METEOROLOGICAL ASPECTS OF AIR CLEANING

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Although there are many topics which should be mentioned while considering meteorological aspects of air cleaning, this opportunity is is being used to review the effects of vertical temperature gradient on stack gas behavior and to show some photographs from the National Reactor Testing Station illustrating typical conditions.

The appearance of stack effluent plumes is regulated largely by the configuration of the vertical gradient of air density, or temperature. With respect to a high stack on nearby level terrain there are five different configurations of the vertical temperature gradient that occur, and these usually have a diurnal cycle.

These configurations, along with the expected behavior of an effluent plume, is shown schematically in Figure 1.

Looping - occurs with a superadiabatic (very unstable) temperature lapse rate. The stack effluent, if visible, appears to loop because of relatively large thermal eddies in the wind flow. Diffusion is rapid, but sporadic puffs having strong concentrations are occasionally brought to the ground near the base of the stack. Looping is favored by fair weather with relatively light winds.

- occurs with a gradient lying between dry adiabatic and isothermal. The effluent stream is shaped like a cone with axis horizontal. The distance from the stack that effluent first comes to the ground is greater than with looping. Mechanical mixing predominates. Although this condition is ideal for calculating ground concentrations by means of diffusion equations, it does not often persist except during cloudy, windy weather. During fair weather, it is transitional and is most likely to occur only for a brief interval about sunset as the strong daytime lapse condition is converted to an inversion.

Fanning - occurs with temperature inversion conditions. Such laminar flow may also occur in a layer of air that is isothermal, depending on wind speed and roughness of terrain. The stack effluent diffuses practically not at all in the vertical, and the effluent trail may resemble a meandering river, widening very gradually with distance from the stack. Depending on the duration of the stable period and the wind speed at stack level, the effluent may travel for many miles with little dilution. With level terrain ground concentrations of effluent do not occur; however, isolated objects which extend up into the plume, or hillsides which are encountered, can receive large concentrations even though miles away from the stack.

Lofting - is usually associated with the transition from lapse to inversion, but may persist at times for one to several hours. Occasionally the inversion does not build up to stack level during an entire night due to interference of winds and/or cloudiness. The zone of stronger effluent concentration, as shown by shading, will depend on the height of the inversion. It is caused by trapping by the inversion of effluent carried into the stable layer by turbulent eddies that penetrate the layer for a short distance.

Except when the top of the inversion is very near the ground, this type may be considered as the most favorable diffusion situation to be encountered. The inversion prevents effluent from reaching the ground; and at the same time the effluent may be rapidly diluted in the lapse layer above the inversion.

Fumigating - occurs at the time that the nocturnal inversion is being dissipated by heat from the morning sun. The lapse layer begins at the ground and works its way upward, rapidly in summer, but slowly in winter. At some time the inversion is just above the top of the stack, and acting as a lid, forces the effluent stream to dilute within the shallow lapse layer near the ground. Large concentrations are brought to the ground along the entire effluent stream by thermal eddies in the lapse layer. Sustained concentrations near the ground will be higher with this situation than with any other.

Smoke experiments were performed by the Weather Bureau using the 250-foot Chemical Plant stack to determine the validity of the associations of plume behavior with the temperature gradient configurations just shown. Pictures of smoke behavior during some of these experiments are shown on the slides to follow.

Figure 2 - Looping condition. 0945 MST, April 9, 1952. Temperature lapse rate was more than three times the dry adiabatic rate (which is 0.54°F./100 ft.) in the lower 250 feet.

Figure 3 - Coning conditions. 1910 MST, April 16, 1952. Lapse rate in lower 250 feet was slightly less than the dry adiabatic rate.

Figure 4 - Fanning condition. 0722 MST, April 11, 1952. Pronounced temperature inversion from the surface to somewhere above 500 feet.

Figure 5 - Lofting condition. 1945 MST, April 16, 1952. Inversion, surface to 200 feet, with lapse above 200 feet.

Figure 6A - Fumigating condition. 0746 MST, April 11, 1952. Lapse layer has worked up just to the 250-foot level. Note that eddies in the lapse layer have begun to penetrate the smoke-bearing layer, as evidenced by streamers extending downward from the concentrated plume.

Figure 6B - Fumigation (continued). 0748 MST. The first streamer reached the ground about 10 stack lengths from the stack about two minutes after streamers began to decend. Inversion based about 300 feet.

