

CHAPTER III

EXPERIMENTAL TECHNIQUE FOR THE MEASUREMENT OF SURFACE TENSION

Introduction

In the light of the **contradictory** results on the surface tension of liquid crystals obtained by the earlier investigators, **it** is clear that **the** selection of the method for the study of the surface tension is indeed very important. After carefully examining the various methods that have been used to study the **surface** tension of ordinary liquids, **it** was decided to **use** the pendant drop method. **We** shall first briefly review the different techniques that are commonly used for liquids **and** then discuss in detail the pendant drop method.

A number of workers¹⁻³ **have** reviewed the different methods adopted for the measurement of **surface** tension of liquids. Only a few of **these**

are in common use. **These** methods are based on observing any one of the **following** aspects:

- 1 the rise of the liquid in a vertical **capillary** tube, or the pressure **required** to **make** the meniscus of the liquid flat at one end of the capillary tube;
- 2 the force required to pull a wire ring or a plate out of the liquid surface;
- 3 the weight or **volume** of the liquid drop falling from a vertical **tube** of known 'size, and
- 4 the maximum pressure required to form bubbles in a liquid from a tube of known **size**.

Adam² **has pointed out** the limitations of each of these methods. In the capillary rise method, the radius of the capillary tube **should** be uniform throughout, which **is very** difficult to **realise** in

practice. ~~The~~ expression for γ is derived with the assumption that the contact angle is **zero**. So the capillary method is not suitable for liquid crystals **as** the contact angle **may** not be **zero**. Moreover the capillary **walls** may influence the orientation **of molecules** at **the free surface** which in turn **may** affect the **surface** tension.

In the drop **volume** method, often only a part of the drop falls as pointed out by **Adam**.² Moreover, the expression for γ is derived assuming that the edge of the drop near the tip of the glass tube is vertical, but very rarely is **it** so.

In the **ring** and the other detachment methods, the contact angle **may** influence the results. The viscous drag of the liquid **may** also affect the results. Errors **may** arise, if the ring or the plate is not suspended perfectly parallel to the liquid surface.

As regards the ~~maximum~~ bubble pressure method, it seems that it does not give consistent readings for highly viscous liquids, as can be judged from Jaeger's results on ethyl *p*-azoxybenzoate (see Fig. 1.7). Thus all the conventional methods discussed so far, have certain drawbacks which make them somewhat unsuitable for the study of surface tension of liquid crystals. On the other hand, 'the pendant drop ~~method~~' appears to be free from these drawbacks. Surprisingly it has ~~not~~ been used so far for liquid crystals. We shall discuss this method at some length presently.

Another method for the measurement of γ which has been used recently^{4,5} is the dynamic light scattering technique. Here, the intensity of the light scattered from the thermally fluctuating free surface is measured. The surface tension is calculated by fitting the power spectrum to Lorentzian models. The method is a good one, in principle, though the error bars tend to be rather large. The trends in the

variation of γ with T for MBBA and CB00A obtained by Langevin⁴ and very recently for PAA by Brown and Mann⁵ are in broad agreement with our determinations. However, we did not consider using this method for our work as a photon correlator was not available in the laboratory.

The pendant drop method

Edgerton et al⁶ had demonstrated that the method of the pendant drop has a number of outstanding advantages, but it was not popular as the procedure of calculation was not simple. Andreas et al⁷ improved the experimental technique as well as the procedure of calculation of the surface tension.

In this method, a small drop of the liquid is suspended from the tip of a vertical glass tube, which is mounted in a thermostat. The surface of the drop is a surface of revolution, whose shape

and size **can** be **determined** by measurements made on a photograph of the drop taken when it is in **static** equilibrium. Since the **equation** governing the **shape** of the drop **involves** (i) the surface tension (γ), (ii) the diameters of the drop at certain **heights**, (iii) the density (ρ) of the liquid, and (iv) the acceleration due to gravity (g), the value of surface tension can be calculated by measuring the **diameters** on the photograph, provided the other **parameters** are known. Some of the main advantages of **this** method are:

- 1 It is a static method **and** hence the results are **not** influenced by the viscous drag of the liquid. So **this** method is suitable for even highly viscous liquids.
- 2 **The** approach to static equilibrium is more rapid **in** this method than in any other method, since **only** a **small** fraction of the total surface of the drop is in direct contact **with** the solid

surface hindering the movement of the liquid.

- 3 **The** surface **tension** values are independent of the angle of contact. **This is** because, in the calculation of surface tension from the profile of the drop, a plane is selected well below the tip of the glass tube. **The excess** of pressure at this plane inside the drop, which involves γ , is **considered** for the derivation of the final formula for the drop shape.
- 4 **Only** a small quantity of the sample (about 0.5 cc) is sufficient for one complete experiment.
- 5 Measurements **can** be made without disturbing the surface physically.
- 6 Surface **tensions** of any magnitude can be **measured**.

Andreas et al have listed **some** further advantages but only the **ones** listed

above are relevant for the present investigations. These authors **have** measured the surface tension values **as small** as 0.3 dynes/cm and **as great as** 370 dynes/cm using this method.

The above advantages make this method probably the ideal one for liquid crystals, particularly because of the following reasons:

- 1 Liquid **crystals** are generally viscous.
In particular **smectics** are highly viscous.
For this reason Schwartz and Moseley⁸ who used the ring method, and more recently Churchill and Bailey⁹, and Gannon and Faber¹⁰, who used the **Wilhelmy** plate method, could not get reproducible results in the **smectic** phase.
- 2 Liquid crystals are **composed** of highly anisotropic molecules. It is **known** that a solid **surface** in contact with the liquid

crystal has a strong influence on the surface orientation which in turn **may** affect the surface tension. In the pendant drop method there **is** no influence of the solid surface.

- 3 Usually liquid crystals are available only in rather small quantities.

Thus after a careful consideration of the merits of pendant drop method, **it** was decided to employ this method for **the** determination of the surface tension of liquid crystals.

It appears relevant to make a remark here, about the variation of surface tension **with** the radius of curvature of the drop. **Tolman**¹¹ has discussed the effect of droplet **size** on surface tension. He has shown theoretically that the surface tension starts decreasing with the radius of curvature (R) only for very small values of R . For example, according to his **calculations**, a decrease

of γ by 4%, requires the radius of curvature to be of the order of 10^{-6} cm. Gibbs¹² also has come to a similar conclusion. Hence, we can **safely** neglect the **effect** of ~~the~~ radius of curvature in the present case, **as** the diameters of the drops used here were greater than 2 mm.

Experimental set up

A schematic diagram of the experimental set up is **shown** in the figure 3.1. A drop of the liquid crystal was formed at the end of a glass (Pyrex) **capillary** tube, **having** a circular cross section. The outer diameter of the tube at the tip was about 2 mm. ~~The~~ end of the tube **was** cut and **ground** perpendicular to the axis of the tube, so that the circular face of the tip is horizontal **when** the tube itself is vertical. It is very important that the tip should have a circular face **as** otherwise the drop **will** not have cylindrical

