

BRITISH RHEOLOGISTS' CLUB

BULLETIN No. 21



Hon. Sec.:

DR. E. W. J. MARDLES,
ROYAL AIRCRAFT ESTABLISHMENT,
FARNBOROUGH, HANTS.

Hon. Editor :

DR. G. W. SCOTT BLAIR,
THE UNIVERSITY, READING.

Hon. Treas.:

DR. V. G. W. HARRISON,
LYNDHURST, LINKS WAY,
LITTLE BOOKHAM, LEATHERHEAD,
SURREY.

Bulletin No. 21

December, 1948

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CLUB NOTES.

Annual General Meeting.

At the Annual General Meeting, the following officers were elected for the ensuing year :

<i>President :</i>	PROF. N. F. MOTT, F.R.S.
<i>Hon. Secretary :</i>	DR. E. W. J. MARDLES
<i>Hon. Treasurer :</i>	DR. V. G. W. HARRISON
<i>Hon. Auditor :</i>	A. DE WAELE, ESQ.

The following were elected to the Committee :

Dr. A. H. Nissan, Mr. J. G. Oldroyd, Dr. G. W. Scott Blair, Mr. W. M. Thring, Mr. A. G. Ward, and, co-opted as North of England Representative, Mr. W. A. Richardson.

The following is an extract from the Hon. Secretary's report, 1947-48 :

B.R.C. Activities.

The Club, in addition to participating in the First International Rheological Congress, the Hague, Holland, September 1948, has met during the past year on the following five occasions :

1. At Newcastle—University of Durham, October 1947—(jointly with the Oil and Colour Chemists' Association and Society of Chemical Industry, Newcastle branches). The subject chosen was **Emulsions and Paints** and the Club's speakers were Dr. Gourlay and Mr. Pryce-Jones.
2. **Rheology in War time for the Army, Navy and Air Force.** This meeting was held in December 1947, at the Royal Society of Arts, London, and the speakers were Dr. A. S. C. Lawrence (Navy), A. W. Ward (Army) and E. W. J. Mardles (Air Force).
3. A Conference was held at the Department of Textile Industries, Leeds University under the presidency of Prof. J. B. Speakman on 19th and 20th March. The subject was **Textile Rheology** and the seven papers with discussion have since been published in the Journal of the Textile Institute.

4. A meeting held jointly with the Society of Glaciology in May 1948 at the Institute of Metals, on the subject of the **Flow of Ice and Metals**. The speakers were Drs. Perutz, Seligman and Orowan.

5. **Summer Visit to the Building Research Station, Garston, and to St. Albans and Verulamium.**

The Club is represented on the British Standards Institution Gum Tragacanth panel and the Tragacanth Sub-Committee of the Society of Public Analysts by Mr. F. S. Higginbotham of the Shirley Institute, on the viscosity panels of the Institute of Petroleum and British Standards Institution by the Hon. Secretary, and Dr. G. W. Scott Blair represents the Club on the Grease Rheology panel of the Institute of Petroleum.

Future Events.

The Committee is arranging the following meetings :

(a) **Mathematics and Rheology** on Tuesday, 4th December under the Chairmanship of Dr. Reiner in London. The subject will be introduced by Drs. Topping and White.

(b) A meeting at Birmingham University in July under the Chairmanship of Prof. Garner on the subject of oils and thickened oils.

(c) A joint meeting with the Chemical Society and Royal Institute of Chemistry (Exeter branches) on the subject of Sedimentation and Suspensions, 6th and 7th May at Exeter.

(d) Annual Conference at Bristol University, September 1949.

Statement of Accounts. Year ending 30th September, 1948.

RECEIPTS.				EXPENDITURE.			
	£	s.	d.		£	s.	d.
Balance Brought Forward ...	106	18	7	Postage ...	17	11	3
Subscriptions ...	262	0	0	Stationery and Printing ...	200	10	2
Donations ...	2	4	0	Overpaid Subs. refunded ...	2	0	0
Receipts re Manchester Conference, 1947 ...	9	4	10	Meetings ...	7	0	6
Receipts re Summer Outing, 1948... ..	6	10	0	Expenses re Summer Outing 1948 ...	7	13	6
Royalties ...	18	2	6	Sundries ...	19	18	10
Bulletins for New York ...	3	10	0				
							£254 14 3
				<i>Add</i>			
				Bank Balance	151	2	1
				Petty Cash ...	2	11	10
				Stamps in hand	1	9	
							153 15 8
	£408	9	11				£408 9 11

This is to certify that I have compared the above statement of Receipts and Expenses with the Club's books and find it to give a correct record of the Club's financial position for the year ended 30th September, 1948.

(Signed) V. G. W. HARRISON,

13th November, 1948.

Hon. Auditor.

Publications Sub-Committee.

On the motion of the Chairman of the Publications Sub-Committee (Dr. G. W. Scott Blair) it was agreed that this standing Sub-Committee be discontinued for the present. It was felt that, while it had served a useful purpose in making arrangements for the publication of a number of Proceedings of Conferences and of the Bulletin, such work might now better be transferred to the General Committee. The members were thanked for their services in the past.

Future Meetings.

Plans for the meetings envisaged in the last Bulletin and quoted in the Hon. Secretary's Report (above) are now well advanced.

The Annual Conference and Annual General Meeting for 1949 will be held in Bristol, September 26th – 29th. The Committee has been considering many suggestions for subjects for discussion. Will members please send their views to the Hon. Secretary **as soon as they receive this Bulletin** ? There should be just time to give them consideration before the programme has finally to be crystallized.

Arrangements for the meeting in Cambridge in March are still in a fluid state. It may be possible to arrange a meeting on The Rheology of Paper also in March.

Members will be informed of the progress of these plans as soon as possible.

Bingham Memorial Award.

Heartiest congratulations to our colleague, Dr. Melvin Mooney—first winner of the Bingham Memorial Award in Rheology. (This award is to be made annually in memory of the pioneer work of Professor E. C. Bingham and is given to workers in U.S.A. and Canada for outstanding contributions to Rheology.)

Post for a Rheologist.

Applications are invited for appointment of Research Officer (Rheologist), Building Research Section, Melbourne, Australia. The nett salary will be within the range £A.494 – 819 with £A.25 annual increments. Further particulars on application to the Chief Scientific Liaison Officer, Africa House, Kingsway, W.C.2, as soon as possible. Refer to appointment No. 2023.