Figure 6C - Fumigation (continued). 0802 MST. By this time strong smoke concentrations appeared on the ground along almost the entire visible length of the plume. Note that the concentrated smoke layer aloft that was visible in Figures 4, 6A and 6B is no longer visible. The entire plume appears to have been mixed downward. Inversion based about 380 feet.

It was mentioned earlier that the types of temperature gradient usually have a diurnal cycle. This is illustrated by figure 7 which gives plots of temperature soundings on a clear day. Note that the fumigating condition (for a 250-foot stack) was present at 0900 MST. By 1100 MST the inversion had dissipated, and looping conditions prevailed until the inversion began to form in the evening. Lofting conditions were present at 1830 and 2000 MST, and fanning conditions at 0200 through 0700 MST the following morning.

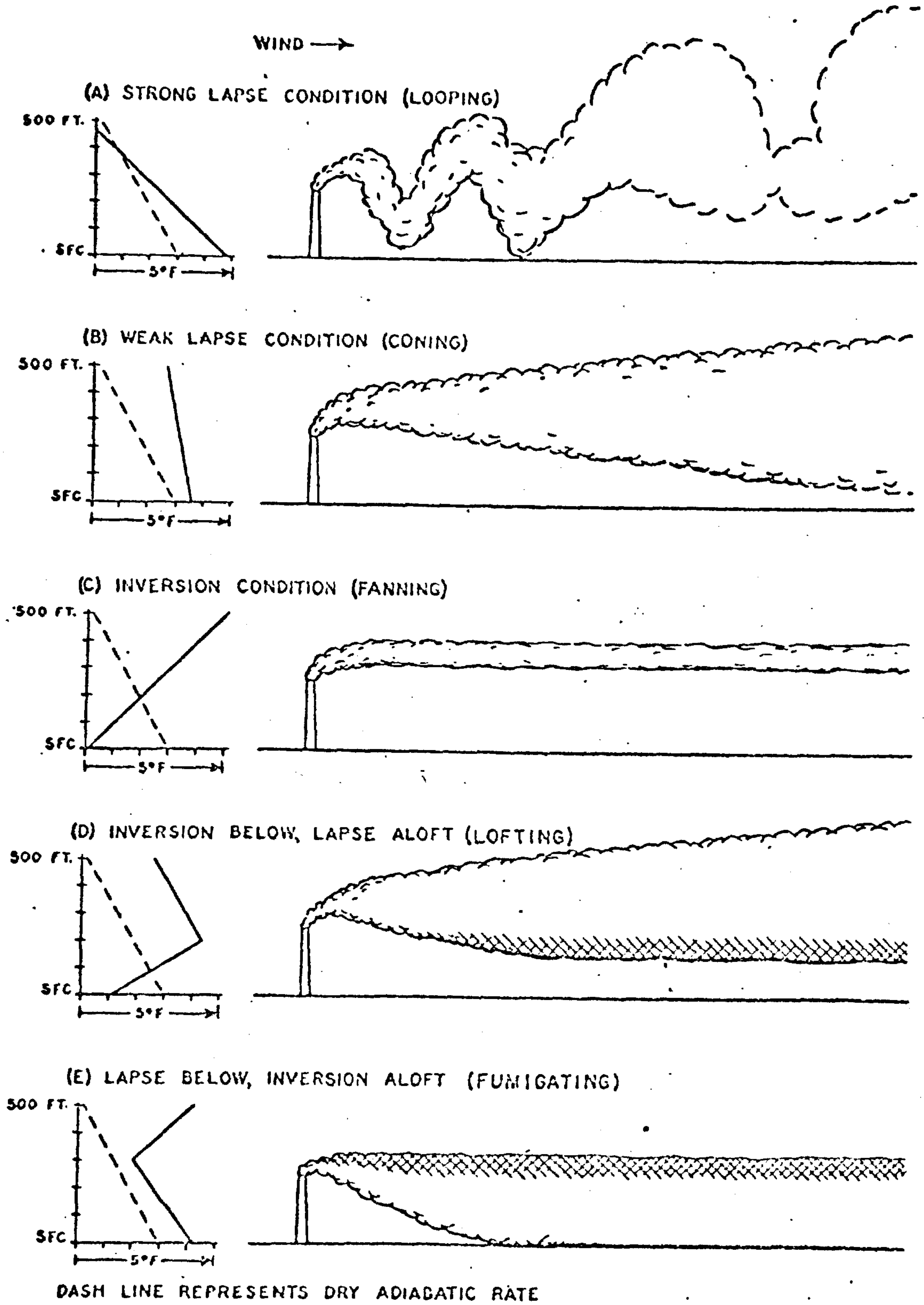

Fig. 1--Schematic representation of stack gas behavior under various conditions of vertical stability.