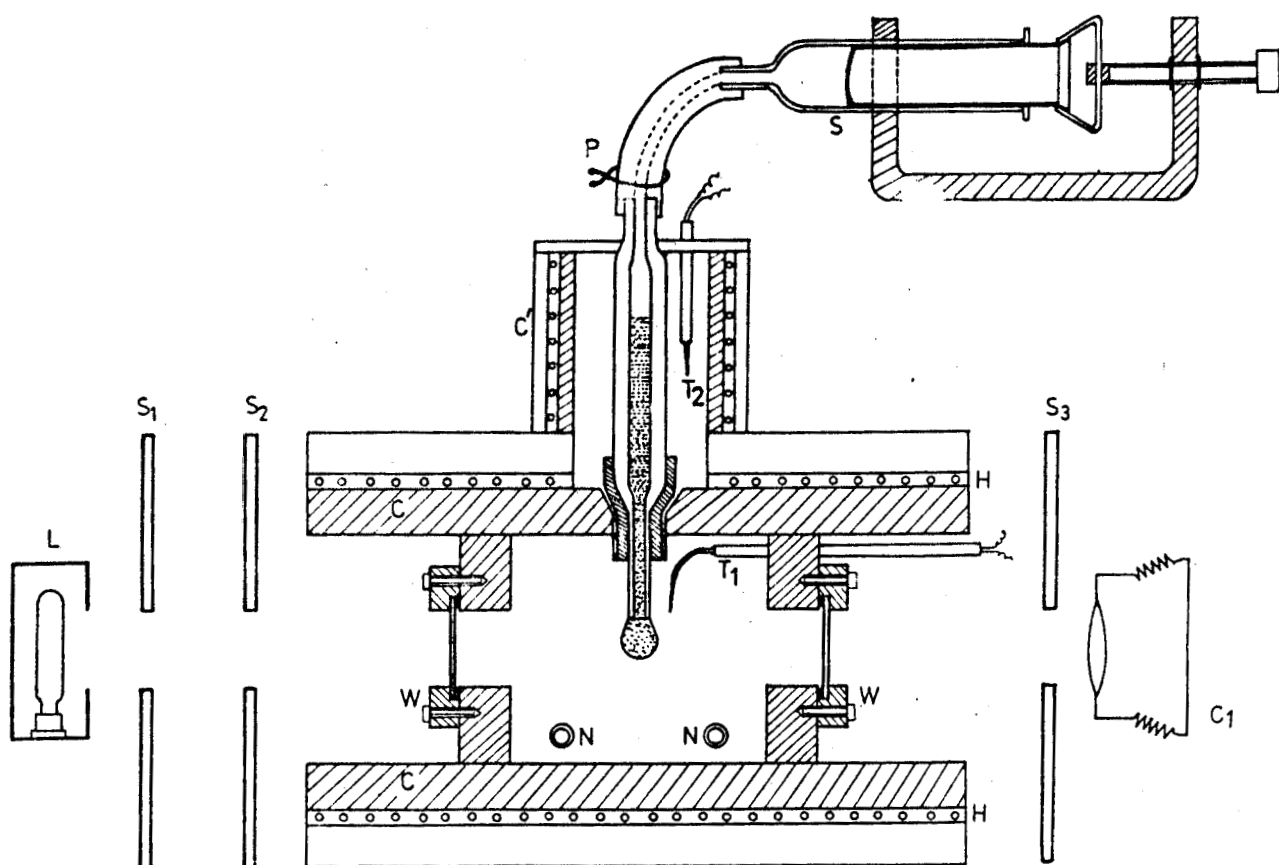


Figure 3.1

Schematic diagram of the **experimental** set up for the determination of γ .

C : copper chamber
W : optically flat **glass** windows
N-N: Inlet & outlet for nitrogen
H-H: Heating elements
C' : Top heater
T₁-T₂: Thermocouples

P : Pinch cock
S : Syringe
L : **Sodium** lamp
S₁, S₂, S₃: Optical stops
C₁ : Camera

symmetry about the vertical axis and the equations that are used to define the drop shape, will not be applicable to **such** a drop. Hence only those tubes, which had a perfectly circular cross section, were selected. ~~The~~ top end of the tube was connected to a hypodermic syringe through a rubber tube. ~~The~~ movement of the piston of the syringe **was** controlled by a fine screw attached to **it** as shown in ~~the~~ diagram. After adjusting the drop to the required size by the movement of the screw, a pinchcock **was** fastened to the rubber tube near the end of the glass tube. This brought the drop to a stable condition, provided the temperature was also stable.

The lower end of the **capillary** tube was introduced inside an air-tight copper chamber **which** could be electrically heated and maintained at **any** desired steady temperature. ~~The~~ **chamber** was massive and hence the thermal oapacity **was** very large. **It** was provided with two optically flat glass windows

on opposite sides in order to facilitate the photography of the drop. **The** design of the chamber was such that, the glass windows were well **inside** the heating elements (see figure), so that there was no condensation of the liquid crystal **vapour** on the inner surface of the windows.

The mechanism of inserting the **glass** tube into the **chamber** was as follows. **The** tube was firmly fixed inside a copper neck using a commercial epoxy (araldite). Since the maximum range of the experiment for **all** the compounds studied was within 200°C, it was quite safe to **use** araldite **as an** adhesive. **The** neck could be screwed into the chamber tightly **forming** an air-tight seal since the neck had a teflon sleeve. **The** chamber had to be made air-tight in order to keep the surface of the drop of liquid crystal in thermodynamic equilibrium with its **vapour**, which is highly essential to study the true **behaviour** of the γ -T curve. **The**

length of the capillary tube was such that the drop formed at the tip of the tube was at the centre of the chamber.

The top portion of the capillary tube was covered by a separate heater whose temperature could be controlled independently. It was essential to maintain the top portion of the glass tube at the same temperature as that of the bottom portion in order to achieve the stability of the drop. The temperature of the drop was measured using a copper-constantan thermocouple (T_1) whose junction was positioned close to the drop. The temperature of the top portion of the tube was measured by using a similar thermocouple (T_2). Both the thermocouples were calibrated earlier by using a standard thermometer.

After inserting the capillary tube filled with the liquid crystal into the chamber, the chamber was flushed with pure and dry nitrogen for about 30 minutes

and then the nozzles (N) were closed so **that** nitrogen was trapped inside **the** chamber. **An** inert atmosphere ~~was~~ necessary to avoid any possible decomposition of the compound. In fact, **it** was ascertained that the compound remained pure during the course of the experiment, by checking that there **was** no difference in its transition temperatures before and after the experiment. Furthermore, **since** the **chamber was** airtight, one could be sure that liquid **crystal** drop ~~was~~ in equilibrium with **its** saturated vapour.

The drop **was illuminated** by monochromatic light **through** one of the windows. A silhouette photograph of the drop **was** formed on the focal plane of a camera placed in front of the **other** window by a suitable **lens** system. Optical stops (s_1, s_2, s_3) were introduced in the path of the light beam in order to **improve** the sharpness of **the** image and to avoid the errors due to perspective. It ~~was~~ checked beforehand,

that the photographic system did not introduce any error by determining the surface tension of pure water and benzene with **this** set up. The values obtained agreed very well with the standard reported values. **The** error was within 1%. Hence the accuracy of measurements is also reckoned to be within this **limit**. The **experiment** was carried out by taking photographs of a single drop at different steady temperatures after ensuring that the drop was in perfect static equilibrium. It was necessary to wait for about 30 minutes to attain a steady temperature. Before taking the photograph, it was ascertained visually that the drop was stationary for at least 15 minutes and also that the temperature was constant **during** this interval. A complete experiment on a single drop, wherein photographs were taken at about 25 different temperatures took 20 to 25 hours. In some cases, where the measurements were done over a wide range of temperature, the duration

of the experiment was about 48 hours.

Calculation of γ from the profile of the drop

Bashforth and Adams¹³ have shown that the surface tension can be calculated from an analysis of the stresses in the static pendant drop. There are two methods to calculate the surface tension from the picture of the drop." The first one is based on measurements taken at the plane of inflection and the second one is based on the measurements taken at a selected plane. In the first method it can be shown that a small error in locating the plane of inflection, finally results in a large error in the value of γ . Hence the second method is used in the present calculations.

Let us choose the lower tip of the drop as the origin, where the axis of cylindrical symmetry cuts the surface of the drop (see fig.3.2). Let the cylindrical axis be the z axis. If 'b' is the

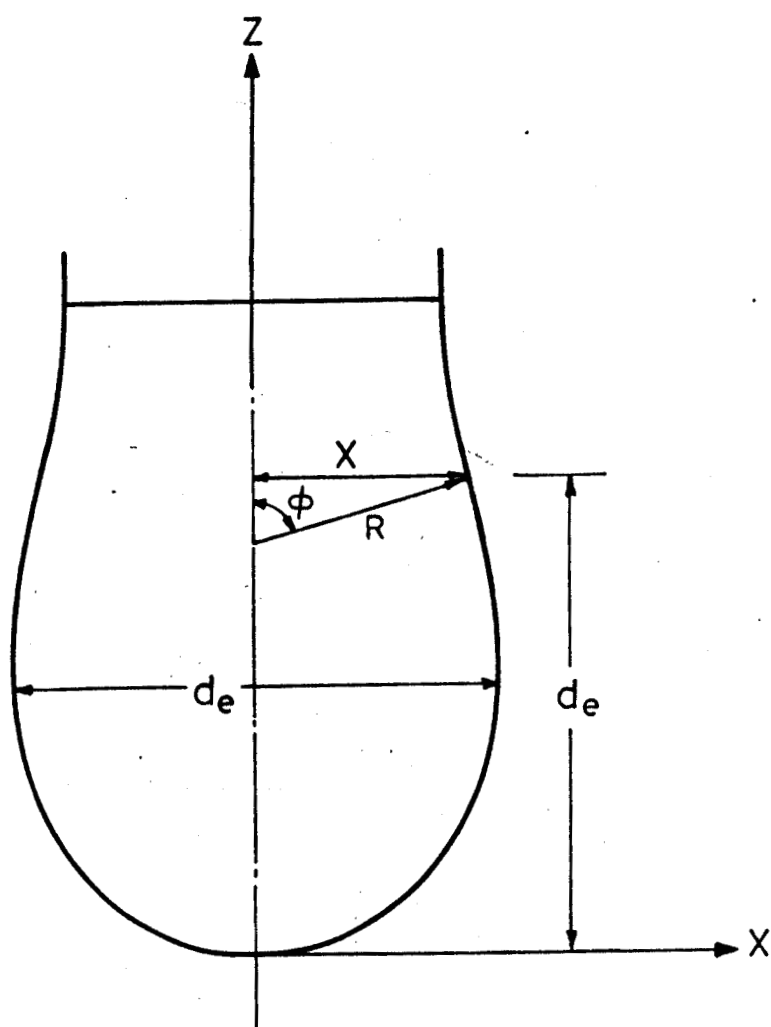


Figure 3.2

The pendant drop profile

radius of curvature at the origin, the ^{excess of} pressure inside the drop immediately above the origin is $2\gamma/b$. If P is the ^{excess of} pressure at a height z along the axis, we have

$$\frac{2\gamma}{b} = P + \rho g z \quad (1)$$

where ρ is the density of the liquid forming the drop, relative to the surrounding fluid, which is the vapour of the liquid in **this** case. We may justifiably neglect the density of the vapour and consider ρ as the density of the liquid. Rearranging (1) we get

$$P = \frac{2\gamma}{b} - \rho g z \quad (2)$$

The pressure P is also given by

$$P = \gamma \left[\frac{1}{R_1} + \frac{1}{R_2} \right] \quad (3)$$

where R_1 and R_2 are the two principle radii of curvature of the drop at the height z . From (2) and (3) we get

$$\gamma\left[\frac{1}{R_1} + \frac{1}{R_2}\right] = \frac{2\gamma}{b} - \rho g z \quad (4)$$