Reprints of the Papers given at the Conference on Fracture, 29th October, 1948.

Reprints of the papers given at the above Conference together with the Discussion, will be available to Members at a cost of 5/- each if sufficient demand is forthcoming. Would members who wish to purchase copies in this way please send a postcard to the Editor in order that the arrangements for ordering can be finalised ?

News of Members.

Mr. H. H. Macey has left the British Ceramics Research Association to join the Board of the Western Counties Brick Co., Exeter.

Dr. H. A. Nancarrow has been appointed Manager of the Physics Division of the Research Department, BX Plastics Ltd., Manningtree, Essex.

Dr. F. I. G. Rawlins has been appointed a Deputy Keeper of the National Gallery.

Prof. M. Reiner has returned home to Haifa, Israel, after a visit to this country following his attendance at the Scheveningen Congress.

CORRESPONDENCE

The following correspondence has passed between the Hon. Secretary and the Organisers of the First International Congress on Rheology :

DELFT, 2nd November, 1948.

Dear Dr. Mardles,

In the name of the Organising Committee of the International Congress on Rheology, 1948, I have the pleasure of thanking the British Rheologists' Club once again for its very kind and cordial co-operation on occasion of the rheological congress at Scheveningen.

It is not only the fact that the initiative for the Congress was started by the British Rheologists' Club, but also the very great support we had during the organisation and the kind gesture of the British Rheologists' Club to contribute £10 to the costs of the Congress have been highly appreciated by the Committee.

In its session of to-day the Committee has requested us to express our very sincere thanks and we hope that you will put this letter before the Board of the British Rheologists' Club.

Yours very truly,

(Signed) $\left\{ \begin{array}{l} \text{J. M. BURGERS, } \textit{President.} \\ \text{R. HOUWINK, } \textit{Hon. First Secretary.} \end{array} \right.$

FARNBOROUGH, 17th November, 1948.

Dear Professor Burgers,

The Committee of the British Rheologists' Club have asked me to express their thanks for the letter of the 2nd November written in the name of the Organising Committee of the International Congress on Rheology, 1948 and signed by yourself as President and Dr. R. Houwink as the Hon. First Secretary. We in turn would like to record the thanks and appreciation of our members, especially those who had the good fortune to participate in the Congress, for all you did for us and in inaugurating so successfully the First Congress in Rheology.

Yours sincerely,

(Signed) E. W. J. MARDLES,
Hon. Secretary, B.R.C.

COOKHAM, 3rd December, 1948.

Dear Dr. Scott Blair,

I was interested in Dr. Reiner's letter, published in Bulletin No. 20.

The advantages of defining the strain tensor (or rate-of-strain tensor) e_{jk} in terms of the displacement vector (or velocity vector) u_i by the formula

$$e_{jk} = \frac{1}{2} \left\{ \frac{\partial u_k}{\partial x_j} + \frac{\partial u_j}{\partial x_k} \right\} \quad (1)$$

are made clear in Professor Jeffreys's book *Cartesian Tensors* (Cambridge, 1931). The alternative definition of the strain tensor, in which the factor $\frac{1}{2}$ is omitted in (1), seems unsatisfactory because, on this definition, the principal components of strain are no longer the proportional extensions along the principal axes; this seems to conflict with the basic concept of strain as proportional extension in simple tension.

Yours sincerely,

(Signed) J. G. OLDROYD.

RHEOLOGY ABSTRACTS

NOTE.—The initials following the Abstracts are those of the abstracting member, except for the following abbreviations for abstracts produced from other journals by permission :

B.C.R.A.	British Ceramics Research Association.
I.D.I.B.	Industrial Diamond Information Bureau.
NICKEL BULL.	Nickel Bulletin.
P.A.T.R.A.	Printing and Allied Trades Research Association.
SCI. ABSTR.	Science Abstracts.
B.S.A.	Building Science Abstracts.

1137. Surface Effects with Single Crystal Wires of Cadmium.

E. N. DA C. ANDRADE and R. F. Y. RANDALL. *Nature*, **162**, 890, 1948.

The authors describe experiments in vacuo (10^{-4} mm. mercury) the results of which confirm the conclusion that "thermal hardening" (Orowan) is due to local surface contamination by gaseous reaction. Surrounding the wire with plating solution was found to lead to an immediate increase of rate of flow up to twenty-fold. The increase is attributed to the action of cadmium ions and the hardening to the formation of a surface oxide film.

E.W.J.M. (See Abstr. 1056).

1138. The Electroviscous Effect with Measurements of Sodium Polymethacrylate Solutions.

A. W. H. ATEN. *J. Chem. Phys.*, **16**, 636, 1948.

The reduction of viscosity by addition of electrolytes to solutions of a (negative) linear polymer is explained in terms of the electrostatic forces present in the solution and the theoretical conclusions are in good agreement with previous and present experimental results.

W.P.F.

1139. Fluid flow in porous media.

R. M. BARRER. *Discussions Faraday Soc.*, No. 3, p. 61, 1948.

A fluid such as water may need to be treated as incompressible, compressible but still condensed, or gaseous, according to conditions of temperature and pressure. Steady and transient states of flow of fluids in these conditions have been briefly considered. The displacement of one fluid by another has been examined and the relative roles played by pressure-head and surface tension. Molecular mechanisms of gas or vapour flow in single capillaries and in porous media, and transition regions from one flow mechanism to another have been particularly considered, from high-pressure flow in wide tubes until the pore radius is so small that the diffusing species move entirely within the range of surface forces.

P.A.T.R.A.

1140. Calibration of X-ray measurement of strain.

J. A. BENNETT and H. C. VACHER. *J. Res. Nat. Bur. Stand., Wash.*, **40**, 285, 1948.

In order to increase the precision of strain determination by X-ray methods, twelve measurements of ring radius were made on each of two patterns for the customary incidence angles of 90° and 45° . For a specimen to which uniaxial stress was applied, a method was developed for handling the data to give one value representative of these twenty-four readings. When these values (obtained on a flat steel specimen loaded in bending) were compared with mechanical strain measurements, it was found that the X-ray measurements were proportional to the maximum principal strain up to the beginning of plastic deformation, and the precision was such that a change corresponding to $1,000 \text{ lb./in.}^2$ should be detectable.

SCI. ABSTR.

