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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

The Frequency of Desiccating Winds in Texas

ROBERT ORTON

Climatological
Services
Division

SILVER SPRING, MD.
February 1973

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ABSTRACT

Desiccating winds, defined as the simultaneous occurrence of relative humidity less than 30 percent, wind speed 15 mi/hr or greater, and temperature equal to or greater than 75°F, are injurious to plants. The complexities of the plant-weather relationships that injure plants are discussed briefly. A series of tables and maps are presented for Texas which show the geographical distribution of the monthly mean number of hours of occurrence when simultaneously the relative humidity is less than 30 percent, the wind speed 15 mi/hr or greater, and the temperature equal to or greater than 75, 80, 85, 90, 95, and 100°F.

1. INTRODUCTION

Desiccating, or drying, winds occur in many desert or semidesert areas of the world, including the southwestern region of the United States. In the south Russian steppes, the sukhovei, as they are called there, are of such agrometeorological concern that they attract considerable investigation and study. Although desiccating winds in the United States have received less attention from our own scientific community, farmers in western Texas, and most likely those in other southwestern States, are quite familiar with the injurious effects of desiccating winds on field crops.

2. DEFINITION

According to Kulik (1957), the onset of a sukhovei is most frequently defined agrometeorologically by a relative humidity lower than 30 percent, temperature of 25°C (77.0°F) or higher, and wind speed over 5 m/s (11.2 mi/hr) at the wind vane level. Russian agronomists adopted these criteria after an analysis of observations at agrometeorological stations on how meteorological conditions affect agricultural crops. These observations, collected over a period of several years, confirmed that the ill effects usually show up in plants when a combination of the above values of relative humidity, temperature, and wind speed occurs.

Strict definition of a desiccating wind, sukhovei, or "dry, hot wind" as it is more commonly called in our country is difficult because of the complexities of plant-weather relationships. From practical considerations, minimum criteria of relative humidity less than 30 percent, temperature equal to or greater than 75°F, and wind speed equal to or greater than 15 mi/hr at the anemometer level were used to define a desiccating wind. These values are close to those which define the sukhovei, and, conveniently, climatological summaries delineating meteorological data according to these categories were readily available for selected National Weather Service Offices (U.S. Weather Bureau 1962-63).

3. VAPOR PRESSURE DEFICIT

Sometimes it is convenient to express the relative humidity and the air temperature by a single value, namely, the vapor pressure deficit (d), the difference between the actual vapor pressure and the saturation vapor pressure:

$$d = e_s - e.$$

Relative humidity (r) is the ratio of the actual vapor pressure to the saturation vapor pressure over water at the same temperature. It is expressed as $r = e/e_s$; or more often as a percentage,

$$R = e/e_s \times 100.$$

From the first equation, then

$$d = e_s (1-r).$$

Saturation vapor pressure tables in both metric and english units may be found in List (1951).

Using the above relationship, the onset of a sukhovei may be defined as occurring when the vapor pressure deficit of the air exceeds 17 mm. Hg. while the wind speed is not lower than 5 m/s.

Table 1 lists vapor pressure deficits at a selected temperatures when r = .30.

4. PLANT INJURY

When plants are exposed to calm air the moisture evaporated by their surfaces creates a humid envelope of air around each transpiring part and prevents further rapid evaporation. In the presence of wind, this protective envelope is constantly blown away and replaced by fresh dry air which continues evaporation at a high rate. The evaporation caused by desiccating winds is so rapid that plants cannot compensate the moisture losses by absorption through the root system. As a result, they lose turgor and wilt. Plants may die even when the soil is moist.

A single set of meteorological parameters identifying desiccating winds is inadequate for agricultural purposes. The same meteorological conditions may be fatal to one crop but have little effect on another. Even for a given crop, the influence of any given combination of meteorological factors varies from year to year and phase to phase. According to Vitkevich (1960) the effect of desiccating winds on crop yields depends not only on the meteorological factors, but also on the variety and condition of the crop, nature and date of cultivation, care for the crop, amount and type of fertilizers used, weather pattern over a period beginning long before the onset of such winds, amount of precipitation, temporal distribution of precipitation, and many other factors. It may appear that all plant damage occurs at the time of the desiccating wind effect, but this is not necessarily true. According to Tsuberbiller (1957) irreversible damage results from the cumulative effects of preceding unfavorable conditions. Extreme values of meteorological factors are "the last straw that breaks the camel's back," as conditions exceed the limit of tolerance of the plants.

4.1 Effects of Water Loss

According to Kulik (1957), an analysis of observations on the condition of agricultural crops attendant to agrometeorological conditions shows that drying of the topsoil is one of the major and most frequent causes of a considerable decrease in crop yield. Kulik concluded that, "In the growth period from sprouting to earing, when the moisture resources in the arable layer are above 20 mm, the effect of sukhoveis consist basically in an acceleration of soil drying. If the active moisture reserves in the 0- to 20-cm layer are below 10 mm, the adverse effects of sukhoveis on plants are direct. A consideration of sukhovei effects should allow for the presence or absence of adequate soil moisture reserves."

Most growing plants are killed by a loss of 40 to 90 percent of their normal water content, or when they come to equilibrium with relative humidities of 92 to 97 percent (Levitt 1956). To survive in its environment, the plant has protective barriers with a very high resistance to water movement, and an ability to replenish its water supply from the soil. Thus, it may be able to maintain a considerably higher vapor pressure than that of its environment for days, months, or even years. In contrast, a plant approaches temperature equilibrium with its environment rather rapidly. Plants differ markedly in their "desiccation resistance" or drought hardiness.

Actual plant injury may be indirect due to upset of the metabolic balance. The first effect of water reduction in leaves has been stated to be stomatal closure, which slows up the movement of carbon dioxide into assimilating leaves, reducing the photosynthetic rate. Also, a plant water loss in excess of 50 to 60 percent is said to cause a decrease in respiration rate (Levitt 1956).

Direct injury results when the water is taken completely out of the plant tissues by desiccation. In the case of small plants or plant parts, the rate of water removal may be important. Slow water removal may allow the plant to go into a resistant, resting state that improves its drought hardiness. When water is made available again there is usually no difference in survival whether the water is added slowly or rapidly. However, some dried plants have been found to survive if allowed to take up water slowly from a saturated atmosphere, but were killed when plunged directly into water (Levitt 1956).

4.2 High Temperature

High temperatures can be as injurious to plants as dehydration. Most plants endure air temperature between 35 and 40°C (95 to 104°F) without harm if the exposure is of short duration, whereas prolonged exposure to these temperatures is usually harmful (Molga 1962). The extent of damage depends also on the development stage of the plant. High temperatures are most harmful in the early development stages. As in the case of drought injury, too-high temperatures may upset the metabolic balance, disturbing respiration and the photosynthetic process.

Considering the effects of temperature alone, where there is no danger of desiccation injury due to low relative humidity, plants are able to survive higher temperatures in dry than in moist air. This is because saturated air prevents the cooling effect of transpiration. It is possible to subject prairie grasses to hot winds at 135 to 145°F without injury, as long as soil moisture is available (Levitt 1956). The growth of plants is stopped at temperatures that are not immediately fatal. The injury at such temperatures is gradual, and the longer the plants are exposed to the high temperatures, the longer it takes them to recommence growth.

According to Levitt (1956), environmental temperatures may exceed the 45 to 55°C (113 to 131°F) range that is usually accepted as the normal temperature limit for most plants. The greatest danger of heat injury occurs when the soil is exposed to insolation reaching temperatures as high as 55 to 75°C (131 to 167°F). The heat-hardiness of plants varies markedly with the environment to which they are adapted. Those that live in hot, sunny regions, such as southern Texas, are the most hardy; shade and aquatic plants are the least hardy. In contrast to frost and drought hardiness, heat hardiness is not increased by subjecting the plant to moderate doses of high temperatures.

4.3 Wind

In a harsh environment which results in desiccation or drought injury to plants, wind is not an essential element since actually it is the presence of a high vapor pressure deficit that is responsible for plant damage; however, wind becomes important as an intensifying factor. Damage to plants occurs at a lower vapor pressure deficit when the wind is strong or prolonged. Thus, indirectly, the presence of strong winds of long duration is important. When the wind attains a certain speed it causes fluttering of the plants which changes the phytoclimate into one considerably less favorable than before. Air movement within the plant cover depends, of course, on the kind of vegetation, stage of development, plant height and density, and various cultural practices. The appreciable deterioration of the phytoclimate due to plant fluttering is particularly dangerous for cereals in the flowering and milk-ripening stages (Kulik 1957). According to data summarized by Tsuberbiller (1957), a wind begins to shake the plants when its speed, at the level of the fringes, exceeds the limiting value of 3 m/s (6.7 mi/hr), which corresponds to about 8 to 10 m/s (17.9-22.4 mi/hr) at the anemometer level. When a wind of moderate speed, 2 to 3 m/s (4.5-6.7 mi/hr) at the level of the top fringe, lasts for a period of 3 to 5 hours, it causes the plants to sway continuously. Ultimately, the dehydrating effect is about the same as that of a strong wind of short duration. (The kinds of plants, and the anemometer height on which Tsuberbiller's conclusions were based, are not known). Some investigators, as reported by Wang (1963), have observed that the bending influence of the wind increases transpiration of plants directly by the alternating contraction and expansion of the intercellular space, facilitating the exit of saturated air and the entrance of dry air. Jensen (1954) made an extensive investigation of the aerodynamics of shelterbelts as they affect the microclimate and crops. He formulated the theory that transpiration in plants as affected by shelterbelt is a function of wind speed and vapor pressure deficit:

$$\text{Transpiration} = (3.7 + 0.5\,U^{0.8})d,$$

where U is the horizontal wind speed in meters per second, and d is the vapor pressure deficit in millimeters of mercury.

Statistical analyses of wind observations show that wind speed usually increases with height. Values of the horizontal wind speed (u) at other than anemometer level can be estimated from a simplified expression of L. Prandtl's law:

$$u = c \log (Z/Z_o) \quad \text{(m/sec)}$$

where Z_o is the roughness parameter with dimensions of length, and c is a constant (Geiger 1965). This equation assumes a neutral or adiabatic temperature distribution, and is a straight line in a system of coordinates u, log Z. Wind flow over vegetation-covered surfaces is almost always turbulent. When strong winds blow over the tops of plants that are easily swayed, such as grass or small grain, wave motions develop as at the boundary surface of water and air. Less pliable or more irregular plant surfaces facilitate the development of large turbulence elements. The equation for wind increase with height under an adiabatic temperature lapse rate and with vegetation cover is:

$$u = c \log (Z-d/Z_o)$$

where d is the "effective" height, not the average height, of the plant cover, and is determined from the wind profile (Geiger 1965). Because of the pliability of grass under the pressure of wind, the value of d is smaller than the actual height of the grass. Values of Z_o and d, determined from a large number of observations, provide a method of estimating the horizontal wind speed at the plant-air boundary surface when the anemometer level is at a different elevation, which is most often the case. Corrections for either stable or unstable temperature profiles can be made although they do not affect wind change with height significantly in the 0- to 6-m layer. Since the equations expressing wind increase with height were derived through statistical analysis, they are applicable only to the mean values of the wind speed determined over a long period of time.

On a surface covered with vegetation, wind speed at the ground surface is low and increases slowly with height. Then above the active crop surface the wind speed rises rapidly at first, then more slowly (Molga 1962).

5. EVAPORATION

In summarizing the effects of desiccating winds on plants, the conclusion is that injury results primarily from excessive water loss from the plant surface, and that the rate at which this evaporation occurs is increased by wind. Strictly speaking, evaporation (vaporization) is defined as the physical process by which a liquid or solid is transformed to a gaseous state. However, in meteorology, it usually is restricted in use to the change of water from liquid to gaseous state (Huschke 1959). Because evaporation from plants is a complex process which is governed not only by physical but also by physiological factors, it is more often termed transpiration, to distinguish the evaporation of a living plant cover from that of an inanimate wet surface. The amount of evaporation from the surface of soil and plants is profoundly influenced by meteorological conditions; particularly moisture deficit, air temperature, wind, solar radiation, soil temperature and air pressure, and also by factors such as topography. Evaporation from plants depends on the color of the part on which rays are incident, and on temperature. Most physical elements controlling evaporation from plants also regulate evaporation from the surface of the soil. In addition, orientation and inclination of the ground are significant, since they influence absorption of solar radiation, and temperature; so are the physical properties of the soil, such as color and texture. Dark soils warm up, and lose moisture through evaporation, more rapidly than do light-colored soils (other properties being similar). Thus the factors influencing evaporation from the surfaces of soil and vegetation are many and varied. All operate simultaneously and with mutual interaction, each depending on the presence and intensity of the other (Vitkevich 1960).

6. DATA

Data for this analysis are taken from table A, "Temperature and Wind Speed-Relative Humidity Occurrences" (U.S. Weather Bureau 1962-63) for selected National Weather Service (NWS) Offices in Texas and adjacent States. For most stations the period of record summarized was 1951-60; for a few stations, only data for the period 1956-60 were available. The anemometer heights from which these basic wind data were taken varied. It was not until the late 1950's and early 1960's that anemometer heights at NWS airport installations were standardized at about 20 feet. Because of the large number of factors involved in estimating the total effect of desiccating winds on plants, this discrepancy in the wind data was not considered significant in the analysis presented here.

Tables 2 through 7 list the mean number of hours each month, at selected NWS locations, when, simultaneously, the relative humidity is less than 30 percent, the wind speed is 15 mi/hr or greater, and the temperature is equal to or greater than 75, 80, 85, 90, 95, and 100°F. Table 8 lists the mean annual number of hours when, simultaneously, the relative humidity is less than 30 percent, the wind speed is 25 mi/hr or greater, and the temperature is equal to or greater than each of the values mentioned above. These mean values, based on a 10-year period of record at most locations, furnish the reader with an estimate of the number of hourly occurrences of desiccating winds, according to the predetermined temperature categories, that may be expected in an average year. In a specific year, the actual number of hourly occurrences may depart considerably from the mean value. Figures 2 through 29 show the geographical distribution of the mean number of hours of occurrence annually, and by months, for selected temperature categories. Maps have been omitted for those months when the mean frequency of occurrence was less than 10 hours.

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Table 1.--Vapor pressure deficit

T		e_s	d		
^oF	^oC	in. Hg.	in. Hg.	mm. Hg.	mb.
105	40.6	2.24	1.57	39.88	53.16
100	37.8	1.93	1.35	34.29	45.71
95	35.0	1.66	1.16	29.46	39.28
90	32.2	1.42	0.99	25.15	33.52
85	29.4	1.21	0.85	21.59	28.78
80	26.7	1.03	0.72	18.29	24.38
75	23.9	0.88	0.62	15.75	20.99

e_s: Saturation vapor pressure over water.

r: Relative humidity.

Table 2.--Mean no. hours with RH < 30%, wind ≥ 15 mi/hr, T ≥ 75°F

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Amarillo	1	3	12	40	48	56	37	38	52	27	3	2	320
Austin	1	5	7	9	3	3	2	2	4	7	*	1	47
Brownsville	1	3	4	7	*	*			*	1	1	1	20
Corpus Christi	2	6	5	9	2	*	*	*	1	3	2	1	31
Dallas	1	5	9	14	8	4	4	8	5	6	2	1	66
El Paso		2	18	74	146	143	59	29	53	32	2	*	559
Fort Worth#	1	4	10	9	4	5	15	13	20	4	4	1	89
Galveston		*	*	2					*	*			3
Houston	1	2	1	5	1			*	2	3		*	16
Laredo	5	12	17	24	17	15	33	32	10	7	5	3	182
Lubbock#	2	5	28	56	69	51	28	15	29	26	8	1	318
Midland#	*	8	24	42	47	33	17	15	17	10	3	1	217
San Antonio	2	7	10	18	7	5	3	7	5	7	1	1	73
Waco#	*	3	6	10	3	4	8	5	15	6	3	2	63
Wichita Falls#	*	4	19	15	6	9	10	16	21	4	2	1	110
Albuquerque			1	15	49	70	37	14	28	9			223
Denver				8	21	53	38	28	21	6			176
Lake Charles	*	*	1	2	2				1	2		*	7
Little Rock		*	2	6	3	*	1	2	3	1	*	*	17
Oklahoma City	*	2	10	14	6	4	6	19	28	10	1	1	101
Shreveport	*	2	3	6	1		*	*	3	1	*		15
Tulsa		1	6	8	3	1	3	11	17	6	*		56
Wichita, Kansas		1	5	15	11	19	25	36	56	15	1		181

Period of record 1956-60, otherwise period of record 1951-60.
* Less than 0.5 hour.

