counts and the specific gravity, the surface area was obtained, using the formula

$$A = 236.1\ (n/s^2)^{1/3} \quad \ldots\ldots\ldots\ldots \quad (1)$$

where A=surface area in square feet per 100 lbs., s=specific gravity of the sand, and n = number of grains per gram in any size of separation.

This method of obtaining surface area is essentially the same as that described by Edwards and uses the basic

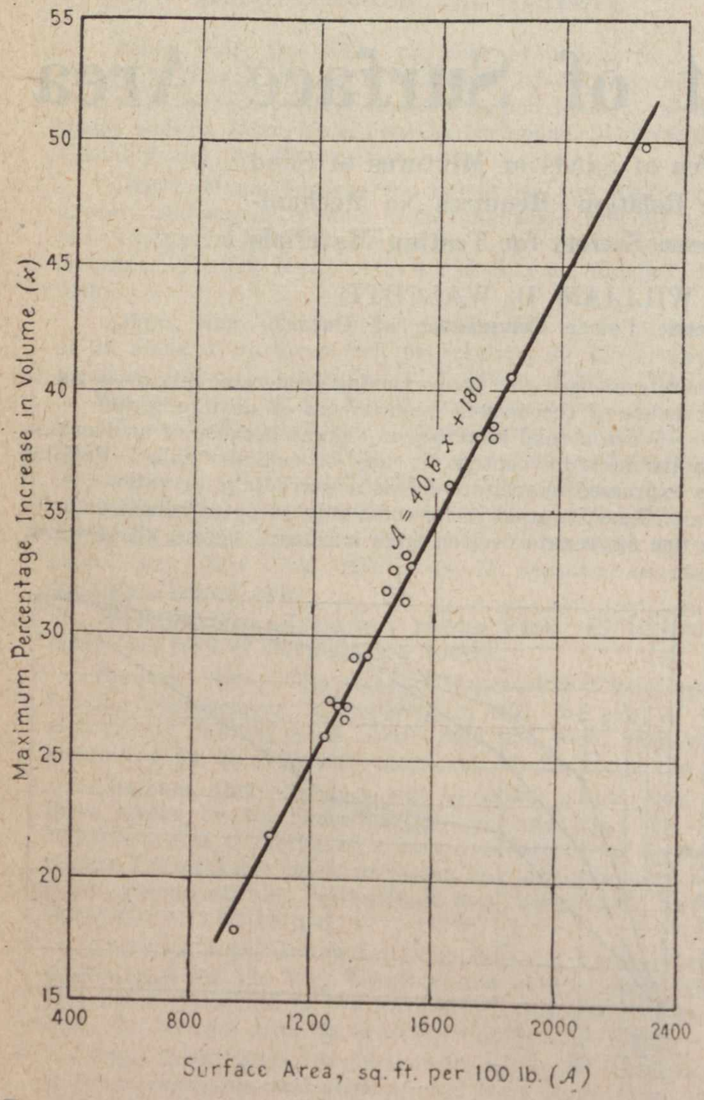

Fig. 3—Relation Between Surface Area and Maximum Bulking for Graded Sands Embodying Results Shown in Table 1

assumption, before noted, that the individual particles of sand are spheres. The surface area for any size as determined by the above formula is called the "unit area" for that size.

The increase in volume resulting from additions of moisture was obtained indirectly by determining the weight per cubic foot of the material, first dry and then moist. Both ⅛ and ¼-cu.-ft.-capacity cubical measures were used at different times. The measure was filled by means of a cylindrical shell, open at both ends. This was placed in the measure, filled with the sand under test and slowly withdrawn. The capacity of the cylinder being slightly greater than that of the measure, an excess of material remained in the latter when the cylinder was removed. This excess was struck off with a straight edge. Several determinations were made on each sand and the results averaged. It was found that the method gave concordant results.

To obtain sands of different degrees of moisture, a predetermined amount of water was added to the dry sand and thoroughly worked into it by kneading.

