Thesis submitted by

"CHOIR" (P. McMahon)

Concerning subsection (e), 608, of the Animal Husbandry section of the Master of Agricultural Science Degree.

AN INVESTIGATION OF METHODS FOR THE ESTIMATION OF MEDULLATION IN WOOL SAMPLES.

CONTENTS.

AN INVESTIGATION OF METHODS FOR THE ESTIMATION OF MEDULLATION IN WOOL SAMPLES.

INTRODUCTION.

In studies of medullation in New Zealand wools the need for an accurate and rapid technique capable of giving a numerical index for the medullation of a sample of wool early became apparent. The matter was complicated by the fact that medullation can only be detected by hand and eye when it exceeds a certain coarseness, and to meet this difficulty the Benzol Test for the detection of hairiness was developed by Elphick. (1932)

The quantitive application of the test has proved difficult; in discussing the evaluation of the medullation revealed Elphick has pointed out that there are three factors which must be considered.

(1) The average diameter of medulla.

(2) The percentage of fibres medullated.

(3) The average distance down the fibres which medullation extends.

In order to arrive at an empirical index he estimated by eye the average percentage of fibres medullated over the staple and weighted the result arbitrarily according to the type of medulla.

After using the method in work on fleece mapping, Elphick came to the conclusion that while it was the best means available at the time for classifying the very large number of samples under examination it could not be regarded as satisfactory owing to the personal element involved, especially since the classification of medulla diameter into three groups masked the comparatively accurate estimation which could be made of the other two factors.

Since the method used was purely empirical it was proposed to relate the figures obtained to the percentage volume of medulla determined by some absolute means. Preliminary investigations on the determination of the Specific Gravity of the wool samples had been commenced when unforeseen circumstances compelled Elphick to discontinue the work.

SOME OBSERVATIONS ON THE ACCURACY OF ELPHICK'S METHOD.

To obtain some idea of the nature of the problems involved about 180 samples from stud Romney ram hoggets were examined using the above method. Repeats on the same samples even after quite short intervals shewed that considerably more experience than that gained by testing a few hundred staples would be necessary before any degree of reliability could be achieved.

In order to obtain an indication as to the effect of the personal factor, four persons experienced in wool research were invited to estimate by eye the percentage of hairy fibres in staples laid out in benzol. Table I shews the results.

TABLE I. ESTIMATION OF PERCENTAGE MEDULLATION BY DIFFERENT PERSONS

	Sample Numbers			
Person	1	2	3	4
A	65	30	25	15
B	75	40	20	15
C	50	45	25	30
D	50	30	20	10

The samples were not disturbed between the estimations and there is reason to believe that the variation would have been greater if similar fresh samples had been taken and teased out separately for each person.

A staple evaluated by Elphick as 22/300, Plate I, was

mounted in kerosene in a tray and covered with a glass plate ruled with parallel lines. With the aid of a travelling binocular, the number of medullated and pure fibres cutting each line was counted, taking no account of the degree of medullation, at every 1/4 inch from the tip. Table II compares the results obtained with Elphick's estimates. It would appear that even with an experienced observer the percentages estimated do not necessarily coincide with the actual figures. From the general appearance of the staple I would suggest that the visual estimate of percentage is affected by the coarseness of the medulla to a much greater extent than might be considered probable.

TABLE II. COMPARISON OF ESTIMATED WITH ACTUAL PERCENTAGES.

DISTANCE FROM TIP Inches	MEDULLATED	NON-MEDULLATED	TOTAL	PERCENTAGE MEDULLATED	ELPHICK'S ESTIMATE
0.25	15	50	75	20.0	
0.5	37	132	169	21.9	
0.75	82	212	294	27.9	60% Moderate
1.0	150	230	380	39.5	
1.25	221	227	448	49.5	
1.5	257	303	560	46.0	
1.75	254	393	647	39.4	10% Slight
2.0	261	456	717	36.4	
2.25	228	517	745	30.6	
2.5	171	601	772	22.0	
Repeats					
1.0	152	213	365	41.6	
1.25	221	231	452	49.0	

I cannot pretend to be able to improve upon Elphick's excellent treatment of the problems of visual estimation of percentage volume of medulla, but would suggest that of the factors affecting the figure obtained the diameter of medulla is the least easy to estimate accurately, while the relation of diameter to volume amplifies any errors. Since Elphick shews that the total range of

medulla volume per unit length varies as much as 256 times, while in practice it is not possible to divide this range into more than four classes, it seems that any attempt at visual estimation of percentage volume of medulla can never give accurate results even assuming accurate estimation of the other factors concerned.

It was suggested that a method of grading based on the estimated percentages of medullated fibres at various levels in the staple might be possible. One hundred and eight samples from six Romney hoggets were graded using a tentative method, but the results were not satisfactory owing to the complex mode of distribution of the medulla over the samples. Until more is known of the genetics of medullation, and the effects of environment upon the expression of e genetic make up of the follicles, the only sound plan is to evaluate medullation by the use of a simple quantitative index.

OTHER INDICES OF THE MEDULLATION INVESTIGATED.

The indices of medullation discussed in the present paper are as follows :-

Part I. The percentage of the total fibre length in the sample affected by medullation.

Part II. The amount of light reflected or absorbed by the wool when immersed in benzol.

Part III. The percentage volume of air space in the sample estimated from accurate determinations of specific gravity.

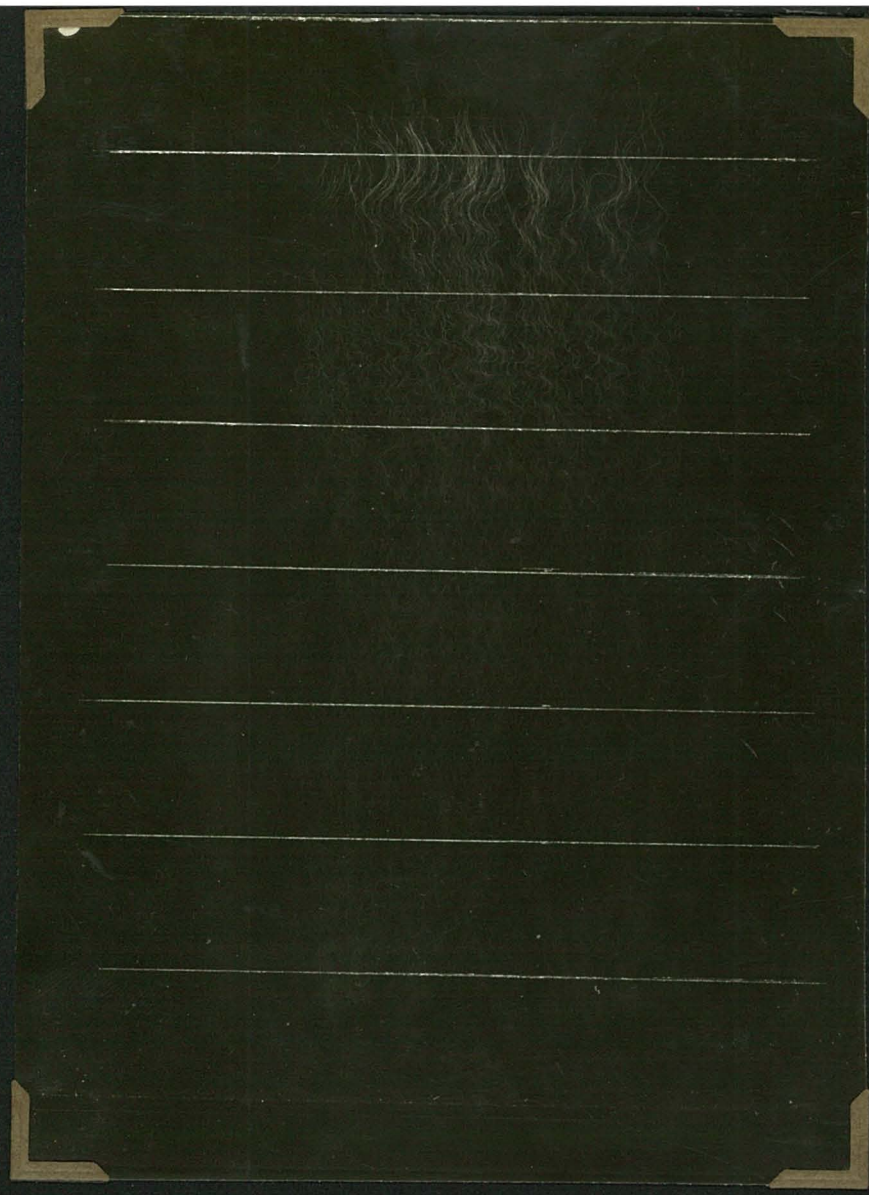
PLATE I

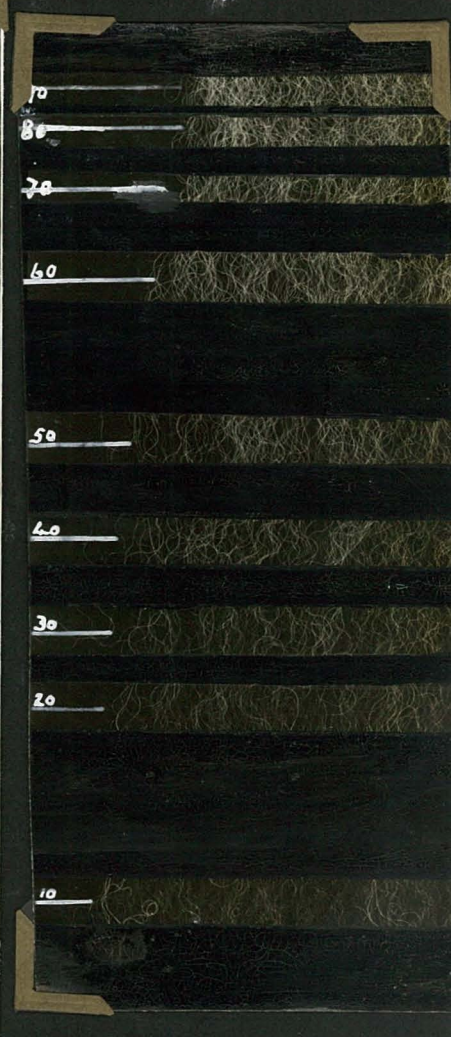
(a) Sample evaluated by Elphick.

(b) "Thickness of spreading" standard (300 fibres /1").

(c) "Percentage" standard.

(Plate 1a was taken by Mr. M. T. Gabriel, the remainder of the photographs reproduced in this thesis are the work of the author).




70
80
70
60
50
40
30
20
10

PART I. THE PERCENTAGE OF THE TOTAL FIBRE LENGTH IN THE SAMPLE AFFECTED BY MEDULLATION.

While not of such a fundamental nature as the percentage volume of medulla, this index offers a sound basis for estimation and selection.

It has already been shewn that unaided visual estimates of percentage medullated fibres for a given region in a staple are apt to be inaccurate and variable from person to person; attempts were made to devise a technique whereby accuracy and standardization could be obtained.

Since Elphick's unpublished experiments on infilling have shewn that there is no certain way of preserving an actual staple shewing a given degree of hairiness indefinitely, one has to fall back on photographs of such standard locks. It had been suggested that it might be possible to produce a series of standard photographs of locks shewing zones over which the percentage of medullated fibres was fairly constant. Several locks were selected and after photographing were counted in kerosene at every 1/4 inch from the tip. (See Appendix A). Very marked differences in the appearance of similar percentages were found to be associated with differences in the thickness of spreading the sample, making a standardization of the latter essential, and the question arose as to the accuracy with which a given degree of spreading could be reproduced. Attempts were made to match the thickness of spreading of a counted staple mounted on black velvet under a glass plate. Scoured samples were teased out roughly with fingers, placed on black velvet and pressed flat with a suitable sheet of glass, the appearance being compared with that of the standard. Small changes in thickness could be made by working the staple with one edge, or a corner, of the glass. In making comparisons it was found that the average size of the spaces be-

between the fibres was the best feature on which to base one's judgment of similar thicknesses of spreading. A medium hand lens power was found helpful.

To test the accuracy of the above method and also to get an indication as to the magnitude of the personal factor, two members of the College Wool Research staff kindly consented to tease out samples to be checked up by microscopic counts. Table III shews the results of these tests. It would appear that while a given thickness of spreading is reproducible with fair accuracy, there is a tendency to concentrate attention on the centre of the staple.

TABLE III. ACCURACY OF TEASING TECHNIQUE.

Person	Lock Number	Distance from Tips.	Fibres per inch. Teased sample	Standard
Writer	1	$1\frac{3}{4}$"	232	296
		$2\frac{3}{4}$	240	282
		3	258	265
		4	278	288
		$4\frac{1}{4}$	267	288
		$4\frac{1}{2}$	261	279
	2	2"	290	300
		3	288	300
		4	290	300
"A"	3	$1\frac{3}{4}$"	224	296
		$2\frac{3}{4}$	246	282
		3	250	265
		4	281	288
		$4\frac{1}{4}$	293	288
		$4\frac{1}{2}$	295	279
"B"	4	3"	218	265
		4	264	288
		$4\frac{1}{4}$	274	288
		$4\frac{1}{2}$	265	279

A thickness of 300 fibres to the inch was considered suitable as a basis for tentative standardization and was adopted in all subsequent work.

The extremely variable nature of the percentage gradient in various samples examined made it obvious that it would be difficult to produce standards with zones showing definite percentages of medullated fibres and attempts were made to devise a means whereby this percentage could be estimated, by comparison with standard photographs, at a number of regions, the results to be averaged to give the mean percentage over the staple.

A comparator whereby a slightly enlarged image of a portion of the sample teased to standard thickness and immersed in benzol could be viewed in the same microscopic field as the photograph did not give satisfactory results either when the images were made to fill apposing halves of the eyepiece field or when one image was colored with a red filter. The apparatus, however, was not particularly suited to the particular type of comparison.

It was suggested that greater accuracy and ease of comparison would result if the attention of the observer were concentrated on a narrow band running across the staple rather than upon the whole sample. A glass cover plate was ground with coarse carborundum leaving 1/4 inch intervals of clear glass at every inch. Water soluble pigment was rubbed into the ground areas, the intention being to shew the wool clearly at the 1/4 inch window intervals, the remainder of the plate being sufficiently opaque to obscure direct vision, while at the same time allowing observation of the general distribution of medullation, e.g., the occurrence of zoning.

Similar 1/4 inch bands were marked out on the standard and a number of samples were examined by various persons using the apparatus but it became apparent that judgment was made on general appearance, involving coarseness of medulla, rather than on percentage of fibres medullated.

The most satisfactory comparison was found to be obtain-

ed by using a grid consisting of lines etched on the cover glass and filled with water soluble pigment. This was placed upon the teased sample and the average distance between hairy fibres crossing the various lines on the plate compared with the average distance between hairy fibres on the standard.

Using this method of estimation repeats on the same samples after re-teasing gave concordant results which were found to compare favourably with the actual percentages of medullated fibres obtained by counting under the microscope. (Table IV).

TABLE IV. COMPARISON OF ESTIMATED PERCENTAGE OF MEDULLATED FIBRES WITH ACTUAL PERCENTAGE.

Level	LOCK A.		LOCK B.	
	Estimated %	Actual %	Estimated %	Actual %
1	40	50	40	33
2	40	35	60	57
3	40	40	80	76
4	35	34	90	84
5	40	36	90	82
6	40	39	60	69
7	40	40	30	41
8	30	35	20	21
9	30	35	10	12
10	25	26		
11	20	18		
12	10	11		

In preliminary work estimations were made at 1/4 inch intervals but in later work it was considered to be sufficient to divide the staple length into seven equal portions, using the 1/4 inch grid, and to take the average of the seven estimations as being representative.

It would appear that a method similar to the above would be capable of expressing, with reasonable accuracy, the percentage of

the total fibre length in the staple affected by medullation, although it cannot be regarded as established without further checking against microscopic counts for samples involving different types and degrees of medullation, different counts, and in particular a study of the number of estimations required on each staple in order to get sufficient accuracy.

Although it has been used for routine work the technique is unsatisfactory for such purposes owing to the length of time required to complete an estimation. It seems reasonable to expect that experience in its use would suggest "short cuts" such as the device of matching the roughly teased sample with standards round about the 300 fibre mark, and using an appropriate percentage standard, rather than working to one set figure.

It seemed desirable to exhaust the possibilities of other methods of measuring medullation before proceeding with the elaboration of the technique above described, since in all scientific work it is general experience that while visual evaluations by comparison with standards is often both simple and accurate, these advantages are offset by the length of time involved.

PART II. THE AMOUNT OF LIGHT REFLECTED OR ABSORBED BY WOOL WHEN IMMERSED IN BENZOL.

It was suggested that examination of wool samples in monochromatic light might indicate further lines of investigation. Raw and scoured wool, as well as a sample in benzol, was examined using various lighting. The only unusual appearance was found in the case of illumination from a quartz mercury vapor source, under which wool heavy in condition gave an orange flourescence. It is possible that if the samples were dyed before viewing under the quartz lamp differences might be observed owing to the varying effects of dyes on medullated and non-medullated wool, and the fact that some dyes flouresce in ultraviolet light.

Since hair reflects considerably more light than pure wool when under the benzol test, it would seem that the amount of light reflected might be expected to serve as an index of the degree of medullation. At first sight it would appear probable that the amount of light reflected would be a function of the surface area of the medulla in the sample, in which case a linear relation between light reflected and percentage volume of medulla would not obtain. A given amount of fine medulla would have a greater surface area, and hence reflect more light, than the same amount of coarse medulla. There are such a large number of factors which might affect the amount of light reflected, however, that one cannot establish a relation on a priori grounds. The effect of the internal structure of the medulla upon its apparent whiteness, the distorting effect on apparent diameter due to the cortex of the fibre acting as a lens, reflection from the ends of small sections when the medulla is discontinuous, and probably many other factors, would have to bb considered.

