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Temperature Trends in Sacramento--Another Heat Island

A. D. LENTINI

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A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

U. S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU

Weather Bureau Technical Memorandum WR-36

TEMPERATURE TRENDS IN SACRAMENTO--ANOTHER HEAT ISLAND

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I. INTRODUCTION

Numerous articles have been written about the heat island effect in cities. These investigations, employing various approaches, offer overwhelming evidence that the effect is pronounced. As far back as 1833, Luke Howard (1) documented London's heat island. Wilhelm Schmidt (2), the first person to use an automobile to obtain thermal cross-sections, did the same for Vienna in 1927. Other studies were conducted for Washington, D. C., by Landsberg (3) and by Sundborg (4,5) for Upsala, Sweden. In 1954, Duckworth and Sanberg's *SURVEY OF ISOTHERMS ON A CLEAR SPRING NIGHT IN THE CITY OF SAN FRANCISCO* (6), was superimposed on a photograph of the city. The temperature of the business district was some 20°F. higher than the lowest observed suburban temperature and about 8°F. greater than the temperature on the fringes of the city. The above are a few of the investigations conducted.

This study of the temperature regime at Sacramento, which has a long period of record (90 years), provides additional evidence supporting the heat island concept. This is especially true when compared to similar data from the University of California at Davis with its rural exposure. The university is only 15 miles from Sacramento over flat terrain; therefore, both should experience the same climatic changes. However, whereas Sacramento's average maximum temperature trend during summer (June-September) and winter (December-March) months is upward due to the heat island effect, the Davis trend is downward. The trend of the Davis minimum temperature for the same periods is upward, opposite that of its maximum temperature trend. This demonstrates a tendency for a nighttime heat island effect. However, the downward trend of the average maximum temperature for Davis does not reflect a heat island effect and is therefore in accord with present theories of Dr. Mitchell (7) climatologist, Environmental Science Services Administration and Dr. Bryson (7) head of the meteorology department at the University of Wisconsin. They state that, overall, the lower atmosphere has been cooling since 1940.

II. DATA

All weather data pertaining to Sacramento were taken from records at the U. S. Weather Bureau Office, Sacramento. The location of past and present thermometer sites for both Sacramento and Davis, Figures 1 and 2, were obtained from station records and daily logs.

Average monthly maximum and minimum temperatures for summer and winter months were compiled for the period of record. Graphs were drawn showing annual variations of the average maximum temperatures for each of the summer months for Sacramento, Figures 3, 4, 5, and 6. Figure 7 shows annual variations of the average maximum temperature for the normally two hottest months (July and August) combined. Average maximum temperatures for the summer months (June-September) were combined for a seasonal average with annual values plotted in Figure 8. Finally, ten year running averages of seasonal maximum and minimum temperatures, both summer and winter, Figures 9, 10, 11, and 12, were graphed for Sacramento and Davis.

Statistics for population and construction for the City of Sacramento, Figures 13 and 14, were obtained from the Sacramento City-County Chamber of Commerce and the City of Sacramento, respectively. Motor vehicle data, Figure 13, were compiled from the records of the California Department of Motor Vehicles. The Sacramento Municipal Utilities District (SMUD) supplied power consumption figures for air-conditioners, while figures for heat produced by motor vehicles were received from the Sacramento County Department of Health.

All data pertaining to Davis were made available through the courtesy of the University of California at Davis.

III. HISTORY OF THERMOMETER EXPOSURE

Over a span of about 90 years, official Weather Bureau thermometer exposure in Sacramento has been at seven different locations within the city (Figure 1). Except for the six years from November 1958 to September 1964, locations were within 5/8 of a mile of each other. The 23rd Street location (Site No. 7) is about two miles from the other sites. It is believed that this location was fairly compatible with the others, since the area surrounding this location was also well urbanized during its period of record. Also, the terrain is level, thereby eliminating effects of hills and valleys. Whatever influence the Sacramento River may have contributed is assumed to be negligible, since the width of the river averages only about 100 yards as it passes through the city. Unfortunately, thermometer elevations above ground varied considerably. However, with the exception of the six years at 23rd Street, thermometer elevations above ground ranged from 85 feet to 106 feet from 1894 to the present. Since these heights are above most of the surrounding buildings, it is believed that there would be no significant difference in temperature within this 20-foot span. Since the time of great urban growth occurred after 1894, temperature records are considered adequate.

At Davis (Figure 2), the thermometer shelter was located on the inner campus of the University of California from June 5, 1910 until July 5, 1960. During this time, new campus buildings were constructed at various locations about the shelter. None of the buildings were very large and, although afternoon circulation was somewhat reduced, reduction was not considered significant enough to affect trends of maximum temperature. However, as will be noted later, this is not the case for minimum temperatures.

From July 5, 1960, to September 1, 1964, the instrument shelter occupied space in an irrigated pasture located about .3 miles west of the inner campus location. A comparison conducted by Dr. Schultz (8) revealed that during summer, with clear skies, the pasture station was 2° to 3°F. cooler in the daytime and about 2°F. cooler at night than the inner campus site. Building construction on the campus continued and edged closer to the thermometer shelter. On September 1, 1964, the shelter was moved to its present location, one mile west of the original inner campus site. This move placed the thermometer in an orchard well away from construction.

IV. INVESTIGATIONS

Mitchell's discussion (9) on the heat island indicates that it is a man-made phenomenon. He compares daily maximum and minimum temperatures for the city of New Haven, Connecticut (10) to that of its neighboring airport. The comparison shows that the heat island effect is weaker on Sundays when the city is relatively quiet. In another investigation (11), Mitchell demonstrates the increase in intensity of the heat island as the city itself grows. He compares the climates of Washington, D. C. and Baltimore to that of a number of rural areas within 50 miles of these cities. He did this in the form of ten year running averages from 1894 to 1954. The comparative study of Sacramento and Davis (Figures 9, 10, 11, and 12) utilizes the same procedures and results appear to parallel Mitchell's.

Figures 3-7 show a general rising temperature trend at Sacramento from about 1910 to 1940, after which the curves more or less level off. This leveling off could be the result of an increasing heat island effect neutralizing the general cooling in the lower atmosphere as described by Mitchell. Temperatures for August and September 1966 and 1967 show a marked rise departing radically from this trend, possibly due to short-term influences.

Fluctuations from year to year for any of the months are evident. For instance, the average maximum temperature for September dropped 10.5°F. from 1899 to 1900 (Figure 6) and 9.0°F. from June 1918 to June 1919 (Figure 3). For August, it rose 8.9°F. from 1954 to 1955 (Figure 5). Fluctuations are still evident for combined months (Figures 7 and 8) but not as great. Average monthly minimum temperatures do not show fluctuations of the magnitude seen in maximum temperatures and are not shown in this study.

Ten year running averages of June - September maximum temperatures for Sacramento (Figure 9) show a general rise for period from about 1912 to 1940. A slight drop is indicated from 1940 to 1955 followed by resumption of the upward trend. A similar plot for Davis shows the same general trends, except there is a much less pronounced rise between 1930 and 1940, and a sharp drop in the early sixties. This sharp drop is suspect due to the influence of irrigation around the Davis thermometer site. Also, Figure 9 shows the Davis maximum temperature averaging higher than Sacramento's. This difference amounts to 5°F. for the 10-year period ending in 1920, decreasing gradually until the curves merge in the middle 1960s. The temperature difference early in the comparative records can apparently be attributed to the difference in thermometer elevations. The Davis thermometer was near ground level and, therefore, probably influenced by strong heating of the ground on sunny days. On the other hand, the Sacramento thermometer was considerably higher, between 85 and 106 feet above ground except for the time between 1958 and 1964 when it was 37 feet above ground. This elevation is above much of the strong heating effect of the ground on the air. Why the gradual confluence of the two curves in Figure 9 after the initial large differences? This can best be attributed to the following causes:

1. The upward trend for Sacramento's maximum temperatures between 1920 and 1940 is due to the heat island effect plus the general warming of the earth as described by Mitchell. After 1940, the effect of the earth's general cooling tended to minimize the heat island effect and caused the leveling off of Sacramento's temperature between 1940 and the early 1960s.

2. Since Davis is essentially a rural exposure, only an apparently slight daytime heat island developed to counter the earth's cooling after 1940, and a downward trend resulted, aided, no doubt, by the cooling effects of irrigation already alluded to above.

3. The comparatively low elevation of the Sacramento thermometer for the 6-year period, 1958-1964, makes Sacramento and Davis maximum temperatures more comparable. Also, the Davis thermometer was in an irrigated area from 1960-1964.

A comparison of Figure 9 with Figure 10 shows a smaller difference between Sacramento and Davis maximum temperatures during winter months than during summer. This is probably due to less intense solar heating of the ground during winter along with frequent low level inversions that last throughout the day. As a result, Sacramento and Davis winter maximum temperature curves coincide about ten years earlier than the summer maximum temperature curves.

In Figures 11 and 12, the ten year running average seasonal minimum temperatures for Sacramento do not show much of a trend toward either warming or cooling. Here the question is raised concerning failure of minimum temperatures in Sacramento to show a rise since other studies show that nighttime heat island effects are more pronounced than daytime effects. The explanation may lie in the elevation of the thermometer above ground from 1894 to the present (discounting the six years at 23rd Street). Heights ranged from 85 to 106 feet. These heights were well above the vast majority of buildings in the downtown area. The relative increase in stability during nighttime hours may, therefore, have prevented low level heat sources reaching up to the level of the thermometer. It is believed that had the thermometer shelter been at ground level, there would most likely be evidence of a pronounced nocturnal heat island.

Davis is considered a rural exposure since, until only recently, the amount of construction was very small compared to Sacramento's. However, as we shall soon see, even a minimum amount of construction appears to produce a nocturnal heat island while the daytime temperatures do not seem to be affected.

