On Changes in the Proportional Elastic Limit of Nickel Steel, With a Note on Calibration of Testing Machines.

W. Kendrick Hatt.*

The variability of the proportional elastic limit of metal due to overstrain and its subsequent recovery after a period of rest, or proper annealing, have been studied by investigators, among whom may be named Bauschinger, Professor Gray and Mr. Muir.

The writer records here the results of experiments on a special nickel steel rolled for the purpose by the Bethlehem Steel Company. The experiments had two ends in view:

1. To calibrate the testing machines of Purdue University, in comparison with the testing machines of the government testing laboratory of the Watertown Arsenal, and those of the University of Illinois.

2. To study the variability of the proportional elastic limit and yield point of this special nickel steel.

The proportional limit here mentioned is that limit beyond which stress ceases to be proportional to strain. The yield point spoken of below is that limit at which a sudden increase in the elongation occurs without an increase in stress.

CALIBRATION.

A testing machine of ordinary screw type consists of a screw press and a large platform scale. It is necessary, of course, to ascertain if the load on the scale beam correctly indicates the pressure on the platform. This is often accomplished by loading the platform with a dead load of pig iron. For light loads the purpose might be served by a calibrated spring. The use of nickel steel bars of high elastic strength furnishes us with a spring of high capacity, whose deformation may be accurately measured. Calibration by means of these bars may be readily effected and relative errors in the machines detected. The absolute error may be known by comparison with a machine that has been calibrated by the dead weight method. The bars can be preserved and used from time to time to detect changes in the machine due to wear of knife edges. This is

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*The main observations on which this note is based were carried out under the author's supervision by Messrs. R. Hitt and J. H. Jascha, senior students in Purdue University, 1901.

a more accurate method than that often used, involving the breaking of a half dozen steel bars from one rod at different laboratories and comparing the average breaking load.

In the work of examining the accuracy of the Purdue University testing machines, three nickel steel bars were used; two with a length between shoulders of 12 inches, and one with a similar length of 30 inches. In the case of the latter bar, it was possible to attach two extensometers to the bar *in tandem*, and by exchanging the position of the extensometers to compare the latter. The modulus of elasticity was measured in case of each bar on the machines of the three laboratories using the extensometers possessed by the three laboratories. One of these extensometers was sent from one laboratory to the other. If the extensometers are alike in their graduation and the modulus of elasticity of the bars is found to be equal on the various machines, the latter may be judged to have no relative errors. The observations at the University of Illinois were taken under the direction of Professor A. N. Talbot.

Taking the average of three bars tested at the three laboratories it appears (Table I) that the value of Young's Modulus at the Purdue laboratory is (in 100,000 pounds per square inch units) 29.22; at Illinois laboratory, 29.33; at Watertown laboratory, 28.66. Between the Purdue laboratory and the Illinois laboratory there is thus a relative difference of only about ⅓ of one per cent., an accuracy much in excess of that needed in any work for which these machines are used.

By interchanging the positions of two extensometers in case of the long bar, an opportunity existed of comparing the indications of two extensometers of different type—the Riehle extensometer (a screw micrometer) and the Johnson extensometer (a roller type). In Table II it is seen that the two extensometers yield identical results.

It is thus assuring to know the reliability of the ordinary type of testing machine and extensometer. If the Watertown machine is correct, the other machines yield results about two per cent. high. The Watertown extensometer, however, was not compared with the other extensometers.

ELASTIC CHANGES.

After the work of calibrating apparatus was complete, two of the bars were used in the study of the variability of the proportional and yield limit.

The results are shown in Table III. These results show that the behavior of nickel steel under overstrain is like to that of ordinary steel, namely:

Overstrain destroys the P-limit, and elevates the Y-limit.

The P-limit may be restored by annealing for a few moments in a bath above 212° F. The P-limit may be also restored by a period of rest. By a process of overstrain and subsequent annealing, the P-limit may be elevated to nearly the ultimate strength.

The decrease of diameter was also measured. The ratio of side contraction to longitudinal extension was found to be nearly ¼, which is the value of Poisson's ratio for this metal.

TABLE I.

Value of E. in 100,000 Units as Derived from Tests on Bars of Nickel Steel at Three Laboratories.

Bar.	Watertown.	Purdue.	Illinois.	Average.
1......................	28.71	29.29	29.40	29.23
2.............	28.59	29.32	29.14	29.14
3...	28 66	29.36	29.20	29.20
Average	28 66	29.22	29.33	

TABLE II.

Comparison of Extensometers

Extensometer.	Illinois, 200,000 Olsen.		Purdue, 300,000 Riehle.	
	Roller.	Screw—1.	Screw—2.	Roller.
Position—				
On top................	29.40	29 40	29.50	......
On bottom	29.00	29.00	......	29.10

TABLE III.

Showing Variability of P-Limit.

Bar No. 1.

Analysis	Carbon	0.27 %
	Manganese	0.58 %
	Silicon	0.214%
	Ph	0.024%
	Sulph	0.036%
	Copper	0.028%
	Nickel	4.552%

No. of Test.	Description of Test.	E. in Units of 100,000 lbs. to square inch.	P-Limit in Units of 1,000.	Y-Limit in Units of 1,000.	Maximum Stress.	Note Effect of Test.
1	Original	29.3	88.0	......	*96.0	Overstrain.
2	45 hours after	26.4	0.0	96.0	98.0	P-limit destroyed.
3	10 minutes after	24.8	0.0	94.0	*100.0	P-limit destroyed.
4	118 hours after and in 450° F. bath	29.0	100.0	116.0	116.0	P-limit restored by annealing.
5	22 hours after	28.2	112.0	117.0	*117.0	Overstrain.
6	After in bath at 218° F.	29.2	109.0	112.0	*114.0	Overstrain restored by annealing.
7	500 hours after	28.0	110.0	116.0	116.0	Overstrain restored by rest.
8	10 minutes after	26.0	110.0	116.0	116.0	Test to destruction 15% elongation, 42% contraction in 8″.

Bar No. 2.

No. of Test.	Description of Test.	E. in Units of 100,000 lbs. to square inch.	P-Limit in Units of 1,000.	Y-Limit in Units of 1,000.	Maximum Stress.	Note Effect of Test.
1	Original	29.7	92.0	95.0	*100.0	Overstrain.
2	15 hours after	26.1	70.0	100.0	*117.0	Overstrain.
3	2 weeks after	24.8	0.0	100.0	109.0	P-limit destroyed.
4	10 minutes after	24.6	0.0	108.0	......	P-limit destroyed.
5	After in bath at 190° F.	25.3	0.0	112.0	115.0	P-limit not restored.

*Indicates that the test overstrained the metal.
E. taken between limits of stress of 25,000 to 85,000.