sample of silica or a particular piece of turbid glass. For this reason, in concluding our work, we have standardized four of our apparatus by the method described above and have then actually measured the strength of light in the beam opposite the end of the illuminometer telescope. These measurements were made by Sergeant 1st Class, V. D. Charleston, by placing at right angles to the beam of light and just opposite the end of the telescope, a piece of translucent glass which transmits a known fraction of the incident light, and then measuring the brightness of the rear side of this glass. In this way it was found that the intensity of illumination in the Tyndall beam for the four different instruments selected as typical was 638, 628, 621 and 689 foot candles. This makes possible a fairly close reproduction of the instruments even if the standard Corning Opal Bulbs should all be destroyed.

It should be pointed out that standardization with the help of a given turbid suspension or a given turbid glass is not only much simpler than the absolute standardization just described above, but leads to more accurate and reproducible results. This arises partly from the fact that this relative method involves an immediate comparison of the Tyndall beam light with the actual illuminometer lamp which is to be used. If the illuminometer lamp is low, the Tyndall beam will be set correspondingly low. A further advantage for the relative method, arises from the fact that the given tube of suspension or turbid glass is inserted in just the same way as the sample tubes which will later be measured, while the disk of opaque glass must be inserted *exactly* at the right point opposite the telescope in order to give correct results.

RELATION BETWEEN THE INTENSITY OF TYNDALL BEAM AND CONCENTRATION OF SUSPENSIONS AND SMOKES.

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The Tyndallmeter described in a previous article[1] was used for determining the way in which the concentration of a suspension or smoke affects the strength of the Tyndall beam from a given source. The work was performed by the Dispersoid Section, Research Division, Chemical Warfare Service, U. S. A.[2]

Silica Suspension.—Using a special sample of silica which had been ground to pass a 200-mesh sieve, suspensions of various concentrations were made up, poured into a cylindrical glass tube about 2″ in diameter and inserted into the examining chamber of the Tyndallmeter and the intensity of the Tyndall beam measured. The results obtained are shown graphically in

[1] Tolman and Vliet, This Journal, 41, 297 (1919).

[2] This article has been approved for publication by Major-General William L. Sibert, Director of Chemical Warfare Service, U. S. A.

Fig. 1; the abscissas give the concentration of the suspension in grams per liter[1] and the ordinates the brightness of the Tyndall beam in apparent foot candles. (The particular Tyndallmeter used with these suspensions was an earlier form than the one described in the article referred to above, the only significant difference being that the light in the Tyndall beam was only about one-fourth that used in all our later work.)

It will be seen that the concentration is fairly proportional to the strength of the Tyndall beam over a wide range. This range is really more significant than might be realized from a mere examination of the plot since the whole region from the lowest point shown on the plot to the Tyndall

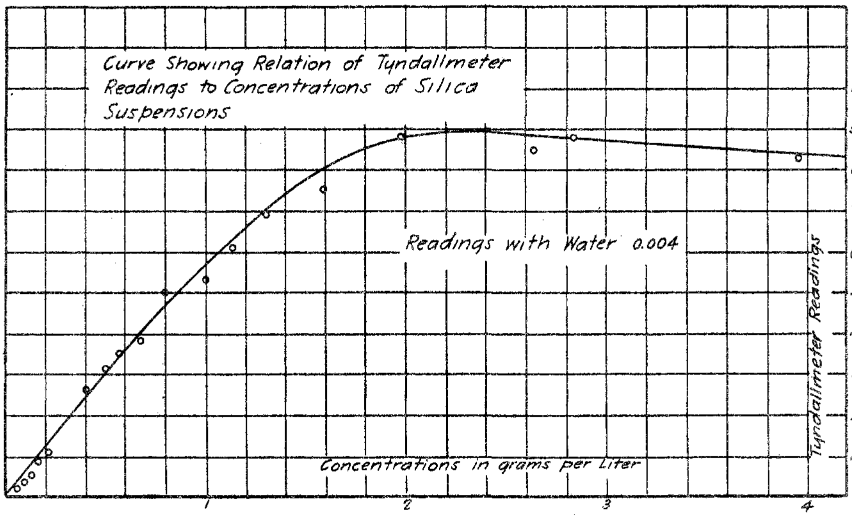

Fig. 1.

beam in water itself is open to examination. The lowest measurement indicated on the plot was made with a suspension so dilute as to appear like pure water to the unaided eye and yet the Tyndallmeter reading is fifty times as great as for water alone.

At high concentrations the Tyndallmeter reading is no longer proportional to the concentration owing to the fact that the solutions become so opaque as to absorb an appreciable fraction of the light. Where the curve bends over the suspensions are so dense as to be quite opaque to the eye when placed in the examining tube.

