Coccidioidin testing of home-raised cattle in Arizona defined geographic boundaries and indicated the relative infectivity of various parts of the endemic area of the State more specifically than skin tests of human beings. The endemic area was found to be practically co-terminous with the Lower Sonoran Life Zone.

Distribution of Coccidioides immitis Determined by Testing Cattle

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GEOGRAPHIC distribution of *Coccidioides immitis* in Arizona has been estimated previously by noting the areas of the State in which cases of coccidioidomycosis in human beings are reported (*1–10*), by several skin test surveys (fig. 1) conducted on various population groups (*10–17*), and by trapping rodents in specific geographic areas and examining them for the presence of *C. immitis* (*18*).

Skin test studies on man, however, have all had shortcomings which make pinpointing the infectivity of a small area difficult. In some instances large areas with little population were not surveyed. Many persons who migrate to Arizona from the midwest have been previously infected with *Histoplasma capsulatum*, a potential cause of a cross reaction to the coccidioidin skin test. Also, persons living in the State travel about a great deal both inside and outside Arizona.

Although only a few studies of coccidioidin skin tests in animals have been reported (*19*, *20*), it has been shown that cattle within the more obviously endemic areas become infected and react to skin tests. This study was undertaken to determine more definitely the extent of the endemic areas and to map the relative infectivity in various parts of Arizona.

Materials and Methods

Between 1954 and 1959, 11,643 cattle were coccidioidin skin tested in the 14 counties of Arizona. The cattle were selected at random in various parts of each county. Few of these animals had been more than several thousand feet from where they were born. Their ages to the nearest year ranged from 1 through 6.

Lot 15087 of coccidioidin was used early in the survey and later lot 59–62 was used. It was standardized to the same sensitivity as lot 15087 by simultaneously testing cattle with both skin test agents and then concentrating the 59–62 behind a collodion filter until the skin test agents gave identical results. Both lots were furnished by Dr. C. E. Smith of the University of California at Berkeley.

The specificity of undiluted lot 59–62 in de-

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tecting cattle experimentally infected with *C. immitis* has been reported (*21*). Several other preliminary experiments were carried out on naturally infected cattle in the endemic area to arrive at a standard testing procedure. They are summarized briefly here.

Each of 181 cattle was injected intradermally with undiluted and with 1:2, 1:5, 1:10, and 1:100 dilutions of coccidioidin. All animals that reacted positively (indurations of more than 5 mm.) to diluted skin test agents also reacted to the same agent when it was used in a more concentrated form. The reverse was often not the case; that is, an animal might react to a concentrated agent but fail to react to a more dilute solution of it. To the undiluted, 135 reacted, 121 reacted to the 1:2, 94 to the 1:5, 78 to the 1:10, and 37 to the 1:100.

Undiluted coccidioidin was injected in the cervical area of 861 cattle. These skin tests were checked at the following intervals with the following numbers of positive reactions: 24 hours, 310; 48 hours, 380; 72 hours, 455; 96 hours, 505; 120 hours, 435; and 144 hours, 263. Of these cattle, 243 were injected simultaneously in the caudal fold area. The cervical area test resulted in 146 positive at 96 hours, and 87 of these same animals had reactions in the caudal fold area. None of the 59 cervical area negative cattle gave independently positive reactions in the caudal fold area. There were fewer positives both before and after the 96-hour reading.

Simultaneously, 264 cattle were injected intradermally in the cervical area with 0.1 ml. doses of undiluted coccidioidin and a control broth handled the same way coccidioidin is in its preparation. The control broth gave negative results in all animals, and the coccidioidin gave indurations of more than 5 mm. in 131 animals at 96 hours.