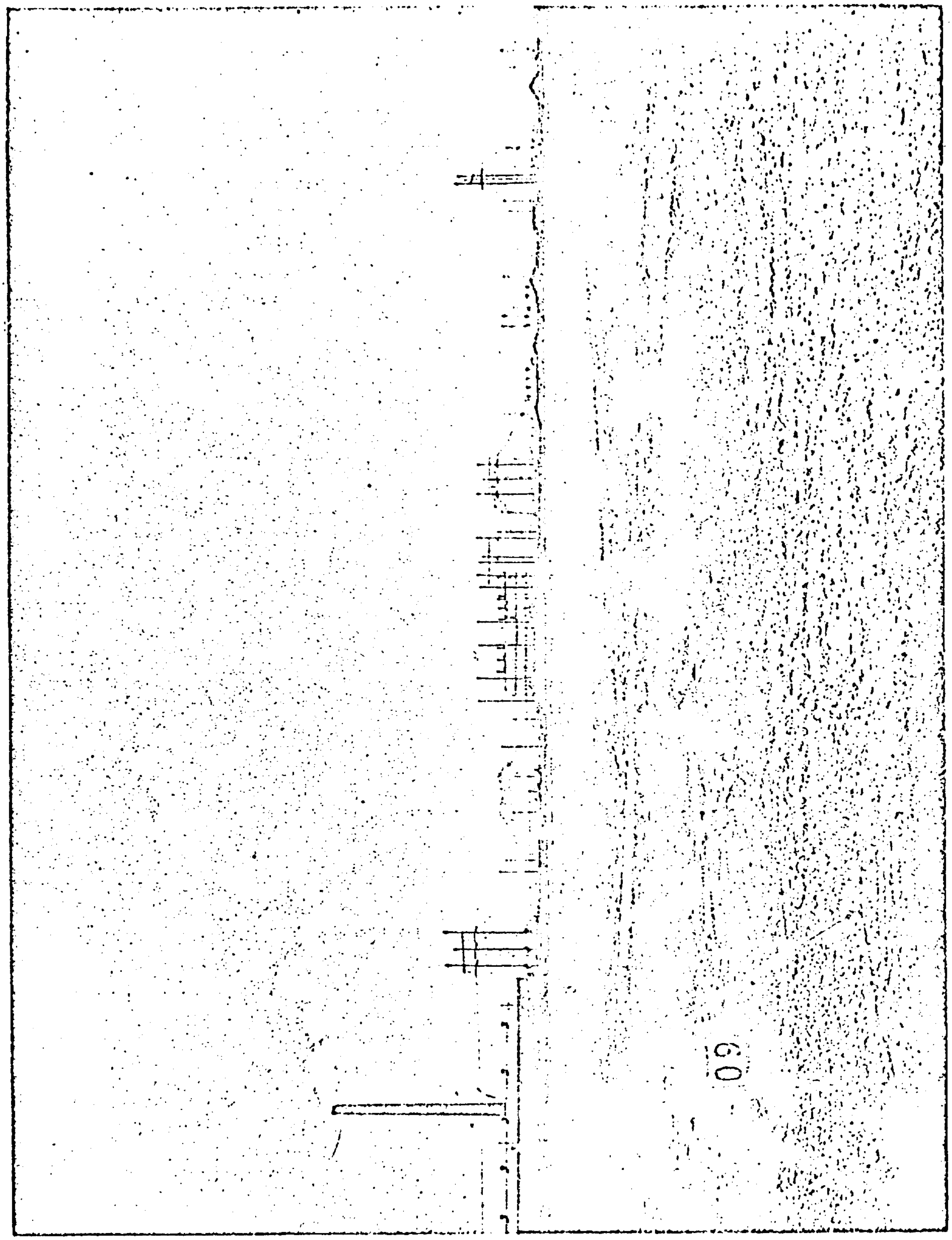

Fig. 2

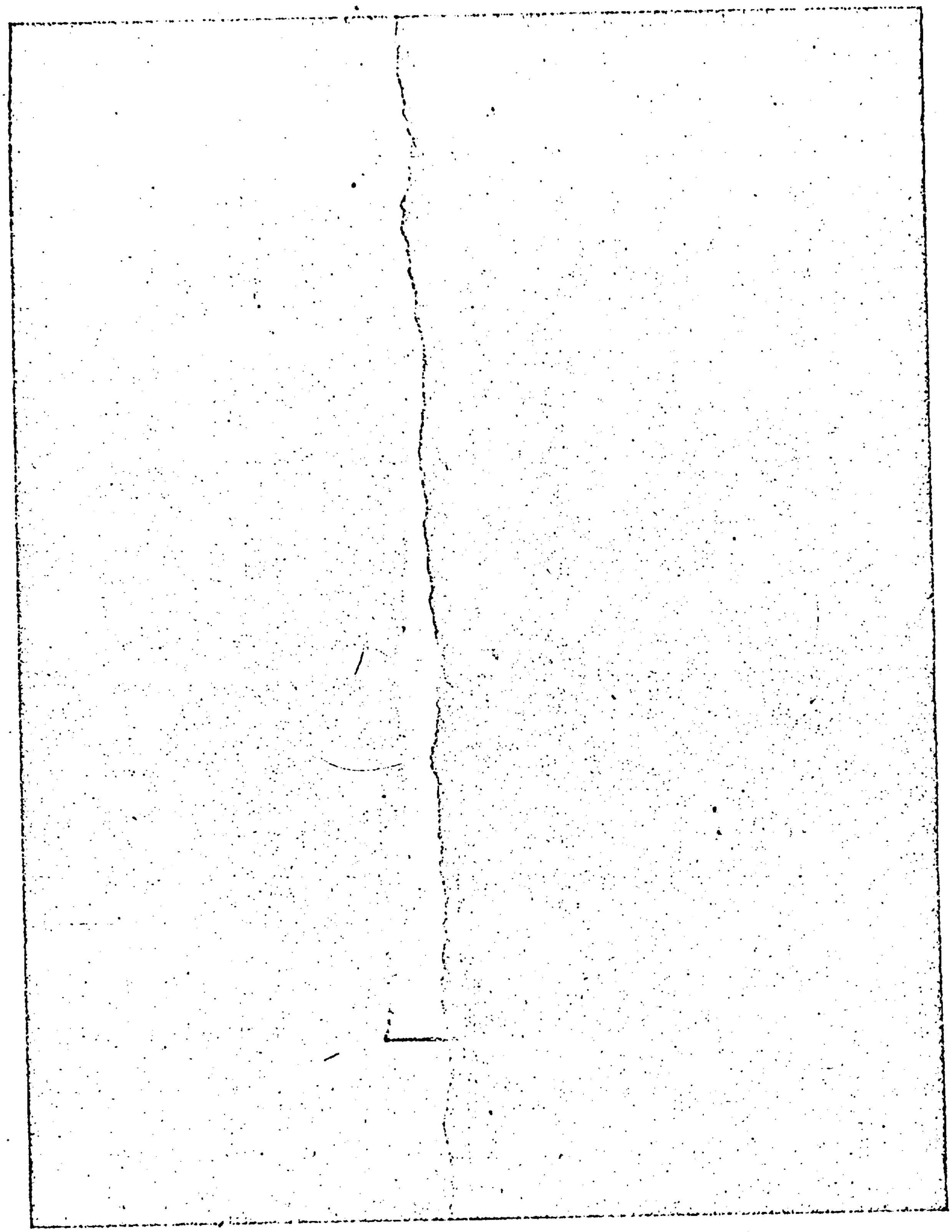