Attempts were made to measure the light reflected from a moderately hairy sample in benzol, when placed in the concentrated

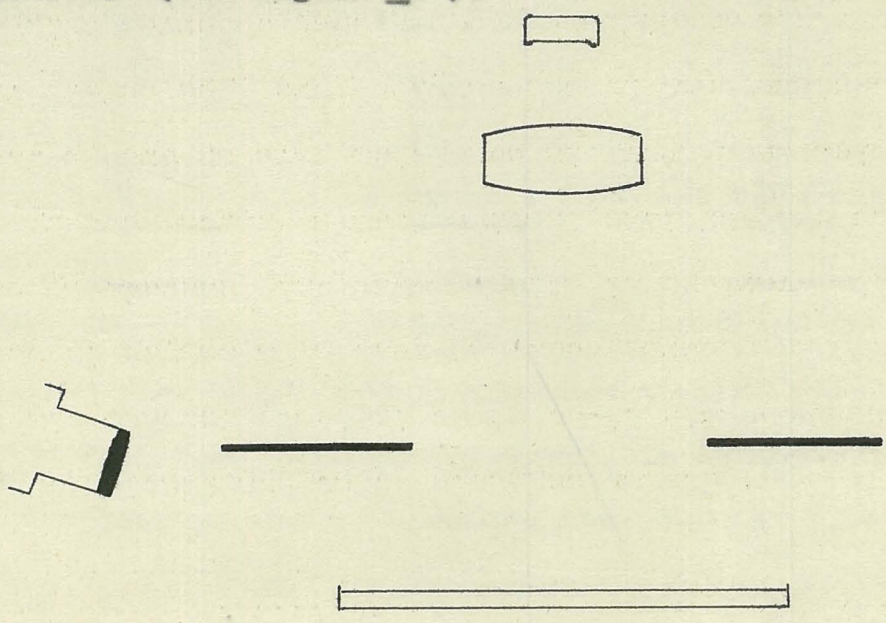
beam from a projection lantern, with a Lumner Brodhun cube but the illumination intensity was too low for the instrument to be successfully used.

PRELIMINARY EXPERIMENTS UTILIZING A PHOTOELECTRIC CELL.

The possibility of utilizing a photo cell for the purpose of measuring the amount of light reflected from samples of wool in the benzol test under standard conditions had been projected for some time. A survey was made of the literature on the subject, (Appendix B), and indicated that a photo cell of the rectifier type would be the most suitable for present purposes.

By courtesy of Standard Telephones and Cables (A'sia) Ltd., Wellington, a Weston Photronic cell was made available for preliminary experiments.

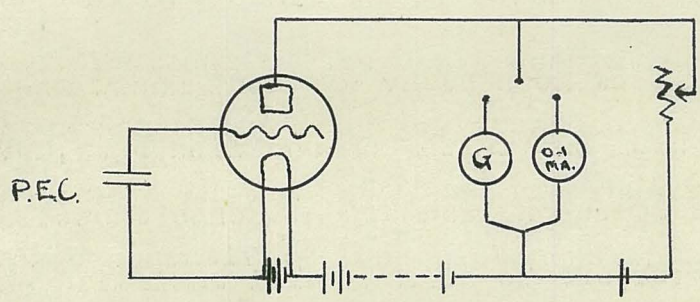
The optical apparatus was the same as that used with the Lumner Brodhun cube, an image of the brightly illuminated benzol test being focussed on the sensitive surface of the cell, which replaced the diffusing screen of the photometer, by means of a large aperture condenser. (See Figure I.).



The E. M. F. produced by the cell was measured using a

Tinsley potentiometer sensitive to 0.02 milli volt (m.v.) and was found to be of the order of 3 m.v. for a moderately hairy staple. A number of readings were taken using this apparatus but it was found that standardization of the potentiometer was necessary every few minutes - presumably owing to changing E.M.F., of the accumulator used.

Since the low internal resistance of the photo-cell (7,000 ohms) obviates the use of electrostatic methods of measurements a vacuum tube voltmeter used with a reflecting galvanometer, as indicating instrument, was decided upon as the most convenient means of measuring the cell E.M.F. The usual circuit (Figure 2) was fitted up and various types of tube tried.



A Phillips A.415 valve was found to give the most stable reading on the galvanometer.

Deflections were obtained by placing a black screen between the lens and the photo-cell and recording the "zero" deflection, the screen then being removed and the deflection again recorded. The apparatus was so arranged that the difference between these two readings was almost entirely due to light from the wool under test.

Table V shews some of the results obtained.

TABLE V. DEFLECTIONS OBTAINED WITH BADLY HAIRY TIPPED SAMPLE IN THE TRAY.

Galvanometer Readings		Deflection
Zero	Screen Removed	
Wool + Tray		
16.7	20.7	4.0
17.2	21.2	4.0
17.2	21.2	4.0
17.6	21.5	3.9
Wool in tray condensed into a much smaller area		
2.1	6.5	4.4
2.6	6.6	4.0
2.8	6.8	4.0
2.9	6.9	4.0
Wool Removed from Tray - Tray Alone		
4.2	5.3	1.1
4.5	5.6	1.1
4.5	5.6	1.1
4.8	5.8	1.0

To obtain an indication of the range of values, a series of graded samples was examined, the results being shewn in Table VI, deflections per unit weight of wool being calculated as a basis of comparison.

TABLE VI. PRELIMINARY DETERMINATIONS OF PHOTO ELECTRIC INDEX OF HAIRINESS.

Sample	Weight	Deflection	Deflection Due to Wool	Deflection per gram
Tray only		1.1		
A Almost Pure	0.29 gr.	1.7	0.6	2.1
B Hairy Tip	0.33	3.0	1.9	5.7
C do do	0.25	3.0	1.9	7.6
Same Sample Condensed	0.25	3.0	1.9	7.6
D General Medullation	0.29	5.5	4.4	15.1
E do do	0.44	8.0	6.9	15.7
F Bad Hairy Tip	0.31	9.3	8.2	27.0
G Hairy Sample	0.35	11.4	10.3	29.5

The photo electric indices are not accurate owing to the fact that the small central bakelite area on the cell used was insensitive to light, hence any portion of the hairiness image falling thereon would not be recorded[1]; moreover the illumination was not even. The results indicate, however, that stable readings may be obtained over a wide range of values.

Table VII shews the results of repeat determinations on some of the above staples after 24 hours, the samples being placed as nearly as possible in their original positions in the tray, - reasonable agreement is indicated.

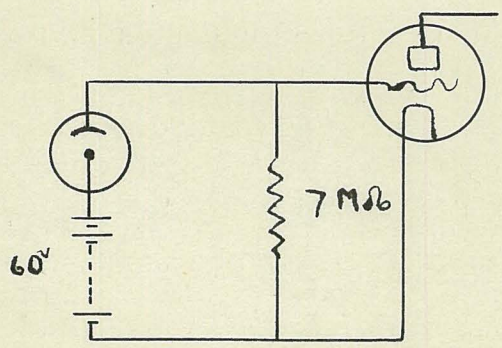
[1] Standard Telephones and Cables advised that cells without the central bakelite area were being manufactured and were available from the U.S.A., to special order.

TABLE VII. COMPARISON OF ORIGINAL AND REPEAT DEFLECTIONS FROM STAPLES AFTER 24 HOURS.

SAMPLE	ORIGINAL DEFLECTIONS	REPEAT
A	1.7	1.7
E	8.0	8.2
F	9.3	8.8
G	11.4	11.3

Experiments with a Vacuum Photo-Cell.

A photo-cell - probably of the vacuum type - kindly loaned by the Dominion Observatory was fitted up in the circuit shewn in Figure 3, and used with the same optical arrangement as before. Stable readings could not be obtained with the temporary electrical apparatus used owing to variable leakage effects, but the sensitivity did not appear to be so great as with the Weston cell.



CONCLUSIONS.

It appeared that a Weston Photronic cell of the type without the central bakelite area, used in conjunction with a well designed vacuum tube voltmeter, would be capable of measuring the light reflected from wool under the benzol test with considerable accuracy - 2 to 3%, provided that a constant source of illumination capable of producing an even brightness over the tray could be obtained, so that a given amount of medulla would

give a constant deflection without reference to its position in the tray.

DEVELOPMENT OF RELIABLE PHOTO-ELECTRIC APPARATUS.

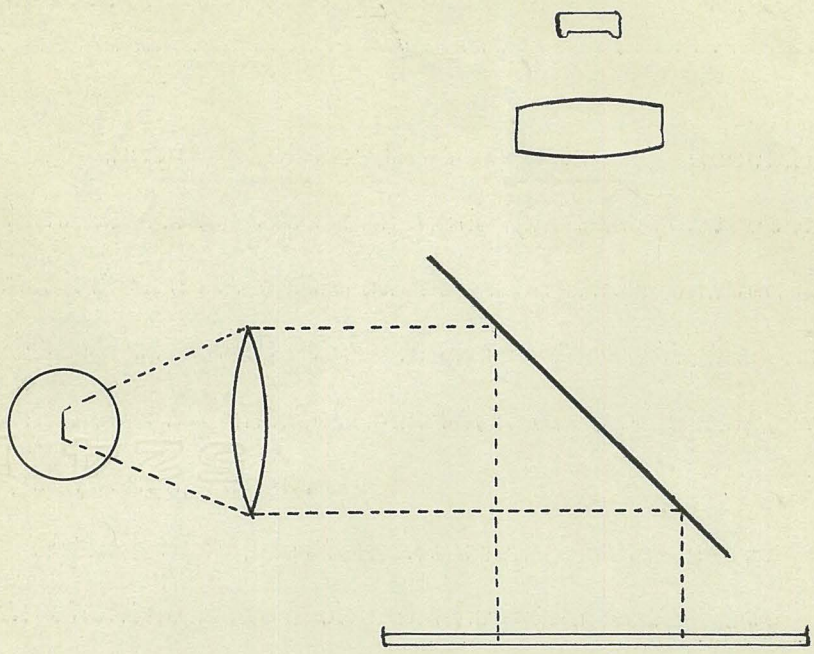
Apparatus similar to that already described was fitted up save that an A615 tube was used in the voltmeter circuit. Pending arrival of a cell with clear disc from United States of America, it was decided to study the problem of obtaining suitable illumination using a small uniform portion of the sensitive surface of the cell previously used.

Using a projection lantern as source of illumination, the deflection obtained from one square inch of white paper when placed in the position of the wool was measured and found to vary as much as 100% in different regions of the tray. Since it was unlikely that the illumination gradient was simple, the average of readings obtained from symmetrical placings of the tray would not be reliable.

Four 40 watt bulbs placed in bright tin reflectors did not give satisfactory lighting.

It was thought that even illumination might result if a beam of parallel light were obtained, using a 500 watt concentrated filament lamp as source, and thrown along the tray. A number of arrangements of lenses and diaphragms were tried in endeavours to achieve these conditions, but it was not possible to combine even illumination with high intensity.

The suggestion was made that uniform illumination might be obtainable by reflecting the light downward on to the wool using a plain sheet of glass through which the light from the tray could at the same time reach the cell. Figure 4. Such an



arrangement was tried but found quite unsatisfactory owing to the inefficiency of the glass as a reflector and the fact that an image of the illuminant was formed in the tray.

EXPERIMENTS USING TRANSMITTED LIGHT.

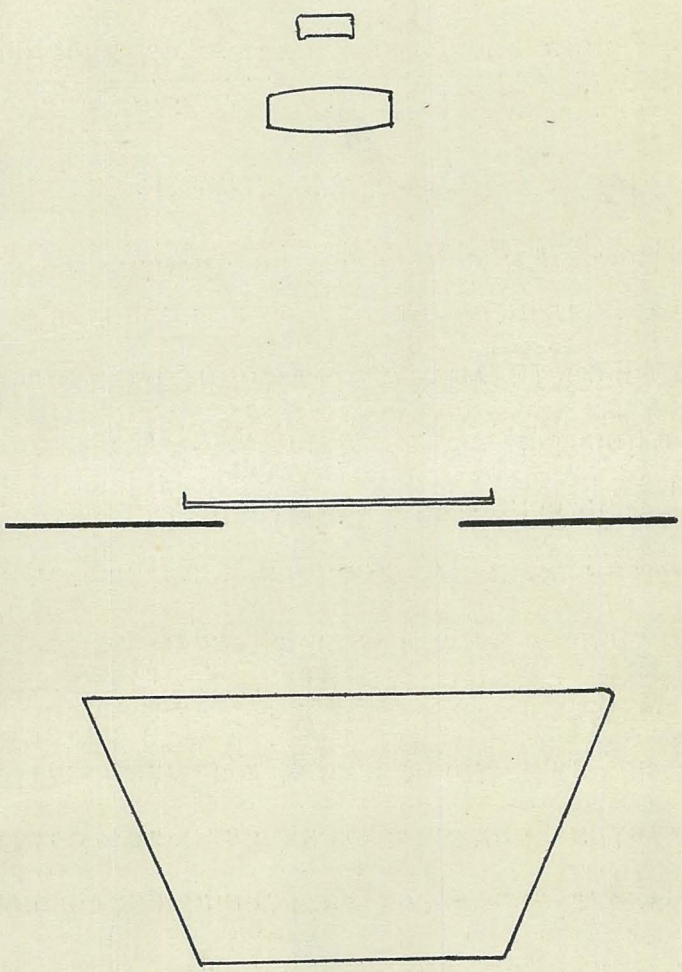
Measurement of the absorbtion of light by the medullated fibre when in benzol had not been looked upon with favour, it being considered easier to measure large variations in a small amount of light, than small variations in a large amount of light, especially since the Photronic cell is considerably more sensitive to small changes in illumination at low intensities. Moreover fluctuation in the source would be of greater importance in the case of transmitted light experiments.

Since even distribution of incident light could readily be obtained, however, the question arose as to whether the degree of absortion would be sufficient to overcome these difficulties.

The possibility of using a small glass trough containing the benzol and wool, almost in contact with the photo-cell and illuminated with a lamp moving along an optical bench, was discar because such a technique would involve a separate test in the c ary tray if the distribution of medullation in the staple was

recorded. From the routine point of view, the method has several advantages and deserves practical trial.

The arrangement in Figure 5 was set up and weighed samples were examined, but the results were unsatisfactory be-



cause stable readings could not be obtained. Table VIII shews the type of reading from "tray only", (successive readings),

TABLE VIII. DEFLECTION PRODUCED WITHOUT WOOL IN THE TRAY.

Deflection.		
From	To	Total
- 22.7	11.9	34.6
- 22.7	11.7	34.4
- 22.7	11.4	34.1
- 22.9	11.1	34.0
- 23.0	11.1	34.1

while Table IX gives the result of tests on graded samples based on averages of four readings for deflection. The refractive index of

TABLE IX. ABSORBTION OF TRANSMITTED LIGHT BY MEDULLATED SAMPLES IN BENZOL.

Sample	Weight	Deflection Tray Alone	Deflection Tray + Sample	Due to Sample	Deflection per gram	Remarks
A	0.38	34.2	33.7	0.5	1.3	Pure
B	0.47	34.2	33.0	1.2	2.5	Hairy Tip
C	0.28	34.2	33.6	0.6	2.1	Small amount of hair.
D	0.41	34.2	31.3	2.9	7.1	Large amount of hair.
A	0.25	34.2	34.0	0.2	0.8	Portion of sample A.
B	0.21	34.2	34.0	0.2	0.9	Portion of sample
B	0.25	34.2	34.0	0.2	0.8	Portion of sample
E	0.36	34.2	29.0	5.2	14.5	Very hairy sample

the benzol was 1.486.

Tests of the illumination with a small piece of black cardboard in various parts of the tray shewed that the distribution of light flux was uniform.

Galvanometer readings were taken at 10 second intervals, the first series with the cell in darkness and the second series with light from the source shining direct upon the cell.

Series (i). 17.2, 17.3, 17.4, 17.4, 17.3, 17.3, 17.4, 17.5,
17.4, 17.5, 17.4, 17.5, 17.5, 17.6, 17.6, 17.6,
17.7, 17.6, 17.6, 17.7, 17.7, 17.6

Series (ii). 21.7, 21.8, 21.8, 22.1, 22.4, 22.2, 22.1,
22.5, 22.2, 22.2, 22.2, 22.2, 22.3, 22.6,
23.1, 22.9, 22.5, 22.4, 22.7, 23.1, 22.5,
22.7.

The swing of the galvanometer with lamps "on" was compared with minor line voltage fluctuations and found to correspond exactly, indicating that the latter were affecting the lamps to an appreciable extent. The question of their elimination was discussed with Mr. W. A. Waters, Chief Engineer of the Manawatu-Oroua Electric Power Board, who stated that the only satisfactory methods would be the use of accumulator supply, or a generator direct coupled to a motor with a heavy flywheel. Both of these, however, were not feasible owing to expense involved.

An attempt was made to estimate an average value of the deflection by observing the swing of the reading over a period of about 20 seconds. Observations on dry wool placed over the aperture in the screen indicated, for results based on one pair of readings only, that the deviation from the true value might be as much as 5%, although fair accuracy could be obtained by averaging 8 to 10 readings.

CONCLUSIONS.

