 31	3	13	16	18	38	13				95 7	2 6	168
Sep 7	7	24	41	18	10					93 5	2 0	168
Sep 14			1	23	54	23				97 5	1 3	168
Sep 20		15	33	24	29					94 8	2 2	144

Table XXI

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Northeast Corner Second Layer Carton Food

Temperature (^{o}F)

Period Ending	89-0	91-2	93-4	95-6	97-8	99-100	101-2	103-4	105-6	$\bar{x}$	S_x	N
Aug 10				11	11	49	29			99 4	1 8	144
Aug 17						13	35	47	5	102 4	1 5	168
Aug 24					5	45	38	12		100 7	1 5	168
Aug 31	6	23	7	20	36	9				95 1	2.9	168
Sep 7	22	36	23	16	3					92.3	2 1	168
Sep 14			7	35	55	4				96 6	1 2	168
Sep 20	8	24	26	31	10					93 8	2 1	144

Table XXII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Middle Layer Outer Carton Facing West Door - Air

Temperature (^{o}F)

Period Ending	61-2	63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	99-0	$\bar{x}$	S_x	N
Apr 19	3	6	7	11	19	20	32	1													70 1	3 5	158
Apr 26						7	49	44													74 2	1 0	158
May 3					11	24	32	33													73 2	1 9	168
May 10						5	29	38	29												75 2	1 6	168
May 17						8	32	60	1												74 6	1 4	168
May 24							4	9	30	33	24										78 6	2 0	168
May 31						4	16	28	32	13	8										76 6	2 3	167
June 7								9	23	52	16										78 9	1 6	168
June 14[a]																							
June 21												5	15	50	30						87 6	1 6	129
June 28[a]																							
July 5																3	46	51			94 4	1 0	95
July 12																	20	46	34	1	95.8	1 5	166
July 19																		19	68	14	97.5	1 0	168
July 26																		7	41	52	98 3	1 1	168
Aug 4																1	8	30	46	15	96 8	1 7	216

[a]Not tabulated because of incomplete data.

Table XXIII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Middle Layer Outer Carton Facing West Door - Food

Temperature (^{o}F)

Period Ending	61-2	63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	99-0	101-2	$\bar{x}$	S_x	N
Apr 19	1	7	8	8	18	17	33	8														70 6	3 5	158
Apr 26							23	76	1													75 0	0.7	158
May 3						4	48	41	8													74.5	1 5	168
May 10							21	16	63	1												76 2	1 7	168
May 17							4	70	27													76 0	0 8	168
May 24							1	10	24	29	36											79 2	2 0	168
May 31							1	32	35	17	15											77 7	1 9	167
June 7									10	60	30											79 7	1 1	168
June 14[a]																								
June 21														49	51							88 7	0 9	129
June 28[a]																								
July 5																	24	73	3			95 1	0 9	95
July 12																	1	54	40	4		96 6	1 2	166
July 19																			54	46		98 5	0 7	168
July 26																			12	85	30	99 3	0 7	168

(cont'd)

Table XXIII (cont'd)

Temperature (^{o}F)

Period Ending	61-2	63-4	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	99-0	101-2	$\bar{x}$	S_x	N
Aug 4																		3	60	37		98 1	0 9	216
Aug 10																		23	64	13		97 3	1 1	144
Aug 17																			43	56	1	98 7	1 0	168
Aug 24																			27	69	4	99 1	0 9	168
Aug 31															1	4	21	21	41	13		96 2	2 1	168
Sep 7															17	75	8	0	1			91 4	1 0	168
Sep 14																6	67	27				93 9	0 9	168
Sep 20																20	51	29				93 7	1 2	144

[a]Not tabulated because of incomplete data

Table XXIV

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Middle Layer Outer Carton Facing Center South End - Air

Temperature (°F)

Period Ending	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	99-0	$\bar{x}$	S_x	N
Apr 19	3	5	6	4	8	25	35	16											75 5	3 5	158
Apr 26						19	44	30	7										78 0	1.6	158
May 3					19	42	28	11											76 1	1 8	168
May 10					4	9	46	33	9										78 1	1 6	168
May 17					5	35	44	16											76 9	1 5	168
May 24					1	4	13	35	42	6									80 1	1 9	168
May 31					5	31	38	18	9										77 3	1 9	167
June 7							21	54	25										79 5	1 3	168
June 14[a]																					
June 21										2	40	51	6						86 7	1 2	129
June 28[a]																					
July 5													10	66	24				93 8	0 9	95
July 12														3	25	42	30	1	95 6	1 6	166
July 19																11	79	10	97 5	0 9	168
July 26																	43	57	98 6	0 8	168
Aug 4															1	12	72	16	97 5	1 0	216

[a]Not tabulated because of incomplete da:

Table XXV

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Yuma

Middle Layer Outer Carton Facing Center South End - Food

Temperature (^{o}F)

Period Ending	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	99-100	101-2	$\bar{x}$	S_x	N
Apr 19	1	6	7	7	24	43	11													73 8	2 8	158
Apr 26						32	68													77 0	0 8	158
May 3					12	49	38	1												76 1	1 3	168
May 10					3	20	66	11												77 2	1 2	168
May 17					1	34	64	2												76 9	1 0	168
May 24					1	5	33	38	23											79 0	1 7	168
May 31						29	52	13	7											77 4	1 6	167
June 7						3	35	58	4											78 8	1 1	168
June 14[a]																						
June 21											73	27								86.1	0 7	129
June 28[a]																						
July 5													2	50	48					92 5	1 0	95
July 12														3	54	41	2			94 5	1 1	166
July 19																15	85			96 9	0 6	168
July 26																1	89	10		97 9	0 6	168

(cont'd)

Table XXV (cont'd)

Temperature (^{o}F)

Period Ending	65-6	67-8	69-0	71-2	73-4	75-6	77-8	79-0	81-2	83-4	85-6	87-8	89-0	91-2	93-4	95-6	97-8	99-100	101-2	$\bar{x}$	S_x	N
Aug 4																10	89	1		97 4	0 7	216
Aug 10																29	69	1	1	97 0	1 1	144
Aug 17																	51	49	1	98 6	1 0	168
Aug 24																	28	68	4	99 1	1 0	168
Aug 31																24	56	20		97 5	1 3	168
Sep 7															35	59	6			94 8	0 9	168
Sep 14																12	80	8		97 5	0.8	168
Sep 20																19	65	16		97 5	1 1	144

[a]Not tabulated because of incomplete data.

Table XXVI

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

South Half Top Carton - Air

Temperature (^{o}F)

Period Ending	91-2	93-4	95-6	97-8	99-0	101-2	103-4	105-6	$\bar{x}$	S_x	N
Aug 10		1	7	19	26	19	22	5	100.3	2.7	144
Aug 17[a]			1	23	43	32			99.6	1.5	168
Aug 24[b]			2	46	51	1			98.5	1.0	168
Aug 31[c]			14	69	17				97.6	1.0	168
Sep 7	5	17	20	24	17	16	1		97.2	2.9	168
Sep 14		4	16	25	28	14	13		99.0	2.6	168
Sep 20	8	22	22	24	16	8			96.3	2.8	144

[a]Position foil-covered.

[b]Foil and glass fiber covered (O C. blanket)

[c]Foil and glass fiber covered (G B. blanket)

Table XXVII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

South Half Top Carton - Food

Temperature (^{o}F)

Period Ending	91-2	93-4	95-6	97-8	99-100	101-2	103-4	105-6	107-8	109-10	111-112	$\bar{x}$	S_x	N
Aug 10			4	14	34	38	10					100.3	4 4	138
Aug 17[a]			1	21	67	8	1	0	0	2	1	99 6	2 2	168
Aug 24[b]			1	56	42	1						98 2	1 0	168
Aug 31[c]			4	83	13							97 8	0 7	168
Sep 7		10	21	35	33	1						97 4	1 9	168
Sep 14		1	7	34	43	16						98 8	1 6	168
Sep 20	2	17	33	26	22							96 5	2 2	144

[a]Position foil-covered

[b]Foil and glass fiber covered (O C blanket).

[c]Foil and glass fiber covered (G B. blanket)

Table XXVIII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

Air Temperature Six Inches Below Roof in Loaded Car

Temperature (^{o}F)

Period Ending	49-58	59-68	69-78	79-88	89-98	99-108	109-18	119-28	129-38	139-48	149-58	$\bar{x}$	s_x	N
Apr 19	9	31	16	7	4	13	7	11	2			83.3	23.0	128
Apr 26	4	32	15	9	6	9	15	10	1			85.5	23.5	158
May 3	18	27	11	11	16	13	4					76.9	17.9	168
May 10	7	25	17	6	10	13	11	10	2			86.1	22.9	168
May 17	16	26	10	10	8	12	11	7	1			82.1	23.0	168
May 24	1	21	21	9	7	7	13	17	5			92.6	24.3	168
May 31	13	24	15	7	9	10	8	13	3			85.0	24.4	167
June 7	4	25	17	7	7	10	13	16	2			89.9	23.8	168
June 14[a]														
June 21		9	26	11	5	8	12	15	7	6		98.0	25.4	129
June 28[a]														
July 5			5	38	11	10	8	14	11	4		102.0	20.9	95

(cont'd)

Table XXVIII (cont'd)

Temperature (^{o}F)

Period Ending	49-58	59-68	69-78	79-88	89-98	99-108	109-18	119-28	129-38	139-48	149-58	$\bar{x}$	s_x	N
July 12			1	34	16	8	11	10	10	10		104 9	21 6	166
July 19				38	15	8	8	14	14	3		104 0	20 4	168
July 26			1	34	16	7	10	16	13	4		104 4	20 1	168
Aug 4			12	31	11	6	10	11	16	4		102 0	22 3	215
Aug 10			6	34	12	8	8	13	16	4		103 7	21 3	144
Aug 17			11	28	10	9	5	8	9	20	1	106 8	25 7	168
Aug 24			5	37	11	7	8	11	16	4		102 7	22 0	168
Aug 31			28	21	10	13	11	14	2			94 8	19 7	168
Sep 7			29	18	10	7	8	10	15	2		98 7	23 8	166
Sep 14			26	21	9	7	5	8	11	13	1	101 2	25 0	168
Sep 20		1	32	17	7	6	10	17	8			96 0	22.4	144

[a]Not used because of incomplete data

Table XXIX

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

Air Temperature Six Inches Above Load in Loaded Car

Temperature (^{o}F)

Period Ending	49-58	59-68	69-78	79-88	89-98	99-108	109-18	119-28	129-138	$\bar{x}$	S_x	N
Apr 19[a]												
Apr 26[a]												
May 3	10	35	13	15	21	6				76 1	14 8	168
May 10	2	27	20	10	13	17	9	2		83 9	18 5	168
May 17	7	32	14	11	11	14	11			80 4	19 0	168
May 24		15	26	11	7	11	23	8		90 7	20 3	168
May 31	6	28	19	10	13	7	17	2		83 0	20 2	167
June 7		23	21	8	8	14	23	2		82 2	19 8	168
June 14[a]												
June 21		4	30	12	9	8	19	11	8	96 0	21 2	129
June 28[a]												
July 5			2	37	15	11	11	17	8	101 0	17 3	95
July 12				31	19	12	11	12	15	103 5	17 9	166

(cont'd)

Table XXIX (cont'd)

Temperature (^{O}F)

Period Ending	49-58	59-68	69-78	79-88	89-98	99-108	109-18	119-28	129-138	$\bar{x}$	S_x	N
July 19				33	19	9	11	18	10	102 9	16 9	168
July 26				29	20	8	13	24	6	103 9	17 0	168
Aug 4			7	34	12	7	13	19	8	100 5	18 7	216

[a] Not tabulated because of incomplete data

Table XXX

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

Air Temperature Six Inches Below Roof in Empty Car

Temperature (^{o}F)

Period Ending	59-68	69-78	79-88	89-98	99-108	109-18	119-28	129-38	139-48	149-58	$\bar{x}$	S_x	N
July 19		3	35	13	6	7	14	12	11		105 1	22 4	95
July 26		22	20	8	6	11	19	11	2		101 4	22 1	166
Aug 4	2	16	23	9	8	8	8	19	7		103 7	24.1	215
Aug 10		6	25	12	9	5	11	19	12		108.3	23 1	130
Aug 17		9	22	11	6	4	8	10	29	1	113 0	26 4	79
Aug 24		8	31	12	6	7	15	18	4		104 4	22 1	167
Aug 31	12	14	20	7	10	12	21	4			95.8	21 7	168
Sep 7	17	17	10	8	4	8	11	23	2		99 5	27 2	92
Sep 14		24	16	11	8	5	5	9	21	1	105 9	27 4	76
Sep 20	5	28	19	9	7	5	7	19	2		97 1	25 2	43

Table XXXI

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

Air Temperature Six Inches Above Floor in Empty Car

Temperature (^{o}F)

Period Ending	59-68	69-78	79-88	89-98	99-108	109-118	119-128	129-138	$\bar{x}$	S_x	N
July 19		3	36	15	13	16	14	4	99.3	16.9	95
July 26		23	20	11	15	21	9		95.4	16.8	166
Aug 4	1	15	26	10	11	15	20	1	97.5	18.4	215
Aug 10		6	27	17	9	14	24	3	101.8	17.8	144
Aug 17		9	22	15	9	8	20	18	105.2	20.2	79
Aug 24		7	33	13	10	16	19	3	98.9	17.1	167
Aug 31	12	18	20	11	19	21			90.1	16.7	168
Sep 7	19	16	14	8	10	24	10		91.6	20.4	92
Sep 14		25	17	13	8	5	25	7	98.9	21.1	76
Sep 20	2	37	14	9	9	9	19		91.5	19.7	43

Table XXXII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

East Door - Inside Surface Temperature

Temperature (^{o}F)

Period Ending	59-68	69-78	79-88	89-98	99-108	109-118	119-28	129-38	139-48	149-58	159-68	$\bar{x}$	S_x	N
July 19			40	10	5	16	17	4	5	4		104 0	21 8	95
July 26		20	22	7	10	20	12	7	2			99 9	20 5	166
Aug 4	1	14	26	8	8	14	14	8	5	2	1	103 0	23 3	215
Aug 10		7	23	13	9	9	19	7	7	5		108 2	23 2	130
Aug 17		8	22	13	5	5	8	18	8	14	1	113 9	27 9	79
Aug 24		7	33	8	8	11	19	9	5	1	1	103 8	21 6	167
Aug 31	10	15	19	10	13	17	5	8	4	1		96 6	22 6	168
Sep 7	14	21	11	7	5	9	14	7	10	3		99 8	28 3	92
Sep 14		22	17	14	3	7	9	15	5	8		105 1	27 1	76
Sep 20	2	35	14	9	5	7	14	2	9	2		97 3	26 0	43

Table XXXIII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

West Door - Inside Surface Temperature

Temperature (°F)

Period Ending	59-68	69-78	79-88	89-98	99-108	109-118	119-128	129-138	139-148	149-158	159-168	$\bar{x}$	s_x	N
July 19			43	12	8	5	12	8	5	3	3	104 2	24 6	95
July 26		23	25	10	8	8	9	6	6	5	1	100 4	25 1	166
Aug 4	1	16	27	12	7	10	8	4	6	7	2	102 6	26 8	215
Aug 10[a]														
Aug 17[a]														
Aug 24[a]														
Aug 31[a]														
Sep 7[a]														
Sep 14[a]														
Sep 20[a]														

[a]Not tabulated because of incomplete data

Table XXXIV

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

South End - Outside Surface Temperature

Temperature (°F)

Period Ending	59-68	69-78	79-88	89-98	99-108	109-18	119-28	129-38	139-48	149-58	159-68	169-78	$\bar{x}$	S_x	N
July 19		3	40	15	12	11	12	7	1				98.6	17 8	95
July 26		25	23	13	11	13	10	5					94 7	18 4	166
Aug 4	1	18	27	13	9	9	11	8	3				97 6	21 0	215
Aug 10		7	30	18	8	8	13	7	7	1			102 2	21 0	130
Aug 17		10	25	13	11	5	10	8	14	4			106 3	25 1	79
Aug 24		5	43	11	8	6	8	11	7	2			101.0	22 6	167
Aug 31	13	19	23	10	10	7	8	6	4	1			92 9	23 1	168
Sept 7	21	20	16	4	7	2	9	9	9	4			96.6	29 5	92
Sept 14		27	21	12	3	8	1	7	7	6	10	1	103 6	30 5	76
Sept 20	2	37	19	9	9	2	9	2	7	2			96.6	28 9	43

Table XXXV

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

Roof Center - Inside Surface Temperature

Temperature (^{o}F)

Period Ending	69-78	79-88	89-98	99-108	109-18	119-28	129-38	139-48	149-58	$\bar{x}$	S_x	N
July 19		16	29	10	7	17	17	4		108 3	18.7	95
July 26		31	15	7	19	20	8			104 0	17.2	166
Aug 4	1	23	24	7	8	19	18	2		106 9	18.8	215
Aug 10		8	33	7	9	21	21	2		110 4	18.1	130
Aug 17		11	28	6	3	6	29	15	1	115 7	22.3	79
Aug 24		21	26	7	8	23	16			107 0	18.0	167
Aug 31	14	24	15	7	18	21	1			99.6	17 7	168
Sept 7	26	16	7	3	5	26	16			102 5	22.8	92
Sept 14	1	33	14	7	3	11	25	7		107.5	22.6	76
Sept 20	12	35	12	7		14	21			100 7	21.9	43

Table XXXVI

Percentage Frequencies, Means and Standard Deviations of Hourly Observations - Yuma

Outside Air Temperature

Temperature (^{o}F)

Period Ending	49-58	59-68	69-78	79-88	89-98	99-108	109-18	119-28	$\bar{x}$	s_x	N
Apr 19	8	30	26	27	10				73 6	10 6	168
Apr 26	4	34	31	20	11	1			73.3	10 7	168
May 3	17	35	27	22					68 9	9 2	168
May 10	6	26	29	24	15				75 2	11.0	168
May 17	11	35	26	26	2				70 7	9 8	168
May 24		18	31	25	24	2			79 6	10 7	168
May 31	8	32	29	23	9				72 3	10 4	168
June 7	1	18	33	28	20				78.1	10 0	168
June 14[a]											
June 21		3	30	30	21	15	1		85 3	11 2	168
June 28[a]											
July 5			2	30	32	26	9		94.8	9 2	168
July 12			1	24	43	30	32		94.7	7 9	168
July 19				30	38	31	1		94 1	7 0	168
July 26				29	31	30	10		95.5	9 3	168
Aug 4			7	33	32	28			91.9	8 4	216
Aug 10			1	31	37	27	4		93 7	8.2	144
Aug 17			1	26	33	33	8		95.8	9 0	168

(cont'd)

Table XXXVI (cont'd)

Temperature (^{o}F)

Period Ending	49-58	59-68	69-78	79-88	89-98	99-108	109-18	119-28	$\bar{x}$	S_x	N
Aug 24				30	34	34	2		95 2	7 8	168
Aug 31		2	23	32	36	7			86 0	9 1	168
Sept 7				21	33	27	18	1	88 2	9 8	168
Sept 14			3	38	27	30	2		92 3	10 0	168
Sept 20			24	33	21	23			88 0	10 3	144

[a]Not tabulated because of incomplete data

Table XXXVII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Camer n

Top Center Carton - Air

Temperature (^{o}F)

Period Ending	64-5	66-7	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	86-7	88-9	90-1	92-3	94-5	96-7	98-9	100-1	$\bar{x}$	S_x	N
June 9		3	3	3	3	5	13	17	13	6	8	6	8	6	2	2				80 7	6 4	167
June 16	3	4	2	12	19	11	9	6	5	6	8	6	5	2						76 8	6 7	168
June 23			2	6	10	12	8	9	8	7	7	3	6	4	9	4	3			81 4	7 7	163
June 30				1	2	3	8	12	12	8	7	6	8	8	6	7	8	2		85.4	7 2	168
July 7							1	7	14	12	17	8	5	8	11	7	5	4		86.9	5 8	166
July 15				2	7	9	8	12	8	8	9	8	9	9	8	1	2			82 8	6 6	192
July 23								4	6	20	14	9	8	8	8	8	5	8	2	88.0	5 9	192
July 30								13	11	18	11	6	6	7	9	9	6	1	1	86 5	6 0	168
Aug 4								14	28	16	10	8	6	5	6	6				84 1	4 8	116
Aug 10							6	19	30	18	13	7	2	2	2					81 8	3 4	122
Aug 17							7	18	27	8	13	5	8	7	6					83 0	4 7	168
Aug 24				1	5	13	16	14	10	8	10	10	11	1						80 4	5 1	166
Aug 31								4	22	15	12	9	6	7	5	11	8			86 4	5 7	137
Sept 7[a]							2	3	14	17	20	22	8	13						84.8	3 4	144
Aug 25[b]							12	17	17	12	4	8	8	8	12							
Sept 1[b]											29	17	8	8	8	8	8	12				

[a]Position foil covered

[b]Single day

Table XXXVIII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Top Center Carton - Food

Temperature (^{o}F)

Period Ending	66-7	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	86-7	88-9	90-1	92-3	$\bar{x}$	S_x	N
June 9	2	2	4	4	5	9	22	15	18	11	5	1			79 3	4 6	167
June 16		3	6	14	15	17	17	14	7	5	2				76 9	4 1	168
June 23		1	0	12	6	12	12	13	11	10	11	8	2		80 5	5 5	163
June 30					2	3	8	13	17	19	13	14	8	2	84 2	4 2	168
July 7							1	4	14	25	31	16	9	1	85 8	2 7	166
July 15						2	9	16	24	26	21				83 1	2 7	192
July 23									5	18	35	24	14	4	87 2	2 3	192
July 30								1	14	29	28	21	6		86 0	2 2	168
Aug 4								8	25	33	23	11			84.6	2 2	116
Aug 10							3	29	43	20	4				82 4	1 6	122
Aug 17							2	29	31	20	16	2			83 0	2 2	168
Aug 24					2	8	20	26	31	11	2				80 9	2 5	166
Aug 31								4	22	25	27	21	1		85 3	2 2	137
Sept 7[a]							1	5	21	16	41	15			85 4	2 3	144
Aug 25[b]							17	12	33	25	12						
Sept 1[b]										4	42	29	17	8			

[a]Foil covered

[b]Single day

Table XXXIX

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

West Half Top Carton - Air

Temperature (^{o}F)

Period Ending	72-3	74-5	76-7	78-9	80-1	82-3	84-5	86-7	88-9	90-1	92-3	$\bar{x}$	S_x	N
Aug 10			2	6	26	31	21	10	2	2		82 9	2 9	122
Aug 17[a]				7	44	28	21					81 8	1 8	168
Aug 24[a]	1	10	20	23	34	9	2					78 8	2 4	166
Aug 31[a]			1	20	35	28	16					81 2	1 9	137
Sept 7[b]				2	3	33	26	12	3			84 4	2.0	144
Aug 25[c]			17	33	21	29								
Sept 1[c]					4	8	29	13	17	12	17			

[a]Foil covered

[b]Foil and glass fiber covered (O. C. blanket)

[c]Single day

Table XL

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

West Half Top Carton - Food

Temperature (°F)

Period Ending	76-7	78-9	80-1	82-3	84-5	86-7	$\bar{x}$	s_x	N
Aug 10			11	54	25	9	83 1	1 6	122
Aug 17[a]		7	68	24			80 9	0 9	168
Aug 24[a]	13	51	32	4			79.1	1 4	166
Aug 31[a]		41	59				79 5	0.8	137
Sept 7[b]			3	56	40		83 2	0 9	144
Aug 25[c]	4	42	54						
Sept 1[c]			12	12	50	25			

[a]Foil covered

[b]Foil and glass fiber covered (O. C. blanket)

[c]Single day

Table XLI

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

East Half Top Carton - Air

Temperature (^{o}F)

Period Ending	74-5	76-7	78-9	80-1	82-3	84-5	86-7	88-9	90-1	92-3	94-5	$\bar{x}$	S_x	N
Aug 10		2	7	29	27	19	11	2	2			82 5	2 7	122
Aug 17[a]			5	48	30	17						81 7	1 6	168
Aug 24[a]		3	17	40	34	5						81 0	1 8	166
Aug 31[b]				44	44	12						81 9	1 2	137
Sept 7	1	2	8	12	10	10	18	14	9	8	9	86 1	4 9	144
Aug 25[c]			12	17	17	17	8	8	21					
Sept 1[c]					4	29	17	17	8	17	8			

[a]Foil and glass fiber covered (G.B.)