Fig. 3

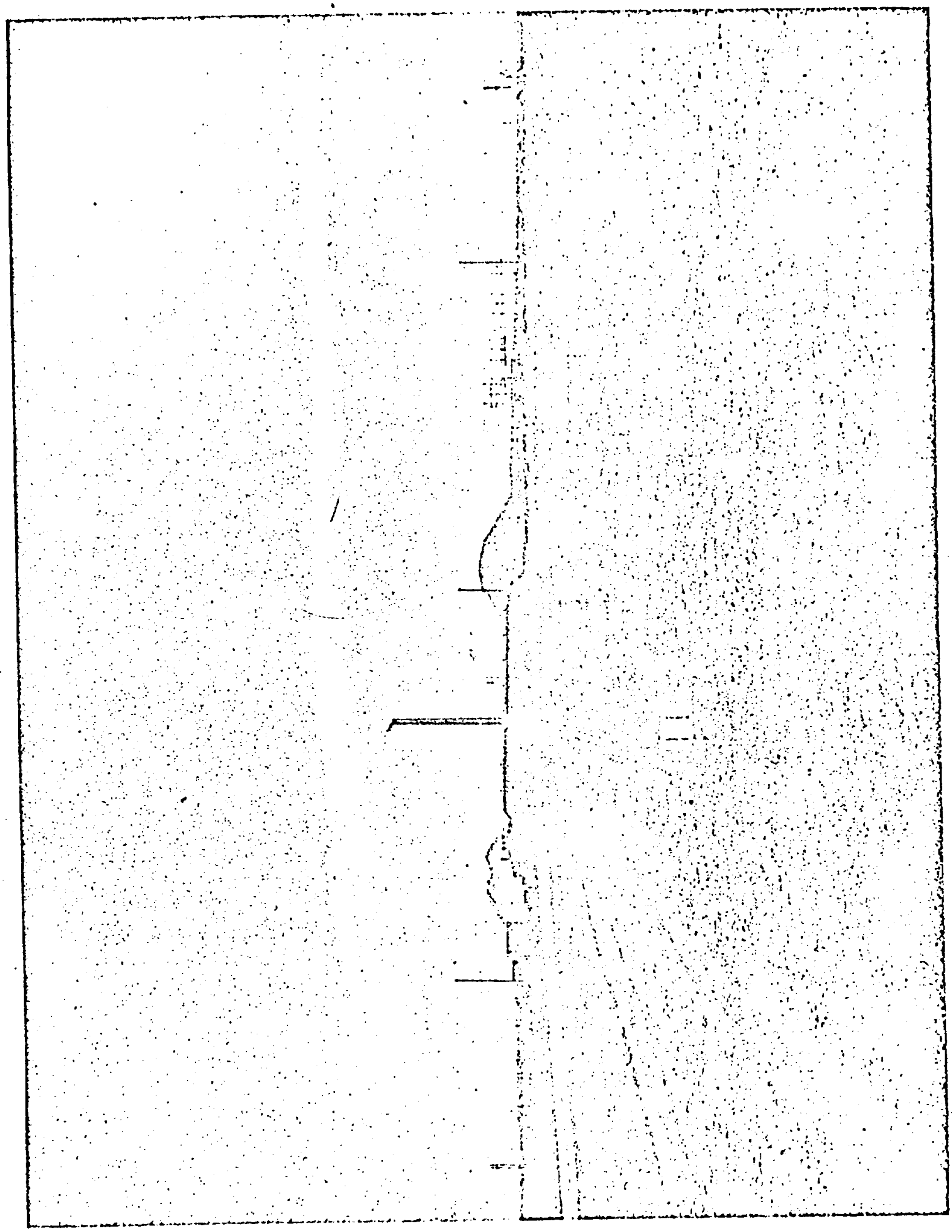