From these preliminary studies it was decided that the coccidioidin would be injected undiluted intradermally in the cervical area

Table 1. Results of coccidioidin tests of home-raised Arizona cattle, by counties

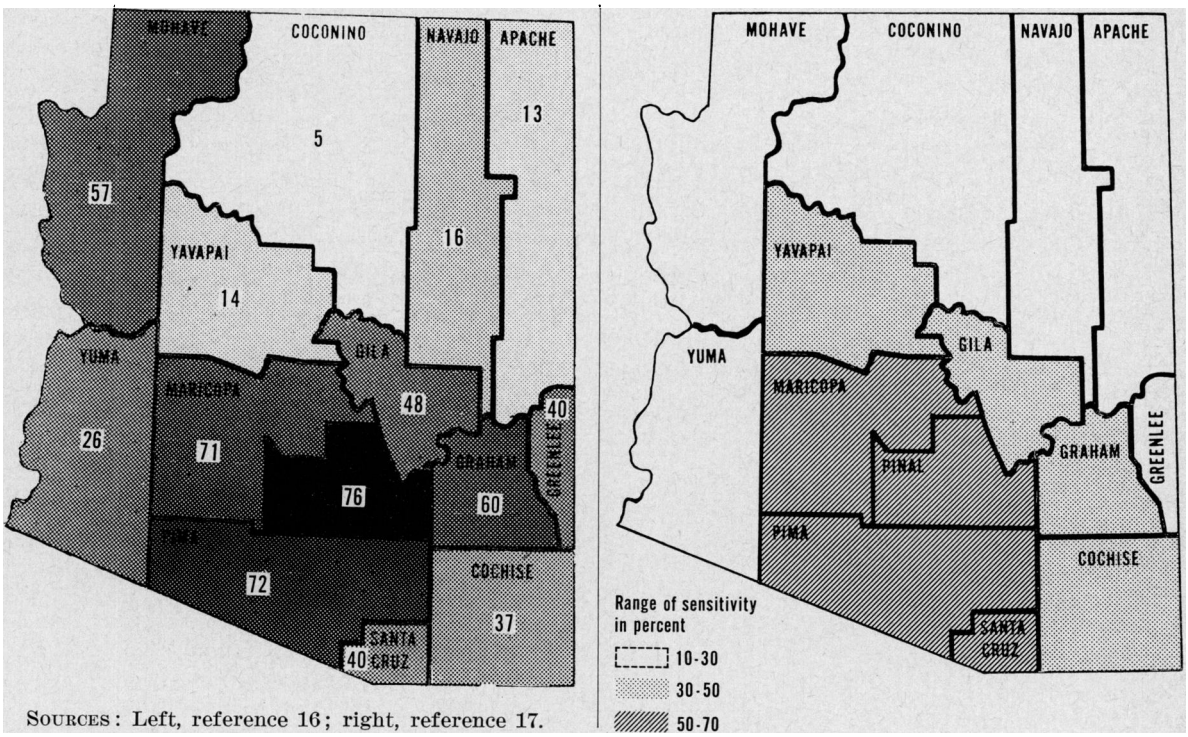
County	Total		Age to nearest year												IAC rates [1]	AC rates [2]
			1		2		3		4		5		6			
	T	P	T	P	T	P	T	P	T	P	T	P	T	P		
Apache	702	0	78	0	320	0	146	0	40	0	68	0	50	0	0	0
Cochise	636	121	15	1	80	16	235	41	115	17	108	25	83	21	.05	.05
Coconino	516	0	68	0	390	0	21	0	16	0	14	0	7	0	0	0
Gila:																
Low altitude	593	377	291	127	238	209	27	14	16	12	13	10	8	5	.28	.25
High altitude	706	1	131	0	374	1	93	0	61	0	32	0	15	0	0	0
Graham	712	260	106	11	159	34	91	28	146	65	118	54	92	68	.17	.15
Greenlee	544	129	107	14	217	51	112	21	45	18	43	11	20	14	.13	.13
Maricopa	1,446	761	367	89	389	179	197	137	213	134	151	113	129	109	.30	.26
Mohave:																
Low altitude	908	120	209	10	354	32	209	36	51	8	53	11	32	23	.11	.11
High altitude	530	7	53	0	142	1	71	2	25	0	78	1	161	3	.003	.01
Navajo	722	10	304	2	203	5	61	1	52	1	61	0	41	1	.003	.01
Pima	623	351	243	71	97	69	87	70	91	64	89	68	16	9	.27	.24
Pinal	579	438	182	97	147	130	106	91	53	44	48	41	43	35	.41	.34
Santa Cruz	629	117	211	24	231	42	123	27	46	15	7	4	11	5	.12	.11
Yavapai:																
Low altitude	585	76	251	18	110	13	139	16	30	4	23	6	32	19	.09	.09
High altitude	635	5	253	1	186	2	131	1	12	0	18	0	35	1	.003	.01
Yuma	577	86	163	11	149	21	192	31	36	9	30	12	7	2	.07	.07
Total	11,643	2,859	3,032	476	3,786	805	2,041	516	1,048	391	954	356	782	315	0.10	0.09

