– Thesis. –

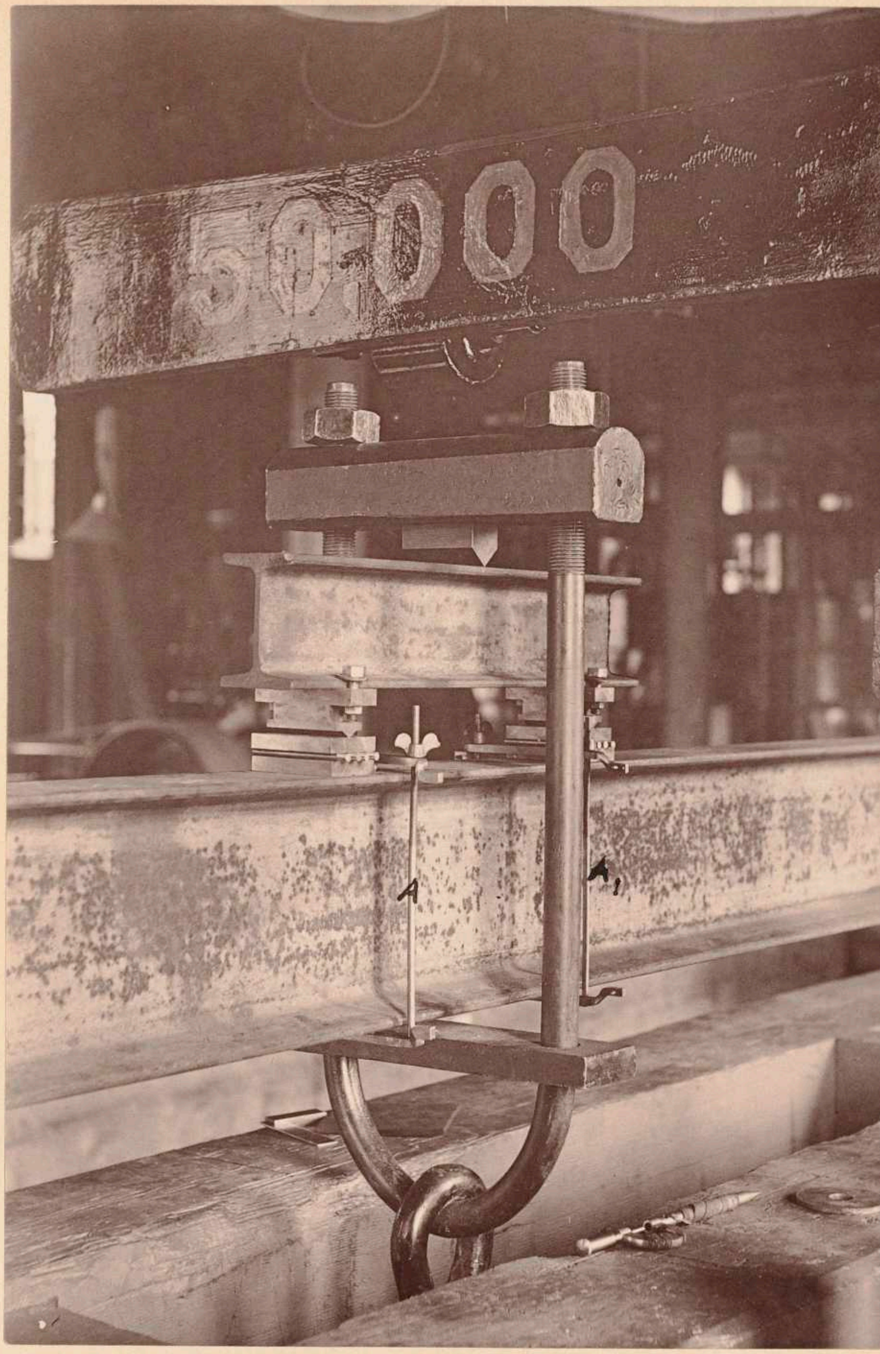
An Experimental Investigation
– of the –
Stresses and Strains in
Iron and Steel I Beams

by

Fred Allen Cole

and

Harrison Irving Cole.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A
A1

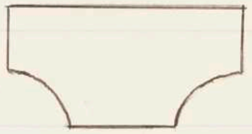
The object of this investigation has been to study the stresses and strains in I Beams, in connection with tests made on specimens taken from the flanges and webs of the beams, with the view of determining what relation exists between the two.

It is believed that at the point in a compressive or tensile specimen at which the metal begins to flow freely the stain is identical with that at which an I beam buckles: on account of the fact, that in the beam most of the metal is concentrated in the flanges, and when these are unable to hold the load the beam will fail

Four beams of American manufacture+ were experimented upon, two of steel and two of iron, one of each an eight inch and the other a six inch beam. The experiments were made on the rough beams as they came from the manufacturer. A length of about twenty inches was cut from each beam before they were strained from which were prepared the tension and compression specimens. The tensile pieces were cut from the bottom flanges and from near the bottom edge of the webs. The compressive specimens were planed from the top flanges. The tensile pieces were of rectangular section and were

+ New Jersey Steel and Iron Co.

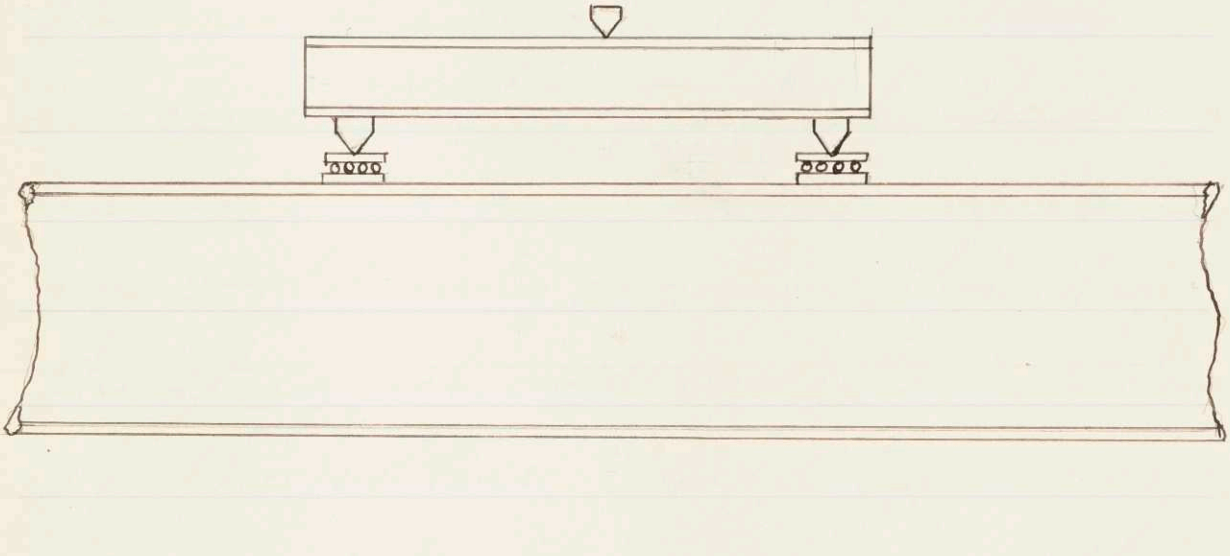
finished on all sides, in the case of the flange pieces, while the web pieces were left rough on the outside surfaces. The compressive specimens were taken from the top flanges in the shape as shown by section in sketch.



With the exception of the curved surfaces they were finished on all sides. The length of these was five inches.