[b]Foil and glass fiber covered (O.C.)

[c]Single day

Table XLII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

East Half Top Carton - Food

Temperature (^{o}F)

Period Ending	76-7	78-9	80-1	82-3	84-5	86-7	88-9	90-1	$\bar{x}$	S_x	N
Aug 10			11	56	23	7	2		83 1	1 7	122
Aug 17[a]			36	62	1				81 9	0 8	168
Aug 24[a]		6	44	46	4				81 4	1 2	166
Aug 31[b]			7	73	20	5			82 9	0 8	137
Sept 7	1	1	7	14	14	9	25	29	86 7	3 5	144
Aug 25[c]			25	17	25	33					
Sept 1[c]				4	17	17	62				

[a]Foil and glass fiber covered (G.B.)

[b]Foil and glass fiber covered (O.C.)

[c]Single day

Table XLIII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Load Center Carton - Air

Temperature ($^{\circ}F$)

Period Ending	66-7	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	$\bar{x}$	S_x	N
June 9	8	11	12	35	34					72 1	2 5	167
June 16		9	34	43	12					71 7	1.6	168
June 23	1	1	19	33	29	17				73.3	2.0	163
June 30			2	19	34	34	11			75 1	1 8	168
July 7		1	0	4	9	23	44	19		77 8	2 2	166
July 15					13	52	34			76 9	1 3	192
July 23						5	25	63	6	79 9	1 4	192
July 30						15	56	27		78 7	1 4	168
Aug 4					1	30	55	13		78 1	1 5	116

Table XLIV

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Load Center Carton - Food

Temperature (^{o}F)

Period Ending	64-5	66-7	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	$\bar{x}$	S_x	N
June 9	1	8	7	23	39	22						71.6	2 3	167
June 16			18	30	46	4						71 2	1 6	168
June 23		1	3	22	40	28	6					72 7	1 9	163
June 30				4	30	34	27	5				74.5	1 8	168
July 7					7	17	37	31	8			76 8	2 0	166
July 15					2	33	44	21				76 2	1 5	192
July 23							6	40	54			79 4	1 0	192
July 30						9	25	42	24			78 1	1 7	168
Aug 4					1	9	36	45	9			77 5	1 5	116
Aug 10						7	40	48	4			77 4	1 2	122
Aug 17						8	64	27				76.9	1 0	168
Aug 24				7	37	41	16					73 8	1 6	166
Aug 31						1	15	48	25			78 6	1 3	137
Sept 7					1	5	23	5	10	36	18	80 5	3 3	144
Aug 25[a]					17	25	42	17						
Sept 1[a]									33	67				

[a]Single day

Table XLV

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Bottom Center Carton - Air

Temperature (^{o}F)

Period Ending	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	$\bar{x}$	s_x	N
June 9	15	75	8						70.4	1.0	167
June 16		36	63	1					71 8	0 8	168
June 23	2	13	84	1					72.2	0.9	163
June 30		8	46	41	5				73 3	1 3	168
July 7		5	10	19	41	19	7		76 1	2 3	166
July 15				4	5	80	11		78 4	1 1	192
July 23						46	54		79 5	0.7	192
July 30						6	85	8	80 6	0 7	168
Aug 4						13	87		80.0	0 5	116

Table XLVI

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Bottom Center Carton - Food

Temperature (^{o}F)

Period Ending	66-7	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	$\bar{x}$	S_x	N
June 9	2	12	74	12							70 5	1 2	167
June 16			43	57							71 6	0 8	168
June 23	1	2	11	86	1						72 1	1.0	163
June 30			6	48	39	6					73.4	1.3	168
July 7			4	9	19	40	20	7			76 2	2 3	166
July 15					3	14	79	3			78.1	1 0	192
July 23						2	46	52			79 4	0 8	192
July 30							17	80	2		80 2	0 7	168
Aug 4							50	50			79 5	0 6	116
Aug 10							2	32	65	1	81 9	1 1	122
Aug 17							9	79	12		80 6	0 8	168
Aug 24						3	48	46	2		79 4	1 1	166
Aug 31						1	82	17			78 9	0 8	137
Sept 7								28	69	3	82 1	1 1	144
Aug 25[a]						8	42	50					
Sept 1[a]								100					

[a]Single day

Table XLVII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Middle Layer Outer Carton Facing South Door - Air

Temperature (^{o}F)

Period Ending	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	86-7	$\bar{x}$	S_x	N
June 9	9	19	21	38	12						73 1	2 3	167
June 16			2	39	59						75 6	1 0	168
June 23		1	8	46	35	10					75 3	1 5	163
June 30					32	38	28	2			78 5	1.6	168
July 7					4	6	19	49	21		82 1	2 0	166
July 15							47	52	2		81 7	1 0	192
July 23							16	35	49		83 3	1 5	192
July 30								51	43	5	83 6	1 1	168
Aug 4				1			1	40	59		83 3	1 1	116

Table XLVIII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Middle Layer Outer Carton Facing South Door - Food

Period Ending	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	86-7	88-9	90-1	$\bar{x}$	S_x	N
							Temperature (^{o}F)								
June 9	6	15	26	32	21								73 4	2 3	167
June 16			1	36	62								75 7	1 0	168
June 23		1	8	45	34	12							75.4	1 6	163
June 30					24	41	31	4					78 7	1 6	168
July 7					3	7	25	47	19				82 0	1 9	166
July 15							46	53	1				81 7	1 0	192
July 23							12	37	50				83 4	1 5	192
July 30								45	47	8			83 7	1 1	168
Aug 4							1	40	59				83 4	0 8	116
Aug 10							15	66	19				82 6	1 0	122
Aug 17							51	49					81 5	0 8	168
Aug 24						13	62	23	2				80 8	1 2	166
Aug 31							1	46	53				83 6	0 9	137
Sept 7								1	5	20	39	35	88 4	1 8	144
Aug 25[a]							33	67							
Sept 1[a]										17	83				

[a] Single day

Table XLIX

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Middle Layer Outer Carton Facing Center East End - Air

Temperature (^{o}F)

Period Ending	68-9	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	86-7	$\bar{x}$	s_x	N
June 9	2	15	21	17	44						74 3	2 4	167
June 16				14	70	16					76 5	1 0	168
June 23		1	2	40	32	26					76.2	1 7	163
June 30					8	34	43	15			79 8	1 6	168
July 7					2	5	16	42	32	2	82 6	1.9	166
July 15							11	77	12		82.6	0 9	192
July 23							5	28	60	7	83.9	1 4	192
July 30								23	65	12	84 2	1.0	168
Aug 4								36	64		83 5	0 9	116

Table L

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Middle Layer Outer Carton Facing Center East End - Food

Temperature (°F)

Period Ending	70-1	72-3	74-5	76-7	78-9	80-1	82-3	84-5	86-7	88-9	$\bar{x}$	S_x	N
June 9	17	20	18	44							74.3	2 5	167
June 16			12	70	17						76 6	1.0	168
June 23	1	2	38	34	25						76.2	1 7	163
June 30				8	34	42	15				79 8	1 6	168
July 7				1	6	16	44	30	2		82 6	1.9	166
July 15						7	81	11			82 6	0 8	192
July 23						4	29	60	7		83 9	1 3	192
July 30							21	67	12		84 3	1.0	168
Aug 4							32	68			83 6	0 9	116
Aug 10						6	67	26			83.0	0.8	122
Aug 17						48	52				81 6	0 6	168
Aug 24					7	67	25				80 9	1 0	166
Aug 31						14	83	3			82.3	0 7	137
Sept 7							3	21	53	22	86.5	1 4	144
Aug 25[a]						54	46						
Sept 1[a]								67	33				

[a] Single day

Table LI

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Air Temperature Six Inches Below Roof - Loaded Car

Temperature (^{o}F)

Period Ending	50-9	60-9	70-9	80-9	90-9	100-9	110-9	120-9	130-9	140-9	$\bar{x}$	s_x	N
June 9	4	11	32	10	8	9	13	8			88 3	20 6	167
June 16	6	38	17	6	6	11	8	4			80 6	20.4	168
June 23		27	23	12	6	8	9	9	5		87 9	22 2	163
June 30		10	35	6	7	7	10	15	4		93.1	22.9	168
July 7		1	39	10	10	10	12	14	2		92 8	20.1	166
July 15	2	28	18	8	6	10	11	12	2		88.5	23.0	192
July 23		3	38	12	9	7	10	8	10		94 4	22 3	192
July 30		21	24	8	5	8	7	14	7		92 6	24 1	168
Aug 4		9	44	13	10	7	8	6			86.0	17 4	116
Aug 10		14	44	13	10	10	6	1			82.8	14.7	122
Aug 17		32	21	10	5	7	5	6	8		87.4	23.9	168
Aug 24	22	28	8	2	5	8	10	13	4		83 8	26.9	166
Aug 31		27	24	7	4	4	5	7	12	8	93.5	28.4	137
Sept 7	3	26	24	11	4	5	6	7	5	3	87.1	23.8	144
Aug 25[a]		41	8	8	4	4	4	8	21				
Sept 1[a]			41	12	0	8	8	8	12	8			

[a] Single day

Table LII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Air Temperature Six Inches Above Load - Loaded Car

Temperature (^{o}F)

Period Ending	50-9	60-9	70-9	80-9	90-9	100-9	110-9	120-9	130-9	$\bar{x}$	s_x	N
June 9	4	12	32	10	10	21	5			84.5	16.1	167
June 16	6	38	18	7	14	13				77.5	15 9	168
June 23		27	23	11	10	12	14	1		84.5	17 8	163
June 30		10	35	8	9	21	12	1		88.5	17.6	168
July 7		4	39	11	12	21	13			89 2	15.9	166
July 15	2	28	18	9	11	22	7			84.1	17 9	192
July 23		4	38	13	7	14	16	5		90 4	17 4	192
July 30		20	25	9	7	16	14	3		87 8	18 6	168
Aug 4		9	44	15	13	12	5			83.4	13 7	116
Aug 10		21	37	13	14	11	2			80 5	12 9	122
Aug 17		34	21	10	8	7	7	7		83 9	19 6	168
Aug 24	26	24	8	5	9	14	14	1		79 2	22.3	166
Aug 31		30	21	7	6	6	9	17	1	89 1	23 4	137
Sept 7	1	24	23	17	5	10	7	7		85 1	18.5	144
Aug 25[a]		37	16	4	8	8	16	8				
Sept 1[a]			41	12	8	4	16	16				

[a] Single day

Table LIII

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Air Temperature Six Inches Below Roof - Empty Car

Temperature (^{o}F)

Period Ending	50-9	60-9	70-9	80-9	90-9	100-9	110-9	120-9	$\bar{x}$	S_x	N
June 9	4	11	33	16	19	12			82.2	13 0	167
June 16	9	42	13	12	21				74.0	13 4	168
June 23	1	27	23	14	14	19	2		82.8	15 2	163
June 30	2	9	31	13	15	22	3		85 9	14 7	168
July 7		5	34	19	18	22	2		86 6	13 2	166
July 15	8	23	17	15	19	14	2		80.9	15 7	192
July 23		6	32	18	14	19	9		88.2	14.9	192
July 30	2	19	24	12	18	19	2		84.4	15 7	168
Aug 4		14	44	18	12	11			80 6	11 8	116
Aug 10		20	39	18	16	5			78.9	11 0	122
Aug 17		24	28	14	12	17			81 8	14.3	168
Aug 24	20	23	14	10	20	12			76.8	17.1	166
Aug 31		17	25	14	9	12	21		88.4	17.7	137
Sept 7	2	28	13	22	13	10	7		82.9	16 4	144
Aug 25[a]		29	16	12	8	21	12				
Sept 1[a]			29	25	8	12	21	4			

[a]Single day

Table LIV

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Air Temperature Six Inches Above Floor - Empty Car

Period Ending	50-9	60-9	70-9	80-9	90-9	100-9	110-9	$\bar{x}$	S_x	N
	Temperature (°F)									
June 9	4	11	35	21	22	3		80 1	11 1	167
June 16	10	41	18	22	7			72 0	11.0	168
June 23	1	26	25	17	19	10		80 4	13.0	163
June 30	2	10	31	18	24	12		83.3	12.2	168
July 7		5	38	20	26	10		84 2	11 0	166
July 15	8	25	18	24	22	2		77.8	12 7	192
July 23		6	34	19	19	20		85 8	12.4	192
July 30	2	19	25	17	25	9		81 6	12.9	168
Aug 4		14	44	23	17			78.6	9 5	116
Aug 10		20	41	24	12	1		77.3	9.3	122
Aug 17		24	31	18	21	3		79 3	11.4	168
Aug 24	18	28	15	22	17			73.7	13.6	166
Aug 31		16	26	16	15	24		85 4	14.0	137
Sept 7	2	28	13	26	11	15		81 3	14.5	144
Aug 25[a]		29	21	12	16	21	4			
Sept 1[a]			29	21	21	25				

[a] Single day

Table LV

Percentage Frequencies, Means and Standard Deviations of Hourly Observations by Weeks - Cameron

Outside Air Temperature

Temperature ($^{\circ}F$)

Period Ending	40-9	50-9	60-9	70-9	80-9	90-9	100-9	$\bar{x}$	s_x	N
June 9		7	17	42	27	4		74 5	9.3	159
June 16		19	43	27	8			67.0	8 7	168
June 23		5	34	28	23	10		74 1	10 2	163
June 30		5	18	35	23	16		77 1	10 1	168
July 7			24	31	29	15		78 3	9 4	166
July 15		20	24	26	25	3		71 2	11 2	192
July 23		1	22	30	22	24		79 3	10 9	192
July 30		9	24	28	25	10	1	75 1	11 3	168
Aug 4		3	33	44	15	4		73 1	7 7	116
Aug 10		2	36	42	16	2		72 4	7.4	122
Aug 17		2	39	28	24	4		73 5	9 2	168
Aug 24	2	32	23	20	22			67.5	11.8	166
Aug 31			40	19	10	19	9	78 4	13 5	137
Sept 7		3	33	22	22	13	3	76.5	11 9	144
Aug 25[a]		4	45	8	16	25				
Sept 1[a]			16	33	16	21	12			

[a] Single day

Appendix B

Figures 21-57. Means, Frequencies, and Standard Deviations of Temperature Observations by Weeks at Yuma and Cameron

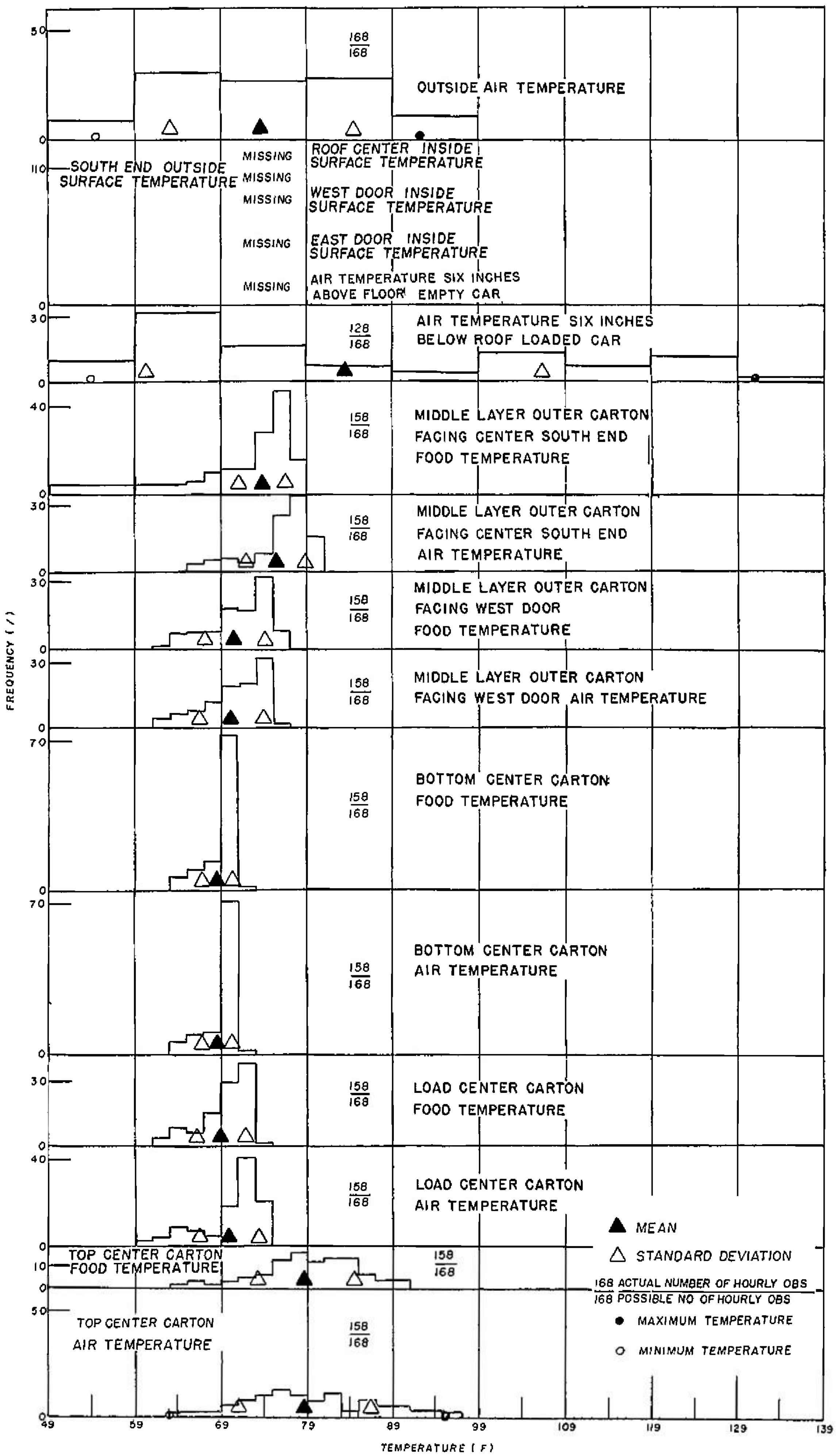

Figure 21. Means, frequencies, and standard deviations of temperature observations by weeks for 13 April - 19 April 1953 - Yuma

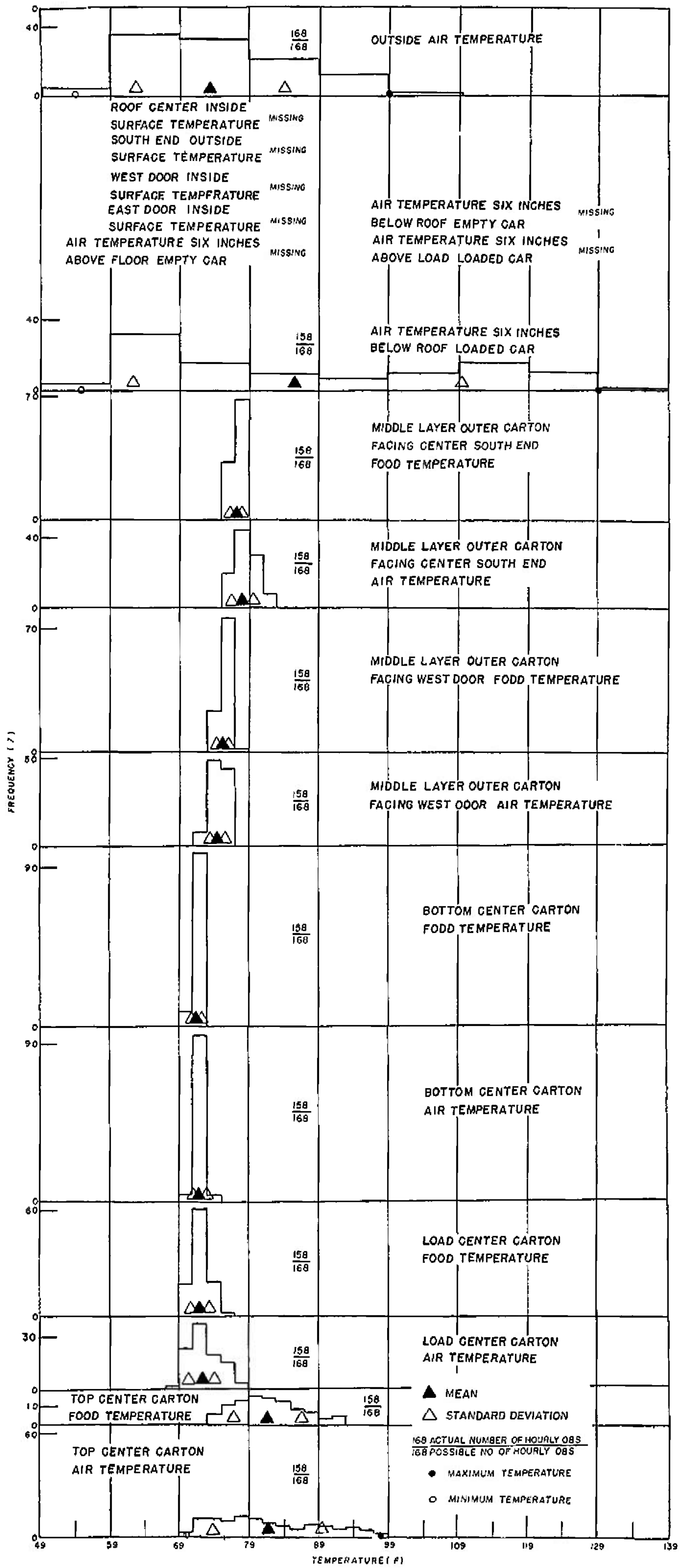

Figure 22. Means, frequencies, and standard deviations of temperature observations by weeks for 20 April - 26 April 1953 - Yuma

