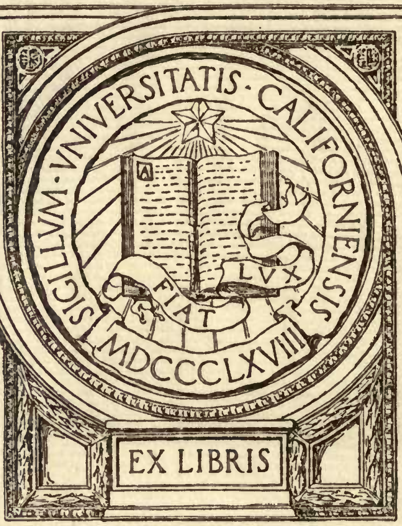
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PAPERS FROM THE DEPARTMENT
OF
ENGINEERING.

No. ~~4~~ 8.—A New Extensometer.

BY

HENRY T. BOVEY, LL.D.

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pp. 1-16, May 22, 1901.

Montreal, 1902.

I.—*A New Extensometer.*

BY HENRY T. BOVEY, M.Inst. C.E., F.R.S.C., Etc.

(Read May 22, 1901.)

The purpose of the present paper is to describe a new extensometer, which has been designed with the object of determining the amount of the longitudinal extension or compression of any given length, parallel to the axis, in a horizontal beam loaded transversely.

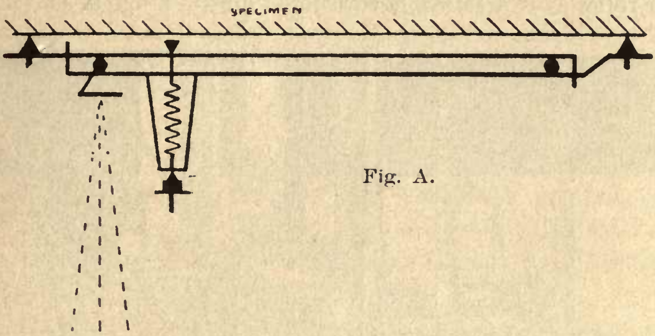


Fig. A.

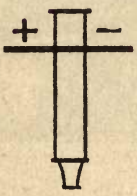


Fig. B.

The device by which the actual deformation is measured consists of a small mirror, suitably mounted on a roller, which is held between the faces of two overlapping longitudinal steel bars (Fig. A). These bars are designed to have a capacity of 8 to 12 inches in length. Each bar is slotted nearly the entire length and, at one end, is bent at right angles and passes into the slot of the companion bar. At its other end, each bar is also slotted transversely, and pass over pivotted knife edge terminals, held in the desired positions on the face of the specimen, by means of spring fingers. Any extension or compression of the specimen between these knife edge points produces a corresponding movement of the bars, thus causing the partial rotation of the mirror, and so giving either a positive or negative reading of the scale of the observing telescope, Fig. B.

The two bars are held in contact with the mirror roller by a small suspension spring, which offers a minimum resistance to any longitudinal movement of the bars. This arrangement constitutes one of the novel features of the instrument. Parallelism of the bars in a horizontal position combined with freedom of movement is maintained by making the bent end pass into the opposite slot; parallelism of the bars relatively to the face of the beam is maintained by means of an additional roller placed between the bars as far as possible from the suspension spring. The suspension spring is situated as near the mirror roller as is practicable with the requisite range of movement.

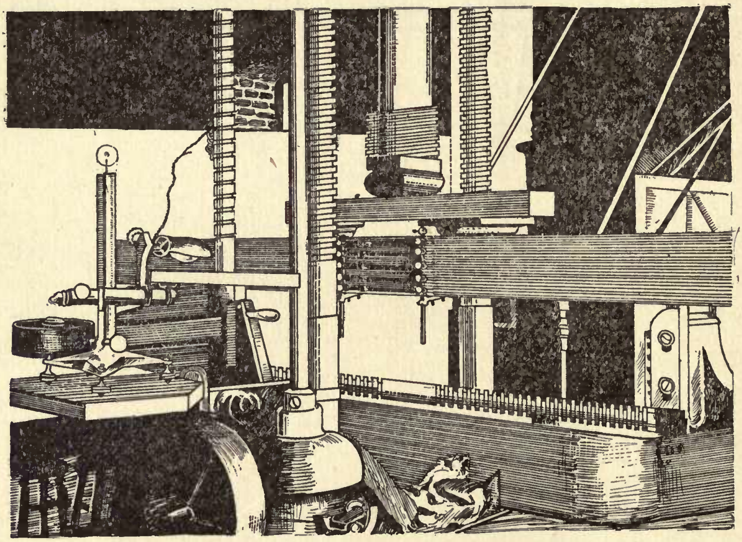


Fig. C.