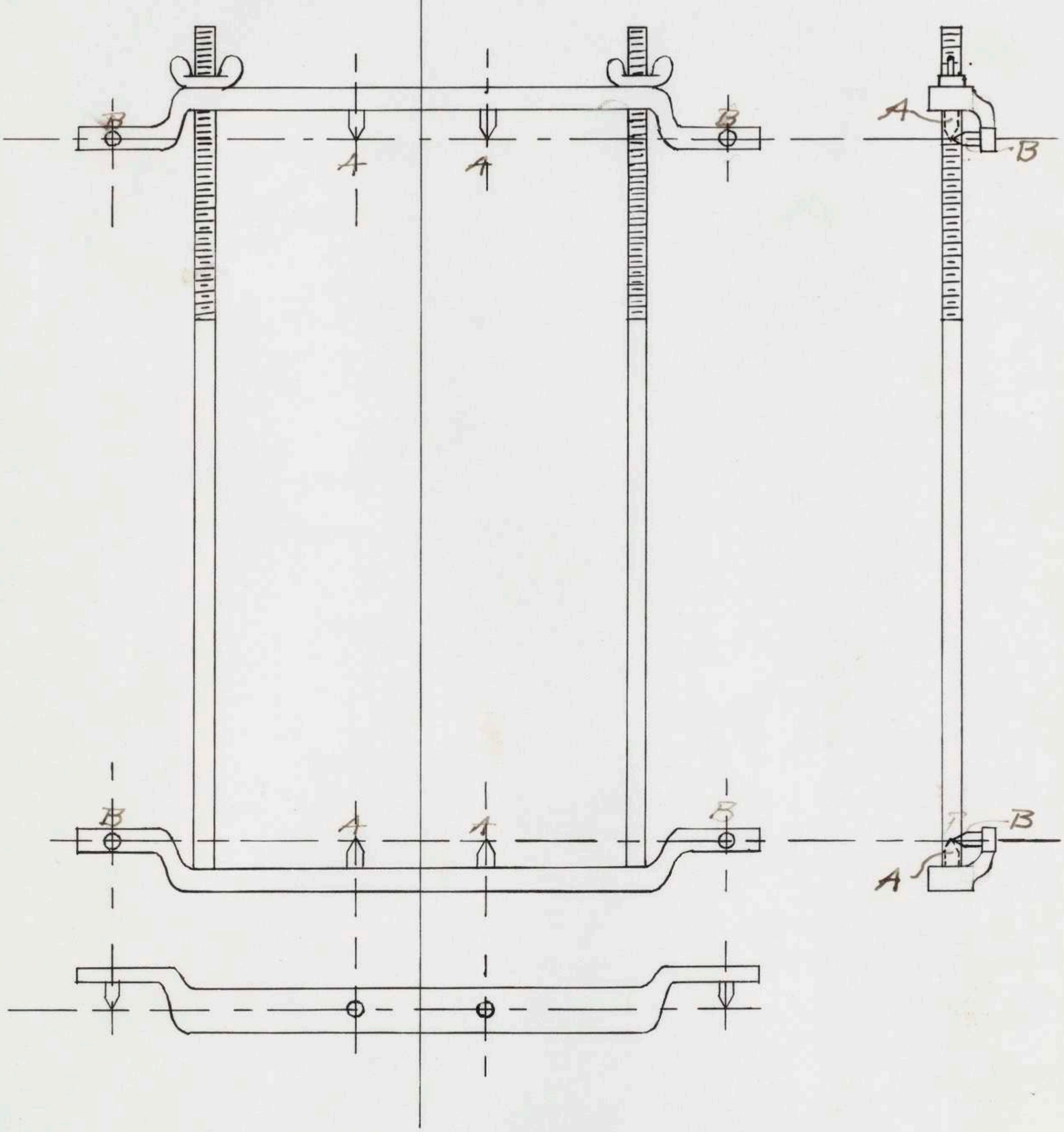
The manner of making the test was as follows.

With a fourteen foot two inches span the loads were applied at two points, each seven inches from the centre of the span, to insure a uniform bending moment in the portion of the beam at which the observations were taken. The following sketch shows the manner in which the load was applied



The rollers which were of Stubbs' steel wire were used, in connection with the plates, which were of polished steel, to insure a vertical load on the beam and at the same time to allow all strains to act freely under load. To show the importance of using smooth surfaces in contact with the rollers, we would say that in the first beam tested (No. IV) the bottom plate was left out the rollers acting directly on the rough surface of the beam in consequence of which, the strains varied in a peculiar manner which we could only account for by the sluggish and uncertain action of the rollers. The difficulty was removed by the insertion of the steel plate in the remainder of the tests. The load as applied also gave us a uniform bending moment between the knife edges. It follows, that in this portion of the beam the shearing stress was zero also that the deflection curve was a circular arc and since the bending moment was constant the intensity of stress to which any one fibre was subjected was also constant, hence we were enabled to measure the amount of extension and compression of the outside fibres in a manner similar to that used in ordinary tension and compression tests. The extensions and compressions were measured by means of two clamps shown in the accompanying photograph, at A and A_{1}, which shows the beam set up in the machine ready for the test.

We would say here that the corrections applied for curvature were so slight as to be negligible.



B
B
A
A
A
B
B
A
A
B
B
A

The accompanying sketch shows an end view of the clamps illustrating the manner in which the clamps were applied and the positions of the steel points A which were set in prick punch marks on the beam and B which were the points between which the measurements were taken. The points B were placed in direct line with those marked A longitudinally, but vertically a slight allowance was made to allow the points A to enter the punch marks and bring B B on a level with the surface of the flanges. This arrangement allowed the measurement of the strains to be taken directly with a micrometer caliper and avoided the trouble and risk of error

arising from intermediate cal-
culation in obtaining the final measurement which would be unavoidable in any other arrange-
ment. The accompanying side ele-
vation further illustrates the ar-
rangement of the clamps. They were applied between the points of application of the load. The measurements of compression and elongation were taken to ten-
thousands of an inch and were ascertained for successive loads from one thousand pounds to the point where the beam buckled

From the fact that the deflect-
ion gives a circular curvature we were enabled by a little cal-
culation to find the radius of curvature and by means of that

find the correction for the length of the arc by the measurements which gave the lengths of the chord. The correction being applied we are able to find the position of the neutral axis and the strain in the extreme fibres for each successive load.

The tensile and compressive tests were made in the usual manner. Reading were taken between the points for each successive load up to the point when the strain exceeded the maximum strain observed in the corresponding beam test. As the compression specimens were not symetrical, the difference between successive readings was calculated with the fact in mind that the strain was proportional to the distance from the centre of gravity.

From the compressive and tensile tests specimens, the results of which are shown in the tables, the accompanying stress-strain diagrams were plotted. The abscissae representing strains per inch of length and the ordinates denoting the stresses in pounds per square inch. Each curve represents the mean value, as near as possible, of the several specimens for each kind of stress in its corresponding beam. Web specimens however, were not used in obtaining the mean of the tension tests but were plotted seperately for obtaining the curves relating to the web stresses in the beam diagrams.

The results of the beam tests were plotted as follows all data being taken from the last load applied at which the beam under consideration buckled. The general theory of beams was followed in every respect.