The minimum temperature curves for Davis, Figures 11 and 12, show a steady rise from the early 1930's; this is directly opposite to the maximum temperature trend. New building construction and street paving were probably significant in bringing about a nighttime heat island effect where none, or only a slight one, had existed before. In other words, during this period, the tendency at the university was toward urbanization. Effects of this tendency are reflected in nighttime temperatures since the increase in construction provided more storage for daytime heat which could be released during nighttime hours. The nighttime heat island at Davis has apparently had more effect on local minimum temperatures since 1940 than the overall cooling of the earth. Between 1958 and the time it was moved in 1960, the thermometer shelter was about 100 feet from a barn which was heated on cold nights. This extra heat is reflected by the peak in the curve at 1960 in Figure 12. After the shelter was moved away from the barn, the minimum temperature curve began a downward trend. At this time (1960), the thermometer was placed in an irrigated pasture. According to Dr. Schultz' figures, this irrigation could introduce errors of up to 0.8°F. in Figures 11 and 12 when averaged over a 10-year period. About ten more years of record would be needed in order to accurately evaluate the probable errors.

V. EFFECTS OF ECONOMIC EXPANSION

With population increase in an area, there necessarily follows economic expansion in order to meet the needs of people. The city becomes a beehive of activity with increased construction. Figure 14 shows accumulated building permits issued annually since 1928. This is for construction of all kinds including electric signs, billboards, gasoline stations, garages, industrial buildings, dwellings, etc. However, permits for renovating and repairs are not included. City core redevelopment has only recently begun so that it can be discounted. Although most construction occurred along the perimeter of the downtown area, it is believed that additional heat was "added" to the city because the expanding perimeter acts as a buffer, making it more difficult for the city core to lose heat to the surrounding environment.

In recent years, use of air-conditioners and refrigeration has grown rapidly. As Sacramento is the state capital, there are many large air-conditioned office buildings in the city. There are also many large stores, hotels, and other types of buildings besides private homes which make widespread use of air-conditioning. Heat removed from these buildings is ejected into the atmosphere, adding to the heat island effect.

The Sacramento Municipal Utilities District has reported many instances of power overloading during summer, some caused by heavy use of air-conditioners. These cases of overloading also indicated an increasing number of air-conditioning units in the Sacramento area.

At first thought, it would seem that extensive use of air-conditioning could add significantly to the heat island effect. However, according to a study made by Sacramento Municipal Utilities District (SMUD), each customer uses an average of 1.23 kw of power per hour in the summer during the warm period of the day in order to operate air-conditioners. In 1967, SMUD customers totaled 207,000. With 1 kwh producing 3413 btu, air-conditioners produce about $.925 \times 10^9$ btu hr^{-1}. It is presumed that on a hot day, the average person runs his air-conditioners 10 hours. This would mean that $.925 \times 10^{10}$ btu are produced by air-conditioning on a hot day. Metropolitan Sacramento is approximately 150 square miles in area. Therefore, to a depth of 100 feet, there is a volume of air of about 4×10^{11} feet^3 over the city. At 95°F., at sea level, air has a density of .071 lbs ft^{-3}. Thus, within the lower 100 feet over metropolitan Sacramento, the mass of air weighs approximately 2.84×10^{10} lbs., and there would be approximately 0.33 btu available per pound of air. Using a specific heat of dry air at constant pressure of .25 btu $lb^{-1}{}^{\circ}F^{-1}$, air-conditioners would cause an overall increase of about 1.3°F. in a volume of stagnant air 100 feet thick over Sacramento on a summer day. The effect of wind on this result is discussed next.

In July, the wind at Sacramento blows from the southerly quadrant (modified sea breeze) about 82% of the time. Wind speeds range from 8 to 24 mph 86% of the time at 5 p.m. local time, with wind speeds 13 to 18 mph almost 50% of the time. It would be reasonable, then, to assume that the average wind vector through Sacramento on a hot day is southerly at 15 mph. Metropolitan Sacramento is about 15 miles long south to north. The air over Sacramento would then change about once per hour during the 10-hour day defined above. The temperature of the air mass advected through Sacramento could then be raised by air-conditioning effects only one-tenth the value calculated for a stagnant air mass, or about .13°F. Therefore, even though air-conditioning is probably used as much in Sacramento as any other city of its size because of the warm climate, it can be discounted as an appreciable source of heat increase in the urban environment.

Annual population figures for the city of Sacramento and annual automobile and truck registrations for Sacramento County have been plotted in Figure 13. Motorcycles have not been included in the vehicle count since they produce relatively little heat. Although only county figures are available for vehicle registration, it is fairly representative of the number of vehicles which pass through the city of Sacramento, since 85% of the population of Sacramento County lives in the metropolitan area (42% live within the city limits).

In area, Sacramento County is small, so it is expected that the remaining 15% of the population's vehicles also pass through the city, some probably quite frequently. Also, there are many commuters from nearby Yolo and Placer counties. Therefore, heat produced by these vehicles can also be added to the heat island effect.

According to figures supplied by the Sacramento County Health Department, enough gasoline is burned in one day in metropolitan Sacramento to produce 8.6×10 btu. Using the same procedure as with air-conditioners, and assuming that all this heat is eventually added to the atmosphere, gasoline consumed by automobiles could add about 12.0°F. to a stagnant air mass over Sacramento in a 24-hour period. In order to consider the daytime heat-island effect, assume that 70% of the traffic occurs during the ten-hour warmest period (10 a.m. to 8 p.m.). This would mean about an 8.4°F. temperature rise during this period assuming no air movement. Using average summer daytime wind speeds as before, advection would lower this figure to only about .84°F. effective rise in temperature on a typical summer day.

In summer, it is estimated that motor vehicles account for about 65% of all heat produced by fuels in metropolitan Sacramento. This means that all fuels burned in the area during the warm season could heat the air over Sacramento to a depth of 100 feet by about 1.3°F. during the warmest 10-hour period of a summer day, allowing for normal wind movement.

Pacific Gas and Electric Company figures show that on a randomly selected December day (actual mean temperature 44°F.), fuel consumed for space heating in metropolitan Sacramento produced about 1.7×10^{12} btu. The Sacramento Municipal Utilities District records show that during a winter day, power used in Sacramento could produce about 5.5×10^{10}btu. Also, gasoline burned for autos would produce 8.6×10^{10} btu per day as mentioned above. It is felt that there are too many unknown factors and variables involved, particularly out-going nighttime radiation and storm effects, to compute quantitative values of the wintertime heat island effect from this data.

VI. SUMMARY AND CONCLUSIONS

The urbanization of Sacramento, with its building growth, population increase and general economic climb, certainly has produced a heat island. Contrary to what some people might have believed, air-conditioning adds a relatively small amount of heat to the summer urban environment. Gasoline burned by autos has a slightly larger effect. The major cause of the summer heat island is most likely the ability of buildings and asphalt paving to absorb and hold incoming radiation, with a lesser but not insignificant cause, fuels burned in the area. Also, the decrease in vegetation which accompanies urbanization cuts down transpiration thereby effectively adding to the heat gain (8).

The downward trend of maximum temperatures at Davis is in general agreement with present theories of the earth's atmosphere cooling since 1940. However, some of the observed cooling at Davis must be attributed to the change of location of the thermometer shelter from 1960 - 1964.

Minimum temperatures at Davis indicate presence of a nocturnal heat island on campus which overcompensates the large scale cooling of the earth. If the Sacramento thermometer shelter were at ground level, there might be a pronounced nocturnal heat island there also--perhaps more dramatic than the daytime heat island. This study also demonstrates that temperature records in an urban environment tend to mask real long-term climatic changes.

The role of air pollution should also be taken into account--effects of water vapor, carbon dioxide, ozone, and smoke. However, as pointed out by Mitchell (12), very few studies have been made relating this subject to the heat island, and it was not possible to include the role of air pollution in this study.

VII. ACKNOWLEDGMENTS

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Sacramento City-County Chamber of Commerce.

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VIII. REFERENCES

(1) Howard, L. "Climate of London Deduced from Meteorological Observation", Harvey and Darton, London, Third Edition, 1833.

(2) Schmidt, W. "Distribution of Minimum Temperature During the Frost Night of May 12, 1927, within Vienna". Forschritte Der Landwertschaft, 1929, pages 681 - 686 (in German).

(3) Landsberg, H.E. "Comfortable Living Depends on Microclimate". Weatherwise, 3-1, 1950, pages 7-10.

(4) Sundborg, A. "Local Climatological Studies in Upsala with Special Regard to the Temperature Conditions in the Urban Area". Geographica (Geological Institute, University of Upsala), February 1951, 111 pages.

(5) Sundborg, A. "Local Climatological Studies of the Temperature Conditions in an Urban Area". Tellus, 2-3, 1959, pages 222-232.

(6) Duckworth, F. S. and Sandberg, J. S. "The Effect of Cities upon Horizontal and Vertical Temperature Gradients". Bulletin American Meteorological Society, 35-5, 1954, pages 198 - 207.

(7) U. S. News and World Report, July 10, 1967, Pages 38 - 40.