T=Number tested. P=Number positive.

[1] Instantaneous annual conversion rates. [2] Annual conversion rates.

NOTE: See technical note p. 961 for method of calculating annual conversion rates.

Figure 1. Percent of sensitivity of white persons 17–21 years of age who were lifetime one-county residents (*left*); percent of sensitivity of 955 students 13–24 years of age who had spent 80 percent of their lives in the State (*right*).



SOURCES: Left, reference 16; right, reference 17.

Table 2. Results of coccidioidin tests of home-raised Arizona cattle, by home altitudes

Altitude (feet)	Total		Age to nearest year												IAC rates[1]	AC rates[2]
			1		2		3		4		5		6			
	T	P	T	P	T	P	T	P	T	P	T	P	T	P		
0–500	577	86	163	11	149	21	192	31	36	9	30	12	7	2	0.07	0.07
500–1,000	770	147	79	0	321	35	177	38	83	20	72	30	38	24	.12	.11
1,000–1,500	1,447	851	420	126	389	211	202	161	191	138	135	110	110	105	.29	.25
1,500–2,000	414	271	129	60	119	87	70	56	30	24	31	22	35	22	.42	.34
2,000–2,500	1,216	728	534	198	335	278	114	84	107	76	102	78	24	14	.28	.24
2,500–3,000	668	246	104	9	142	33	88	28	133	59	114	52	87	65	.17	.15
3,000–3,500	887	126	381	28	171	21	202	25	43	8	37	9	53	35	.10	.10
3,500–4,000	1,173	246	318	38	448	93	235	48	91	33	50	15	31	19	.12	.11
4,000–4,500	746	136	55	3	125	18	238	41	128	23	112	27	88	24	.06	.05
4,500–5,000	1,099	11	268	1	300	2	202	3	37	0	96	1	196	4	.003	.01
5,000–5,500	337	10	142	2	99	5	29	1	21	1	19	0	27	1	.01	.01
5,500–6,000	373	0	162	0	103	0	31	0	28	0	37	0	12	0	0	0
Above 6,000	1,936	1	277	0	1,085	1	261	0	120	0	119	0	74	0	0	0
Total	11,643	2,859	3,032	476	3,786	805	2,041	516	1,048	391	954	356	782	315	0.10	0.09

T=Number tested. P=Number positive.
[1] Instantaneous annual conversion rates. [2] Annual conversion rates.

NOTE: See technical note p. 961 for method of calculating annual conversion rates.

and that indurations of more than 5 mm. in diameter at 96 hours would be considered positive.

The skin test agents were injected in many cattle at the same time that their blood was being collected for brucellosis serology. In each county some of the same cattle were also tested with other skin test agents, 841 with histoplasmin and 763 with haplomycin.