Fig. 4

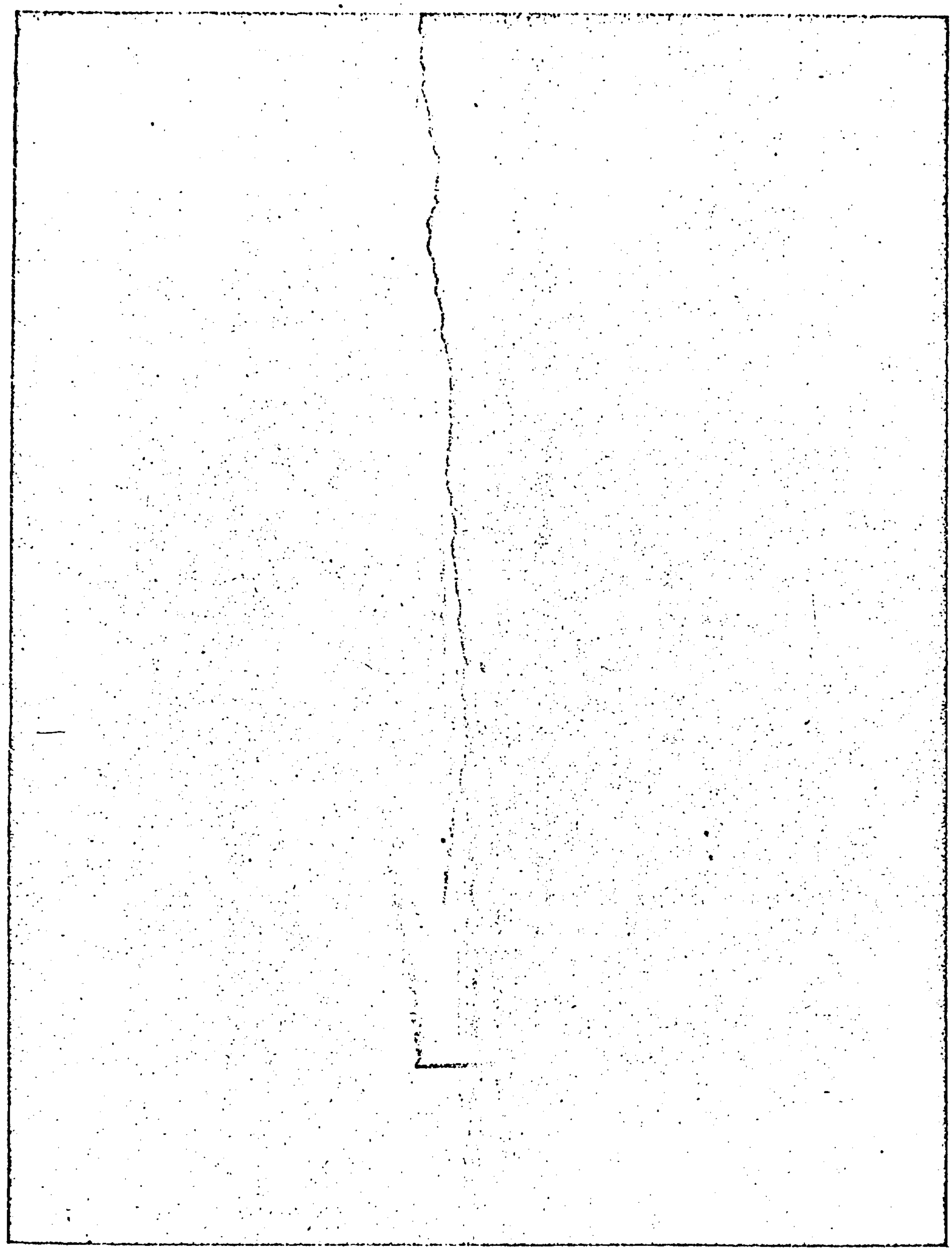

Fig. 5