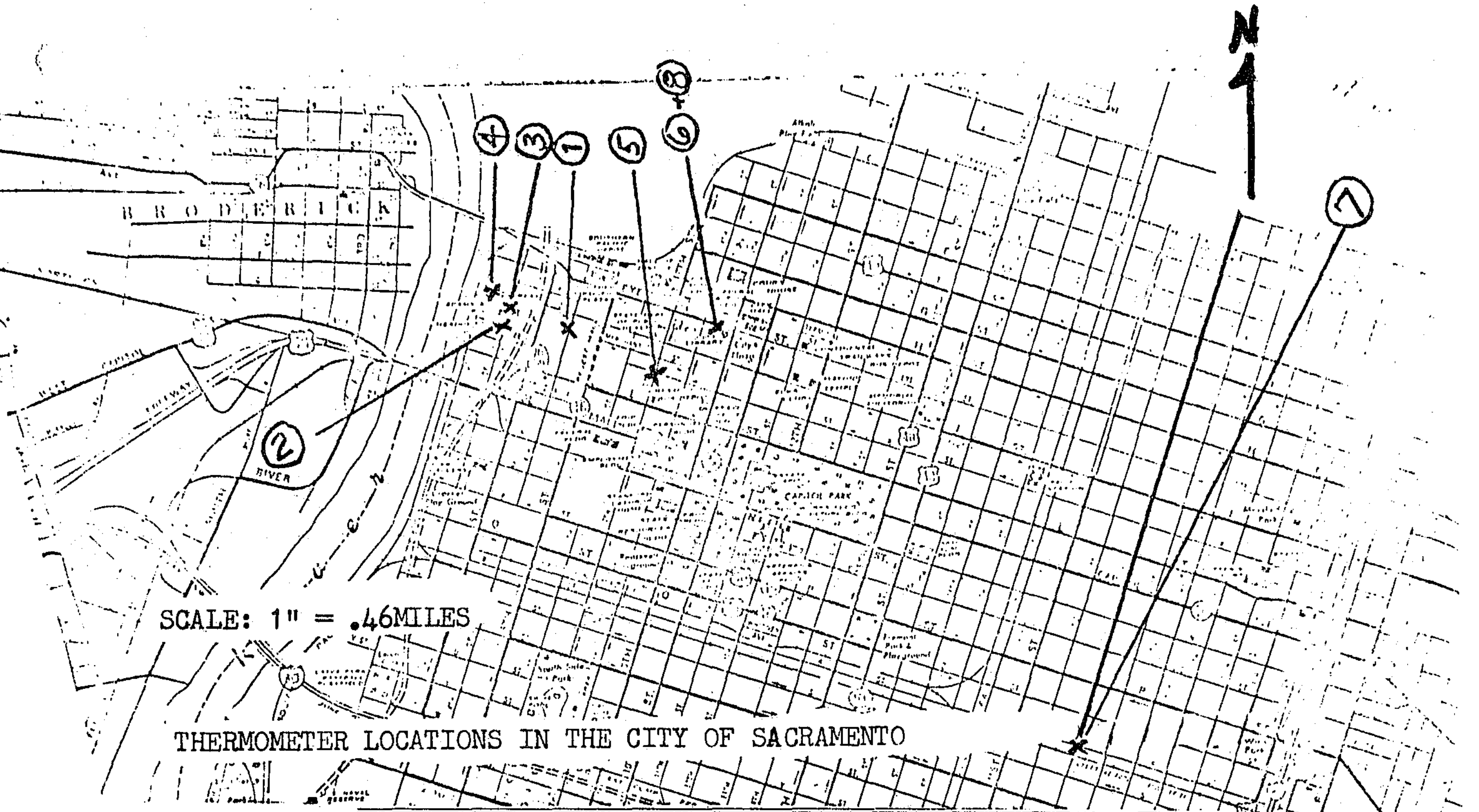
(8) Schultz, H. B. "Comparison of Hourly Temperatures in Various Environments within 300 Yards at Davis, California". Weekly Weather and Crop Bulletin, September 22, 1958.

(9) Mitchell, J. M. "The Temperature of Cities". Weatherwise, 14-6, 1961, Pages 224 - 229.

(10) Mitchell, J. M. "On the Causes of Instrumentally Observed Secular Temperature Trends". Journal of Meteorology, 10-4, 1953, Pages 224 - 261.

(11) Mitchell, J. M. "The Measurement of Secular Temperature Change in the Eastern United States". Research Paper #43, U. S. Weather Bureau, Washington, D. C., 1961, 80 pp.

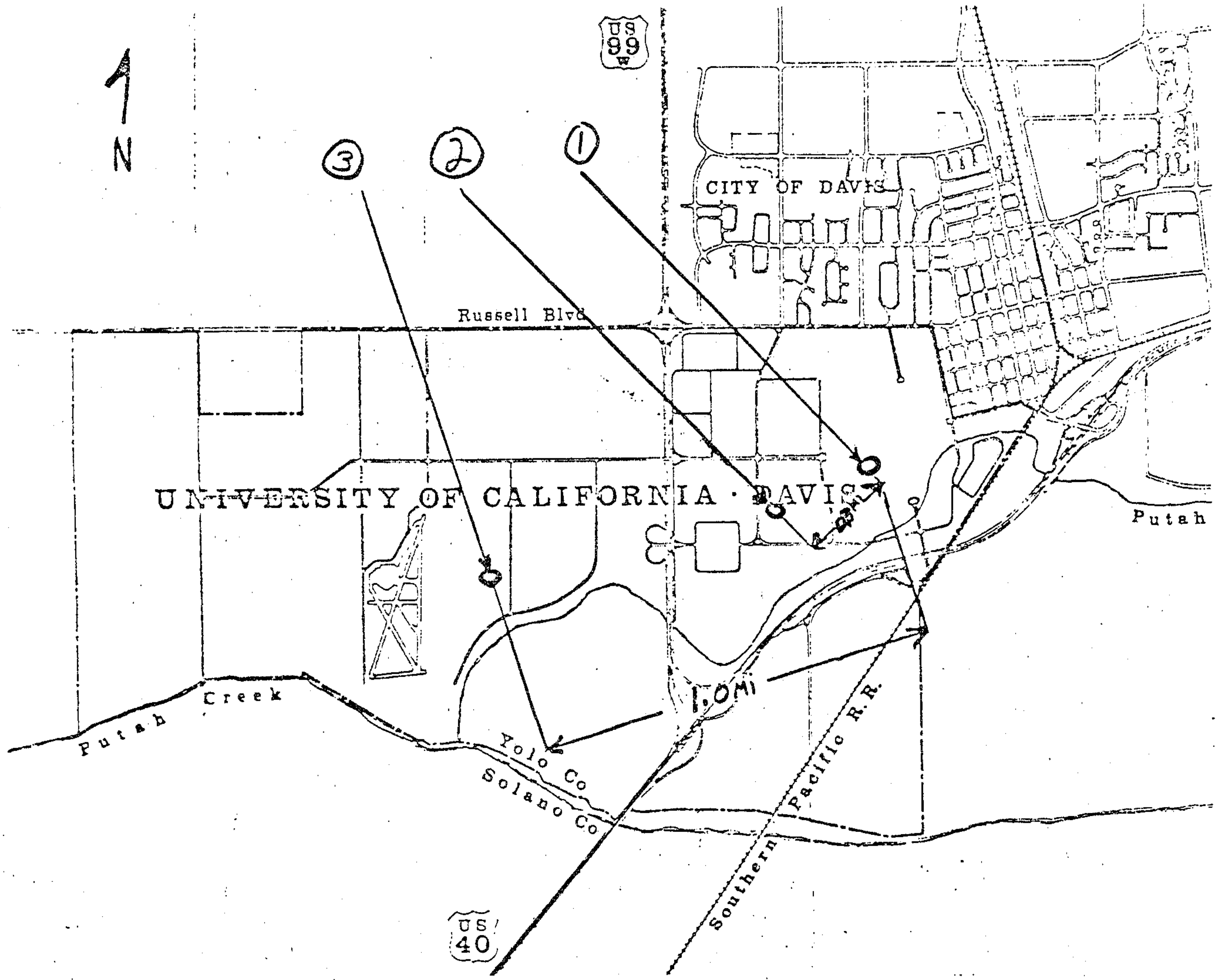
(12) Mitchell, J. M. "The Thermal Climate of Cities". Symposium, Air Over Cities, Technical Report A62-5 Department of Health, Education and Welfare, Held November 6-7, 1961, Cincinatti, Ohio, Pages 131 - 142.



THERMOMETER LOCATIONS IN THE CITY OF SACRAMENTO

	Location	Occupied from	Occupied to	Airline distance and direction from previous location	Latitude North	Longitude West	Elevation above Sea level: Ground at temperature site	Elevation above GROUND	Elevation above GROUND: Extreme thermometers
1	4th & J Streets St. George Building	7- 1-77	11-27-79		-	-	-		46
2	Second & K Streets Fratts Building	11-28-79	5-31-82	570 ft.WSW	38° 35'	121° 31'	30		37
3	1006 Second Street Arcade Building	6- 1-82	1-31-84	100 ft. N	-	-	26		37
4	117 J Street Lyon & Curtis Building	2- 1-84	4-30-94	200 ft.WSW	38° 34.6'	121°29.6'	28		62
5	7th & K Street Old P. O. Building	5- 1-94	10-31-33	2250 ft.ESE	38° 34.8'	121°29.6'	26		106
	" " "	"	"	"	"	"	26		106
	" " "	"	"	"	"	"	26		106
6	9th and I Street P. O. & Court House Bldg.	11- 1-33	4- 9-51	1375 ft. NE	38° 35'	121° 30'	25		87
	" " "	4- 9-51	3-20-52	"	"	"	25		92
	" " "	3-20-52	11-19-58	No Change	"	"	25		87
7	1725 23rd Street, 2nd Fl. State of Calif. Bldg.	11-19-58	9-28-64	1.4 mi. SSE	38° 34.0'	121°28.7'	23		37
8	9th and I Street P. O. & Court House Bldg	9-28-64	Present	1 mi. WNW	38° 34.5	121°29.8	19		85

FIGURE 1



THERMOMETER LOCATIONS ON THE CAMPUS OF THE UNIVERSITY OF CALIFORNIA - DAVIS

	DATE	LOCATION
1)	6/5/1910	Inner campus site - ground level
2)	7/5/1960	.3 miles west of inner campus site - ground level
3)	9/1/1964	1.0 miles west of inner campus site - ground level