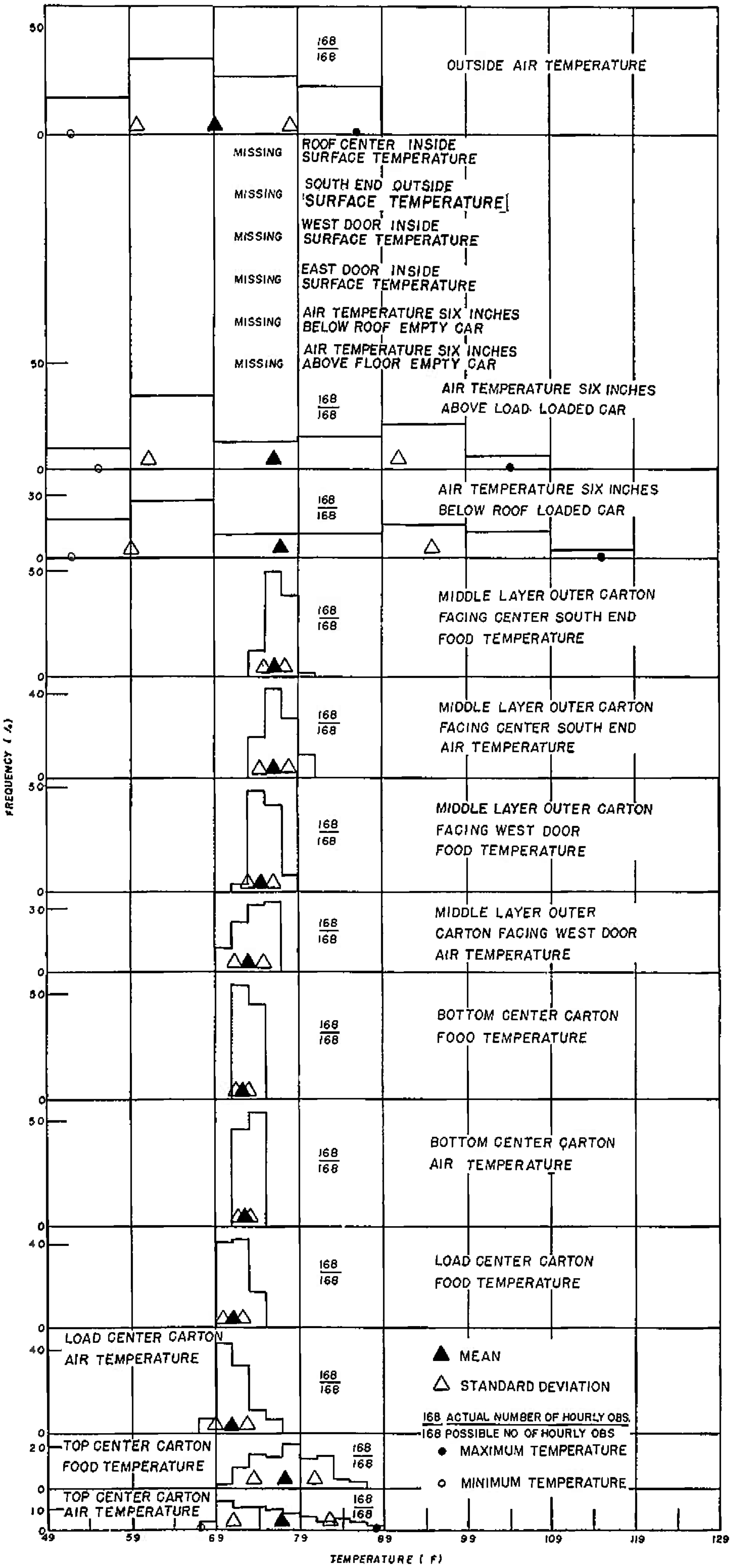

Figure 23 Means, frequencies, and standard deviations of temperature observations by weeks for 27 April - 3 May 1953 - Yuma.

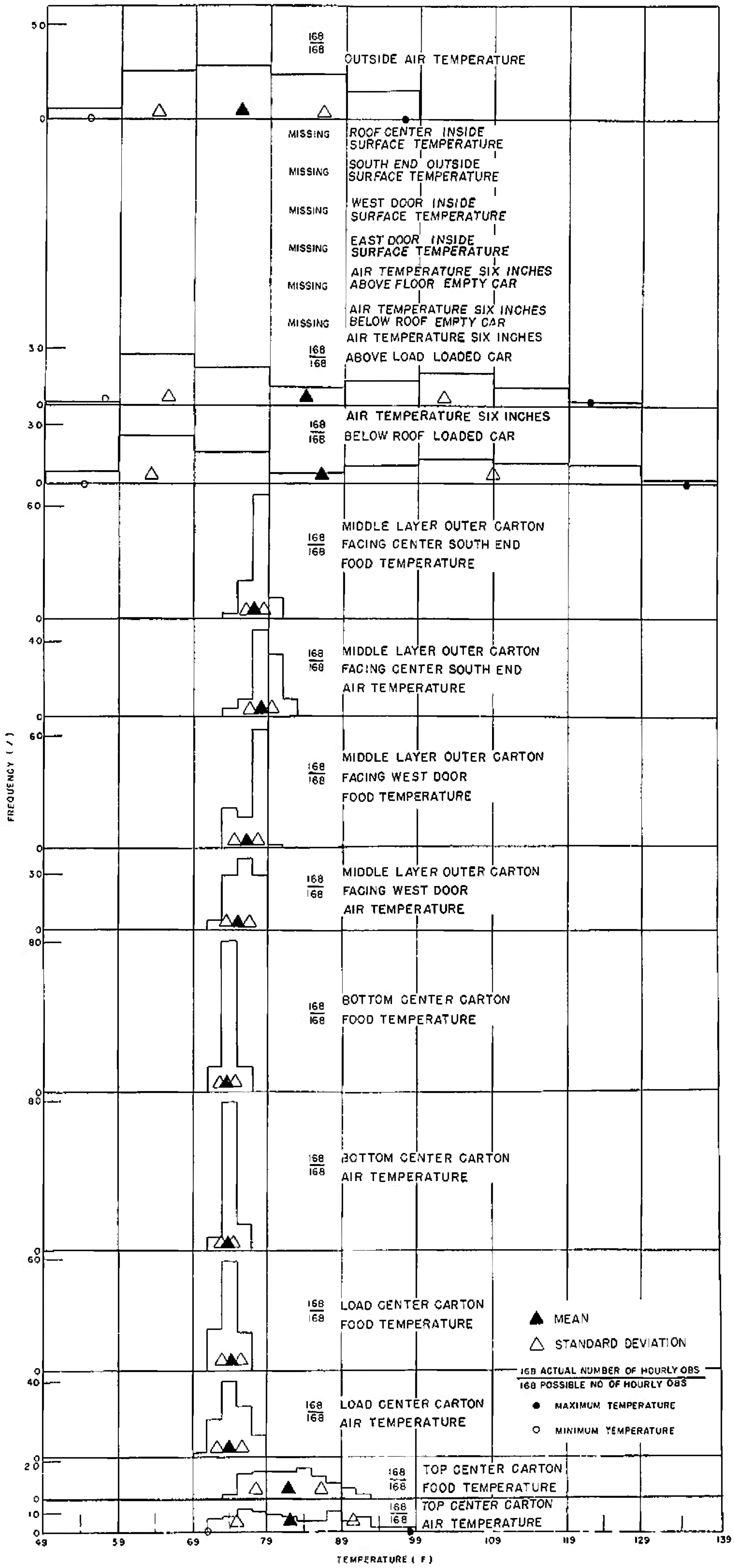

Figure 24 Means, frequencies, and standard deviations of temperature observations by weeks for 4 May - 10 May 1953 - Yuma

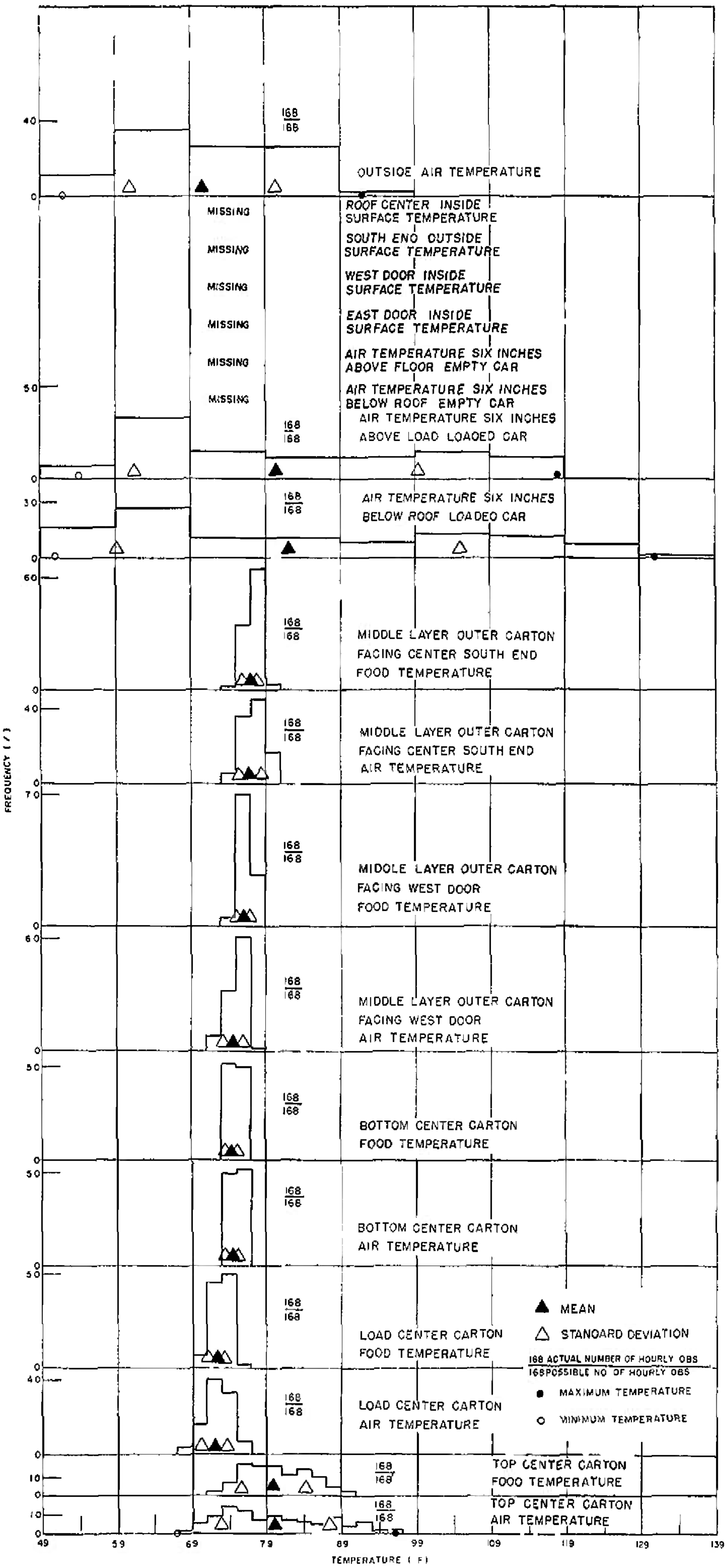

Figure 25 Means, frequencies, and standard deviations of temperature observations by weeks for 11 May - 17 May 1953 - Yuma.

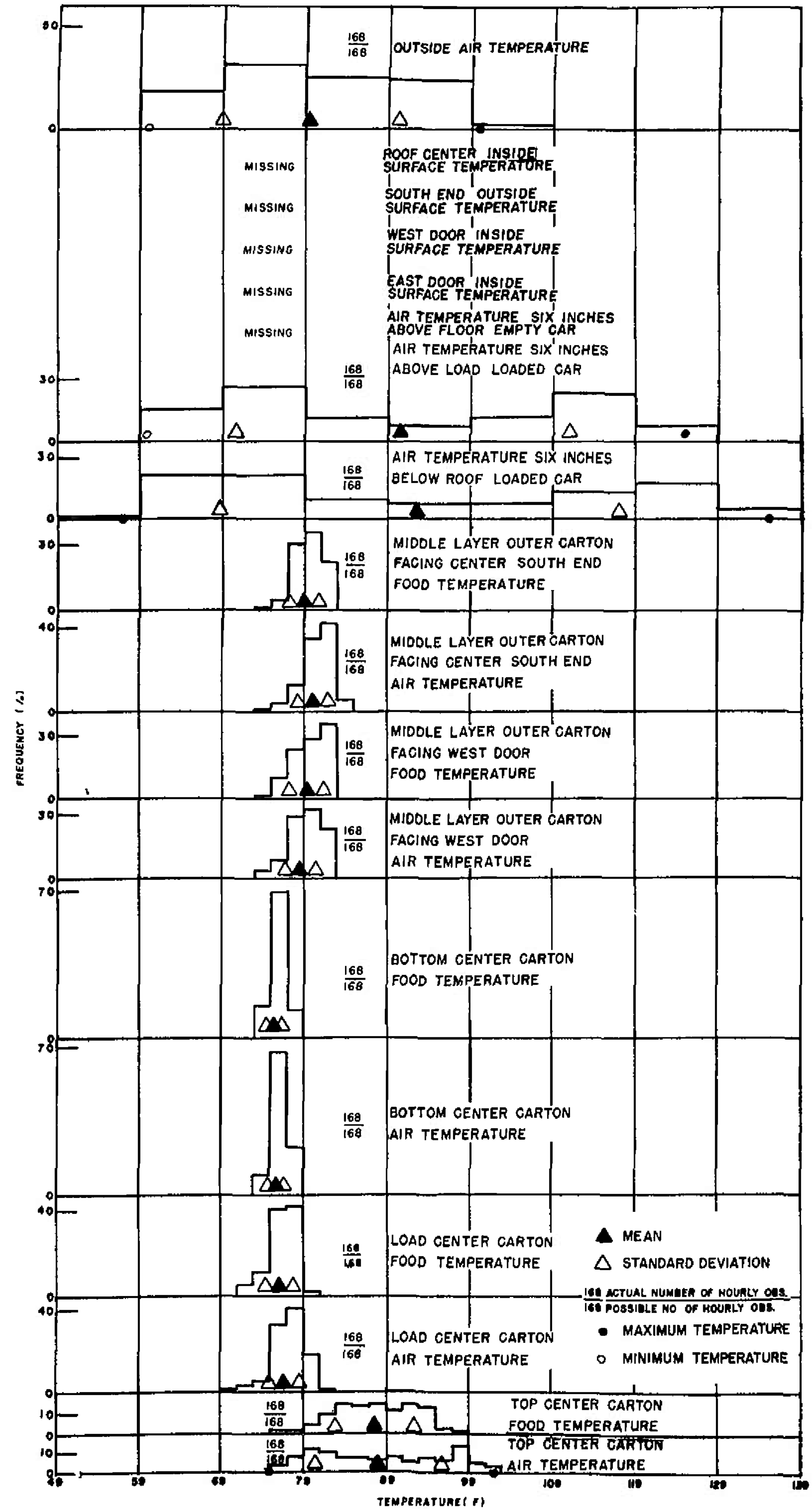

Figure 26. Means, frequencies, and standard deviations of temperature observations by weeks for 18 May - 24 May 1953 - Yuma.

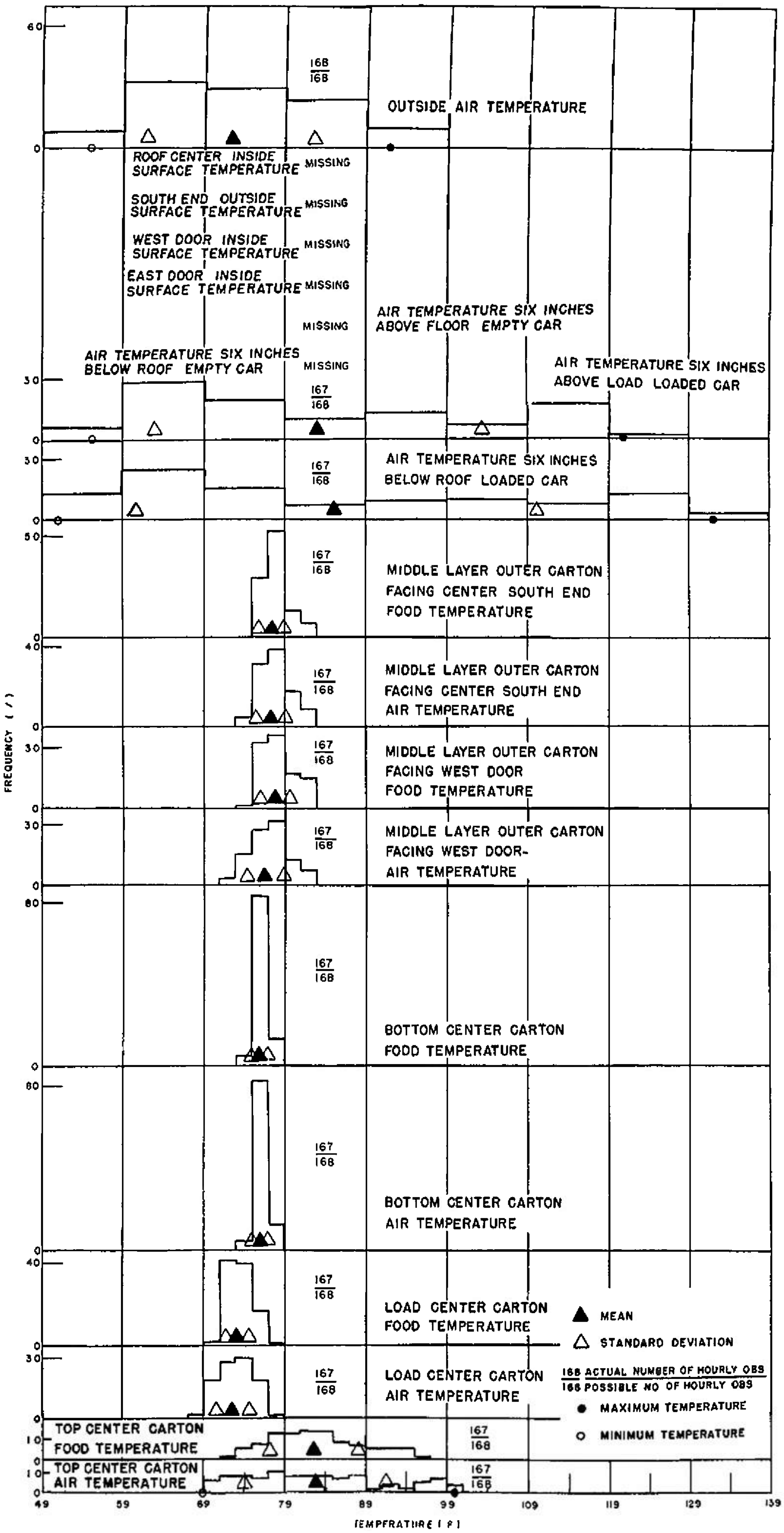

Figure 27. Means, frequencies, and standard deviations of temperature observations by weeks 25 May - 31 May 1953 - Yuma

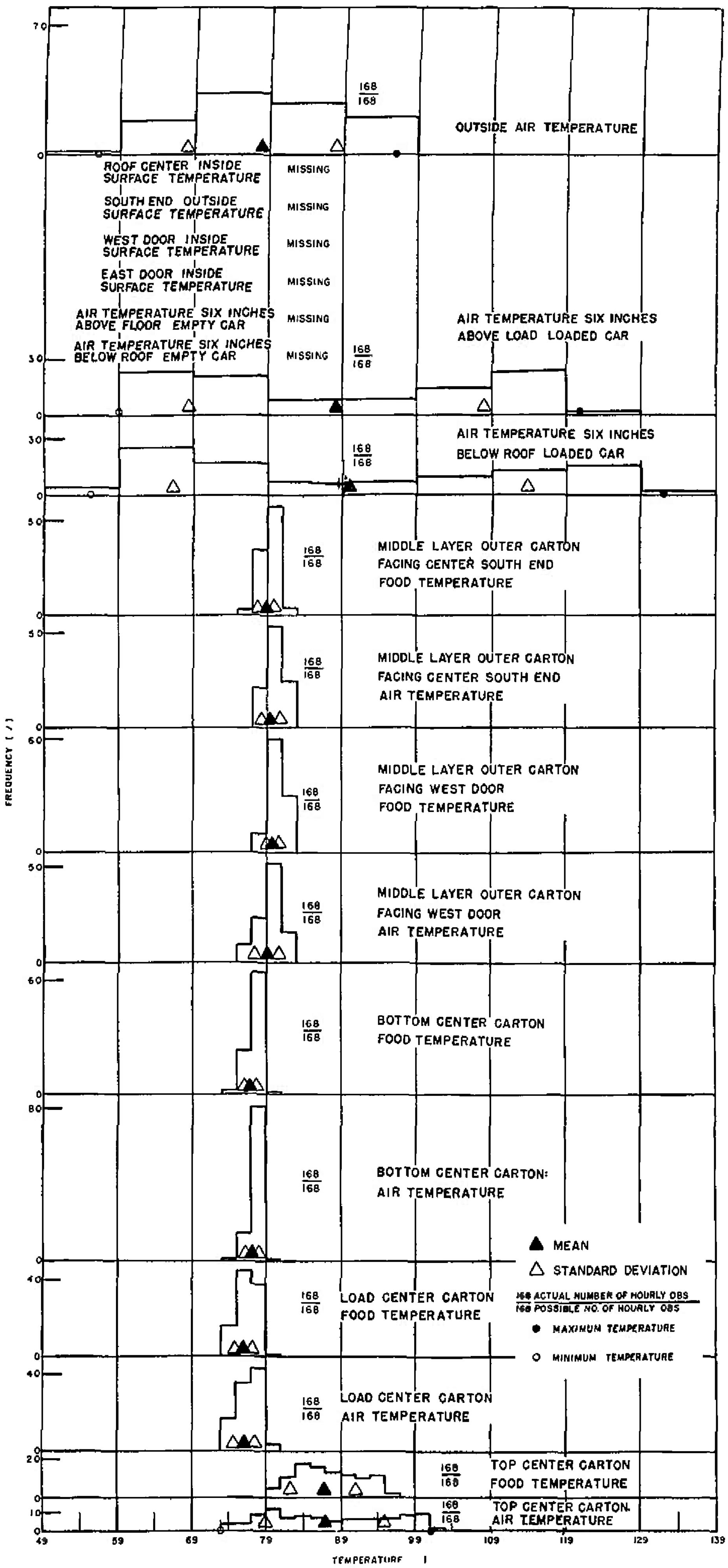

Figure 28. Means, frequencies, and standard deviations of temperature observations by weeks for 1 June - 7 June 1953 - Yuma.