Table 3.--Mean no. hours with RH < 30%, wind ≥ 15 mi/hr, T ≥ 80°F

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Amarillo		*	2	23	38	54	37	38	46	16	*		256
Austin	*	2	3	6	3	3	2	2	4	3	*	*	32
Brownsville	1	2	2	7	*	*			*	1	*	1	14
Corpus Christi	*	3	4	8	1	*	*	*	1	2	*	*	19
Dallas	*	3	6	9	7	4	4	8	5	4	1		50
El Paso		*	2	31	101	129	59	29	44	19	*		414
Fort Worth#	*	2	6	5	4	5	15	13	18	2			70
Galveston		*		1					*				2
Houston	*	1	1	3	1			*	1	*			8
Laredo	1	7	13	20	16	15	33	32	10	6	2	2	158
Lubbock#		1	11	35	57	51	28	15	26	19	*	1	242
Midland#		4	10	31	38	33	17	15	15	8	*	1	170
San Antonio	1	3	6	10	6	5	3	7	5	4	1	*	49
Waco#	*	2	4	4	2	4	8	5	14	4	1	*	47
Wichita Falls#	*	2	14	11	6	9	10	16	19	4	*		94
Albuquerque				5	29	60	34	13	19	3			162
Denver				1	8	40	34	24	12	1			120
Lake Charles		*	*	1	1				1	*			4
Little Rock			1	3	2	*	1	2	2	1			12
Oklahoma City		*	4	8	5	4	6	19	26	7			78
Shreveport		1	2	4	1		*	*	3	1			10
Tulsa		*	3	4	2	1	3	11	14	4			42
Wichita, Kansas		*	3	7	9	19	25	35	50	10			156

Period of record 1956-60, otherwise period of record 1951-60.
* Less than 0.5 hour.

Table 4.--Mean no. hours with RH < 30%, wind ≥ 15 mi/hr, T ≥ 85°F

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Amarillo			*	9	24	48	36	36	35	5			195
Austin	*	2	1	3	2	3	2	2	4	2			22
Brownsville	*	*	2	4	*	*			*	*		*	7
Corpus Christi	*	1	1	4	1	*	*	*	*	1			9
Dallas		1	3	4	6	4	4	8	4	2			35
El Paso			*	6	50	104	55	26	29	6			276
Fort Worth#		2	2	3	3	4	15	13	16	2			60
Galveston				*									*
Houston		*		1	1			*	1	*			3
Laredo	*	4	8	14	14	15	33	32	9	3	1	1	136
Lubbock#			1	15	39	49	28	14	21	9			175
Midland#		*	1	14	28	32	17	15	14	5			124
San Antonio		2	2	6	4	5	3	7	4	1	*		34
Waco#		2	1	2	2	4	8	5	12	3			37
Wichita Falls#		1	7	7	5	9	10	16	16	3			77
Albuquerque					13	39	24	10	9				95
Denver					1	21	21	15	5				64
Lake Charles				1	1				1				2
Little Rock			*	1	2		1	1	1	*			6
Oklahoma City			1	4	4	4	6	19	22	3			62
Shreveport			*	1	1		*	*	2	*			5
Tulsa			1	2	1	1	3	11	12	2			32
Wichita, Kansas			1	4	8	19	24	34	40	4			133

Period of record 1956-60, otherwise period of record 1951-60.
* Less than 0.5 hour.

Table 5.--Mean no. hours with RH < 30%, wind ≥ 15 mi/hr, T ≥ 90°F

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Amarillo				1	7	38	33	30	16	*			126
Austin		1	*	1	1	2	2	2	3	1			13
Brownsville		*	1	2					*				2
Corpus Christi		1	*	1	1	*	*	*	*				3
Dallas			2	*	3	4	4	8	3	*			24
El Paso				1	19	63	38	18	11	*			149
Fort Worth#			1	1	2	4	15	12	13				49
Galveston													0
Houston					*				*	*			1
Laredo		2	3	9	12	15	33	32	9	2	1	*	119
Lubbock#				5	17	41	27	12	12	1			115
Midland#			*	3	14	27	17	13	8				81
San Antonio		*	1	2	2	4	3	7	3	1	*		22
Waco#			*	1	1	4	8	5	10	1			29
Wichita Falls#			1	4	4	7	10	15	13	1			55
Albuquerque					3	20	12	4	2				40
Denver					*	8	7	5	1				22
Lake Charles					*				*				*
Little Rock					*		1	1	1				3
Oklahoma City				2	1	3	6	18	16	1			47
Shreveport					*		*	*	2				3
Tulsa			*	*	1	1	3	10	10	1			24
Wichita, Kansas				1	5	19	23	32	27	1			107

Period of record 1956-60, otherwise period of record 1951-60.
* Less than 0.5 hour.

Table 6.--Mean no. hours with RH < 30%, wind ≥ 15 mi/hr, T ≥ 95°F

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Amarillo					2	18	14	11	2				47
Austin						2	2	2	1				8
Brownsville			*	*					*				*
Corpus Christi		*		*	1		*		*				1
Dallas			*		1	4	4	8	1	*			17
El Paso					2	24	16	4	1				47
Fort Worth#			*			4	14	10	6				36
Galveston													0
Houston													0
Laredo		1	2	4	7	14	33	32	7	1	*		101
Lubbock#				*	4	22	16	4	3				49
Midland#					3	16	10	5	1				34
San Antonio			*	*	*	3	3	6	1				14
Waco#						4	7	4	4	1			19
Wichita Falls#				*	1	6	9	10	8	*			37
Albuquerque					*	6	4	1					10
Denver						1	1						2
Lake Charles									*				*
Little Rock							1	1	1				2
Oklahoma City					*	3	6	15	5	1			28
Shreveport							*	*	1				2
Tulsa						1	2	9	6				17
Wichita, Kansas					2	15	21	26	14				77

Period of record 1956-60, otherwise period of record 1951-60.
* Less than 0.5 hour.

Table 7.--Mean no. hours with RH < 30%, wind ≥ 15 mi/hr, T ≥ 100°F

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Amarillo					*	4	2	1					7
Austin						1	1	1	*				2
Brownsville													0
Corpus Christi													0
Dallas						1	2	4	*				8
El Paso					*	4	3	*					7
Fort Worth#						2	8	6	1				16
Galveston													0
Houston													0
Laredo			1	1	2	7	20	25	2	1			59
Lubbock#						4	4						8
Midland#					*	5	1		*				6
San Antonio						1	1	2	*				4
Waco#						1	4	2	*				8
Wichita Falls#						3	4	6	1				15
Albuquerque							*						*
Denver							*						*
Lake Charles													0
Little Rock							*	1	*				1
Oklahoma City						1	2	7	*				10
Shreveport							*	*	1				1
Tulsa						*	2	6	2				10
Wichita, Kansas						6	12	14	2				33

Period of record 1956-60, otherwise period of record 1951-60.
* Less than 0.5 hour.

Table 8.--Mean annual no. hours with RH < 30%, wind ≥ 25 mi/hr, and T ≥ indicated

	75°	80°	85°	90°	95°	100°
Amarillo	43	26	17	8	3	*
Austin	2	1				
Brownsville	3	2	1	*		
Corpus Christi	5	3	1	*	*	
Dallas	4	3	2	*		
El Paso	77	47	27	12	4	1
Fort Worth#	9	4	3	1	1	
Galveston	1	1	*			
Houston	2	1	*			
Laredo	4	3	2	2	2	1
Lubbock#	57	32	17	9	2	
Midland#	7	4	*	*	*	*
San Antonio	3	2	1			
Waco#	8	4	3	2	2	1
Wichita Falls#	5	4	3	1		
Albuquerque	20	14	7	2	*	
Denver	16	9	4	1		
Lake Charles						
Little Rock	1	*				
Oklahoma City	21	14	10	6	4	1
Shreveport	2	1				
Tulsa	3	2	1	*		
Wichita, Kansas	22	18	15	13	8	3

Period of record 1956-60, otherwise period of record 1951-60.
* Less than 0.5 hour.

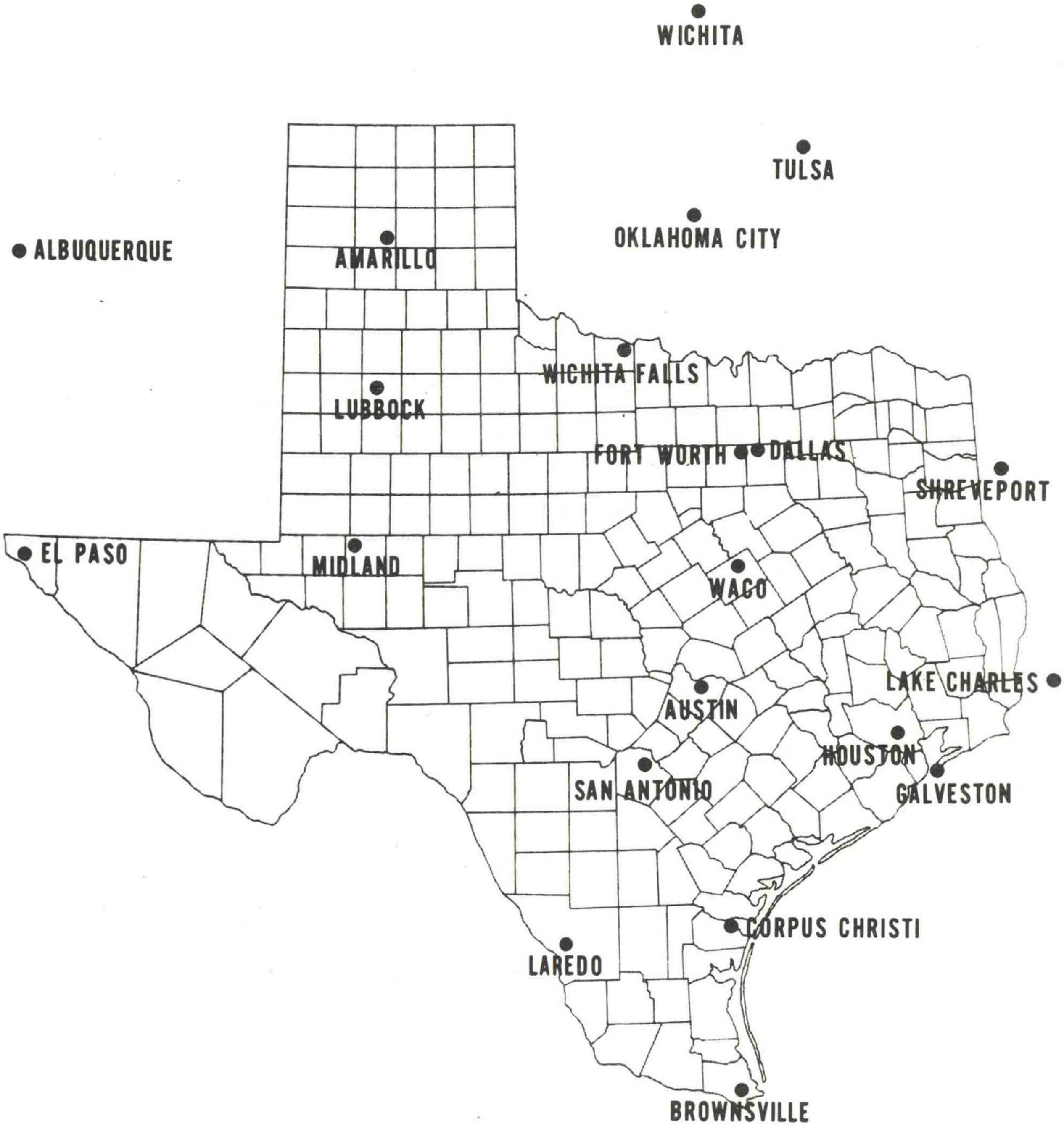

Figure 1.--Stations from which data were used.

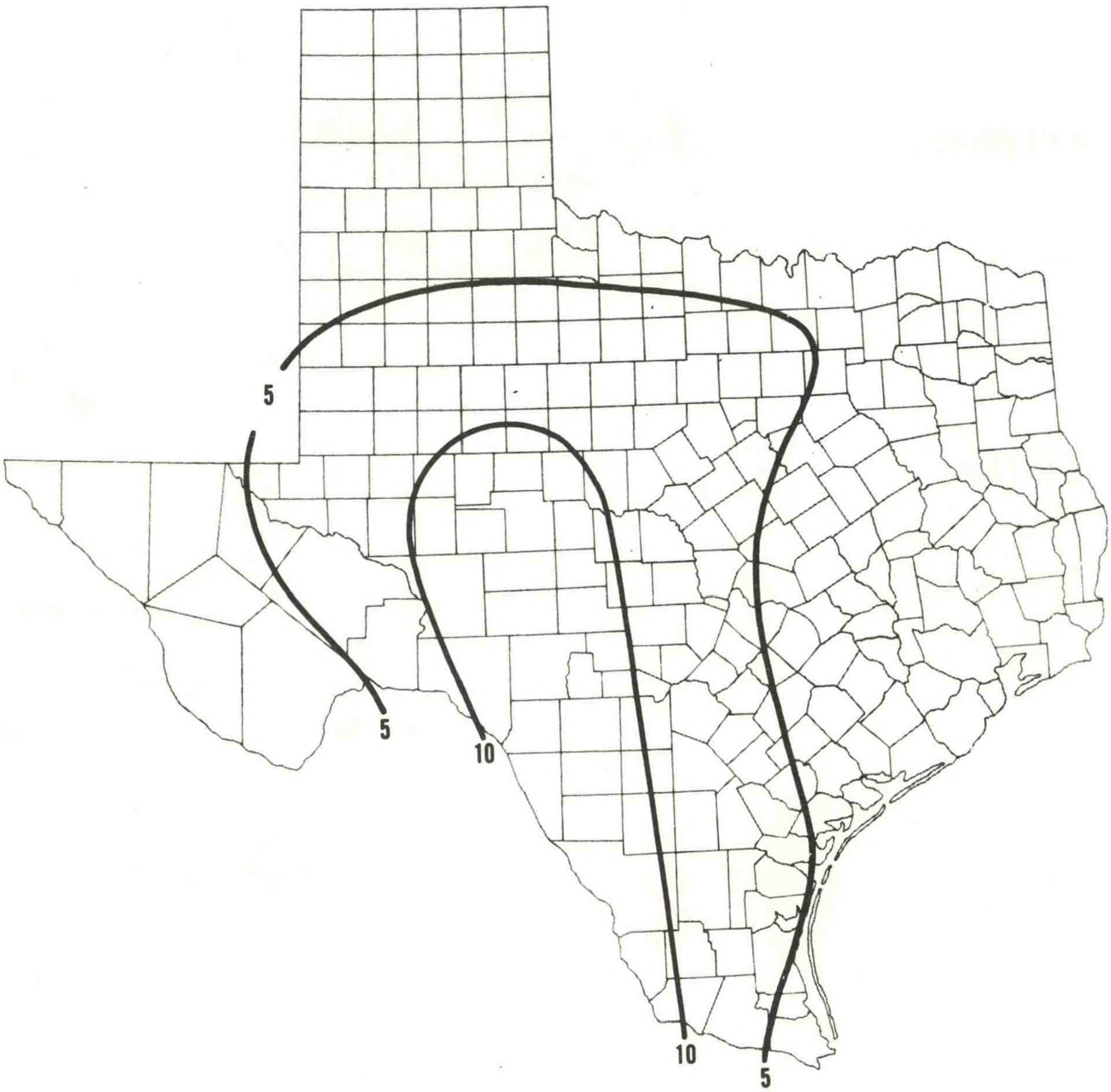

Figure 2.--Mean no. hours with RH < 30%, wind ≥ 15 mi/hr, T ≥ 75°F, February.

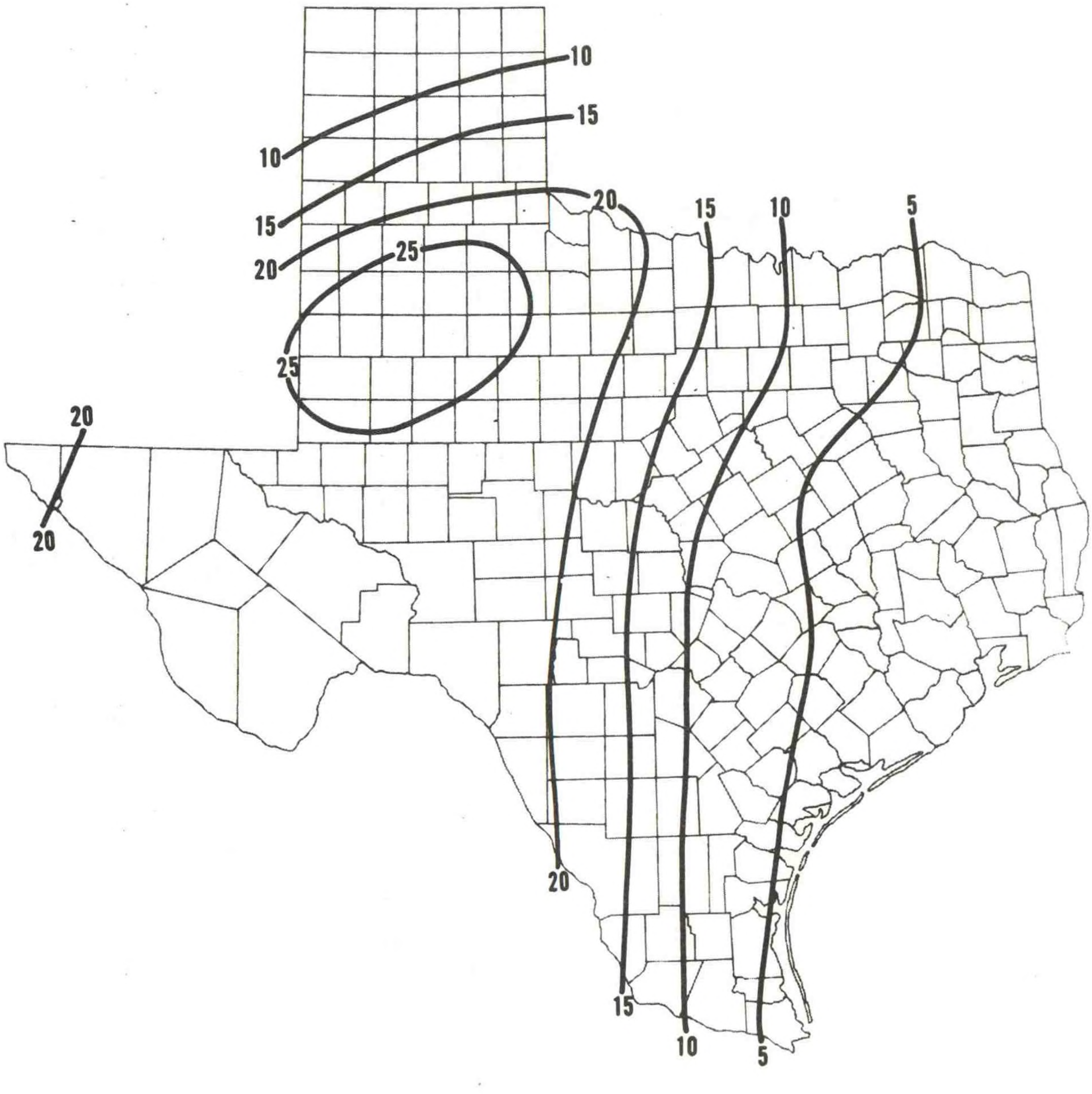

Figure 3.--Mean no. hours with RH < 30%, wind ≥ 15 mi/hr, T ≥ 75°F, March.