FIGURE 2

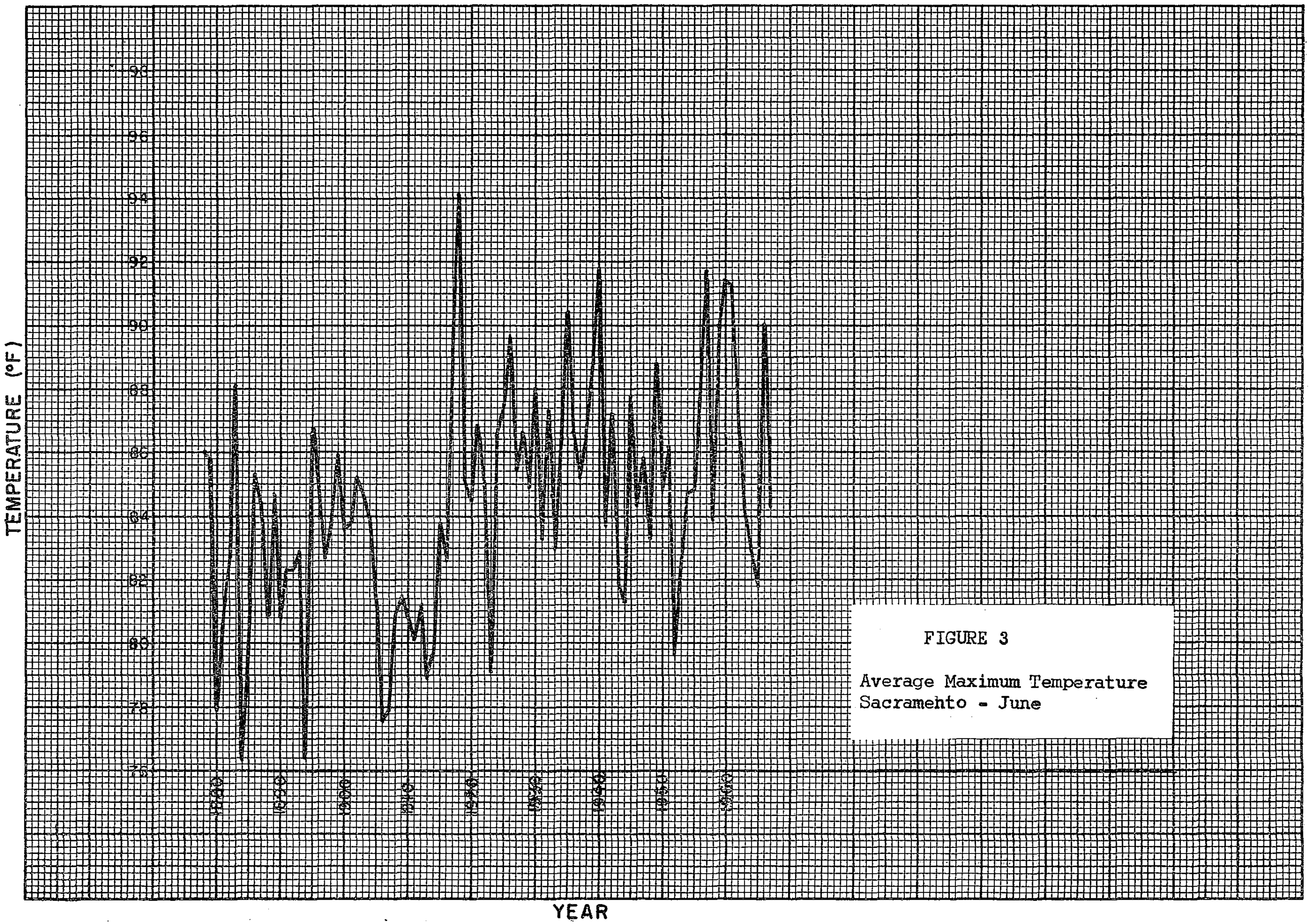


FIGURE 3

Average Maximum Temperature
Sacramento - June

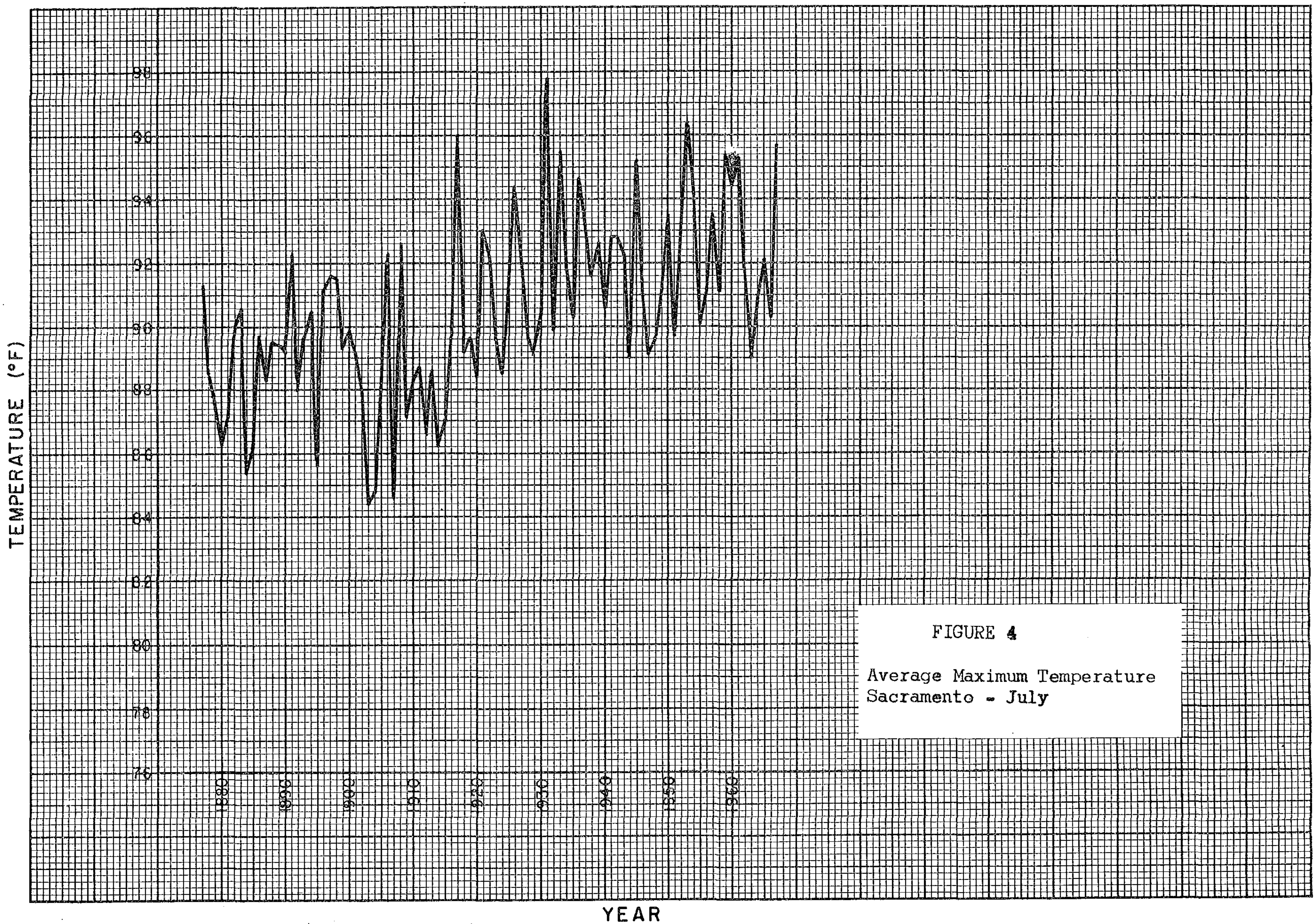


FIGURE 4

Average Maximum Temperature
Sacramento - July

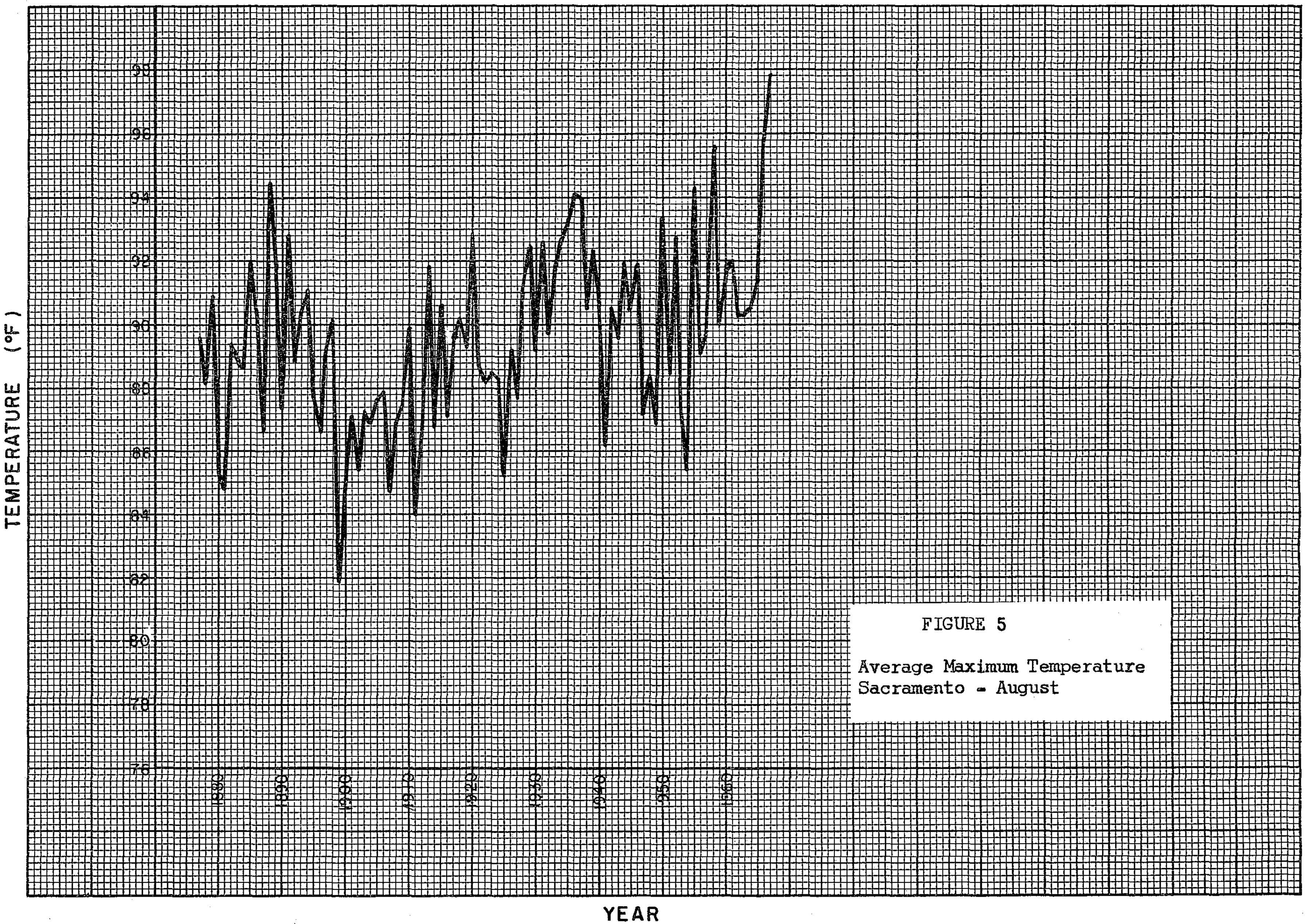


FIGURE 5

Average Maximum Temperature