Ammonium Chloride Smoke.—Similar measurements to determine the relation between Tyndall beam and concentration were made with ammonium chloride smoke. The smoke was generated by leading together at known rates hydrogen chloride and ammonia gases with suitable dilution. This generation of smoke was carried out in an apparatus

[1] By concentration we shall understand in general, mass of suspended material per unit volume, not number of particles.

substantially the same as one developed by Major R. E. Wilson, of the Defense Chemical Research Section, Research Division, Chemical Warfare Service. In order to get reproducible results it was necessary to have the gases and air of dilution completely dry owing to the ease with which ammonium chloride particles pick up moisture and thus suffer a change in reflecting power.

After generation the smoke was led through the examining chamber in a steady stream. The concentration of the smoke was varied by means

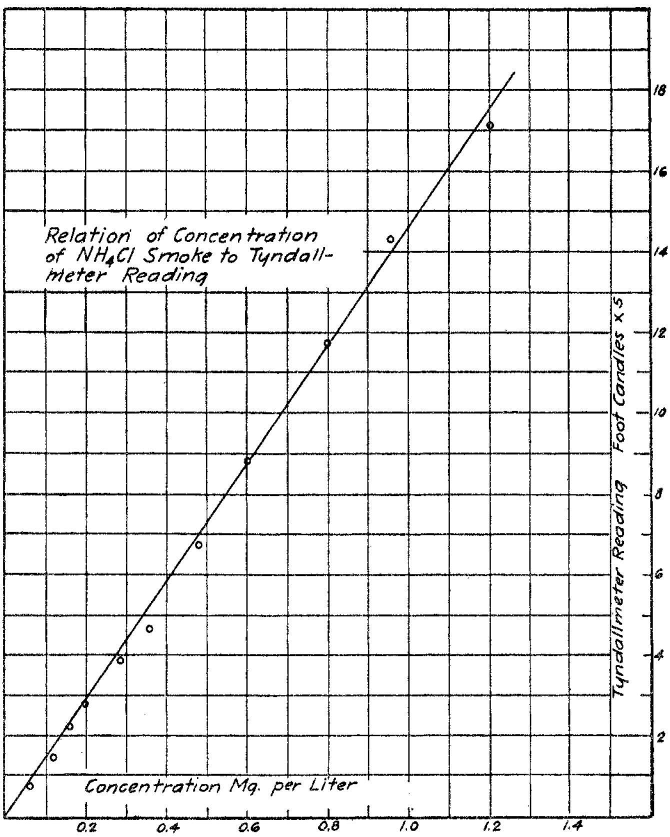

Fig. 2.

of the air of dilution and the Tyndallmeter reading for different concentrations determined. The results obtained are shown graphically in Fig. 2 with concentrations as abscissas and Tyndallmeter readings as ordinates. Fig. 3 shows on an enlarged scale the experimental results obtained at very low concentrations. The enormous range over which concentration and Tyndallmeter reading are proportional in this smoke is to be noted.

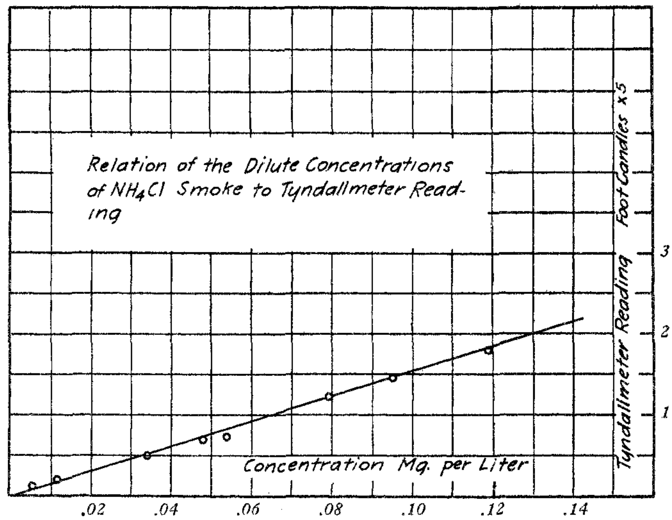

Fig. 3.

Conclusions.

These measurements indicate that in general for liquid suspensions and smokes we may expect a strict proportionality between concentration and strength of Tyndall beam, provided, of course, that the concentrations do not become high enough so that the opacity of the suspension appreciably affects the result.

The proportionality between the strength of Tyndall beam and the concentration of a suspension had already been shown by Mecklenburg[1] for colloidal stannic acid and for sulfur suspensions. It is important to note that the same relation holds for smokes.

It should be noted that the different suspensions of silica were all made with varying amounts of the same material and hence there was no difference in average size of particle at the different concentrations. As to the average size of the particles of the ammonium chloride smoke we have at present no definite information. The concentrations of the ammonia and hydrogen chloride gases which were led together to obtain the different concentrations of smoke were not the same in the different runs, but how great an effect, if any, this would have on the size of particle is not known. Under the circumstances we may conclude that the strength of Tyndall beam is proportional to the concentration of suspensions and smokes provided the size of particle remains unaltered. A later article will discuss the effect of size of particle.

[1] *Kolloidzeitschr.*, **14**, 172 (1914); **15**, 149 (1914); **16**, 97 (1915).