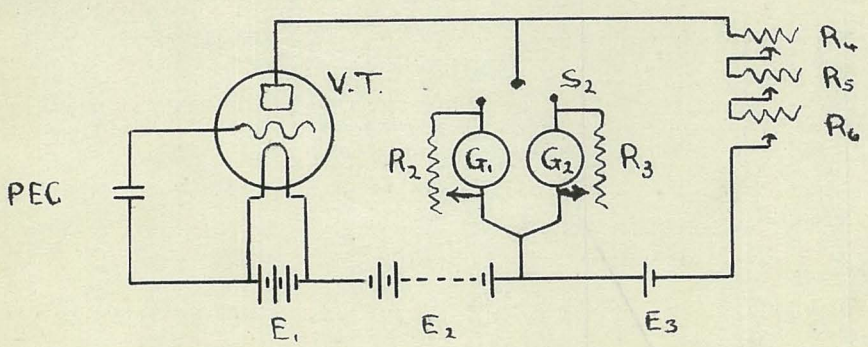
Any method relying on the measurement of the light absorbed by the medullation while at the same time retaining the staple in the same physical condition as in the ordinary test, cannot give satisfactory results since the proportion of light absorbed to the other sources of variation in the reading is not sufficiently high, the possibility of error being between 5 and 10% of the actual absorbtion.

APPARATUS FINALLY ADOPTED.

Since most of the difficulty experienced in obtaining intense yet even illumination was due to the action of the inverse square law, attempts were made to avoid this by the use of light sources of large size relative to their distances from the illuminated surface. High power opal lamps were found to fulfil this condition and the arrangement shewn in Plate IIa., consisting of four 150 watt bulbs was found to be satisfactory when used in conjunction with the photo cell without central bakelite area which arrived at this stage.

Various lens' systems were tried, the most satisfactory arrangement being the original condenser together with one lens from the condenser of a projection lantern.

Plate IIa., shews the optical apparatus in its final form with the velvet draping used to exclude external light removed to shew arrangement of tray, lamps, screen, lens and cell. A general view of the photo-electric apparatus is shewn in Plate IIb., while Figure 6 shews the schematic diagram of the electrical apparatus.



Difficulty experienced in obtaining sharp limitation of the area "scanned" was obviated by masking out unwanted portions of the image of the tray on the surface of the cell itself using rectangular aperature 0.8" x 1.3" which, with the optical system used, corresponded with a similar area 4" x 7" marked on the tray

within which the sample was placed.

I am indebted to Mr. J. Walker of the Palmerston North Technical School for the loan of a Weston A. C. Voltmeter by the aid of which the voltage applied to the lamps was maintained, save where otherwise stated, at as close as possible to 226 V using a 5 ohm rheostat.

Owing to the fairly high temperature coefficient especially at low illuminations, the photo cell was imbedded in plasticene so that any temperature change would not be rapid. The bulb of a thermometer was inserted into the plasticene and the temperature recorded taken as indicating roughly the temperature of the cell.

The amount of wool taken was determined by weighing the scoured samples after conditioning in the air of the laboratory for 2 - 3 hours. A Bunge damped balance was used, the weights being recorded to three places.

Deflections were obtained by taking the difference between the reading on the galvo., scale with the lamps off and the reading with the lamps on.

Unless otherwise stated the refractive index of the benzol used was 1.496 at 20° C.

PLATE II.

(a) THE OPTICAL APPARATUS WITH OUTSIDE COVER REMOVED.

D Diaphragm to prevent direct rays from the lamps reaching the lens and cell.

c Condensing lenses to focus an image of the test on the sensitive surface of the cell.

PEC Photonic cell imbedded in plasticene.

T Thermometer.

(b) GENERAL VIEW.

o The optical apparatus.

S Switch to control lamp.

V Voltmeter indicating lamp voltage.

R_1 5 rheostat to control lamp voltage.

R_2 7 " " " sensitivity of rough galvo.

R_3 10,000 " " " " " reflecting meter.

R_4 50,000 rheostat in galvo. balancing circuit

R_5R_6 500 " " " " "

S_2 Change-over switch for galvanometers.

G_1 Rough galvanometer.

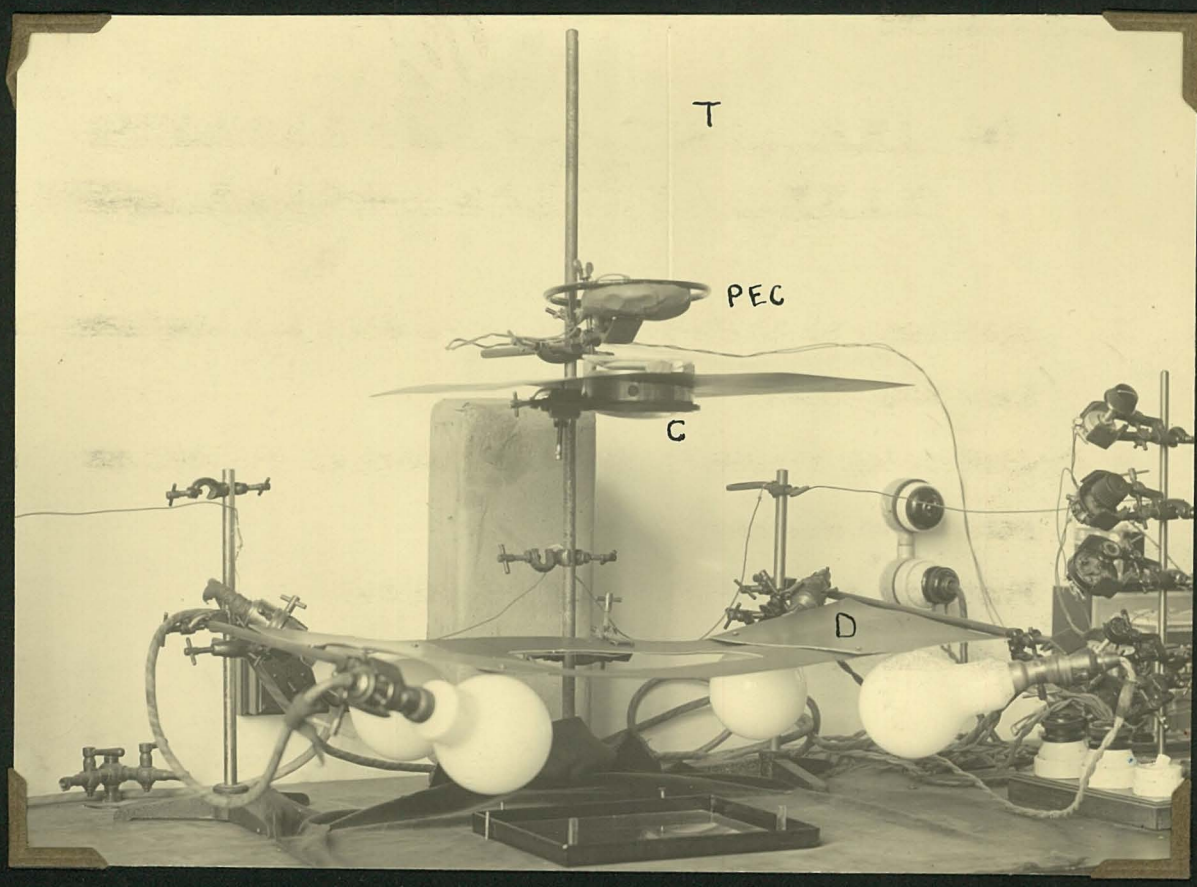
G_2 Reflecting "

V.T. Phillips Miniwatt A 615 valve.

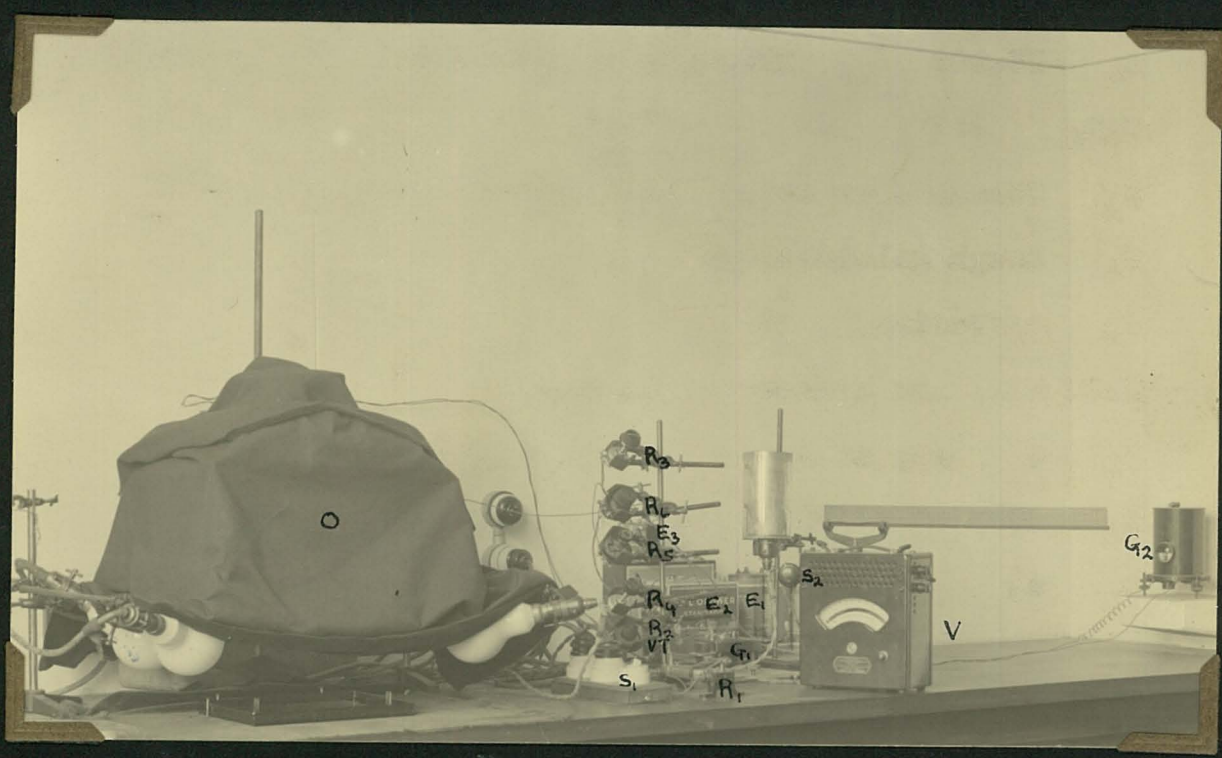
E_1 6 dry cells - filament supply.

E_2 60 " " - plate "

E_3 4½ " " - in balancing circuit.



a



b

FACTORS AFFECTING THE RELIABILITY OF THE PHOTO-ELECTRIC INDEX DETERMINED WITH THE ABOVE APPARATUS.

The following factors affecting the accuracy of the results obtained are discussed :-

(1) The constancy of the deflections.

(2) The standards used.

(3) The effect of variations in cell temperature.

(4) The effect of variations in lamp voltage.

(5) The evenness of the illumination.

(6) The effect of variations in refractive index of the benzol used.

(7) The effect of variations in spreading the sample.

(8) The accuracy with which results can be reproduced.

(9) The range of values.

(10) The effect of "smokiness".

THE CONSTANCY OF THE DEFLECTIONS.

Under given conditions it has been found that the deflection obtained is very reliable - successive readings taken almost invariably agree exactly while variation is seldom greater than 0.2 cm. on the galvo. scale.

Typical readings are shewn in Table X.

TABLE X. TYPICAL DEFLECTIONS OBTAINED.

Description	Scale Reading From	To	Deflection.
Tray alone.	13.4	11.0	2.4
	13.5	11.1	2.4
	13.7	11.2	2.5
	13.7	11.3	2.4
Tray + sample shewing fair amount of hairiness.			
	0.2	8.2	8.0
	0.1	8.1	8.0
	0.1	8.3	8.2
Tray + hairy sample	12.6	- 5.0	17.6
	12.6	- 5.0	17.6
	12.5	- 5.1	17.6
Standard grey surface	11.7	- 1.2	12.9
	12.4	- 0.4	12.8
	12.5	- 0.4	12.9

STANDARDS USED.

When the main part of this work was commenced, ie., the investigation of photometric methods of measuring medullation utilizing a photo-cell, it was hoped that it would be possible to complete the work to the stage of constructing an instrument suitable for routine purposes and standardized against the results of density determinations. It was soon realized, however, that there would not be sufficient time to complete such a project satisfactorily and no attempts were made to construct final permanent standards. Some remarks on this subject are included in the section on

suggestions for future work.

To ensure that results obtained throughout the series of experiments would be reasonably comparable the sensitivity was adjusted by varying the placing of the lamp and the sensitivity control R_3 to give a deflection of 2.4 cm. from the tray alone, and 12.9 cm. from a standard grey enamel surface larger than the area scanned by the cell. The latter scheme cannot be considered altogether satisfactory but in no case was there any marked variation in the calibration throughout an experiment. Typical results are shewn in Table XI.

TABLE XI. STANDARD READINGS OBTAINED DURING EXPERIMENT ON EFFECT OF CHANGE IN REFRACTIVE INDEX OF BENZOL.

	Deflection	Cell Temperature
Grey Standard at beginning of Experiment	12.9	20.0°
Tray only " " " "	2.5	20.0
" " half way through "	2.5	20.0
" " at end of "	2.5	20.4
Grey Standard " " " "	12.8	20.4

THE EFFECT OF VARIATIONS IN CELL TEMPERATURE.

The published coefficient of the cell indicates that fairly marked errors may be introduced if the temperature is not kept reasonably constant. An attempt was made to obtain a measure of the possible error when dealing with low light intensities. Table XII shews results obtained which indicate that while cell

TABLE XII. EFFECT OF CELL TEMPERATURE ON DEFLECTION FROM GREY STANDARD SURFACE.

Temperature Recorded	Deflection from Grey Standard.
15.5°	13.8 cm.
16.1	13.3
17.2	12.7
18.3	12.4

temperature has a fairly marked effect on E.M.F., generated, especially at low temperatures, no appreciable error could arise from this source so long as conditions remain reasonably constant. Prior to taking a series of readings the lamps were always left running for 5 - 10 minutes in order to allow the cell to reach a temperature above that of the room and which would remain more or less constant while readings were being taken.

THE EFFECT OF VARIATIONS IN LAMP VOLTAGE.

Accurate figures for the effect of change in voltage applied to the lamps on the reading could not be obtained owing to minor fluctuations in the former which prevented readings being made closer than one volt.

Table XIII shews that provided the line voltage is maintained at a reasonably constant level, no great error from this source need be expected.

TABLE XIII. EFFECT OF VARIATIONS IN LAMP VOLTAGE ON DEFLECTION FROM GREY STANDARD.

Lamp Voltage	Deflection from Grey Standard.
224 volts	12.5 cm
225	12.7
226	12.9
227	13.0
228	13.3
230	13.5

It is important to note that the effects of variations in cell temperature and lamp voltage only become apparent as an error in cases where the deflection is large, i.e. for very hairy samples where great accuracy is not required.

THE EVENNESS OF THE ILLUMINATION.

No difficulty was experienced in adjusting the position of the lamps to give reasonably even illumination by altering the angle of the lamps to the tray until the deflection obtained from a coin placed in the benzol was substantially the same in all parts of the tray.

In an experiment designed to demonstrate any unevenness in the illumination, a bundle of hairy fibres 2" long and weighing 0.159 gr. was taken to represent a lock with bad hairy tip and the deflection was recorded with this sample in various parts of the tray.

The range of variation in the deflection was from 7.0 to 7.4 cm. Now had this sample been a complete staple the 0.159 gr. hair would have been associated with at least 0.4 gr pure wool which would add only 0.5 cm to the deflection, so that the greatest possible variation between readings due to the effect of uneven illumination would be from 7.5 cm to 7.9 cm producing a variation in the photo-electric index of from 13.5 cm/gr to 14.1 cm/gr or about 4per cent.

In later experiments the lamps were more carefully adjusted to reduce this error to a maximum of about 2%.

Inherent variations in the sensitivity of various portions of the cell surface could not be distinguished

THE EFFECT OF VARIATIONS IN REFRACTIVE INDEX OF BENZOL USED.

Judging from visual impressions it was expected that the refractive index of the benzol in which the wool was immersed

would affect the value of the photo-electric index. The results given in Table XIV shew the magnitude of the variation in deflection and photo-electric index when "benzol" of varying refractive indeces was used.

TABLE XIV. EFFECT OF VARIATION IN REFRACTIVE INDEX OF BENZOL ON DEFLECTION AND PHOTO-ELECTRIC INDEX.

Refractive Index ($20^{\circ}C$)	1.4797		1.4900		1.4952		1.5000	
Sample	Dfl.	Dfl. grm	Dfl	Dfl. grm	Dfl.	Dfl. grm	Dfl.	Dfl. grm
A Pure Wool 0.714 gr	1.5	2.1	1.3	1.8	0.9	1.3	0.8	1.1
B Pure Wool 0.520	1.1	2.1	0.9	1.7	0.6	1.2	0.6	1.2
C Few Hairs 0.465	1.4	3.0	1.1	2.4	1.0	2.2	1.0	2.2
D Slightly hairy tip 0.556	1.9	3.4	1.5	2.7	1.3	2.3	1.1	2.0
E Hairy Sample 0.476	13.8	28.5	12.7	26.8	12.4	26.2	12.7	26.8

Variation within reasonable limits 1.490 - 1.500 appears to have no marked effect on the result.

THE EFFECT OF VARIATIONS IN SPREADING THE SAMPLE.

Table XV records the results of experiments on the effect of very marked changes in the degree of spreading of the sample when under test.

TABLE XV. THE EFFECT OF VARIATIONS IN SPREADING ON DEFLECTION AND PHOTO-ELECTRIC INDEX.

