For $p(z)$ not a constant IIc. is the only solved form.

IIIa. $\phi(z) = \varphi(az)$; $f(z^{\frac{2\pi i}{\log a}})$

IIIb. $\phi(z) = b\,\phi(az)$; $z^{-\frac{\log b}{\log a}} \cdot f(z^{\frac{2\pi i}{\log a}})$

IIIc. $\phi(z) = z\,\phi(az)$; $\prod_{m=0}^{\infty}(1 + a^m z) \cdot \prod_{m=1}^{\infty}(1 + \frac{a^n}{z}) \cdot f(z^{\frac{2\pi i}{\log a}})$

IIId. $\phi(z) = p(z)\,\phi(az)$; $(p(o) = 1)$; $\tau(z) \cdot f(z^{\frac{2\pi i}{\log a}})$.

The $\tau(z)$ has the same number of branches as $p(z)$. It may be algebraic. When transcendental ∞ is its only essential singular point.

The solution of any equation of form III. consists of a product of solutions of the four types given.

New Mechanical Computer. By Fred Morley.

A New Apparatus for Photographic Surveying. By Fred Morley.

Crushing Strength of Wrought Iron Cylinders. By W. K. Hatt and L. Fletemeyer.

Tests of a Wrought Iron Car Axle. By W. F. M. Goss.

While much has been written concerning the variety and intensity of the stresses which service conditions impose upon car axles, there have been presented but few descriptions of the behavior of such axles when under stresses that are simple and definite in character. Interesting material of the latter class is supplied by a recent test of a 60,000-pound axle made in the Engineering Laboratory of Purdue University.

The axle tested was supplied by the Bass Foundry and Machine Works, of Fort Wayne. It is said to have been made of No. 1 wrought railroad scrap, and to have been selected at random from a lot of 100 which were being shipped to a railroad company, and with it there was delivered to the laboratory a small test specimen which had been drawn down from the crop end of the axle. As prepared for the tests the axle carried two 33-inch cast wheels, and it was tested under transverse stresses, while the small specimen was subjected to tensional tests. The work was executed by Mr. J. H. Klepinger, who perfected details in the general plan and was painstaking in the manipulation of the apparatus.

The tests were made on a 300,000-pound Riehle testing machine, a general view of which, with the axle in place for testing, is shown by Fig. 1. Fig. 2 gives the dimensions of the axle and the details of the arrangements for applying loads. The axle was supported by cast iron blocks, AA, four inches in breadth, shaped to the form of a bearing, and extending from the center to the outer end of the journal. The actual points of support were located in the center of these blocks. Load was applied to the wheel treads through steel rollers, BB, which, at the beginning of the test, were located 4 feet 10 inches apart; that is, at a point corresponding to a position three-fourths of an inch outside of the inner or "gauge face" of the rail upon which it may be supposed the wheels were set to run. In this manner stresses were imposed upon the axle which were in every way similar to those which might have been imposed by a car, if the axle had been in service, but to give greater facility in testing, the usual order was reversed, the rails being assumed to be above the axle and the car below.

Fig. 2 shows also the means employed in determining the deflections corresponding to different loads. At each end of the axle there was attached a light arm (bb), extending at right angles both to the axle and to the plane of the stresses to which it was subjected. Over these was stretched a fine wire parallel to the axis of the axle. The wire passed through the web of the wheels, in holes which were drilled for the purpose, and made sufficiently large to give ample clearance. The whole length of wire between the arms (bb) was at all times perfectly free, and the arrangement was such that although the axle might be bent by loads applied to it, the wire would remain straight. Three micrometers attached to blocks clamped about the axle served to locate the latter with reference to the wire, and thus to determine the deflection. A fourth micrometer was used to measure distances between the wheels' flanges in a line parallel with the axle and 16½ inches distant from its center.

Loads were applied at C in 5,000 pound increments, and all micrometers were read before each change of load. In this way a maximum load of 85,000 pounds was applied, under which the axle showed unmistakable signs of failure, the elastic limit having been reached with a load of 55,000 pounds. The results are presented graphically by Fig. 3, in which the curve marked "center" represents the deflections of the center of the axle as determined by the middle micrometer, Fig. 2; the curves marked "right" and "left" represent corresponding deflections for points 18 inches either side of the center. Deflections of the axle involved changes in the gauge of the wheels as measured above or below the axle, the extent of which is indicated by Fig. 4.