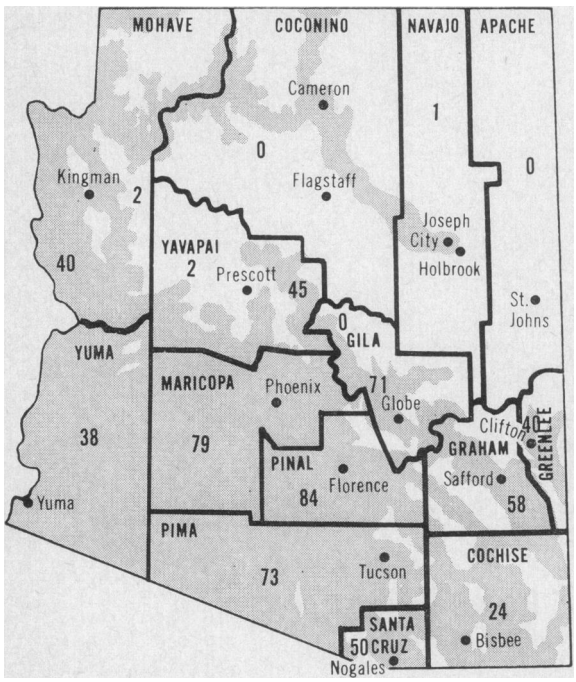
Histoplasmin lot D–2770 was also used in testing 841 of the coccidioidin-tested animals. Haplomycin lot "Phillips 4, antigen 16" was used in testing 763 of them. These two skin test agents, supplied by Dr. M. L. Furcolow and Dr. R. W. Menges of the Communicable Disease Center, Public Health Service, were injected and read by the same method used for coccidioidin.

Results

The results of the coccidioidin tests are summarized in tables 1 and 2 and figures 2 and 3. The conversion rates to a positive reaction for each geographic area were computed by a method outlined by Manos (*22*). From various areas of each county of Arizona 11,643 home-raised cattle 1–6 years of age were coccidioidin tested and 2,859, or 24.6 percent, were found to be positive.

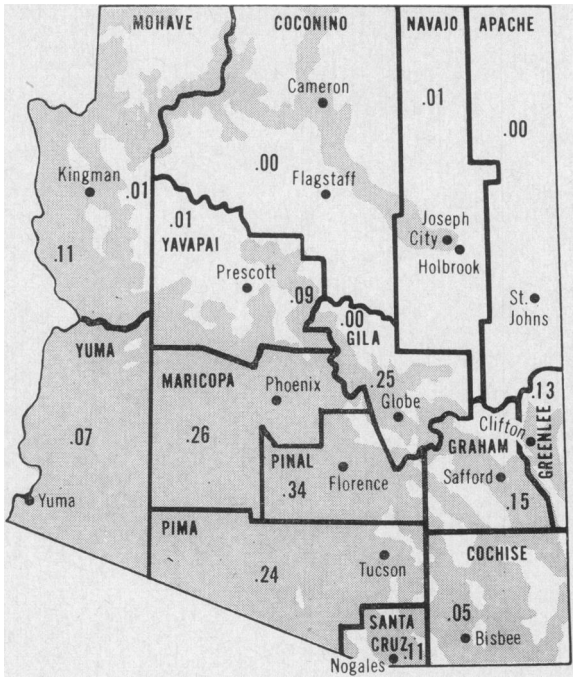
High annual conversion rates (0.24 and

Figure 2. Percent of coccidioidin sensitivity by counties in tests of 1,736 cattle 5 and 6 years of age [1] in Arizona



[1] The prevalence of coccidioidin sensitivity in persons who do not move about a great deal is comparable to the prevalence of coccidioidin sensitivity in cattle in the same area. Persons who have lived in an area for 12 years or more have about the same rates as 5- and 6-year-old cattle.

Figure 3. Annual conversion rates [1] to a positive coccidioidin test among 11,643 cattle in Arizona



[1] The annual conversion rates, calculated by the Manos method, are almost the same as the actual human infection rates.