The strain at the maximum load was laid off on the axis of abscissae, at the same scale as was plotted the strains in the specimens, and an ordinate erected cutting the mean curve of the flange in question. The stress represented by this intersection was assumed to be the stress reached in the outside fibre at the time of rupture per sq.in. and per inch of width of the section at that point. For convenience the scale was then reduced and the remainder of the diagram plotted with stresses proportional to the distance from the neutral axis, calculated for each beam, and to the width of the section. The resultant area, if the conditions hold, must give the stress, compressive and tensile, which is distributed over the section. From these diagrams the moments of stress on the sections of the different beams was calculated and compared with the moment actually know to have been applied in the beam machine and the results noted.

Table of Results of the Calculations

No	I	II	III	IV
	michells			
1	774150.	650116.	315276	377754
2	740648.	685000.	316090	382373
3	44762.	37076.	38310	46380
4	42078.	35218.	35471	42885
5	40255.	36319.	35564	43470
6	t 38000.	32100	34000	39200
	c 36400.	37000	35000	37700
	mean 37200.	34550	34500	38450
7	t 1.90 sq. in.	2.75 sq in	3.20 sq in	1.75 sq in
	2.20 sq in	2.75 " "	2.55 " "	1.15 sq. in.

The results to enable us to compare the stresses and strains in the beams with the same in the direct tests are recorded in the table on page 13. In this table the following results have been recorded. Line 1 gives the maximum bending moment actually known to have been ~~subjected~~ applied to the beam. Number 2 gives the bending moment as calculated from the diagram, the tensile and compressive curves being used for the computation. Number 3 gives the values for the modulus of rupture as computed from known moment for the most extreme fibre, more properly, the supposed stress in the outside fibres as commonly computed. Numbers 4 and 5 give the stress at the centre of gravity of the flange, in the same manner of computation as in no. 3. The flange is considered as concentrated at its centre of gravity and the value of I computed by multiplying its area into the square of the distance to the centre of gravity of the beam. No 4 is for the known moment and no 5 for the calculated. In number 6 are given the stresses, tensile and compressive, to which the direct specimens were subjected at a strain equal in magnitude to the corresponding maximum strain in the beams. No 7 gives the areas from the beam diagrams showing the agreement or disagreement of the areas on the tension and compression sides of each beam.

Discussion of Results.

On examination of the table of results it will be noticed that the areas of the two sides of the diagrams are equal in but one case, and that not in our most favorable test. In accordance with the theory of beams, if true up to the breaking point, this inequality should not exist. The cause of this discrepancy would be difficult to explain. Possibly it is in part due to the fact that mean areas of the flanges were considered in stead of the actual areas of sections, but the difference was so slight that it could not possibly account for the total divergence

What we wish particularly to compare are the relations existing between the fibre stresses in the flanges and in the direct tests of the metal. By referring to the table we find that the fibre stress as calculated for the most extreme fibre in the usual manner is considerably greater than the maximum stress as found from the diagram of the specimen tests. On the other hand we find that the stress as computed at the mean fibre of the flange agrees very closely with the maximum stress as obtained from the diagrams, there being in the case of the iron beams less than 3% (about 2.5%) of difference but the computed still remains the higher. The steel beams have given a much greater variation the average of the two tested giving as high as 8% of variation. The Steel beams however, we do not consider as representative from the fact, as before mentioned, that beam no. IV, tested with out the rollers free to move, was one of the steel beams, therefore we have been left with proper data for only one beam making it impossible to obtain average results with anything like surety. On account of this fact our conclusions point more especially to the iron than the steel beams although we still believe the steel beams to follow the same laws approximate at least.

In the beam tests at rupture of the beam we found an average total elongation of about 00.88 %. At this amount of strain the variation in stress is very slight for quite a considerable variation in the strain and we would infer from that fact that at the strain in a tensile specimen, of the material of the I beam in question, of .00.88 % the stress would approximate very closely to the proper ~~safe~~ fibre stress to be ~~allowed~~ used in the calculation of the strength of the beam. And further would add that the variation if any would in all probability fall on the side of safety

We consider the tension test the proper one to use in this trial because in the compression test the stress is apt to increase more rapidly after passing the elastic limit than in the tension test thus making an average per centage of strain difficult to establish

In closing we would say that we feel confident that the proper criterion of the modulus of rupture of an I beam is the stress of a tension specimen under an average strain very near that before mentioned (00.86%) and further more the value of y in the formula $M = \frac{fI}{y}$ should be taken as the distance to the mean fibre of the flange, to the centre of gravity, and the flange considered as concentrated at its centre of gravity

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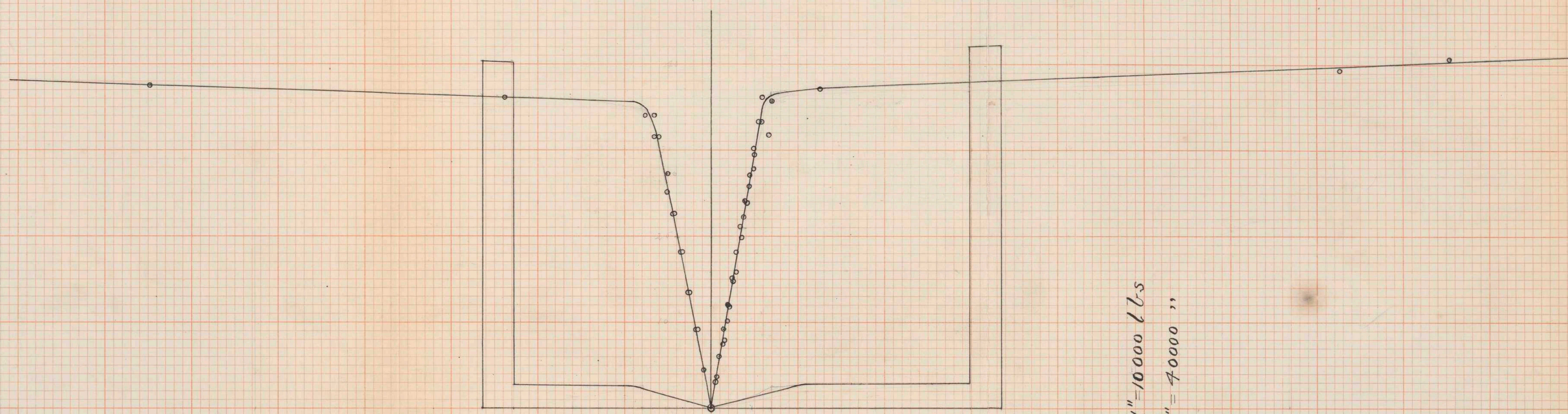
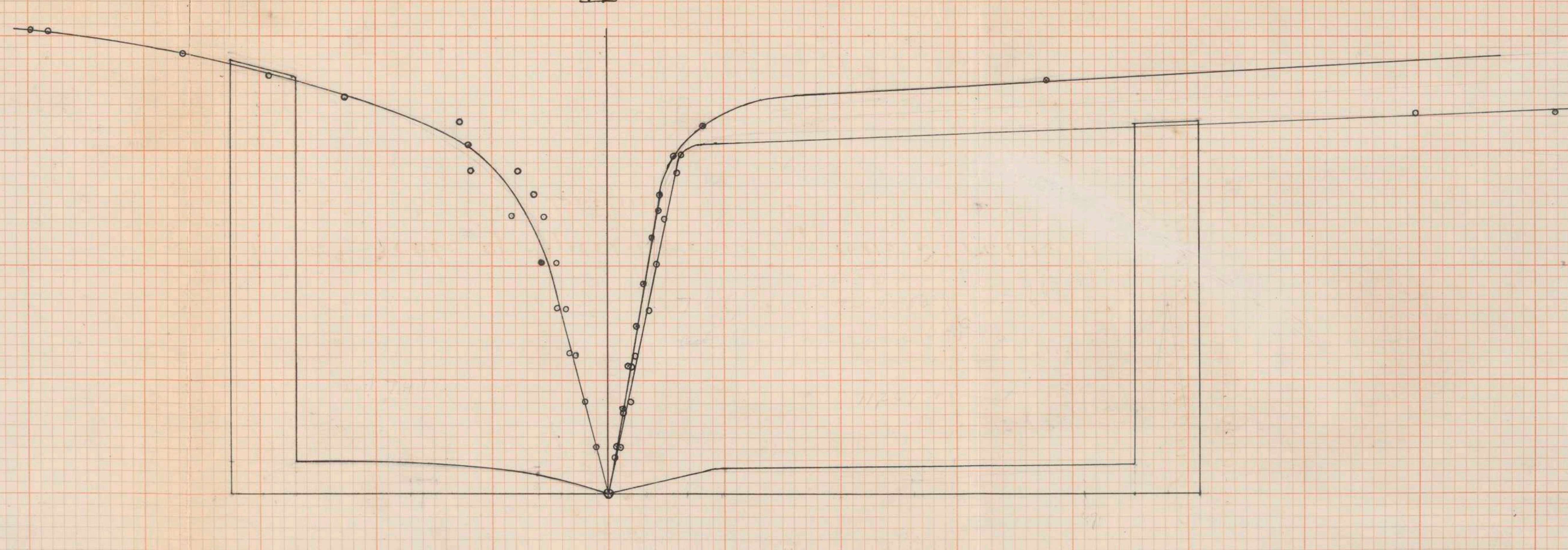
I