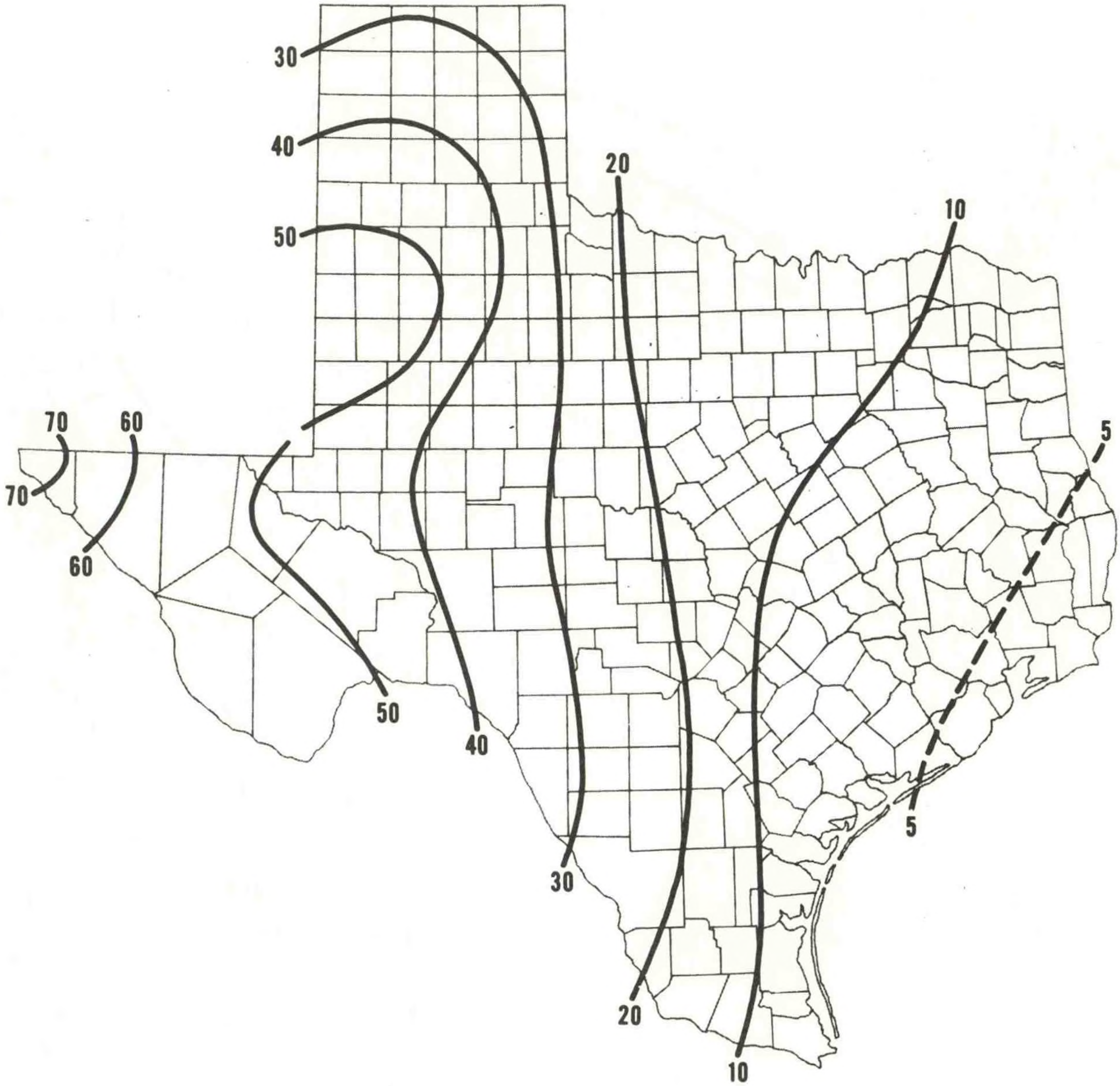

Figure 4.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥ 75°F, April.

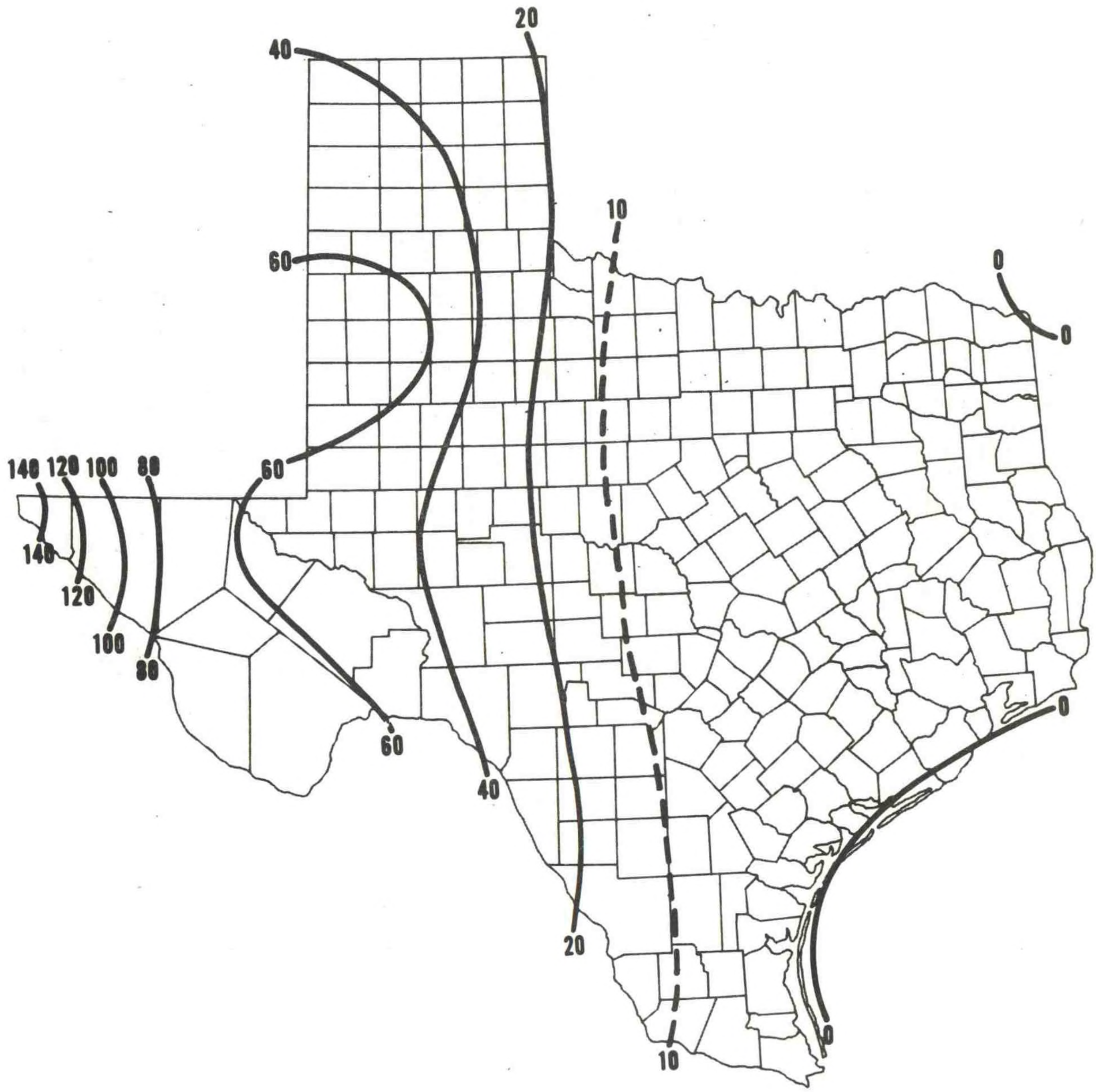

Figure 5.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥75°F, May.

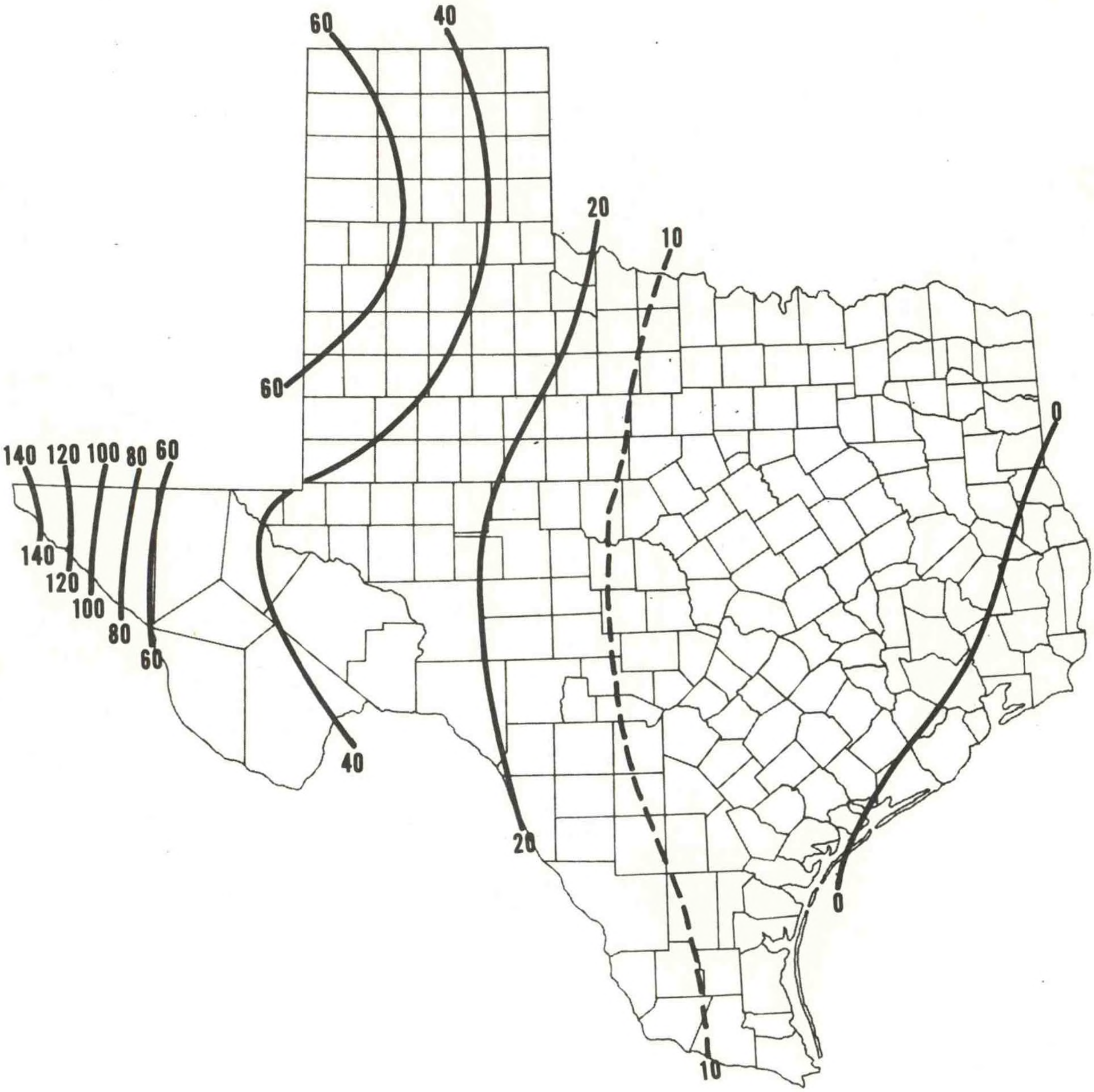

Figure 6.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥75°F, June.

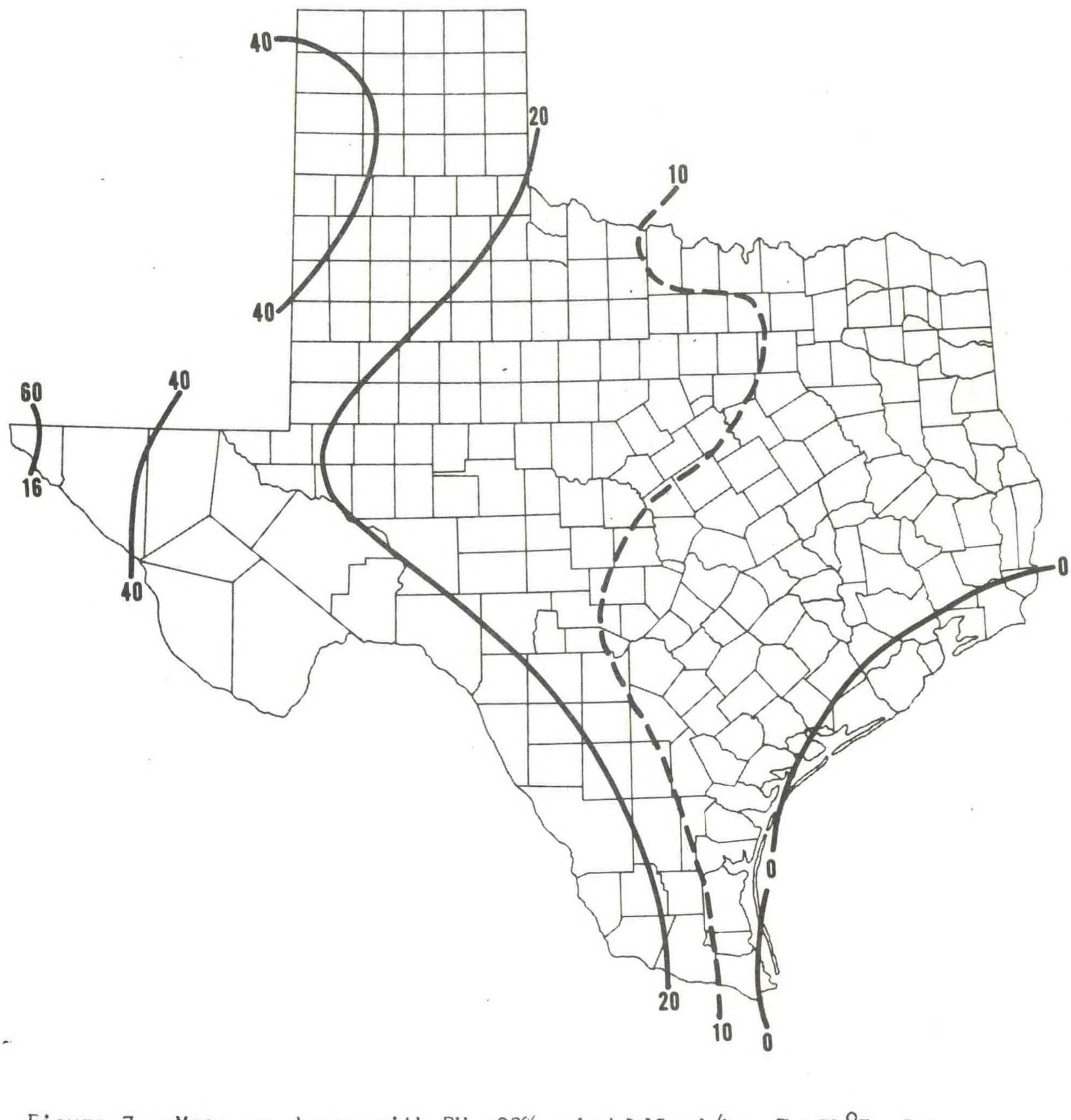

Figure 7.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥75°F, July.