1141. On the Transformation of "Solid" Foam to a "Fluid" Foam under Shear.

M. BLACKMAN. *Trans. Faraday Soc.*, **44**, 205, 1948.

The empirical fact that fire-fighting foams which appear very viscous in a relatively undisturbed condition may be delivered through hoses in the same way as water suggests that a breakdown of the "solid" foam takes place under some critical shear stress. Experiment shows a diminution in viscosity from 10^5 – 10^9 poises to ~ 1 poise at the highest shear rates used.

W.P.F.

1142. An Interpretation of Viscosity of Liquids.

R. C. L. BOSWORTH. *Trans. Faraday Soc.*, **44**, 308, 1948.

An expression is derived for the viscosity of a liquid on the assumption that the carriers of momentum are "phonons" i.e. particles equivalent to the mechanical waves postulated in the Einstein and Debye theories of specific heats. Good agreement with experimental data is found for normal but not for associated liquids. By using the relation between free volume and the velocity of sound as given by Kincaid and Eyring the equation may be transformed to one giving viscosity in terms of molecular weight and free volume similar to the empirical expression of Macleod.

W.P.F. (See Abstr. 429, 840).

1143. Influence of Homogeneous Deformation on the Internal Friction of a Solid Solution.

C. BOULANGER. *C.R. Acad. Sci., Paris*, **226**, 1170, 1948.

Experiments were done on 80/20 NiCr alloy, the internal damping and its rate of decrease immediately after deformation being measured as a function of amount of permanent elongation. The residual internal damping after ageing was also measured. The results are interpreted in terms of the dislocation theory.

SCI. ABSTR.

1144. The Compression of 39 Substances to 100,000 kg/cm².

P. W. BRIDGMAN. *Proc. Amer. Acad. Arts Sci.*, **76**, 55, 1948.

The apparatus and method are outlined, and the results given in tables: twenty-two elements, nine bimolecular compounds, quartz and six glasses were investigated.

SCI. ABSTR.

1145. Rough Compression of 177 Substances to 40,000 kg/cm².

P. W. BRIDGMAN. *Proc. Amer. Acad. Arts Sci.*, **76**, 71, 1948.

Results for various plastics, glasses and minerals, fifteen elements, eight inorganic and ten organic compounds with transitions, twenty-five miscellaneous compounds and twenty-two compounds with *o*-, *m*- and *p*-forms are given in tables.

SCI. ABSTR. (See Abstr. 580, 745, 746, etc.).

1146. A Correction in Viscometry due to Varying Hydrostatic Head.

J. E. CAFFYN. *Proc. Phys. Soc., Lond.*, **61**, 367, 1948.

The varying head gives rise to a correction to the viscosity if the latter is calculated from the applied pressure only. This is worked out in general; and the special cases of viscometers with cylindrical and biconical bulbs and cylindrical bulbs with conical ends are considered in detail.

SCI. ABSTR.

II47. Some Physical Aspects of Water Flow in Porous Media.

P. C. CARMAN. *Discussions Faraday Soc.*, No. 3, p. 72, 1948.

When flow in a porous medium is controlled by viscosity only, it obeys the Koreny-Carman law with remarkable accuracy, and it is pointed out that the only rational pore diameter calculable from permeability measurements is $d_2 = 4 \times$ (hydraulic radius) (m). Certain conditions must be fulfilled for permeability measurements to have significance for calculation of pore diameters or specific surface, and these are discussed in some detail. As the permeability method for specific surface is well established, attention is merely directed to its extension to give both density and diameter of cellulose fibres in paper pulps. Pore diameters as normally calculated by the bubble pressure method are equal to $4 \times$ (hydraulic radius) and should therefore equal d_2 , calculated from permeability. The method, however, is open to considerable uncertainty and error.

P.A.T.R.A. (See Abstr. 685).

II48. The Extrusion of Plastic Sheet through Frictionless Rollers.

G. F. CARRIER. *Quart. Appl. Math.*, **6**, 186, 1948.

From the basic equation of the Saint Venant-Mises theory of slow plane plastic flow, a one-dimensional theory of the flow field, including the stress analysis, is developed.

SCI. ABSTR.

II49. The Thermodynamics of a Strained Elastomer II. Compressibility.

L. E. COPELAND. *J. Appl. Phys.*, **19**, 445, 1948.

Adiabatic compression measurements on well cured elastomers under pressures up to 5,000 lbs./sq. in. lead to values for first and in some cases second order compressibility coefficients and also linear isothermal compressibility. With elongation to 200% the thermal expansion of a natural rubber gum stock was found to increase slightly presumably due to crystallisation effects.

W.P.F. (cf. Mooney, Abstr. 1171).

II50. The Thermodynamics of a Strained Elastomer III. The Thermal Coefficient of Modulus and the Statistical Theory of Elasticity.

L. E. COPELAND and M. MOONEY. *J. Appl. Phys.*, **19**, 450, 1948.

Published thermoelasticity data are critically analysed by means of thermodynamic equations developed in the first paper of the series. Equations known to be of the correct form are fitted to the experimental data and it is shown that several elastomers depart from the predictions of the statistical theory. Thermoelastic measurements in torsion confirm that stress is proportional to absolute temperature.

W.P.F. (See Abstr. 4, 222, 340, 482).

II51. A Theory of the Internal Ballistics of the "Hoch-Und-Neiderdruck Kanone".

J. CORNER. *J. Franklin Inst.*, **246**, 233, 1948.

During the war the Germans developed guns with a constriction between chamber and bore so that the pressure in the chamber was substantially higher than that in the bore. It is shown that a simple theory of such guns can be devised, which is adequate for analysis of firing trials and for testing the claims advanced for this idea. The claim of a high piezometric efficiency is not supported by this theoretical analysis.

M.W.T.

1152. Sequestration, Dispersion and Dilatancy.

T. H. DAUGHERTY. *J. Chem. Educ.*, **25**, 482, 1948.

Three simple lecture experiments are described to demonstrate the phenomena of sequestration, dispersion and dilatancy, which employ a complex sodium phosphate glass represented by the commercial product Calgon. The terms sequestration, dispersion, and dilatancy are defined and industrial application of the first two have been cited. No industrial application of dilatancy is known to the author.

(Author's Abstract).

1153. Intrinsic Viscosity, Diffusion and Sedimentation-rate of Polymers in Solution.

P. DEBYE and A. M. BULCHE. *J. Chem. Phys.*, **16**, 573, 1948.

The main feature of the theoretical approach by Debye, referred to in Abstract are presented.