The two principle radii of curvature are given by

$$R_1 = [1 + (dz/dx)^2]^{3/2} / (d^2z/dx^2) \quad (5)$$

and

$$R_2 = \frac{x}{\sin \varphi} = x[1 + (dz/dx)^2]^{1/2} / (dz/dx) \quad (6)$$

Substituting (5) and (6) in (4) and rearranging we

get

$$\begin{aligned} (d^2z/dx^2) / [1 + (dz/dx)^2]^{3/2} + (dz/dx) / [1 + (dz/dx)^2]^{1/2} x \\ = \frac{2}{b} - \frac{\rho g z}{\gamma} \end{aligned} \quad (7)$$

Multiplying (7) by $[1 + (dz/dx)^2]^{3/2}$ we get

$$\begin{aligned} d^2z/dx^2 + (dz/dx)[1 + (dz/dx)^2]^{1/x} \\ = \left[\frac{2}{b} - \frac{\rho g z}{\gamma} \right] [1 + (dz/dx)^2]^{3/2} \end{aligned} \quad (8)$$

If we set $X = x/b$ and $Z = z/b$ which is equivalent to taking b as the unit of length, (8) takes the form

$$\frac{1}{b} \frac{d^2 z}{dx^2} + \left(\frac{dz}{dx}\right) \left[1 + \left(\frac{dz}{dx}\right)^2\right] \frac{1}{xb} = \left[\frac{2}{b} - \frac{\rho g z b}{\gamma}\right] \left[1 + \left(\frac{dz}{dx}\right)^2\right]^{3/2} \dots (9)$$

or

$$\frac{d^2 z}{dx^2} + \left(\frac{dz}{dx}\right) \left[1 + \left(\frac{dz}{dx}\right)^2\right] \frac{1}{x} = \left[2 - \frac{\rho g z b^2}{\gamma}\right] \left[1 + \left(\frac{dz}{dx}\right)^2\right]^{3/2} \dots (10)$$

$$\text{Writing } \frac{\rho g b^2}{\gamma} = \beta \quad (11)$$

we get

$$z'' + \frac{z'}{x} [1 + (z')^2] = (2 - \beta z) [1 + (z')^2]^{3/2} \quad (12)$$

This derivation follows that of Bashforth and Adams with the modification that the **signs** of **ρ** and **β** are taken to be positive for **pendant** drops. Equation (12) contains two parameters ' **β** ' and ' **b** ' which characterise a particular drop shape. **The value** of **b** gives the **size** of the **drop** and the value of **β** gives the **shape** of the drop. There is no way of finding the values of **b** and **β** precisely and quickly by using the picture of the drop. So **Andreas** et al have transformed

equation (11) to a **form** which uses **parameters** that **can** be measured easily and accurately. They define the shape of the drop by a ratio

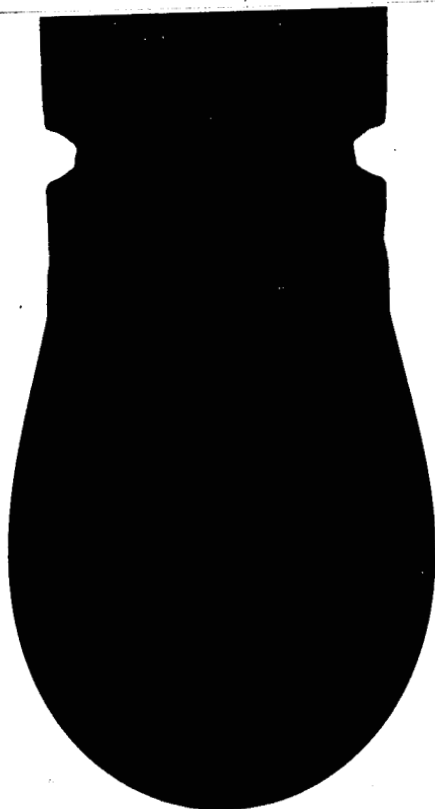
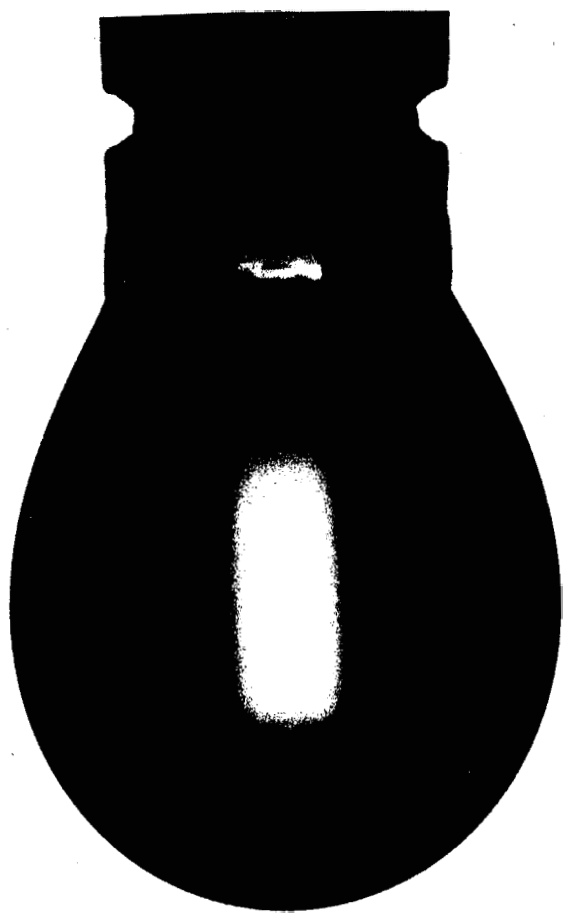
$$S = d_s/d_e \quad (13)$$

where d_e is the **maximum** or **equatorial** diameter of the drop and d_s **is** the diameter of the drop at a height **equal** to d_e from the vertex. It is clear that different **values** of S **characterise** different shapes of the drop. Fig.3.3 shows the **photographs** of two drops suspended **from** the **same** glass tube. One is a drop of water ($\gamma \sim 72 \text{ dyne cm}^{-1}$) and the other is a drop of CBOOA ($\gamma \sim 26 \text{ dyne cm}^{-1}$) in the **nematic** phase. We can see that there is a large difference **in** the **shapes** of the drops. (The groove seen on the glass tube just above the tip was made for the **calcu-**
lation of the exact magnification by measuring the diameters along the groove, in the **photograph** and in the actual tube itself. ^{A knowledge of the} **magnification** is required to calculate the actual value of d_e from the measured

Figure 3.3

Photographs of the pendant drops :

Top - water ; Bottom - CBOOA .



value in the photograph).

Another quantity which is a function of the drop shape is the ratio of the equatorial diameter d_e and the radius of curvature at the origin b . Using this ratio Andreas et al.⁷ define a new quantity 'H' by the relation

$$H = \beta (d_e/b)^2 \quad (14)$$

It is seen that H is also a function of the drop shape. γ can be expressed in terms of H and d_e by rearranging (11)

$$\gamma = \frac{g \rho b^2}{\beta} = \frac{g \rho d_e^2}{\beta (d_e/b)^2} \quad (15)$$

From (14) and (15) we get

$$\gamma = \frac{g \rho d_e^2}{H} \quad (16)$$

Equation (16) can be used for calculating γ by using a table of S vs. H which can be constructed by numerical solution of the fundamental equation (12) which

defines the shape of the drop. *But* Andreas et al constructed the table of S vs. $1/H$ by measuring S for drops of various sizes and shapes of pure water whose surface tension is known accurately. They also verified the correctness of their table by measuring the surface tension of many organic liquids. The values obtained by them agreed very well with the standard values reported. Later Fordham,¹⁴ Niederhauser and Bartell¹⁵ and Stauffer¹⁶ compiled more accurate tables by numerical solutions of the fundamental differential equation.

Ryong-Joon Roe et al¹⁷ made a further improvement wherein it is possible to verify *that* the drop has attained static equilibrium. Instead of selecting one plane at height $z = d_e$, they selected five planes at heights $z_n = \frac{n}{10} d_e$, ($n = 8, 9, 10, 11, 12$). If d_n is the diameter of the drop in the n^{th} plane five characteristic ratios are defined by

$$S_n = d_n/d_e \quad (n = 8, 9, 10, 11, 12)$$

which uniquely define the drop shape. It is clear that d_{10} and S_{10} are identical with d_s and S respectively, used by earlier workers. The values of $1/H$ determined by different S_n values **measured** from the same photograph should be the same, if the drop is in static equilibrium at the time of taking the photograph. If the values are different, it means that the drop had not attained equilibrium and the photograph has to be discarded. In effect, the method tests the conformity of the **drop** shape to the differential equation at different selected heights.