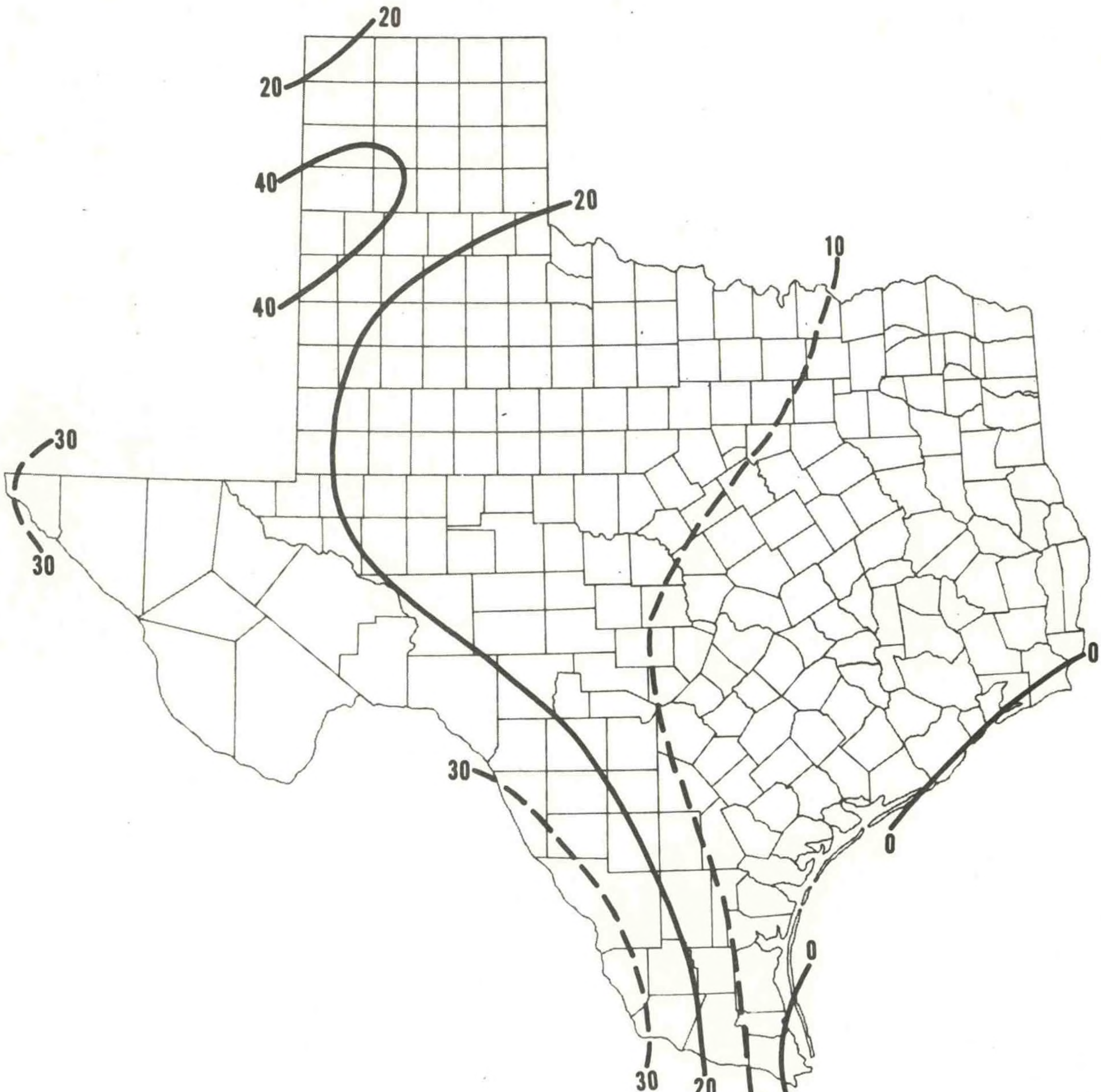

Figure 8.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥75°F, August.

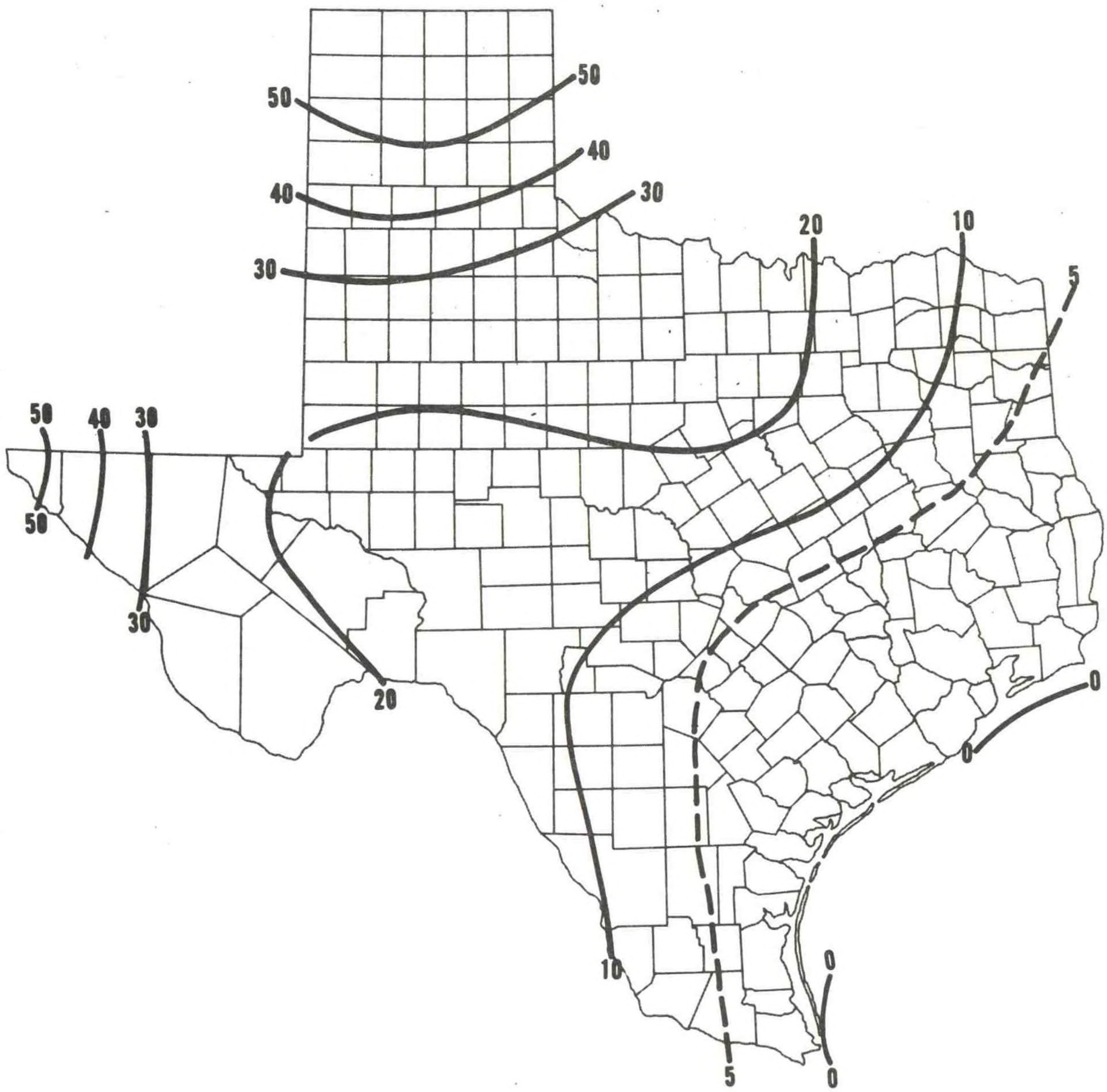

Figure 9.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥75°F, September.

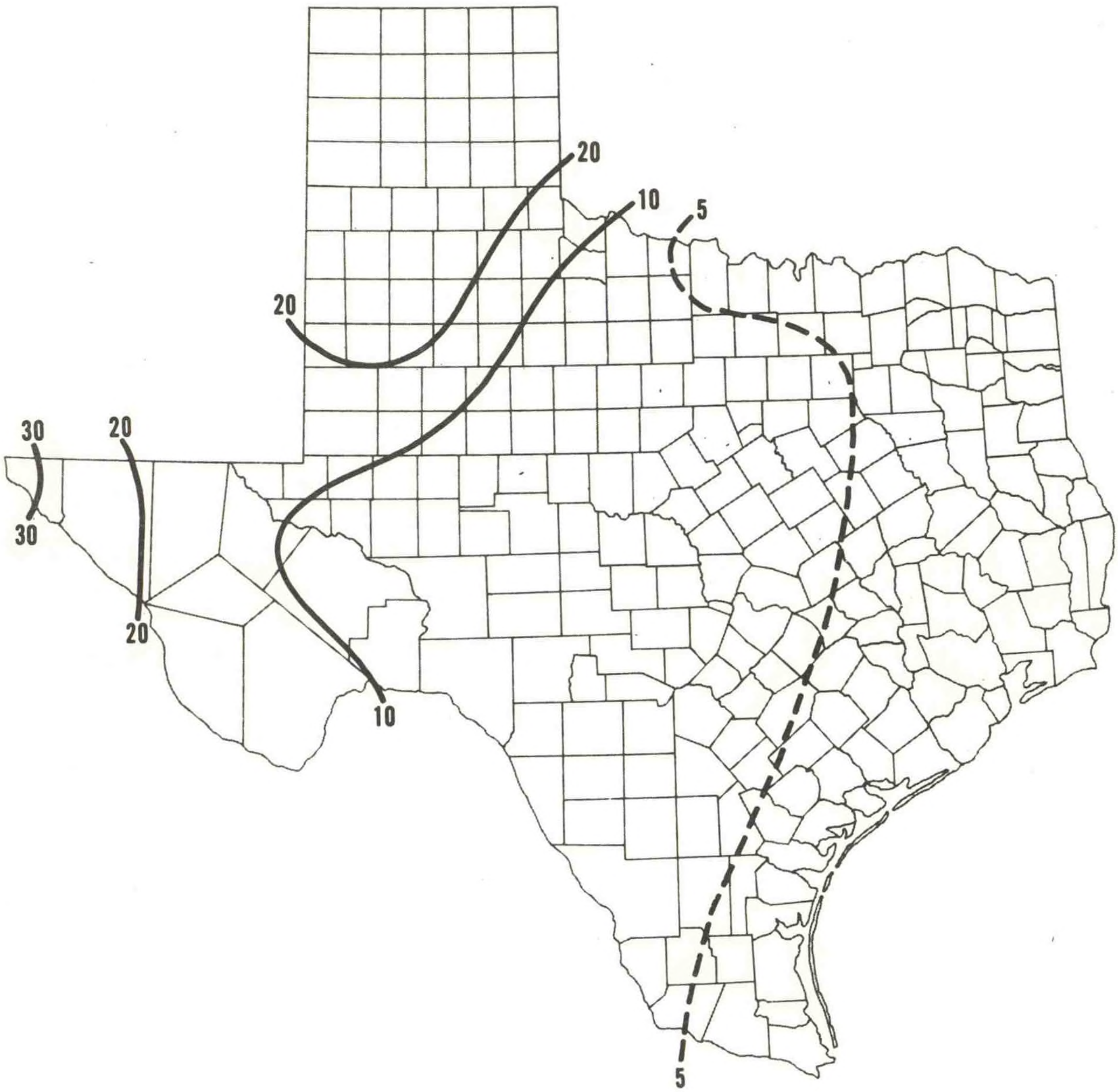

Figure 10.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥ 75°F, October.

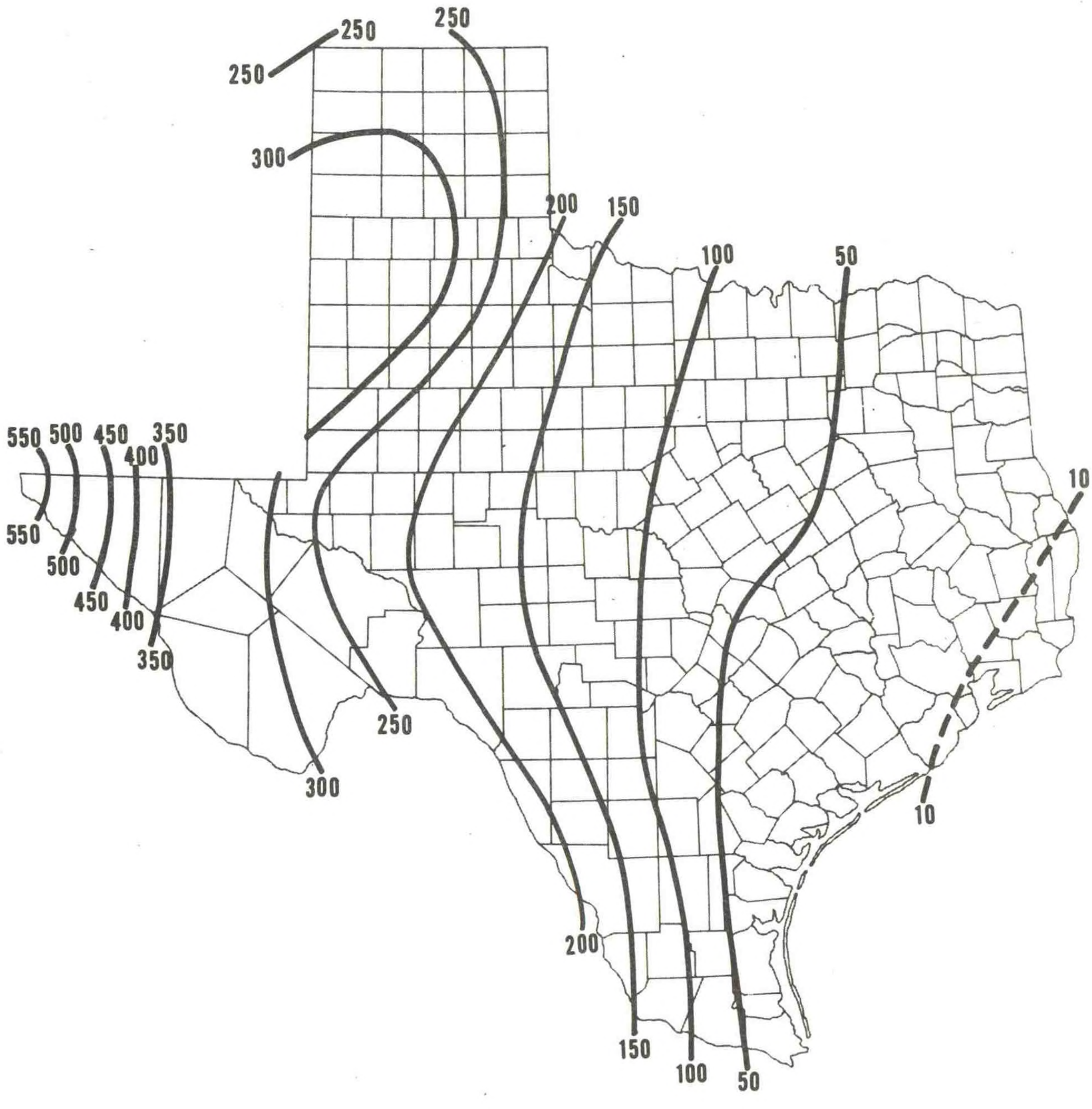

Figure 11.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥75°F, Annual.