Sample	Treatment	Deflection	Deflection/gram.
A	Average Spreading	1.4	2.5
0.556 gr.	Folded over to cover ½ original area	1.5	2.7
Slight	do do do do ½ do do	1.6	2.9
hairy	Added more benzol to tray	1.6	2.9
tip	Opened out to original size	1.4	2.5
B	Average Spreading	0.9	1.3
0.715	Folded over to cover ½ original area	1.0	1.4
Pure 2			
Kempa.			
C	Average Spreading	0.25	1.1
0.234	Condensed, but not greatly	0.25	1.1
Pure	Opened out to twice original area	0.25	1.1
D	Average Spreading	10.4	38.5
0.269 gr.	Opened out to 1½ original area	10.1	37.5
Hairy	Folded over to cover ½ this area	10.8	40.0
	do do do do ½ do do	10.6	39.4
E	Average Spreading	8.6	39.0
0.210	Opened out slightly	8.2	37.3
Hairy	Folded over to cover ½ this area	8.8	40.0

These results confirm the general impression gained from numerous incidental experiments made at various times while examining samples under the photo-electric apparatus - to wit, that any effect of spreading is not marked. In no case have any large variations in the index been found to be due to abnormal spreading while in the cases cited above an appreciable change in the index occurs only when there is considerable change in the area covered by the sample. Since in this experiment all readings were repeated 3 times, while in only one case was deviation in successive readings greater than 0.2 cm., it is probable that the differences recorded are significant.

ACCURACY WITH WHICH RESULTS CAN BE REPRODUCED.

Although mechanically, the apparatus used can only be described as of a very makeshift and temporary nature, it is interesting to record a series of repeats on identical samples under routine conditions. Fourteen samples were examined and used for demonstration purposes being left dry in benzol trays on the laboratory bench away from direct sunlight for three weeks before being re-examined.

The results of both examinations are given in Table XVI. It is probable that the variations in case of samples P E I (b), P E 2 (b), P E 4 (b) are due to infilling.

TABLE XVI. REPEATS ON SAME SAMPLES AFTER 3 WEEKS' INTERVAL.

	Series i			Series ii		
Sample	Weight	Deflection	Deflection per gram	Weight	Deflection	Deflection per gram
$PE1_a$	0.412	0.8	1.9	0.412	0.7	1.7
b	0.417	0.9	2.2	0.416	0.7	1.7
$PE2_a$	0.393	1.0	2.5	0.390	0.9	2.3
b	0.337	1.3	3.9	0.342	1.0	2.9
$PE3_a$	0.307	3.1	10.1	0.305	3.1	10.1
b	0.298	9.0	9.7	0.295	2.8	9.5
$PE4_a$	0.303	1.1	3.6	0.292	1.0	3.4
b	0.281	1.2	4.2	0.274	0.9	3.3
$PE5_a$	0.411	13.5	33.0	0.408	14.2	35.0
b	0.232	6.6	29.0	0.229	6.6	29.0
$PE6_a$	0.191	3.8	20.0	0.191	3.8	20.0
b	0.294	8.3	28.0	0.295	8.4	28.5
$PE7_a$	0.225	8.9	40.0	0.224	8.9	40.0
b	0.277	10.3	37.0	0.271	10.6	39.0

RANGE OF VALUES.

Photographs of some of the samples reported in Table XVI are shown in Plate III, and give a rough idea of the range of values covered. The appearance of these must be regarded as approximate only, owing to the difficulty of securing standardization in the photography.

READINGS OBTAINED ON "SMOKY" SAMPLES.

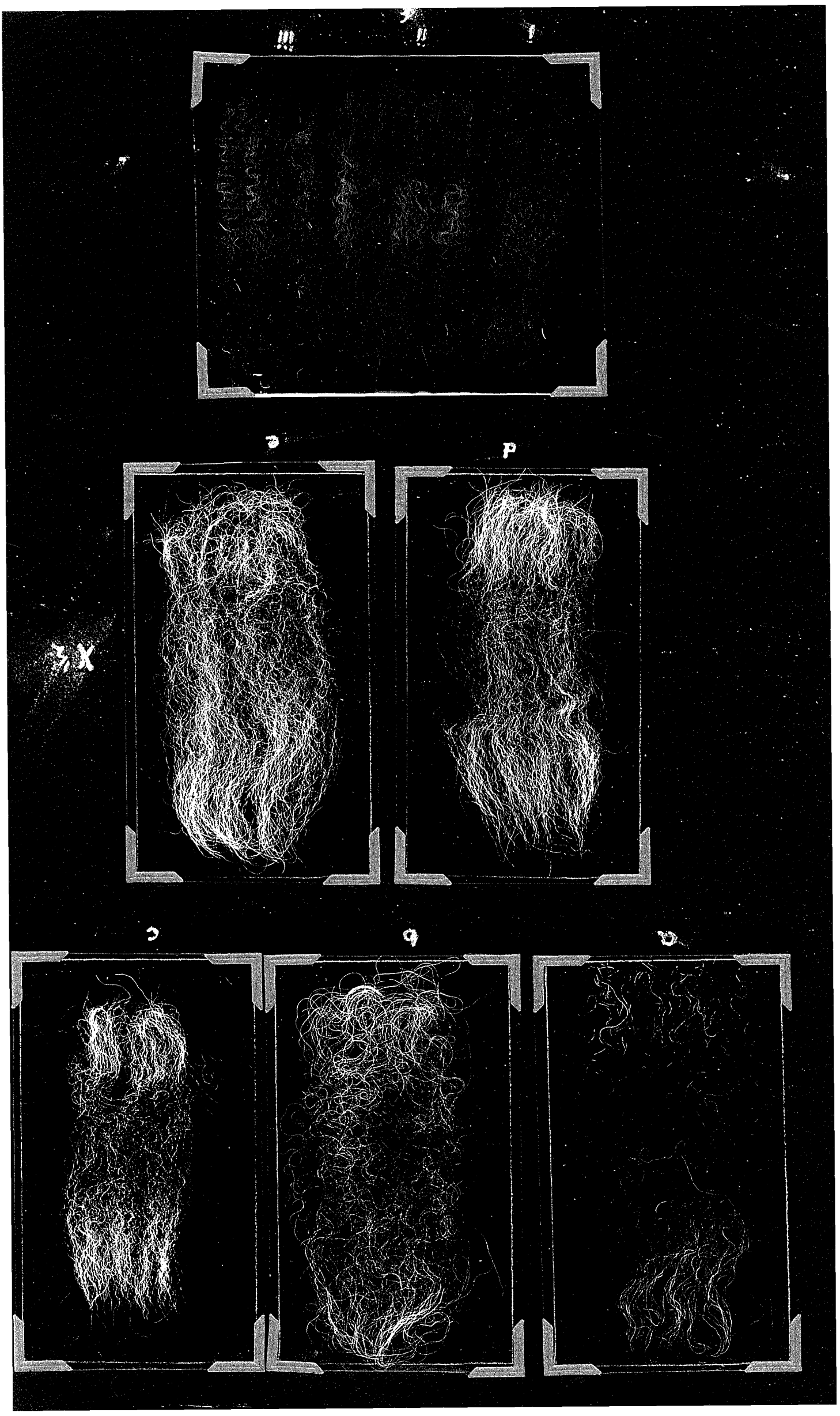
I am indebted to Mr. A. C. Morton for supplying several samples of wool shewing smokiness. The results are shown in Table XVII and an idea of the appearance of the samples may be gained from Plate III f although it is extremely difficult to reproduce the appearance of the samples exactly.

TABLE XVII. PHOTO-ELECTRIC INDICES FOR SMOKY SAMPLES.
(See Plate I).

Sample	Weight	Deflection	Deflection/ gram
1	0.187 gr	0. 3	1. 6
2	0.232	0. 4	1. 7
3	0.245	0. 4	1. 6
4	0.353	0. 7	2. 0
5	0.222	0. 4	1. 8

PLATE III. SAMPLES EXAMINED UNDER THE PHOTO-ELECTRIC APPARATUS.

(a)	P E 2_1	2. 5 cm/gr
(b)	P E 3_1	10. 1 " "
(c)	P E 6_1	20. 0 " "
(d)	P E 5_2	28. 6 " "
(e)	P E 7_1	39. 6 " "
(f)	Smoky Samples	
	i Nr 2	1. 7 " "
	ii " 4	2. 0 " "
	iii " 5	1. 8 " "



COMPARISON OF PHOTO-ELECTRIC INDICES WITH SPECIFIC GRAVITY OF SAME SAMPLE.

In the course of developing the technique of accurate specific gravity determination for wool samples, a number of samples were examined under the photo-electric apparatus prior to density determination being made. Sampling errors were avoided by examining the whole of the density samples staple by staple, and it is interesting to note the significant variations between locks drawn from the same bulk sample, which confirm Elphick's observations as to the variability between adjacent staples.

Table XVIII gives data relating to seven determinations by both methods. The percentage air space was calculated from the formula

$$\text{Airspace } \% = \frac{D_k - D_m}{D_k} \times 100$$

where D_k is the S.G. of pure keratin.
D_m " " " of the sample measured.
D_k is assumed to be constant. This assumption is probably correct for samples taken from the same animal, but there are strong indications of variation between individuals

TABLE XVIII. COMPARISON OF PHOTO-ELECTRIC INDEX WITH SPECIFIC GRAVITY AND PERCENTAGE AIR SPACE.

Sample	Weight	Deflection	Deflection per grm	Mean photo-electric index.	Specific Gravity	Approx. air spac %.
PEI_a	0.627	1.3	2.1			
b	0.767	1.5	2.0	2.0	1.299	0.00
c	0.647	1.2	1.9			
$PE2_a$	0.471	1.0	2.1			
b	0.583	1.3	2.2	2.3	1.297	0.15
c	0.662	1.7	2.6			
$PE3_a$	0.653	5.5	8.4			
b	0.548	4.9	8.9	8.6	1.275	1.85
c	0.537	4.5	8.4			

TABLE XVIII. (Cont'd).

Sample	Weight	Deflection	Deflection per gram	Mean photo-electric index	Specific Gravity	Approx. air space %.
$PE4_a$	0.519	2.6	5.0			
b	0.480	1.9	4.0			
c	0.572	2.7	4.7	4.4	1.297	0.15
d	0.44o	1.7	3.9			
$PE5_a$	0.485	13.4	27.6			
b	0.613	18.6	30.4			
$PE6_a$	0.347	9.7	28.0	28.4	1.199	7.70
b	0.355	9.5	26.7			
PE7 a	0.410	21.2	51.7			
b	0.426	17.7	41.5			
c	0.400	15.6	39.2	42.8	1.142	12.10
d	0.211	7.4	35.0			

Specific Gravity and percentage air space are plotted against photo-electric index in Figure 7. It would appear that there is a definite relation between the photo-electric index and the S.G. of the sample, but one is not justified in drawing final conclusions from such a small number of comparisons.

It should be noted that neither Specific Gravity nor percentage air space in the fibre is an accurate measure of percentage volume of medulla since Barker and King (1926) have shown that the proportion of air space in medulla is not constant when a wide range of hair types is considered.

For accurate calibration of the photo-electric apparatus, it may be necessary to perform all comparisons on a defined medulla type, and to express all measurements in terms of this.

DESIGN OF APPARATUS FOR ROUTINE WORK.

Among the refinements which would be made in an apparatus designed for routine work, several points may be noted.

STANDARDIZATION.

The choice of a suitable method of standardization is of the utmost importance, since calibration of the apparatus in absolute terms can only be checked by long and laborious methods. Since infilling rules out the possibility of using samples of wool of known medullation as permanent standards, we have to devise an artificial standard which can be calibrated and used under conditions resembling those ruling for the examination of wool samples as closely as possible.

This would involve the standard being used immersed in benzol in the actual tray used for the examination of wool samples, thus avoiding any error due to imperfections in the tray.

Various suggestions for design of suitable standards have been made from time to time.

(1) A spiral of Platinum wire of specific dimensions.

(2) Slabs of opal glass.

(3) Slabs of enamelled metal of suitable size and colour

(4) Slabs of ground glass, the ground surface being protected from benzol by some suitably sealed glass cover.

(5) Photographic standards suitably mounted to protect them from the action of benzol.

(6) Gauzes of specified dimensions constructed from some non-corrodible metal.

LINE VOLTAGE STABILITY AND ILLUMINATION.

Pulvertaft and Lemon (1933) have described a method by which fluctuations in cell output due to the effects of line voltage variations on the illuminants may be overcome, but their method is only applicable where a potentiometric method of measuring the cell E.M.F. is in use, and it is questionable whether such could be applied where the cell output is low.

The possibilities of controlling the line voltage deserves further investigation.

CELL TEMPERATURE.

Romain 1933 has shewn that while in rectifier type photo-cells, the total generated current is proportional to the illumination over a very wid e range, and is little affected by surrounding conditions encountered in ordinary use, the leakage through the internal resistance of the cell is subject to considerable variations. He points out that if the external resistance of the cell circuit, i.e. that of the indicating device, is kept small in proportion to the internal resistance, variations in the external current, due to the variations in the internal leakage which is in parallel, will also be small. This condition does not, of course, obtain when a th ermionic voltmeter is used to measure the cell E.M.F., since the grid fi lament resistance of the valve is always high. The question arises as to whether a means of measurement more satisfactory from this point of view could be obtained, or whether it is better to retain the pr esent arrangement and control the cell temperature artificially. It would appear to be a simple matter to place the cell in a well lagged enclosure, one side of which would be formed by the lens. Possibly awater cooling coil might be introduced into the enclosure with advantage, or again, the cell cooling coil might be imbedded in some suitable substance to ensure rapid conduction of heat from the cell to the coil.

One experimenter obtained an improvement in stability by placing his cell in an evacuated enclosure.

IMPROVEMENTS IN ILLUMINATION.

It is practically impossible to obtain a surface which will be absolutely dead black, i.e. will absorb 100% of th e light which falls upon it, and it has been found that light from the lower surface of the screen D Plate II reaches the cell surface by reflection in the tray, thus increasing the reading

obtained for the tray alone. Experience in the photographing of samples in benzol has indicated certain lines along which this feature could be to a large extent eliminated.

ELECTRICAL APPARATUS.

While no marked instability has been found to be due to lack of sheilding of the electrical equipment, it is probable that the building up of the apparatus into a more permanent form, in which all batteries etc. could be readily sheilded, would result in improved performance.

GENERAL CONVENIENCE.

Minor improvements such as the use of a foot switch to control the illumination, the placing of the galvanometer scale in a more convenient position, the arrangement of guides to ensure that the tray could be moved more readily, should be effected in an apparatus designed for routine use.

GENERAL CONCLUSIONS.

As a result of these investigations, it appears that a routine instrument could be constructed along the lines of the apparatus described, capable of giving results of considerable accuracy in terms of light reflected from wool samples under the benzol test. How closely this index is related to the percentage volume of medulla cannot yet be stated, but it would appear that even if exact agreement is not obtained, the method described is capable of making finer distinctions than can be made by the human eye, and is at the same time capable of exact standardization, thus eliminating the personal factor.

From the point of view of time required to complete an estimation, an all important factor in routine work, the photometric method compares very favourably with that of Elphick, especially when it is remembered that weighing the samples after the examination in benzol would considerably expedite the treatment of pure wool samples, which could be classed by eye. Since the present apparatus was not specially designed for convenience in working, no record of time taken in evaluations was kept, but under reasonable conditions a single operator should be able to scour, examine and weigh at least 20 - 30 samples per hour.

These features should make the instrument of the greatest value both from the point of view of the research worker requiring accurately to measure the medullation revealed in benzol, and from that of the sheep breeder in connection with certification schemes.

PART III. THE DETERMINATION OF SPECIFIC GRAVITY OF WOOL SAMPLES.

INTRODUCTION.

Since, as explained above, the light reflected from a sample of wool in benzol is only an empirical index of medullation, it has to be related to the percentage volume of medulla determined by some other method. Following Elphick's lead, the possibility of determining the Specific Gravity of wool samples with sufficient reliability to enable accurate values to be given to the proportion of medulla present, has been investigated. If the specific gravity of pure wool is constant, and it has been generally accepted as being substantially so, and the specific gravity of the medullated samples can be determined, a simple calculation gives the percentage volume of air space in the fibre and hence an indication of the percentage volume of medulla, provided we are not dealing with material in which the medulla is either very coarse or very fine - Barker & King (1926).

Owing to the fact that the investigations on photo electric technique and density technique were carried on in parallel, the accuracy required of the latter was not known at the commencement of the work. In order to have some standard of accuracy at which to aim, it was onsidered that both methods should be able to measure the medullation of a sample recorded as about 10 on Elphick's scale of hairiness. Such a sample might have 40% of its fibres medullated for an average of 20% of their length with "moderate" medulla (16/300). The proportion of the total volume of the wool occupied by medulla would be $\frac{1}{450}$ and if for purposes of approximate calculation we assume that this medulla contains no solid matter, and that the density of keratin is 1.304 (King, 192[illegible] the density of the medullated sample will be about 1.302. Thus

Thus, if differences in medullation corresponding to 10/300 are to be recognised, an accuracy in the density determination of 0.1% or better is required. Such an accuracy appears to have been obtained by King.

It should be noted that while for purposes of general comparison with photo-electric indices over the extreme range of hairiness the density range is large, and great precision is not essential, for comparison over the range met with on average animals (0 - 10 on the scale of photo-electric indices) accuracy of at least 0.1% is desirable in the specific gravity determination.

As stated before, it was originally hoped that it would be possible to complete this work in the time available by the production of a photometric instrument suitable for routine purposes, and carefully standardized. It was soon realised that such a project was impossible, and it was considered to be more profitable to study the sources of error in the technique of specific gravity determination with a view to their elimination in future work, than to apply the rough method to the purpose of calibrating an instrument not in its final form. At the same time, it was considered desirable to examine a small number of samples by both methods to determine the approximate range of values.