NOTE: Only cattle that spent their entire lives on the ranch where they were born were tested. Two percentages are given for Mohave, Yavapai, and Gila Counties; one for tests within the Lower Sonoran Life Zone, the other for tests above the zone. All tests in Greenlee County were within the zone; all tests in Coconino County were above the zone.

above) were found in cattle in the three counties (Pinal, Maricopa, Pima) known to have high human conversion rates. The cattle in the low altitude areas of Gila County were also found to have high annual conversion rates, particularly the areas around the artificial lakes on the Salt River.

Medium annual conversion rates (0.11–0.15) were found in cattle in the low altitude areas of Mohave County as well as in Graham, Greenlee, and Santa Cruz Counties.

Low annual conversion rates (0.05–0.09) were found in cattle in Cochise and Yuma Counties, and the low altitude areas of Yavapai County.

Navajo County and high altitude areas of Yavapai and Mohave Counties had a few coccidioidin reactors, resulting in an annual conversion rate of 0.01 for each of the three counties.

No coccidioidin-positive cattle were found in the high altitude areas of Gila County or in Coconino or Apache Counties.

The areas of the State in the altitude range of 1,000 to 2,500 feet had high annual conversion rates (0.24 and above). The rates were lower at less than 1,000 feet altitude and became progressively lower with increases in altitudes above 2,500 feet, so that at 4,500 feet the rate became negligible (0.01), and at 5,500 feet and above it was 0.00.

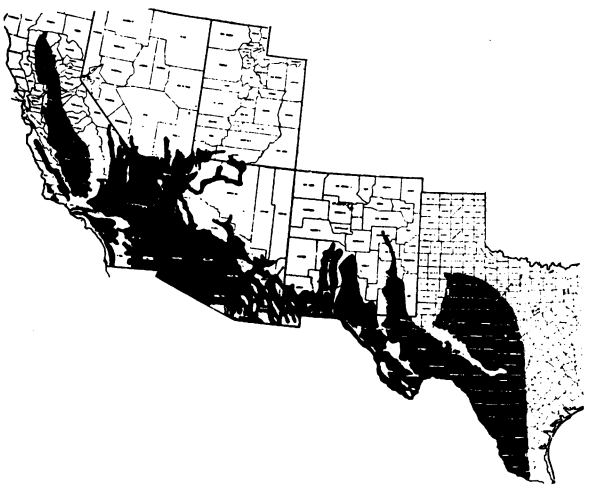
Although several herds of cattle at altitudes above 4,500 feet had been fed sizable quantities of feed raised in the parts of the State where cattle had high annual conversion rates, only a few animals in these herds were coccidioidin positive.

Of the 841 cattle tested with histoplasmin, 11 gave positive reactions, but all were also coccidioidin positive. There were 18 cattle positive to haplomycin of 763 tested; these same 18 were also coccidioidin positive. The histoplasmin- and haplomycin-positive reactions were found in cattle in areas of high endemicity for coccidioidomycosis.

Discussion

The skin test surveys on humans in Arizona that are summarized in figure 1 indicate that the number of infections is greater in south

Figure 4. The Lower Sonoran Life Zone of the United States. The endemic area of coccidioidomycosis is almost identical to the zone.



central Arizona than in the northeast part of the State. Figures 2 and 3 showing the cattle test data indicate much sharper differences of infectivity of the various areas of the State. The similarity of the endemic area for coccidioidomycosis with the Lower Sonoran Life Zone, a climate zone (fig. 4), has already been discussed (*23*, *24*).

The Lower Sonoran Life Zone of the Northern Hemisphere has high January and July temperatures and rainfall ranging up to 20 inches per year. The evaluation of three items of climate in combination, the average January temperature, the average July temperature, and the average annual rainfall, yields a good basis for estimating the prevalence of coccidioidomycosis. The July mean temperature of areas of high infectivity is above 80° F. Some infection occurs in areas with July mean temperatures as low as 77° F., but not often below this. The January mean temperature is above 45° F. in areas of high infectivity. Some infections occur where the January mean temperature is as low as 35° F., but not often below this. The annual rainfall is about 5 to 20 inches in the more obviously endemic areas. As rainfall gets progressively less than 5 inches, infectivity of the area drops. Infections do not occur in areas with more than 20 inches unless there are particularly high temperatures to reduce precipitation effectiveness.