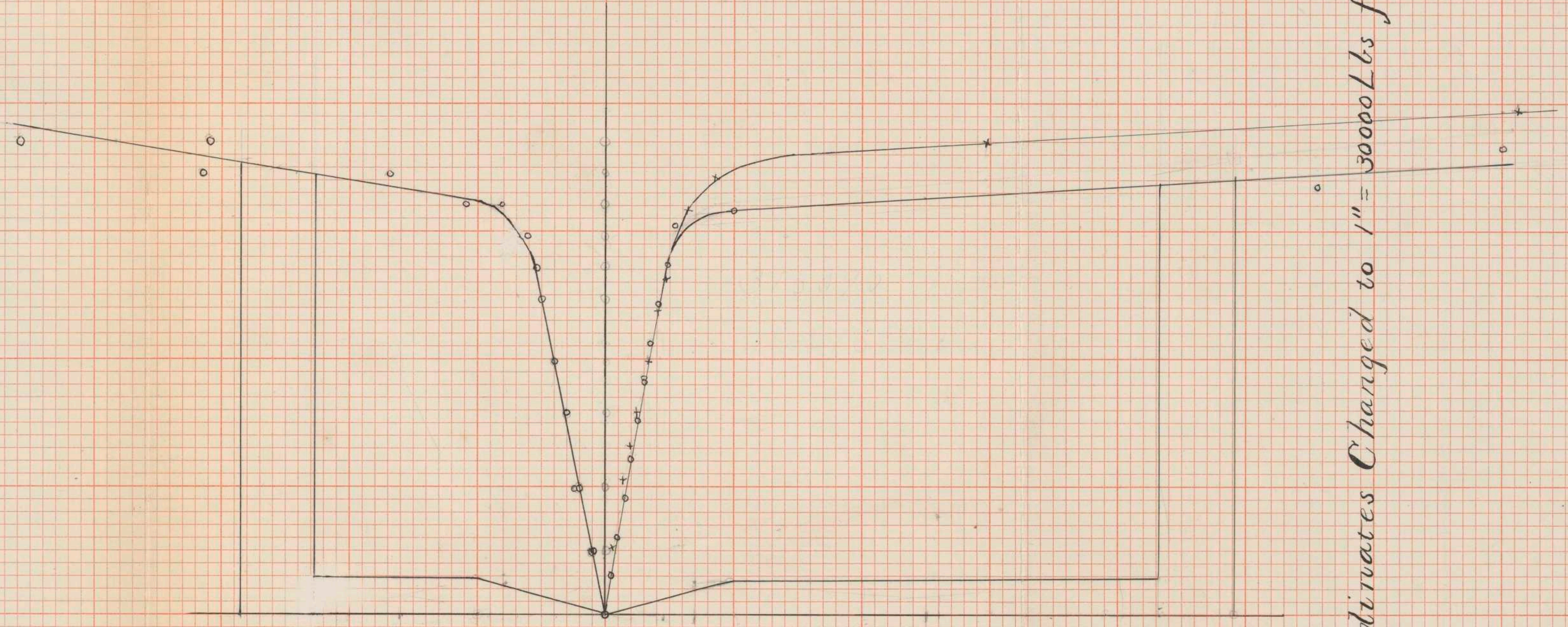
1" = .002" = Scale of Specimen Diagram Strains
1" = .002" = " " Beam " "

Scale for Specimens 1" = 10000 lbs
" " Beams 1" = 40000 "