The frame carrying the mirror, being attached to the top of the roller, is bent down in front of the bars, so that the mirror is thus pivoted directly in front and allows the extensometer to be made less than 1-inch in width—an important consideration when it is desired to use as many instruments as possible at one time. The length of surface over which the distortion is measured with the present instruments may vary from 8 to 12 inches.

The value of the rotation of the mirror produced by the extension or compression in that part of the beam over which it is situated is observed by means of an ordinary reading telescope, with cross-hairs, Fig. C. The telescope is carried on a suitable head, which can be moved vertically by means of a small windlass at the base. The pillar on which this head is moved up or down to the required position is of triangular section, which prevents any axial movement. The scale is fixed on the head carrying the observing telescope and remains in a constant position relatively to the telescope. A preliminary calibration of the whole of the arrangement is made to determine the distance of the scale from the axis of rotation of the mirror. Thus the exact value of the movement occurring in any one extensometer on the face of the beam, may be read off, by bringing the telescope into line with that particular mirror.

It is not absolutely necessary to have more than one measuring device, which may be shifted from position to position, and the beam subjected to repeated loads, the resulting values obtained in each position being the same as though a number of the instruments were used at one time. In order to save time, however, by diminishing the number of loadings, as many extensometers might be placed on the beam as the width of the beam will allow.

A number of experiments have been made with extensometers of this description and have shown them to be of exceeding delicacy. Small loads of even a few pounds are immediately indicated by the movement of the cross hairs over the scale.

(Of course devices of much cruder design and construction are quite sufficient when larger deformations than those within the elastic limit are produced, and such devices are now being constructed and used in the McGill laboratory.)

The following experiments will, to some extent, indicate the nature of the apparatus and the results seem to justify certain interesting and important inferences.

In these experiments, which are all within the elastic limit, the distance between the extensometer points, i.e., the length under observation, is in each case 8 inches, and the beam supports are 60 inches centre to centre. The loading is of two kinds:

(1) The beam is loaded in the centre (Fig. D);

(2) The beam is equally loaded at two points equidistant from the centre and the loads are such that the maximum bending moment is the same as the maximum bending moment when the load is at the centre (Fig. E).

The deflection was carefully measured in each case, but was so small as to have no appreciable effect upon the 8-in. distance between the extensometer points.

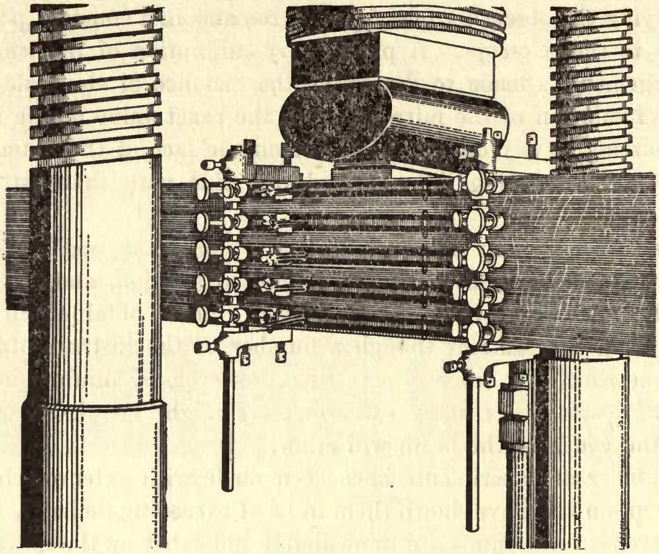


Fig. D.