The Lower Sonoran Life Zone in Arizona

reaches its coldest limits at just above 5,000 feet altitude in most parts of the State. However, the upper limits of the zone are affected somewhat by the latitude and the general slope of the land. Table 2 reveals the gradual drop in conversion rates as the altitude increases above 2,000 feet. The areas of the State that are below 1,000 feet have high January and July temperatures, but also have low rainfall, usually averaging less than 5 inches per year. These areas appear to be too dry for good propagation of this fungus.

Land below 5,000 feet altitude along the Little Colorado River between Cameron and Joseph City is indicated as Lower Sonoran in figures 2 and 3. This was classified at one time as Lower Sonoran (*25*) but later was dropped (*26*). Since the only positive animals found in Navajo County were 10 animals at Joseph City, fed locally raised feed, we thought it best to indicate the difference of opinion on the extent of the zone in this area (fig. 4). No tests were made on cattle in the Grand or Little Colorado Canyons; consequently, there were no positives found to affect Coconino County data.

Comparison of the data for cattle with those for persons reveals that cattle become infected at about twice the rate for persons living in the same area. A previous Arizona study revealed the tendency for the prevalence of positive skin test reactions of persons to level off after 12 years of exposure (*17*). In cattle it was found that after 6 years of exposure there was also a marked leveling off. Because of this, all animals beyond 6 years of age were eliminated from this study. This leveling off is no doubt related to the reversions of positives to negatives. The annual conversion rates from negative to positive in a previous study (*17*) on human beings, as calculated by the Manos method, was a little less than half that found for the cattle in this study when the rates were calculated by the same method.

The annual rate of conversions to positives among cattle (table 1) is almost identical to that found in skin tests of persons in Maricopa, Pima, and Pinal Counties (*10*, *12*, *13*) during the first year of exposure. Therefore, the rates for cattle (fig. 3) are indicative of the actual percent of a susceptible human population that becomes infected per year for each county.

Other studies by Maddy on cattle in these same counties in which cattle were coccidioidin tested every few months revealed that the conversion rates to positive were about double those indicated by the annual conversion rates for cattle in this study, using the Manos method. No doubt this also reflects the loss of positives among infected cattle over a period of a few years.

Comparison of data for persons and cattle also indicates that the prevalence of coccidioidin sensitivity of cattle 5 and 6 years of age (fig. 2) is about the same as that found when persons with 12 years or more of exposure in the endemic area are tested.

This study revealed for the first time that the low altitude areas of Yavapai and Mohave Counties and additional areas of Gila County are endemic for coccidioidomycosis. The absence of test results positive only to histoplasmin and haplomycin indicated that all reactions to these two test agents were cross reactions caused by *C. immitis* infections in cattle. Therefore, it is believed that the cattle tested in this study were not infected with *H. capsulatum* or *Haplosporangium parvum*.

In this study fomites, such as feeds raised in endemic areas, did not appear to be good vehicles for transmission of *C. immitis* to cattle in nonendemic areas fed these feeds.

We believe this study has served as an example of how an animal with a limited home range, that also acquires an infection common to man, can be used to delineate the geographic distribution of the infective agent. For instance, if a good blastomycin could be produced, perhaps a skin test survey of home-raised cattle in selected areas of central and eastern United States would also reveal useful ecologic data on blastomycosis.

Summary

From various areas of each county of Arizona, 11,643 home-raised cattle 1–6 years of age were coccidioidin tested and 2,859, or 24.6 percent, were found to be positive. Whereas previous human skin test surveys have given only indefinite indications of the extent of the endemic areas, this study revealed rather definite boundaries and the relative infectivity of

various parts of the endemic area of the State. The endemic areas were found to be practically co-terminous with the Lower Sonoran Life Zone.