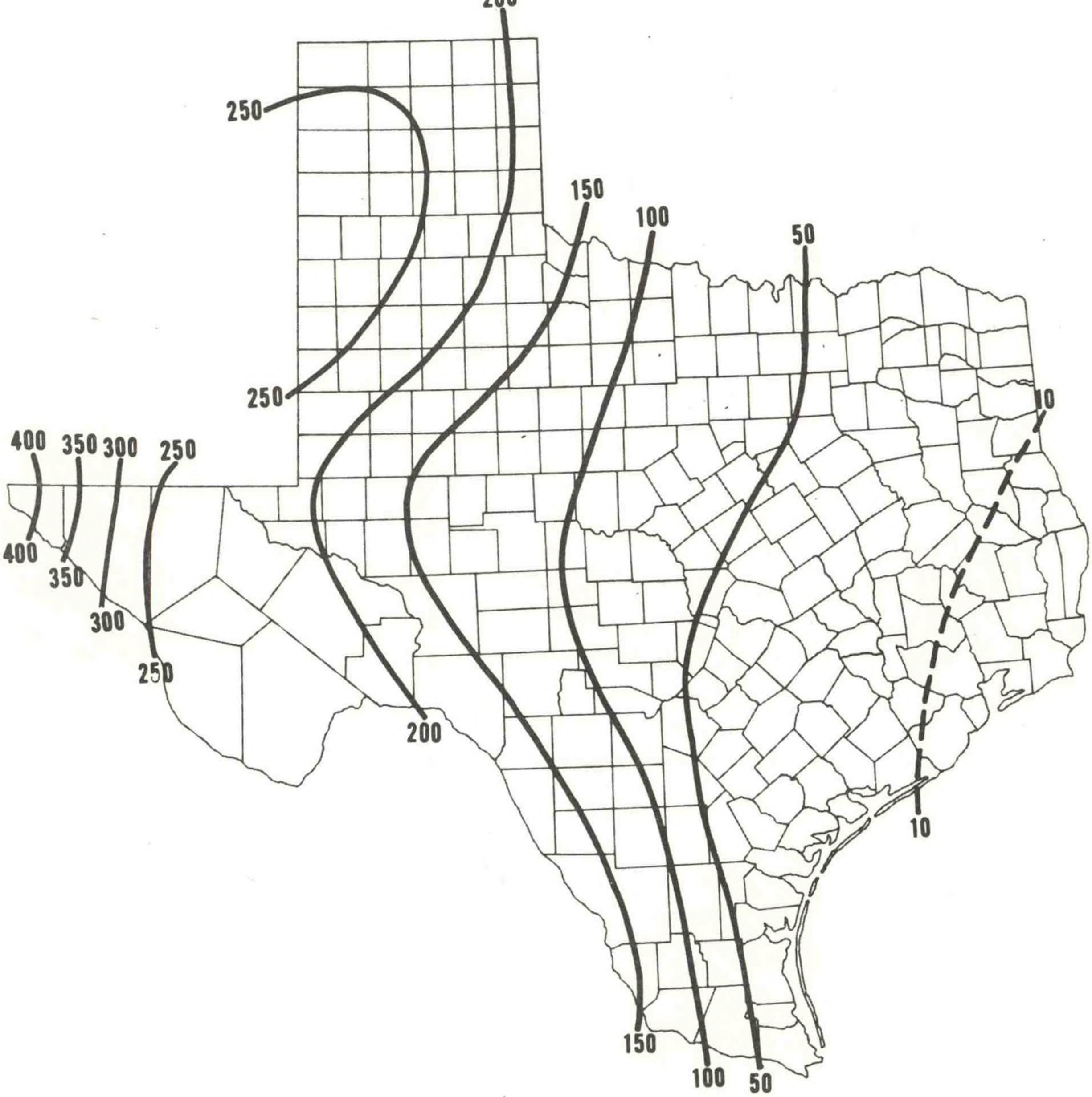

Figure 12.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥ 80°F, Annual.

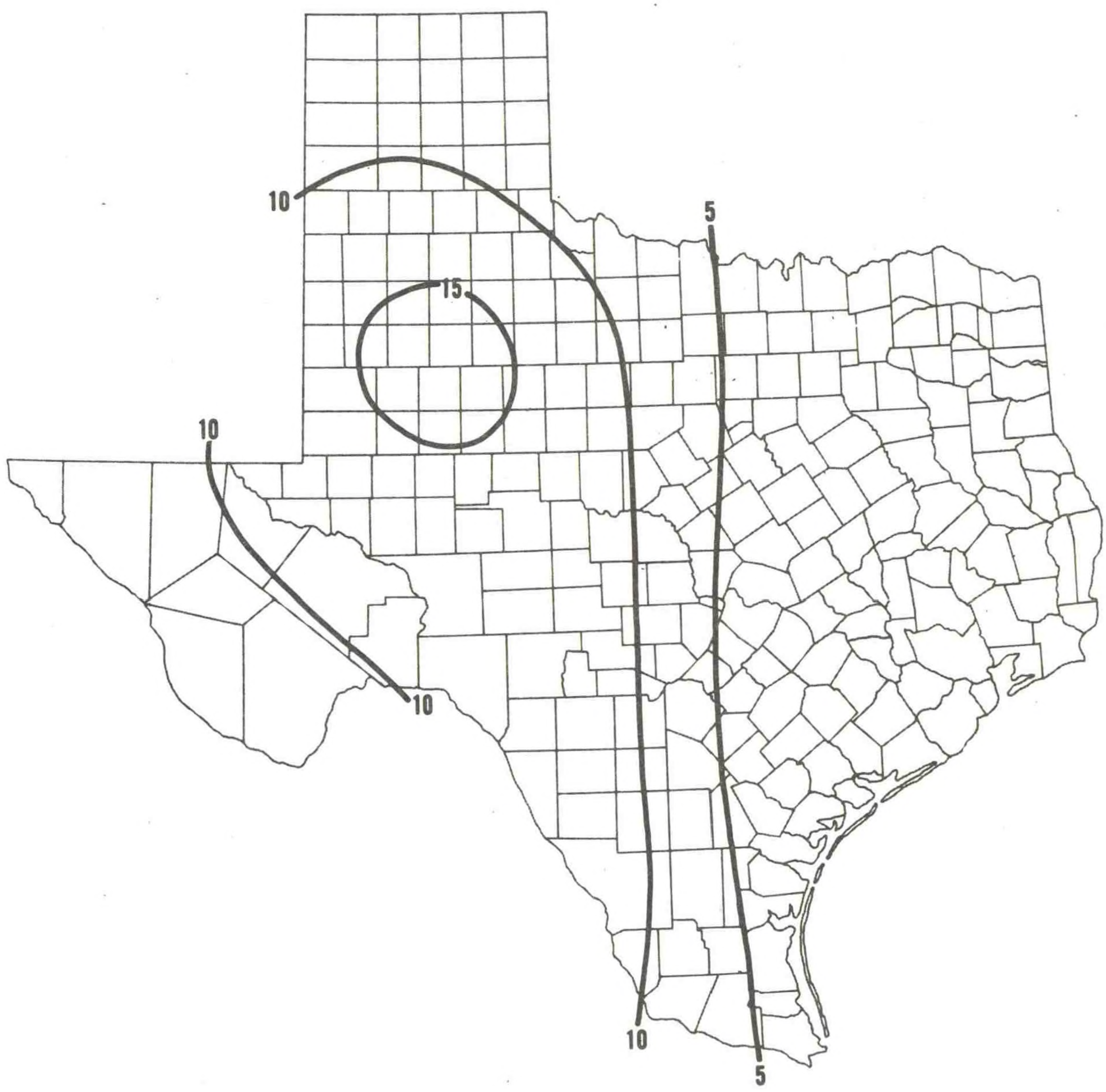

Figure 13.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥85°F, April.

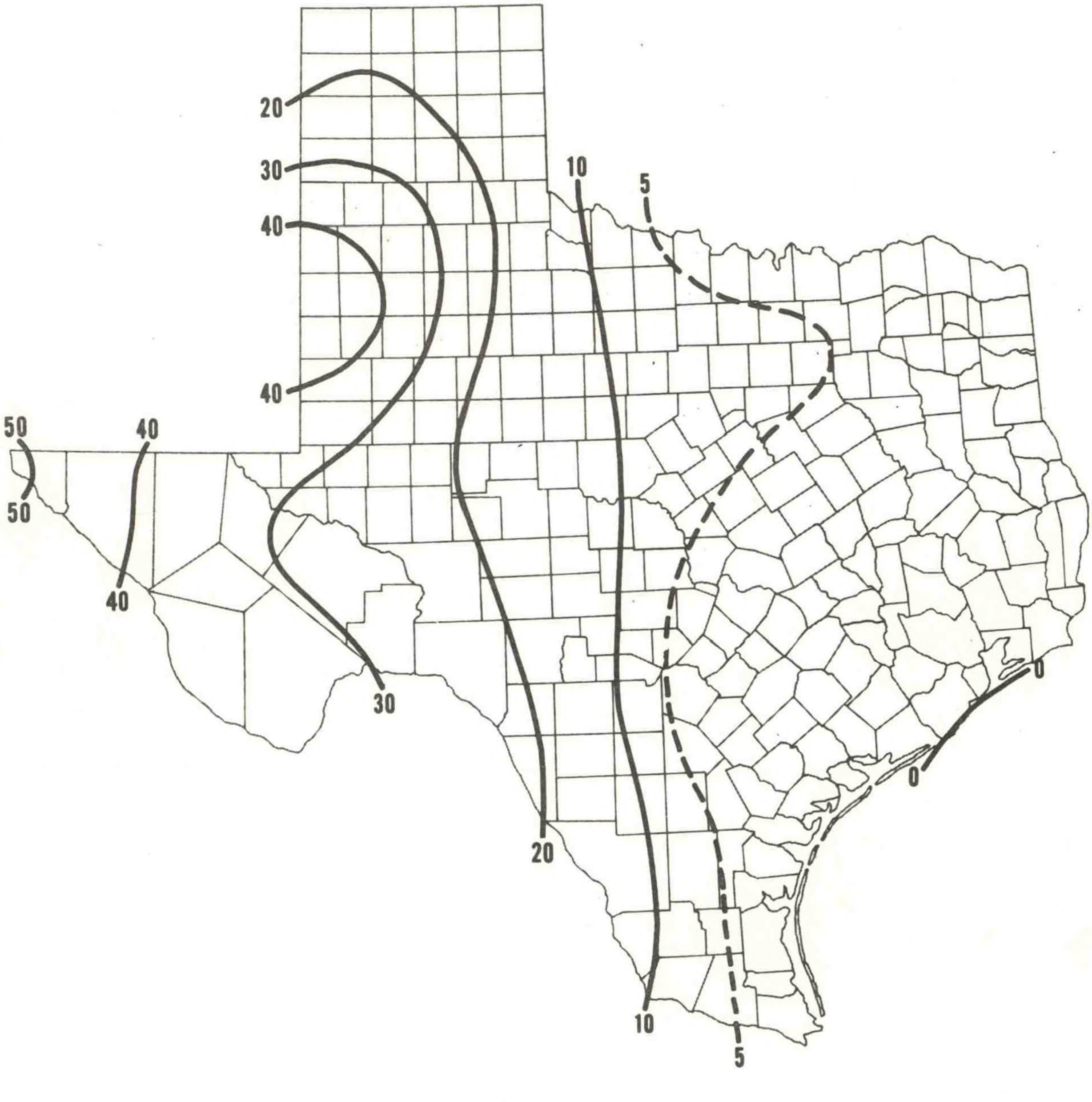

Figure 14.--Mean no. hours with RH < 30%, wind ≥ 15 mi/hr, T ≥85°F, May.

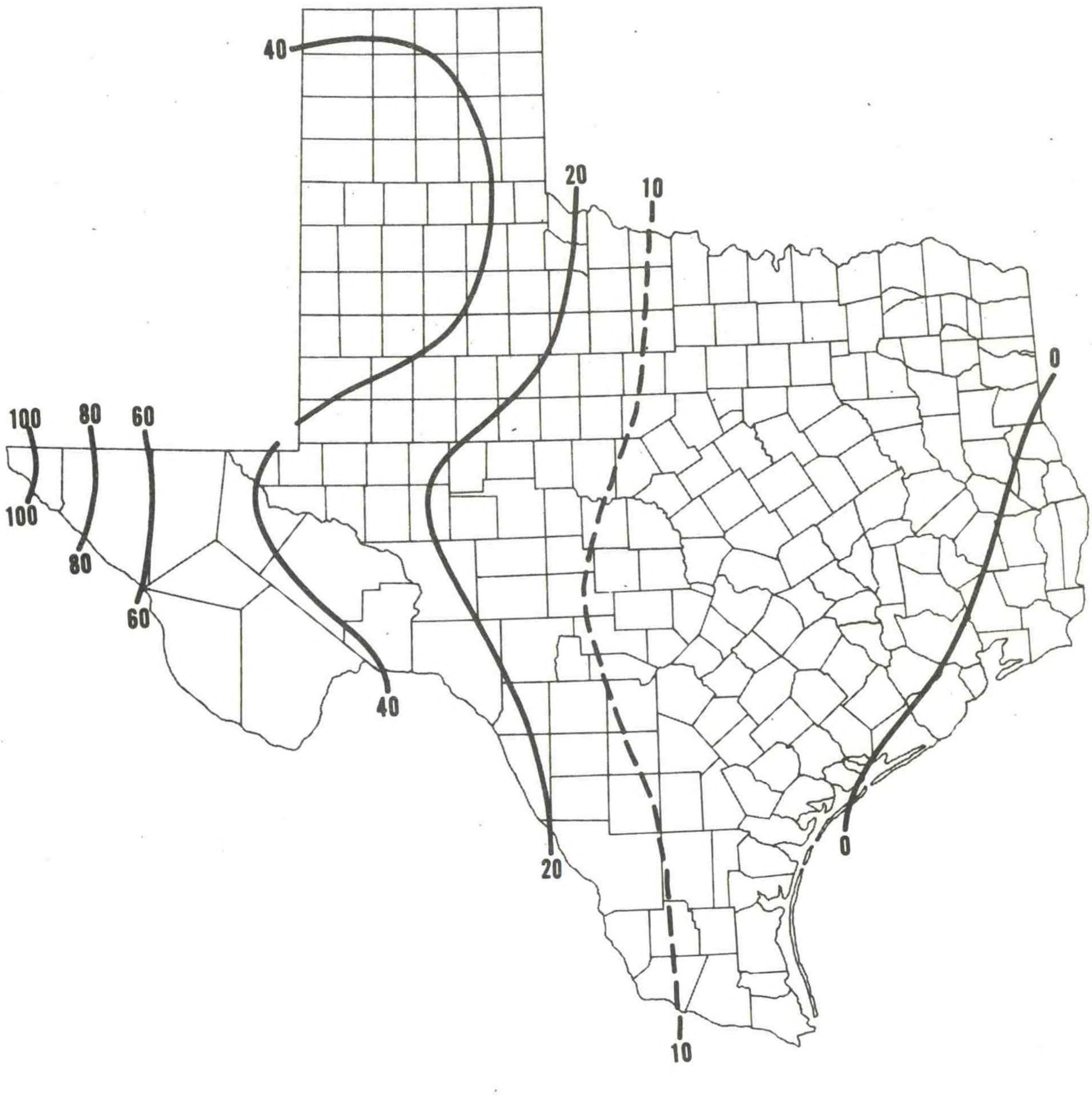

Figure 15.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥85°F, June.

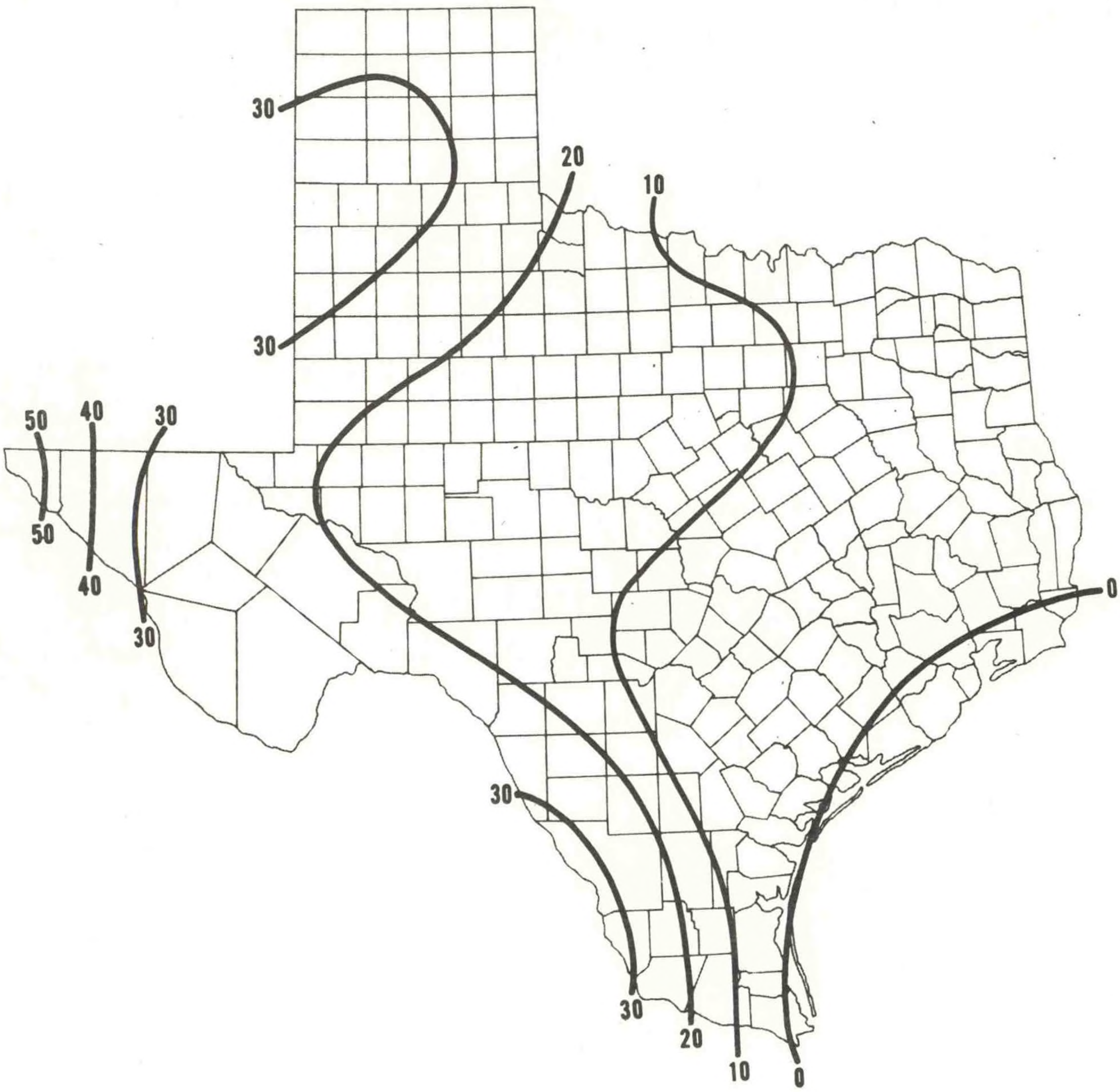

Figure 16.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥85°F, July.