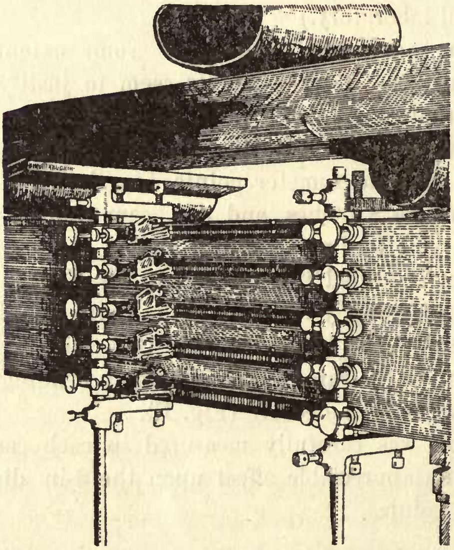


Fig. E.

Table showing mean strain in 7.1-in. × 3.33-in. cast iron beam under three different systems of loading.

Compressive strains +
Tensile “ –
Extensometers 1.6-in. c. to c.

The strains are, in each case, the means of *five* observations.

TOTAL STRAINS AT DIFFERENT POSITIONS OF EXTENSOMETERS.

IN MILLIONTHS OF AN INCH.

	Load in lbs.	I.	II.	III.	IV.	V.
Load at centre.	000	000000	000000	000000	000000	000000
	800	+ 234	+ 117	+ 1	– 107	– 227
	1600	+ 465	+ 235	+ 000	– 225	– 456
	2400	+ 688	+ 344	– 003	– 347	– 696
	3200	+ 872	+ 419	– 050	– 514	– 977
	4000	+ 1075	+ 500	– 080	– 666	– 1249
Loads 10-ins. from centre.	000	000000	000000	000000	000000	000000
	1200	+ 249	+ 126	+ 2	– 115	– 240
	2400	+ 505	+ 259	+ 004	– 230	– 474
	3600	+ 710	+ 351	– 023	– 381	– 752
	4800	+ 968	+ 487	– 020	– 494	– 983
	6000	+ 1220	+ 623	– 017	– 612	– 1219
Loads 20-ins. from centre.	000	000000	000000	000000	000000	000000
	2400	+ 277	+ 157	+ 25	– 86	– 204
	4800	+ 502	+ 264	+ 012	– 214	– 452
	7200	+ 743	+ 387	+ 007	– 340	– 698
	9600	+ 984	+ 506	000	– 469	– 947
	12000	+ 1232	+ 625	– 003	– 597	– 1194

Diagrams 1 to 3 have been prepared from the above results, and seem to justify the following inferences:—

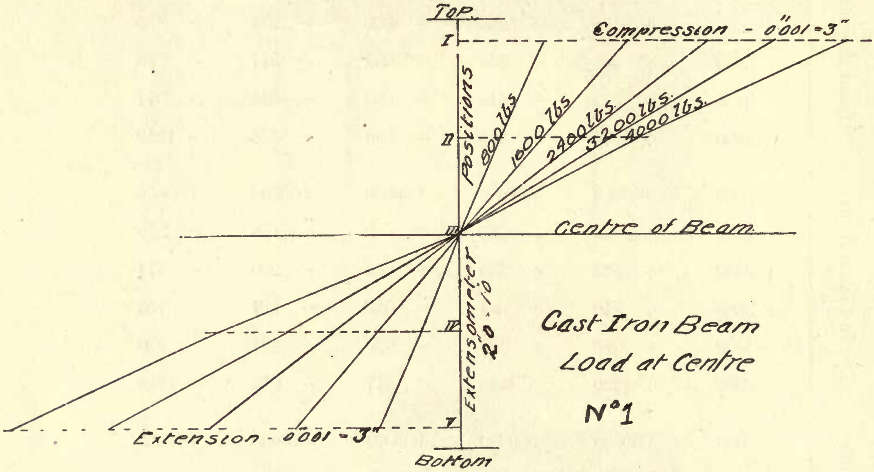
(1) The first set of readings for each of the tests indicates a generally greater deviation from the mean than the subsequent readings. This is particularly noticeable in the case where the loads are 20-ins. from the centre, when the neutral surface moves apparently towards the tension side.