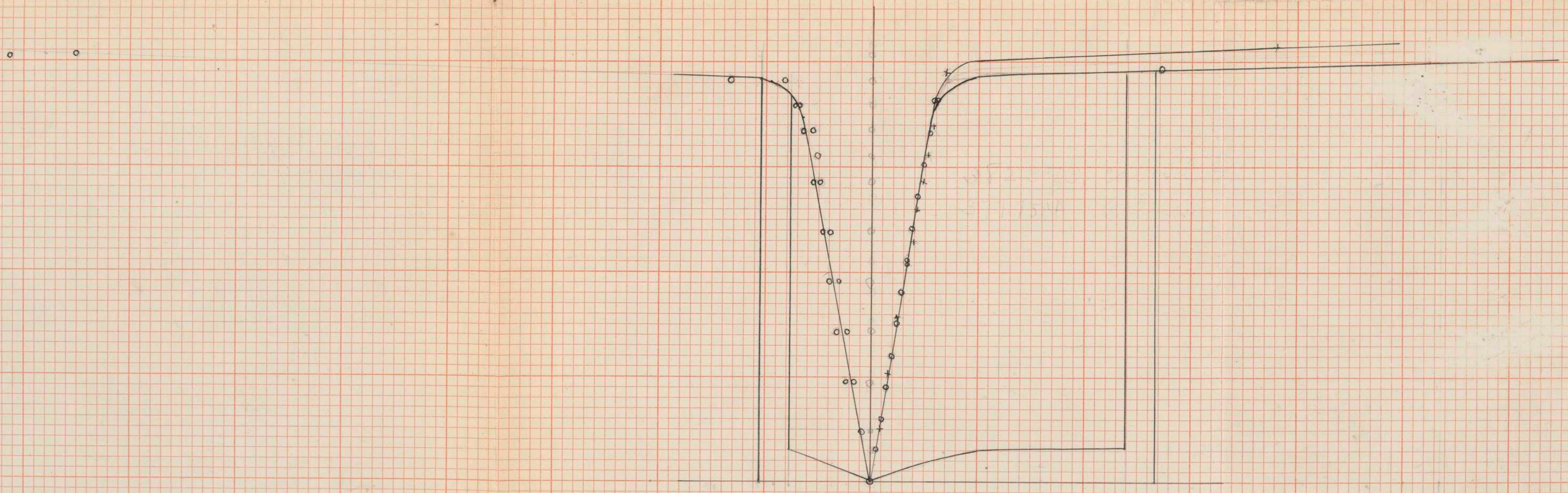
II



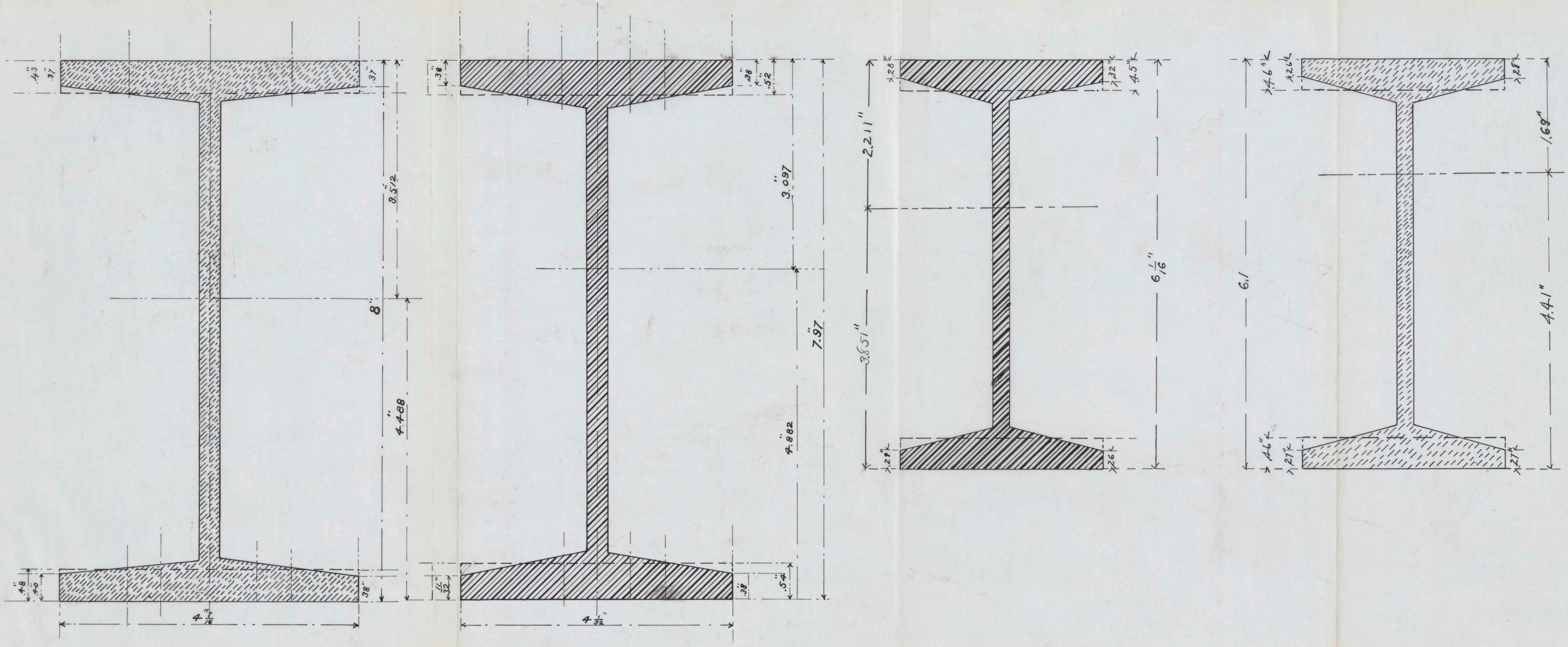
III



IV



Scale of Ordinates Changed to 1" = 30000 Lbs for Beams III and IV


3.512"
8"
4.488"
3.097"
7.97"
4.882"
2.211"
3.851"
6 1/16"
6.1
1.69"
4.41"

I — Beam No. I Steel —

Bottom Flange Record

Loads	Readings		Mean	Diff	Remarks
1000	2978	3108	3043	0007	
2000	2982	3117	3050	0007	
3000	2991	3122	3058	0008	
4000	2994	3132	3063	0005	
5000	3000	3141	3071	0008	
6000	3008	3149	3079	0008	
7000	3018	3158	3088	0009	
8000	2979	3108	3043	0045	
9000	3023	3163	3093	0005	
10000	3033	3173	3103	0010	
11000	3038	3180	3109	0006	
12000	3043	3189	3116	0007	
13000	3051	3198	3125	0009	
14000	3058	3205	3132	0007	
15000	3067	3212	3140	0008	
1000	3077	3217	3147	0007	
16000	3107	3230	3169	0022	Maximum
17000	3173	3297	3235	0066	strain at-
18000	3255	3320	3288	0053	tained
19000	3638	3383	3511	0223	= .0669"
19600	3902	3508	3705	0194	Buckled

I

Beam No I Steel
Top Flange Record.

Loads	Micrometer Readings		Mean	Differences	Remarks
1000	2692	3010	2851	0009	
2000	2683	3000	2842	0009	
3000	2678	2990	2834	0008	
4000	2670	2983	2827	0007	
5000	2663	2978	2821	0006	
6000	2658	2970	2814	0007	
7000	2653	2958	2806	0008	
8000	2650	2951	2801	0005	
9000	2644	2943	2794	0007	
10000	2638	2934	2786	0008	
11000	2632	2927	2780	0006	
12000	2628	2918	2773	0007	
13000	2621	2911	2766	0007	
14000	2618	2898	2758	0008	
15000	2614	2890	2752	0006	
1000	2691	3008	2850	0006	
16000	2611	2873	2742	0010	
17000	2610	2837	2724	0018	
18000	2633	2755	2694	0030	
19000	2733	2289	2511	0183	
19600	2843	1822	2333	0178	

Maximum strain = .0527" I = 69.18

" Bending Moment 774150

" Fibre stress by formula $f = \frac{My}{I} = 44762$

I — Lower Flange —

Specimen from No. I Steel Beam

Loads Actual	Loads Per sq. in.	Readings 1	Readings 2	Mean	Diff'r'n'cs	Strains per in
2000	3025	4342	3334	3838	.0009	.00009
4000	6050	4352	3342	3847	.0009	.00018
6000	9076	4363	3350	3857	.0010	.00028
8000	12101	4375	3359	3867	.0010	.00038
10000	15126	4385	3369	3877	.0010	.00048
12000	18151	4396	3378	3887	.0010	.00058
14000	21176	4407	3387	3897	.0010	.00068
16000	24202	4417	3398	3908	.0011	.00079
18000	27227	4427	3408	3918	.0010	.00089
2000	3025	4350	3326	3838	0080	
20000	30252	4437	3418	3928	.0010	.00099
22000	33277	4448	3428	3939	.0011	.00110
24000	36302	4453	3439	3946	.0007	.00117
26000	39328	5895	4872	5384	.1338	.01455
28000	42353	6482	3450	5966	.0582	.02037
40700	61563	broke				

Section (original) .6611 □" Fractured .3503 □" (44.5 %)

Elongation 2.57" = 25.7 % E = 30,246,000.