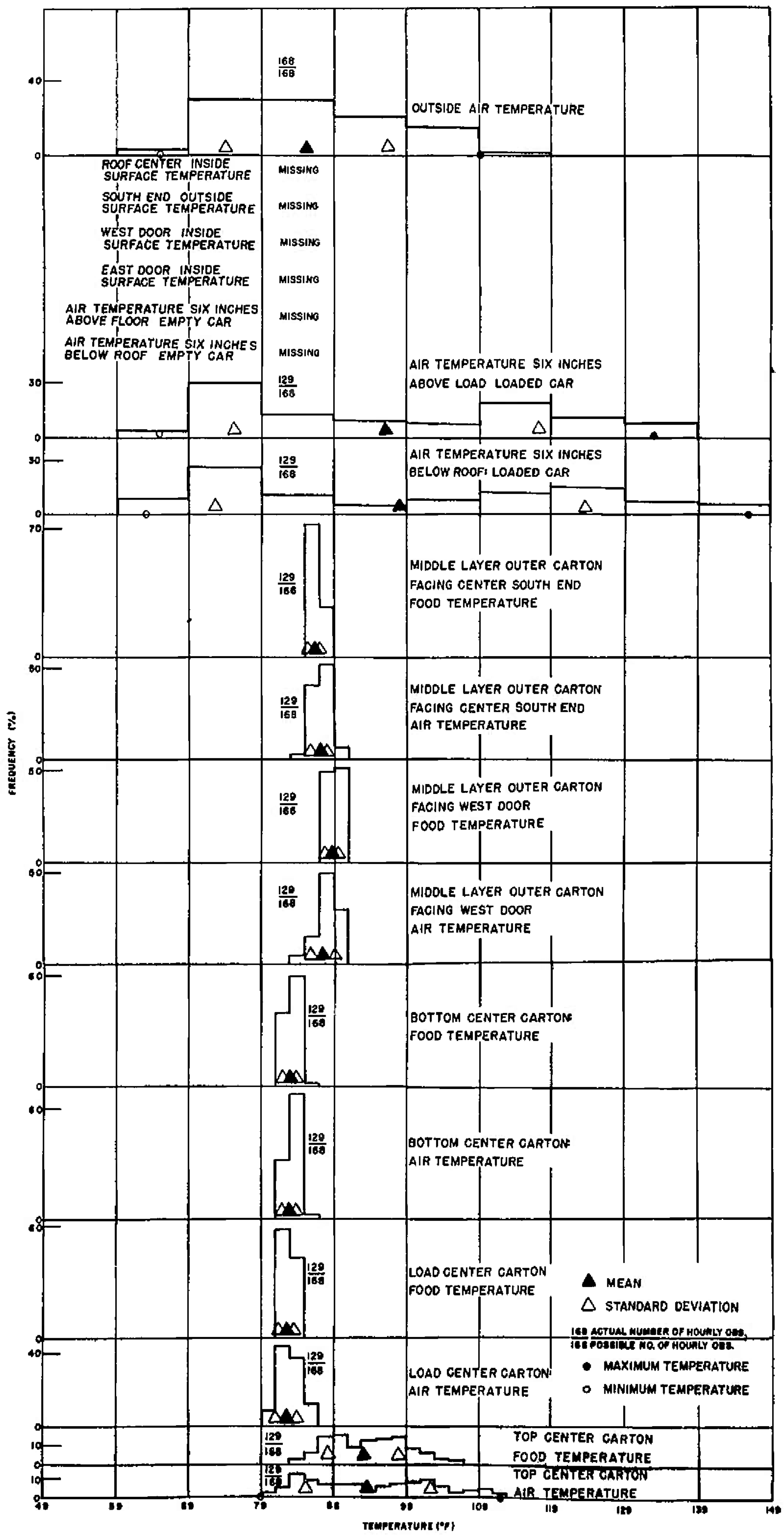

Figure 29. Means, frequencies, and standard deviations of temperature observations for 15 June - 21 June 1953 - Yuma.

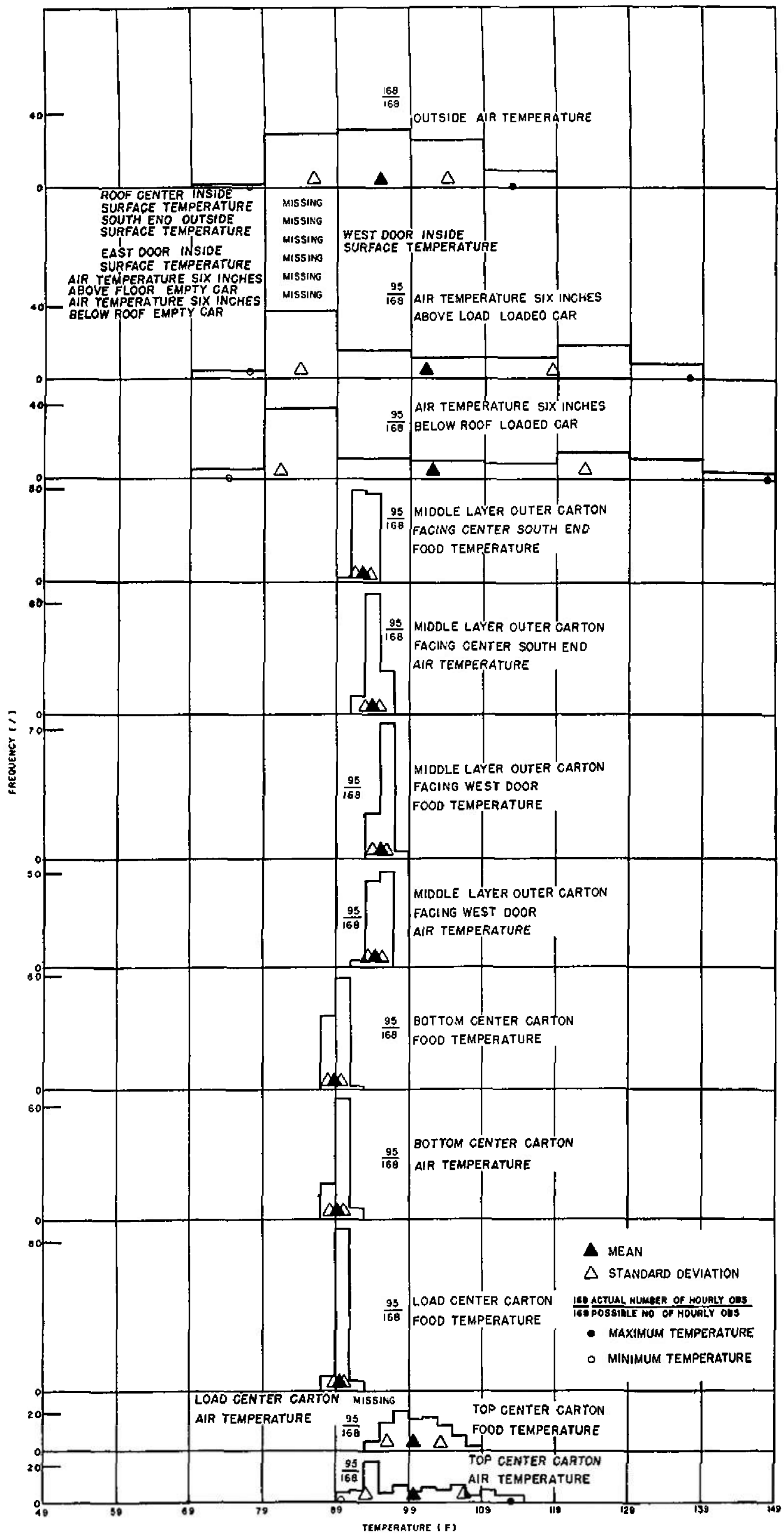

Figure 30. Means, frequencies, and standard deviations of temperature observations by weeks for 29 June - 5 July 1953 - Yuma.

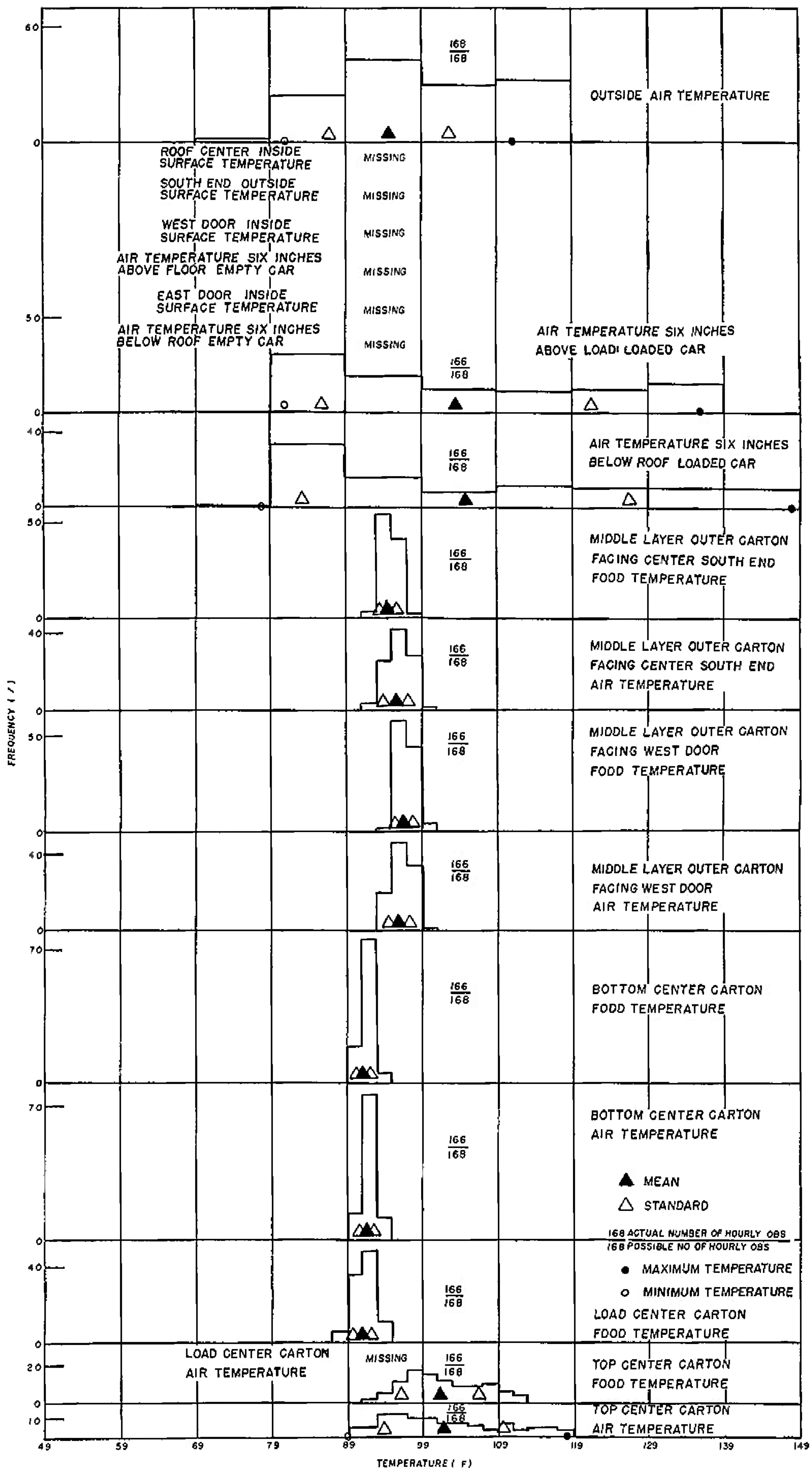

Figure 31. Means, frequencies, and standard deviations of temperature observations by weeks for 6 July - 12 July 1953 - Yuma

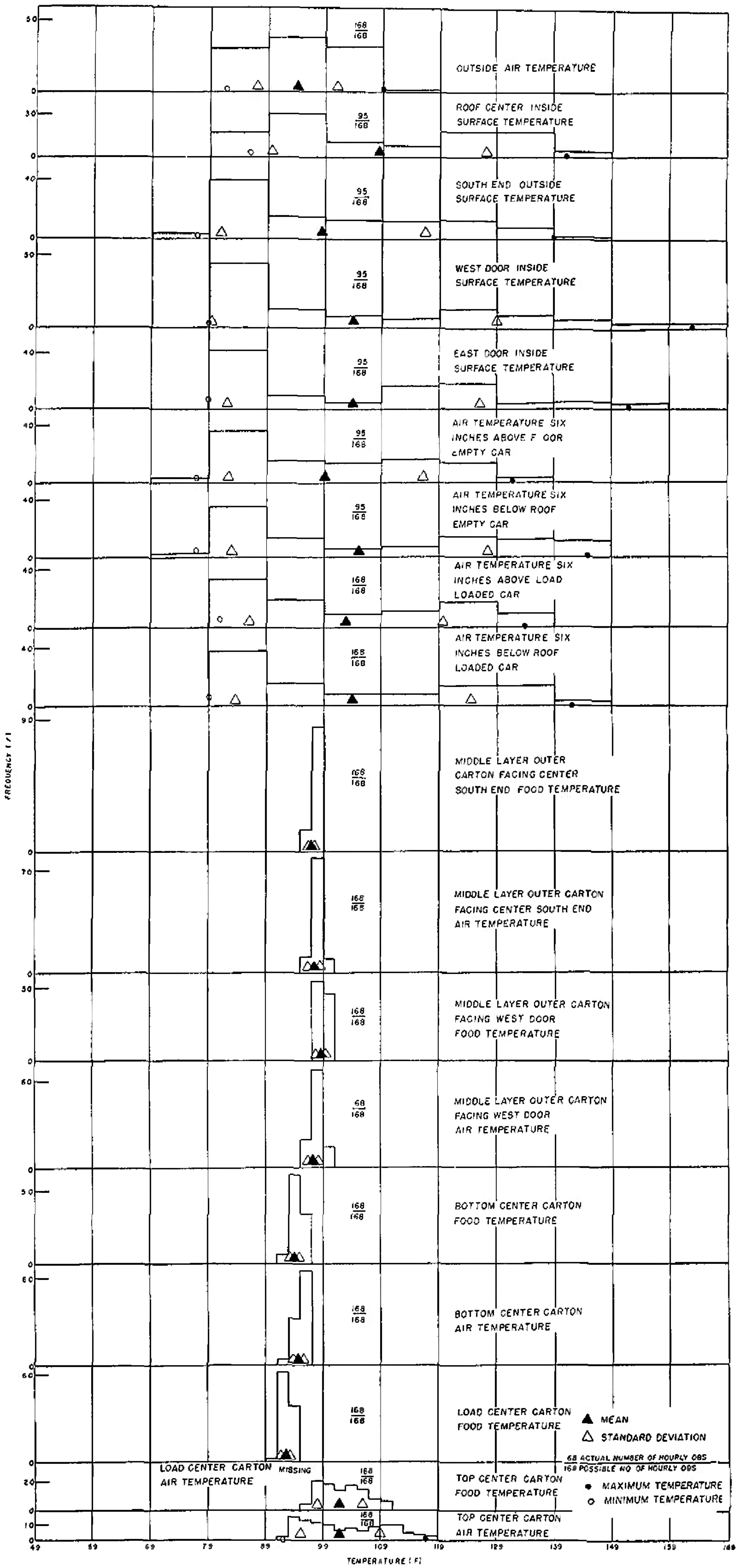

Figure 32. Means, frequencies, and standard deviations of temperature observations by weeks for 13 July - 19 July 1953 - Yuma.

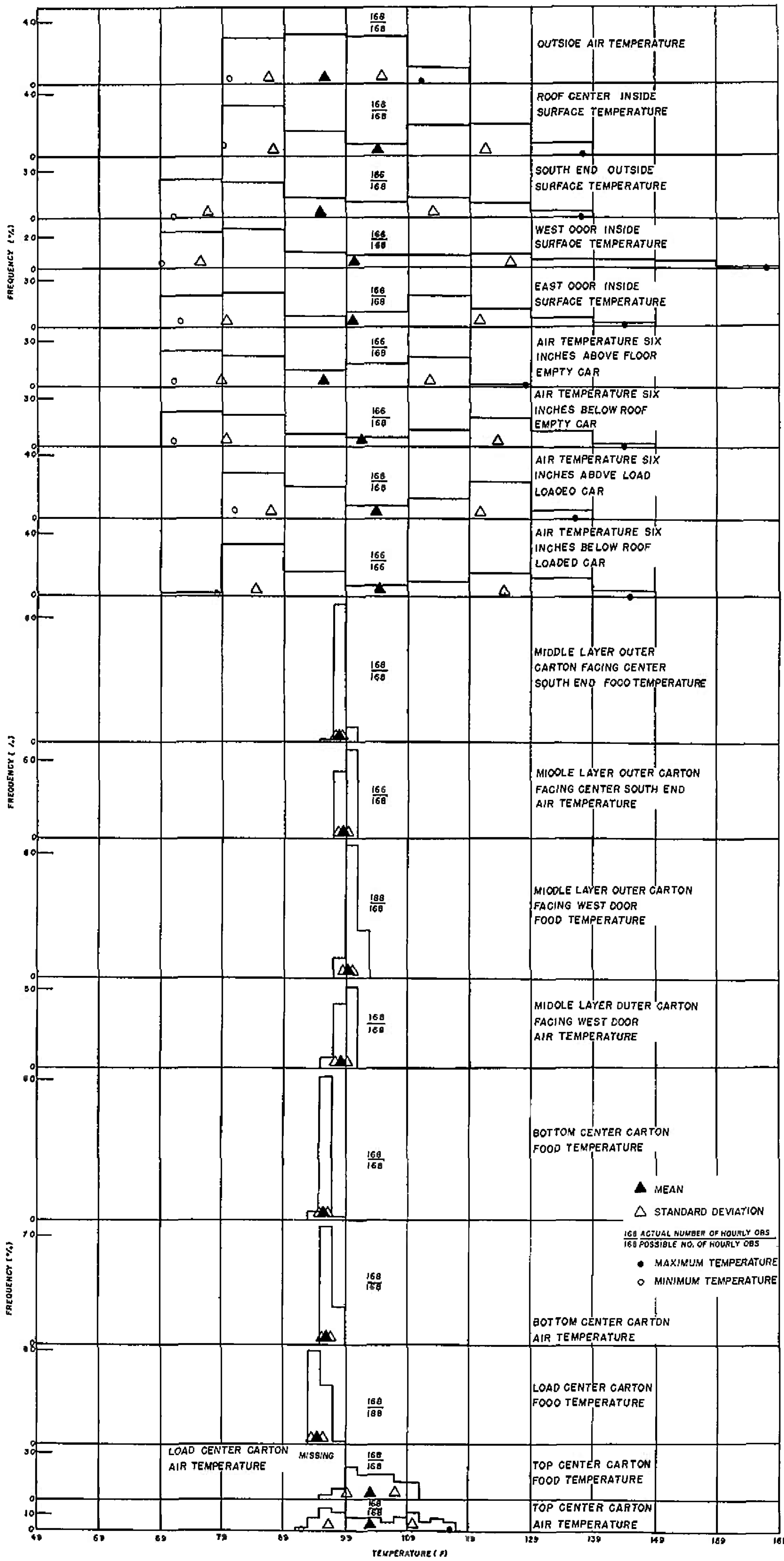

Figure 33. Means, frequencies, and standard deviations of temperature observations by weeks for 20 July - 26 July 1953 - Yuma.