W.P.F. (cf. Kirkwood, 1168).

1154. Investigations on the Viscosity of Solutions of Polyisobutylene in Mineral Oils.

I. Dependence of Viscosity on Concentration and Molecular Weight.

G. I. FUKS and N. G. PUCHKOV. *Kolloidnyi Zhurnal*, **10**, 371, 1948.

The relative merits of various modifications of Stavdinger's Equation are discussed.

G.W.S.B.

1155. Creep, Recovery and Permanent Set for GR-S and Hevea.

S. D. GEHMAN. *J. Appl. Phys.*, **19**, 456, 1948.

Creep under tensile load, recovery and permanent set of Hevea and GR-S rubbers was investigated at 35° C. and with loading times up to 1,000 hours. Results indicated the presence of different bond structures in the two materials. Correction of the experimental curves for permanent deformation rendered them practically linear against log time.

W.P.F. (See Abstr. 134).

1156. A Theory of Commercial Yarn Testing.

C. J. GEYER, C. H. REICHARDT, and G. HALSEY. *J. Appl. Phys.*, **19**, 464, 1948.

A method is derived for applying the Eyring three element model to textiles. The experimental measurements are concerned with creep at constant rate of loading and relaxation at constant rate of elongation. The method is useful for the routine characterisation of textile yarns.

W.P.F.

1157. Frictional Electrification of Sand.

E. W. B. GILL. *Nature*, **162**, 568, 1948.

Sand is made to pass through a funnel and to collect on the floor some three feet below. The flow of the sand is over in half a minute. A metallic collector plate—three yards away from the funnel—is connected to the insulated quadrant of a Dolezalek electrometer. While the sand is dropping the electrometer does not indicate any charge, but soon after there is for three or four minutes, a slowly increasing deflection owing to a positive charge, reaching a maximum of a volt or so, and then gradually returning to zero. These observations are tentatively explained by the migration of a cloud of dust whose light particles carry positive charges whilst the large particles carry negative charges.

R.S.

1158. Frictional Electricity.

E. W. B. GILL. *Phys. Rev.*, **74**, 842, 1948.

Reference is made to Debeau's observation of the variation of contact electrification with the pressure of the surrounding gas atmosphere when small insulating particles pass through a metal funnel. The suggestion is offered for investigation that the frictional charges are very large and after the stream has slid some distance over the metal the charge per unit volume is sufficient to create a large potential difference between the particles and the metal with the dielectric breakdown potential of the surrounding atmosphere putting an automatic limit on the final charge on the particles. The author calculates from Debeau's results at 1 mm. pressure that in the stem of the metal funnel through which the particles pass the potential difference between the centre and the sides is of the order of 400 volts which is of the order of the minimum sparking potential.

R.S.

1159. An Accurate Microviscometer.

E. GLYNN and L. GRUNBERG. *J. Inst. Petrol.*, **34**, 331, 1948.

A microviscometer based upon the method devised by Bingham and Murray (*Proc. Amer. Soc. Test. Mater*, **23**, 655, 1923), wherein the flow of the liquid from a reservoir under a constant applied pressure into a horizontal empty capillary tube is measured, is described. The radius chosen for the diameter of the capillary depends on the viscosity to be measured: for viscosities 1–100 poise, $d = 0.01$ cm.; for viscosities 100–1,000 poise, $d =$ up to 0.03 cm. The weights of liquid used in the respective cases range from 10 to 15 mg. and 40 to 80 mg. The accuracy obtainable $\approx 0.5\%$.

SCI. ABSTR.

1160. Moderately turbulent Flow.

G. HAMEL. *Z. angew. Math. Mech.*, **28**, 65, 1948.

A turbulence function $T^2(y)$ may be introduced without any particular assumptions into the consideration of a plane, steady, moderately turbulent flow in a parallel strip by the simple introduction of a function Ψ as an additional independent variable beside it, and by neglecting terms involving γ^2 . ($\bar{y}$ is the average of y for constant Ψ). $T^2(\bar{y})$ then has the constant boundary value 1 and elsewhere is >1 , except for a laminar flow. There is a univalent mutual relation between turbulence function and velocity distribution. The average value of the pressure drop for constant Ψ contains no contribution due to acceleration.

SCI. ABSTR.

1161. An X-ray Method of Measuring Poisson's Ratio.

R. F. HANSTOCK and E. H. LLOYD. *Proc. Inst. Mech. Engrs., Lond.*, **157** (*War Emergency Issue No. 26*) 52, 1947.

The specimen, which is a small tensile test piece, is examined at various loads by a high-angle "back-reflection" X-ray technique. At any load (the value of which need not be known) X-ray patterns are obtained for various angular settings of the specimen relative to the incident X-ray beam, and, for each setting, the shift of the diffraction lines from their original position gives the strain in a direction normal to the reflecting crystallographic planes. The strains corresponding to various angular settings of the specimen, for any one load, give a linear graph when plotted against a simple function of the orientation of these crystallographic planes, and from this graph Poisson's ratio is directly obtained. For the Al alloy "Hiduminium RR.56" the ratio = 0.36. The method described has an accuracy as good as that of the ordinary mechanical method, and provides values which apply to a single set of crystallographic planes in a polycrystalline metal.

SCI. ABSTR.

1162. The Effect of Low Temperatures on the Breaking Strength of Sheet Glass.

A. J. HOLLAND. *J. Soc. Glass Tech.*, **32**, 5 (T), 1948.

Increases of $\sim 20\%$ on lowering the temperature from 18.5° to -40° are reported. Steady loading and impact tests were made on several hundred specimens. SCI. ABSTR.

1163. Paper as a Visco-Elastic Body. IV. Mechanical Conditioning of Paper and Interpretation of Stress-Strain Curves.

B. IVARSSON. *Svensk Papperstidning*, **51**, 383, 1948.

During extension paper undergoes progressive changes in its mechanical properties. This means that the paper becomes more elastic and also stiffer: the so-called mechanical conditioning. The changes in properties which occur in a paper on repeated loading and de-loading have been investigated in a tensile tester (stress-strain recorder). The properties are similar to those found in many textile fibres, e.g., rayon. The resilience of the paper is used to calculate the mechanical conditioning effect. This increases during the first load cycles particularly. It is, however, impossible to impart reproducible values to the paper by means of a small number of load cycles. The changes in the paper brought about by mechanical conditioning effects render difficult the mathematical interpretation of the extensibility diagram according to the theories drawn up by Eyring and Halsey and modified for paper by Ivarsson and Steenberg. These relations are now studied more closely by application of the theory to the individual parts of the stress-strain diagram. Calculations based on a single branch of the curve—i.e., the loading or the de-loading part—are not sufficiently accurate. Satisfactory agreement between theory and experiment is, however, obtained if the calculation is carried out for a loading and de-loading cycle carried out in the later part of the stress-strain curve—i.e., at a state where only irreversible changes take place in the paper. Eyring's viscosity law only appears to hold in an approximate way for paper, so that a detailed study of the viscosity curve appears desirable.

