

AN EXPERIMENTAL INVESTIGATION OF THE SHATTER OF SALT PARTICLES ON CRYSTALLIZATION

By James P. Lodge and Ferdinand Baer

University of Chicago¹

(Manuscript received 8 February 1954)

The elegant work of Dessens (1946) on the capture of haze droplets on spider webs, and subsequent study of their nuclei, raised one concomitant question which has not yet been answered unequivocally. Dessens observed that the final crystallization of the droplet nucleus was sometimes accompanied by violent shattering of the particle, and this has been postulated as a mechanism for obtaining both smaller and more numerous salt particles from primary sea-spray droplets. His method suffers two drawbacks, however: first, it is very tedious to examine enough particles to evaluate statistically the frequency of this event, and second, the presence of the spider web makes it uncertain that the data obtained are applicable to particles in the free air.

The writers used the recently developed Millipore analytical methods (Lodge, 1953) to study this problem. The technique allows the determination of both size and number of salt particles with considerable precision down to less than 0.5- μ diameter.

The apparatus consisted of a vertical glass column, 2.5 m high and 8.5 cm in diameter. The top and bottom were closed with rubber stoppers; the lower one was provided with one tube for the introduction of 3 per cent salt brine and another, bent into an inverted J, which delivered a jet of air downward against the surface of the solution. The interaction of this jet with the brine, then, generated bubbles and spray droplets which acted as a source of the salt particles used in this experiment. The stopper in the top of the column had a single hole, through which a closely fitting rubber tube passed. A standard Millipore holder, attached to this tube, hung a short distance down into the column; hence, all air entering the column through the jet left through the Millipore, and sampling was quantitative.

The entering air was metered, filtered and, when desired, humidified. Relative humidity was controlled inside the column by an electrical heating jacket, about 1.4 m long, beginning 30 cm above the brine surface, which was capable of producing air temperatures as high as 80C at the center, thus dropping the relative humidity to as low as 10 per cent. The incoming air was adjusted to give a flow rate up the column (assuming a flat velocity profile) of 2 cm/sec. At this velocity, all particles smaller than 25 μ would have been carried up the tower. Thus, when heat was applied, all particles spent at least 70 sec in the heated zone.

After sampling for 10 min, the Millipore filters were tested in the usual manner to develop the characteristic reactions for the presence of chloride particles, and examined under the microscope (Lodge, 1953). The reaction sites were counted according to eight size classes, and from the observed sizes of the sites the original sizes of the salt particles could be determined (Lodge and Fanzoi, to be published). A typical sample showed about 10^8 particles, based on the count of a suitable aliquot (usually *about* 0.003).

Pairs of runs made consecutively agreed very well, both in particle-size distribution and in absolute number of particles. Greater variations were noticed among experiments done on different days, so runs were always made in pairs, one at reduced relative humidity, the other near saturation, without heating.

Had the type of shatter postulated by Dessens occurred, it would be expected that heating would increase the total number of particles, simultaneously causing a shift toward smaller sizes in the distribution curve. Instead, no effect whatever was noticed in four pairs of runs. Data for a typical pair of runs are shown in table 1.

Next, the possibility was considered that the transit time of the particles through the heated zone was too short to allow for complete evaporation. Therefore the column was run without a Millipore in place, until a steady state had been reached. Then the air was turned off for 10 min, a time calculated to be sufficient to allow a large portion of the particles to settle back down the tower. Finally the Millipore was put in place, and the air was again run for 2 min, the approximate time for a particle just above the brine surface to reach the filter. Hence, with the heater running, many of the particles remained in the heated zone for some 12 min at 10 per cent relative humidity. The data were again indistinguishable for the heated and unheated cases.

TABLE 1. Effect of drying on size distribution of sodium chloride.

Dry diameter	No. at 100% R.H.*	No. at 10% R.H.*
<1 μ	64	65
1-2 μ	81	82
2-3 μ	46	47
3-4 μ	41	28
4-5 μ	19	18
5-6 μ	16	9
6-7.5 μ	6	2
>7.5 μ	1	0
Total	274	251

* Number in an 0.28 per cent aliquot.

¹ The research reported in this paper has been sponsored by the Geophysics Research Directorate, Air Force Cambridge Research Center, under Contract AF19(604)-618.

While it is realized that this does not represent an exact duplication of common meteorological conditions, it appears that shatter, if any exists, should be more pronounced at the high temperatures, and hence high evaporation rates, used in this experiment. It was not possible to ascertain visually whether the particles arriving at the filter were wet or dry. However, 12 min at 10 per cent relative humidity would seem more than sufficient for drying. For example, the formula of Howell (1949) gives a time of the order of only 0.3 sec for the evaporation of droplets of the size involved here.

It is concluded that the type of shatter proposed by Dessens cannot play any important role in meteorological phenomena. The reason for this is very probably the following: the phenomenon of shatter, or decrepitation, on drying is well known for large crystalline aggregates, being caused by the entrapment of water inside an outer crystalline shell (Ranz and Marshall, 1952). It thus represents the failure of

solute diffusion within the drop to keep up with evaporation. In large drops, a millimeter or so in diameter, diffusion times through the drops are of the order of tens of seconds, and so such behavior is not surprising. However, in droplets of the size considered here, these times are instead fractions of a millisecond, and hence very fast compared with evaporation. Thus, the absence of shatter in particles in the size range considered is in accord with known principles of evaporation and diffusion.

REFERENCES

- Dessens, H., 1946: Les noyaux de condensation de l'atmosphère. *C. R. Acad. Sci. (Paris)*, **223**, 915.
- Howell, W. E., 1949: The growth of cloud drops in uniformly cooled air. *J. Meteor.*, **6**, 134-149.
- Lodge, J. P., 1953: *A new technique for the analysis of micron-sized particles*. Pap. given before 124th Nat. Meeting, Amer. chem. Soc., Chicago, 6-11 Sept.
- Ranz, W. E., and W. R. Marshall, Jr., 1952: Evaporation from drops. *Chem. Engr. Progress*, **48**, 173.