Ryong Joon Roe et al carried out the numerical integration of the fundamental differential equation (12) which defines the drop shape, by the fourth order Runge-Kutta-Gill method. The plane of-the **maximum** diameter and the points (x_n, z_n) ($n = 8, \dots, 12$) were located by the **use** of a squeezing algorithms, i.e., by taking alternately positive and negative S values of successively smaller magnitudes around

the desired point until the error ~~was~~ within 0.00001. They constructed five tables giving $1/H$ as a function of s_n ($n = 8, \dots, 12$) by parabolic interpolation of the primary data as computed above. They have also made an **analysis** of the errors that arise in determining the values of $1/H$. These errors depend on the **accuracy** of **measurements** of d_e , z_n and d_n , and the shape of the drop. They have estimated the percentage error in $1/H$ **when** the probable error in **measuring** d_e **is** 1%, for each value of s_n . These are given in the last column under the head 'p' in each table. The tables show that the **error** is **least** in the case of $1/H$ values obtained from **the** table **corresponding** to s_{12} and it is maximum in the case of s_8 .

In **the** present calculations the author has used the tables corresponding to s_9 and s_{10} . **Only** those photographs for which the difference in $1/H$ **values** corresponding to s_9 and s_{10} **waa** less **than** 1%, were selected and γ ~~was~~ calculated using the mean value

of $1/H$. If the difference was greater than 1% in any photograph, it was discarded on the ground that the drop *might* not have attained equilibrium. Actually very few photographs had to be discarded like that.

The values of $1/H$ corresponding to S_{11} and S_{12} were not considered for the following reasons. In order that the planes corresponding to Z_{11} and Z_{12} were within the drop, the drop had to be very large. The stability of such a drop was critical. Many times it was not possible to get these planes inside the drop. Even if we could manage to get them inside, they would be very close to the tip of the glass tube and hence there could be an influence of the solid surface at these planes. The values of $1/H$ corresponding to S_8 were not considered because, the percentage of error is large in this case, as can be seen from the tables given at the end of the chapter.

The diameters of the drop were **very** carefully measured **using** a comparator, with which an **accuracy** of 0.001 mm could be achieved. The diameter ' d_e ' on the photograph ~~was~~ of the order of 50-60 mm. The actual value of d_e which was of the order of 2.5 mm, ~~was~~ determined by calculating the magnification produced in the photograph. The error in the measurement of d_e on the photograph along with the error in the magnification, finally resulted in a **maximum** error of 0.1% in the **actual value** of d_e . For the values of S_9 and S_{10} obtained by the photographs, the corresponding **maximum** error in $1/H$ ~~was~~ of the order of 1% **as** per the tables. Hence the estimated maximum error in the **value** of y was of the order of 1.2%, which is of the same order as obtained **when** the measurements were done on water and benzene.

The errors due to density values are negligible because they are less than 0.1 % in all the cases. Indeed

in some cases an accuracy of 1 part in 10^6 is claimed.

In this manner the surface tension - temperature characteristics of liquid crystals in the smectic, *nematic* and isotropic phases have been studied under equilibrium conditions, the results of which are discussed in the next two chapters.

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Tables of S_n vs. $1/H$ (after ref.17)

TABLE 2.1A 1/H VS S 8

6 x 5 8	0	1	2	3	4	5	6	7	8	9	P
5.30	1.02771	1.02532	1.02294	1.02056	1.01820	1.01584	1.01349	1.01116	1.00883	1.00651	24.64
5.31	1.00419	1.00189	.99960	.99731	.99505	.99279	.99054	.98830	.98606	.98384	24.16
5.32	.98162	.97941	.97720	.97501	.97282	.97064	.96847	.96631	.96415	.96201	23.61
5.33	.95987	.95774	.95561	.95350	.95139	.94930	.94721	.94513	.94306	.94100	23.17
5.34	.93894	.93689	.93485	.93282	.93079	.92877	.92675	.92475	.92275	.92075	22.66
5.35	.91877	.91679	.91481	.91285	.91089	.90894	.90701	.90508	.90315	.90123	22.26
5.36	.89932	.89742	.89552	.89363	.89174	.88986	.88799	.88612	.88426	.88240	21.78
5.37	.88055	.87871	.87688	.87505	.87322	.87140	.86960	.86780	.86601	.86422	21.41
5.38	.86244	.86066	.85889	.85713	.85537	.85361	.85187	.85012	.84839	.84666	20.97
5.39	.84493	.84321	.84150	.83979	.83809	.83639	.83470	.83302	.83135	.82968	20.63
5.40	.82801	.82635	.82470	.82305	.82140	.81976	.81813	.81650	.81488	.81326	20.22
5.41	.81165	.81004	.80843	.80684	.80524	.80365	.80207	.80050	.79893	.79736	19.90
5.42	.79581	.79425	.79270	.79116	.78962	.78808	.78655	.78502	.78350	.78198	19.53
5.43	.78047	.77896	.77746	.77596	.77447	.77298	.77149	.77001	.76854	.76707	19.23
5.44	.76561	.76415	.76269	.76124	.75979	.75835	.75691	.75548	.75405	.75262	18.89
5.45	.75120	.74978	.74837	.74696	.74556	.74416	.74276	.74137	.73998	.73860	18.61
5.46	.73723	.73585	.73448	.73312	.73176	.73040	.72905	.72770	.72635	.72501	18.28
5.47	.72367	.72234	.72101	.71968	.71836	.71704	.71572	.71441	.71311	.71181	18.03
5.48	.71051	.70921	.70792	.70664	.70535	.70407	.70280	.70152	.70026	.69899	17.73
5.49	.69773	.69647	.69521	.69396	.69271	.69147	.69023	.68899	.68775	.68653	17.49
5.50	.68530	.68408	.68286	.68164	.68043	.67922	.67802	.67681	.67561	.67442	17.21
5.51	.67322	.67203	.67085	.66966	.66848	.66731	.66613	.66496	.66380	.66263	16.99
5.52	.66147	.66032	.65917	.65802	.65687	.65572	.65458	.65344	.65231	.65118	16.73
5.53	.65005	.64892	.64780	.64668	.64556	.64444	.64333	.64222	.64112	.64002	16.52
5.54	.63892	.63782	.63673	.63564	.63455	.63347	.63239	.63131	.63023	.62916	16.28
5.55	.62808	.62702	.62595	.62489	.62383	.62277	.62171	.62066	.61961	.61857	16.09
5.56	.61752	.61648	.61545	.61441	.61338	.61235	.61132	.61030	.60927	.60825	15.87
5.57	.60724	.60622	.60521	.60420	.60319	.60218	.60118	.60018	.59918	.59819	15.69
5.58	.59720	.59621	.59522	.59424	.59326	.59228	.59130	.59032	.58935	.58838	15.48
5.59	.58741	.58644	.58548	.58452	.58356	.58260	.58165	.58070	.57975	.57880	15.32
5.60	.57786	.57692	.57598	.57504	.57410	.57317	.57224	.57131	.57038	.56946	15.12
5.61	.56853	.56761	.56669	.56578	.56486	.56395	.56304	.56213	.56123	.56033	14.97
5.62	.55942	.55853	.55763	.55673	.55584	.55495	.55406	.55317	.55229	.55141	14.80
5.63	.55053	.54965	.54877	.54789	.54702	.54615	.54528	.54441	.54355	.54269	14.66
5.64	.54183	.54097	.54011	.53926	.53840	.53755	.53670	.53585	.53501	.53416	14.49
5.65	.53332	.53248	.53164	.53081	.52997	.52914	.52831	.52748	.52665	.52583	14.36
5.66	.52500	.52418	.52336	.52254	.52173	.52091	.52010	.51929	.51848	.51767	14.21
5.67	.51686	.51606	.51525	.51445	.51365	.51285	.51206	.51126	.51047	.50968	14.10
5.68	.50889	.50810	.50732	.50653	.50575	.50497	.50419	.50341	.50263	.50186	13.97
5.69	.50108	.50031	.49954	.49877	.49800	.49724	.49648	.49571	.49495	.49419	13.86