I — Lower Flange. —

Specimen from No I Steel Beam

Loads		Readings		Mean	Diff.	Strains Total per in.
Actual	Per sq. in.	1	2			
2000	3701	4399	3208	3804	,0013	,00013
4000	7402	4416	3217	3817	,0013	,00026
6000	11103	4432	3226	3829	,0012	,00038
8000	14804	4446	3235	3841	,0012	,00050
10000	18505	4459	3245	3852	,0011	,00061
12000	22206	4472	3258	3865	,0013	.00074
14000	25907	4487	3268	3878	,0013	,00087
16000	29608	4502	3280	3891	,0013	,00100
18000	33309	4522	3284	3903	,0012	,00112
2000	3701	4425	3183	3804	,0099	
20000	37010	4533	3300	3917	,0013	,00125
22000	40711	6100	4869	5496	,1579	,01704
24000	44412	6122 6890	4894 5648	6269	,0773	,02477
33600	62177	broke				

Cross Section (original) .5404□" Fractured .2376□" (44%)

Elongation (max) 2.66" = 26.6% E = 29,906,500.

I

— Web —

Specimen from No I Steel Beam

Loads Actual	Loads Per sq. in.	Readings 1	Readings 2	Means	Diff'nc's Per in.	Str'ns Per in.
2000	3975	4012	3322	3667	.00014	.00014
4000	7949	4018	3346	3682	.00015	.00029
6000	11924	4027	3364	3696	.00014	.00043
8000	15898	4037	3380	3709	.00013	.00056
10000	19873	4047	3398	3723	.00014	00070
12000	23848	4057	3415	3736	.00013	00083
14000	27,822	4068	3430	3749	00013	00096
2000	3975	4010	3326	3668	00081	
16000	31797	4080	3449	3765	.00016	00112
18000	35771	4090	3495	3793	.00028	.00140
20000	39746	6323 6318	5772 5758	6043	02250	.02390
22000	43721	7343	6851	.7097	.01054	.03444
29000	57632	broke				

Gross Section (original) .5032 sq. in. Fractured .2300" (45.7%)

Elongation 2.3" = 23% E = 29,441,200

I — Upper Flange —

Specimen from No I Steel Beam

Loads		Readings		Differences		Strains
Actual	Per sq. in.	— a —	— b —	Actual	Per in.	Per in.
4000	4533	5250	6230	,0007	,00018	,00018
8000	9066	5235	6230	,0007	,00018	,00036
12000	13599	5225	6237	,0007	,00018	,00054
16000	18133	5218	6220	,0007	,00018	,00072
20000	22666	5210	6214	,0007	,00018	00090
24000	27199	5204	6208	,0006	,00015	00105
28000	31732	5193	6195	,0012	00030	00135
4000	4533	5237	6223	,0037	,00093	,00228
30000	33999	5184	6190	,0007	,00018	,00246
32000	36266	5117	6132	,0068	,00170	,00416
34000	38531	4665	5810	,0387	,00968	,01384
36000	40799	4515	5715	,0120	,0030	,01684

Area of Cross Section ,882 sq. in. E = 29,724,000.

I — Upper Flange —

Specimen from No I Steel Beam.

Loads		Readings		Differences		Strains
Actual	Per sq. in.	— a —	— b —	Actual	Per in.	Per in.
4000	4533	5241	6099	.0006	.00015	.00015
8000	9066	5228	6099	.0006	.00015	00030
12000	13599	5219	6096	.0007	.00018	.00048
16000	18133	5212	6089	.0007	.00018	.00066
20000	22666	5208	6082	.0006	.00015	.00081
24000	27199	5203	6074	.0007	.00018	.00099
4000	4533	5238	6100	.0031	.00078	
28000	31732	5196	6066	.0008	.00020	.00119
30000	33999	5191	6059	.0006	.00015	.00134
32000	36266	5065	5908	.0139	.00347	.00481
34000	38531	4701	5615	.0326	.00815	.01296
36000	40799	4586	5514	.0108	.00270	.01566

Area of Section = .882 sq. in. E = 28,347,000.

II

— Beam No II Iron —

Bottom Flange Record

Load	Readings		Mean	Diff.	Remarks
1000	2445	3335	2890	0006	
2000	2452	3339	2896	0006	
3000	2461	3347	2904	0008	
4000	2470	3351	2912	0008	
5000	2480	3359	2920	0008	
1000	2445	3335	2890	0040	
6000	2491	3368	2930	0010	
7000	2499	3372	2936	0006	
8000	2512	3382	2947	0011	
9000	2534	3400	2967	0020	
10000	2562	3420	2991	0024	
11000	2631	3492	3062	0071	
12000	2647	3554	3101	0039	
13000	2725	3630	3178	0077	Maximum
14000	2808	3710	3259	0081	strain at-
15000	2890	3813	3352	0093	tained
16000	3424	4039	3734	0082	=.0102"
16400	3707	4100	3904	0170	Buckled

II — Beam No II Iron —

Top Flange Record

Load	Readings		Mean	Diff.	Remarks
1000	3712	2882	2797	0009	
2000	2705	2871	2788	0009	
3000	2694	2862	2778	0010	
4000	2691	2852	2772	0006	
5000	2685	2845	2765	0007	
1000	2712	2882	2797	0060	
6000	2676	2838	2757	0008	
7000	2669	2832	2751	0006	
8000	2660	2823	2742	0009	
9000	2652	2815	2734	0008	
10000	2643	2806	2725	0009	
11000	2626	2789	2708	0019	
12000	2613	2781	2697	0011	
13000	2592	2763	2678	0019	
14000	2565	2747	2656	0022	
15000	2541	2709	2625	0031	Maximum
16000	2416	2328	2372	.0253	strain=.0650"
16400	2582	1530	2156	.0216	Buckled

Maximum Bending Moment 649,116.

Specimen from Bottom Flange of Number II Iron Beam, Tensile.

Loads		Micrometer Reads		Mean.	Strains	
Actual	Per sq. in.	No. 1.	No. 2.		Actual	Per. in.
2000	3717.	4198	3483	.3841		
4000	7435	4208	3497	3853	.0012	.00012
6000	11153	4221	3509	3865	.0012	.00012
8000	14870	4235	3522	3878	.0013	.00013
10000	18587	4248	3533	3891	.0013	.00013
12000	22306	4259	3549	3904	.0013	.00013
2000	3717	4194	3488	3841	.0063	.00063
14000	26023	4268	3569	3919	.0015	.00015
16000	29740	4304	3605	3955	.0036	.00036
18000	33459	5834 5824	5099 5102	5465	.1510	.01510
27600	51302	Broke here				

Section (original) .5380 Fractured .3294 (61.2%)

Elongation 2.44" = 24.4%   E 29,500 000

II

— Bottom Flange —

Tensile Specimen from No II Iron Beam

Loads		Readings		Mean	Strains	
Actual	Per Sq.in.	No.1	No.2		Actual	Per.in.
2000	3701	4040	3508	3774		
4000	7403	4053	3520	3787	.0013	.00013
6000	11104	4066	3533	3800	.0013	.00013
8000	14806	4079	3547	3813	.0013	.00013
10000	18508	4092	3558	3825	.0012	.00012
12000	22208	4104	3569	3837	.0012	.00012
2000	3701	4031	3518	3775	.0062	.00062
14000	25909	4121	3572	3847	.0010	.00010
16000	29612	4158	3591	3875	.0028	.00028
18000	33312	4852	5438	5145	.1270	.01270

Section (original) .5403 □" Fractured .3375 □" (62.5%)

Ultimate extension 2.2" = 22% E = 29,840,000

— Web — Iron

Tensile Specimen from No. II Steel Beam

Loads Actual	Loads Per sq. in.	Readings 1	Readings 2	Mean	Strains Actual	Strains Total per in.
2000	4015.	3630	4322	3976	.0019	.00019
4000	8029	3635	4355	3995	.0019	.00038
6000	12043	3640	4366	4003	.0008	.00046
8000	16058	3650	4395	4023	.0020	.0066
10000	20072	3660	4415	4038	.0015	.00081
2000	4015	3614	4340	3977	.0061	
12000	24087	3676	4431	4054	.0017	.00098
14000	28102	3690	4462	4076	.0022	.00120
16000	32116	3711	4529	4120	.0044	.00164
18000	36129	4144	5046	4595	.0475	.00639
20000	40145	5632	6622	6127	.1532	.02171
26400	52991	broke at lower clamp.				