P.A.T.R.A. (See Abstr. 990)

1164. Viscosity—Volume Relation for Ether.

A. JOBLING. *Nature*, **162**, 620, 1948.

In a graph relating relative volume and viscosity values obtained by calculation from the combined data of Bridgman and Faust it is shown that the temperature effect becomes progressively less as the volume increases and finally disappears when the viscosity is a function of volume only and is independent of temperature. Batschinski's equation $\eta = c/v - w$ where c and w are constants and v the specific volume, represents the observed behaviour.

E.W.J.M.

1165. The Mechanism of the Reversible Thermal After-Effects in Glass at Ordinary Temperatures.

G. O. JONES. *Proc. Phys. Soc., Lond.*, **61**, 320, 1948.

An explanation is suggested for the after-effects which are responsible for the zero-depression in Hg-in-glass thermometers. A rough relation is established between these effects and the delayed elastic effects shown under ordinary mechanical stress. It is assumed that the thermal after-effects are delayed elastic strains resulting from stresses between regions of slightly differing composition, the origin of the stresses being the differing contractions of these regions during cooling from the annealing temperature. The model offers explanations for some detailed features of the behaviour, requiring inhomogeneities corresponding to differences of only a few per cent. in the proportions of the main constituents to account for the observed effects.

SCI. ABSTR. (See Abstr. 329, 991, 1095).

1166. Undular Flow of Thin Layers of a Viscous Fluid. I. Free Flow.

P. L. KAPITSA. *J. Exp. Theor. Phys.*, **18**, 3, 1948.

The paper deals with the flow of thin layers of a viscous liquid under the action of a constant volume force, allowing for surface tension. An approximate solution of the equation of flow was found which showed that the undular flow established experimentally by a series of workers had a more stable character than the laminar flow. Wave shape, phase velocity, and amplitude are given. The theoretical values of the critical factors Re_K characteristic for the inception of the undular flow agree with the experimental data. The rapid dispersion of colouring matter along the flow observed by Friedman and Miller is quantitatively explained by the undular character of the flow.

SCI. ABSTR.

1167. Undular Flow of Thin Layers of a Viscous Liquid. II. Flow in Contact with a Gas Flow and with Heat Transfer.

P. L. KAPITSA. *J. Exp. Theor. Phys.*, **18**, 19, 1948.

The paper deals with the inter-reaction of a gas flow with the flow of a liquid. On the assumption of an interruption in the gas flow occurring where it makes intimate contact with the wave surface of the liquid it becomes possible to explain and define numerically the increased pressure drop in a gas streaming through pipes with moist walls. The expression for the critical velocity at which the gas current is "choked" in a vertical pipe along the walls of which there is a liquid counterflow is in good agreement with test results. Finally, the increase of the thermal conductivity of thin layers of a liquid in an undulating condition is estimated.

SCI. ABSTR.

1168. The Intrinsic Viscosities and Diffusion Constants of Flexible Macromolecules in Solution.

J. G. KIRKWOOD and J. RISEMAN. *J. Chem. Phys.*, **16**, 565, 1948.

A theory of the intrinsic viscosities and translational diffusion constants of flexible macromolecules is developed on the basis of the random coil model with hindered internal rotation. Proper account is taken of the hydrodynamic interaction of the monomer units of the molecule and of inhibited flow through the chain. The theory leads to results quantitatively similar to those obtained by Debye on the basis of a molecular model consisting of a sphere containing a uniform distribution of of resisting points. However, significant quantitative differences between the two theories are found.

Author's Abstract. (See Abstr. 481).

1169. The Young's Modulus and Strain Coefficient of Resistivity of some Bismuth-Rich Alloys.

G. C. KUCZYNSKI. *J. Appl. Phys.*, **19**, 683, 1948.

The modulus of elasticity was found to decrease rapidly in the region of solid solutions for the Bi-Pb, Bi-Sn, Bi-Se, Bi-Ni alloys tested. The strain coefficient of resistivity increased rapidly in the same region while corresponding stress coefficient remained constant.

W.P.F.

1170. Method for the Absolute Measurement of Dynamic Properties of Linear Structures at some Frequencies.

W. J. LYONS and I. B. PRETTYMAN. *J. Appl. Phys.*, **19**, 473, 1948.

A method is described for the measurement of dynamic stretch modulus, coefficient of internal friction and energy loss of textile yarns and cords at frequencies

> 100 c.p.s. Results are given for a number of textiles and for Fiberglas and steel. The internal friction co-efficient is found to vary hyperbolically with frequency.

W.P.F. (See Abstr. 478, 709).

1171. The Thermodynamics of a Strained Elastomer. I. General Analysis.

M. MOONEY. *J. Appl. Phys.*, **19**, 434, 1948.

Assuming that the volume of an elastomer is a linear function of temperature and pressure the basic equations of thermodynamics are integrated, leading to expressions for entropy and energy of deformation in terms of observable quantities. It is shown that the super-elastic functions of deformation previously proposed have a very general validity.

W.P.F. (See Abstr. 4, 222, 340, 482).

1172. Methods for Measuring Dynamic Mechanical Properties of Rubber-like Materials.

A. W. NOLLE. *J. Appl. Phys.*, **19**, 753, 1948.

Experimental arrangements are described for the measurement of the complex differential dynamic Young's modulus of rubber-like materials in the frequency range 10^{-1} to 10^{-5} cycles per second. Five methods are needed to cover this range: (a) a measurement of the natural frequency of oscillation and decrement of a rocking beam oscillator the restoring force being supplied by the rubber, (b) measurement of the resonant frequency and resonance bandwidth of a rubber reed in forced oscillation, (c) measurement of phase velocity and attenuation of longitudinal waves in a thin rubber strip, (d) measurement of the frequency of longitudinal wave resonance and bandwidth of a half wave transmission line, (e) measurement of change in resonant frequency and bandwidth of a magnetostrictive rod when a rubber sample is pressed against its end.