The actual readings of all micrometers are given in the tabulated statement below:

LOAD.	Micrometer Readings at Different Loads.								Total Deflection.			
	Center.	Dif. of Center.	Left.	Dif. of Left.	Right.	Dif. of Right.	Flange.	Dif. of Flange.	Center.	Left.	Right.	Flange.
	.084	......	.250	......	.176	......	.145	......	......	......	......	......
5,000	.111	.027	.275	.025	.200	.024	.175	.030	.027	.025	.024	.030
10,000	.138	.027	.297	.022	.220	.020	.199	.024	.054	.047	.044	.054
15,000	.151	.013	.310	.013	.233	.013	.228	.029	.067	.060	.057	.083
20,000	.190	.039	.339	.229	.264	.031	.265	.037	.106	.089	.088	.120
25,000	.226	.036	.365	.026	.288	.024	.290	.025	.142	.115	.112	.145
30,000	.255	.029	.388	.023	.311	.023	.315	.025	.171	.138	.135	.170
35,000	.284	.029	.412	.024	.334	.023	.369	.054	.200	.162	.158	.224
40.000	.315	.031	.435	.023	.357	.023	.370	.001	.231	.185	.181	.225
45,000	.347	.032	455	.020	.380	.023	.401	.031	.263	.205	.204	.256
50,000	.377	.030	.485	.030	.405	.025	.438	.037	.293	.235	.229	.293
55,000	.414	.037	.513	.028	.434	.029	.476	.038	.330	.263	.258	.331
60,000	.455	.041	.546	.033	.465	.031	.522	.046	.371	.296	.289	.377
65,000	.504	.049	.582	.036	.498	.033	.564	.042	.420	332	.322	.419
70,000	.559	.055	.627	.045	.543	.045	.633	.069	.475	.377	.367	.488
75,000	.616	.057	.675	.048	.585	.042	.716	.083	.532	425	.409	.571
80,000	.761	.145	.782	.107	.683	.098	.839	.123	.677	.532	.507	.694
85,000	.963	.202	.936	.154	.816	.133	1.068	.229	.879	.686	.640	.923

The dimensions of the axle were such (Fig. 2) that when loaded to its elastic limit, the maximum fiber stress at its center was 29,730; at 18 inches from the center 22,100 pounds, and at the neck of the journal 20,600 pounds.

The axle tested was designed for use under a freight car of 60,000 pounds capacity, the car itself weighing about 20,000 pounds. Each of the four axles under such a loaded car, therefore, must withstand a static load of 20,000 pounds, which load would develop a maximum fiber stress in the center of the axle tested of 10,810 pounds. In comparing these values with those obtained in the tests as given in the preceding paragraph, it is important to remember that the stresses to which car axles are subjected when in service arise from complicated conditions, and that their value can not be determined from static conditions alone.

The test specimen which was forged down from the crop end of the axle was turned down in the center for a distance of 8.5 inches and tested under tension. The results are as follows:

Diameter in inches	1.875
Area of cross section	2.755
Total load, pounds	140,700.
Ultimate strength, pounds, per square inch	51,070.
Elastic limit	30,000.
Modulus of elasticity	29,671,000.

Area at point of fracture—

Per cent. of original area	61.6
Elongation in 8 inches, per cent	27.3

Finally one end of the test specimen was exposed to the action of acids, and the etching thus produced used in printing Fig. 5. This figure, therefore, shows the disposition and relative density of the various layers of iron composing the specimen. The symmetrical arrangement of curved lines, which is so noticeable, is due evidently to the hammering of the round section of the axle to a square section in the process of forging the end of the axle down to the size of the test specimen.

While the tests show the iron of the axle to have been of excellent quality, the most significant fact developed is that concerning the amount of distortion which such an axle will withstand without taking a permanent set.

It would at first sight appear impossible that by loads applied at the journals a common car axle could be deflected at its center as much as a third of an inch without exceeding its elastic limit, but an analysis of the data given will fully justify such a conclusion. The results show also that a deflection of the axle well within the elastic limit of the material may be sufficient to produce a temporary change of gauge in the wheels mounted upon it of quite three-tenths (0.3) of an inch.

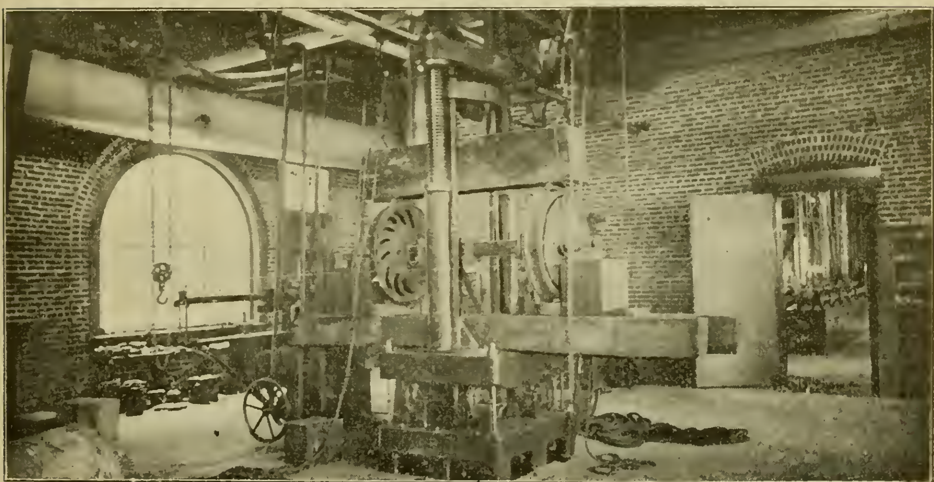

Fig. 1. Tests of a Wrought Iron Car Axle.