Section (original) .4982 □" Fractured .3976 □" (79.2%)

Elongation 1.37" = 13.7% E = 26760000.

II — Upper Flange. —

Specimen from No II Iron Beam.

		Readings		Differences		Strains
		— a —	— b —	Actual	Per in	Per in.
4000	4040	5339	6380	.0008	.0002	.0002
8000	8081	5325	6380	.0008	.0002	.0004
12000	12121	5315	6370	.0010	.00025	.00065
16000	16162	5299	6368	.0008	.0002	.00085
20000	20200	5280	6360	.0013	.00033	.00098
24000	24243	5261	6341	.0019	.00048	.00146.
4000	4040	5302	6365	.0058	.0015	.00296
28000	28280	5232	6313	.0029	.00073	
32000	32324	5174	6252	.0060	.0015	.00446
36000	36363	5062	6130	.0117	.0029	.00736
4000	40400	4885	5947	.0180	.0045	.01183
44000	44440	4682	5700	.0225	.00563	.01749

Area of Section .990 sq.in.

II

- Upper Flange -

Compressive Specimen from No II Iron Beam

Loads		Readings		Differences		Totals
Actual	Per sq. in.	— a —	— b —	Actual	Per in.	per in.
4000	4040	4730	6439	.0008	.0002 .0002	.0002
8000	8081	4723	6431	.0008	.00013	.0004
12000	12121	4716	6428	.0005	.00018	.00017
16000	16162	4708	6423	.0007	.00015	.00035
20000	20200	4700	6419	.0006	.00055	.00050
4000	4040	4723	6439	.0022	.00023	
24000	24243	4690	6412	.0009	.00018	.00073
26000	26263	4683	6405	.0007	.00028	.00091
28000	28280	4675	6392	.0011	.00085	.00119
30000	30300	4650	6351	.0034	.0014	.00204
32000	32324	4606	6289	.0054	.0020	.00344
34000	34340	4504	6230	.0080	.0013	.00544
36000	36363	4474	6160	.0052	.0015	.00674
38000	38380	4397	6080	.0079	.0023	.00824
40000	40400	4311	5987	.0090	.0025	.01054
42000	42420	4215	5885	.0099	.0034	.01304
44000	44440	4093	5739	.0134		.01644

Area of Section .990" E = 29380000

Beam No III Iron

Bottom Flange Record

Loads	Micrometer Readings				Mean	Diff
1000	2779	2779	2845	2845	2812	.0017
2000	2785	2787	2871	2871	2829	.0017
3000	2861	2861	2896	2896	2849	0020
4000	2820	2820	2920	2920	2870	0021
1000	2772	2772	2866	2866	2819	0051
4000	2830	2828	2918	2918	2874	
4500	2839	2839	2926	2928	2883	0009
5000	2862	2862	2939	2939	2901	0018
5500	2942	2941	2945	2948	2944	0043
6000	3008	3010	3002	3003	3006	0062
6500	3092	3097	3074	3078	3085	0079
7000	3182	3180	3108	3111	3145	0060
7500	3278	3288	3233	3236	3257	0112
7900.	3459	3466	4892	4091	3777	0520

Maximum strain .0982"

III — Beam No III Iron —

Top Flange Bend

Loads	Micrometer Readings				Mean	Diff
1000	1780	1780	3375	3375	2577	.0017
2000	1750	1750	3370	3371	2560	.0017
3000	1731	1731	3362	3360	2546	.0014
4000	1710	1710	3352	3350	2531	.0015
1000	1768	1768	3395	3395	2581	.0050
4000	1714	1712	3352	3350	2532	
4500	1700	1700	3343	3345	2522	.0010
5000	1689	1690	3339	3340	2515	.0007
5500	1678	1678	3325	3325	2502	.0013
6000	1647	1648	3322	3323	2485	.0017
6500	1617	1618	3313	3315	2466	.0019
7000	1583	1586	3311	3315	2449	.0017
7500	1492	1489	3348	3342	2418	.0031
7900	0248	.0250	3882	3792	2023	.0395

Maximum strain .0571"

III

— Lower Flange —

Specimen from No III Wrt. Iron Beam

Loads Actual	Loads Per sq. in.	Readings 1	Readings 2	Mean	Diff.	Strain Totals Per in.
2000	3048	3611	4307	3959	.0009	.00009
4000	6096	3621	4315	3968	.0009	.00018
6000	9143	3636	4325	3981	.0013	.00031
8000	12191	3645	4332	3989	.0008	.00039
10000	15239	3659	4341	4000	.0011	.00050
12000	18287	3669	4352	4011	.0011	.00061
14000	21335	3681	4363	4022	.0011	.00072
16000	24382	3691	4377	4034	.0012	.00084
18000	27430	3703	4388	4046	.0012	.00096
2000	3048	3623	4300	3962	.0084	
20000	30478	3718	4398	4058	.0012	.00188
22000	33526	4738	5388	5063	.1005	.011085
24000	36574	5028	5680	5354	.0291	.013995
26000	39621	6337	6978	6658	.1304	
34700	52879	broke				

Cross Section (original) .6562 sq. in.; Fractured .4332 (66.33)%

Elongation 2.12" = 21.2 % E = 29.028000.

III

— Web —
Specimen from No III Wrt. Iron Beam

Loads Actual	Loads Per sq. in.	Readings 1	Readings 2	Mean	Diff.	Strain Total per in.
2000	5277	3091	4826	3859		.00010
4000	10553	3106	4650	3878	.0019	.00029
5000	13196	3112	4662	3887	.0009	.00038
6000	15826	3121	4673	3897	.0010	.00048
7000	18469	3130	4683	3907	.0010	.00058
2000	5277	3091	4627	3859	.0048	.00048
8000	21108	3140	4697	3919	.0012	.00070
9000	23746	3149	4712	3931	.0012	.00082
10000	26385	3159	4725	3942	.0011	.00093
11000	29024	3172	4741	3957	.0015	.00108
12000	31662	3188	4766	3977	.0020	.00128
13000	34300	3215	4827	4021	.0044	.00172
14000	36939	3607	5197	4402	.00421	.00593
15000	39577	4439	6030	5235	.00833	.01426
16500	43535	broke				

Area of Section (original) .3790 □" Fractured .3087 (81.45%)

Elongation 3.75" = 37.5% E = 27,485,000

III

— Upper Flange —

Specimen from No. III Wrt. Iron Bars

Loads		Readings		Differences		Strains
Actual	Per sq. in.	— a —	— b —	Actual	Per in.	Totals per In.
4000	4938	5273	6146	.0009	00023	00023
8000	9877	5280	6122	.0009	.00023	00046
12000	14815	5282	6109	.0006	.00015	00061
16000	19754	5280	6095	.0008	.00020	00081
20000	24692	5273	6086	.0008	.00020	.00101
24000	29630	5269	6062	.0015	.00038	.00139
4000	4938	5290	6110	.0835	00088	
26000	32100	5249	6019	.0132	00080	.00219
28000	34569	5086	5855	.0164	.00410	.00629
30000	37038	4978	5005	.0479	.01198	.01827

Area of Cross Section .810 sq. in.