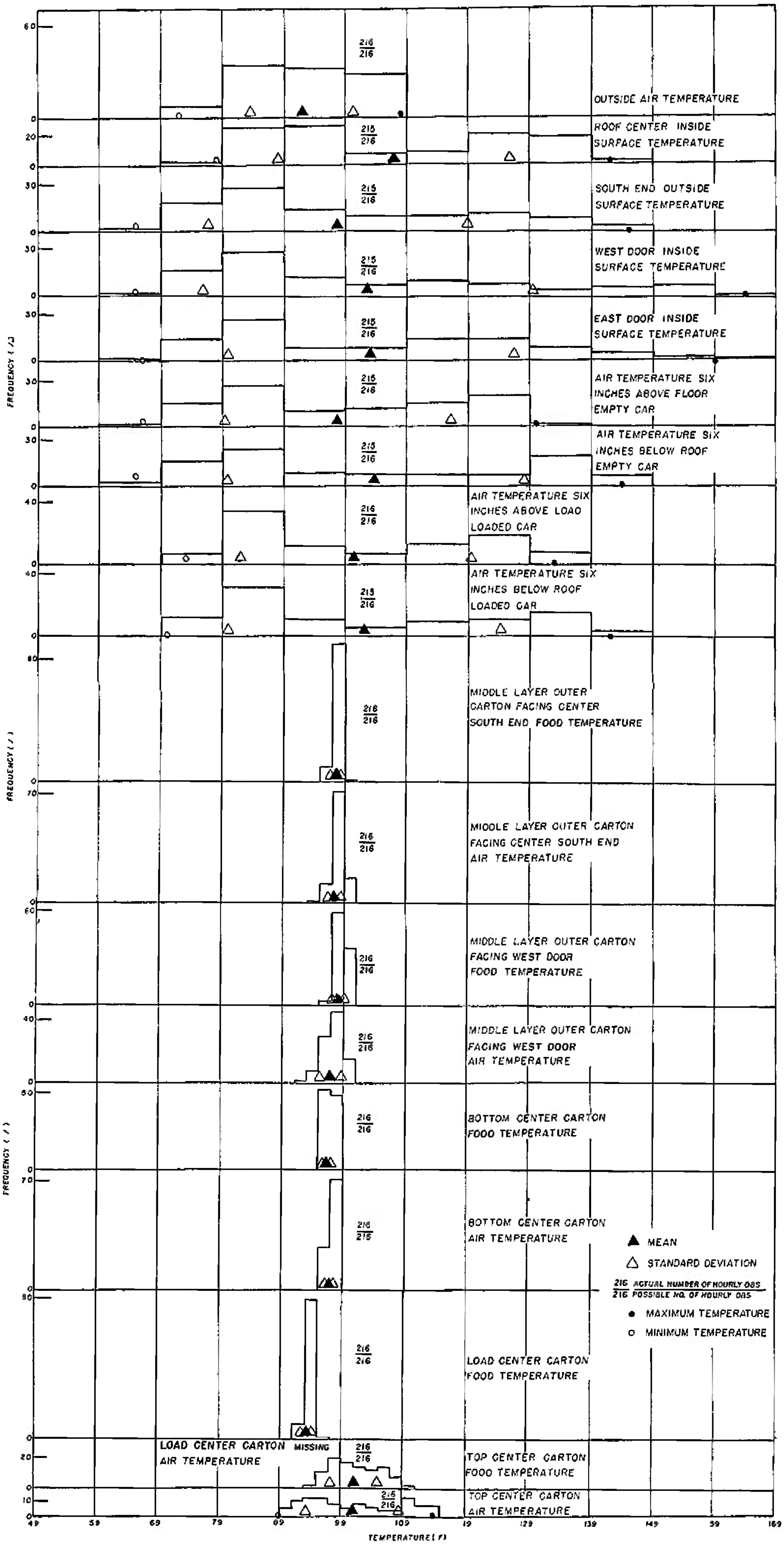

Figure 34 Means, frequencies, and standard deviations of temperature observations by weeks for 27 July - 4 August 1953 - Yuma.

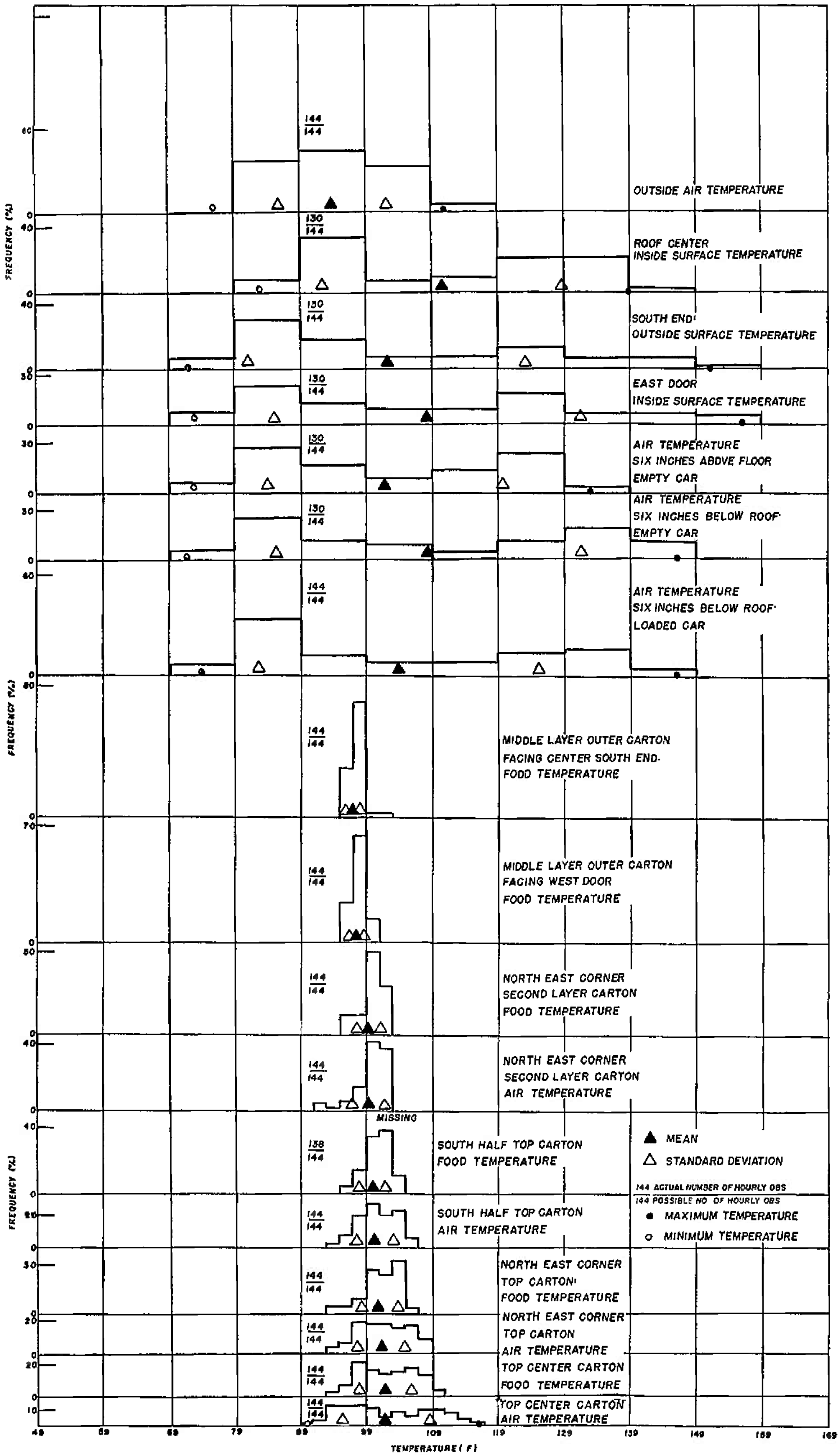

Figure 35. Means, frequencies, and standard deviations of temperature observations by weeks for 5 August - 10 August 1953 - Yuma

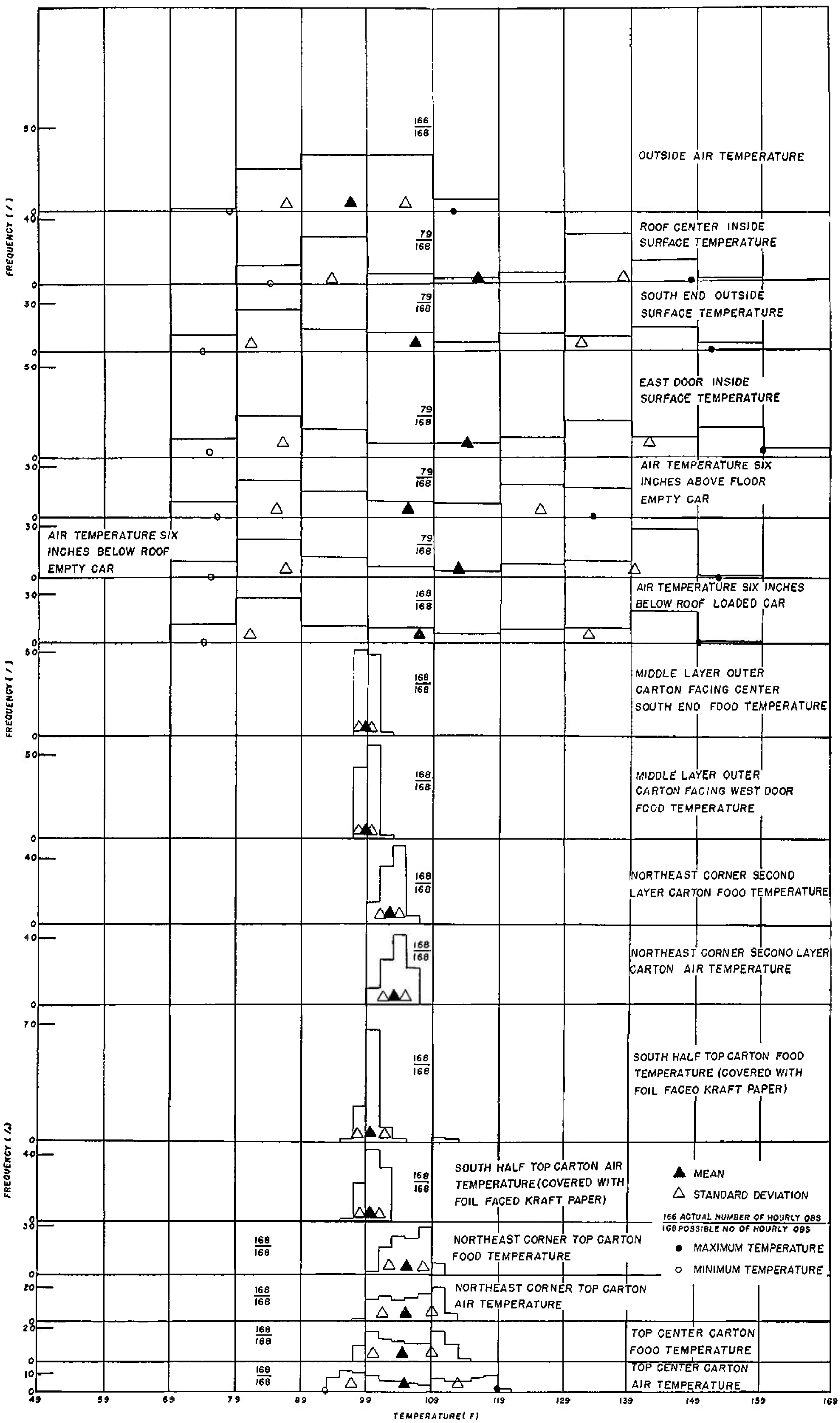

Figure 36 Means, frequencies, and standard deviations of temperature observations by weeks for 11 August - 17 August 1953 - Yuma

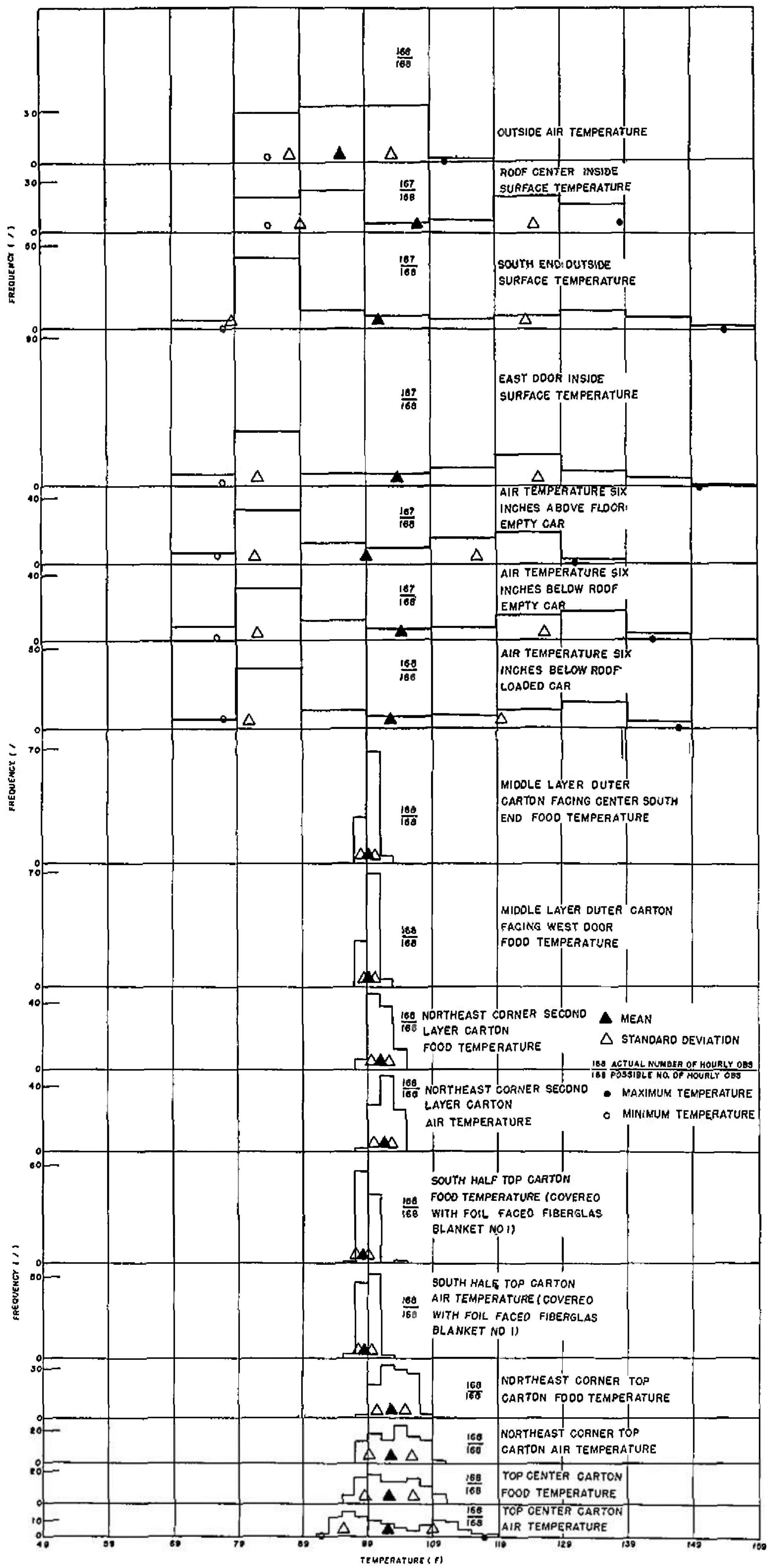

Figure 37. Means, frequencies, and standard deviations of temperature observations by weeks for 18 August - 24 August 1953 - Yuma.

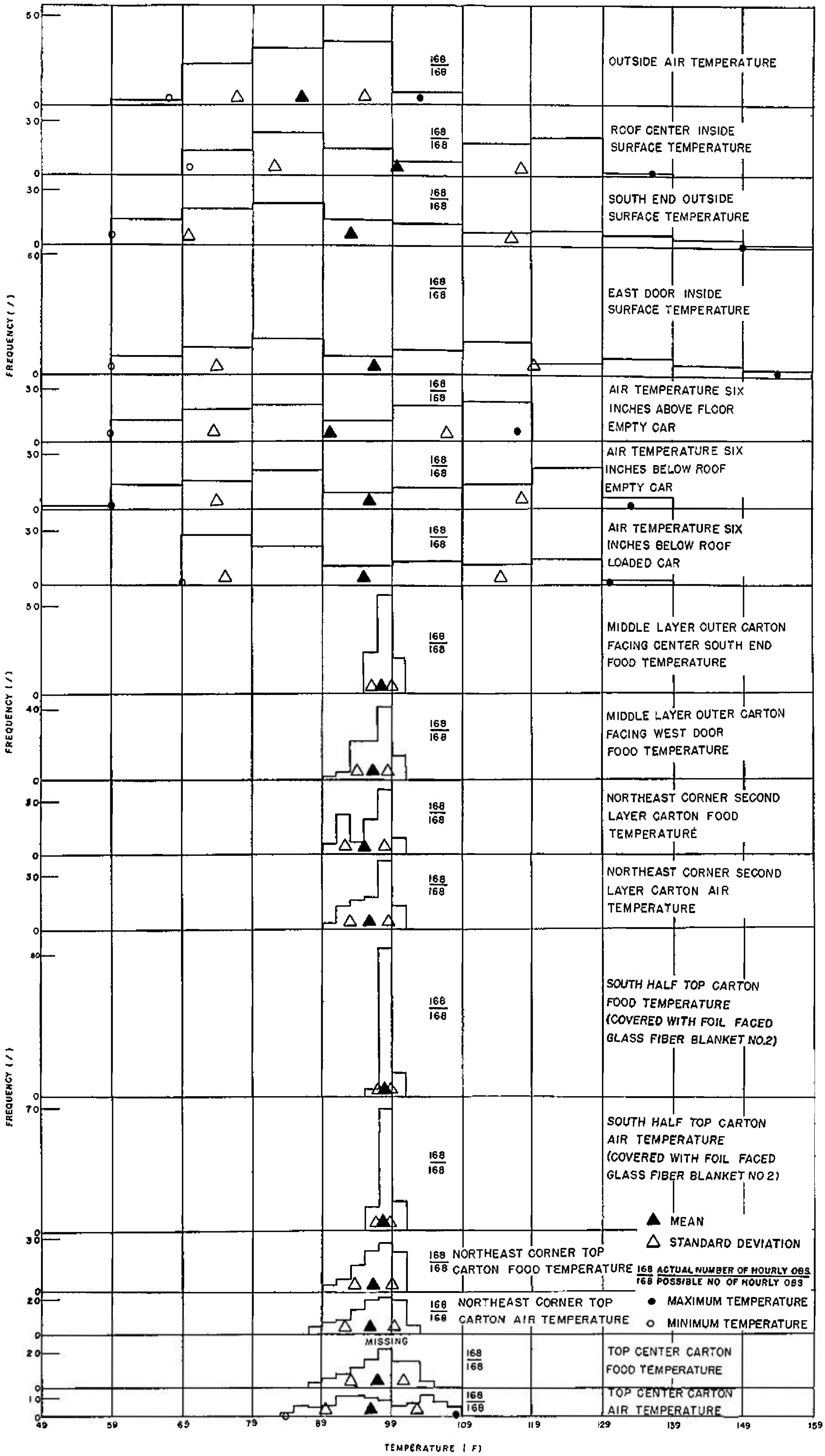

Figure 38. Means, frequencies, and standard deviations of temperature observations by weeks for 25 August - 31 August 1953 - Yuma.

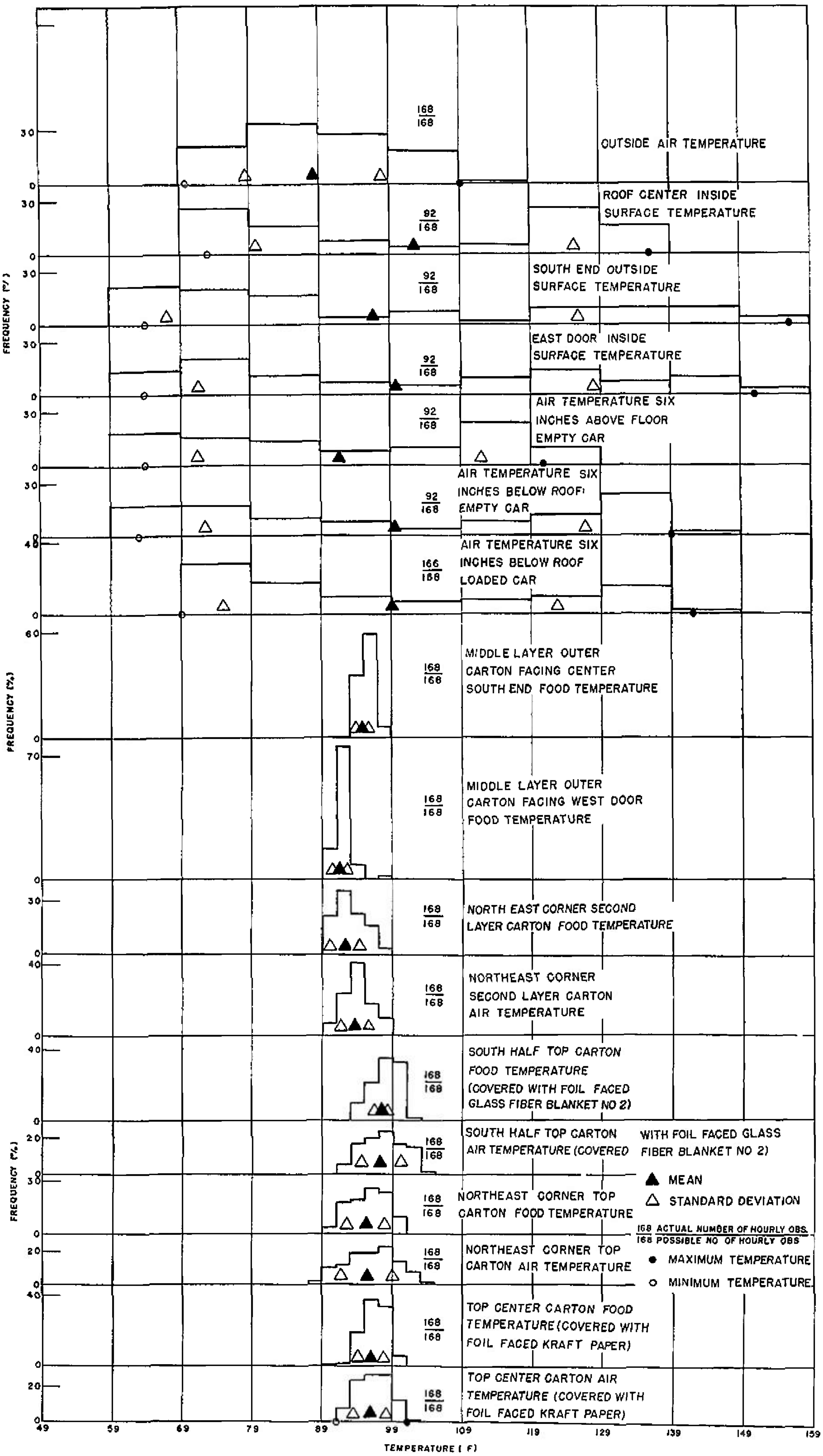

Figure 39 Means, frequencies, and standard deviations of temperature observations by weeks for 1 September - 7 September 1953 - Yuma.