TABLE 2.18 1/H VS S 8

6 X S 8	0	1	2	3	4	5	6	7	8	9	P
5.70	.49344	.49268	.49193	.49117	.49042	.48967	.48892	.48817	.48743	.48668	13.74
5.71	.48594	.48520	.48446	.48372	.48298	.48225	.48151	.48078	.48005	.47932	13.65
5.72	.47859	.47786	.47714	.47641	.47569	.47497	.47424	.47353	.47281	.47209	13.55
5.73	.47138	.47066	.46995	.46924	.46853	.46782	.46711	.46641	.46570	.46500	13.46
5.74	.46430	.46360	.46290	.46220	.46150	.46081	.46011	.45942	.45873	.45804	13.37
5.75	.45735	.45666	.45597	.45528	.45460	.45392	.45323	.45255	.45187	.45120	13.31
5.76	.45052	.44984	.44917	.44849	.44782	.44715	.44648	.44581	.44514	.44447	13.23
5.77	.44380	.44314	.44247	.44181	.44115	.44049	.43983	.43917	.43852	.43786	13.17
5.78	.43720	.43655	.43590	.43524	.43459	.43394	.43329	.43264	.43200	.43135	13.12
5.79	.43070	.43006	.42942	.42878	.42814	.42750	.42686	.42622	.42558	.42494	13.07
5.80	.42431	.42367	.42304	.42241	.42178	.42115	.42051	.41989	.41926	.41863	13.05
5.81	.41801	.41738	.41676	.41613	.41551	.41489	.41427	.41365	.41303	.41241	13.02
5.82	.41179	.41117	.41056	.40994	.40933	.40871	.40810	.40749	.40688	.40627	13.02
5.83	.40566	.40505	.40444	.40383	.40323	.40262	.40202	.40141	.40081	.40020	13.01
5.84	.39960	.39900	.39840	.39780	.39720	.39660	.39600	.39540	.39481	.39421	13.03
5.85	.39362	.39302	.39243	.39183	.39124	.39065	.39005	.38946	.38887	.38828	13.05
5.86	.38769	.38710	.38651	.38592	.38534	.38475	.38416	.38358	.38299	.38241	13.11
5.87	.38182	.38124	.38065	.38007	.37949	.37890	.37832	.37774	.37716	.37657	13.17
5.88	.37599	.37542	.37484	.37426	.37368	.37310	.37252	.37194	.37137	.37079	13.23
5.89	.37021	.36963	.36906	.36848	.36790	.36732	.36675	.36617	.36560	.36502	13.37
5.90	.36445	.36387	.36330	.36272	.36215	.36157	.36100	.36042	.35985	.35927	13.50
5.91	.35870	.35812	.35755	.35697	.35640	.35582	.35525	.35468	.35410	.35353	13.72
5.92	.35295	.35237	.35180	.35122	.35064	.35006	.34948	.34890	.34832	.34774	13.94
5.93	.34717	.34659	.34601	.34543	.34485	.34427	.34369	.34310	.34252	.34193	14.17
5.94	.34134	.34076	.34017	.33958	.33898	.33839	.33780	.33721	.33662	.33603	14.69
5.95	.33544	.33484	.33424	.33364	.33303	.33243	.33182	.33121	.33059	.32997	15.15
5.96	.32936	.32875	.32814	.32753	.32691	.32629	.32566	.32503	.32439	.32374	15.66
5.97	.32309	.32244	.32178	.32111	.32044	.31982	.31919	.31854	.31788	.31720	17.23
5.98	.31650	.31579	.31507	.31432	.31357	.31279	.31200	.31120	.31038	.30954	19.07

TABLE 2.2A 1/P VS S ?

3 X S 9	0	1	2	3	4	5	6	7	8	9	P
2.31	1.09129	1.08852	1.08577	1.08302	1.08028	1.07755	1.07484	1.07213	1.06944	1.06675	16.59
2.32	1.06408	1.06141	1.05876	1.05612	1.05348	1.05086	1.04825	1.04565	1.04307	1.04050	16.21
2.33	1.03793	1.03538	1.03284	1.03030	1.02778	1.02526	1.02275	1.02025	1.01776	1.01529	15.77
2.34	1.01281	1.01035	1.00790	1.00546	1.00303	1.00060	.99819	.99579	.99340	.99102	15.42
2.35	.98865	.98629	.98393	.98159	.97925	.97692	.97460	.97228	.96998	.96768	15.02
2.36	.96540	.96312	.96084	.95858	.95633	.95408	.95184	.94962	.94740	.94520	14.69
2.37	.94320	.94081	.93862	.93644	.93427	.93211	.92996	.92781	.92567	.92354	14.32
2.38	.92141	.91930	.91719	.91508	.91299	.91090	.90882	.90676	.90470	.90265	14.02
2.39	.90060	.89856	.89653	.89451	.89249	.89048	.88847	.88648	.88448	.88250	13.68
2.40	.88052	.87855	.87659	.87463	.87268	.87074	.86881	.86688	.86496	.86305	13.40
2.41	.86114	.85924	.85735	.85546	.85358	.85170	.84983	.84797	.84611	.84426	13.08
2.42	.84242	.84058	.83874	.83692	.83510	.83329	.83148	.82969	.82789	.82611	12.82
2.43	.82433	.82255	.82078	.81902	.81726	.81551	.81376	.81202	.81028	.80855	12.53
2.44	.80683	.80511	.80340	.80169	.79999	.79830	.79661	.79493	.79325	.79158	12.28
2.45	.78991	.78825	.78660	.78495	.78330	.78166	.78002	.77839	.77677	.77515	12.01
2.46	.77353	.77192	.77032	.76872	.76713	.76554	.76396	.76238	.76081	.75924	11.78
2.47	.75768	.75612	.75457	.75302	.75147	.74993	.74840	.74687	.74534	.74382	11.53
2.48	.74231	.74080	.73929	.73779	.73630	.73481	.73332	.73184	.73037	.72889	11.31
2.49	.72742	.72596	.72450	.72305	.72159	.72015	.71871	.71727	.71583	.71440	11.08
2.50	.71298	.71156	.71015	.70874	.70733	.70593	.70453	.70314	.70175	.70036	10.85
2.51	.69898	.69760	.69623	.69486	.69349	.69213	.69077	.68942	.68807	.68673	10.67
2.52	.68539	.68405	.68272	.68139	.68007	.67875	.67743	.67611	.67480	.67350	10.45
2.53	.67220	.67090	.66960	.66831	.66702	.66574	.66446	.66318	.66191	.66064	10.27
2.54	.65938	.65812	.65686	.65561	.65436	.65311	.65187	.65063	.64939	.64816	10.08
2.55	.64693	.64570	.64448	.64326	.64205	.64083	.63963	.63842	.63722	.63603	9.91
2.56	.63483	.63364	.63245	.63127	.63008	.62891	.62773	.62656	.62539	.62422	9.73
2.57	.62306	.62190	.62075	.61959	.61844	.61730	.61616	.61502	.61388	.61275	9.57
2.58	.61162	.61049	.60937	.60824	.60713	.60601	.60490	.60379	.60268	.60158	9.40
2.59	.60048	.59938	.59828	.59719	.59611	.59502	.59394	.59286	.59178	.59071	9.25
2.60	.58964	.58857	.58750	.58644	.58538	.58432	.58327	.58221	.58116	.58012	9.10
2.61	.57908	.57804	.57700	.57596	.57493	.57390	.57288	.57185	.57083	.56981	8.94
2.62	.56879	.56778	.56677	.56576	.56475	.56375	.56275	.56175	.56075	.55976	8.81
2.63	.55877	.55778	.55680	.55581	.55483	.55386	.55288	.55191	.55094	.54997	8.67
2.64	.54900	.54804	.54707	.54612	.54516	.54421	.54325	.54231	.54136	.54042	8.55
2.65	.53947	.53853	.53760	.53666	.53573	.53480	.53387	.53294	.53202	.53110	8.42
2.66	.53018	.52926	.52835	.52743	.52653	.52562	.52471	.52381	.52291	.52201	8.31
2.67	.52111	.52022	.51932	.51843	.51754	.51666	.51577	.51489	.51401	.51313	8.19
2.68	.51226	.51138	.51051	.50964	.50878	.50791	.50705	.50619	.50533	.50447	8.07
2.69	.50361	.50276	.50191	.50106	.50021	.49936	.49852	.49768	.49684	.49600	7.97