E = 28.219.000.

III — Upper Flange —

Specimen from A o III Wrt. Iron Beam

Loads		Readings		Differences		Strains
Actual	Per sq. in.	— a —	— b —	Actual	Per in.	Totals per in.
4000	4938	5183	6189	.0008	.0002	.0002
8000	9877	5171	6186	.0008	.0002	.0004
12000	14815	5160	6181	.0008	.0002	.0006
16000	19754	5154	6173	.0007	.00018	.00078
20000	24692	5146	6164	.0008	.0002	.00098
4000	4938	5184	6182	.0028		
22000	27161	5145	6157	.0004	.0002	.00108
24000	29630	5140	6150	.0006	.00015	.00123
26000	32100	5120	6139	.0016	.0004	.00163
28000	34569	4902	5942	.0158	.00194	.00358
30000	37038	4775	5846	.0112	.00280	.00638

Area of Cross Section .810 sq. in.

E = 28,218,700

IV — Beam No IV Steel —

Bottom Flange Record

Loads	Micrometer Readings				Mean	Diff.
1000	3003	3003	2661	2662	2832	.0019
2000	3022	3021	2680	2681	2851	.0019
3000	3039	3040	2703	2704	2872	.0021
3500	3046	3046	2718	2716	2882	.0010
4000	3060	3059	2723	2722	2891	.0009
1000	3013	3015	2670	2670	2842	.0049
4500	3068	3068	2734	2732	2901	.0009
5000	3082	3080	2747	2745	2914	.0013
5500	3081	3080	2755	2757	2918	.0004
6000	3094	3094	2772	2770	2933	.0018
6500	3107	3107	2790	2790	2949	.0015
7000	3110	3109	2831	2835	2971	.0022
7500	3138	3141	2880	2882	3010	.0039
8000	3186	3184	2941	2940	3063	.0053
8500	3260	3261	2981	2980	3146	.0083
9500	3338	3360	3302	3302	3331	.0185

Maximum strain .0534"

IV — Beam No IV Steel —

Top Flange Record

Loads	Micrometer Readings				Mean	Diff.
1000	2590	2590	2937	2938	2764	.0014
2000	2575	2573	2926	2927	2750	.0014
3000	2559	2558	2911	2912	2735	.0015
3500	2548	2548	2911	2910	2729	.0006
4000	2544	2544	2901	2900	2722	.0007
1000	2600	2600	2945	2945	2773	.0007
4500	2540	2540	2896	2896	2718	.0005
5000	2531	2530	2890	2889	2710	.0008
5500	2527	2527	2883	2883	2705	.0005
6000	2517	2517	2878	2879	2698	.0007
6500	2509	2508	2871	2872	2690	.0010
7000	2491	2492	2870	2868	2680	.0010
7500	2477	2478	2861	2863	2670	.0010
8000	2462	2460	2852	2852	2657	.0013
8500	2452	2450	2830	2830	2641	.0016
9500	2298	2300	2812	2812	2556	.0085

Maximum strain .0209"

— Lower Flange —

Tensile Specimen from No. 4. Steel Beam

Loads Actual	Loads Per sq. in.	Micrometer Readings No 1	Micrometer Readings No 2	Mean	Strains Actual	Strains Per Sq. in.
2000	3024	3817	3828	3823	.0010	.0001
4000	6049	3827	3839	3833	.0007	.00007
6000	9073	3833	3847	3840	.0010	.0001
8000	12097	3845	3855	3850	.0010	.0001
10000	15122	3853	3867	3860	.0009	.00009
12000	18146	3861	3877	3869	.0009	.00009
14000	21171	3870	3886	3878	.0010	.0001
16000	24195	3882	3894	3888	.0010	.0001
18000	27219	3893	3903	3898	.0011	.00011
20000	30243	3906	3912	3909	.0011	.00011
22000	33267	3919	3920	3920	.0097	.00097
2000	3024	3810	3835	3823	.0008	.00008
24000	36291	3942	3919	3931	.0430	.0043
26000	39315	4399	4322	4361	.1609	.01609
28000	42339	{6027 6009	5920 5916}	5970	.0793	.00793
30000	45363	6820	6705	6763	.0936	.00936
32000	48387	7756	7643	7699		
40750	61600 ~~71828~~	broke here		E = 31,200,000. Extension 2.78" = 27.8%		

Area Original .6613 ; Fractured .2332 (35.3%)

IV

— Web —

Tensile Specimen from No IV Steel Beam

Loads Actual	Loads Per sq. in.	Readings 1	Readings 2	Mean	Strains Actual	Strains Total per in.
2000	5197	4447	3426	3937	.0016	.00016
4000	10395	4460	3446	3953	.0016	.00032
6000	15593	4472	3468	3970	.0017	.00049
8000	20790	4488	3489	3988	.0018	.00067
2000	5197	4447	3426	3937	.0051	
9000	22856	4500	3496	3998	.0010	.00077
10000	25987	4506	3506	4006	.0008	.00085
11000	28586	4516	3516	4016	.0010	.00095
12000	31185	4525	3527	4026	.0010	.00105
13000	33784	4532	3538	4035	.0009	.00114
14000	36382	4540	3550	4045	.0010	.00124
15000	38981	4548	3570	.4059	.0014	.00138
16000	41490	5138 5152	4199 4199	4672	.0623	.00761
23900	62108	broke	here			

Section, original, .3848 sq. in.; Fractured, .1955 (50.1%)

Elongation 2.6" = 26% E = 30,580,000.

IV — Upper Flange —

Compressive Specimen from No IV Steel Beam

Loads		Readings		Differences		Strains
Actual	Per sq. in.	— a —	— b —	Actual	Per 1 in.	
4000	4779	5165	6078	.0009	.00023	.00023
8000	9558	5154	6070	.0009	.00023	.00046
12000	14337	5144	6065	.0007	.00018	.00064
16000	19116	5136	6061	.0006	.00015	.00079
2000	23895	5128	6059	.0005	.00013	.00092
24000	28674	5118	6053	.0008	.0002	.00112
28000	33453	5114	6045	.0007	.00018	.00130
4000	4779	5155	6078	.0037	.00093	
30000	35842	5108	6042	.0005	.00013	.00143
32000	38232	5097	6036	.0009	.00023	.00166
34000	40621	4578	5488	.0534	.01335	.01501
36000	43011	4424	5402	.0120	.0030	.01801

Section .837 sq. in. E 30,830,000

IV

— Upper Flange —

Compressive Specimen from No. IV Steel Beam

Loads		Readings		Strains		
Actual	Per sq. in.	— a —	— b —	Actual	Per in.	Total per in.
4000	4779.	5752	6174	.0006	.00015	.00015
8000	9558	5762	6155	.0006	.00015	.00030
12000	14337	5766	6141	.0006	.00015	.00045
16000	19116	5764	6131	.0006	.00015	.00060
20000	23895	5759	6123	.0007	.00017	.00077
24000	28674	5750	6117	.0008	.0002	.00099
4000	4779.	5753	6175	.0033	.00088	
26000	31064	5745	6118	.0002	.00005	.00102
28000	33453	5743	6115	.0003	.00008	.00110
30000	35842	5719	6120	.0010	.00025	.00135
32000	38232	5698	6042	.0052	.0013	.00148
34000	40621	.5247	5420	.0543	.0136	.01508
36000	43011	5184	5326	.0079	.00198	.01706

Specimen 4" long, area (by weighing) .837 □"

E = 29,600000.