Sacramento - August

K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

-15-

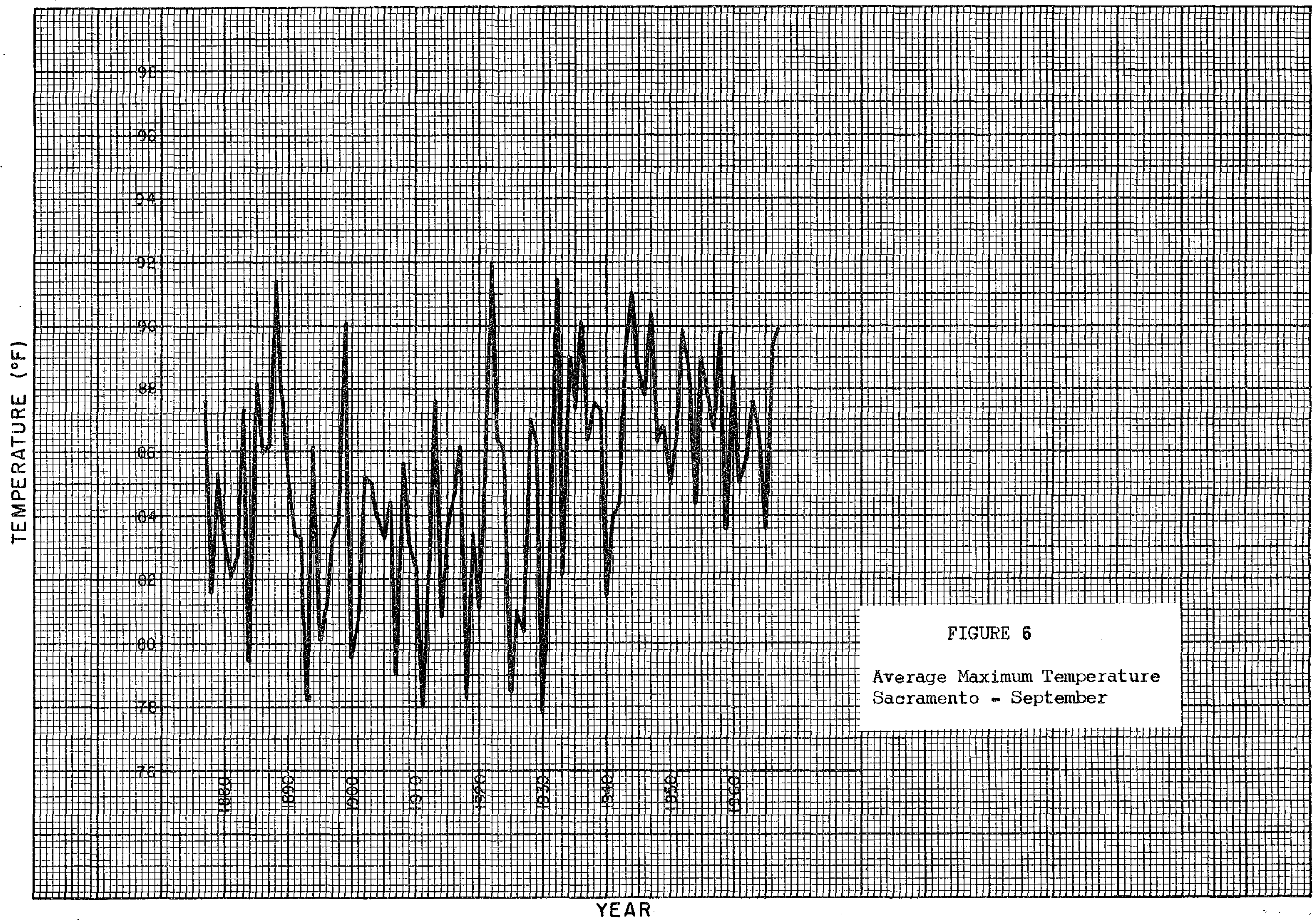


FIGURE 6

Average Maximum Temperature
Sacramento - September

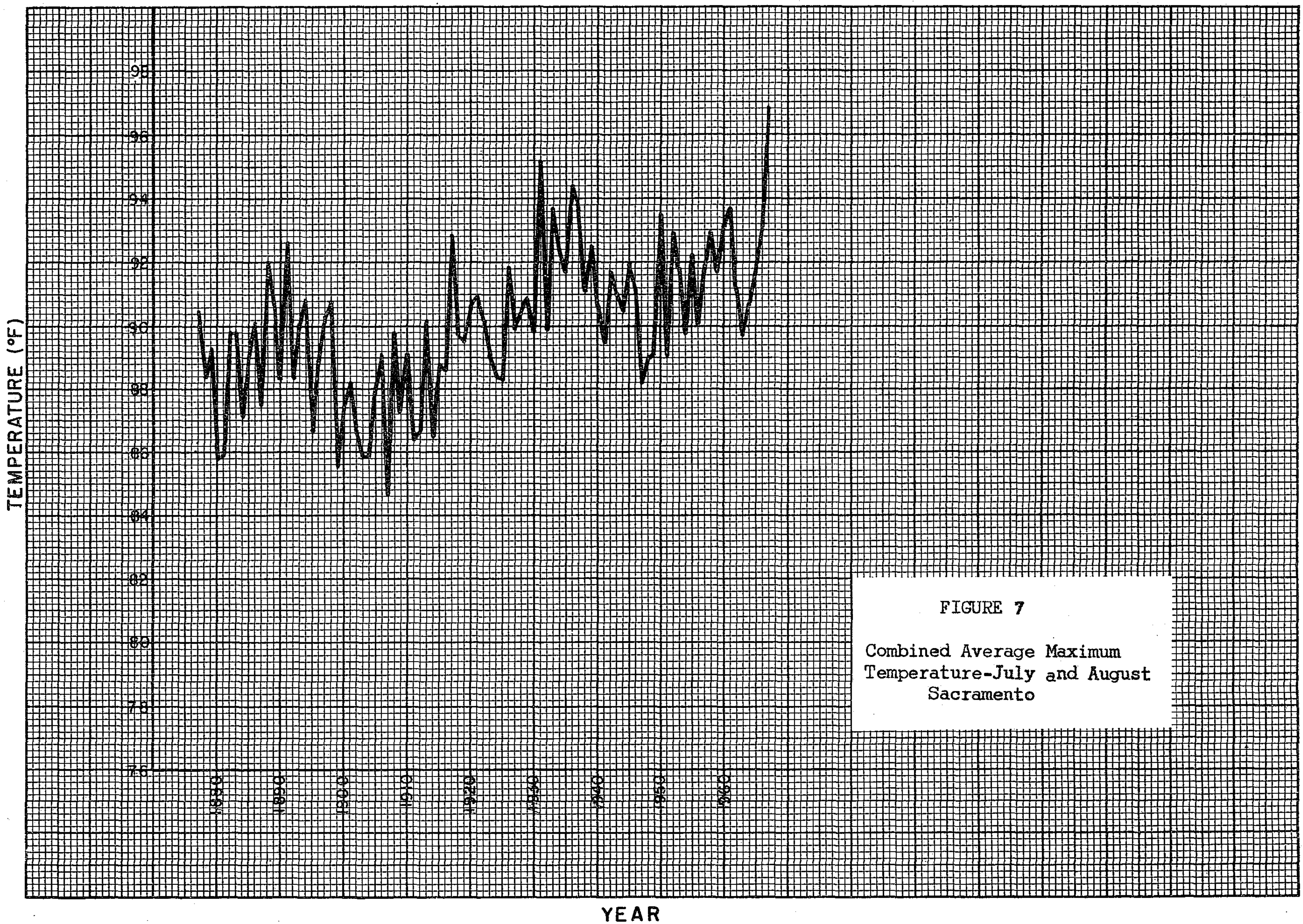


FIGURE 7

Combined Average Maximum Temperature-July and August Sacramento