In the following pages a considerable amount of attention is paid to minute details of more or less common manipulations. This is necessary in view of the accuracy required for it is shewn that all weighings must be accurate within 1 milligram if a precision of 0.1% is to be obtained in the final figure.

A study of the available literature (Appendix C) led to the adoption of the following tentative technique.

EXPERIMENTAL.

Material for "Pure-Wool" Estimations.

Bulk sample D3 was selected from the shoulder of a well-grown Stud Romney fleece. A few kemps and stray medullated fibres were carefully removed by sorting in benzol.

Scouring the Samples.

A method of scouring similar to that used by Roberts 1932 based on Barritt & King's procedure, was used. After a preliminary rinse in benzol, the teased sample was extracted for 15 minutes in each of three successive lots of commercial benzol maintained at 45° C.

A sample of the benzol used shewed a negligible amount of non volatile matter (0.004%).

After the odor of benzol had vanished, the samples were extracted in distilled water at 55°C forthree changes each of 15 minutes duration. The sample was rinsed in clear distilled water when changing from one bath to the next.

Drying the Samples.

The greater part of the moisture mechanically adhering to the fibres was removed by pressing between clean filter papers and the remainder driven off by drying at 105° C. for 30 minutes. The sample was transferred to the S.G. bottle and completely dried by passing hot dry air through the wool by means of a glass tube passing right to the bottom of the bottle.

The drying apparatus is shewn in Plate IV a. Air from a filter pump blower is passed through two scrubbers of sulphuric acid, two calcium chloride towers, a tower containing P_2O_5 and is finally heated by passing through a spiral consisting of 10 feet of 3/16th" copper tubing within the oven. A plug of wool was placed in the joint of the copper and glass tubing to prevent any scale from the tubing gaining access to the bottle. Constant weight was obtainable to 0.1 mg on a 2 gr sample (See page).

It was found necessary to connect a 100 watt bulb across the oven contacts in order to by-pass the radio-frequency produced by sparking and which otherwise produced disturbances in the nearby photo-electric apparatus.

Details of exact temperatures and times of immersion in the scouring liquids as well as periods of drying in the oven, were recorded in all cases.

The S. G. Bottle.

A 50 c.c. S.G. bottle was selected and the stopper reground. To lessen the loss by evaporation, a small glass cap was constructed and after many failures a method was obtained by which it could be fitted to the neck of the bottle by an air tight ground glass joint.

After the usual cleaning, the cap and stopper were dried in alcohol and ether, the bottle itself being dried in the oven at 105°C and cooled in a dessicator prior to weighing.

The Volume of the Bottle.

The volume of the bottle was obtained by filling with freshly boiled and cooled conductivity water, adjusting at standard temperature and weighing.

The conductivity water had been standing in a flask of Chances glass for about six months prior to its being used and it has since been realised that there was an appreciable amount of dissolved glass. Repeat determinations made during the course of the investigations did not differ appreciably, save in the case of the final determination made, using fresh conductivity water, which gave a volume lower by 1 part in 50,000.

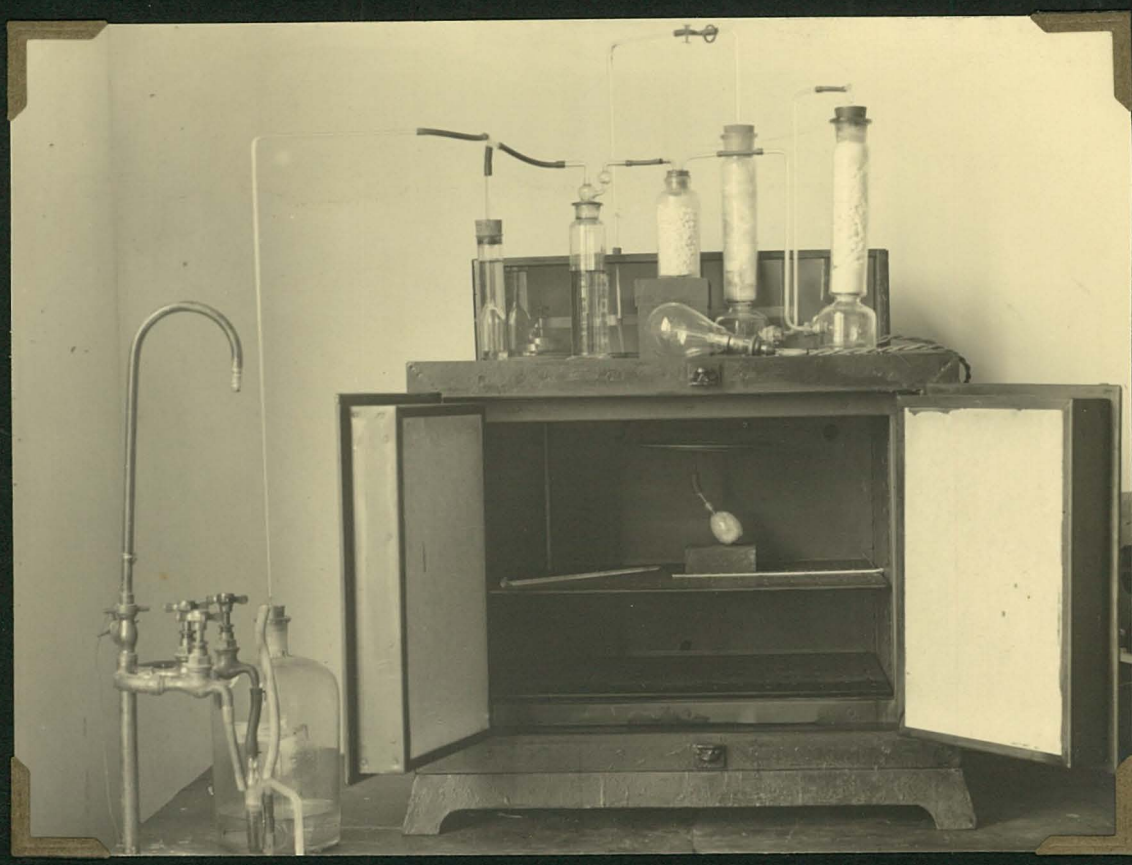
Vincent 1934 records the fact that the density of water kept in glass vessels changes slightly due to solution of glass, while Gilfillan 1934 and Washburn & Smith 1934, record small differences in the density of water purified from various sources.

Errors due to these factors were neglected for the comparative purposesof the present investigation.

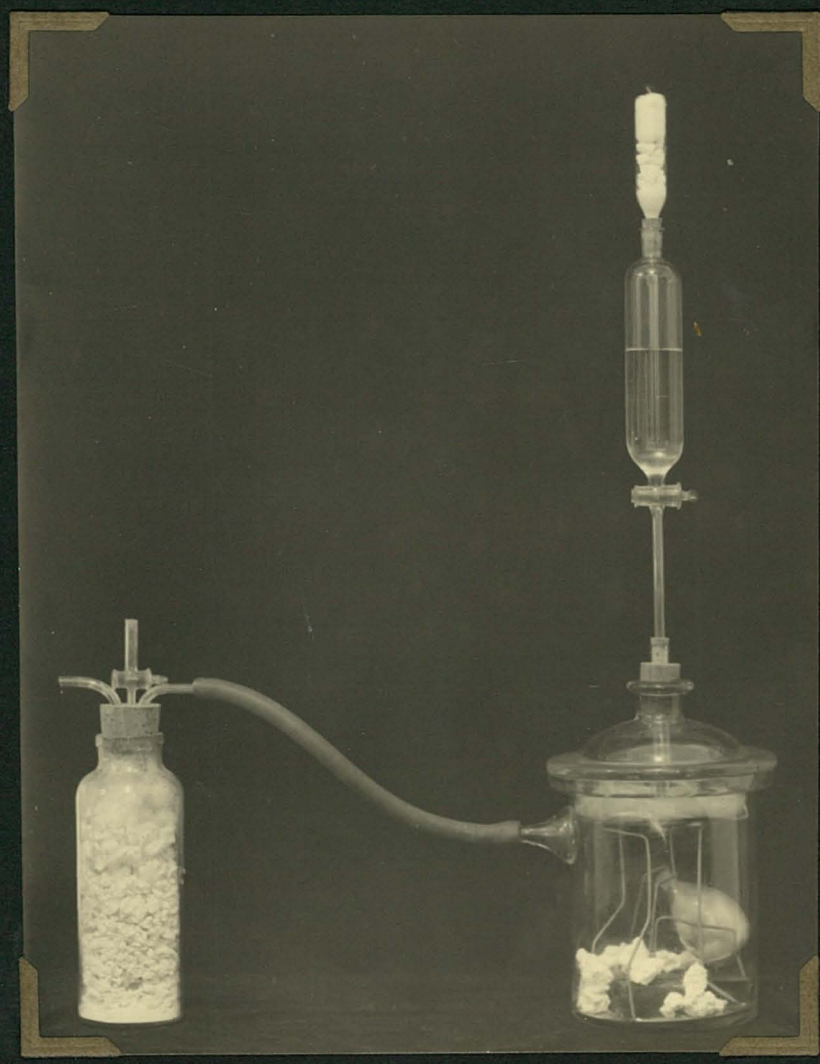
PLATE IV.

(a) THE DRYING APPARATUS.

(b) THE FILLING APPARATUS



a



b

Adding the Benzene.

"Pure, crystallizable" benzene was used and dried over calcium chloride.

The apparatus shewn in Plate IV was used to introduce the dry benzene into the bottle containing the dried wool. For the first five determinations the atmosphere of the dessicator was dried using calcium chloride, but from nr. VI onwards a dry atmosphere was maintained by the use of phosphorus pentoxide supported above the level of the bottle in addition to calcium chloride in the bottom of the dessicator.

Difficulty was experienced in the first determinations owing to air becoming entangled in the wool fibre during filling. Filling under partial vacuum and boiling under reduced pressure did not prove satisfactory. Usually the bubbles were found to disappear on standing for 18 - 24 hours. The method finally adopted and which proved entirely satisfactory, was to suck out the bubbles with a syringe filled with benzene and attached to a long hypodermic needle. Further, provided not more than about 1.7 gr. of wool were taken, air bubbles seldom occurred, although a careful search was made in every case before inserting the stopper.

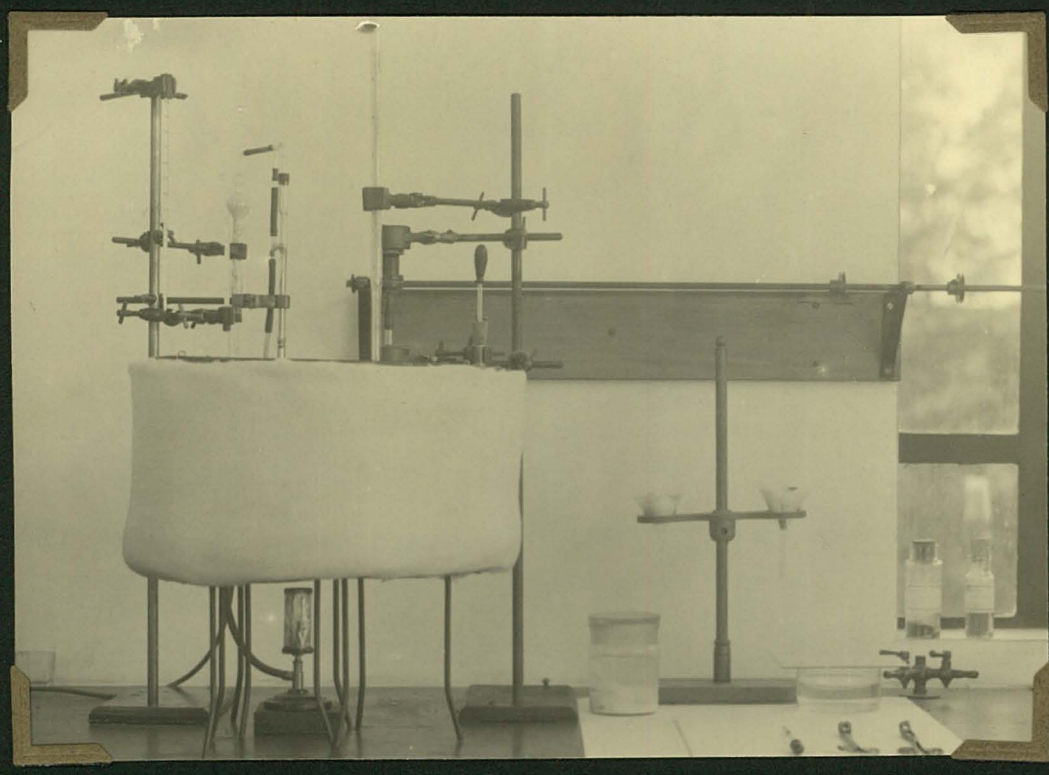
The Thermostat.

Plate Va shews the thermostat used throughout the experiments. A Beckman thermometer was standardised so that a reading of 3.150 corresponded to 25°C as recorded by a N.P.L. calibrated thermometer. Provided the gas pressure remained constant and the room was free from draughts, it was found that the thermostat maintained a temperature constant to about 0.01°C., while for periods of 15 - 30 minutes the temperature could be relied on to at least 0.002°C. See p.

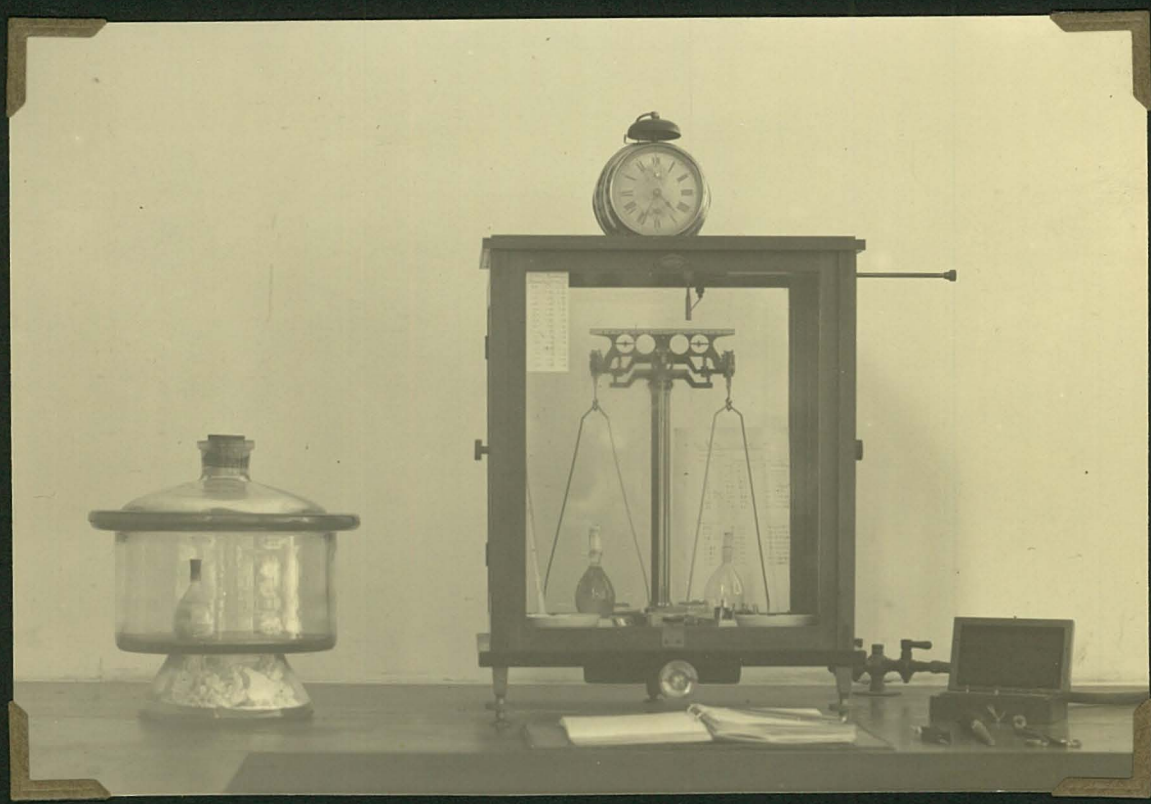
PLATE V.

(a) THE THERMOSTAT.

(b) THE BALANCE.



a



b

The stoppered and loosely capped bottle was fixed in a scanty lead framework to hold it in position without pressure and distortion, and immersed in the thermostat to the level of the base of the stopper for at least one hour. At the end of the period the inside of the cap, the top of the bottle, and the stopper were dried with filter paper. Evaporation from the capillary was replaced using a fine hypodermic needle attached to a glass syringe. A slight excess of benzene was added - sufficient to produce a globule just over the opening of the capillary, this was allowed to evaporate, and at the instant that the liquid was level with the top of the stopper, the cap was dropped into place, the bottle immediately removed from the bath, and the cap pushed hard home preparatory to drying and weighing.

WEIGHING: The Balance and Weights.

Weighing was performed by the usual method of swings. With experience, no difficulty was experienced in estimating the turning points to 0.2 of a scale division when errors due to parallax were avoided. Nine or more turning points were always observed, and provided the magnitude of the oscillation was not greater than about 3 scale divisions, successive turning points were found not to differ by more than 0.1 scale division, save for certain exceptions discussed later.

TABLE XIX. THE SENSITIVITY OF THE BALANCE.