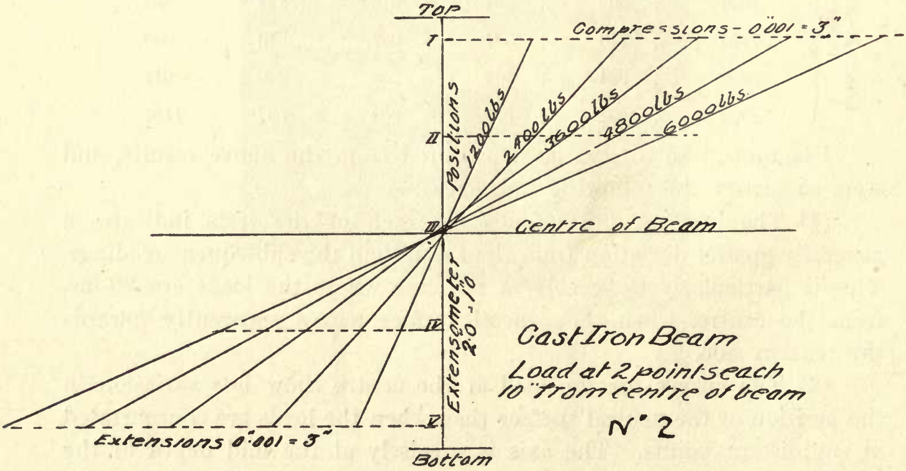
(2) The curves for the load at the centre show less variation in the position of the neutral surface than when the loads are concentrated at equidistant points. The axis is precisely at the mid depth of the

beam up to 2,400-lbs., but beyond this load there is a perceptible movement towards the compression side.

(3) The diagram for the beam under loads 10-ins. from the centre shows a slight movement of the neutral surface towards the tension side for the smaller loads, but under 3,600 lbs. it suddenly moves to the compression side, and then gradually returns towards the centre under still higher loads.

(4) Loads at 20-ins. from the centre show that the neutral surface is much nearer the tension side for the smaller loads, but gradually moves to a position slightly on the compression side for the higher loads.





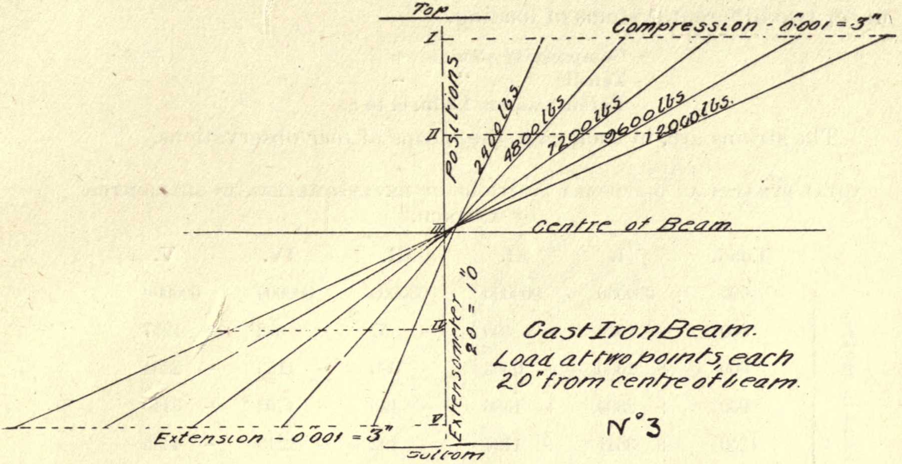


Table showing mean strains in 5.1-in. × 3.48-in. red oak beam, under two different systems of loading.

Compressive strains +
Tensile " –
Extensometers 1.1-in. c. to c.

The strains are, in each case, the means of *four* observations.

TOTAL STRAINS AT DIFFERENT POSITIONS OF EXTENSOMETERS, IN MILLIONTHS OF AN INCH.