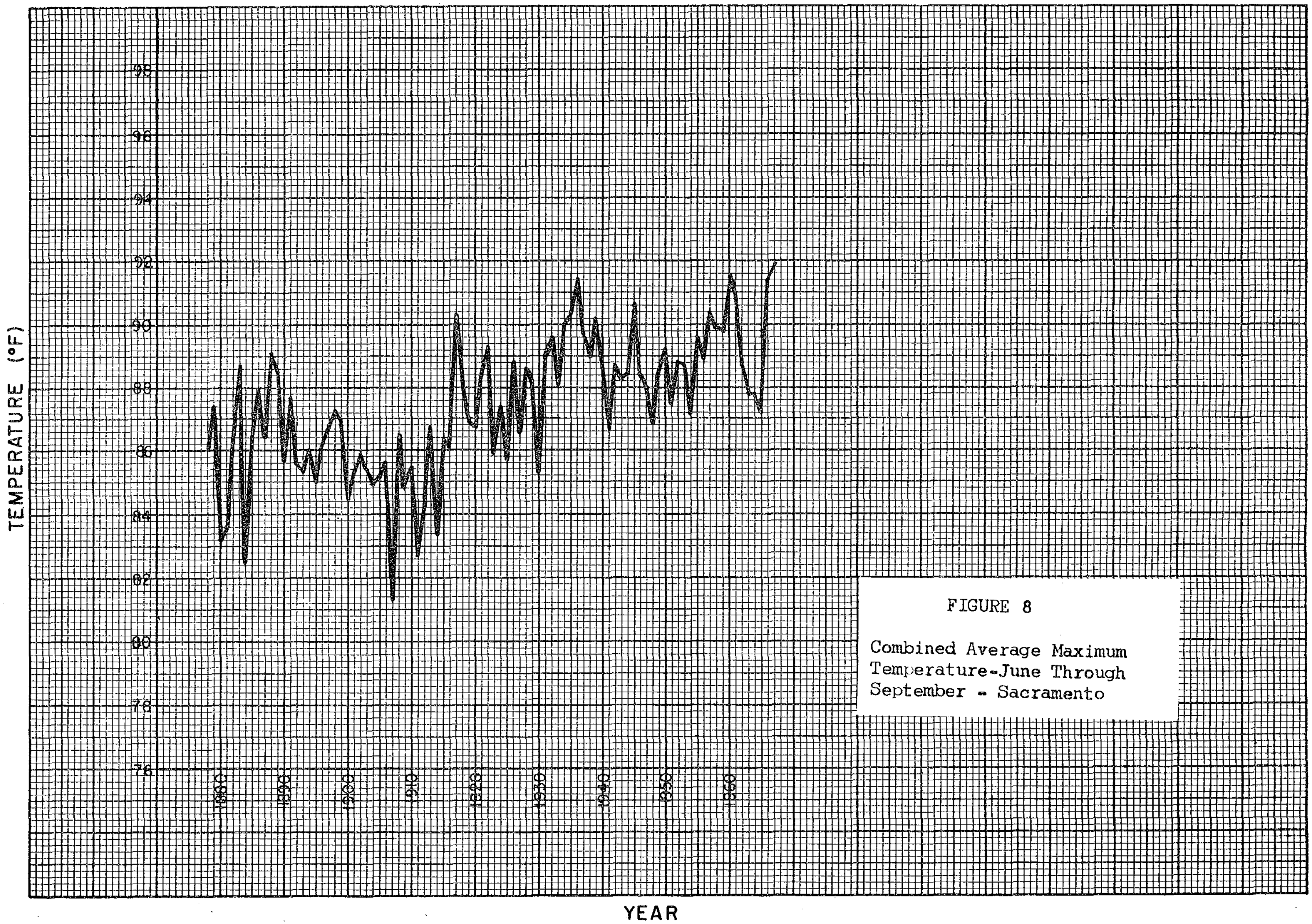


FIGURE 8

Combined Average Maximum Temperature-June Through September - Sacramento

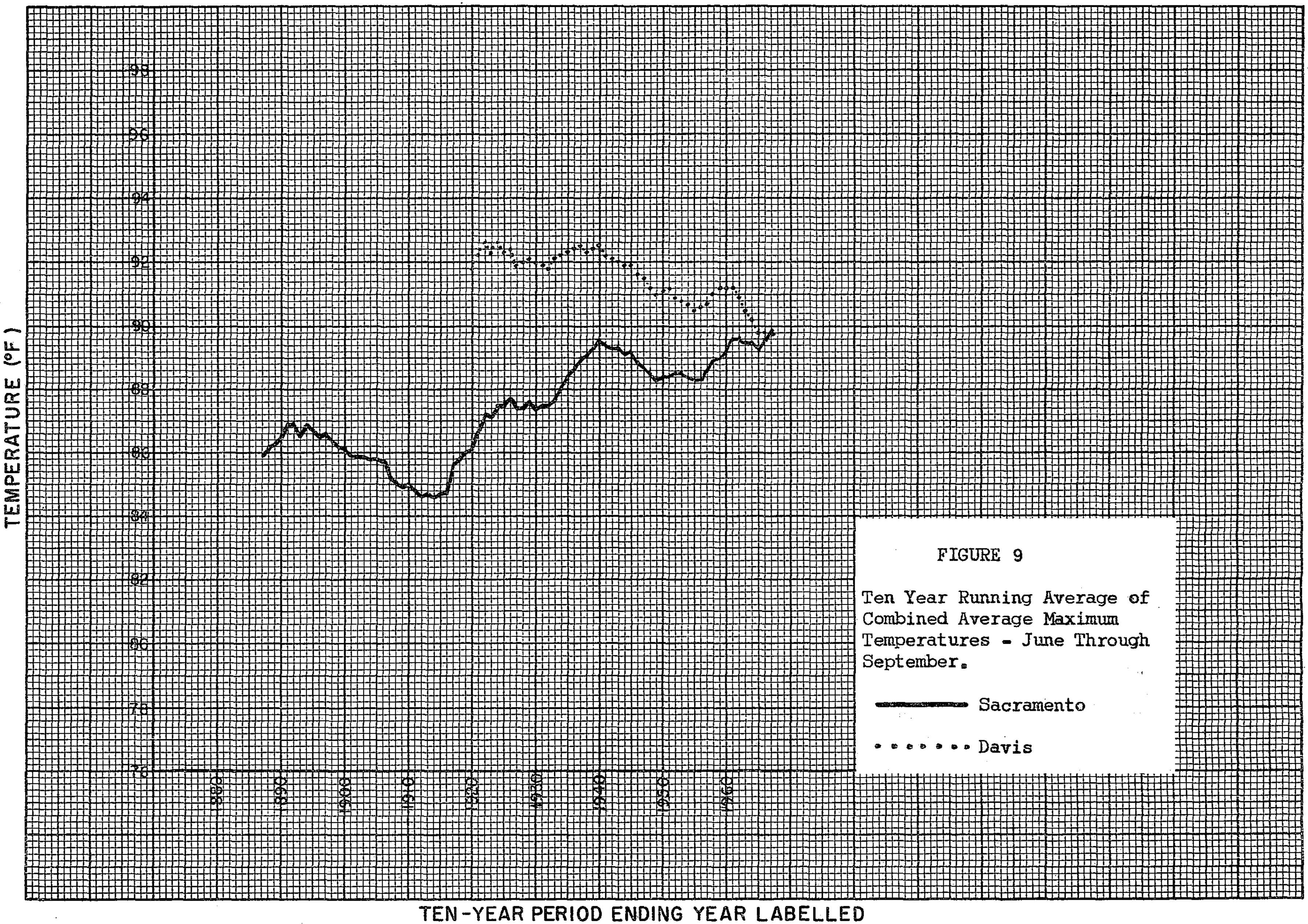


FIGURE 9

Ten Year Running Average of Combined Average Maximum Temperatures - June Through September.