LOAD	R.P.	R.P. with 1 mg added.	DEFLECTION due to 1 mg. (in scale divisions).
10	9. 6	6. 7	2. 9
20	10. 3	7. 4	2. 9
30	11. 5	8. 7	2. 8
50	10. 3	7. 5	2. 8
70	11. 9	9. 1	2. 8
100	14. 3	11. 5	2. 8

Table XIX shews the deflection produced by the addition of 1 mg. to one pan at various loads and from these figures the balance was calibrated.

The weights used were compared with N.P.L. standard weights on two occasions during the work and corrections were made on all weighings. Table XX shews the comparisons obtained.

TABLE XX. ACCURACY OF WEIGHTS USED.

Standard Weight	Routine Weight	
	19 :1 :34	17 :4 :34
50.0000 gr.	50.0015 gr.	50.0019 gr.
20. 0000	20.0005	20.0006
10 .0000	10.0003	10.0003
10 .0000	10.0004	10.0005
5 .0000	5.0003	5.0002
2 .0000	2.0000	2.0000
1 .0000	1.0000	1.0000
1 .0000	1.0000	1.0000
1 .0000	1.0000	1.0000
0.5000	0.5000	0.5000
0.2000	0.1999	0.1999
0.1000(Identified)	0.0995	0.0995
0.1000 (")	0.1000	0.1000
0.0500	0.0500	0.0500
0.0200	0.0200	0.0200
0.0100	0.0100	0.0100
0.0100	0.0100	0.0100

While the changes recorded are probably significant, the only serious deviation occurred in the 50 gr. weight which had a small corroded area and was not in use.

The weighing apparatus is shown in Plate V b.

The Routine of Weighing.

An attempt to obtain consistent weights of the bottle alone without the use of a counterpoise failed owing to uncertain adsorptio of a moisture film on the glass. Consistent results were obtained by counterpoising with a similar bottle of approximately even weight, both bottles receiving exactly the same surface treatment prior to weighing, as follows :-

Using a pair of cork-tipped tongs the counterpoise was wetted in the thermostat dipped twice into a bath of alcohol, twice into ether, then polished with a clean linen cloth doubled to avoid temperature conduction from the hand, and placed on the balance pan.

The bottle to be weighed was then removed from the dessicator or thermostat, treated in exactly the same manner as the counterpoise and placed on the balance pan. The weights and rider were adjusted, the resting point determined after 5 minutes, and the weight calculated.

Buoyancy corrections were not made on the first determinations since it seemed that they would be unnecessary for comparative purposes. See p. 52.

RESULTS OBTAINED.

The figure obtained for the density of pure wool from sample D 3 in determination Nr i was 1.305 gr/ml $25/4^{o}$, but in the light of later work it appears certain that this value is inaccurate. Although the greatest care was taken, it was impossible to foresee all the possibilities, and there were several sources of error, notably the addition of the benzene to the bottle containing the dry wool.

An outstanding feature was that while the volume of the bottle appeared constant - since it contained a constant weight of water - 8 determinations of the weight of benzene contained varied from 43.4685 gr to 43.4707 gr. On the assumption that the weight of the wool benzene mixture was subject to the same fluctuation, the possible error for wool density results based on one determination for each benzol weighing was 0.25%, the possible range of values being from 1.3032 to 1.3063 gr/ml $25/4^{o}$.

At the time it was thought that the deviations in weights were due to the high volatility of the benzene resulting in a variable loss by evaporation, the cap of the bottle not being a perfect fit.

It seemed possible that such an error could be reduced by cooling the bottle immediately on removal from the thermostat and since the weight of water contained by the bottle had been found to be constant under previous conditions it was decided to determine the effect of cooling on this weighing.

Immersion in ice water for five minutes produced too great a degree of cooling and a moisture film was found to condense on the cold glass immediately after polishing. Cooling in running tap water at 18° C. gave the same effect but to a much less degree, the weight of bottle and water being higher after such cooling than when the original method was used by a constant amount of 1.2 m.g.

A repeat by the original method shewed that after being subjected to a wide range of temperatures the volume of the bottle remained constant.

It seemed reasonable to suppose that the cooled figure would be on the whole less reliable than the uncooled figure since the latter would be less likely to be affected by prevailing atmospheric conditions. Moreover, it seemed probable that the permissible reduction in temperature, if marked condensation was to be avoided, would not be sufficient to reduce the evaporation of the benzene appreciably.

Two alternative lines of attack were suggested -

(1) The use of a lower thermostat temperature.

(2) The use of a less volatile density liquid.

Since the first alternative was quite impracticable under prevailing weather conditions, the physical characteristics of the other liquids recommended by King as suitable for use in determining the density of wool were considered - Table XXI.

TABLE XXI. PHYSICAL CONSTANTS OF LIQUIDS.

	Benzene C_6H_6	Xylene $C_6H_5(CH_3)_2$ (o.m.p.)	Toluene $C_6H_5CH_3$	Nitrobenzene $C_6H_5NO_2$
Density of Wool (king)	1.304		1. 306	1. 306
Boiling Point	80. 36°	(142° (139 (138	111°	210°
Specific Gravity	$0.879^{20°}$	$0.88^{20°}_{(0)}$	0.866	$1.2033\ \frac{20°}{4°}$
Solubility in Water (gr per 100 cc.)	$0.07^{22°}$	insol.	insol.	V. sl. sol.
Viscosity	$0.00649^{20°}$	0.00807(0)	$0.00586^{20°}$	-
Coeff of Expansion X10-5	124	101(m)	109	-

Of these nitrobenzene would appear to be the most suitable owing to high boiling point and high S.G., giving increased accuracy, a suitable supply was not available, however, and determination nr ii was made using Toluene as the density liquid.

A new S.G. bottle was constructed using an improved technique for grinding on the cap by means of which an airtight (dry) junction could be obtained.

That the use of toluene prevented any loss by evaporation was shewn by the fact that on several occasions there was no change in weight of the bottle and contents when left on the balance pan for periods of up to ½ hour. Further, on one occasion the bottle containing toluene was left to stand over night, and on re-weighing, shewed a loss in weight of only 0.3 mg. even though the liquid had distilled out through the capillary and condensed on the inside of the cap forming a ring of liquid at the level of the ground glass joint.

In determination nr. ii difficulty was again experienced in securing complete removal of air bubbles from the toluene wool mixture and the bottle was allowed to stand for 15 hours before the first weighing by the end of which period all the air bubbles had risen and the density of the wool was found to be 1.309 gr/ml. $25/_5$. Repeat weighings at 16, 17, and 18 hours from filling, shewed an apparent increase in density to the final figure 1.315 after 18 hours.

The weights of toluene contained in the bottle still shewed variability, however, and it was evident that some property of the organic liquids other than volatility was bringing about variation which did not occur when water was weighed under exactly similar conditions.

Since the present methods seemed incapable of giving the desired accuracy, the details of the determination were examined with a view to isolating sources of error.

The most obvious physical property wherein benzene and toluene both differ from water, is their coefficient of thermal expansion, which is about 5 times as great as the coefficient for water.

Now for 50 c.c. of water at a temperature of about 25°C the change in volume brought about by a change in temperature of 0.01°C is 0.0001 c.c. and the error in weighing corresponding to a deviation in the temperature of the bottle contents of 0.01°C from the standard value would be approximately 0.1 mg.

In the case of benzene the corresponding change in volume is 0.0007 c.c. and the error in weighing about 0.5 mg.

Similarly, if a small proportion of the total volume of the bottle, e.g. 2 c.c. were to differ from the standard temperature by 0.3° C., as might possibly occur if the bottle were not thoroughly immersed in the thermostat, the error would be less than 0.2 mg. for water but nearly 0.7 mg. for benzene.

If accurate results are to be obtained in weights of a constant volume of liquids such as benzene, possible variations in density due to temperature effects must be eliminated, and it was

decided to immerse the bottle as deeply as possible and to control the temperature to 0.002° C. In actual practice, it was found more convenient to allow the thermostat to come to its own level in the vicinity of the standard temperature and to apply a small correction, than to endeavour to adjust the gas regulator to maintain a predetermined temperature. As the correction was always small, the pressure of wool in the bottle or other source of error in the value of the actual coefficient of expansion of the bottle contents, would have a negligible effect.

Green, 1908, in connection with determination of density of solutions, has pointed out that the true density D is given by the formula

$$D = \frac{M}{W}\ (1 + 0.0012/\ D - 00012)$$

where W and M are apparent weights of water and solution, respectively, required to fill the bottle.

The corrections to be made on the apparent weight of the bottle and contents in order to eliminate the buoyant effect of the air, were investigated. It was found that if the density of the air of the balance case was taken as constant, an error of 5% of the value of the correction could arise and since the apparent weight of 50 cc benzene of density 0.88 gr/cc is 0.0524 gr less than the weight in vacuo, there is the possibility of 2.5 mg. error. For the benzene wool mixture the error is similar, while for water weighings it is very slightly less.

For the other weighings concerned, the 5% fluctuations in vacuum corrections are negligible. Since the fractional weights are of nickel of substantially the same density as the integers, it is permissible to subtract the apparent weight of the bottle i.e. weights necessary in addition to the glass counterpoise, from the weight of bottle and contents, and to make the buoyancy correction on the difference. Had the fractional weights been of Aluminium, this would not have been possible.

It was obvious that the possibility of variations in the corrections rather than the corrections themselves, were important, as pointed out by Green.

The density of the air is affected by three factors -

Temperature.

Pressure.

Humidity.

Reilly Rae & Wheeler (1926) point out that a change in temperature of 5° C will alter the apparent weight of 50 cc air by 1 mg. while a change in height of barometer of 1 cm. will alter the apparent weight of 50 cc air by 0.8 mg. The effect of a change of 10% round about 60% relative humidity is to change the weight of 100 cc air by 0.1 mg.

In all subsequent weighings the temperature of the balance case was recorded to 0.1° by an accurate thermometer placed near the left hand pan, while the pressure of the atmosphere was measured with a Fortin barometer. The possibility of error in weighing 50 cc benzene owing to temperature corrections not being made on the latter, is unlikely to exceed 0.1 mg.

Calculations from the partial pressure of water vapour in the atmosphere indicated that in the case under consideration, the possible variations could not affect the weights most senstive to errors in the buoyancy corrections by more than 0.3 mg. so that humidity changes were neglected.

An attempt was made to keep the humidity of the balance case approximately constant by the use of saturated solutions to minimise variations in humidity and to standardize adsorption of water on to the polished glass surface.

The factors given by Kaye & Laby were used in making all corrections.

Earlier in the investigation, certain effects were noted, which were traced to the presence of electric charges on the bottles as the result of polishing. It was found that if a bottle were polished and held just above one pan, the attraction was sufficient to take the pointer right off the scale - the charge being held for over 10 minutes in a dry atmosphere. It is quite impossible to forecast the final effect of such a charge upon the weighing, since

numerous objects all fall within the field of the bottle. The difficulty was avoided by the use of crystals of Uranium nitrate in the balance case near the bottles, the charge being dissipated within a few minutes. (See page however).

In the weighing of the bottles and contents after removal from the thermostat, there are several factors to be considered in deciding upon the technique. It is a standard rule that objects shall not be weighed when their temperature differs from that of the air in the balance case. The usual method of attaining this is to leave the object in the balance case for a considerable time before weighing. Such a procedure also standardizes the moisture adsorption error. It was not applicable to the present investigation, however, owing to the volatility of the liquid being weighed. Generally, vapour was found to distil out through the capillary, condensing upon the inner surface of the cap and running down to the ground glass joint where capillary forces carried it to the outside.

The loss from this source was later found to be very variable, but most troublesome in cold weather, since the condensation was then more rapid and changes in weight of 0.5 mg. have been observed in 5 - 10 minutes in some cases. It was obvious that the actual weighing must be performed very soon after removal from the thermostat and before the bottle could reach room temperature, thus allowing the possibility of convertion currents within the balance case. It seemed unlikely that the effect of these would be appreciable in any but the coldest weather.

If the cap of the bottle were not always airtight a further factor to be considered would be the contraction in volume of the benzene after the removal from the thermostat - often of the order of 0.5 cc. If air were admitted under the cap, variations would be appreciable.

The possibility of error in volume of the bottle due to difference in temperature between the glass of the neck and the stopper was considered, but it was

found that a temperature difference of 10°C would only result in a volume error of 0.0001 c.c.

Errors due to inaccurate adjustment of the level of liquid in the capillary are unlikely since a change in level of 0. 5 m.m. would only change the volume by 0.0004 c.c.

It was decided to investigate the accuracy obtained using the refined technique.

The weight of the bottle empty was found to be constant to 0.1 mg. provided the atmosphere of the empty bottle was in equilibrium with that of the balance case. After polishing, the bottle reached correct weight within 3 minutes of being placed in the balance case and there was no significant change in weight during the succeeding ten minutes.

It is interesting to note that during observations covering some 4 months no chance deviation greater than 0.1 mg. in the weights necessary to counterpoise the bottle empty has been observed.

Figures obtained on different days for weight of water contained in the bottle are shown in Table XXII.

Note: In the tables which follow, the following symbols have been used in connection with weighings :-

Wa - Weight of bottle contents in air (gr).

h - Barometric P. in mm. mercury.

T - Temperature of balance case.

T' - Temperature of thermostat as recorded on Beckman thermometer.

G' - Density of air of balance case $\times 10^{-6}$ gr per c.c.

C - Corrections on apparent weights in 10th of mg for buoyancy and temperature.

W_v - Weight of contents of bottle in vacuum at thermostat temperature T of 25°.

TABLE XXII. WEIGHT OF WATER CONTAINED IN THE BOTTLE AT 25° C.

Day	Wa	h	T	T'	G'	C	W_v
Mon.	52.2589	764	17.6	3.140	1221	567-1	52.3154
Wed.	52.2595	759	19.9	3.130	1204	559-2	52.3152
Sat.	52.2588	764	20.1	3.170	1211	562+2	52.3152
	Volume of bottle			52.4685 ml.			

while similar data for Benzene weighings are shown in Table XXIII.

TABLE XXIII. WEIGHT OF BENZENE CONTAINED IN THE BOTTLE AT 25° C.

Day	Wa	h	T	T'	G'	C	W_v
Fri.	45.5915	754	16.0	3.150	1211	571 0	45.6486
Sat.	45.5915	758	17.5	3.146	1211	571.2	45.6488

Weights taken on Thursday for which h was not known, all agree within themselves if h is assumed to be 755 mm.

Thurs.	45.5920	755(?)	19.0	3.160	1201	565.5	45.6490
"	45.5916	755	19.5	3.170	1199	565.10	45.6491
"	45.5923	755	19.2	3.152	1200	565 1	45.6490
	Density of Benzene			0.870021	per ml.	$25°/_4°$.	

To get an indication of the range of values, a grossly medullated sample was selected for the next determination.

In the second determination the weight of the wool had increased slightly at the final weighing, and it was thought possible that slight decomposition similar to that observed by Raynes, 1927, might have occurred. During the drying of sample nr iii investigations were carried out which indicated that moisture was

being picked up by the dried wool while cooling in the dessicator. Owing to danger of fracture the bottle had not been stoppered until it was removed cool from the dessicator for weighing, thus permitting the absorption (in the dessicator) of any moisture present, especially since the use of phosphorus pentoxide in drying the wool would givebetter dessication than the calcium chloride used in the dessicator.

It was found possible to obtain reliable constant weight within 0.1 mg by stoppering the bottle with a sound soft cork on removal from the oven, and during cooling in the dessicator. See Plate $\overline{V}_b$.

Table XXIV records the results of the wool benzene weighings and the apparent density of the sample at various lengths of time after filling the bottle (Nr iii).

TABLE XXIV. DENSITY OF SAMPLE Nr iii.

Weight of dry sample in vacuo 1.7481

Weight of wool and benzol contained in the bottle at 25° C.

Day	Time	Wa	H	T	T'	G'	c	W_v	Density of Sample 25°/4°
Wed.	1750	45.7931	771	19.3	3.151	1225	575,0	45.8506	0.9839
Thur.	1335	45.8040	770	18.0	3.157	1229	575,4	45.8619	0.9911
	1457	45.8063	769	18.5	3.151	1225	575,0	45.8638	0.9924
	2245	45.8079	769	17.5	3.150	1232	580,0	45.8659	0.9937
Fri.	1325	45.8130	767	19.3	3.157	1218	572,4	45.8706	0.9968
	1708	45.8125	766	20.5	3.167	1212	569,9	45.8703	0.9966
Sat.	1545	45.8190	766	21.7	3.150	1209	568,0	45,8758	1.0002

The apparent density of the hair is lower than was expected. In view of the fact that the filling was not considered satisfactory, it is almost certain that the low value was due to the presence of airbubbles among the opaque fibres. Later determinations on other samples would indicate that the density of this sample should be nearer 1.1gr/ml but time has not been available

to repeat the estimation.

Several factors were suggested as possible causes of the gain in weight of the benzene -wool mixture indicating a gain in density of the fibres.

(1) Contamination of fibre with moisture dissolved by the benzene at the opening of the capillary, the benzene acting as a "carrier" for the water which became concentrated in the fibre.

(2) A penetration of the benzene into the air spaces of the medulla. At the end of the determination, a number of fibres were examined under the microscope and some infilling was observed extending as much as 1/4" into the ends of the medulla. It cannot be said whether this infilling would be sufficient to cause the gain in density observed.

As a check on the scouring technique, the benzene from the S. G. bottle was filtered into a tared glass dish, a further 50 cc of fresh benzene being used for washing. The residue obtained on evaporation and drying was not significantly greater than that obtained in a blank determination on fresh benzene indicating that all benzol soluble matter had been removed in the preparation of the sample.