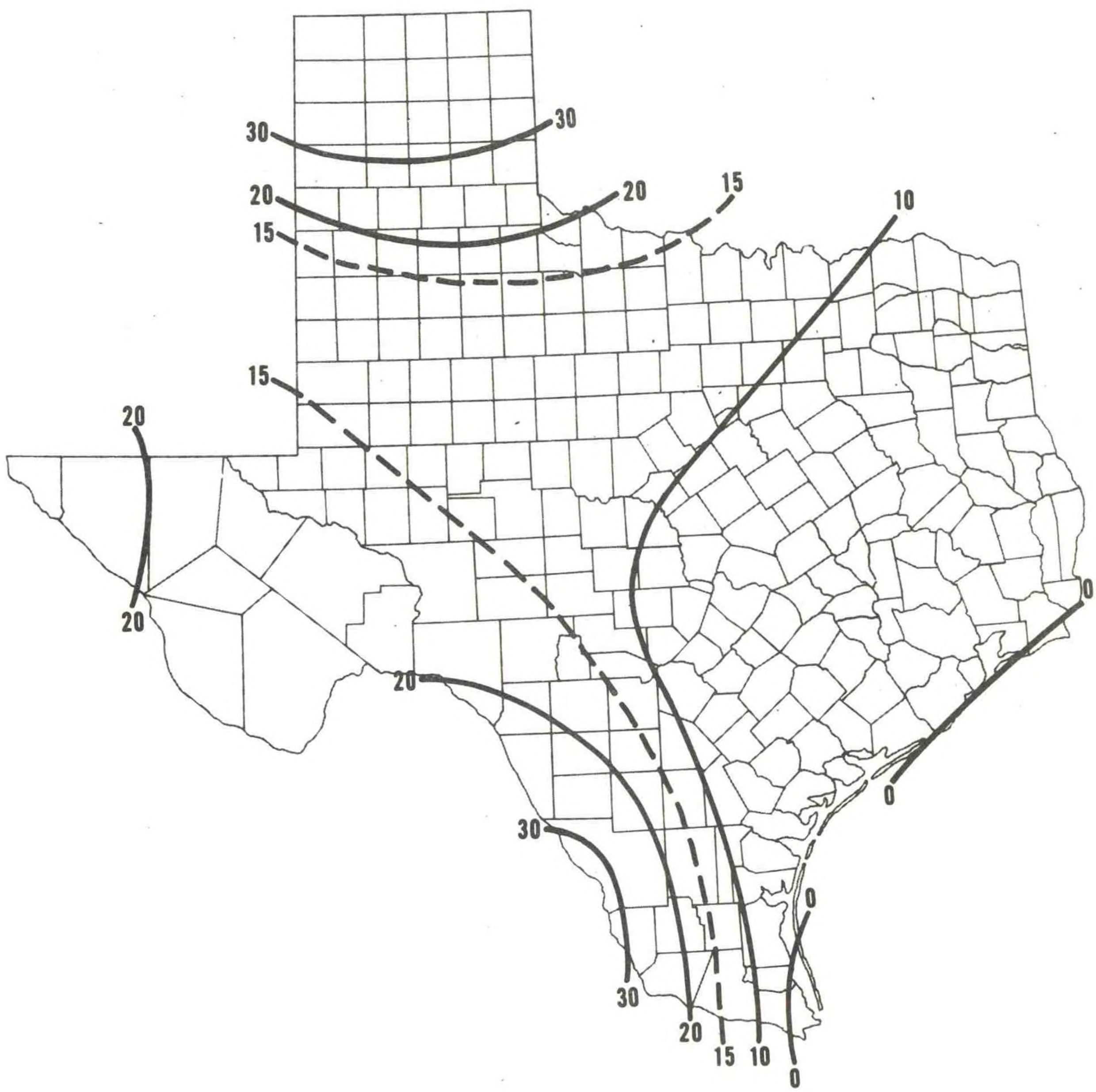

Figure 17.--Mean no. hours with RH $<$ 30%, wind $\geq$15 mi/hr, T $\geq$85^{o}F, August.

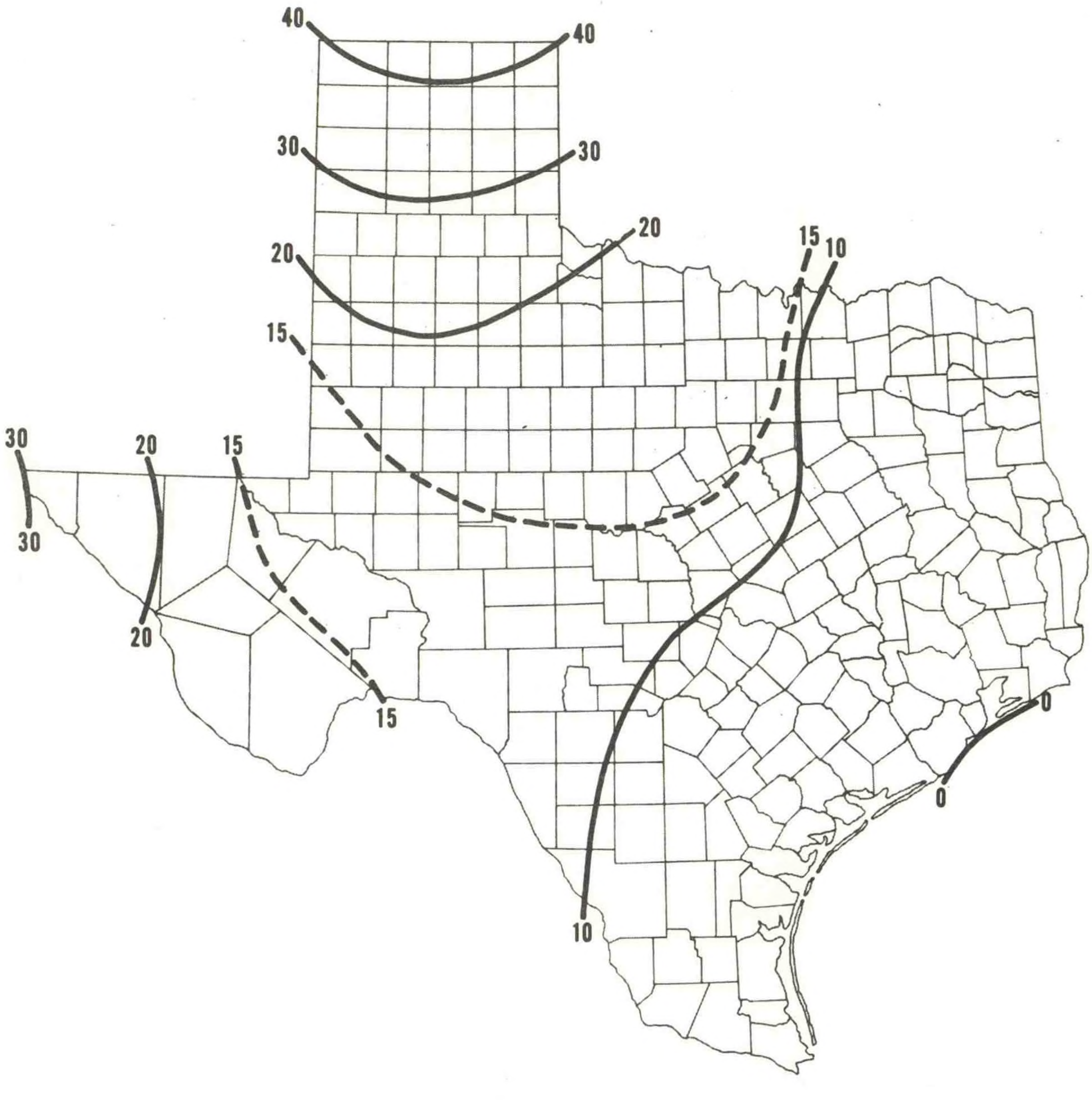

Figure 18.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥85°F, September.

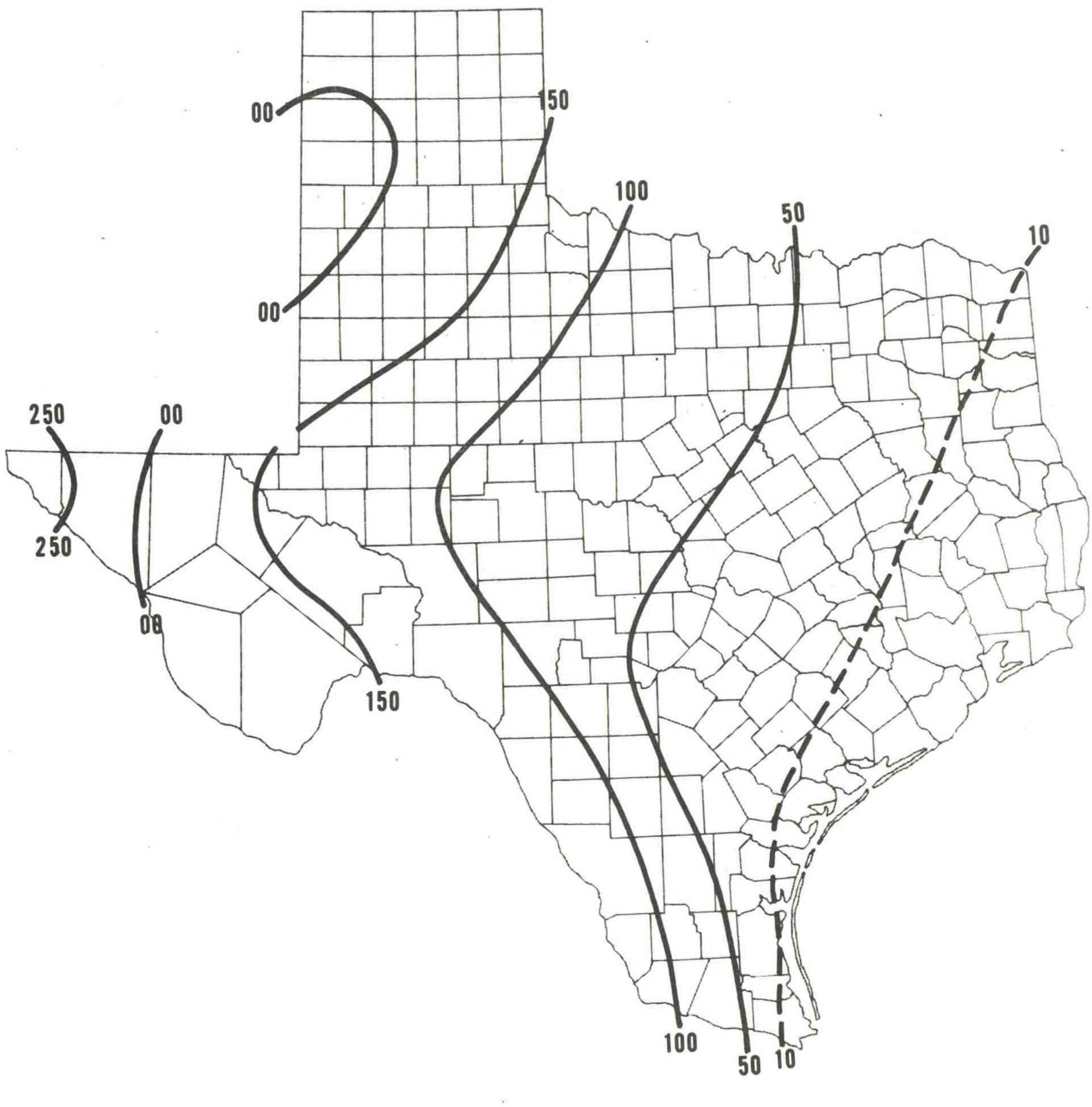

Figure 19.--Mean no. hours with RH <30%, wind ≥15 mi/hr, T ≥85°F, Annual.

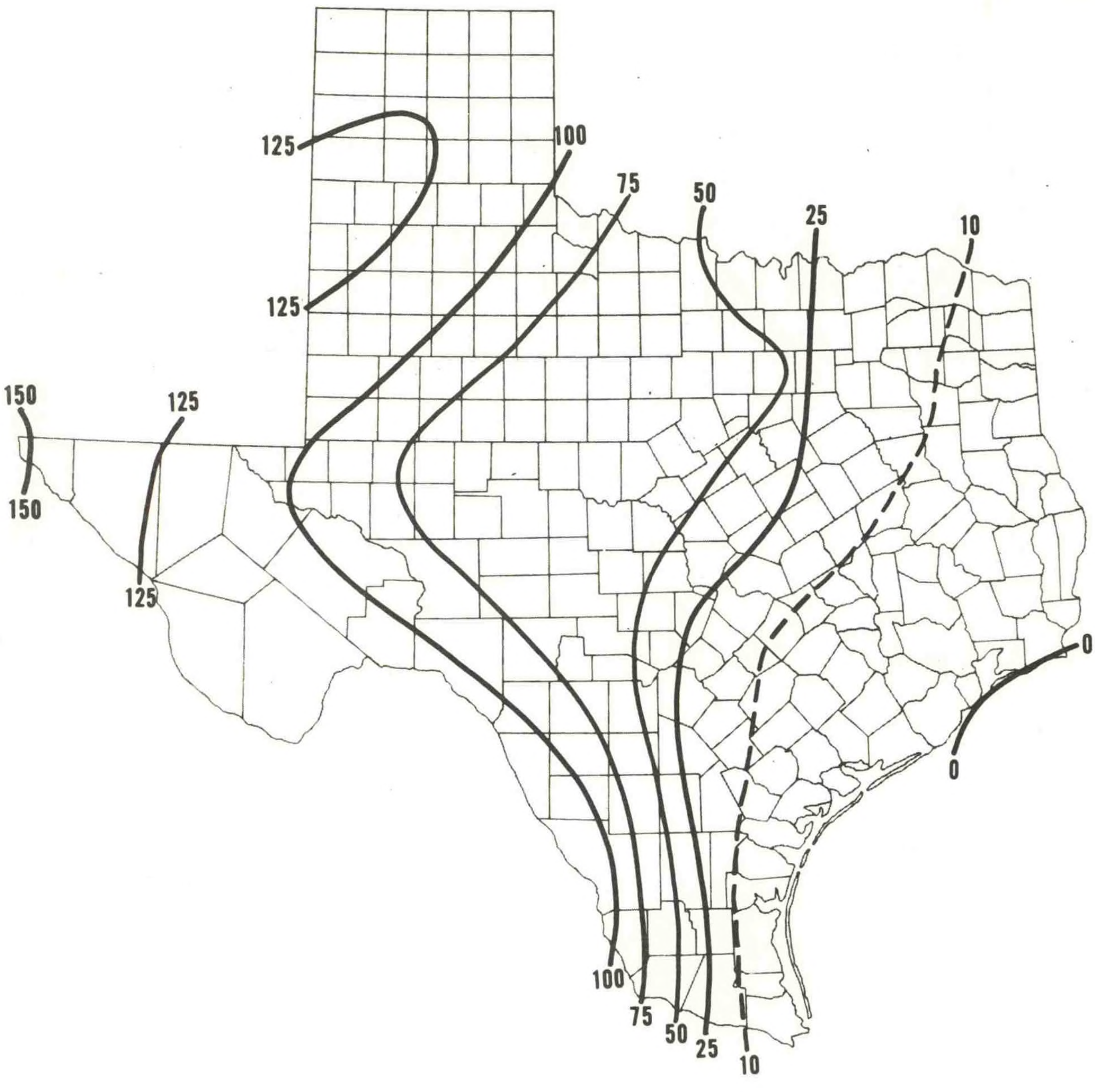

Figure 20.-- Mean no. hours with RH <30%, wind ≥15 mi/hr, T ≥90°F, Annual.

