A Laboratory Apparatus for Measuring the Lateral Strains in Tension and Compression Members, with some Applications to the Measurement of the Elastic Constants of Metals. By E. G. Coker, M.A. (Cantab.), D.Sc. (Edin.), F.R.S.E., Professor of Mechanical Engineering and Applied Mathematics, City and Guilds Technical College, Finsbury, London. (With a Plate.)

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The recognition of the importance of lateral strain in the theory of elasticity, as now taught in most engineering colleges, makes it very desirable that students should make experiments upon the lateral contraction of tension specimens and the lateral extension of compression pieces with the same facility that they now determine the values of Young's modulus and the modulus of shear.

With this purpose in view, the author designed an instrument which has been very thoroughly tested by student-use for the past two years in the testing laboratory of M'Gill University.

For the object in view it was necessary to make an apparatus of simple construction, easily operated and understood, and capable of standing a considerable amount of wear and tear without injury, while at the same time it must be capable of measuring with accuracy linear strains of the order of $\frac{1}{20,000}$ of an inch.

After some minor alterations, an apparatus was constructed which fulfilled these requirements.

The instrument is shown in sectional elevation by fig. 1, and in part sectional plan by fig. 2, and it consists essentially of a pair of tubular arms *A*, connected by a flexible steel plate *B*, which forms the fulcrum. This plate is very thin, in order to allow the arms to turn in the plane passing through their axes, and is very deep, to give the necessary rigidity perpendicular to the plane of motion, and thereby ensure that the arms have no other motion. The plate is gripped by a pair of collars *C*, mounted on the arms *A*, and provided with grooved ends and tightening screws.

The instrument is attached to the specimen by a pair of screws

D, threaded through nuts formed on the arms and provided

with lock nuts, and the pressure of the screw points on the specimen is regulated by a spring threaded over a hollow spindle *E* pivoted to one arm, this spindle being guided by a second, *F*, pivoted to the other arm: the compression of the spring is regulated by a nut *G* upon the outer spindle.

The free ends of the tubes are prolonged beyond the screw grips, and one of them is fitted with an ebony finger *H*, having a thin steel plate *I* secured to its outer end, which presses against a double knife-edge *J*, seated in a shallow V-notch cut in the end of the other arm.

This knife-edge carries a mirror *K* pivoted upon a vertical spindle, and capable of adjustment about an horizontal axis also. An adjusting screw *L*, secured in one of the collars, bears against the specimen, and keeps the instrument from swinging round on the points of the screws.

With this arrangement any alteration in the diameter of the specimen between the screw points causes a movement of the outer end of one arm relatively to the other, and a proportional rotation of the knife-edge and its attached mirror is obtained. This rotation is observed by a telescope and scale placed at a convenient distance away, and a measure of the change in the

diameter of the specimen is thus obtained. A photograph of the apparatus is shown in fig. 3 mounted upon a tension specimen.

The value of a unit of the scale was obtained by calibrating the instrument by a Whitworth measuring machine, and it was found that, with the scale 24·8 inches distant from the mirror, one division of the scale corresponded to one-millionth of an inch.

At first some minor difficulties were experienced owing to the longer branches of the tubes being insufficiently rigid, and they were therefore trussed, with good effect, and afterwards pieces of hard wood, of square section, were forced down the tubes; this overcame the difficulty completely. As the instrument was wholly of brass, some difficulty was experienced owing to small changes of temperature in the laboratory, which sometimes altered the zero of the instrument during a test; this error was guarded against by lagging with chamois leather.

The instrument, when used in conjunction with an apparatus for measuring longitudinal strain, gives a measure of Poisson's ratio $\frac{1}{m}$ if the material fulfils the conditions assumed by the theory of elasticity; and knowing the value of Young's modulus E , we can easily calculate the modulus of shear C and the bulk modulus D from the formulæ

$$C = \frac{1}{2} \frac{m}{m+1} E$$

$$D = \frac{1}{3} \frac{m}{m-2} E$$

As an example of this we may quote a test of a piece of machinery steel in tension, when the lateral extensometer above described and a Ewing extensometer were secured to the specimen.