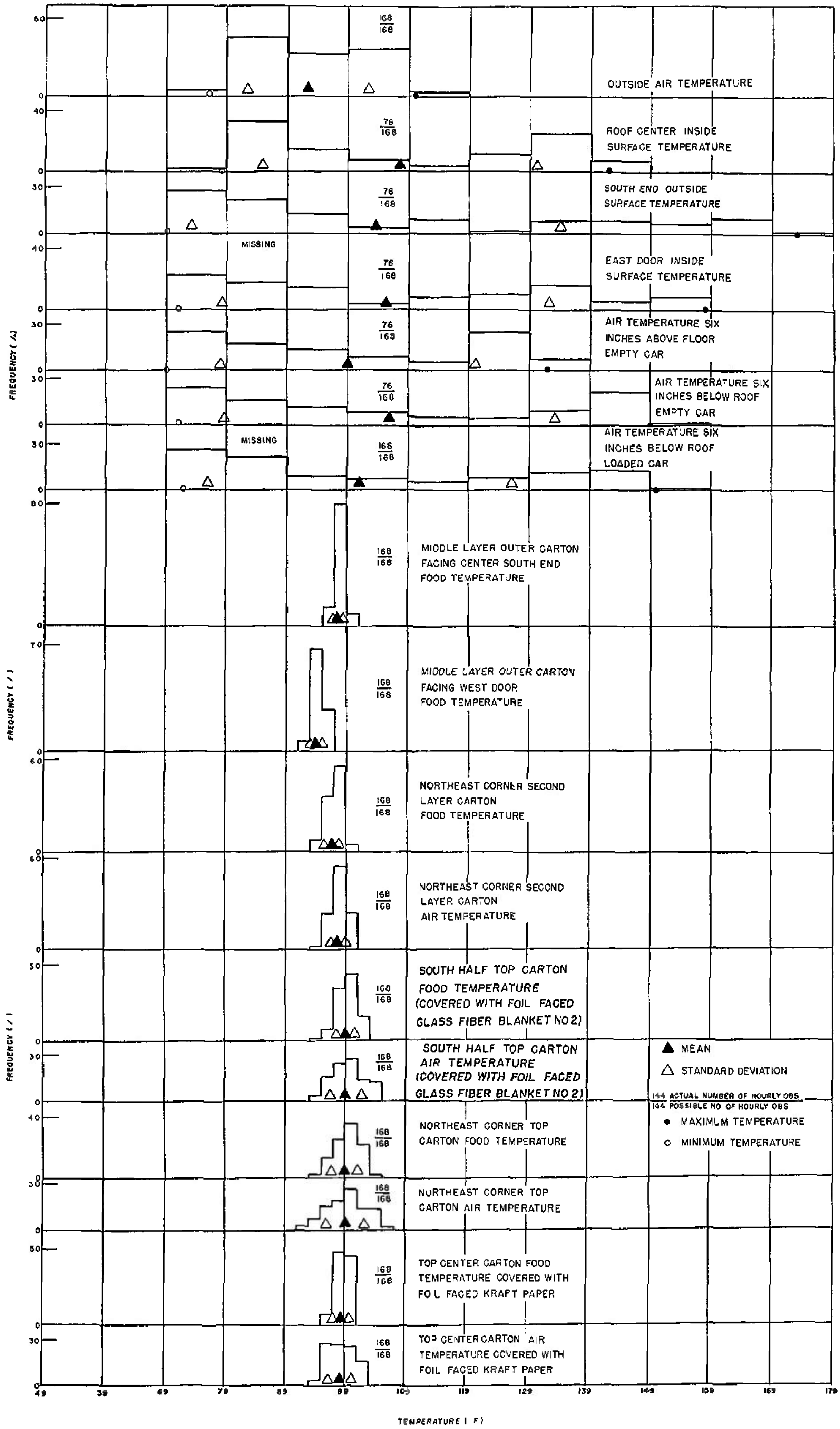

Figure 40 Means, frequencies, and standard deviations of temperature observations by weeks for 8 September - 14 September 1953 - Yuma.

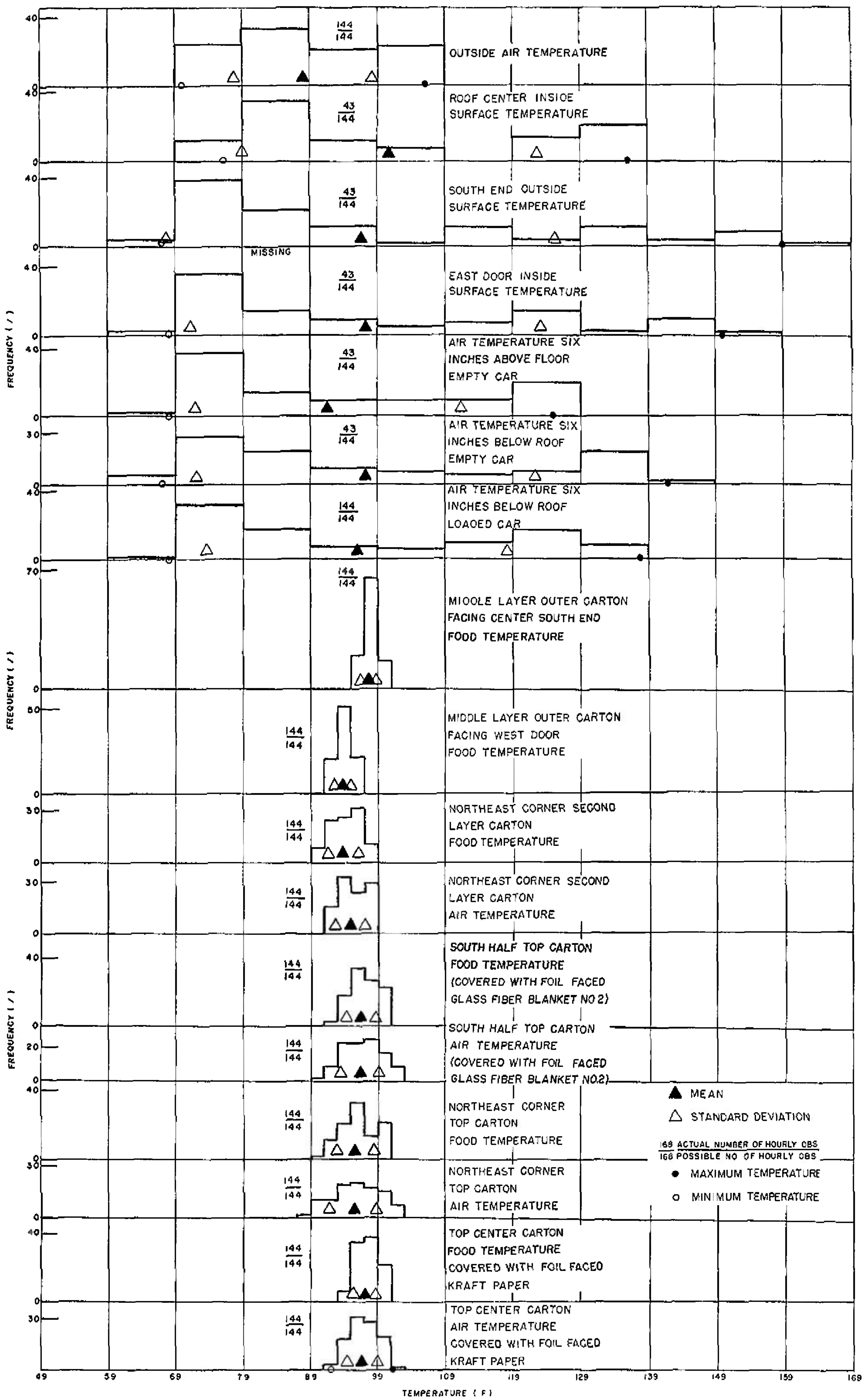

Figure 41. Means, frequencies, and standard deviations of temperature observations by weeks for 15 September - 20 September 1953 - Yuma

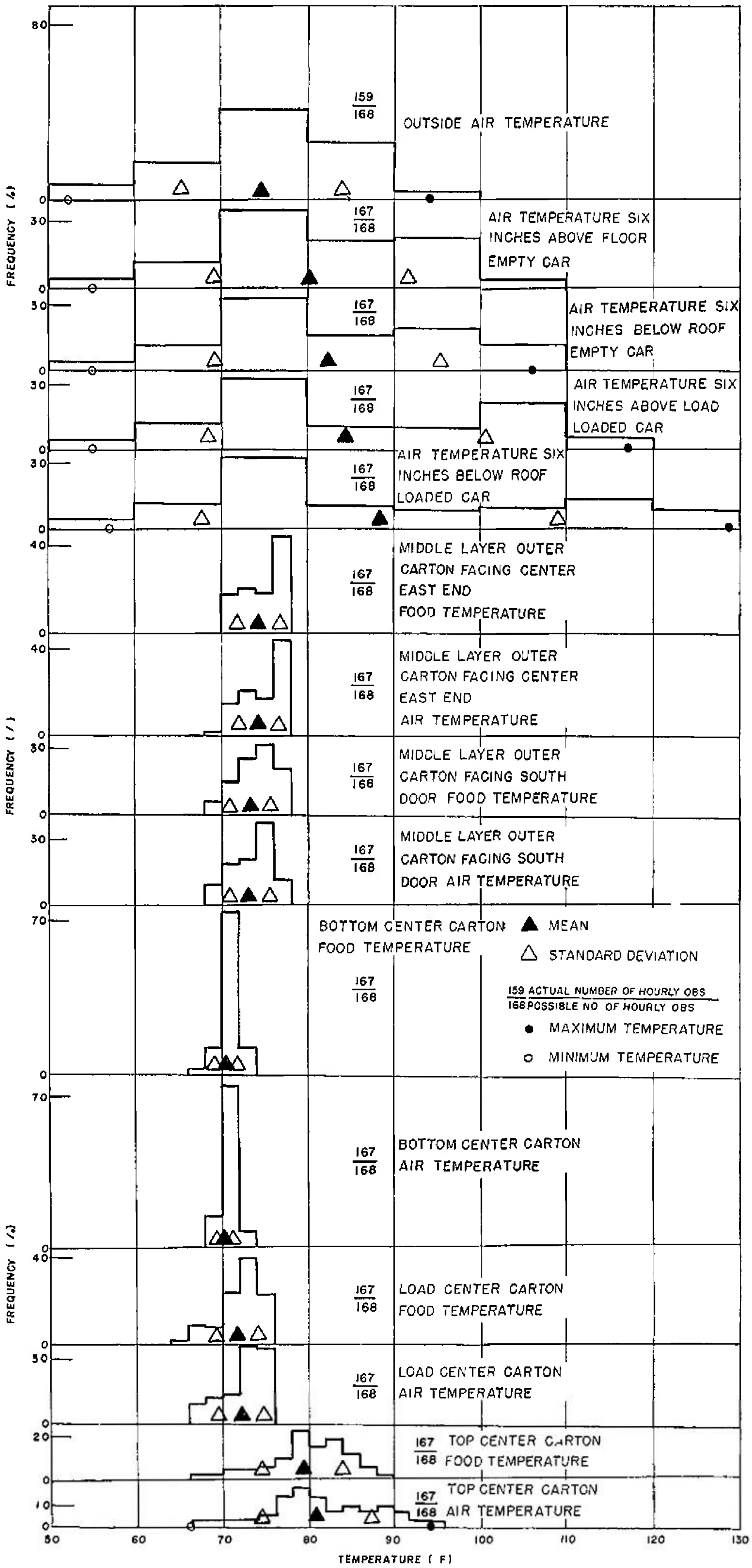

Figure 42. Means, frequencies, and standard deviations of temperature observations by weeks for 1 June - 9 June 1953 - Cameron

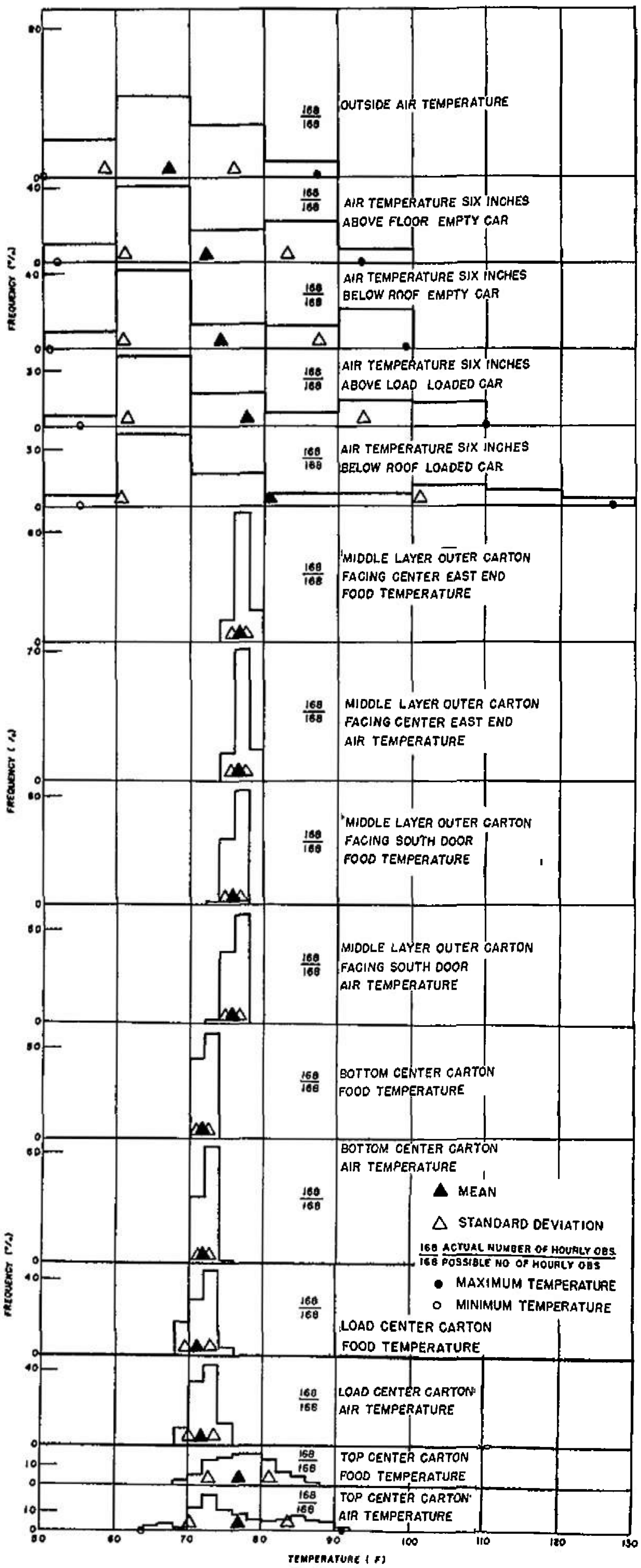

Figure 43. Means, frequencies, and standard deviations of temperature observations by weeks for 10 June - 16 June 1953 - Cameron.

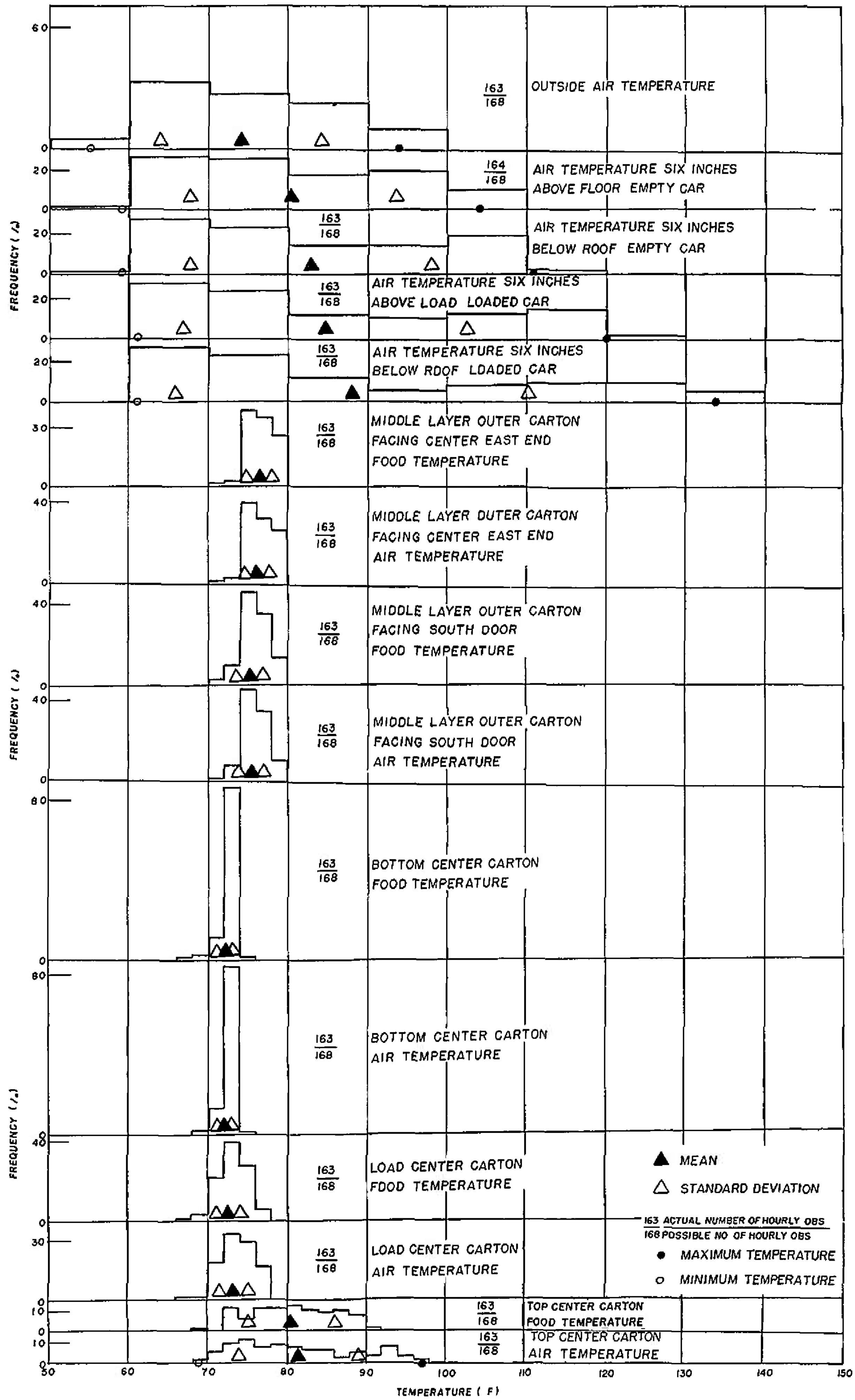

Figure 44. Means, frequencies, and standard deviations of temperature observations by weeks for 17 June - 23 June 1953 - Cameron

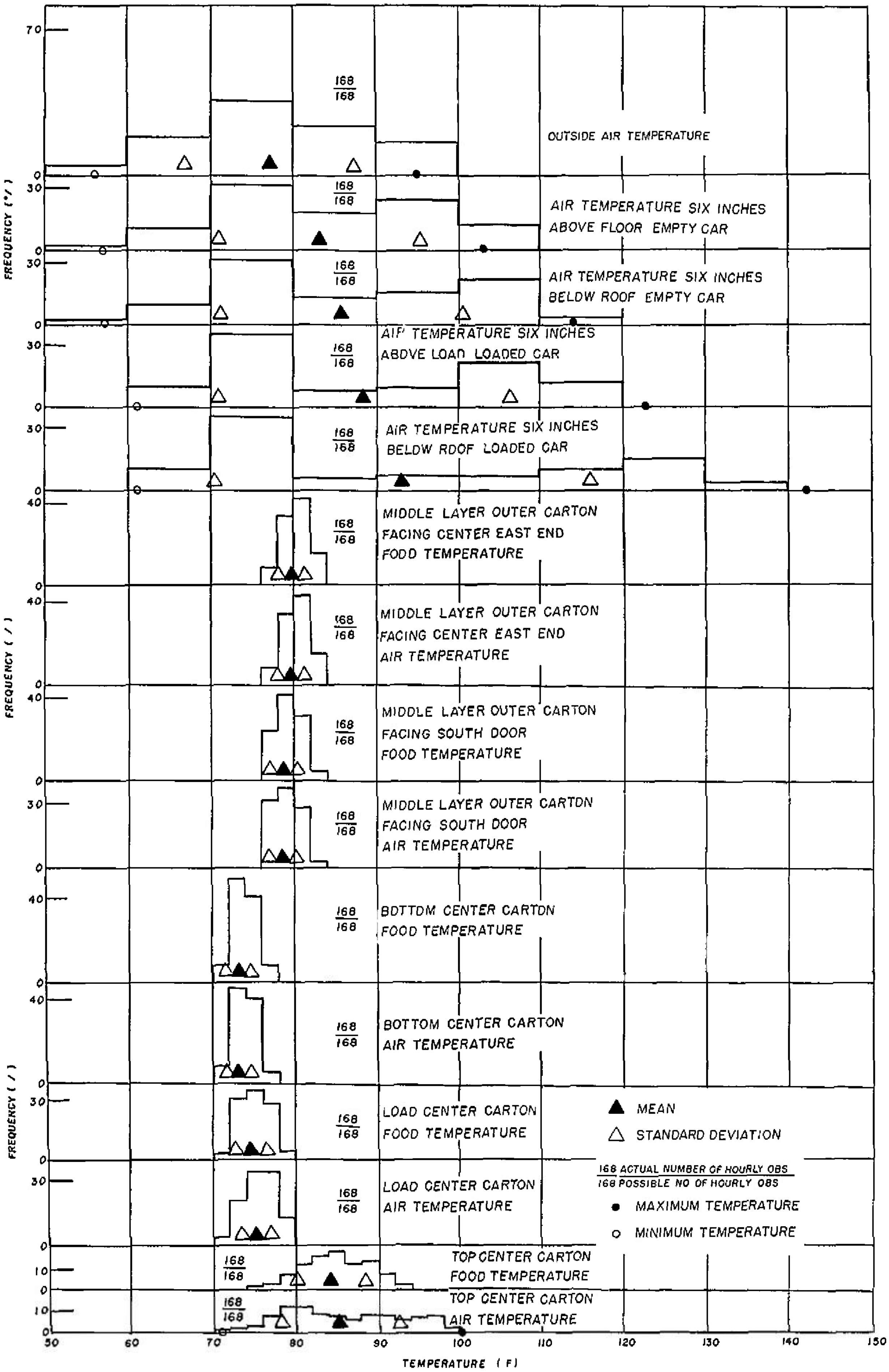

Figure 45. Means, frequencies, and standard deviations of temperature observations by weeks for 24 June - 30 June 1953 - Cameron.