TABLE 2.2B 1/H VS S 9

3 X S 9	0	1	2	3	4	5	6	7.	8	9	P
2.70	.49517	.49433	.49350	.49267	.49184	.49102	.49019	.48937	.48855	.48773	7.87
2.71	.48691	.48610	.48529	.48447	.48366	.48286	.48205	.48125	.48045	.47965	7.78
2.72	.47885	.47805	.47726	.47646	.47567	.47488	.47409	.47331	.47252	.47174	7.68
2.73	.47096	.47018	.46940	.46862	.46785	.46708	.46631	.46554	.46477	.46400	7.60
2.74	.46324	.46246	.46172	.46096	.46020	.45944	.45869	.45793	.45718	.45643	7.51
2.75	.45568	.45494	.45419	.45345	.45271	.45197	.45123	.45049	.44976	.44902	7.42
2.76	.44829	.44756	.44683	.44610	.44537	.44465	.44393	.44320	.44248	.44176	7.36
2.77	.44105	.44033	.43962	.43890	.43819	.43748	.43677	.43606	.43536	.43465	7.28
2.78	.43395	.43325	.43255	.43185	.43115	.43045	.42976	.42907	.42837	.42768	7.22
2.79	.42699	.42631	.42562	.42493	.42425	.42357	.42288	.42220	.42152	.42085	7.16
2.80	.42017	.41949	.41882	.41815	.41748	.41681	.41614	.41547	.41480	.41414	7.11
2.81	.41347	.41281	.41215	.41149	.41083	.41017	.40952	.40886	.40821	.40755	7.05
2.82	.40690	.40625	.40560	.40495	.40431	.40366	.40302	.40237	.40173	.40109	7.00
2.83	.40045	.39981	.39917	.39853	.39789	.39726	.39662	.39599	.39536	.39473	6.97
2.84	.39410	.39347	.39284	.39222	.39159	.39097	.39034	.38972	.38910	.38846	6.93
2.85	.38786	.38724	.38662	.38601	.38539	.38478	.38416	.38355	.38294	.38233	6.91
2.86	.38172	.38111	.38050	.37989	.37928	.37868	.37807	.37747	.37687	.37626	6.89
2.87	.37566	.37506	.37447	.37387	.37327	.37267	.37208	.37148	.37089	.37029	6.87
2.88	.36970	.36911	.36851	.36792	.36733	.36674	.36616	.36557	.36498	.36440	6.88
2.89	.36381	.36323	.36264	.36206	.36148	.36089	.36031	.35973	.35915	.35857	6.86
2.90	.35799	.35741	.35683	.35626	.35568	.35511	.35453	.35396	.35338	.35281	6.91
2.91	.35223	.35166	.35109	.35052	.34994	.34937	.34880	.34823	.34766	.34709	6.93
2.92	.34652	.34596	.34539	.34482	.34425	.34369	.34312	.34255	.34199	.34142	6.97
2.93	.34085	.34029	.33972	.33916	.33859	.33802	.33746	.33690	.33634	.33577	7.06
2.94	.33521	.33464	.33408	.33352	.33295	.33239	.33182	.33125	.33069	.33012	7.14
2.95	.32955	.32899	.32843	.32786	.32730	.32674	.32617	.32560	.32503	.32446	7.26
2.96	.32389	.32332	.32275	.32218	.32160	.32102	.32045	.31988	.31932	.31875	7.48
2.97	.31817	.31760	.31702	.31643	.31585	.31526	.31467	.31407	.31348	.31288	7.67
2.98	.31227	.31167	.31106	.31044	.30983	.30921	.30859	.30796	.30733	.30670	8.23

TABLE 2.3A 1/P VS S10

2 X S10	0	1	2	3	4	5	6	7	8	9	P
1.25	1.08206	1.07980	1.07754	1.07529	1.07305	1.07081	1.06858	1.06635	1.06413	1.06192	11.25
1.26	1.05971	1.05751	1.05531	1.05312	1.05094	1.04876	1.04659	1.04443	1.04228	1.04013	11.04
1.27	1.03799	1.03583	1.03372	1.03160	1.02948	1.02736	1.02526	1.02315	1.02106	1.01897	10.78
1.28	1.01688	1.01480	1.01273	1.01066	1.00859	1.00654	1.00448	1.00244	1.00040	.99836	10.57
1.29	.99634	.99432	.99230	.99030	.98829	.98630	.98430	.98231	.98033	.97836	10.32
1.30	.97638	.97442	.97246	.97050	.96855	.96660	.96466	.96273	.96080	.95887	10.13
1.31	.95695	.95504	.95313	.95122	.94933	.94744	.94555	.94367	.94180	.93993	9.94
1.32	.93806	.93620	.93434	.93249	.93064	.92880	.92696	.92513	.92330	.92148	9.72
1.33	.91966	.91785	.91604	.91424	.91244	.91065	.90886	.90708	.90530	.90353	9.53
1.34	.90176	.90000	.89824	.89649	.89474	.89300	.89126	.88952	.88779	.88606	9.32
1.35	.88434	.88262	.88091	.87920	.87749	.87579	.87410	.87241	.87072	.86904	9.15
1.36	.86737	.86570	.86403	.86237	.86071	.85905	.85740	.85576	.85412	.85243	8.95
1.37	.85085	.84922	.84759	.84597	.84435	.84274	.84113	.83953	.83793	.83633	8.78
1.38	.83474	.83316	.83157	.83000	.82842	.82686	.82529	.82373	.82217	.82062	8.59
1.39	.81907	.81752	.81593	.81444	.81290	.81137	.80985	.80832	.80681	.80529	8.43
1.40	.80378	.80227	.80077	.79927	.79778	.79629	.79480	.79332	.79184	.79036	8.28
1.41	.78689	.78542	.78396	.78250	.78104	.77959	.77814	.77669	.77525	.77381	8.10
1.42	.77437	.77294	.77151	.77009	.76867	.76725	.76584	.76443	.76302	.76162	7.96
1.43	.76022	.75883	.75743	.75604	.75466	.75328	.75190	.75052	.74915	.74778	7.79
1.44	.74642	.74505	.74369	.74234	.74099	.73964	.73830	.73696	.73562	.73429	7.65
1.45	.73296	.73163	.73031	.72898	.72767	.72635	.72504	.72373	.72243	.72112	7.50
1.46	.71982	.71853	.71724	.71595	.71466	.71338	.71210	.71082	.70955	.70828	7.36
1.47	.70702	.70575	.70449	.70323	.70198	.70073	.69948	.69823	.69699	.69575	7.22
1.48	.69451	.69326	.69205	.69082	.68959	.68837	.68715	.68594	.68473	.68352	7.09
1.49	.68231	.68111	.67991	.67871	.67752	.67632	.67513	.67395	.67276	.67158	6.95
1.50	.67040	.66923	.66805	.66688	.66572	.66455	.66339	.66223	.66108	.65993	6.83
1.51	.65878	.65763	.65649	.65534	.65420	.65307	.65193	.65080	.64967	.64855	6.70
1.52	.64742	.64630	.64518	.64407	.64296	.64185	.64074	.63963	.63853	.63743	6.58
1.53	.63634	.63524	.63415	.63306	.63198	.63089	.62981	.62873	.62765	.62658	6.46
1.54	.62551	.62444	.62337	.62231	.62124	.62019	.61913	.61808	.61702	.61598	6.35
1.55	.61493	.61388	.61284	.61180	.61077	.60973	.60870	.60767	.60664	.60561	6.23
1.56	.60459	.60357	.60255	.60153	.60052	.59951	.59850	.59749	.59649	.59549	6.13
1.57	.59449	.59349	.59249	.59150	.59051	.58952	.58854	.58755	.58657	.58559	6.02
1.58	.58461	.58364	.58266	.58169	.58072	.57976	.57879	.57783	.57687	.57591	5.92
1.59	.57496	.57401	.57306	.57211	.57116	.57021	.56927	.56833	.56739	.56646	5.82
1.60	.56552	.56459	.56366	.56273	.56180	.56088	.55996	.55904	.55812	.55721	5.73
1.61	.55629	.55538	.55447	.55356	.55266	.55175	.55085	.54995	.54905	.54816	5.63
1.62	.54726	.54637	.54548	.54459	.54371	.54282	.54194	.54106	.54018	.53931	5.54
1.63	.53843	.53756	.53669	.53582	.53495	.53409	.53323	.53236	.53151	.53065	5.45
1.64	.52979	.52894	.52809	.52724	.52639	.52554	.52470	.52386	.52301	.52218	5.37