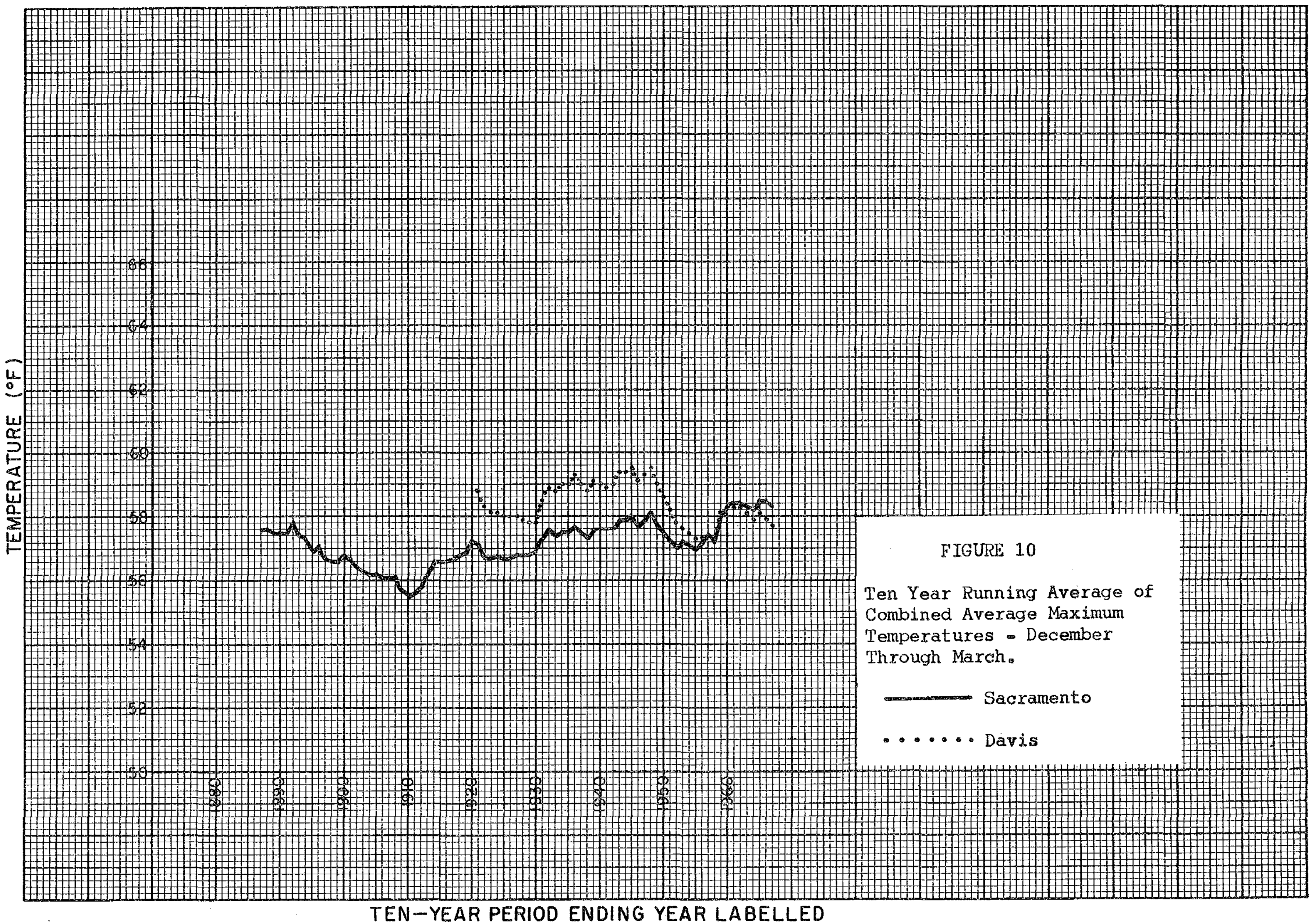


FIGURE 10

Ten Year Running Average of Combined Average Maximum Temperatures - December Through March.

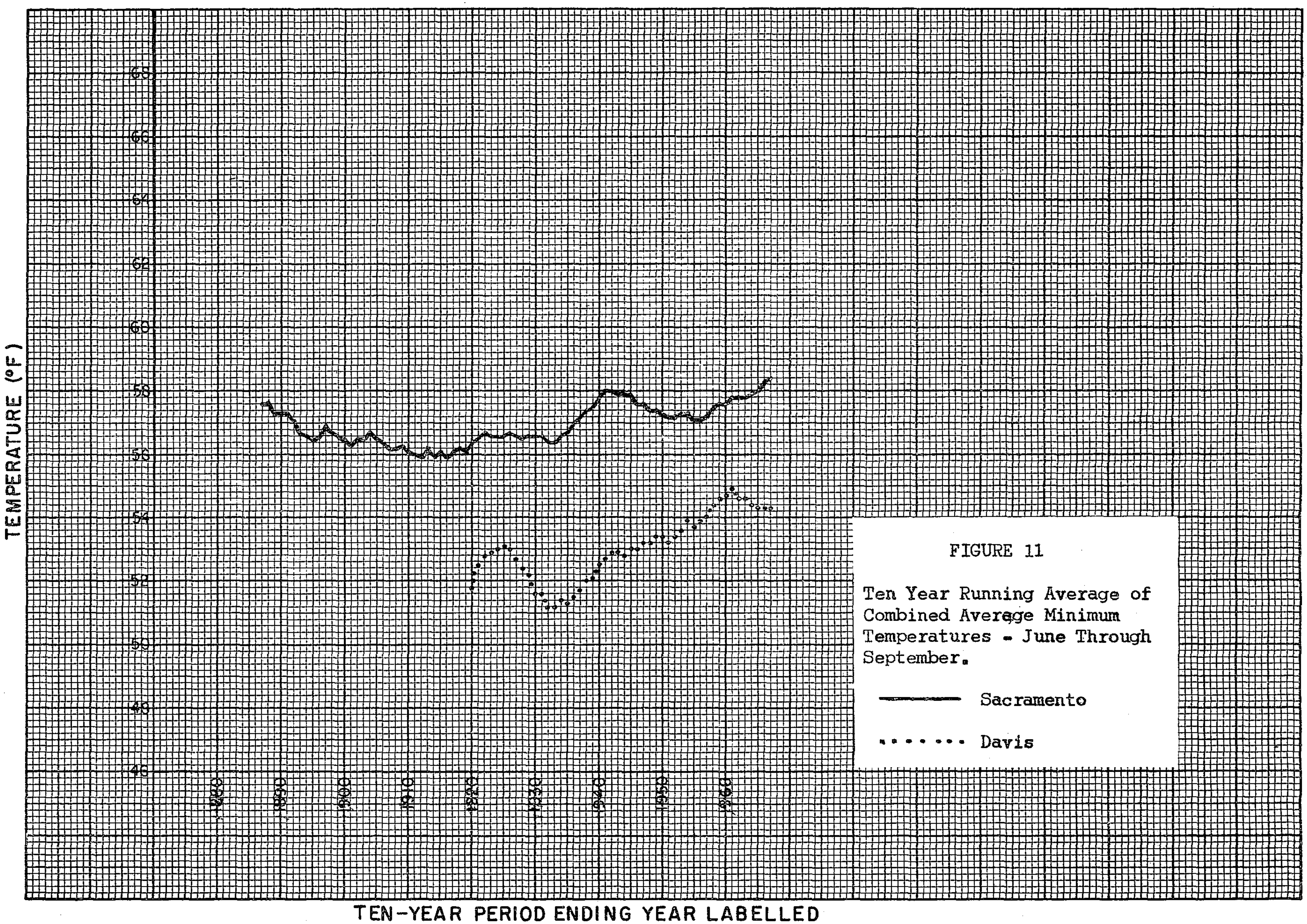


FIGURE 11

Ten Year Running Average of Combined Average Minimum Temperatures - June Through September.

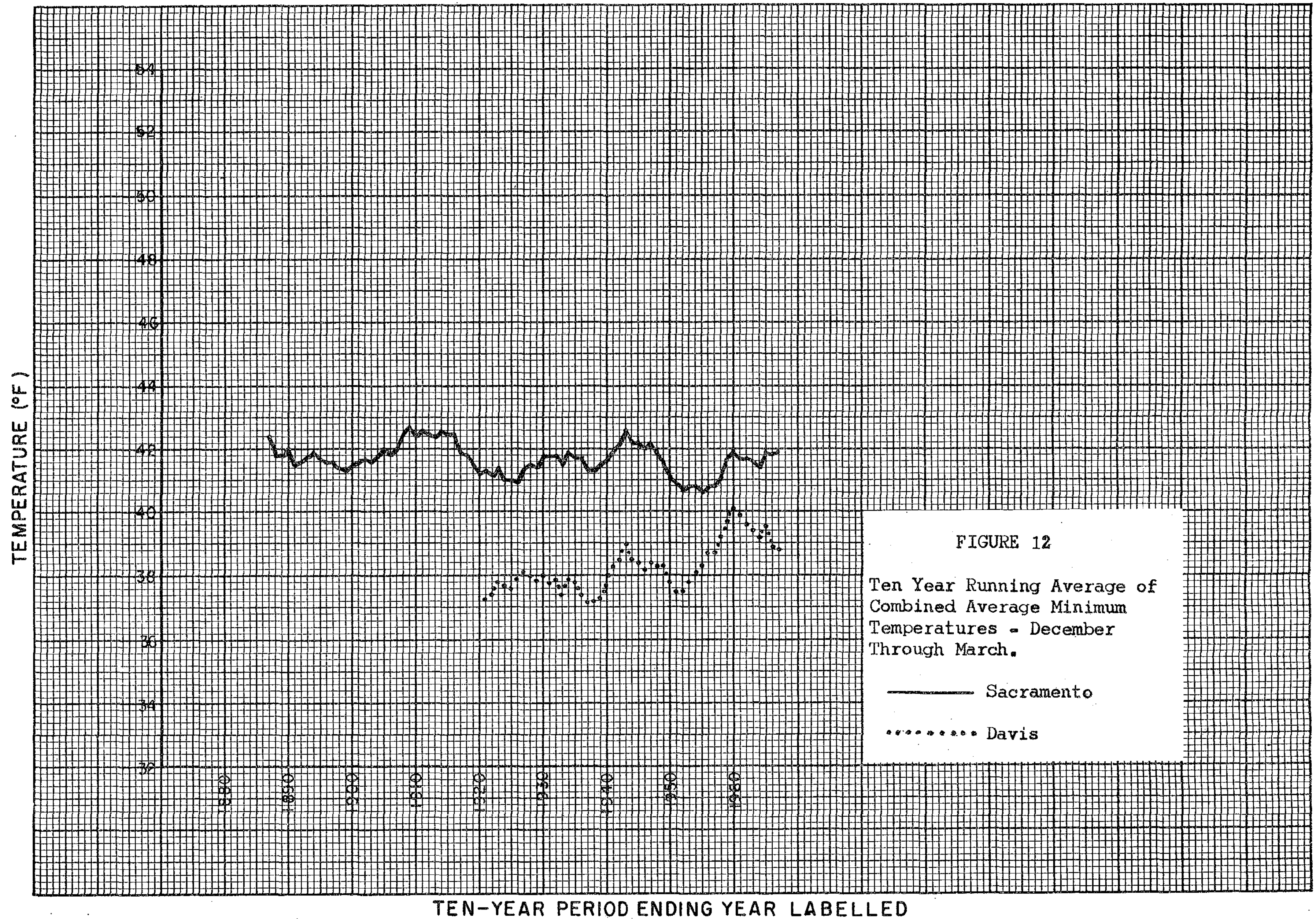


FIGURE 12

Ten Year Running Average of Combined Average Minimum Temperatures - December Through March.