	Load.	I.	II.	III.	IV.	V.
Load in centre.	000	000000	000000	000000	000000	000000
	300	+ 1451	+ 666	– 157	– 920	– 1796
	600	+ 2804	+ 1340	– 300	– 1784	– 3434
	900	+ 4069	+ 1961	– 448	– 2611	– 5005
	1200	+ 5240	+ 2589	– 598	– 3417	– 6446
	1500	+ 6419	+ 3179	– 763	– 4220	– 7926
Loads at 7½-ins. from centre.	000	000000	000000	000000	000000	000000
	400	+ 1259	+ 437	– 493	– 1254	– 2200
	800	+ 2730	+ 1178	– 620	– 2165	– 3920
	1200	+ 4072	+ 1873	– 777	– 3030	– 5587
	1600	+ 5392	+ 2588	– 984	– 3883	– 7258
	2000	+ 6741	+ 3375	– 1073	– 4648	– 8829

Table showing mean strains in a 5.9-in. × 4.94-in. white pine beam, under two different systems of loading.

Compressive strains +
Tensile " –
Extensometers 1.3-in. c. to c.

The strains are, in each case, the means of *four* observations.

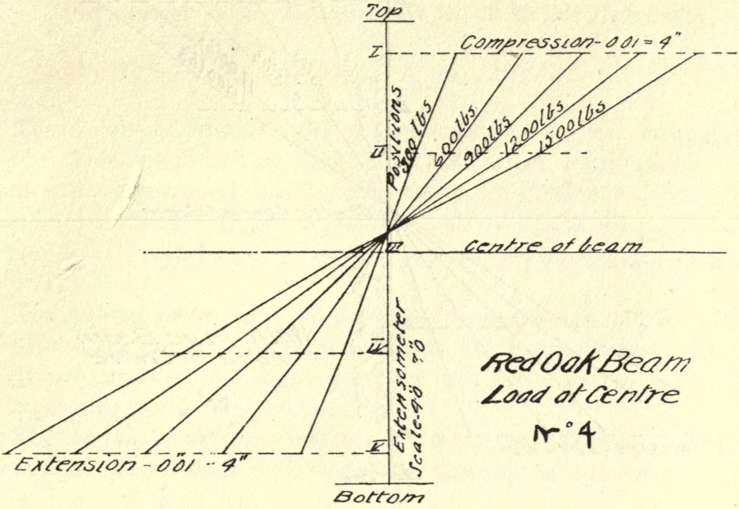
TOTAL STRAINS AT DIFFERENT POSITIONS OF EXTENSOMETERS, IN MILLIONTHS OF AN INCH.

	Load.	I.	II.	III.	IV.	V.
Load in centre.	000	000000	000000	000000	000000	000000
	300	+ 1049	+ 500	– 57	– 592	– 1207
	600	+ 2009	+ 0962	– 090	– 1155	– 2364
	900	+ 2869	+ 1386	– 135	– 1705	– 3440
	1200	+ 3641	+ 1797	– 192	– 2215	– 4435
	1500	+ 4367	+ 2192	– 248	– 2672	– 5385
Loads at 7½ ins. from centre.	000	000000	000000	000000	000000	000000
	400	+ 1084	+ 472	– 199	– 756	– 1406
	800	+ 2211	+ 1070	– 157	– 1352	– 2642
	1200	+ 3251	+ 1575	– 194	– 1979	– 3828
	1600	+ 4271	+ 2071	– 237	– 2546	– 4914
	2000	+ 5306	+ 2579	– 255	– 3059	– 5952

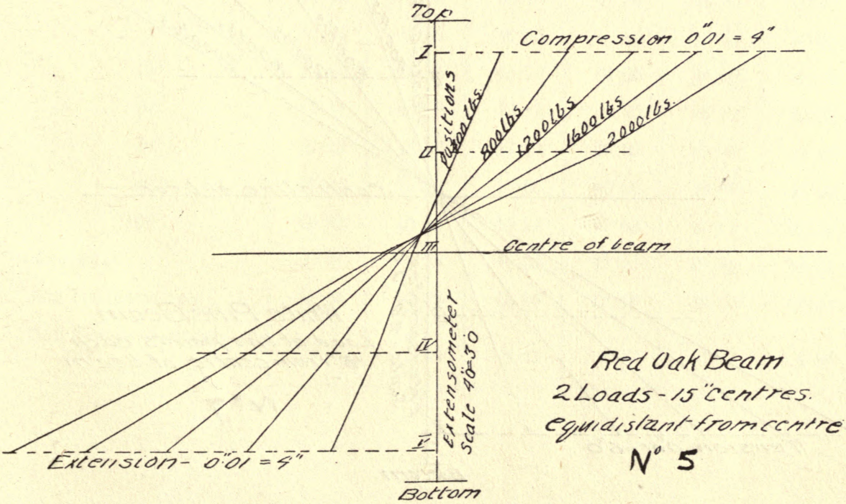
From the above results diagrams 4 to 7 have been prepared, and seem to justify the inferences:

(1) That when a beam is loaded at the centre, the position of the neutral surface, under increasing loads remains practically unchanged and is a little nearer the compression than the tension side.

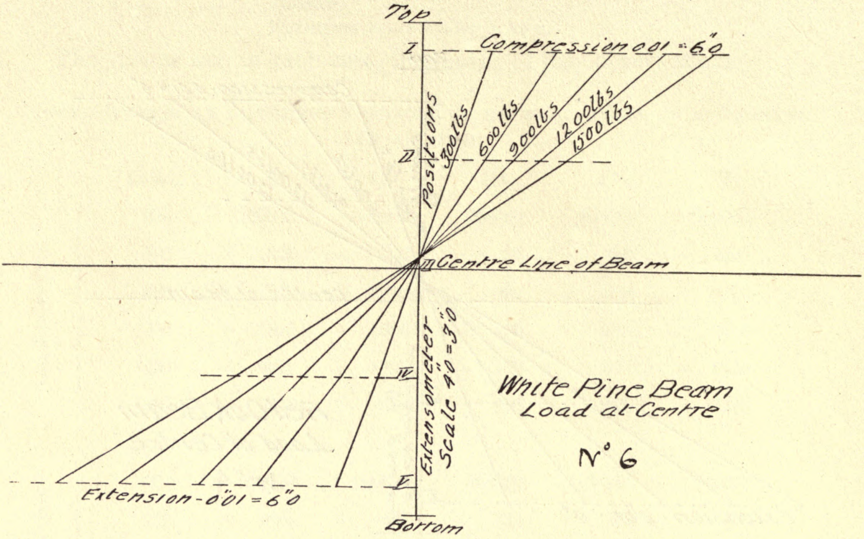
(2) That when loads are concentrated at points equidistant from the centre, the neutral surface, under the smaller loads, is at some considerable distance from the mid depth on the compression side. This distance diminishes as the load increases, and under the heaviest loads the neutral surface seems to have gradually returned to nearly the same position as when the beam was loaded at the centre.