Further determinations were carried out on pure wool samples. As it was thought just possible that some of the increase in apparent density shown in Table XXIV might be due to absorption of benzene by keratin, nr iv was allowed to soak in benzene for 18 hours before taking the first reading, while for nr V the first reading was taken just two hours after filling the bottle. The results are shown in Tables XXV and XXVI, and at the time the concordance of the initial figures was deemed to prove that there was no absorption of benzene by the wool and that the increase was due to moisture gained by the wool in the manner described. Later work has substantiated this latter conclusion, although it seems almost certain that the actual density figures were erroneous, and most of the sudden rise in density was due to

poor temperature control. See p.

TABLE XXV. APPARENT DENSITY OF SAMPLE Nr iv (pure wool).

Weight of Wool in Vacuo 2.3847 gr.

Weight of Wool & Benzene contained in bottle at 25° C.

Day	Time	Wa	h	T	T'	G'	c	W_v	Density of Wool 25/4.
Fri.	1545	46.3700	768	21.4	3.137	1213	567.6	46.4261	1.2908
	1718	46.3693	768	21.1	3.140	1211	567-5	46.4255	1.2904
Sat.	1710	46.3785	768	20.0	3.147	1217	569-1	46.4353	1.2983
Mon.	1711	46.3811	761	20.6	1.138	1205	564-6	46.4369	1.2996
Tue.	1320	46.3807	756	22.5	3.157	1189	556+4	46.4367	1.2994
Wed.	2048	46.3802	761	18.7	3.181	1212	566+15	46.4383	1.3007

TABLE XXVI. APPARENT DENSITY OF SAMPLE Nr v (pure wool).

Weight of Wool in vacuo 1.7075

Weight of Bottle and Wool and Benzene

Day	Time	W_a	h	T	T'	G'	c mg	W_v	Density of Wool 25/4
Mon.	1715	46.1486	771	22.0	3.162	1214	56.2 + .6	46.2054	1.2909
	1926	46.1486	771	21.2	3.173	1217	56.9 + 1.1	46.2066	1.2942
	2350	46.1510	772	19.9	3.181	1223	57.3 + 1.5	46.2098	1.2942
Tues.	1029	46.1508	774	20.8	3.153	1223	57.3 + .2	46.2083	1.2948
	1347	46.1514	773	21.0	3.158	1221	57.1 + .4	46.2089	1.2948
	2356	46.1513	773	19.3	3.183	1228	57.5 + 1.6	46.2104	1.2965
Wed.	1633	46.1528	772	22.2	3.157	1214	56.9 + .4	46.2101	1.2962
Sat. 7th.	1610	46.1536	768	21.6	3.175	1211	56.7 + 1.2	46.2115	1.2978
Sat. 14th.	1430	46.1595	768	17.9	3.178	1226	57.4 + 1.4	46.2183	1.3055

It was thought possible that the wide temperature range of bottle might have resulted in some change in volume similar to that recorded for thermometer bulbs, and the weight of benzene contained in the bottle was re-determined. Table XXVII shews the results which are in agreement with those previously obtained (Table XXIII) indicating that no appreciable change has occurred in the volume of the bottle.

TABLE XXVII. WEIGHT OF BENZENE CONTAINED IN THE BOTTLE.

W_a	h	T	T'	G'	c	W_v
45.5904	766	18.3	3.170	1222	574+10	45.6488
Bottle dried in oven at 105° for 1 hour cooled and weighed then determination of benzene weight repeated immediately						
45.5911	765	18.3	3.155	1220	574+ 3	45.6488

Sidgwick, 1920, has pointedout that Calcium Chloride does not give perfect dryness when used for dehydration of benzene, at its freezing point benzene in contact with Calcium Chloride still retains about 9% of its total water; phosphorus pentoxide, however, gives complete dryness although if left in contact with any but the purest benzene for any length of time , a dark coloration is produced.

To obtain the S.G. of dry wool, the benzene must be dried with phosphorus pentoxide as it passes into the bottle, while the atmosphere of the filling apparatus must be thoroughly dessicated. To obtain these conditions in the next determination Nr vi, therefore, the liquid was passed through a tube containing glass wool and fresh phosphorus pentoxide before entering the bottle, while a shelf was constructed in the dessicator above the level of the bottle, and on this further phosphorus pentoxide was laid in glasswool.

The figure obtained for the S.G. of the sample was 1.2890 gr/ml $25^{o}/_{o}$.

At the time the determination was mde, the lower value was deemed to indicate more complete dehydration of the wool.

An attempt was made to determine the S.G. of the benzol from the bottle after the determination, in order to detect any change due to the phosphorus pentoxide but the result was considered inaccurate owing to the use of an unsuitable bottle which did not allow complete immersion in the thermostat.

A further S.G. determination (nr vii) on pure wool, using exactly the same technique as previously, save that the phosphorus pentoxide in the filling apparatus was not fresh, although it appeared to be in good condition, gave the figure 1.2973 gr/ml $25^{o}/_{4}$.

The sudden jump in value of S.G. from 1.2890 gr. per ml. to 1.2973 gr per ml. for wool from the same source, was very surprising, and it was decided to repeat the determination on the identical sample of wool, redrying without removing same from the bottle. The figure obtained was 1.2972 gr/ml $25/_{4}$.

The excellent agreement obtained was taken to indicate that the figures were significant. Several suggestions were advanced to account for the increase in S.G.

(1) The phosphorus pentoxide was exhausted and giving up water to the benzene.

(2) Something from the phosphorus pentoxide has passed through with the benzol and contaminated the wool, changing its density. The filtering arrangement and the size of the jet were such as to make the passage of a solid particle practically impossible.

(3) There was an actual difference in the original density of the wool possibly brought about in the course of the scouring or drying procedure.

To elucidate these difficulties, it was decided to repeat the determination by the original method without passing the benzene over phosphorus pentoxide. The shelf was, however, retained in subsequent experiments. A density of 1.2953 gr/ml. $25/_{4}$

was obtained.

It would appear that while the wool may have received some moisture from the P_2O_5 this would not account for the whole of the effect. There was a very slight increase in dry weight of the sample of wool, whigh might be taken to indicate a gain of a small quantity of matter from the drying agent. Since this matter must have passed into the wool in solution in the benzene, a repeat using the original method should give a lower result, since the clean benzene usedin the last determination might be expected to remove the greater part of the foreign substance. A further determination gave slightly lower dry weight of wool supporting such a suggestion, but the final S.G. was substantially the same - 1.2956 gr/ml. $25/_4$ - indicating that whatever was removed from the wool affected both weight and volume to the same extent.

In view of these facts, an actual difference in density of the original sample appeared at the time to be the most likely source of the discrepancy between detem ination nr vii and previous results, and it was decided to examine pure wool taken from a widely different region on the same fleece in the hope of finding a fairly large deviation.

Accordingly a sample of britch wool, shewing slightly hairy tip, was taken and all medullated fibre shewing in the benzol test removed and stored.

The density of the pure wool was found to be 1.2960 gr/ml $25^0/_4$ After the first determination, the sample was re-dried and a repeat determination made, giving the figure 1.2959 gr/ml $25/_4$.

In order to get an indication of the density of the original sample, the medullated portions were scoured and added to the wool already in thebottle. Determinations of these (ix) gave 1.2912 gr/ml $25^0/_4$ and a repeat of 1.2913 gr/ml $25^0/_4$.

The results from determinations(viii) and(ix)are of great importance in that they shew that the difference in S.G. between pure wool and a sample containing only a small amount of hair is measurable since the sample D3 would have been given a value of 20 - 30 by Elphick and gives a photo-electric index of 2.3 Since

the latter method is capable of making at least 4 grades between such a sample as D3 and pure wool, an accuracy in the density determination of 1 in the 3rd decimal is necessary if the two methods are to be comparable, thus confirming the theoretical considerations advanced on p. 40.

Between determinations ix and ixa the stock of benzene used for the determinations was replenished. Data on the new stock is given in Table XXVIII. The fact that there is good agreement between ix and ixa indicates that determinations made using the new stock should be comparable with previous results. At this time, also, the volume of the bottle was checked and found to be in good agreement with values previously obtained.

TABLE XXVIII. WEIGHT OF BOTTLE AND WATER.

W	W_a	h	T	T'	G'	c	W_v
54.0010	52.2586	758	18.9	3.185	1206	560 ± 4	52.3150
		WEIGHT OF BOTTLE AND BENZENE.					
47.3340	45.5916	754	17.1	3.173	1207	568 + 11	45.6495
47.3334	45.5910	755	17.3	3.180	1208	569 + 15	45.6494

S.G. of Benzene - 0.870036 gr per ml.

The search for variations in the S.G. figure for different wools was continued with examination of wool from bulk sample P E I. The wool was slightly stronger than the previous pure wool sample, but had poor character, and a trace of medullation Photo-electric index about 1.8.

The density determination (Nr X & Xa) gave the figures 1.2985 and 1.2987 gr/ml $25/_4$.

In view of the fact that the sample is slightly medullated, it would appear highly probable that the density of the keratin in sample P E I is slightly greater than that in sample D3.

The fact that no significant difference in S.G. was found between two pure wool samples from widely separated points on the body of one animal, casts doubt on the conclusion that the low values obtained in the case of nr s iv & v are due to actual differences in the density of the wool. Accordingly the greater part of the wool from nr v was re-examined, giving the figures 1.2959, 1.2983, 1.2983 gr/ml. 25/4, which are the first of a series of unsatisfactory results attributed to low room temperatures. A complete discussion is reserved until later, but it may be fairly safely assumed that the values obtained for iv and v were due to high room temperature, and that the later values are the more nearly accurate.

A further sample P E2 from the same animal as P E 1 was now examined. The photo-electric index for this sample was 2. 3 Density figures obtained were 1.2982 and 1.2973 gr/ml 25/4 and the agreement not being as good as previously obtained.

It was decided to investigate the irregularity with a view to estimating the magnitude of the possible error.

The data available seemed to indicate that irregular weights were found associated with low room temperature and also with an apparent instability of the balance in weighing, thought possibly to be due to convection currents.

To control the first possibility, a new S.G. bottle possessing a longer neck was selected and fitted with an airtight cap as before. In previous work the S.G. bottle had been immersed in the thermometer to a level slightly above that of the lower end of the stopper, deeper immersion not being possible owing to the danger of wetting the lower edge of the cap. With the new bottle immersion to about 3/16" inch above the level of the base of the stopper was possible, thus lessening any error due to a cooled surface layer of water in the thermostat in very cold weather.

Data obtained with the new bottle are shewn in Table XXIX. The last two benzene weighings were taken with the bottle well immersed, and the stirrer driven vigorously, the density of the benzene calculated from these being identical with the value obtained previously and confirmed several times during the investigations.

TABLE XXIX. WEIGHTS OF WATER AND BENZENE CONTAINED IN BOTTLE 49

	Wa	h	at 25°C. T	T'	G'	c	W_v
Water	52.0726	745	14.5	3.140	1202	555.1	52.1280
Benzol	45.4308	745	14.3	3.150	1203	564	45.4872
" same day	45.4309	745	14.0	3.170	1206	566 ± 10	45.4881
" same day	45.4304	748	15.4	3.150	1207	566	45.4870
Water next day	52.0709	763	15.2	3.140	1229	568-1	52.1276
" " day	52.0712	761	15.4	3.160	1226	566 + 1	52.1279
Benzol " day	45.4290	759	18.7	3.160	1210	566 + 5	45.4861
	45.4286	759	18.5	3.165	1211	567 + 8	45.4861

Volume of Bottle - 52.2807 ml.

Density of Benzene) from last two results) - 0.870036 gr per ml.

Determination Nr xii was repeated using bottle nr 49 giving a density of 1.2962 and 1.2963 gr/ml 25 /4. It appeared as if the thermostat had not been bringing the temperature of the bottle to exactly that recorded on the thermometer, and for the remainder of the investigations the bulb of the latter was placed close to the bottle, both being in the direct wash from the stirrer, which was driven vigorously.

At one stage it had been thought just possible that variations in the scouring technique might induce variations in the density of the wool samples. Such effects could only be due to variations in the extraction with distilled water, since the

amount of matter removed from a scoured sample by benzene is negligible (p.), while the concordance of repeat results shew that even prolonged soaking of the scoured sample in benzene has no measurable effect on its Specific Gravity. A sample of wool from D3 was taken and scoured as usual in benzene, but given twice the normal time in distilled water, i.e. 3 changes each of 30 minutes duration. No significant difference from the values previously obtained for D3 samples was apparent. Although the greatest care was taken to avoid any error due to insufficient temperature control, several of the results shewed rather wide divergence and it seemed possible that the error associated with low temperatures was due to other factors besides deviation from the standard temperature at the time of capping the bottle.

The possibility of uneven expansion of the balance arms associated with a wide temperature range in the laboratory, was considered and in subsequent determinations some 20 pairs of weighings were made by the method of Gauss. The differences between apparent weights taken with the bottle on opposite pans for loads of 45 - 47 gr. varied from about 0.2 mg to 0.7 mg being greatest for the right hand pan, indicating that the deviation was not due to heating of that side of the beam above the warm bottle. In some cases the bottle was re-weighed on the original pan to prove that the variability of the difference was not due to evaporation of the liquid.

No connection was found between balance case temperature and the magnitude of the deflection.

A further series of 20 pairs of weighing was made in investigating the possibility of error due to convertion currents. After removal from the thermostat, the bottle was first weighed in the ordinary manner, immediately placed in water just below room temperature for 3 minutes, then dried and weighed as before.

The "cooled" weight was the greater in every case by amounts varying from 0.4 to 1.4 mg., but the possibility of evaporation loss reduces the value of the results. No correlation with balance case temperature was found.

The phenomena associated with static changes on the bottle were also investigated. Under suitable conditions these could be detected on the bottles after completion of the weighing, 5 - 6 minutes after polishing, and such a condition was found to be associated with apparent instability of the balance; frequently the swing was found to increase in magnitude after release of the beam. The use of a very slightly humid cloth for polishing was found to be the simplest means of avoiding marked charges on the bottles. Differences in apparent weight of up to 0.4 mg were found on discharging the bottles over Uranium nitrate, but the change in weight was not disassociated from effects due to gradual cooling of the bottle contents in all cases.

These investigations were carried out during determinations nr xiii (P E 4) xiv (P E 3) xv (P E 7) xvi (P E 5 & 6).

GENERAL SUMMARY OF DENSITY FIGURES.

Number	Density $25/4^{o}$	Remarks.
i	1.305) Based	Pure Wool. 1st determination.
ii	1.309) on apparent weights	" " Determination using toluene.
iii	0.9839	Very hairy sample. Air in bottle (?).
iv	1.2908	Pure Wool In accurate
v	1.2909	" " "
vi	1.2890	" " P_2O_5 used to dry the benzene.
vii	1.2973	" " " " " " " "
viia	1.2972	Repeat on vii.
viib	1.2953	" " " No. P_2O_5 used to dry benzene
viic	1.2956	" " " " " " " " "
viii	1.2960	Pure Wool from hairy tipped staple.
viiia	1.2959	Repeat on vlll.
ix	1.2912	Nr viii together with hairy portion of the staple.
ixa	1.2913	Repeat on ix.
x	1.2985	Almost Pure Wool. P E I.
xa	1.2987	Repeat on x.
Va	1.2959	Repeat on Nr V
Vb	1.2983	" " " "
Vc	1.2983	" " " "
xi	1.2982	Sample P E 2 using bottle Nr 2.
xia	1.2973	Repeat on xi.
xib	1.2962	" " " using bottle 49.
xic	1.2964	" " " " " "
xii	1.2960	Pure Wool. Extra scouring. Average value. 6 Determinations.
xiii	1.2971	P E 4 Average value . 7 Determinations.
xiv	1.2743	P E 3 Average value 4 determinations.
xv	1.1432	P E 7 Average value 4 determinations.
xvi	1.199	P E 5 & 6 One determination.

GENERAL DISCUSSION.

In reviewing the results presented with a view to evaluating the reliability of the method, one is struck by the large number of variable factors which must be standardized and from the point of view of investigation of technical method it is fortunate that the work was spread over a long period of time involving extreme seasonal conditions.

The writer is convinced that the failure to achieve the desired degree of accuracy in the earlier determinations and also toward the latter end of the work was due to lack of controlled room temperature affecting a large number of minor factors.

At the time when determinations iii, iv, v, and vi, were made in February 1934, the room temperatures were extremely high. In the case of iv a rough thermometer near the thermostat registered slightly over 25° C. and it is significant to note that for the initial weighing in these four determinations the temperatures recorded in the balance case, located in the coolest part of the room, are the highest observed. One has no hesitation in stating that the benzene wool mixture was not at the standard temperature at the time of capping the bottle due probably to a warm surface layer of liquid in the thermostat, together with inadequate stirring. The fact that weights of benzene contained in the bottle taken about the same time, but on cooler days, agree with later values, confirms the above conclusions.

Agreement shewn by repeat determinations in the case of nrs vii viii ix x xi b & c, together with agreement between contemporary determinations of the density of the benzene, make it highly probable that these results are significant to about 0.05 % - the chances of over 6 successive close agreements in paired results being due to mere coincidence are remote. Under these circumstances, it seems highly probable that while the density of pure wool for samples from one fleece is substantially constant, i.e. about 1.296 gr/ml., the density of pure wool from another animal (sample P E 1) is greater by a significant amount,

especially since a slightly medullated sample from the same fleece has a density of 1.296 gr/ml. Further, from a third very hairy animal, a sample P E 4 shewing a fair amount of discontinuous medulla (P E index 3.5) had a specific gravity of 1.297 gr/ml. indicating that if pure wool were obtainable from this sample, the specific gravity would be even greater than that of the other pure samples examined.

These facts are interesting in that data on the specific gravity of pure wool from individual animals has not hitherto been recorded; King gives figures for different types of top of widely varying origin, but does not record the presence or absence of slight amounts of medullation.