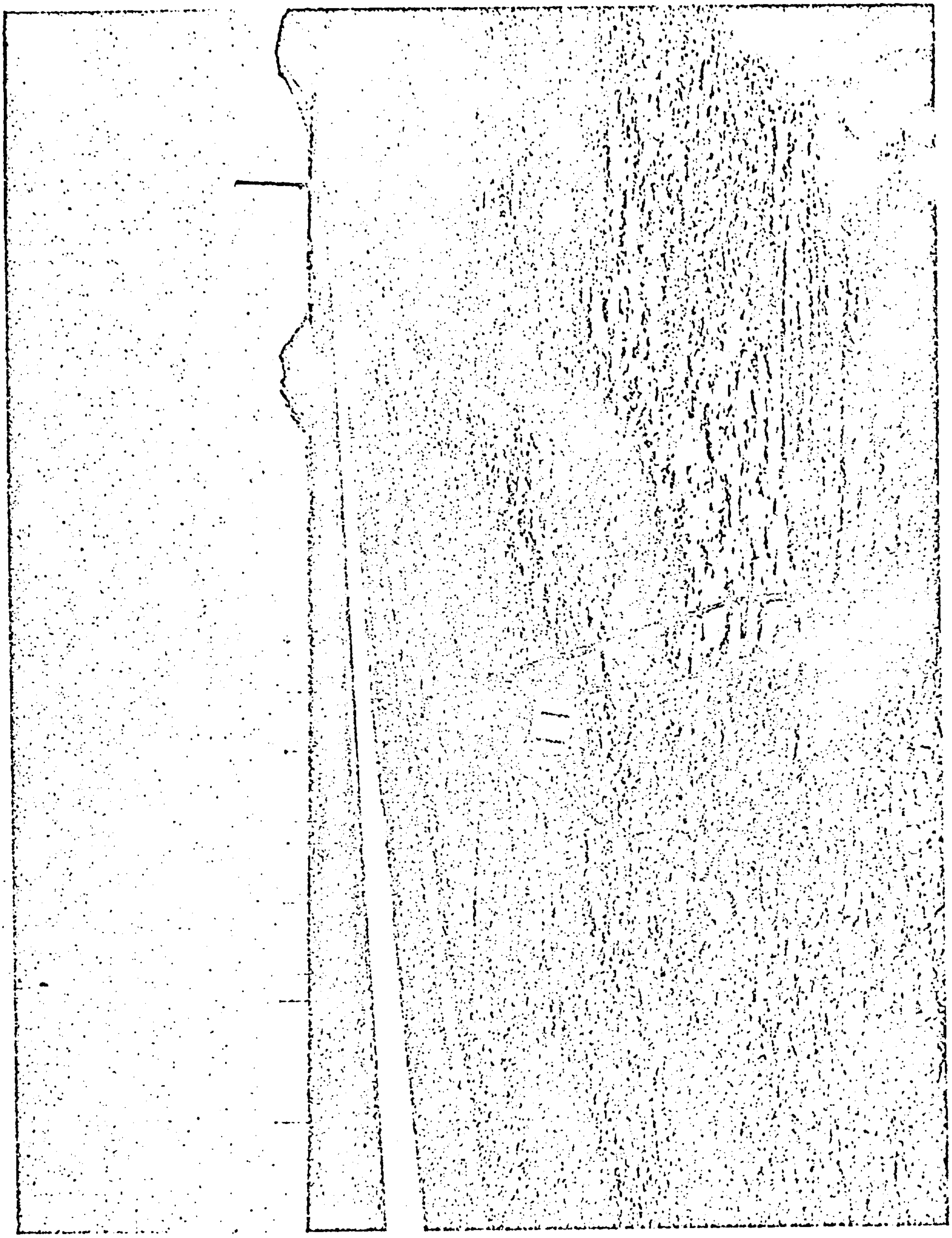

Fig. 6A

Fig. 6B

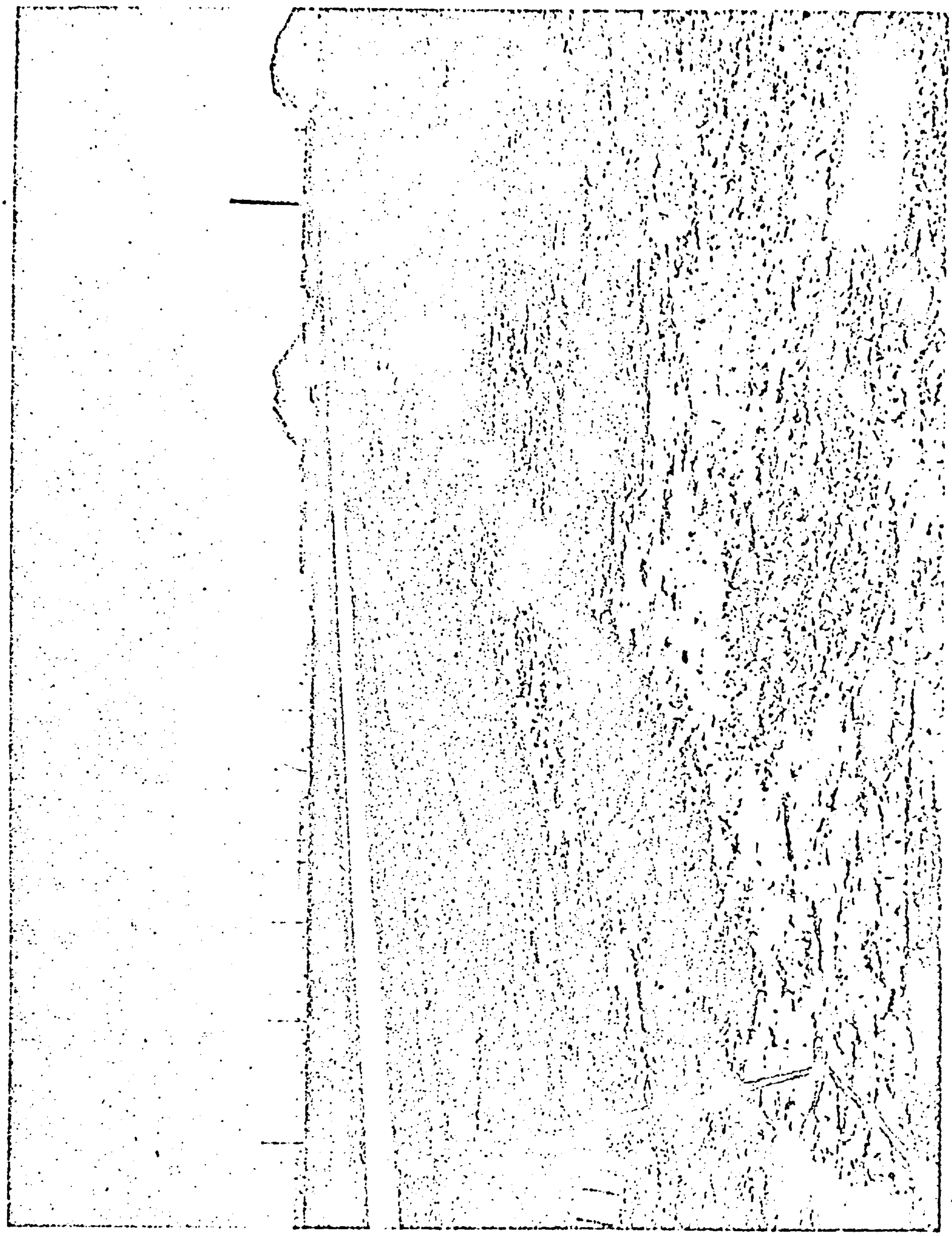