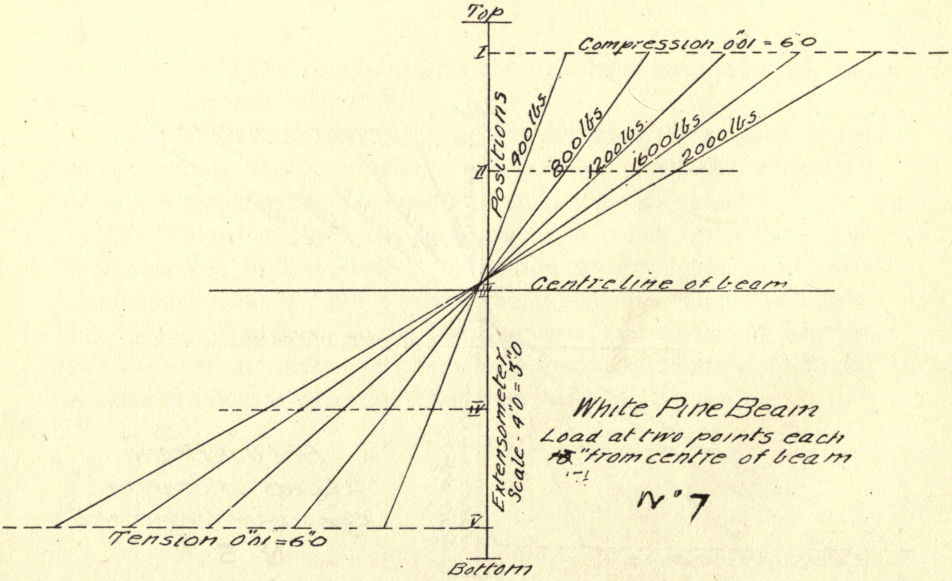


Red Oak Beam
Load at Centre
N° 4



Red Oak Beam
2 Loads - 15" centres.
equidistant from centre
N° 5


Top
I
Compression 0"01 = 6"0
300 lbs
600 lbs
900 lbs
1200 lbs
1500 lbs
II
Positions
III
Centre Line of Beam
IV
V
Extensometer Scale 4"0 = 3"0
Extension - 0"01 = 6"0
Bottom
White Pine Beam
Load at Centre
N° 6


Top
I
Compression 0"01 = 6"0
400 lbs
800 lbs
1200 lbs
1600 lbs
2000 lbs
II
Positions
III
Centre line of beam
IV
V
Extensometer Scale · 4"0 = 3"0
Tension 0"01 = 6"0
Bottom
White Pine Beam
Load at two points each ~~18~~ " from centre of beam
N° 7

II.—*Soil Temperatures. Observations with Electrical Resistance Thermometers at McGill College, Montreal.*

By Professor C. H. McLEOD, Ma.E., of McGill University.

(Read May 30, 1900.)

The following summary of the observations of soil temperatures for the three years ending May 8th, 1900, is in continuation of the results already communicated to the Section by Professor Callendar and myself. An account of the apparatus employed and the method of reduction will be found in the Transactions of the Society for 1895, 1896 and 1897.

The annual curves for the mean air temperature and for the temperature of the soil at the several depths at which the thermometers were buried, are presented for the three years in a form similar to the charts accompanying the earlier reports.

The annual mean temperature for each year since the commencement of the observations is given below; the year in each case beginning and ending with May 8th.

ANNUAL MEAN TEMPERATURES AT THE SEVERAL DEPTHS TO WHICH THE THERMOMETERS ARE BURIED. (The year extends from May 8 to May 8).

Depth	1895-96	1896-97	1897-98	1898-99	1899-1900	Average
1″	51·48	51·60	50·48	48·59	49·99	50·43
4″	47·12	44·97	46·94	46·46	46·48	46·39
10″	46·65	45·25	45·70	46·85	46·52	46·19
20″	47·17	45·30	45·82	46·75	46·62	46·33
40″	47·00	45·72	45·73	46·99	46·81	46 45
66″	47·00	45·91	45·66	46·97	46 38	46·38
108″	46·82	45·53	45·29	47·53	45·83	46·20
Averages..............	47·61	46·33	46·52	47·16	46·95	46·91
Air Temperatures.... .	42·65	42·53	43·05	42·79	43 18	42·84
Soil Temp. in excess of air.................	4·96	3·80	3·47	4·37	3·77	4·07

THERMAL DIFFUSIVITY.

The value of the thermal diffusivity has been computed for suitable intervals of time covering the entire period now reported on. The results are tabulated below, and are also represented graphically on the accompanying plate. These results show that the value of k/c is, for the lower strata, in general less than the average, but that for a short time in the spring or early summer, the contrary is true. The latter condition probably corresponds to a stage in which the moisture of the melting snow has penetrated to the lower depths, and the upper layers are relatively dryer.

When the ground is protected by snow and there is no percolation, the value of k/c is seen as in former years to be a minimum and very constant, the average value corresponding to ·0015, which, as stated in former communications, may bo taken as the value of diffusivity due to pure thermal conduction for the sandy soil in question in a dry condition. All values above this being due more or less to influence from percolation. The normal value for the full depth, under average conditions of soil, during the summer months, may be put at ·0075.

VALUES OF THERMAL DIFFUSIVITY OF THE SOIL FROM MAY 15TH, 1897, TO MAY 2ND, 1900.