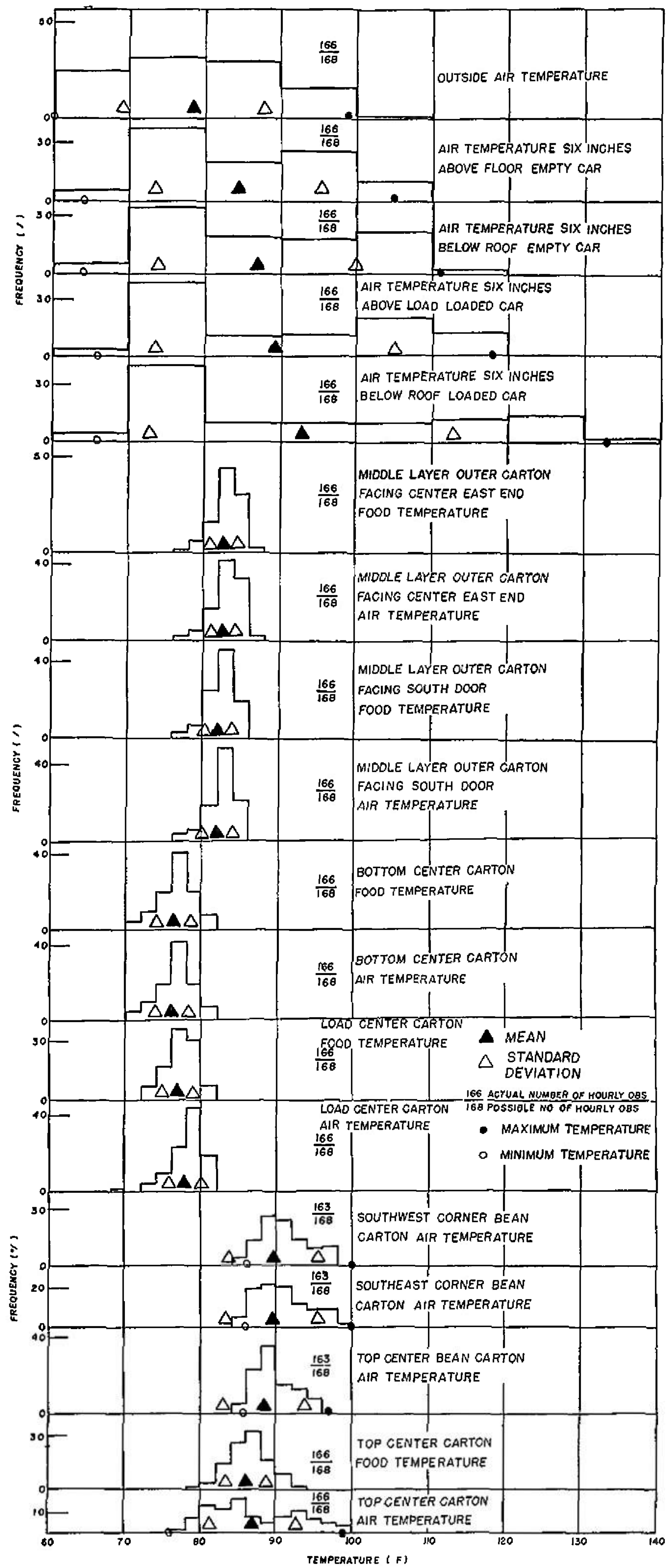

Figure 46 Means, frequencies, and standard deviations of temperature observations by weeks for 1 July - 7 July 1953 - Cameron.

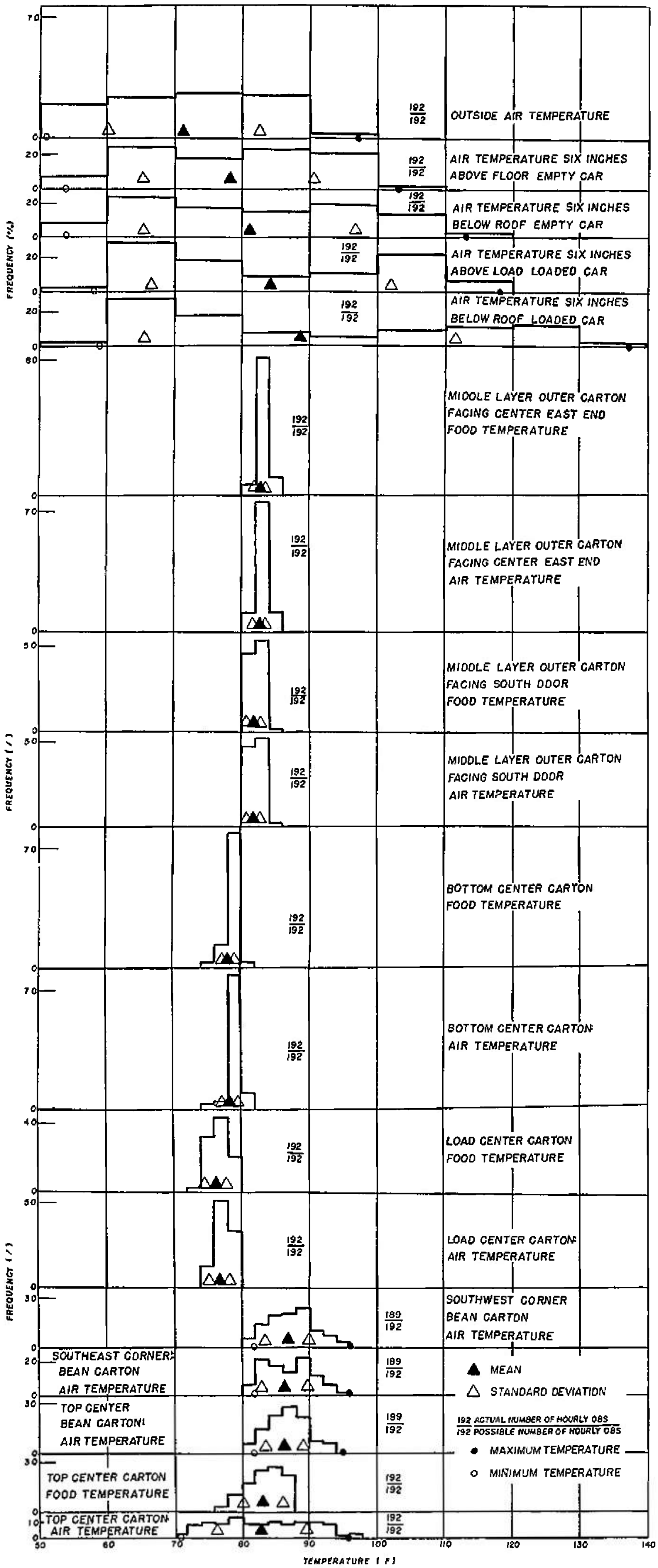

Figure 47. Means, frequencies, and standard deviations of temperature observations by weeks for 8 July - 15 July 1953 - Cameron.

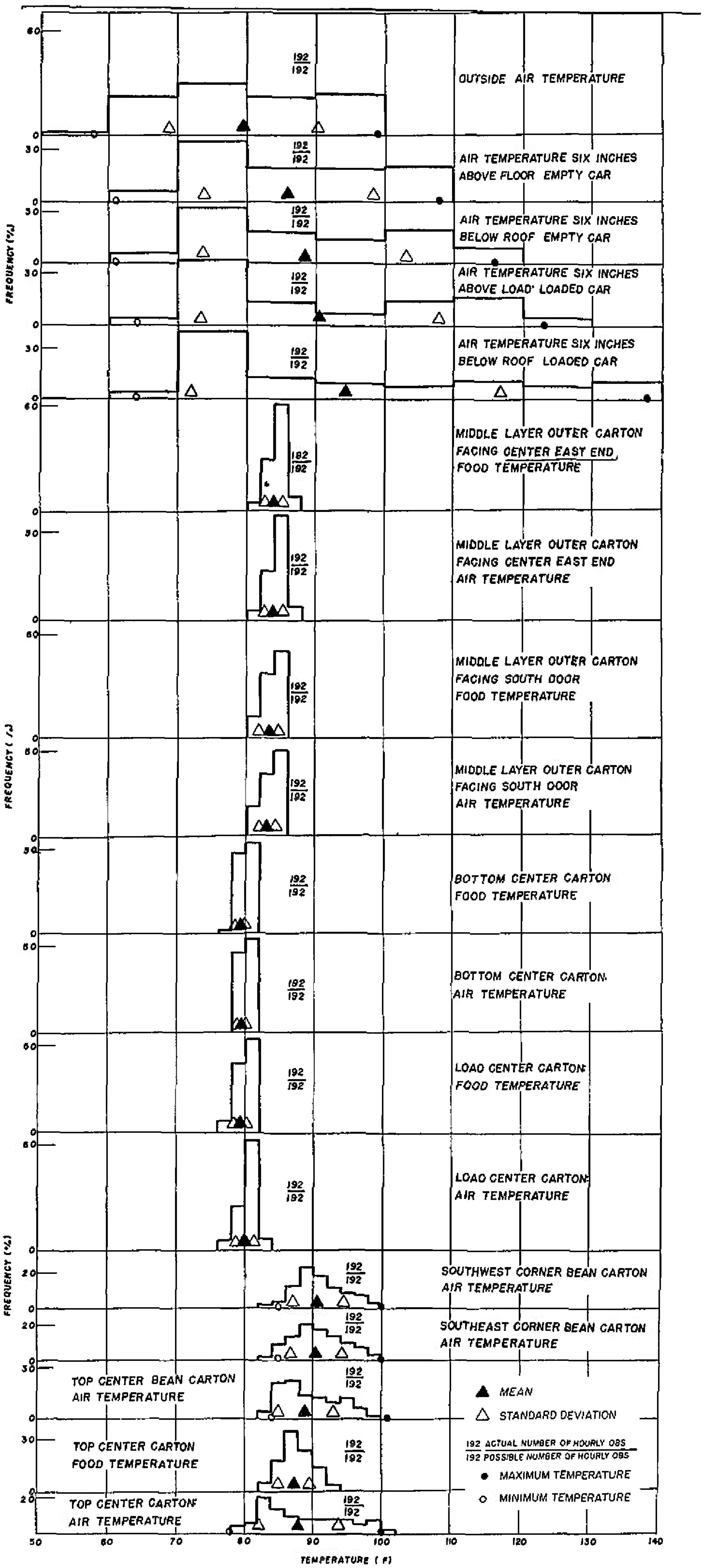

Figure 48. Means, frequencies, and standard deviations of temperature observations by weeks for 16 July - 23 July 1953 - Cameron.

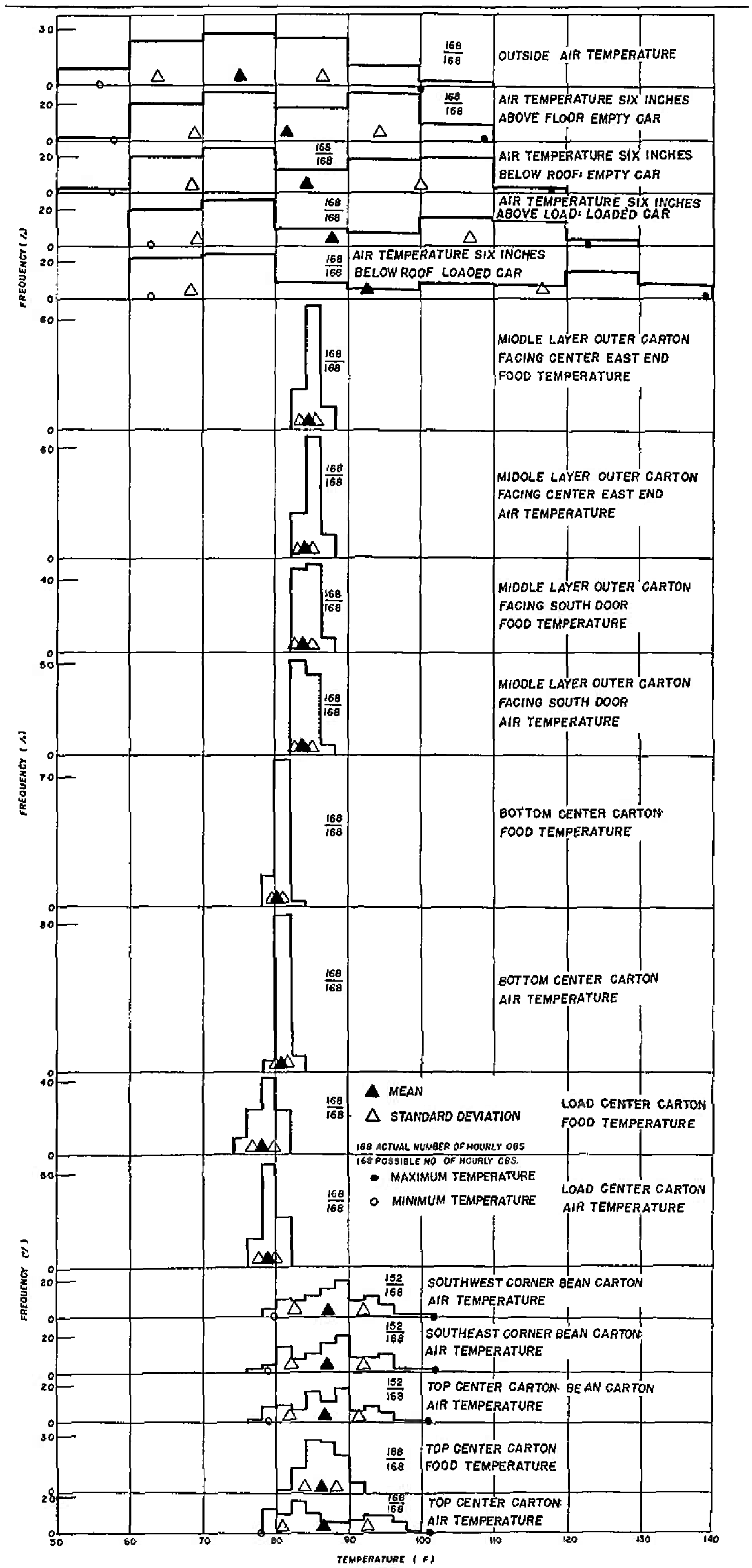

Figure 49. Means, frequencies, and standard deviations of temperature observations by weeks for 24 July - 30 July 1953 - Cameron.

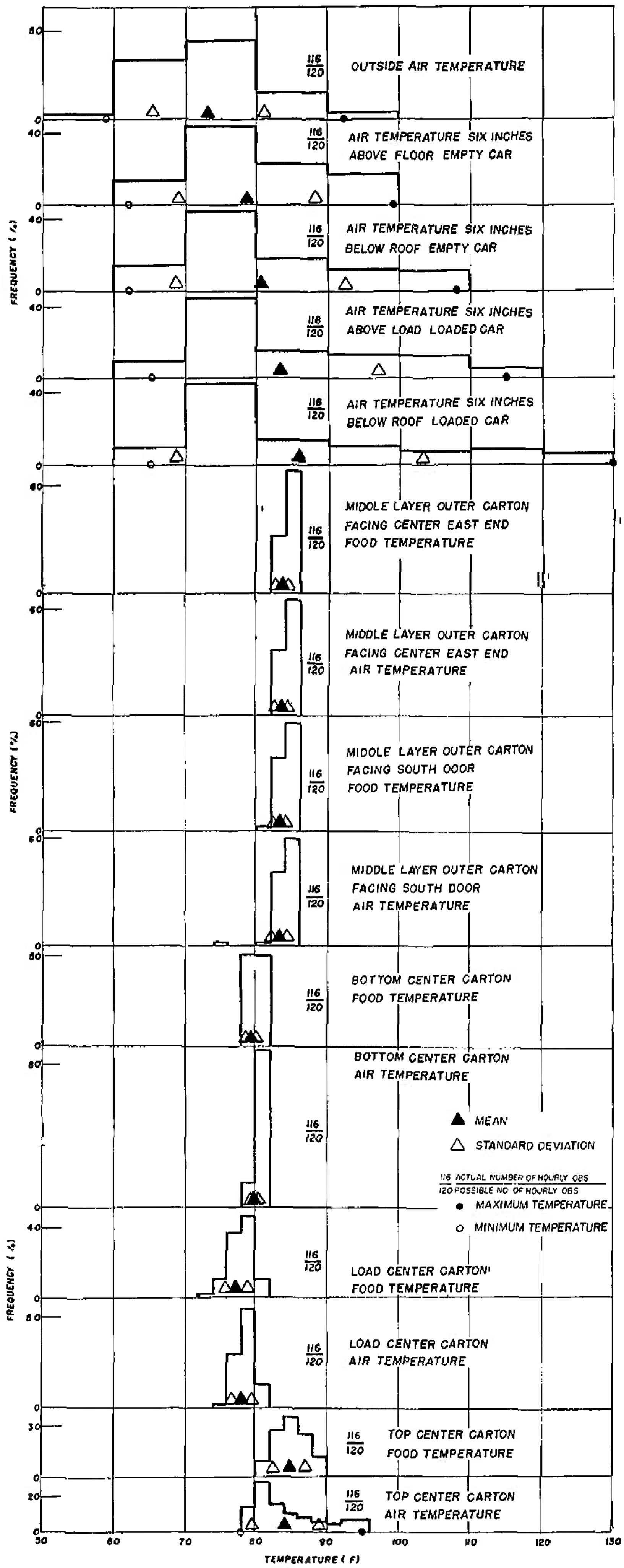

Figure 50. Means, frequencies, and standard deviations of temperature observations by weeks for 31 July - 4 August 1953 - Cameron.

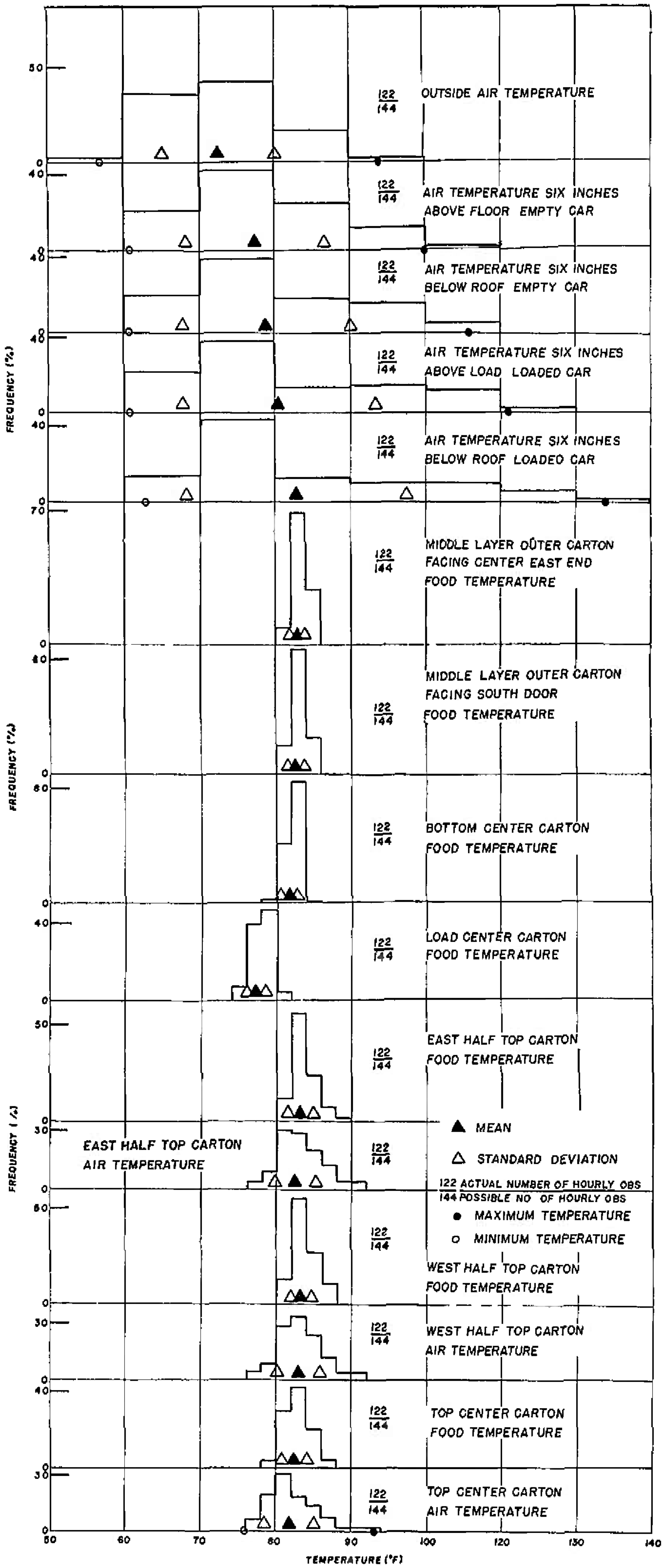

Figure 51. Means, frequencies, and standard deviations of temperature observations by weeks for 5 August - 10 August 1953 - Cameron

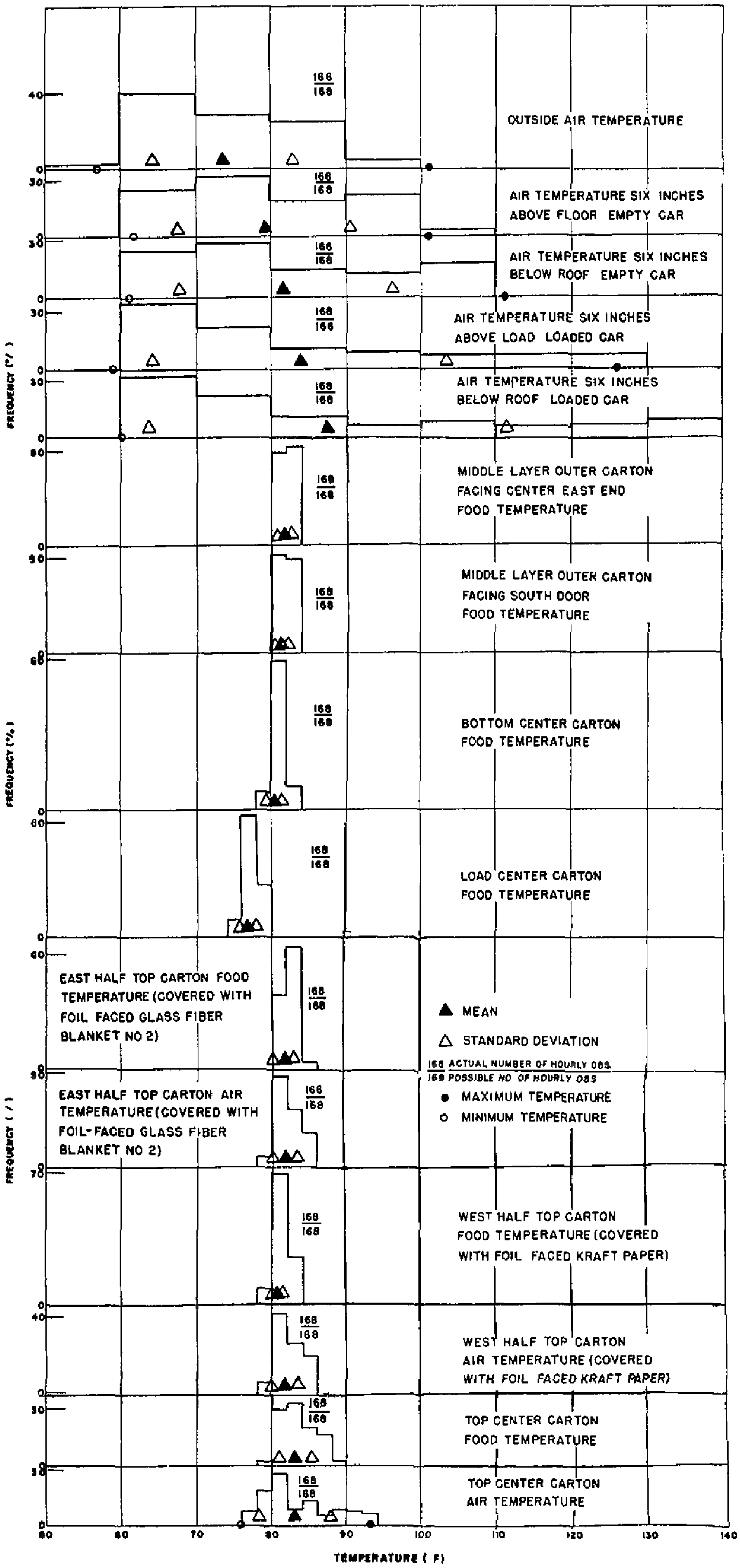

Figure 52. Means, frequencies, and standard deviations of temperature observations by weeks for 11 August - 17 August 1953 - Cameron