It should be noted that the present results are not directly comparable with those of King who based his calculations on apparent weights and the density of water at 25° C.

With reference to the inconsistent results obtained in July and August 1934, it is unfortunate that the anomalies did not appear sufficiently early to allow a complete study to be made. A factor which was not standardized in these and in the later of the consistent results was the force used in inserting the stopper. It is possible that a small error might arise from this source.

The writer inclines to the view that the deviations were more probably due to low and variable room temperatures affecting a number of independent factors among which may be noted :

(1) Convection currents within the balance case due to the warm bottle.

(2) Effect of low room temperature upon the temperature control attained in the thermostat.

(3) Effect of temperature difference between bottle and atmosphere on moisture adsorbtion and condensation on the glass surface.

(4) Small changes in the relative lengths of the balance arms.

In further work on the density of wool and hair, it would be advisable to house the thermostat and balance in a room where the temperature would be more even, and, if possible, of constant humidity.

It should be noted that the variations discussed above

would not affect the comparison of the results with photo-electric indices, in the first place since the accuracy required in these cases of gross hairiness is not great, while the deviations are small, and secondly, since in searching for the source of error, the determinations concerned were repeated several times.

GENERAL SUMMARY.

1. Studies of Elphick's visual method of evaluating medullation revealed by the Benzol Test shewed that the results obtained were subject to considerable variation.

2. An investigation of the sources of error suggested methods of standardization resulting in a tentative technique capable of accurately expressing medullation in terms of the percentage of the total fibre length in the sample affected, but the technique is not suited for routine work.

3. Preliminary experiments with a photo-electric cell indicated that it would be possible to measure the amount of light reflected from wool in benzol, under standard conditions, with considerable accuracy.

4. Attempts to measure the light absorbed by wool in benzol gave unsatisfactory results.

5. After experiencing considerable difficulty in obtaining suitable illumination of the sample a workable apparatus was constructed capable of measuring the light reflected from the test, within a given solid angle, in terms of galvanometer deflection per gram of wool.

6. Factors affecting the reliability of the result were investigated and it was found that even with temporary apparatus the errors did not exceed 2%.

7. For eight comparisons a linear relationship was found to exist between the photo-electric index of hairiness and the percentage air space calculated from accurate measurements of the specific gravity of the sample.

8. A detailed investigation was made of the sources of error in the determination of the specific gravity of wool samples by pyknometric methods with a view to applying the perfected method to accurate calibration of the photo-electric instrument.

9. It was found possible to reduce the error to 0.05%.

10. During the investigation pure wool samples from three different fleeces were examined and for these three fleeces the specific gravity of pure wool was found to vary directly with the degree of hairiness in other parts of the fleece.

ACKNOWLEDGMENTS.

I wish to place on record my debt of gratitude to the Principal and members of the Staff at Massey Agricultural College, and the Dairy Research Institute, for guidance, helpful criticism, and the opportunity of discussing sundry problems connected with my work.

I wish to thank also the Physics Department of Victoria University College, Wellington, for the loan of apparatus and, in particular, Mr. G. A. Peddie, without whose advice and assistance the physical section of the work could not have been initiated.

BIBLIOGRAPHY.

Anderson, W.T., 1934, Rev. Sci. Inst. V 127

Barker, S.G., & King, A.T., 1926 J. Text Inst. XVII 68

Barritt, K., and King, A.T., 1926, J. Text. Inst. XVII T 386

Bergman, L., 1933, Zeits. F. Tech. Phys. XIV 157

Davidson, G.F., 1927, J. Text. Inst. XVIII T 175

Elphick, B.L., 1932, J. Text. Inst. XXIII T 367

Elphick, B.L., 1933, Personal communication

Gilfillan, J., 1934, J. Am. Chem. Soc. L VI 406

Goodwin, W.N., 1933, Technical Data - Weston Photronic Cell

Green, 1908, J. Chem. Soc. A ii 826

Hampson, R.E.V. & Richards H.W. 1934, J. Text Inst. XXV T 106

King, A.T., 1926, J. Text. Inst. XVII T 53

Lange, B., 1932, Zeits. F. Tech. Phys. XIII 600

de Mosenthal, H., 1907 J. Soc. Chem. & Ind. XXVI 443

Pulvertaft, R.J.V., & Lemon, C. G., 1933, J. Hyg. XXXIII 245

Raynes, S.L., 1927, J. Text. Inst. XVIII T 46

Reilly, J. Rae, W.N., & Wheeler, J.S., 1926, Physico-Chemical Methods

Roberts, A.F., 1930, J. Text Inst. XXI T 127

Romain, B., 1933, Rev. Sci. Inst. IV 83

Sidgwick, N.V., 1920, J. Chem. Soc. C XVII T 1340

Story, S.W. & Kalichevsky, V.A., 1933, Ind & Eng Chem. (An. Ed) V 214

Vincent, P.C., 1934, Proc. Phys. Soc. (Lond.) VL 833

Washburn & Smith, 1934, Bur. Stds. J. Res. XII 305

Wood, L.A., 1933, Rev. Sci. Inst. IV 435

APPENDIX A. DATA RELATING TO COUNTS OF STAPLES AND PRODUCTION OF STANDARD PHOTOGRAPHS.

Table i. Count on Lock 2. Plate VIa .

Line	Distance from tip	Total Medullated	Total Non-Medullated	Total Fibres	% Medullated
1	0.00"	46	1	47	98
2	0.25	135	25	160	84.4
3	0. 5	251	45	296	84.8
4	0.75	368	59	427	86.2
5	1. 0	378	69	447	84.6
6	1.25	367	102	469	78.3
7	1. 5	375	143	518	72.4
8	1.75	324	193	517	67.7
9	2. 0	307	259	566	54.1
10	2.25	220	309	529	41.6
11	2. 5	194	356	550	35.3
12	2.75	181	379	560	32.3
13	3. 0	124	446	570	21.8
14	3.25	56	471	530	10.6
15	3. 5	52	518	570	9.1

Table ii. Count on Lock 3 Plates VI b and VI c.

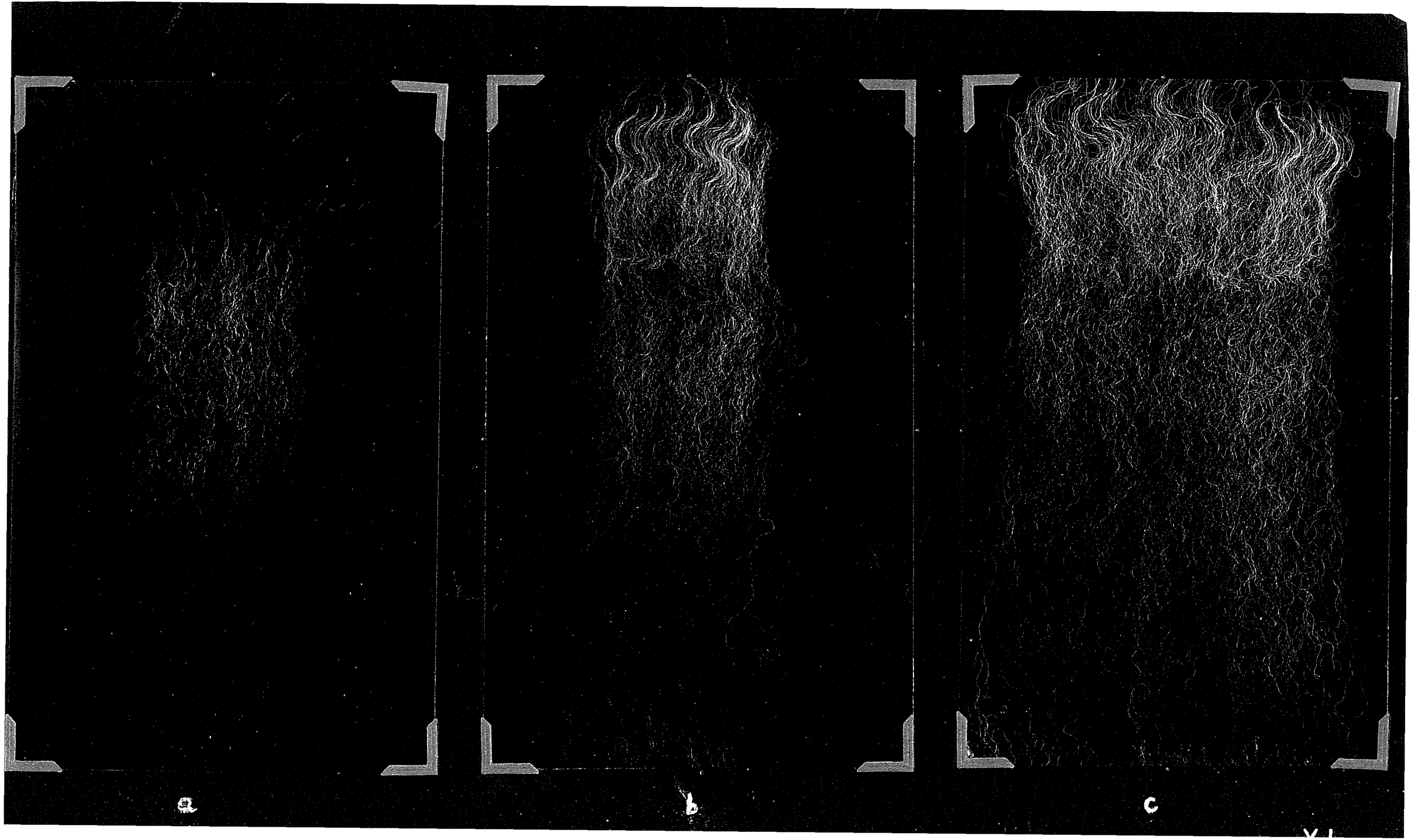
Line	Distance from tip	Total Medullated	Total Non-Medullated	Total Fibres	% Medullated
1	0.00"	97	50	140	69
2	0.25	333	92	425	78
3	0. 5	519	59	578	90
4	0.75				
5	1.0	699	36	735	95
6	1.25	740	59	799	93
7	1. 5	622	162	784	79
8	1.75	600	206	806	74
9	2.0	533	271	804	66
10	2.25	505	335	840	60
11	2. 5	531	398	929	57
12	2. 75	470	433	903	52
13	3.0	445	405	850	52
14	3.25	413	441	854	48
15	3.5	404	532	936	43
16	3.75	355	582	937	38
17	4. 0	293	658	951	31
18	4.25	244	707	951	26
19	4. 5	175	745	920	19
20	4.75	170	759	929	18
21	5. 0	123	777	900	14
22	5.25	107			12

PLATE VI.

(a) Lock Nr 2 in benzol at standard thickness of spreading (300 fibres / 1").

(b) Lock Nr 3 in benzol at 2 x the standard thickness.

(c) Lock Nr 3 in benzol at standard thickness of spreading.


a
b
c

APPENDIX B SOME NOTES ON PHOTO - CELLS IN GENERAL AND THEIR UTILIZATION IN PHOTOMETRY.

During the last few years, numerous devices have been described in which the photo-electric effect, i.e. the fact that when light falls on certain metals it causes them to emit electrons at a rate proportional to the total amount of light without regard to its distribution over the emitting surface, has been utilized in photometry. Generally, the cell has been used to indicate balance in null methods. By various optical devices, beams from the unknown and from the standard source ofillumination, are allowed to fall on the cell in rapid succession, an arrangement being introduced into one beam whereby its intensity can be varied until the output of the cell remains constant. In this way errors due to changes in the constants of the photo-cell are eliminated, since it is used as an indicator only, just as a galvanometer may be used to indicate conditions of balance in a Wheatstone bridge circuit.

In some cases, direct reading measurements have been made using an electrometer, or a thermionic valve amplifier and galvanometer, as the indicating instrument. Where the photo-electric current is large, and where great precision is not required a galvanometer can be used in the cell circuit directly.

The difficulty with most of the above devices lies in the fact that generally speaking the null methods involve elaborate and expensive optical apparatus, while even to utilize direct reading methods requires the resources of a physical laboratory.

During the last two years, however, it has been shewn that photo-cells of the rectifier type can be utilized very simply for light measurements of a general laboratory type.

LITERATURE.

A review was made of the literature available on the subject of rectifier type cells, shewing that they are of considerab greater sensitivity than the types previously available, while they have the added advantage of robustness - a very necessary consideration in apparatus designed for routine work. Further,

provided the cells are not subjected to temperatures over 50° C., high humidity, or high voltage, the response remains constant to a high degree of accuracy over long periods of time (Goodwin, 1933). Recently Anderson, 1934, working on measurements of the ultraviolet output of quantity mercury - arc lamps, states that for the rectifier cells tested in his laboratory over a period of three years, no appreciable loss in sensitivity has been indicated. Hampson & Richards, 1934, quote tests made at the National Physical Laboratory giving the same conclusion.

These facts are of importance in that neither complicated optical apparatus nor ultra-sensitive measuring instruments are necessary as is the case with vacuum or gas filled cells where accurate measurements are required.

Lange, 1932, has successfully used a rectifier type cell in a microphotometer while Bergman, 1933, describes a device embodying a selenium rectifier cell for measuring reflection factors.

Pulvertaft & Lemon, 1933, investigated a large number of different types of photo-cell in connection with measurement on the opacity of bacterial cultures (indicating the grow th rate of the organisms) and found that cells of the rectifier type gave by far the most satisfactory results. The method used was to place the tube containing the culture between a standard light source and the cell, measuring the E.M.F. generated by the latter with a Cambridge potentiometer.

Story & Kalichevsky, 1933, successfully measured the light absorbed by petroleum oils using a Photonic cell, which according to Wood, 1933, is of the selenium rectifier (vorterwand) type. The cell was placed immediately behind a trough containing the liquid to be examined and exposed to light from a lamp movable along an optical bench. The distance of the lamp from the trough and cell was altered to give a standard deflection on a galvanometer connected with the latter, and the absorption of the liquid calculated from the inverse square law.

Quite recently Hampson & Richards have used a pair of rectifier cells to measure the whiteness of fabrics. One cell was exposed to a small area of the unknown fabric while the other was exposed to light from a standard white surface of variable area, both standard and unknown being illuminated from the same source. The area of the standard surface was adjusted until the output of the two cells balanced.

APPENDIX C. SOME NOTES ON METHODS FOR THE DETERMINATION OF SPECIFIC GRAVITY OF TEXTILE MATERIALS.

The literature available on the accurate determination of Specific Gravity of textile materials is not extensive.

de Mosenthal, 1907, examined the density of cotton and nitrated cotton in water, using 100 c.c. Regnault pyknometers. Air was removed, after the addition of water to the cotton, by boiling under reduced pressure. The failure of the water to rise in the neck of the pyknometer under the bell jar of the air pump upon exhaustion or to fall when air was admitted, was taken as an indication that all the air had been removed.

Some determinations were made using benzene but the results were not considered very reliable owing to the high coefficient of expansion of that liquid.

For wool, cotton etc., Reilly Rae & Wheeler, 1925, suggest the use of volumenometer methods depending on the determination of volume of a given enclosure of air by noting the alteration in pressure required to increase or decrease that volume by a known amount both before and after the introduction of the solid under examination and claim an accuracy of up to 0.1%.

King, 1926, in an excellent paper on the Specific Gravity of wool and its relation to swelling and sorbtion in water and other liquids, points out that figures obtained by previous workers differ owing to the fact that attention has not been paid to absorption by the wool of the density liquid while the regain has not been specified.

He determined the Specific Gravity of dry wool in a large number of liquids and concluded that the varying values obtained were due to absorption by the fibre - an apparent density only being obtained owing to varying contraction of total volume of wool and liquid. The effect was found to be at a minimum with benzene, toluene, nitrobenzene and olive oil : of these, benzene was found to be the most suitable liquid for general use. Determinations made using this liquid gave the specific gravity of wool as 1.304, 25/25

and no appreciable variation was found in wool from widely differing sources save where lower values were obtained associated with medullation.

With regard to technique employed, it is unfortunate that minute details could not be given owing to space limitations. The sample for investigation was extracted in a Soxhlet apparatus with pure alcohol and the S. G. bottle containing the wool dried at 102 °C. in a vacuum dessicator under reduced pressure to constant weight. The liquid appears to have been introduced into the bottle under partial vacuum in order to avoid air bubbles which readily become entangled in the fibres.

Davidson, 1927, determined the specific volume of cotton cellulose in water, toluene and helium. For the determination in liquids the cotton was dried in an ordinary S.G. bottle at 110°C., weighed, covered with liquid at about 50°C., and the air removed by boiling under reduced pressure. The temperature was adjusted in a thermostat, the stopper was inserted, and the bottle wiped and weighed. The procedure of boiling out and weighing was repeated until a constant weight was obtained. The method was not found to be of great precision, especially with organic liquids, owing to their high coefficient of expansion and the loss by evaporation.

The determination in Helium was made using a volumenometer, the accuracy being of the order of 0.5%.

Elphick 1933, determined the density of some samples of tops in benzene using a 50 c.c. S. G. bottle to which a roughly ground cap was fitted to retard evaporation. The wool was dried in the bottle at 105 ° C. using a current of dry air.

After weighing, the bottle with the wool was placed slightly tilted in a small vacuum dessicator and benzene dried over Calcium Chloride was allowed to drip slowly onto the inner lip of the neck whence it ran gently down the side of the bottle; as the level of the benzene rose it wetted the wool and generally carried all the air before it. Any small bubbles which remained were removed by manipulation with a glass rod.

The temperature was adjusted in a thermostat, the cap fitted, and the whole cooled in the cold water, then wiped and placed in the balance case for 2 minutes before weighing.