Fig. 6C

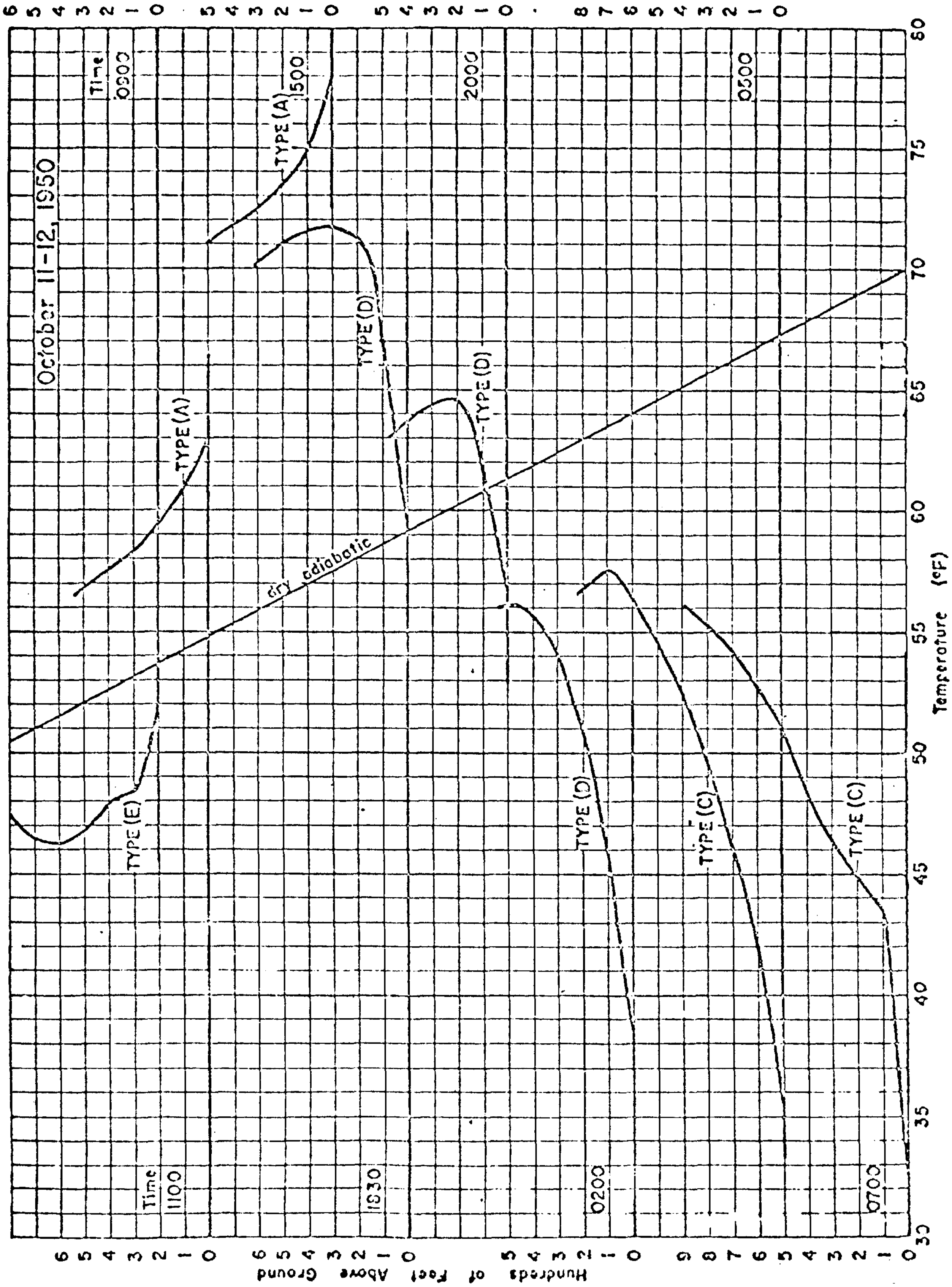

Fig. 7--Temperature soundings on a day with clear skies and light winds.