W.P.F. (See Abstr. 716).

1173. Measurement of Young's Modulus for Threads and Films by a Dynamic Method.

R. PINOIR and A. DUBOIS. *J. Phys. Radium (Sér. 8)* **9**, 20, 1948.

A method is outlined for measuring the dynamic modulus of elasticity of threads and films. It consists in determining the velocity of wave propagation in the specimen; the wave being produced by a hammer striking the specimen support, while its time of departure and arrival, at a given test point, are recorded on a c.r.o. By synchronizing the frequency of the hammer blows with the sweep frequency of the spot, a steady picture is obtained. The method has been applied to several plastics, such as nitrocellulose, cellulose acetate, vinyl resins, nylon, etc., with an accuracy of $1\frac{1}{2}\%$ in the determination of E .

SCI. ABSTR.

1174. Theory of Plastic Flow versus Theory of Plastic Deformation.

W. PRAGER. *J. Appl. Phys.*, **19**, 540, 1948.

Typical theories of plastic flow and plastic deformation are discussed and the concept of neutral changes of stress is introduced. A neutral change of stress can be considered as a limiting case of either loading or unloading. It there seems reasonable to demand that the stress-strain relations for both loading and unloading should predict the same change of strain when applied to a neutral change of stress. It is shown that this condition is satisfied by the theories of plastic flow but not by the theories of plastic deformation.

Author's Abstract. (See Abstr. 347, 603, 635).

1175. Unsteady Flow in Open Channels.

H. J. PUTMAN. *Trans. Amer. Geophys. Un.*, **29**, 227, 1948.

Massau's original papers treat more complicated cases, but a résumé based on the special case of flow in rectangular channels illustrates the general line of attack.
SCI. ABSTR. (See Abstr. 166, 210).

1176. Large Elastic Deformations of Isotropic Materials. IV. Further Developments of the General Theory.

R. S. RIVLIN. *Philos. Trans. A.*, **241**, 379, 1948.

The equations of motion, boundary conditions and stress-strain relations for a highly elastic material can be expressed in terms of the stored-energy function, which may be defined for a particular material in terms of the invariants of strain. The form in which the equations of motion, etc., are deduced does not permit the evaluation of the forces necessary to produce a specified deformation unless the actual expression for the stored-energy function in terms of the scalar invariants of the strain is introduced. The equations are now transformed into forms more suitable for carrying out such an explicit evaluation. As examples, the surface forces necessary to produce simple shear in a cuboid of either compressible or incompressible material and those required to produce simple torsion in a right-circular cylinder of incompressible material are derived.

SCI. ABSTR. (See Abstr. 1017, 1018).

1177. The Forces of Static and Kinetic Friction.

R. SCHNURMANN. *An. Acad. Brasil Ciencias*, **20**, 197, 1948.

The author discusses general principles of friction measurement, in particular the force-velocity characteristic of frictional contacts, the jerky motion of frictional contacts (with contact electrification), the electro-static component of the force of friction and effect of frictional heat.
E.W.J.M.

1178. Study of the Berthelot Method for Determining the Tensile Strength of a Liquid.

A. F. SCOTT, D. P. SHOEMAKER, K. N. TANNER, and J. G. WENDEL. *J. Chem. Phys.*, **16**, 495, 1948.

An attempt was made to test directly the supposition that the high values for the tensile strengths of liquids as found by the Berthelot method are due to the trace of air ordinarily present in the Berthelot tube. A method is described for preparing Berthelot tubes in an evacuated system, using water from which air had been carefully removed. Measurements with these air-free tubes yielded thirty-two atmospheres as the average maximum hydrostatic tension that water can withstand. This value for the maximum tension is in good accord with the evidence of other investigators.

SCI. ABSTR. (See Abstr. 646).

1179. Measurement of the Slipperiness of Walkway Surfaces.

P. A. SIGLER, M. N. GEIB, and T. H. BOONE. *J. Res. Nat. Bur. Stand., Wash.*, **40**, 339, 1948.

The mechanics of walking as related to slipping and the design of testing instruments are briefly discussed. In order to test floors in actual service a portable slipperiness tester of the pendulum-impact type was designed and constructed. The design is based on the hypothesis that, in the process of ordinary walking, slipping is most likely to occur when the pavement surface is first contacted by the edge of the heel. The instrument and test procedure are described. The effects of varying some of the

constants of the instrument, such as the angle of contact between the test heel and the pavement surface, and the pressure between the heel and the pavement, are discussed. Typical results obtained with both rubber and leather test heels and under both dry and wet conditions are given for various flooring and finishing materials. In general, the traction furnished by dry rubber heels is much better than that obtained with dry leather heels. Good antislip properties under wet conditions are usually associated with rough particles that project through the film of water and thus prevent its action as a lubricant.

SCI. ABSTR.

1180. **Temperature and Pressure Phenomena in the Flow of Saturated Liquids.**

R. S. SILVER. *Proc. Roy. Soc. A.*, **194**, 464, 1948.

The rate at which evaporation can occur from a surface is limited by the rate of heat flow into the surface. Because of this, when a liquid at its boiling point commences to flow, the proportion of vapour which forms as a result of the Bernoulli fall in pressure is less than is calculated from adiabatic expansion. A theory for the actual amount of vapour which will form is given, together with an analysis of its effect upon the velocity of flow and the quantity of fluid passed by a nozzle. It is found that although the system consists of a central core of liquid and an envelope of vapour, the calculated limiting velocity of flow, which is the velocity of pressure propagation in the system, is low. The order of magnitude is 20 m/sec as compared with 400 and 1,500 m/sec for vapour alone and liquid alone respectively. There is a corresponding critical pressure, analogous to that in a gas nozzle, but in contrast to the gas case, both the critical pressure and the limiting velocity itself are functions of the diameter and length of nozzle. Experiments are described which confirm these theoretical deductions in all respects, and which also show good quantitative agreement with calculated velocities, critical pressures, and amount of discharge and of evaporation. On the basis of this experimental verification general phenomena to be expected in pressure propagation through liquids near saturation temperature are discussed.

SCI. ABSTR.