TABLE 2.35 17- V- 510

2 X S10	0	1	2	3	4	5	6	7	8	9	P
1.65	.52134	.52050	.51967	.51884	.51801	.51718	.51635	.51553	.51470	.51388	5.28
1.66	.51305	.51224	.51143	.51061	.50980	.50899	.50818	.50737	.50657	.50576	5.20
1.67	.50496	.50416	.50336	.50256	.50177	.50097	.50018	.49939	.49860	.49781	5.13
1.68	.49703	.49625	.49545	.49468	.49390	.49313	.49235	.49158	.49080	.49003	5.05
1.69	.48926	.48850	.48773	.48696	.48620	.48544	.48468	.48392	.48316	.48241	4.98
1.70	.48166	.48090	.48015	.47940	.47866	.47791	.47717	.47642	.47568	.47494	4.91
1.71	.47420	.47347	.47273	.47200	.47126	.47053	.46980	.46908	.46835	.46762	4.85
1.72	.46690	.46619	.46546	.46474	.46402	.46331	.46259	.46188	.46117	.46046	4.78
1.73	.45975	.45904	.45833	.45763	.45692	.45622	.45552	.45482	.45412	.45343	4.72
1.74	.45273	.45204	.45135	.45065	.44996	.44928	.44859	.44790	.44722	.44654	4.66
1.75	.44585	.44517	.44449	.44382	.44314	.44247	.44179	.44112	.44045	.43978	4.61
1.76	.43911	.43844	.43778	.43711	.43645	.43579	.43513	.43447	.43381	.43315	4.55
1.77	.43249	.43184	.43119	.43053	.42988	.42924	.42859	.42794	.42729	.42665	4.51
1.78	.42601	.42536	.42472	.42408	.42344	.42281	.42217	.42153	.42090	.42027	4.46
1.79	.41964	.41901	.41838	.41775	.41712	.41650	.41587	.41525	.41463	.41401	4.41
1.80	.41338	.41277	.41215	.41153	.41092	.41030	.40969	.40908	.40846	.40785	4.37
1.81	.40725	.40664	.40603	.40543	.40482	.40422	.40362	.40301	.40241	.40181	4.33
1.82	.40122	.40062	.40002	.39943	.39883	.39824	.39765	.39706	.39647	.39588	4.30
1.83	.39529	.39471	.39412	.39354	.39295	.39237	.39179	.39121	.39063	.39005	4.27
1.84	.38947	.38889	.38832	.38774	.38717	.38659	.38602	.38545	.38488	.38431	4.24
1.85	.38374	.38316	.38261	.38205	.38148	.38092	.38035	.37979	.37923	.37867	4.21
1.86	.37811	.37755	.37700	.37644	.37588	.37533	.37478	.37422	.37367	.37312	4.19
1.87	.37257	.37202	.37147	.37092	.37038	.36983	.36929	.36874	.36820	.36765	4.18
1.88	.36711	.36657	.36603	.36549	.36495	.36442	.36388	.36334	.36281	.36227	4.16
1.89	.36174	.36120	.36067	.36014	.35961	.35908	.35855	.35802	.35749	.35696	4.15
1.90	.35644	.35591	.35539	.35486	.35434	.35381	.35329	.35277	.35225	.35173	4.14
1.91	.35121	.35069	.35017	.34965	.34913	.34862	.34810	.34758	.34707	.34656	4.15
1.92	.34604	.34553	.34502	.34451	.34399	.34348	.34297	.34246	.34195	.34145	4.15
1.93	.34094	.34043	.33992	.33941	.33891	.33840	.33790	.33739	.33689	.33639	4.17
1.94	.33588	.33538	.33488	.33438	.33388	.33337	.33287	.33237	.33187	.33137	4.19
1.95	.33087	.33037	.32987	.32937	.32888	.32838	.32788	.32739	.32689	.32639	4.23
1.96	.32590	.32540	.32490	.32441	.32391	.32341	.32292	.32242	.32192	.32143	4.27
1.97	.32093	.32043	.31994	.31945	.31895	.31846	.31797	.31747	.31698	.31648	4.35
1.98	.31598	.31548	.31498	.31448	.31398	.31348	.31298	.31248	.31197	.31147	4.44
1.99	.31096	.31045	.30995	.30944	.30893	.30842	.30791	.30740	.30689	.30637	4.60

TABLE 2.40 1/H VS S11

X S11	0	1	2	3	4	5	6	7	8	9	P
.45	1.07541	1.07570	1.07300	1.07030	1.06761	1.06493	1.06226	1.05959	1.05693	1.05428	7.60
.46	1.05163	1.04900	1.04637	1.04375	1.04114	1.03853	1.03593	1.03334	1.03076	1.02818	7.45
.47	1.02561	1.02305	1.02049	1.01794	1.01540	1.01287	1.01034	1.00782	1.00530	1.00280	7.27
.48	1.00030	.99780	.99532	.99284	.99037	.98791	.98546	.98301	.98056	.97813	7.11
.49	.97570	.97327	.97086	.96845	.96605	.96365	.96126	.95888	.95650	.95413	6.94
.50	.95177	.94941	.94707	.94473	.94239	.94006	.93774	.93543	.93312	.93081	6.78
.51	.92852	.92623	.92394	.92167	.91939	.91713	.91487	.91262	.91037	.90814	6.63
.52	.90590	.90368	.90146	.89925	.89704	.89484	.89265	.89046	.88828	.88610	6.46
.53	.88393	.88177	.87961	.87745	.87531	.87317	.87103	.86891	.86679	.86467	6.32
.54	.86256	.86046	.85836	.85627	.85419	.85211	.85003	.84797	.84590	.84385	6.16
.55	.84179	.83975	.83771	.83568	.83365	.83163	.82961	.82760	.82560	.82360	6.02
.56	.82161	.81962	.81764	.81566	.81369	.81173	.80977	.80781	.80587	.80392	5.87
.57	.80196	.80005	.79813	.79621	.79429	.79238	.79048	.78858	.78669	.78480	5.72
.58	.78292	.78104	.77917	.77730	.77544	.77358	.77173	.76988	.76804	.76621	5.58
.59	.76438	.76255	.76073	.75892	.75711	.75531	.75351	.75171	.74992	.74814	5.44
.60	.74636	.74458	.74281	.74105	.73929	.73754	.73579	.73405	.73231	.73058	5.31
.61	.72885	.72712	.72540	.72369	.72198	.72027	.71857	.71688	.71519	.71350	5.18
.62	.71182	.71015	.70848	.70681	.70515	.70349	.70184	.70019	.69855	.69691	5.04
.63	.69528	.69365	.69202	.69040	.68879	.68718	.68557	.68397	.68237	.68078	4.92
.64	.67919	.67761	.67603	.67446	.67289	.67132	.66976	.66820	.66665	.66510	4.80
.65	.66356	.66202	.66049	.65896	.65743	.65591	.65439	.65288	.65137	.64986	4.67
.66	.64836	.64687	.64538	.64389	.64240	.64093	.63945	.63798	.63651	.63505	4.56
.67	.63359	.63214	.63069	.62924	.62780	.62636	.62493	.62350	.62207	.62065	4.44
.68	.61923	.61782	.61641	.61501	.61360	.61221	.61081	.60942	.60804	.60665	4.33
.69	.60528	.60390	.60253	.60116	.59980	.59844	.59709	.59574	.59439	.59304	4.23
.70	.59170	.59037	.58904	.58771	.58638	.58506	.58374	.58243	.58112	.57981	4.12
.71	.57851	.57721	.57592	.57462	.57334	.57205	.57077	.56949	.56822	.56695	4.02
.72	.56568	.56442	.56316	.56190	.56065	.55940	.55816	.55691	.55567	.55444	3.92
.73	.55321	.55198	.55075	.54953	.54831	.54710	.54589	.54468	.54347	.54227	3.83
.74	.54108	.53988	.53869	.53750	.53632	.53514	.53396	.53278	.53161	.53044	3.74
.75	.52928	.52812	.52696	.52580	.52465	.52350	.52236	.52121	.52007	.51894	3.65
.76	.51781	.51667	.51555	.51442	.51330	.51218	.51107	.50996	.50885	.50775	3.57
.77	.50664	.50554	.50445	.50335	.50226	.50118	.50009	.49901	.49793	.49686	3.49
.78	.49578	.49472	.49365	.49259	.49153	.49047	.48941	.48836	.48731	.48626	3.41
.79	.48522	.48418	.48314	.48211	.48108	.48005	.47902	.47800	.47697	.47596	3.34
.80	.47494	.47393	.47292	.47191	.47091	.46990	.46890	.46791	.46692	.46592	3.27
.81	.46494	.46395	.46297	.46199	.46101	.46003	.45906	.45809	.45712	.45616	3.20
.82	.45520	.45424	.45328	.45233	.45138	.45043	.44948	.44853	.44759	.44665	3.14
.83	.44572	.44478	.44385	.44292	.44199	.44107	.44015	.43923	.43831	.43740	3.09
.84	.43649	.43558	.43467	.43376	.43286	.43196	.43106	.43017	.42927	.42838	3.03

TABLE 2.49 1/H VS S11

1 X S11	0	1	2	3	4	5	6	7	8	9	P
.85	.42749	.42661	.42572	.42484	.42396	.42309	.42221	.42134	.42047	.41960	2.98
.86	.41873	.41787	.41701	.41615	.41529	.41444	.41359	.41274	.41189	.41104	2.94
.87	.41020	.40936	.40852	.40768	.40685	.40601	.40518	.40435	.40353	.40270	2.90
.88	.40188	.40106	.40024	.39942	.39861	.39780	.39699	.39618	.39537	.39457	2.87
.89	.39377	.39297	.39217	.39137	.39058	.38979	.38900	.38821	.38742	.38664	2.83
.90	.38585	.38507	.38430	.38352	.38274	.38197	.38120	.38043	.37966	.37890	2.81
.91	.37813	.37737	.37661	.37585	.37509	.37434	.37359	.37284	.37209	.37134	2.79
.92	.37059	.36985	.36910	.36836	.36762	.36689	.36615	.36542	.36468	.36395	2.77
.93	.36323	.36250	.36177	.36105	.36032	.35960	.35889	.35817	.35745	.35673	2.76
.94	.35602	.35531	.35460	.35389	.35319	.35248	.35178	.35107	.35037	.34967	2.76
.95	.34897	.34828	.34758	.34689	.34619	.34550	.34481	.34413	.34344	.34275	2.76
.96	.34207	.34138	.34070	.34002	.33934	.33866	.33799	.33731	.33664	.33596	2.77
.97	.33529	.33462	.33395	.33328	.33261	.33195	.33128	.33062	.32995	.32929	2.79
.98	.32863	.32797	.32731	.32665	.32600	.32534	.32468	.32403	.32337	.32272	2.81
.99	.32206	.32141	.32076	.32011	.31946	.31881	.31817	.31752	.31687	.31622	2.87
1.00	.31557	.31493	.31428	.31363	.31298	.31233	.31168	.31103	.31038	.30973	2.93