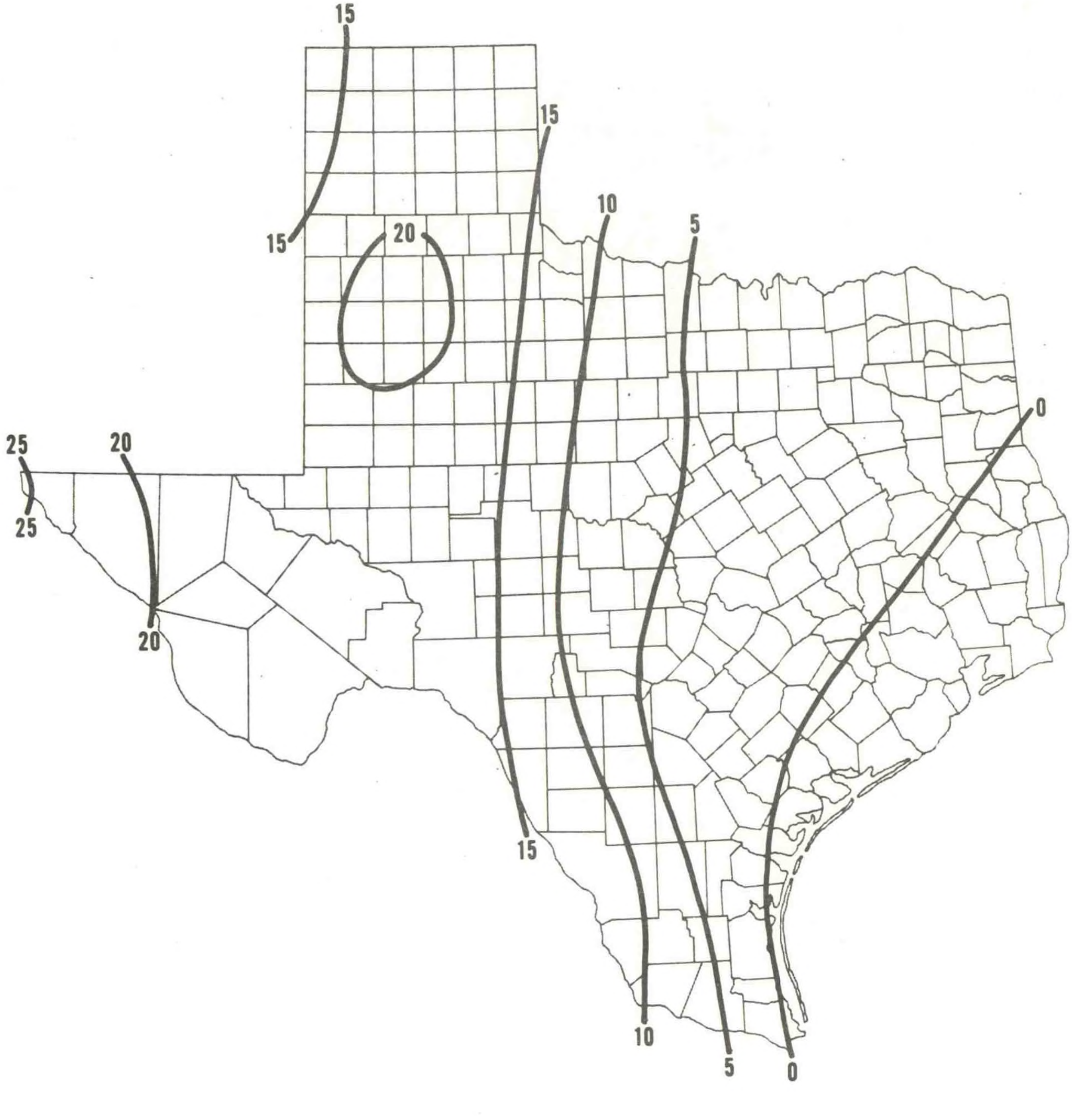

Figure 21.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥95°F, June.

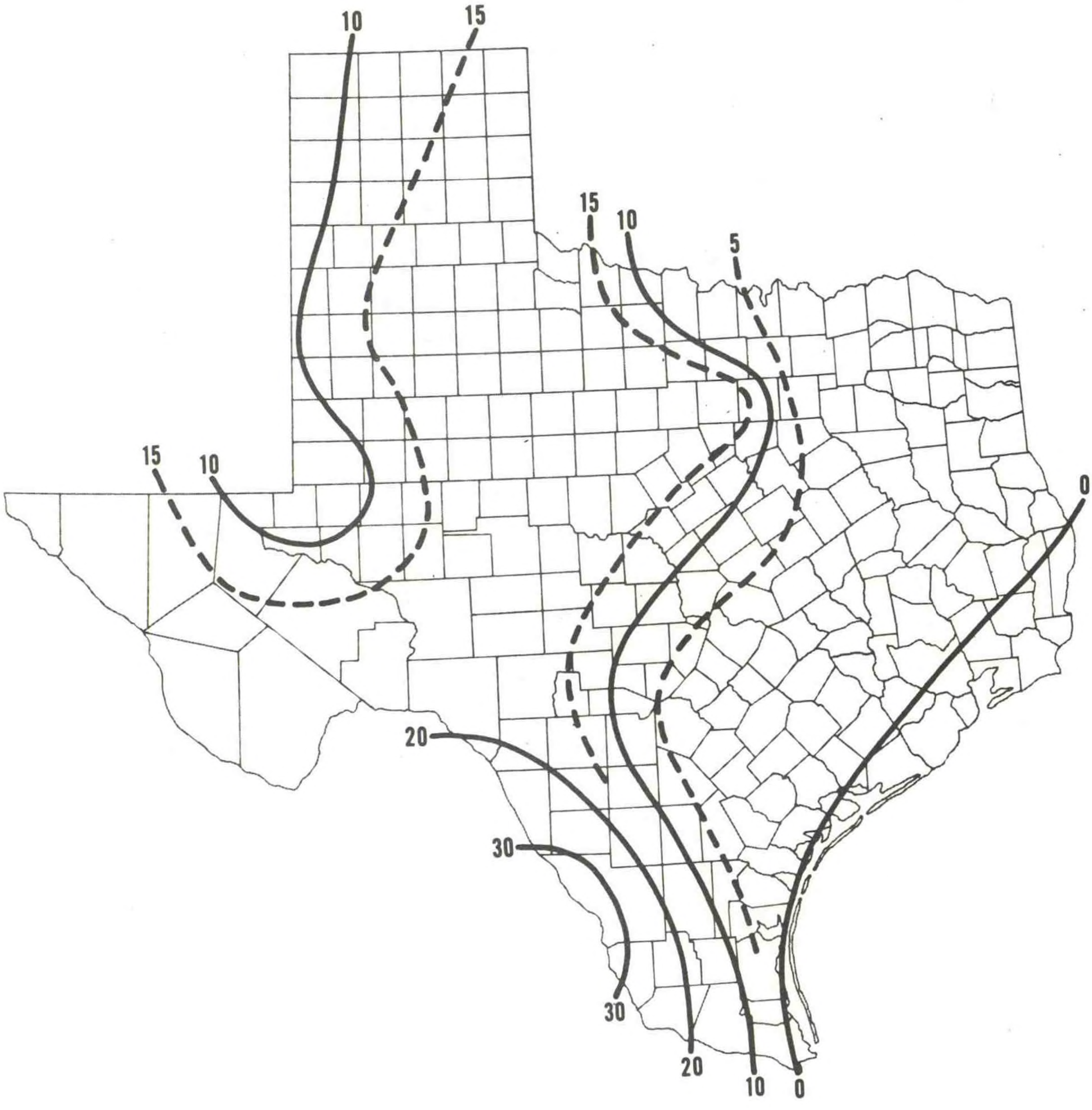

Figure 22.--Mean no. hours with RH $<30\%$, wind ≥ 15 mi/hr, T $\geq 95^{o}F$, July.

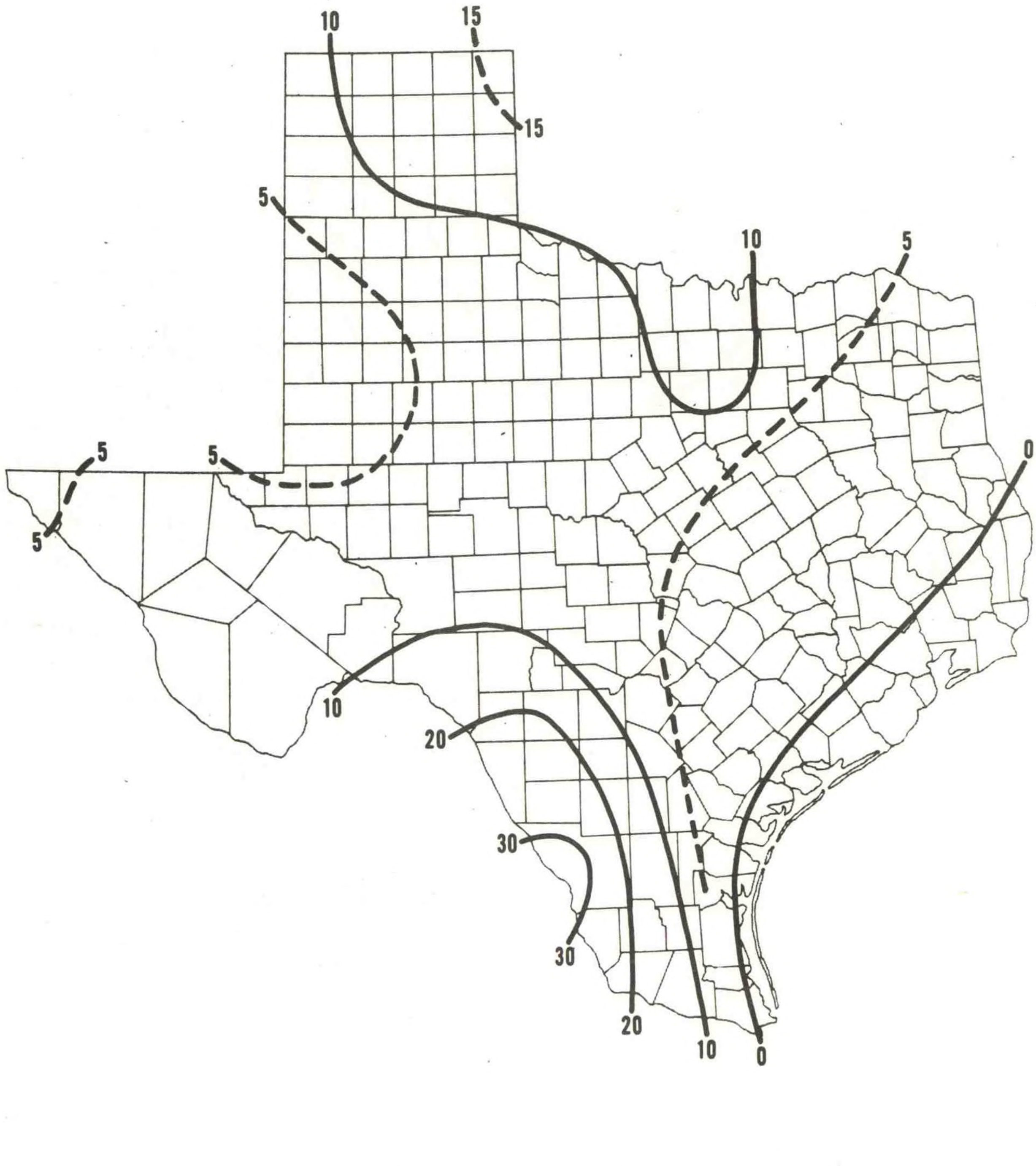

Figure 23.--Mean no. hours with RH < 30%, wind ≥15 mi/hr, T ≥95°F, August.

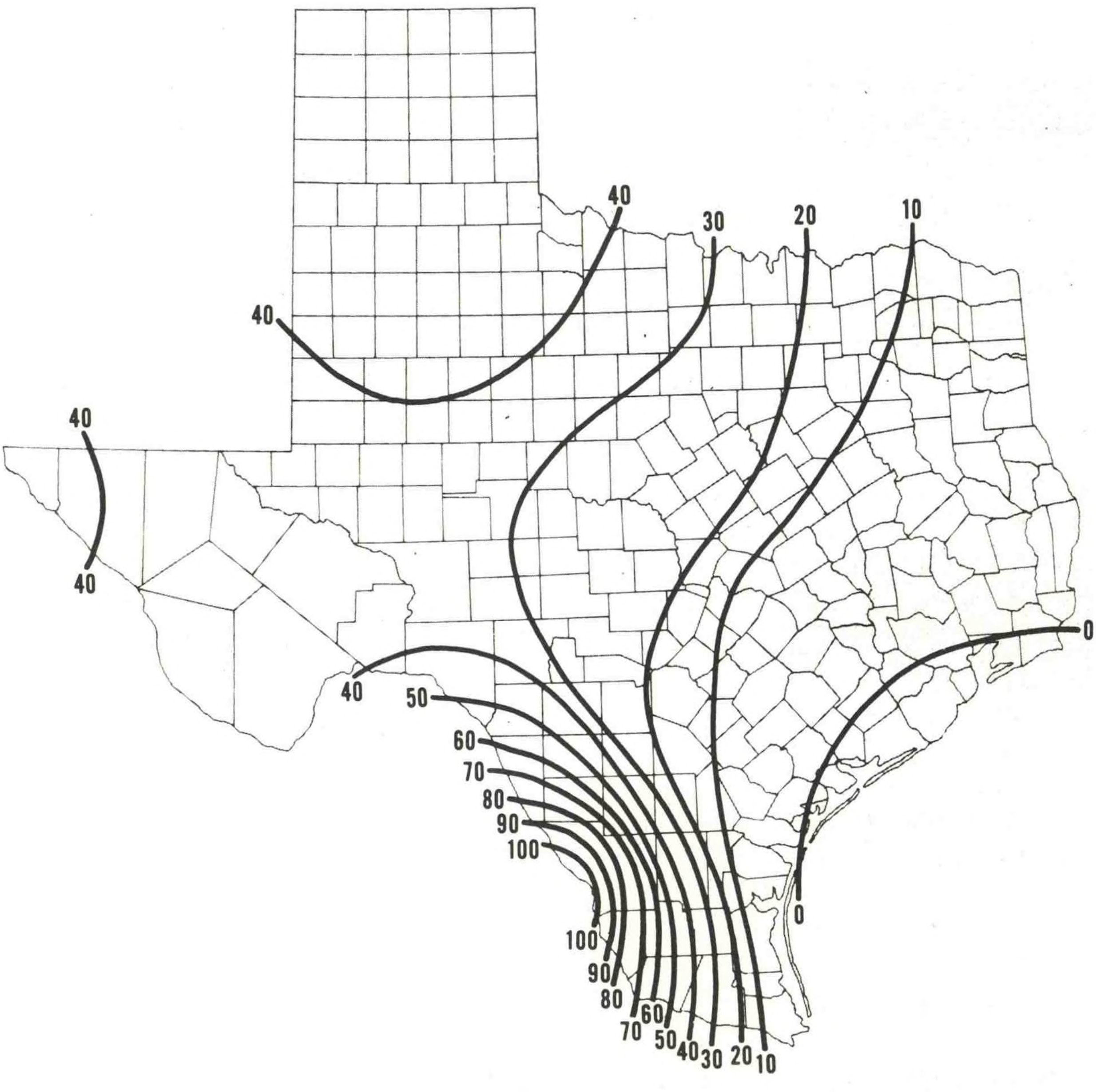

Figure 24.--Mean no. hours with RH <30%, wind ≥ 15 mi/hr, T ≥95°F, Annual.

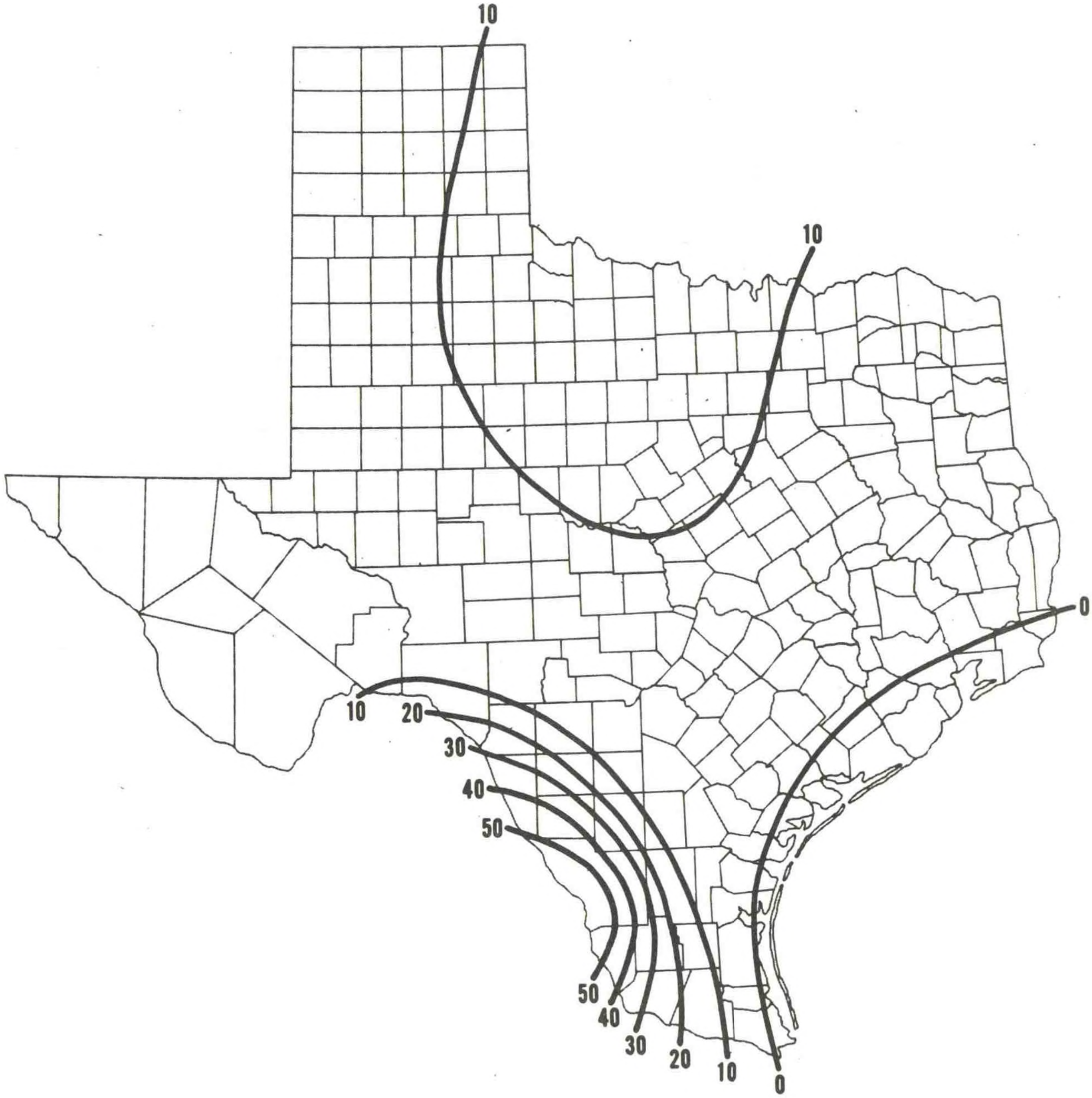

Figure 25.--Mean no. hours with RH $<30\%$, wind ≥ 15 mi/hr, T $\geq 100^{\circ}F$, Annual.