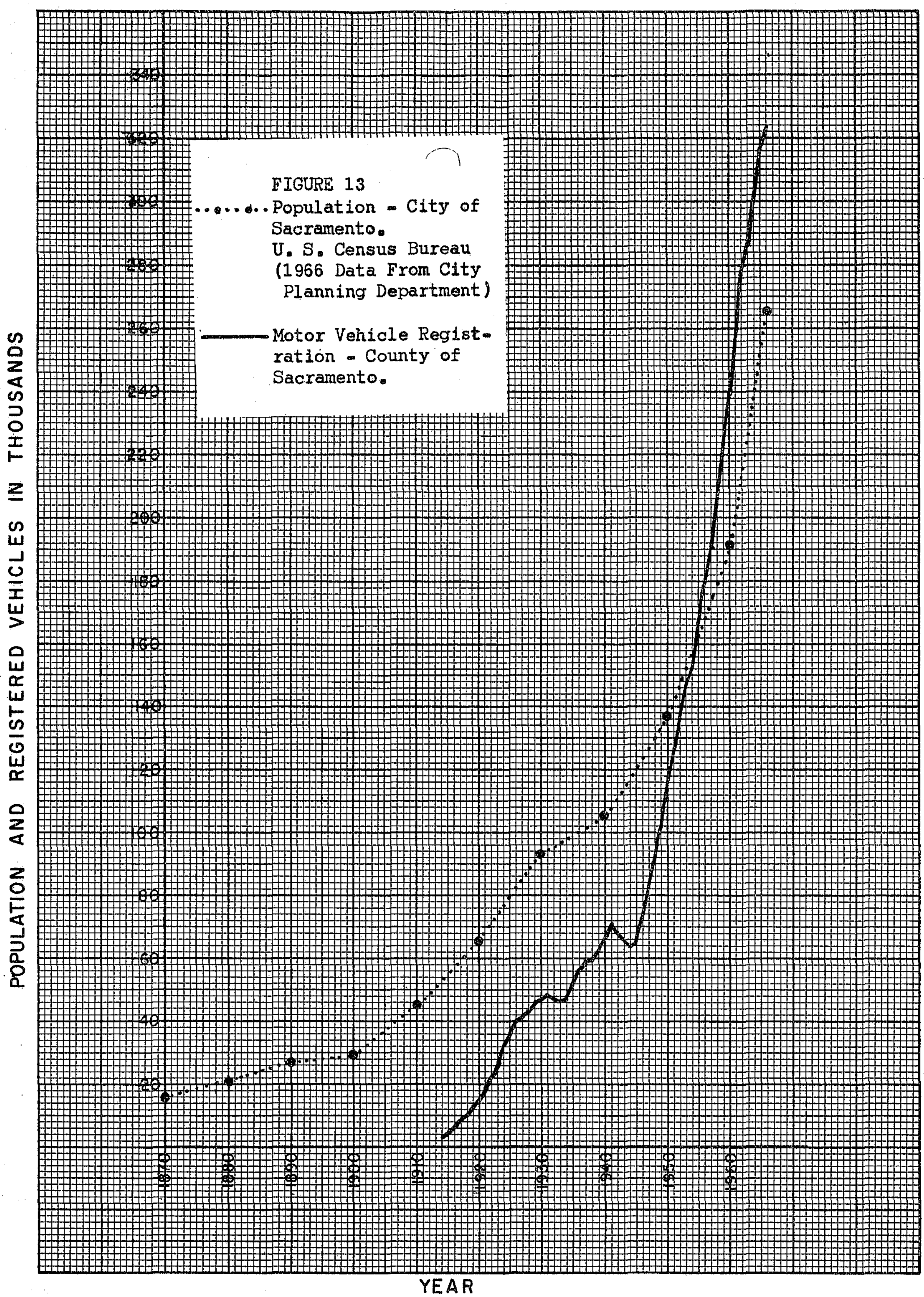


FIGURE 13
Population - City of Sacramento.
U. S. Census Bureau
(1966 Data From City Planning Department)
Motor Vehicle Registration - County of Sacramento.
POPULATION AND REGISTERED VEHICLES IN THOUSANDS
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
YEAR

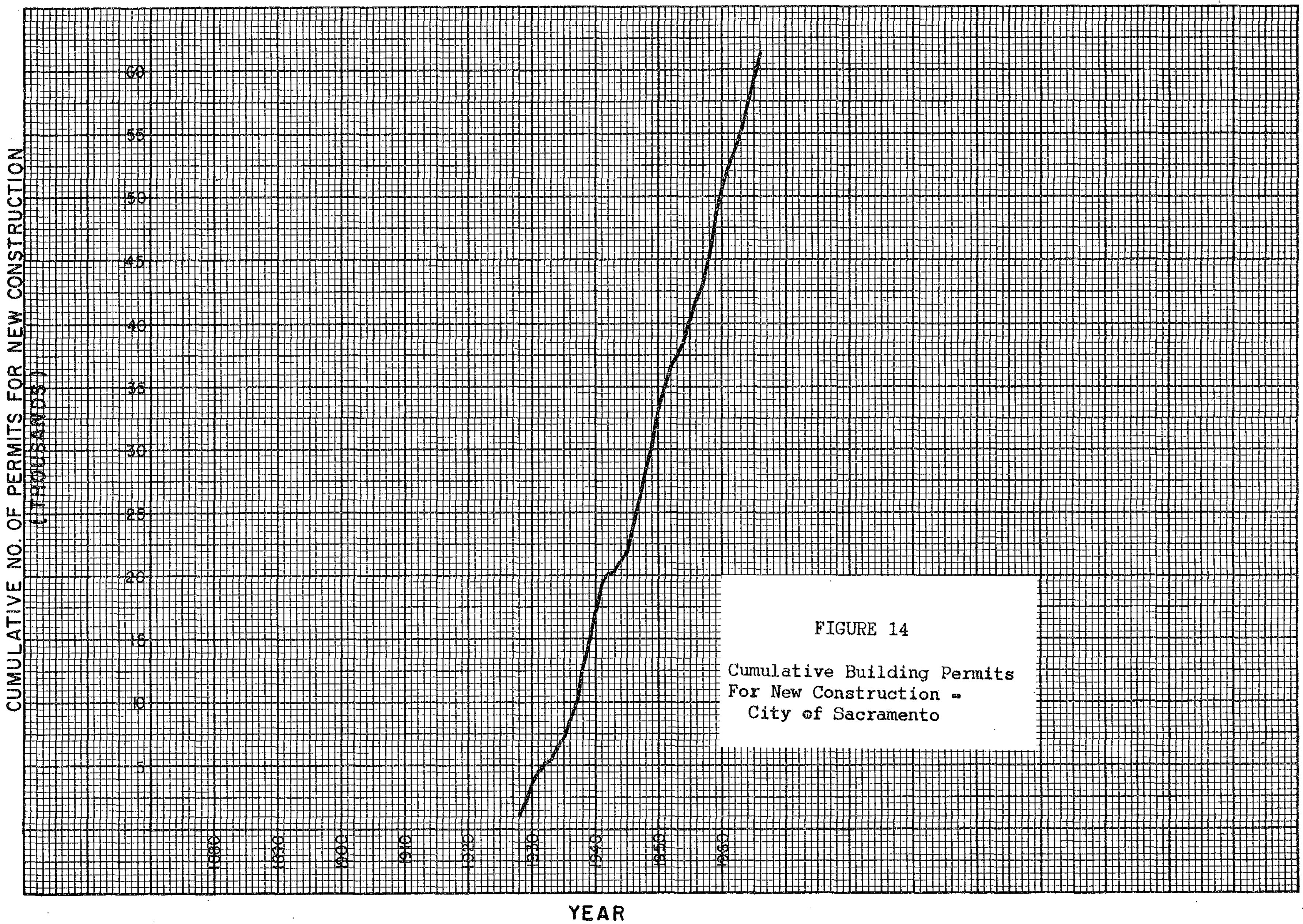


FIGURE 14

Cumulative Building Permits For New Construction - City of Sacramento

Western Region Technical Memoranda: (Continued)

No. 24 Historical and Climatological Study of Grinnell Glacier, Montana. Richard A. Dightman. July 1967.

No. 25 Verification of Operational Probability of Precipitation Forecasts, April 1966 - March 1967. W. W. Dickey. October 1967.

No. 26 A Study of Winds in the Lake Mead Recreation Area. R. P. Augulis. January 1968.

No. 27 Objective Minimum Temperature Forecasting for Helena, Montana. D. E. Olsen. February 1968.

No. 28* Weather Extremes. R. J. Schmidli. April 1968.

No. 29 Small-Scale Analysis and Prediction. Philip Williams, Jr. May 1968.

No. 30 Numerical Weather Prediction and Synoptic Meteorology. Capt. Thomas D. Murphy, U.S.A.F. May 1968.

No. 31 Precipitation Detection Probabilities by Salt Lake ARTC Radars. Robert K. Belesky. July 1968.

No. 32 Probability Forecasting. Harold S. Ayer. July 1968.

No. 33 Objective Forecasting. Philip Williams, Jr. August 1968.

No. 34 The WSR-57 Radar Program at Missoula, Montana. R. Granger. October 1968.

No. 35 Joint ESSA/FAA ARTC Radar Weather Surveillance Program. Herbert P. Benner & DeVon B. Smith. December 1968.

*Revised