The low altitude areas of Yavapai and Mohave Counties and additional areas of Gila County were established as endemic areas for the first time, and several areas of the State of above 5,500 feet altitude, previously in a suspect classification, were found to be noninfective to cattle.

The annual conversion rates for cattle, calculated by the Manos method, were found to be almost identical with the actual human infection rate per year in those counties where this relationship was studied.

TECHNICAL NOTE

To calculate the instantaneous annual conversion rates and the annual conversion rates of cattle in this study, the Manos method was used. The plotting of the complements of the sensitivity prevalence rates, p, against age, t, on semilogarithm paper in reverse is equivalent to plotting π against t on ordinary graph paper, where $\pi = \log_e \frac{1}{1-p}$. The slope r of such a graph at any point is equal to $\frac{d\pi}{dt}$ which is equal to $\frac{\frac{dp}{dt}}{1-p}$, that is, the instantaneous rate of change in prevalence divided by the proportion of negative reactors at that age. If there is no reversion, the slope r is therefore equal to the instantaneous conversion rate. This is true only in an abstract sense, however, if the conversion rate varies with time.

If t is expressed in years, then r is the instantaneous annual conversion rate. It can also be thought of as the annual attack rate, where the attacks that occur on the nonreactors result in conversions, but where some of the attacks occur on animals already positive. The proportion of conversions that would actually be observable in a 1-year period would be equal to $1-e^{-r}$. This quantity is always less than r, but the difference is small except in highly endemic areas. It is this quantity that is commonly called the annual conversion rate in the literature.

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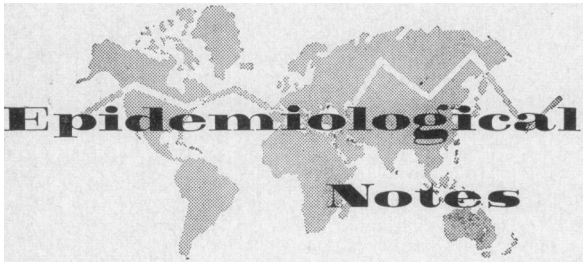

Deaths from Electric Current

Accidental deaths caused by electric current numbered 1,030 in 1957. Of these, an estimated 650, or 63 percent, resulted from injuries sustained while at work. The category of work injuries with the largest number of deaths, estimated at 150, was that involving contact between the booms of cranes or similar machines and high-tension wires. Decedents in these accidents included helpers and other workers who were holding guy wires or were otherwise in contact with the machines, as well as operators.

The item on the death certificate asking for the decedent's usual occupation yields minimal data because of the frequent use of general terms such as "maintenance worker" or "laborer." About 120 of the decedents, however, were listed as linemen, with another 120 reported as electricians. While persons in these occupations have a higher than average exposure to lethal voltages, they probably have a greater than average awareness of the hazards and have received more comprehensive safety training concerning electricity than most other workers. Nonetheless, the fatalities represented by these occupations contributed roughly 37 percent of work injury deaths from this cause.

The following tabulation, which classifies deaths according to the manner of injury and whether or not injury took place at work, is based on a 10 percent sample of deaths assigned to accidents caused by electric current (category E914, International Lists). Data include only deaths occurring within the continental United States.

Manner of injury	*Number of deaths*
Work injury:	
Contact of cranes or similar machines with high-voltage lines	150
Other work contact with high-voltage lines	290
Other specified work injuries	120
Unspecified work injuries	90
Nonwork injury:	
Electrical tools and equipment, not at work	80
Accidents involving household appliances	50
Accidental contact at play	90
Other specified nonwork injuries	80
Unspecified accidents, not stated as work injuries [1]	80
Total	1,030

[1] Including 20 deaths specified as from nonwork injuries.

—WARREN W. MORSE, *analytical statistician, National Office of Vital Statistics, Public Health Service.*