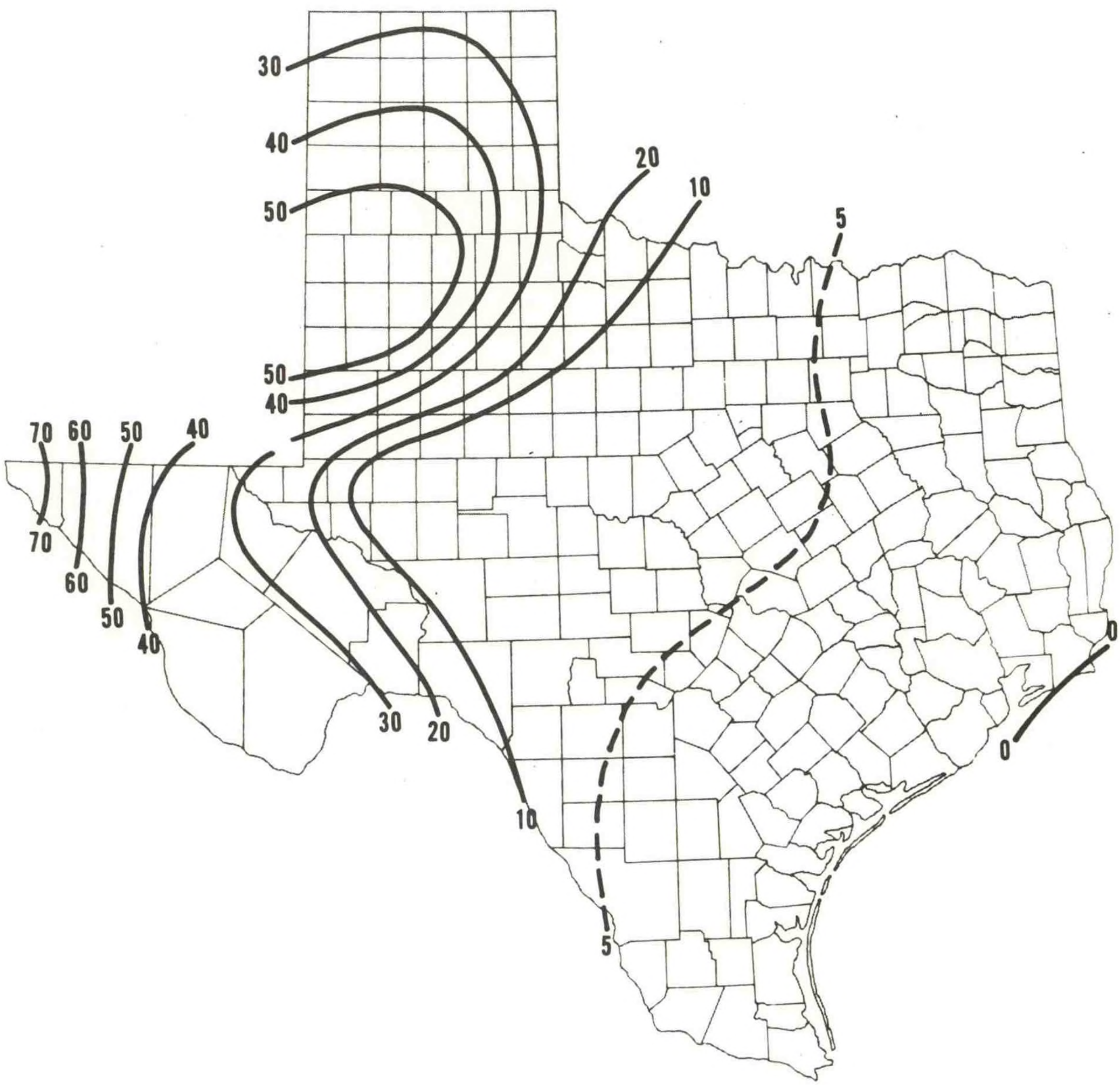

Figure 26.--Mean no. hours with RH < 30%, wind ≥ 25 mi/hr, T ≥ 75°F, Annual.

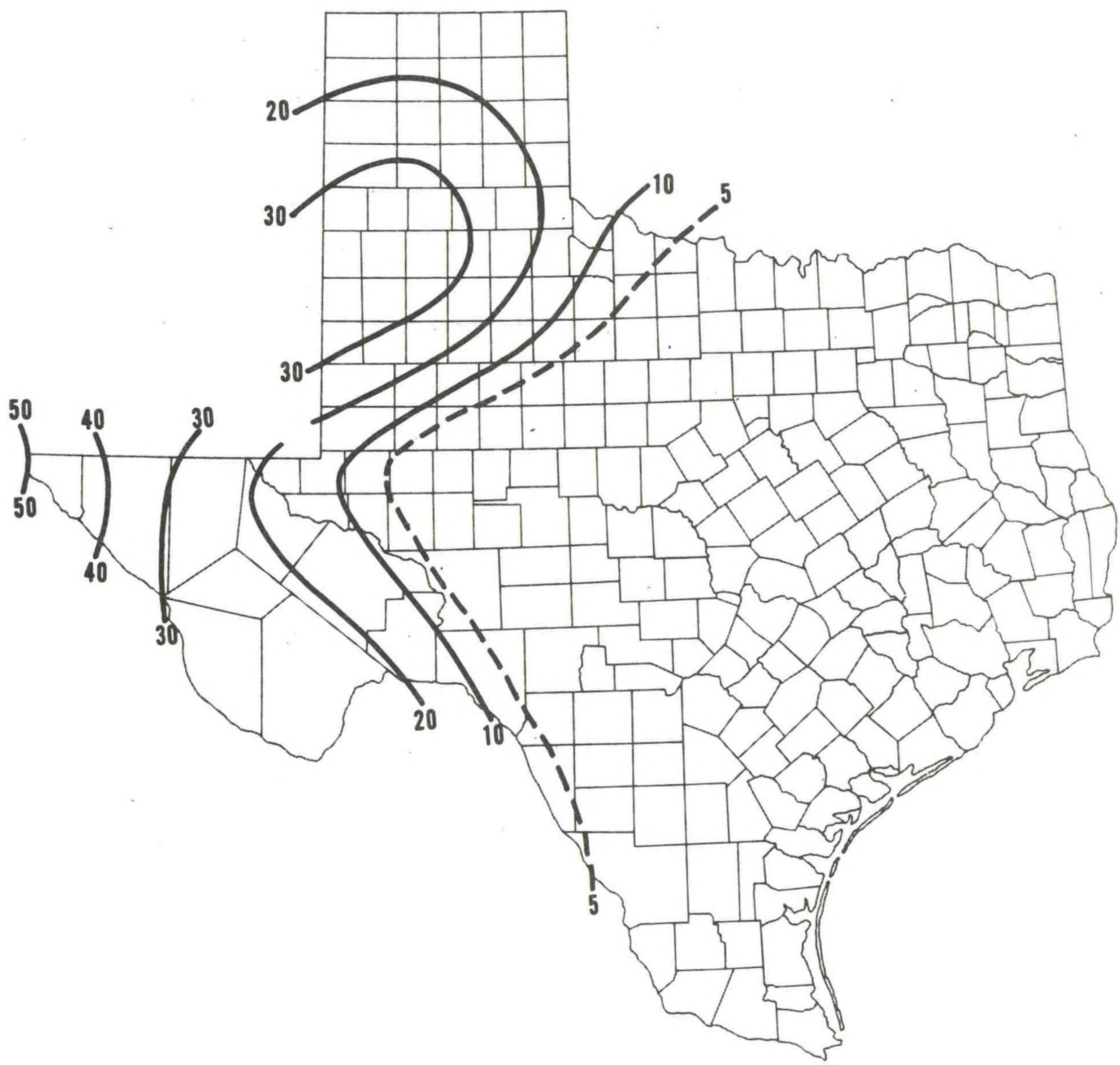

Figure 27.--Mean no. hours with RH <30%, wind ≥25 mi/hr, T ≥80°F, Annual.

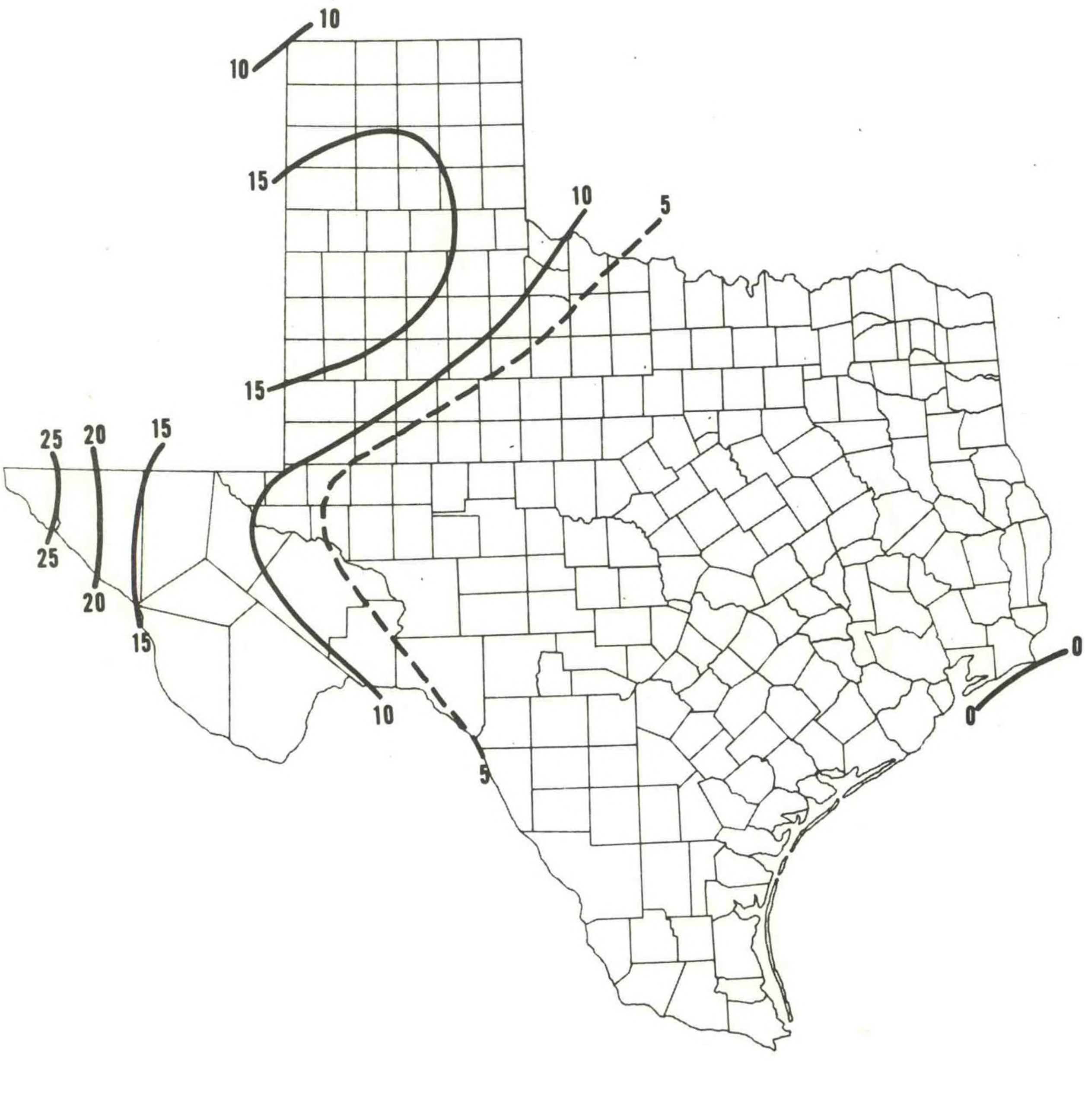

Figure 28.--Mean no. hours with RH <30%, wind ≥25 mi/hr, T ≥85°F, Annual.

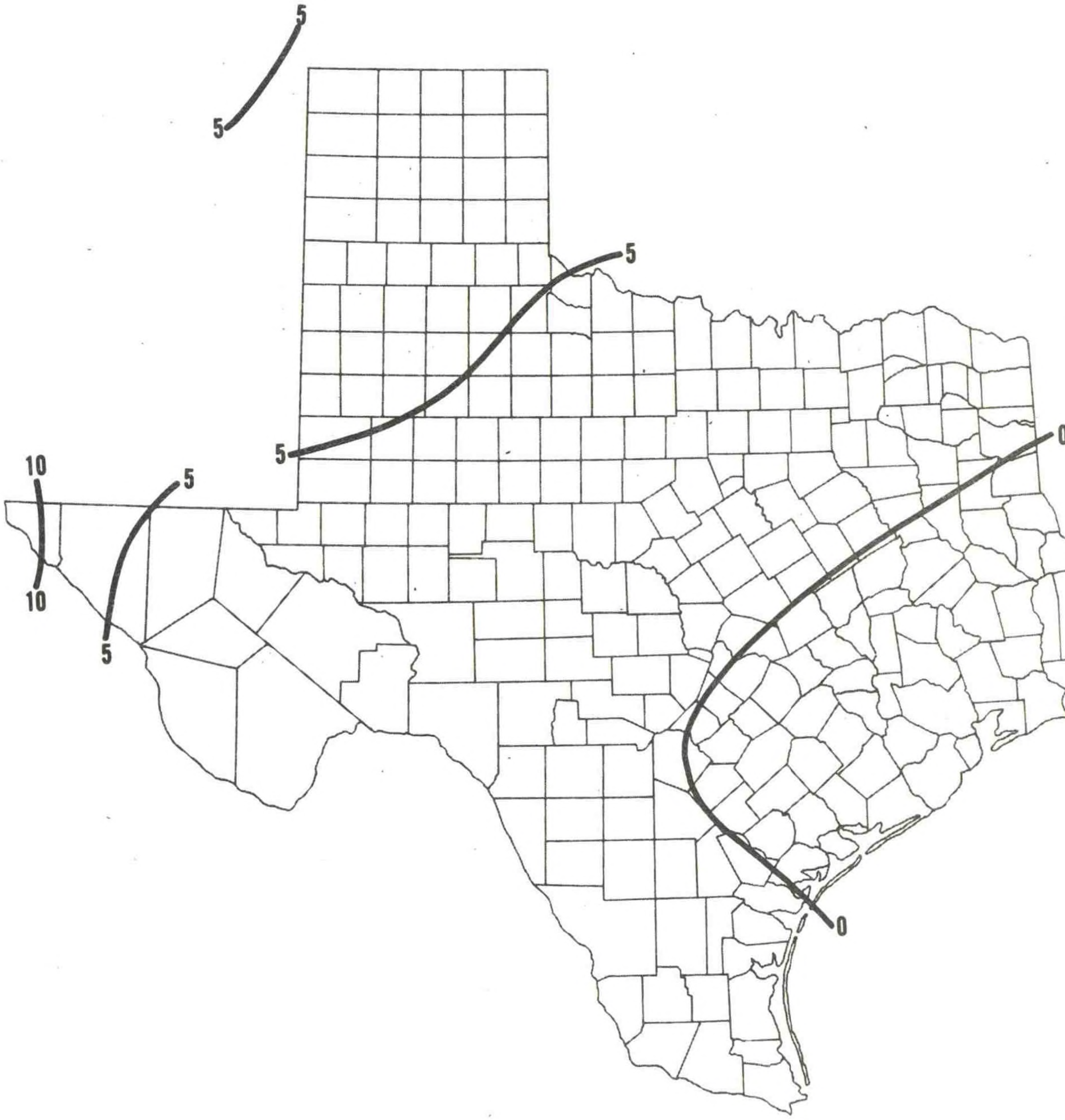

Figure 29.--Mean no. hours with RH $<30\%$, wind ≥ 25 mi/hr, T $\geq 90°F$, Annual.