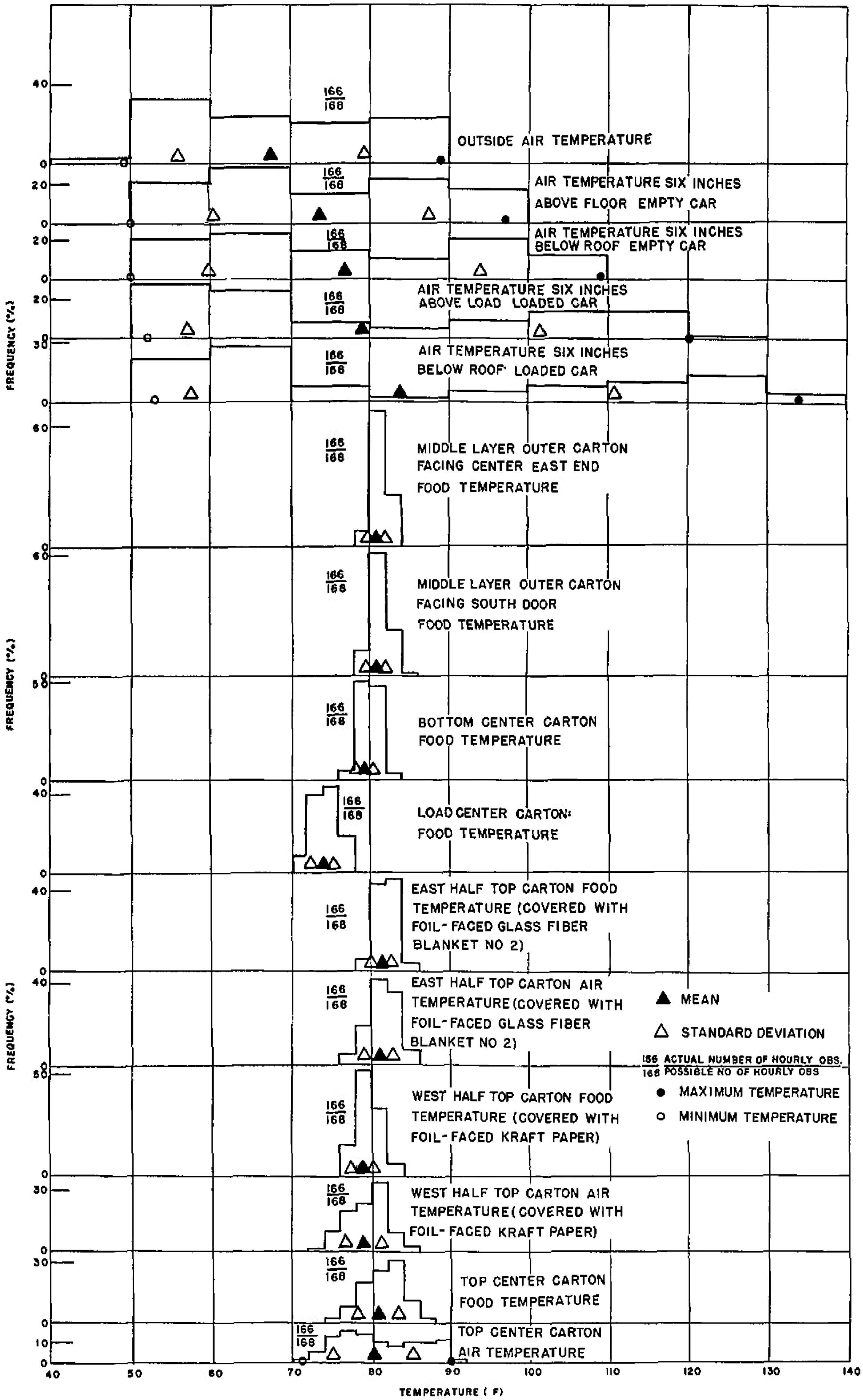

Figure 53. Means, frequencies, and standard deviations of temperature observations by weeks for 18 August - 24 August 1953 - Cameron.

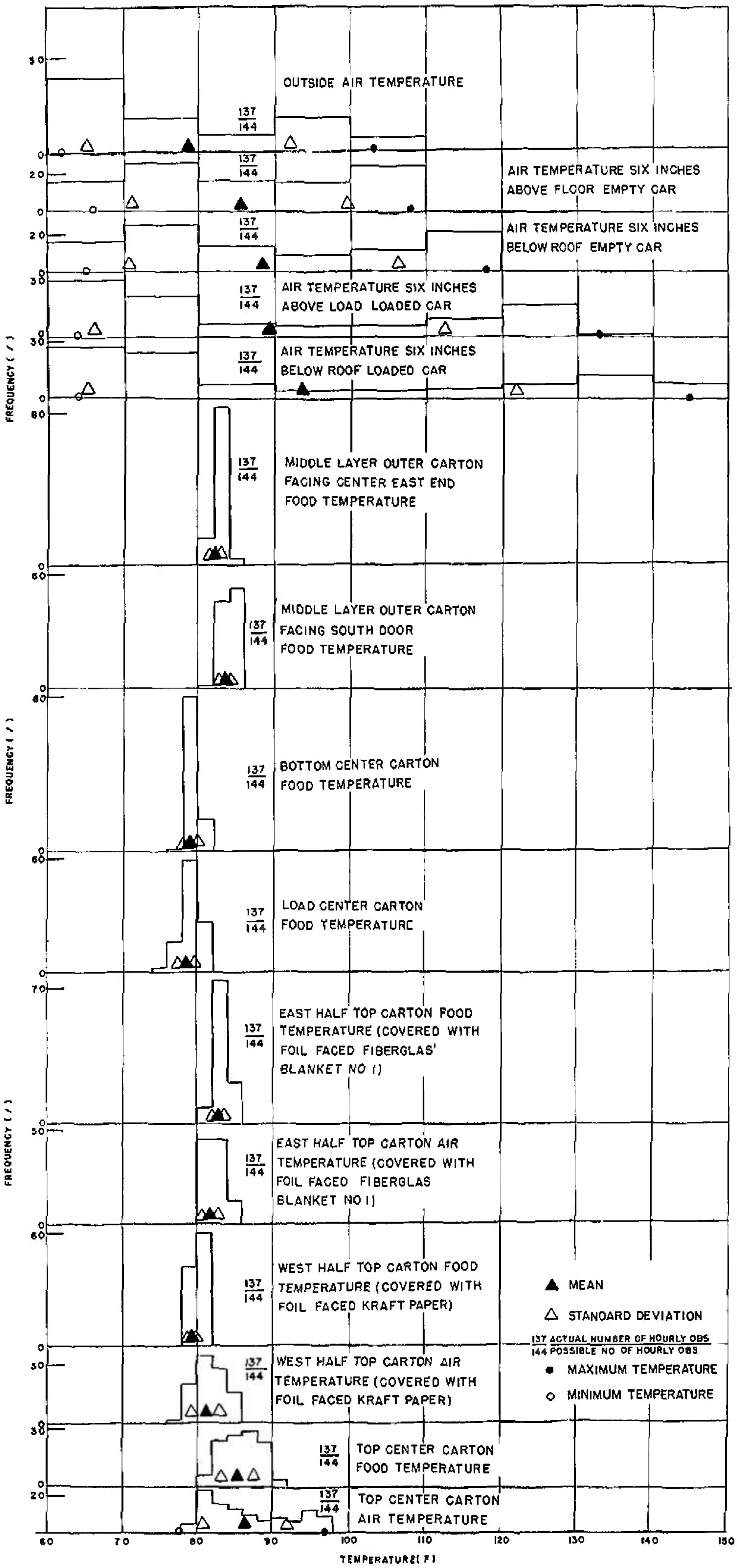

Figure 54. Means, frequencies, and standard deviations of temperature observations by weeks for 26 August - 31 August 1953 - Cameron.

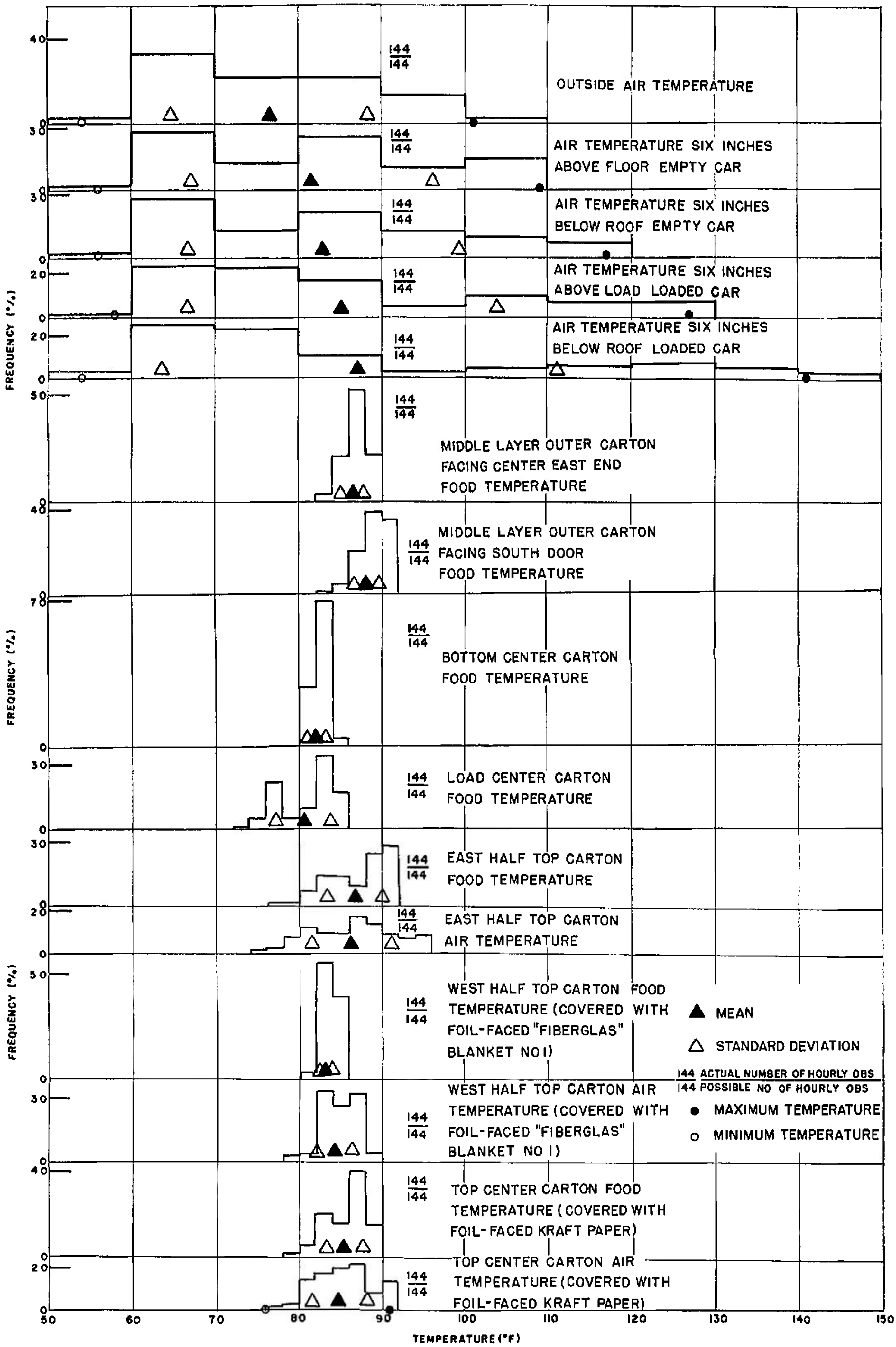

Figure 55. Means, frequencies, and standard deviations of temperature observations by weeks for 2 September - 7 September 1953 - Cameron.

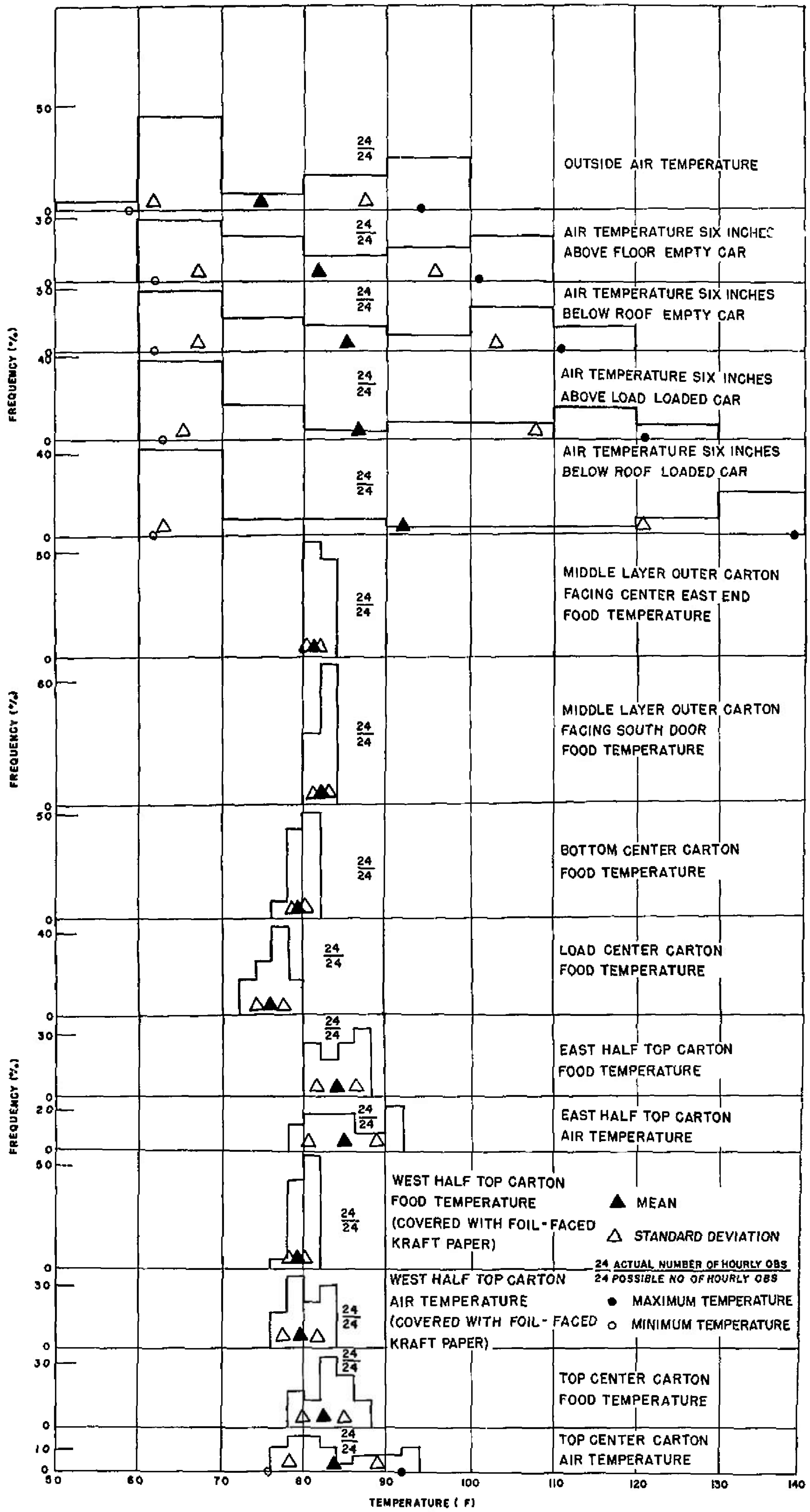

Figure 56 Means, frequencies, and standard deviations of temperature observations for 25 August 1953 - Cameron.

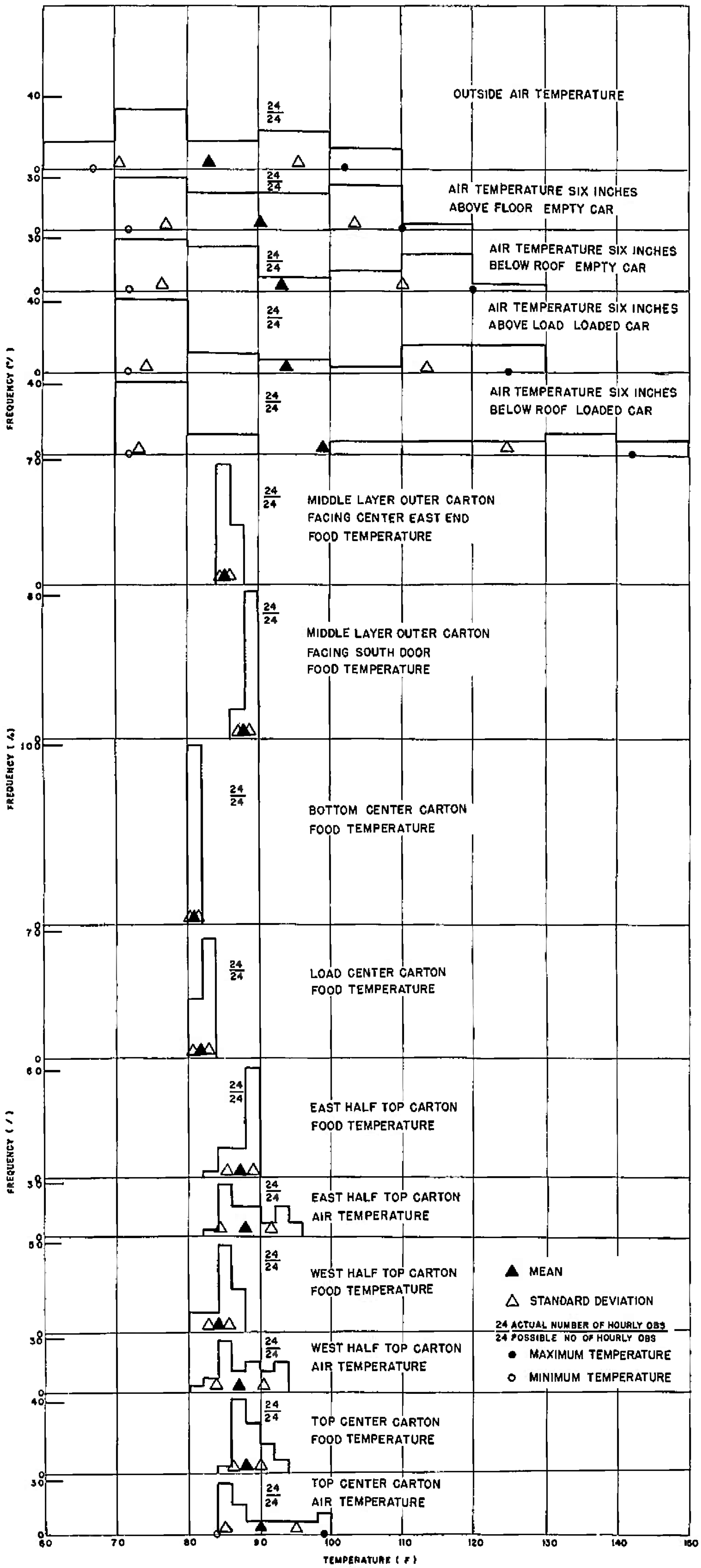

Figure 57. Means, frequencies, and standard deviations of temperature observations by weeks for 1 September 1953 - Cameron.

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13 ABSTRACT

This report contains the detailed computer analysis of the frequencies, means and standard deviations of temperature observations made at 18 positions located in empty and loaded boxcars (two at each location) at both Yuma, Arizona and Cameron Station, Virginia (Washington, DC)

It is a comparative study of storage temperature distribution in storage air and in food in storage cartons in a desert subtropical versus a humid subtropical climate

Detailed analysis of outer and inner wall surface temperatures is also reported

The effect of both radiation and heat barrier insulation is a reduction of maximum temperatures by 10-15°F and mean temperatures by 5 F° in the more severe Yuma storage Foil-faced Kraft paper is as effective as more expensive types of insulation

The temperature distribution data are reported both graphically and in tables for each position for the total period and for separate weeks

Storage temperature weekly means are shown to be highly correlated with outside air temperature means

It is shown that if an empirical food degradation-temperature relationship is known, storage life in boxcars may be predicted

Since the predictive relation between mean storage air temperature and outside air temperature appears similar at Yuma and Cameron, one may make moderately dependable predictions of food storage life or of effective temperature for laboratory simulation of food storage in boxcars at widely different locations and exposures

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	ROLE	WT	ROLE	WT	ROLE	WT
Analysis	8					
Temperature	8		8,7,6		7	
Observation	9		8			
Mean	9		0			
Frequency distribution	9		0			
Divergence	9		0			
Boxcars	9		9,6		7	
Yuma, Arizona	0					
Cameron Station, Virginia	0					
Storage stability	4				7	
Food	4		9		7	
Thermal degradation	4				7	
Insulation					6	
Air			6			

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