The experiment gave the following results :—

Steel specimen 1·01 inches in diameter.

Length under test 8·00 inches.

Ewing Extensometer, one division = $\frac{1}{50,000}$ of an inch.

Lateral Extensometer, one division = $\frac{1}{1,000,000}$ of an inch.

The accompanying table of observations (page 455) shows that the mean longitudinal strain per unit of length is ·0000825 inches, and the mean lateral strain ·0000206, corresponding to a value for m of 4·01, and the value of E , obtained in the usual manner, is 30,250,000, the units being pounds and inches.

Load Pounds.	Longitudinal Strain.		Lateral Strain.	
	Reading.	Δ	Reading.	Δ
1,000	0	- 34	0	- 20
3,000	34	- 32	20	- 22
5,000	66	- 33	42	- 21
7,000	99	- 33	63	- 22
9,000	132	- 33	85	- 21
11,000	165		106	
0	0		0	

The values of C and D are respectively 12,378,000 and 20,603,000, with the same units.

As a further example we may quote the case of a wrought-iron bar in tension, having a diameter of 1 inch, the test being similar to the one previously described. The readings obtained were—

Load Pounds.	Longitudinal Strain.		Lateral Strain.	
	Reading.	Δ	Reading.	Δ
1,000	0	- 37	0	- 25
3,000	37	- 35	25	- 25
5,000	72	- 34	50	- 25
7,000	106	- 37	75	- 24
9,000	143	- 36	99	- 25
11,000	179	- 36	124	- 22
9,000	143	- 35	102	- 24
7,000	108	- 36	78	- 24
5,000	72	- 35	54	- 25
3,000	37	- 37	29	- 25
1,000	0		4	

And from these readings we derive the following values :—

$$\begin{aligned} m &= 3\cdot64 \\ E &= 28,450,000 \\ C &= 11,160,000 \\ D &= 21,048,000 \end{aligned}$$

Other metals were also experimented upon, and in some cases under compression, when the longitudinal strain was measured by a compressometer of Professor Ewing's design. It will be sufficient to quote the results of these experiments without the detailed observations, which present no peculiarity except that, in the cases of cast-iron, brass, and copper, the stress strain curve for a complete cycle of stress was a very narrow loop. In these cases the mean value of the strains for the whole range of stress was taken for calculating the values of the constants. The results, including the tests above cited, were as follows :—

Tension Experiments.

Specimen.	<i>m</i>	E	C	D
Machinery Steel, . .	4·01	30,250,000	12,378,000	20,603,000
Wrought-Iron, . .	3·64	28,450,000	11,160,000	21,048,000
Rolled-Brass, . .	3·10	14,700,000	5,557,000	13,809,000
Rolled-Copper, . .	3·02	10,100,000	3,794,000	9,640,000

Compression Experiment.

Specimen.	<i>m</i>	E	C	D
Machinery Steel, . .	4·09	29,600,000	11,891,000	19,310,000
Wrought-Iron, . .	3·58	28,100,000	11,000,000	21,200,000
Rolled-Brass, . .	3·12	14,820,000	5,620,000	13,750,000
Cast-Iron,	4·07	14,900,000	5,950,000	9,750,000

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These results correspond with those obtained by Bauschinger,* Stromeyer,† Morrow ‡ and others.

It should be noted, in conclusion, that the specimens of material for the tension and compression specimens were not identical, but they were taken from the same consignments.

* *Der Civilingenieur*, vol. xxv., 1879.

† "Experimental Determination of Poisson's Ratio," *Proc. R.S.*, 1894.

‡ "On an Instrument for Measuring the Lateral Contraction of the Bars, and on the Determination of Poisson's Ratio," *Phil. Mag.*, 1903.

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