Knowing the weight per cubic foot of the sand, both dry and moist, the percentage increase in volume due to the added moisture was calculated from:—

$$P = 100\ [W_1\,(1 + r) - W_2] \div W_2 \quad \ldots\ldots \quad (2)$$

where P = per cent. increase in volume, r = ratio of water added to weight of dry material, W_1 = weight per cubic foot of dry material, and W_2 = weight per cubic foot of moist material.

Fig. 1 shows the percentage increase in volume obtained in this manner for three sands: a fine, a medium and a coarse. The mechanical analyses of the same sands are shown in Fig. 2. These curves are representative of those obtained throughout this investigation.

A study of these tests revealed the interesting fact that the maximum percentage increase in volume, or bulking, is related to surface area. When plotted against surface area the points fall approximately on a straight line (Fig. 3). The equation of this straight line is

$$A = 40.6\,x + 180 \quad \ldots\ldots\ldots\ldots \quad (3)$$

in which A = surface area in square feet per 100 lbs. and x = maximum increase in volume in per cent.

It may seem odd that the relation between bulking and surface area is independent of the percentage of water used to cause it. This would not be so were it not for the varying

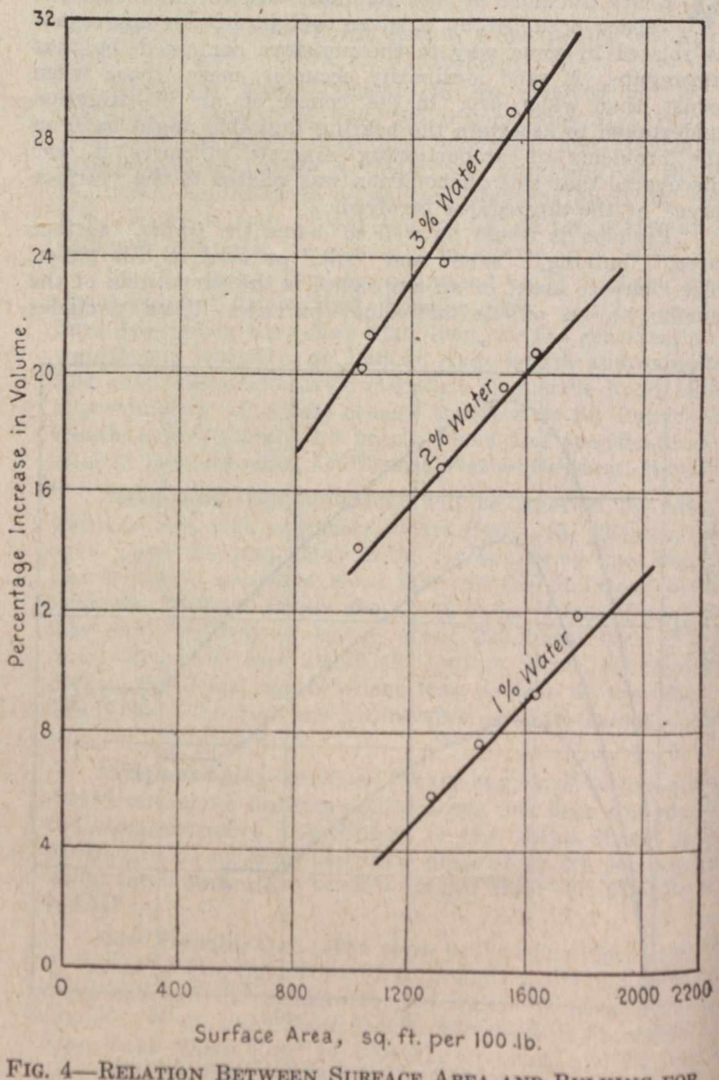

Fig. 4—Relation Between Surface Area and Bulking for Different Moisture Content

silt contents of the sands. Fig. 4 shows a relation between bulking and surface area for one, two and three per cent. additions of water. However, to show this relationship it was necessary to plot only results from sands having approximately equal silt content. Other sands of different silt content would not conform to these curves.

Any silt contained in a sand will commence to absorb moisture as soon as water is added. This absorbed water takes little or no part in the bulking phenomenon. It is the