1181. **A Theory of Transient Creep in Metals.**

C. L. SMITH. *Proc. Phys., Soc.*, **61**, 201, 1948.

A new approach to the theory of transient creep in metals is described and the relation $\epsilon = \text{const.} T(1 - e^{-Ct})/t$ deduced, connecting the creep strain ϵ , the absolute temperature T and the time t , C is a constant. The relation is compared with experimentally obtained curves.

Author's Abstract. (See Abstr. 915).

1182. **Strain Energy in Greatly Deformed Elastic or Inelastic Anisotropic Engineering Metals.**

K. H. SWAINGER. *J. Franklin Inst.*, **245**, 501, 1948.

The equilibrating stresses on an orthogonal element in a strained body induce normal strains defined as relative displacement per unit length of deformed body. This vector "straining"-displacement must be a point function for continuity of the solid. The work done by the forces on the faces of an orthogonal element of unit volume in the loaded body during a differential increase of deformation is found. Integration gives the total work done on the element from the initial unstrained state up to the current state of deformation.

SCI. ABSTR. (See Abstr. 919, 1031, 1032, 1130, etc.).

1183. **Micro-Hardness Testing of Materials.**

E. W. TAYLOR. *Engineering*, 10th September, 1948.

In studying alloys it is very valuable to have a method which will give information on the physical properties of individual crystals or components ; one way of doing this is by using a micro-indenter which can make an impression at a very accurately located point in the surface which has been polished and etched to reveal the structure. A micro-hardness tester has been developed which can be mounted on the stage of a standard projection microscope and give a chosen load varying from 1-500 grammes on a Vickers diamond pyramid. The latter has the advantage over the Brinell ball that all impressions are geometrically similar. A number of impressions are shown with various loads and with hardness figures varying between 930 and 20. The instrument can also be used for scratch tests, a method which is particularly useful when it is not easy to distinguish visually between two constituents. M.W.T.

1184. **Application of Dynamic Similarity to Metal Structures with Elastic and Plastic Flow.**

M. W. THRING. *Nature, Lond.*, **162**, 193, 1948.

Dynamic similarity structures for metals depend upon dimensionless criteria in much the same way as fluid flow systems. When momentum and elasticity are the main factors, the velocities must be constant (that is, the time scale must be shortened proportionally in reducing from original to model). When elasticity and plasticity are the main factors, inertia being neglected, the time scale must be the same in model and original. The criterion in this case is deduced for a Kelvin solid only, but the assumptions on which similarity is based for problems where plasticity is important are discussed, together with the metal phenomena open to such treatment. SCI. ABSTR.

1185. **Structural Viscosity as the Cause of Lubricating Properties.**

H. UMSTÄTTER. *Technik*, **1**, 46, 1946.

The viscosity of colloidal lubricants decreases with increasing velocity gradient. Tangential pressure plotted *v*. velocity gradient on a log/log scale gives the "flow curves" for the material, the gradient of which is a measure of lubricating value called "slipiness." Structure-viscous oils are shown to give more uniform hydraulic pressure distribution in bearing clearances than standard oils. This enables a reduction in bearing sizes for a given load when using structure-viscous oils. The optimum results are obtained when the "slipiness" is a max. for the max. velocity gradient occurring in the bearing. SCI. ABSTR. (See Abstr. 299).

1186. **Etude d'une Methode de Mesure du Coefficient de Diffusion de Translation.**

G. VALLET. *Mem. Services chim. Etat.*, **33**, 247, 1947.

Principe de la méthode : on met en évidence le gradient de concentration en faisant interférer deux faisceaux de lumière polarisée qui traversent une cuve parallélipédique contenant la solution examinée. Les différences de marche introduites à différentes hauteurs sont fonctions du gradient ; le retard apporté sur chacun des faisceaux n'étant pas le même, on obtient une lumière elliptique dont les éléments sont fonctions du retard introduit. La correction due à la courbure des rayons est rendue très faible par la construction de l'appareil. Cette méthode est très rapide ; une heure et demie suffisent pour une détermination. Les expériences ont porté sur le saccharose. Erreur probable $\sim 1\%$ sur une mesure, ce qui est 10 fois meilleur que les résultats de Thouvert ou ceux d'Ohlholm, dont l'erreur est environ 11%. A.D-D.

II87. Viscosity of Solutions and Suspensions.

V. VAND. *J. Phys. and Coll. Chem.*, **52**, 277, 300, 314, 1948.

A theoretical formula for the viscosity of a suspension of rigid spheres taking into account their collisions and mutual interactions is derived. The correction for wall effects in measuring instruments is investigated theoretically. Satisfactory agreement with experimental results is found for a suspension of glass spheres in zinc iodide solution. Application of the first formula to solutions of sucrose gives data on hydration, collision constants and densities of the molecules and their hydration envelopes.

W.P.F. (See Abstr. 926).

II88. The Relationship between Stress and Strain for Homogeneous Deformation.

E. VOCE. *J. Inst. Met.*, **74**, 536, 1948.

A simple relationship with a rational basis has been found to connect stress with strain for a series of homogeneous compression curves published by Cook and Larke. At large deformations each of the curves becomes asymptotic to a definite stress, and the difference between this final stress and the threshold stress at which plastic deformation begins to become appreciable may therefore be regarded as the total stress capacity of the material. Similarly, the difference between any particular applied stress and that which is finally attained is the stress capacity remaining available after the application of the stress in question. Defining the plastic modulus, comparable with the elastic modulus, as the rate of change of stress with respect to true (logarithmic) strain, it is shown that the plastic modulus at any instant $\propto$ the available stress capacity. The same relationship appears to hold for tension as well as for compression as long as the deformation remains homogeneous. E.g., it seems to be true up to the incidence of necking in the tensile test, and even beyond it in special circumstances. While this relationship cannot be regarded as established, it is tentatively put forward and discussed with illustrative examples. SCI. ABSTR.

II89. Conditions of Flow of Two Contiguous Dispersed Masses, each having the Properties of a Visco-Plastic Body.

M. P. VOLAROVICH and A. M. GUTKIN. *Kolloidnyi Zhurnal*, **10**, 329, 1948.

A study of the behaviour of two materials having different apparent viscosities (η_1 , η_2) and yield-values (θ_1 , θ_2) with an interfacial frictional stress (θ_{12}) proportional to the applied pressure. The effects of variations in the relative magnitudes of η_1 , η_2 , and θ_1 , θ_2 , θ_{12} , on the flow of the combined mass of material are discussed.

