time. It was desirable, however, for us to have a continuous record, not only of the amount of pollution, but also of the effects of atmospheric conditions upon the distribution of solids after their emission from stacks or other sources.

With the helpful cooperation of members of the staff of the Westinghouse research laboratories, experiments were made first for work at short range, and in consequence a combination has been developed that may be used at night or in the daytime. It consists essentially of a source light with a modulator, a receiver and amplifier, tuned, and an indicator or recorder, calibrated. It differs from "smoke indicators" in that it need not be attached to a smoke-pipe or stack and also in that it operates independently of any influence from daylight or artificial light other than that from the controlled source.

At the suggestion of W. A. Hamor, assistant director, Mellon Institute, the apparatus has been named the *capnometer* (> Greek *kapnos,* smoke, and *metron,* measure), for its purpose is to measure smoke—*capnometry.*

From the results of the work done in the laboratory, there is every indication that the apparatus will be very helpful in the capnometric part of Mellon Institute's program and in securing data concerning the influence of furnace and firing conditions, precipitation, wind velocities, etc., upon the density due to pollution of the atmosphere.

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SPECIAL ARTICLES

A THEORY OF THE RING METHOD FOR THE DETERMINATION OF SURFACE TENSION

DURING the last few years several papers concerning various phases of the ring method for the determination of surface tension have appeared in SCIENCE. It is desirable that this discussion also appear here especially because it is closely related to one of these papers. An experimental study of the ring method by Harkins, Young and Cheng[1] has shown that this method, as usually carried out, does not give true surface tension values. The results of Harkins and his collaborators are expressed in the form of a series of empirical correction curves which involve a value of the surface tension given by an absolute method. They have demonstrated that the value of the surface tension as given by the pull on a ring and the relationship

$$W = 4\pi R\gamma \qquad (1)$$

must be modified by these correction curves if that value is to be regarded as being, in fact, that of surface tension. The purpose of this preliminary paper is to announce that a theoretical basis for this empirical correction procedure has been developed, thus making the ring method, as modified, an absolute one, since by it surface tension may be determined without reference to any other method.

The basis of our theory is Laplace's equation for stable liquid surfaces expressed in the particular form applicable to surfaces of revolution, with the capillary constant (a^2) eliminated,

$$\frac{du}{d\bar{x}} + \frac{u}{\bar{x}} = \pm 2\bar{y} \qquad (2),$$

where u is the sine of the angle made by a tangent to the surface at any point $(\bar{x}, \bar{y})$ with the $\bar{x}$-axis. The $\bar{x}$-axis in this case is chosen at the undisturbed level of the liquid, and the $\bar{y}$-axis is the axis of symmetry. In this form the equation expressed shapes of surfaces, not their actual dimensions. If the latter are to be expressed, a^2 or its equivalent $\frac{2\gamma}{gd}$ must be known, where γ and d are respectively the surface tension and density of a particular liquid. Barred symbols as used by us are dimensionless, thus $\bar{x} = x/a$ and $\bar{V} = V/a^3$. But we shall speak of them, for convenience, as lengths and volumes. This equation formulates the shapes of all types of stable liquid surfaces of revolution. The ring method involves two of these types, the meniscus and the surface held up by a wetted disk. To get the actual shapes of these surfaces the equation must be integrated, which must be done in this case by series.

The shapes of the meniscus formed inside the ring are obtained by numerical integration in the ordinary way. But the integration for the outer slope presents a difficulty in that there is no known point at which to start. We have obviated this difficulty by an assumption which, however, introduces an error much less than any in the experimental procedure. These two integrations give a cross section of the liquid raised by the ring in any position. It takes the form of two curves tangent to a circle, one curve being the shape of the meniscus, the other being that of the outer slope, and the circle being the cross section of the wire, of radius r, of which the ring is made.

The volume below these surfaces is calculated. It

[1] Harkins, Young and Cheng, SCIENCE, 64: 93, 1926.

is found to pass through a maximum as the distance of the ring from the x-axis increases. Our theory identifies the weight of this maximum volume below the surfaces with the maximum pull on the ring as found experimentally. Harkins, Young and Cheng plot a function of this maximum pull, R^3/V, where R is the radius of the ring and V is the volume of the liquid equivalent to the weight measured by this pull, against γ/p, a curve for each value of $\frac{R}{r}$, where γ is the surface tension of the liquid as determined by a reference method, and p is the pull on the ring divided by $4\pi R$. We show that γ/p is equal to $2\pi\overline{R}/\overline{V}$, a ratio which does not involve the determination of γ by any other method. Now the correction curves found by Harkins and his collaborators are identical with the curves calculated by us from the maximum volume below the surfaces and plotted as indicated, *i.e.*, $\overline{R}^3/\overline{V}$ by $2\pi\overline{R}/\overline{V}$ for a particular $\overline{R}/\overline{r}$. Our calculated curves are probably not as precise as the experimental ones because of the lack of sufficient calculated surfaces and the errors due to the consequent interpolations. But the excellent agreement that is obtained shows that the same values of γ, within the small error of both methods, are obtained whether the relative corrections of the Harkins procedure or the absolute corrections as calculated by us are used. Thus the ring method may now be considered an absolute one, since by it surface tension may be determined without reference to any other procedure. A detailed discussion of this theory is to be published soon.

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PROLONGED EFFECT ON DIGITALIS PURPUREA OF EXPOSURE UNDER ULTRA-VIOLET-TRANSMITTING GLASS

FOR the past three years, a study has been made of the effect produced upon *Digitalis purpurea* L. by exposure in the greenhouse stage under an ultra-violet-transmitting glass. *D. purpurea* is well known as the common garden foxglove, and is also a very important medicinal plant. In 1927 and again in 1928, seedlings were grown about three months under an ultra-violet-transmitting glass, with controls under ordinary glass in an adjacent section of the same greenhouse. Thus it was possible to eliminate differences of temperature, moisture and other factors.

Both series were then grown in adjacent beds under open field culture conditions; and in each year, as reported[1] at the Nashville and New York meetings, the treated plants proved considerably superior to their controls in the content of the characteristic active principles.

The final report now to be given concerns the history of the 1928 plants during their second season of growth, this species being biennial. By careful mulching they were brought through the winter in good condition. Our capricious Michigan weather in 1929 made it necessary to water the plants last summer throughout a season marked by severe drought; but all were treated the same, and had attained the normal early blooming stage at the time the samples were harvested.

For many years it was held that second-year leaves were more potent than first-year herbage but eventually this idea was refuted. We now know from numerous tests that greater activity occurs during the first year of a digitalis plant's life. Therefore, it is to be noted that the actual percentages now given, obtained from second-year growth, are not as high as those previously reported from first-year leaves; but the relative values are again confirmed; the treated plants have the higher potency. Exact values are as tabulated below, all methods having meticulously followed those heretofore used.

Treated group.....	250 per cent. of standard
Control group.....	165 per cent. of standard

Increase of potency, 51.5 per cent.

It thus seems clearly established that *D. purpurea* is benefited permanently by exposure during seedling development under glass that affords an increased amount of ultra-violet radiation. Where digitalis passes its whole cycle under natural, out-of-door conditions in a mild climate, this fact may not be of great significance, but for successful culture of high-grade plants in Michigan we must depend in large measure upon indoor protection during the seedling stage. It is gratifying, therefore, to know that modern methods of glass making have increased the efficiency of greenhouse propagation.

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[1] A. McCrea, SCIENCE, 67, No. 1732, 1928; 69, No. 1798, 1929.

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