TABLE 2.5A 1/H VS S12

1 X S12	0	1	2	3	4	5	6	7	8	9	P
.30	1.04963	1.04753	1.04544	1.04337	1.04130	1.03923	1.03717	1.03512	1.03307	1.03103	4.56
.31	1.02899	1.02696	1.02494	1.02292	1.02091	1.01890	1.01690	1.01490	1.01291	1.01092	4.54
.32	1.00894	1.00697	1.00500	1.00304	1.00108	.99913	.99719	.99526	.99333	.99141	4.50
.33	.98950	.98753	.98556	.98378	.98183	.97999	.97810	.97622	.97435	.97248	4.46
.34	.97061	.96875	.96689	.96504	.96319	.96135	.95951	.95768	.95586	.95403	4.42
.35	.95222	.95041	.94861	.94681	.94502	.94323	.94145	.93967	.93789	.93612	4.36
.36	.93435	.93259	.93083	.92908	.92733	.92559	.92385	.92211	.92038	.91865	4.32
.37	.91693	.91521	.91350	.91179	.91008	.90838	.90669	.90500	.90332	.90164	4.27
.38	.89996	.89829	.89662	.89496	.89330	.89164	.88999	.88834	.88669	.88505	4.22
.39	.88341	.88178	.88015	.87852	.87690	.87528	.87367	.87206	.87045	.86886	4.17
.40	.86726	.86567	.86408	.86250	.86092	.85934	.85776	.85619	.85463	.85307	4.12
.41	.85151	.84995	.84840	.84685	.84530	.84376	.84222	.84069	.83916	.83763	4.06
.42	.83611	.83459	.83307	.83156	.83006	.82855	.82705	.82555	.82406	.82257	4.00
.43	.82108	.81950	.81812	.81664	.81516	.81369	.81222	.81076	.80930	.80784	3.95
.44	.80636	.80493	.80348	.80204	.80060	.79916	.79773	.79630	.79487	.79345	3.89
.45	.79203	.79061	.78920	.78778	.78638	.78497	.78357	.78217	.78077	.77938	3.83
.46	.77799	.77660	.77522	.77383	.77246	.77108	.76971	.76834	.76698	.76561	3.77
.47	.76426	.76290	.76155	.76020	.75885	.75750	.75616	.75482	.75349	.75215	3.72
.48	.75082	.74950	.74817	.74685	.74553	.74421	.74290	.74159	.74028	.73898	3.66
.49	.73768	.73638	.73509	.73380	.73251	.73122	.72993	.72865	.72737	.72610	3.60
.50	.72482	.72355	.72228	.72102	.71976	.71850	.71724	.71598	.71473	.71348	3.54
.51	.71224	.71099	.70975	.70852	.70728	.70605	.70482	.70359	.70236	.70114	3.48
.52	.69992	.69870	.69749	.69628	.69507	.69386	.69265	.69145	.69025	.68905	3.42
.53	.68786	.68667	.68548	.68429	.68311	.68193	.68075	.67957	.67840	.67722	3.36
.54	.67606	.67489	.67372	.67256	.67140	.67024	.66909	.66794	.66679	.66564	3.30
.55	.66449	.66335	.66221	.66107	.65994	.65881	.65768	.65655	.65542	.65430	3.25
.56	.65318	.65206	.65094	.64983	.64871	.64760	.64650	.64539	.64429	.64319	3.19
.57	.64209	.64099	.63990	.63881	.63772	.63664	.63555	.63447	.63339	.63231	3.13
.58	.63124	.63016	.62909	.62802	.62696	.62589	.62483	.62377	.62271	.62166	3.08
.59	.62060	.61955	.61850	.61746	.61641	.61537	.61433	.61329	.61226	.61122	3.02
.60	.61019	.60916	.60814	.60711	.60609	.60507	.60405	.60303	.60201	.60100	2.97
.61	.59999	.59898	.59798	.59697	.59597	.59497	.59397	.59298	.59198	.59099	2.91
.62	.59000	.58901	.58803	.58704	.58606	.58508	.58410	.58313	.58215	.58118	2.86
.63	.58021	.57925	.57828	.57732	.57636	.57540	.57444	.57348	.57253	.57158	2.81
.64	.57063	.56968	.56873	.56779	.56685	.56591	.56497	.56403	.56310	.56217	2.76
.65	.56124	.56031	.55938	.55846	.55753	.55661	.55569	.55478	.55386	.55295	2.71
.66	.55204	.55113	.55022	.54931	.54841	.54751	.54661	.54571	.54481	.54392	2.66
.67	.54302	.54213	.54124	.54036	.53947	.53859	.53770	.53682	.53594	.53507	2.61
.68	.53419	.53332	.53245	.53158	.53071	.52984	.52898	.52812	.52726	.52640	2.57
.69	.52554	.52469	.52383	.52298	.52213	.52128	.52044	.51959	.51875	.51791	2.52

TABLE 2.58 1/11 VS S12

1 X S12	0	1	2	3	4	5	6	7	8	9	P
.70	.51707	.51623	.51539	.51456	.51372	.51289	.51206	.51124	.51041	.50958	2.48
.71	.50876	.50794	.50712	.50630	.50549	.50467	.50386	.50305	.50224	.50143	2.44
.72	.50063	.49982	.49902	.49822	.49742	.49662	.49582	.49503	.49424	.49344	2.40
.73	.49265	.49187	.49108	.49029	.48951	.48873	.48795	.48717	.48639	.48562	2.36
.74	.48484	.48407	.48330	.48253	.48176	.48100	.48023	.47947	.47871	.47795	2.32
.75	.47719	.47643	.47568	.47492	.47417	.47342	.47267	.47192	.47118	.47043	2.29
.76	.46969	.46895	.46821	.46747	.46673	.46600	.46526	.46453	.46380	.46307	2.25
.77	.46234	.46162	.46089	.46017	.45944	.45872	.45800	.45728	.45657	.45585	2.22
.78	.45514	.45443	.45372	.45301	.45230	.45159	.45089	.45019	.44948	.44878	2.19
.79	.44808	.44739	.44669	.44599	.44530	.44461	.44392	.44323	.44254	.44185	2.17
.80	.44117	.44048	.43980	.43912	.43844	.43776	.43708	.43641	.43573	.43506	2.14
.81	.43439	.43372	.43305	.43238	.43172	.43105	.43039	.42973	.42906	.42840	2.12
.82	.42775	.42709	.42643	.42578	.42513	.42447	.42382	.42317	.42253	.42188	2.09
.83	.42123	.42059	.41995	.41931	.41867	.41803	.41739	.41675	.41612	.41549	2.07
.84	.41485	.41422	.41359	.41296	.41233	.41171	.41108	.41046	.40984	.40922	2.06
.85	.40859	.40799	.40736	.40674	.40613	.40551	.40490	.40429	.40368	.40307	2.04
.86	.40246	.40185	.40125	.40064	.40004	.39944	.39884	.39824	.39764	.39704	2.03
.87	.39645	.39585	.39526	.39467	.39407	.39348	.39289	.39231	.39172	.39113	2.02
.88	.39055	.38997	.38938	.38880	.38822	.38764	.38706	.38649	.38591	.38534	2.01
.89	.38477	.38419	.38362	.38305	.38248	.38192	.38135	.38078	.38022	.37965	2.00
.90	.37909	.37853	.37797	.37741	.37685	.37630	.37574	.37518	.37463	.37408	2.00
.91	.37353	.37293	.37243	.37188	.37133	.37078	.37024	.36969	.36915	.36861	1.99
.92	.36807	.36752	.36698	.36645	.36591	.36537	.36484	.36430	.36377	.36324	2.00
.93	.36271	.36218	.36165	.36112	.36059	.36006	.35954	.35901	.35849	.35797	2.00
.94	.35744	.35692	.35640	.35588	.35537	.35485	.35433	.35382	.35331	.35279	2.00
.95	.35228	.35177	.35126	.35075	.35024	.34973	.34922	.34872	.34821	.34771	2.01
.96	.34720	.34670	.34620	.34570	.34520	.34470	.34420	.34370	.34321	.34271	2.02
.97	.34222	.34172	.34123	.34074	.34025	.33975	.33926	.33877	.33829	.33780	2.04
.98	.33731	.33683	.33634	.33586	.33538	.33489	.33441	.33393	.33345	.33297	2.05
.99	.33249	.33201	.33153	.33106	.33058	.33010	.32963	.32916	.32868	.32821	2.07
1.00	.32774	.32727	.32680	.32633	.32586	.32539	.32492	.32446	.32399	.32352	2.09
1.01	.32306	.32259	.32213	.32166	.32120	.32074	.32028	.31982	.31936	.31890	2.13
1.02	.31844	.31798	.31752	.31707	.31661	.31615	.31569	.31524	.31478	.31432	2.15
1.03	.31387	.31341	.31296	.31250	.31205	.31159	.31114	.31068	.31023	.30978	2.20
1.04	.30932	.30887	.30842	.30796	.30751	.30706	.30661	.30615	.30570	.30525	2.26