Period	No. of days	Diffusivity Depth of Soil. 20″ to 60″	 60″ to 100″	 20″ to 100″	Rain per day
1897					
May 15 to June 4	20	·0059	·0067	·0063	″·132
June 4 to 19	15	·0119	·0059	·0087	·055
June 19 to July 1	12	·0051	·0052	·0056	·198
July 1 to 15	14	·0059	·0053	·0056	·218
July 15 to 31	16	.....	·0038	·0059	·086
July 31 to August 16	16	......	·0037	...	·052
September 21 to October 7	16	·0054	·0047	·0052	·019
October 7 to 23	16	·0049	·0031	·0042	·026
October 23 to November 8	16	·0038	·0033	·0037	·097
November 8 to 23	15	·0040	·0029	·0037	·035
November 23 to December 9	16	·0112	·0038	·0061	·069
1898					
January 3 to February 11	39	·0009	·0010	·0010	·016
February 18 to March 19	29	·0064	·0014	·0026	·038

Values of Thermal Diffusivity.—*Continued.*

Period	No. of days	Diffusivity			Rain per day
		Depth of Soil			
		20″ to 60″	60″ to 100″	20″ to 100″	
1898					
April 12 to 22	10	·0061	·0084	·0064	″·093
April 22 to May 5	13	·0079	·0103	·0088	·015
May 5 to 20	15	·0049	·0077	·0056	·076
May 20 to June 6	17	·0073	·0057	·0067	·087
June 6 to 21	15	·0145	·0047	·0071	·193
June 21 to July 6	15	·0210	·0044	·0091	·171
July 6 to 21	15	·0153	·0030	·0101	·062
July 21 to August 15	25	·0061	·0038	·0047	·074
September 15 to October 1	16	·0030	·0042	·0033	·267
October 1 to 17	16	·0042	·0021	·0037	·152
October 17 to November 1	15	·0041	·0034	·0038	·142
November 1 to 15	14	·0049	·0031	·0041	·030
November 15 to December 1	16	·0071	·0040	·0054	·006
December 1 to 23	22	·0042	·0033	·0037	·025
1899					
December 23, 1898, to January 21	29	·0037	·0027	·0030	·074
January 21 to February 20	30	·0018	·0015	·0016	·004
February 20 to April 3	42	·0021	·0021	·0021	·065
April 3 to 18	15	·0078	·0813	·0236	·082
April 18 to 27	9	·0088	.....	·0098	·016
April 27 to May 5	8	·0058	·0068	·0064	·010
May 5 to 15	10	·0063	·0066	·0064	·047
May 15 to 30	15	·0064	·0065	·0062	·063
May 30 to June 15	16	·0064	·0066	·0065	·063
June 15 to July 1	16	·0023	·0053	·0033	·091
July 1 to 16	15	·0078	.0052	·0065	·283
July 16 to August 5	20	·0045	·0048	·0047	·186
September 5 to 26	21	·0050	......	·0062	·111
September 26 to October 10	14	·0039	·0031	·0038	·136
October 10 to 26	16	·0038	·0049	·0043	·031

VALUES OF THERMAL DIFFUSIVITY.—*Continued.*

Period	No. of days	DIFFUSIVITY			Rain per day
		Depth of Soil			
		20″ to 60″	60″ to 100″	20″ to 100″	
1899					
October 26 to November 4	9	·0026	·0037	·0028	″·323
November 4 to 9	5	·0082	·0045	·0070	·122
November 9 to 24	15	·0048	·0032	·0041	·028
November 24 to December 8.........	14	·0037	·0024	·0029	·021
December 8 to 23....................	15	·0069	·0028	·0042	·136
December 20 to January 7, 1900.....	15	·0035	·0026	·0029	·001
1900					
January 7 to 22	15	·0070	·0020	·0031	·078
January 22 to February 15...	24	·0036	·0009	·0014	·136
February 24 to March 21............	25	.....	·0013	......	·005
April 5 to 16	11	·0039	·0186	·0106	·024
April 19 to May 2	13	·0053	·0062	·0055	·030

The accompanying plate will serve to illustrate the form of the curves from which these results have been derived. The heavier lines are the curves for the dates, which limit the periods for which the values of diffusivity have been computed. The lighter lines are the curves for intervening days, and have been used to obtain a better average value of the tangent directions at the upper and lower limits.