G.W.S.B. (See Abstr. 570).

II90. Thixotropy and the Mechanics of Burrowing in the Lugworm (*Arenicola Marina*).

G. P. WELLS. *Nature*, **162**, 652, 1948.

The author contradicts the view that the movement of the lugworm is dependent on the thixotropic property of sand and explains it as being "more like a digging rabbit which scratches and shovels the earth away."

E.W.J.M.

II91. Strength of Metals.

W. A. WOOD and W. A. RACHINGER. *Nature*, **162**, 891, 1948.

Measurements by X-ray diffraction methods have been made with the body-centred cubic metals, iron, tantalum, etc. and the values obtained have been related to the maximum tensile strength of the metals. The values given suffice to indicate that the calculated strength scale = $G d / L$ where G is in tons/sq.in., d the atomic spacing in the slip direction and L the crystallite size.

E.W.J.M. (See Abstr. 1051, 1052).

PROPERTIES OF ROAD TARs AND ASPHALTIC BITUMENS
IN RELATION TO ROAD CONSTRUCTION

This brochure prepared by Dr. A. R. Lee and issued by the D.S.I.R., July 1948, discusses the properties of road tars and bitumens and their significance in terms of the behaviour of the surfacings in which they are employed.

Matters of particular interest which are included relate to adhesion, viscosity, temperature susceptibility, stress rate of flow relations, structural viscosity effects, weathering and durability.

It is considered that adhesion and viscosity are the important physical characteristics of road tars and bitumens and, to a less extent, brittleness and tensile strength. Deterioration of surfacings is considered to occur largely through the combined action of traffic and weather and the durability of many surfacings, particularly the open and medium-textured ones, is determined largely by the resistance of the binder to weather action. Weather action consists in the displacing effects of water which tends to break down adhesion and oxidation which tends to produce brittleness.

D.C.B.

BOOK REVIEWS

PLASTICITY AS A FACTOR IN THE DESIGN OF DENSE BITUMINOUS ROAD CARPETS

L. W. NIJBOER. (*Elsevier Publishing Co., Amsterdam*) (pp. XV + 179 + 51 diagrams)

Various attempts have been made from time to time to design asphalt mixtures on scientific lines, but the English technologist has, until now, been unwilling to accept any basis of design other than that of practical experience. It is, therefore, noteworthy that Dr. Nijboer has published, in the present volume, a serious and strictly scientific attempt to analyse the mechanical processes to which bituminous road materials are subjected and to design road carpets that possess a "Prandil bearing capacity" equal to the inflation pressure of pneumatic tyres. The author admits freely that the analysis is not yet so far developed that stringent specifications can be set up for the composition of mixtures that have to meet definite demands of traffic, but he has certainly progressed a long way towards that goal, and brings within sight the time when we shall have the same degree of safety in bituminous construction as that obtained in the structural design of other—mainly elastic—materials, such as steel and concrete.

Dr. Nijboer's work is largely based on the triaxial shear test method, known from soil mechanics, and he shows how the results of such tests may be worked out graphically with the help of Mohr's circles so as to describe the resistance of bitumen-aggregate mixtures to plastic flow by three physical constants, a coefficient of friction, a viscosity and an initial resistance.

The work is not confined to stability under standing loads, but deals also with the kneading action of traffic, whilst a useful section discusses problems in connection with compaction by rolling. It is interesting to read Dr. Nijboer's conclusion that the demands for stability under moving traffic at low chippings content are less

severe than those for stationary traffic, but with high chippings content the reverse position applies and mixtures of the asphaltic concrete type have to be designed for stability under moving traffic. The importance of the filler/bitumen ratio is stressed throughout.

The book is well produced with clear type and although printed in Holland there are few typographical errors. The reader is rarely seriously inconvenienced by such words as "Tot" instead of "To". A good index and an ample bibliography are provided, whilst an extensive table of definitions and symbols is particularly valuable.

D.C.B. (Abridged).

PLASTICITY IN ENGINEERING

PROFESSOR F. K. TH. VAN ITERSON.

Blackie and Son, Ltd., London.

In these days, the general problem of plasticity plays an important part in the consideration of the particular combination of stresses causing failure, whence it appears that applications are to be found in the development of materials for certain forming operations, the design of guns, soil mechanics, geology, and seismology. In the case of the strength of materials, approach to the problem is difficult from either the experimental or the theoretical side, since beyond the yield point the ordinary kind of strain measurements cannot be translated in terms of stress, and no equations for the process have been derived from purely theoretical reasoning. From this and the fact that the utility of complex and large structures often depends on the plastic properties of the material, it is clear that the accumulation of experimental data is of first importance to the designer of such structures. In his book, Professor van Iterson throws further light on the subject by introducing an idea of plastic flow which differs in noteworthy particulars from that presented by Dr. Nadai in his well-known work on plasticity and, at the same time, elucidates the matter by reference to tests which have not been published previously.

Starting with the elementary concepts of internal strain and plasticity, the author discusses in a concise, yet informative, style such details as deformation at sharp corners, and between parallel and inclined plane surfaces, before turning to the consideration of plastification caused by the relative movement of material in the annular space between two concentric cylinders, a simple example of which occurs in the cutting of clay with a wire. In this manner the reader arrives at Chapter X, where the laws of three-dimensional plastic flow are formulated on the basis of tests specially arranged for the purpose. The treatment here and in other sections of the book is greatly enhanced by the use of the concept of a plastic sector for exhibiting the distribution of strain, which has much to do with the patterns that frequently appear with remarkable regularity and symmetry on the surface or in the section of a specimen stressed beyond the proportional limit of the material. The value of this concept is best illustrated, perhaps, in Chapter XXIII, on application of the theory to particular problems, of which the plastic region of a rounded groove in a bar under tension and of material subjected to the action of a cutting tool are typical examples.

Throughout the twenty-seven chapters of this study of the numerous ramifications of the subject, the serious reader will find much useful information concerning recent research. He will also find occasion to review his theoretical knowledge, as may be indicated by reference to the chapter under the heading "Do Slip Planes Occur in Plastic Flow?" After remarking that, in the plastic state, the material resembles a liquid, with the difference that in a liquid the three principal stresses are alike, whereas in a solid they may be all different, Professor van Iterson proceeds to show that any conception of slip planes is misleading. The book will undoubtedly receive the attention it deserves in the laboratory and drawing office, as well as in the class-room.

Engineering.