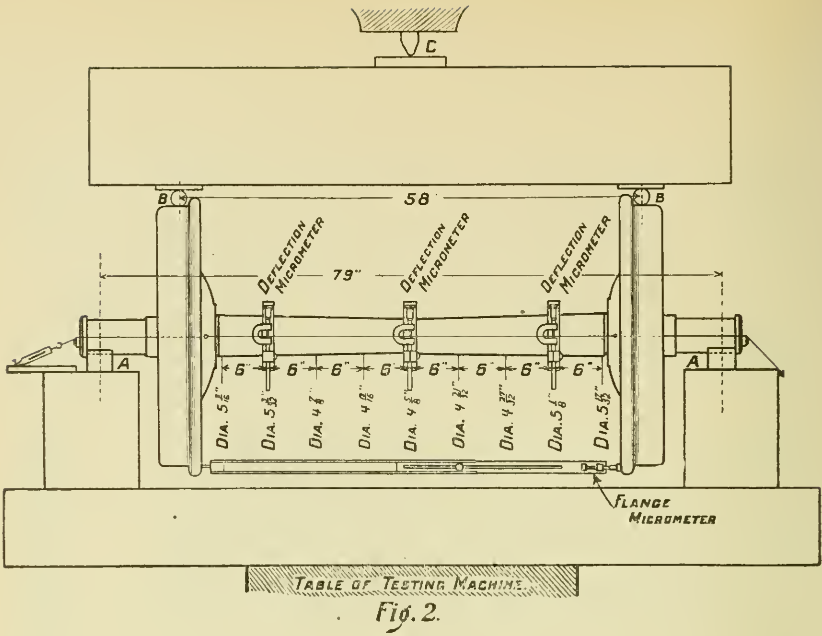

Fig. 2. Tests of a Wrought Iron Car Axle.

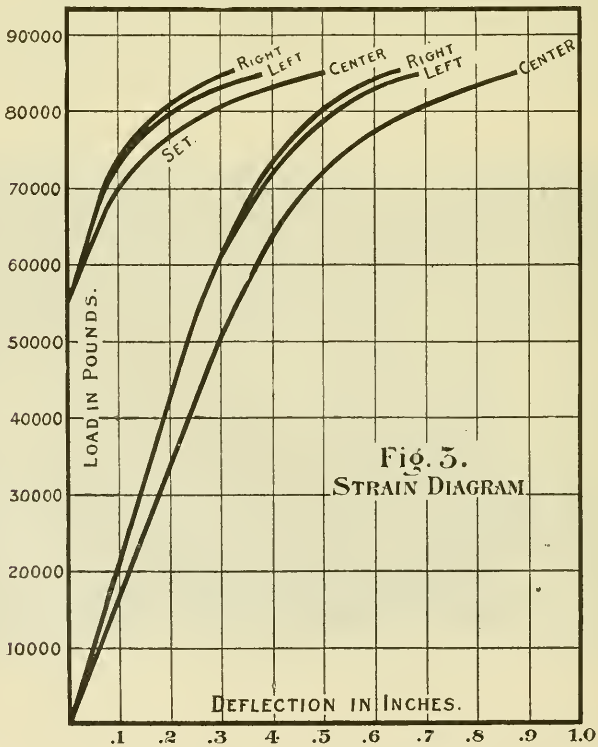

Fig. 3. Tests of a Wrought Iron Car Axle.

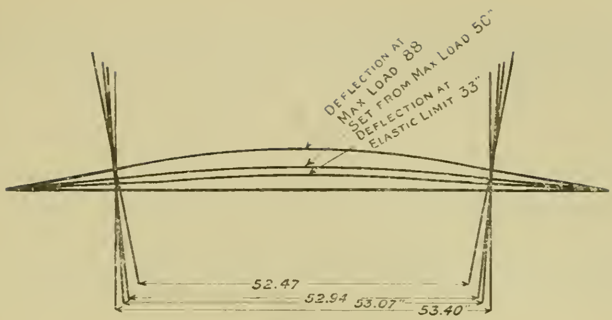

Fig. 4.

Fig. 4. Tests of a Wrought Iron Car Axle.

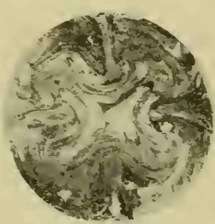

Fig. 5.

Fig. 5. Car Axle.

SUBDIVISION OF POWER. BY J. J. FLATHER.

While economy in the use of power should be secondary to increased output, yet careful attention to details will often greatly reduce the useless waste of power.

It is well known among engineers that there is a very great percentage of loss due to shaft friction, which, in shops where the buildings are more or less scattered, is probably not far from 75 per cent. of the total power used. In two cases known to the writer these losses are 80 and 93 per cent. respectively.

No matter how well a long line of shafting may have been erected, it soon loses its alignment, and the power necessary to rotate it is increased.

In machine shops with a line of main shafting running down the center of a room, connected by short belts with innumerable countershafts on either side, often by more than one belt, and, as frequently happens, also connected to one or more auxiliary shafts which drive other countershafts, we can see why the power required to drive this shafting should be so large.