# LETTERS TO THE EDITORS

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## Artificial Stimulation of Rain

DURING the past summer here, the South African Council for Scientific and Industrial Research, with the assistance of the Division of Meteorology and the South African Air Force, arranged a series of experiments to examine the practical possibilities of the artificial stimulation of precipitation.

As natural conditions in the Transvaal in summer are particularly favourable for the development of convective cloud, the experiments were directed mainly to an investigation of the effects produced by the release of 'dry ice' into developing cumulus cloud or incipient thunderstorms.

Experiments were carried out from January to April, 1948, on days on which fairly numerous thunderstorms were expected to occur, and selected clouds were 'seeded' with 'dry ice', development being observed by means of a 3-cm. radar, the aerial system of which consisted of a rotating parabolic reflector producing a 2°-beam, the elevation of which was manually adjustable. Display was by PPI, and arrangements provided for the aircraft position to be indicated directly on the screen. A photographic record of the screen on 16-mm. film was made automatically at predetermined intervals.

'Dry ice', crushed to $\frac{1}{4}$–$\frac{3}{4}$ in. mesh, was dropped within, or 200–400 ft. above the tops of, thirty-six cumulus clouds on six days, and the following is a summary of the results of the photographic record of the radar display.

| | | | |
|---|---|---|---|
| 1. | No echoes observed .. .. .. .. .. | 4 | occasions |
| 2. | Echoes doubtful owing to permanent echoes and close-in clutter .. .. .. .. .. | 8 | ,, |
| 3. | Echoes of less than 15 min. duration : | | |
| | (*a*) First appearance in less than 30 min. .. | 4 | ,, |
| | (*b*) ,, ,, between 30 and 90 min. .. | 4 | ,, |
| | (*c*) ,, ,, after more than 90 min. .. | 2 | ,, |
| 4. | Echoes of more than 15 min. duration : | | |
| | (*a*) First appearance in less than 30 min. .. | 7 | ,, |
| | (*b*) ,, ,, between 30 and 90 min. .. | 5 | ,, |
| | (*c*) ,, ,, after more than 90 min. .. | 2 | ,, |

'Dry ice' was dropped when air temperatures were between 7° F. and 29° F., and at a rate ranging from 20 lb. to 200 lb. per minute, into cumulus cloud which observation showed to consist of supercooled water droplets. Echoes from clouds seeded at the lower temperatures occurred more consistently than those from clouds seeded at temperatures nearer freezing; but from the limited number of experiments, no conclusions could be reached regarding the comparative effectiveness of the different quantities of 'dry ice' employed.

The experiments indicate that the use of 'dry ice' undoubtedly had the effect of inducing precipitation at an earlier stage in the life of the cloud than is normally the case. Such precipitation was often associated with lightning and, on one occasion at least, lightning was observed below a cloud fifteen minutes after it had been seeded, although its imminence was not suggested by the development and general appearance of the cloud.

The information at our disposal is not sufficient to draw any conclusions as to whether this stimulated precipitation affected the intensity of rainfall which would probably have occurred later from the seeded clouds, and whether it prolonged its duration or extended the area over which it fell.

Temperature observations made during these flights with a sensitive electrical thermometer show remarkably large temperature variations in horizontal flight. In one case a difference of 7° F. during a few miles of horizontal flight in clear air at about 20,000 ft. was noted. Temperatures recorded within cumulus clouds were frequently lower than those observed in clear air at the same pressure just outside the cloud.

We wish to thank the Director of the Division of Meteorology, the Director-General and officers of the South African Air Force, and Messrs. National Chemical Products for their generous co-operation and help in these experiments.

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## Condensation of Water Vapour Below 0° C.

AN apparatus has been constructed which permits ultra-microscopic observation of individual condensation nuclei in an expansion chamber. The chamber may be cooled by immersion in a low-temperature bath, and the air in it supersaturated on further cooling by sudden small expansions. The object has been to study cloud formation at temperatures below 0° C., particularly in order to discover under what conditions ice crystals appear and whether they are the result of direct sublimation from vapour to ice or of the condensation and subsequent freezing of water droplets. This question has considerable meteorological importance, since the presence of ice crystals in a cloud is often supposed to be essential to the development of rain.

*Outdoor air.* Experiments with outdoor air have shown that above — 32° C. condensation occurs almost entirely in the form of water droplets, and that ice nuclei, if present, do not exceed 1 per c.c. When the final temperature at the end of the expansion falls below a threshold, which appears to vary between — 32° C. and — 35° C., clouds are usually seen to contain ice crystals in numbers up to 20 per c.c., although water droplets remain far more numerous and may be about 1,000 per c.c. The number of ice crystals does not noticeably increase when final temperatures are lowered from — 35° C. to — 40° C., nor with increasing supersaturation. Between — 41° C. and — 42° C., however, a very sharp increase occurs, and below — 42° C. clouds are composed mainly, if not entirely, of ice crystals.

An important feature of all ice crystal formation in outdoor air is that it occurs only when the air, initially saturated with respect to ice, is cooled by expansion to the dew-point (to saturation with respect to water). This strongly suggests that the crystals are formed not by direct sublimation but by the condensation and immediate freezing of water droplets (no case has been observed of the freezing of a fully grown water droplet). It is therefore proposed that such ice nuclei should be known as 'freezing nuclei', and that the term 'sublimation