In steels containing from 0.25 to 0.4 per cent. of carbon comparable results may be obtained in regard to shock-resistance by means of a number of blows. These tests may be made on any of the forms of impact machine described,

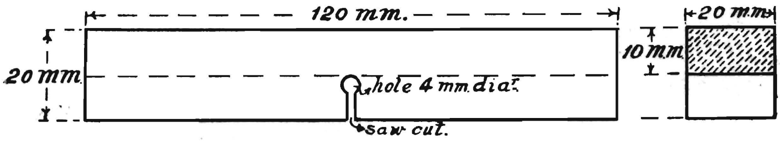

FIG. 11.

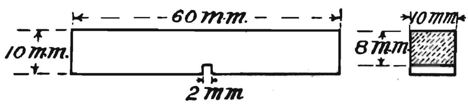

FIG. 12.

excepting the Guillery; but a simple form of machine for experiments on notched bars has been devised by Messrs. Seaton and Jude*, consisting of a rod weighing six pounds, falling freely through a height of 24 inches. For the determination of the shock-resistance by means of a single blow, the Charpy, Frémont and Guillery machines are the most satisfactory.

All impact tests with notched bars show that there is no correlation between the results of tension tests made with gradually-applied loads, and those obtained by impact. A steel which gives excellent results in ordinary tension tests, and in shock tests on unnotched bars, may give widely divergent results if subjected to shock tests with notched bars. Statical bending tests with notched bars give interesting results, but necessarily less decided than in shock tests. In the case of metals of average fragility, the values of the energy of rupture or resilience obtained by static bending tests are greater than those obtained by percus-

* Proc. Inst., Mech. Engineers, Nov. 1904. This machine has been re-designed and improved by Prof. R. Scott, of Christchurch College, New Zealand.

sion tests, but with very tough materials the opposite takes place, at least, in certain cases, thus the values of the energy of rupture obtained by static tests with acute notches are notably lower, than those which are obtained by dynamic tests with the same bars. A notable series of tests upon notched bars was carried out by M. Mesnager, Director of the Laboratory de l'Ecole des Ponts et Chauséces, Paris, with a view to ascertain the conditions which should be laid down in specifications relating to the performance of tests upon the fragility of metals. They were carried out upon bars, rectangular, in cross-scection, upon two supports, a moving weight travelling at a known speed, striking them midway. The bars were notched on the face opposite to that struck. M. Frémont's machine, with decending weight, and M. Charpy's apparatus with oscillating weight, were employed in the tests. In the former apparatus, the weight of 10 kilogrammes, falling from a height of 4 metres, impinged upon test-bars, 30 millimetres long, 10 millimetres wide, and 8 millimetres thick (*i.e.*, in vertical measurement). The lower face (that cf 10 m.m.) bore a notch, made by means of a saw, one millimetre deep, and one millimetre broad, the angles at the bottom of the cut being slightly rounded. Hence, the cross-sectional area of the test-bars in the place of the notch was 70 square millimetres. The supports were 23 millimetres apart. The energy remaining in the ram after the blow was measured by the flexion of a spring. The machine was carefully calibrated. The Charpy machine consisted of an oscillating ram, 50 kilogrammes in weight, and fell from a height of 3 metres upon test-bars, 160 millimetres long, 20 millimetres wide, and 20 millimetres thick. A circular hole, 4 millimetres in diameter, was drilled one millimetre from the lower face of the test piece, and this last one millimetre was cut through with a saw. Thus, the cross-sectional area at the plane of the notch was 15 x 20 eq. 300 square millimetres; or in the case of sheets, was 15 t, where t was the thickness. The energy remaining after the blow was measured by the height to which the ram rebounded. The tensile strengths of the steel operated upon varied from 50,000 to 113,000 pounds per square inch (or 35 to 80 kilogrammes per square millimetre). The Frémont tests were on small pieces, and the Charpy tests on large pieces. The angle of rupture of the test piece was carefully measured.

The angle of rupture of the test piece is proportional to the energy of rupture per square c.m. The angle of rupture, or bending, is the angle that one half of the test piece turns through relatively to the other half during the process of bending and breaking. When the test piece is not completely broken by the impact, it is necessary to break it, and bring the pieces together in the same position which they occupied before rupture. It is not easy to measure the angle of rupture, more especially when the fracture is uneven, such as a concave surface on one half the test piece, and a convex surface on the other half.

The conclusions arrived at by M. Mesnager are as follows:—

1. Generally speaking, the results vary less in the case of the large test pieces with cylindrical notches, than in the small.

2. The relationship between the number of kilogrammetres per square centimeter of the section broken, and the angle of deformation expressed in degrees is given by the following equations:—

Small test pieces (as defined above), $K = 0.375D$.
Large test pieces (as defined above), $K^1 = 1 + 0.58D^1$.

3. Hence the measurement of the angle of rupture may be substituted for that of the work absorbed in the rupture.

4. The relationship between the tensile strength expressed in kilogrammes per square centimetre, the angle of rupture, and the number of kilogrammetres per square centimetre, are given by the following approximate formulæ:—

Small test pieces, $R + 2.66D = 95$; $R + 7.1K = 95$.
Large test pieces, $R^1 + 1.72D^1 = 87$; $R^1 + 3K^1 = 90$.

5. A porous metal appears to absorb more energy in rupture than one that is sound.

6. Among homogeneous metals, the large test pieces yielded remarkably regular results.

7. The large test pieces give the same results whether the notch is made with a drill or with a milling tool.

8. Variations of 5 millimetres in the distance between the supports, and in the thickness of the large test pieces, only affect the results to a small extent, provided the section to be broken remains the same.

9. The width of the notch, on the other hand, exerts a great influence upon the results.

The following are some of the results obtained by M. Mesnager, with a Charpy machine:—

Type of Notch.	Mild structural steel, annealed.		Axle and Tyre Steel Annealed.			
	Shock.	Static Test.	Shock.			Static Test.
	$v = 7.75$m		$v = 7.75$m	$v = 6.65$m	$v = 4.65$m	
Circular hole 8.mm diar.	15·2	15·3 18·2	17·8	...	...	...
,, ,, 4.mm diar.	...	...	12·7	12·2 12·2	13·4 13·1	11·5 ...
,, ,, 3.mm diar.	2.95	11·5 8·1	10·9	...	...	18·2
Tiangular Notch ...	1·7	2·7 3·4				

Type of Notch.	Axle and Tyre Steel Hardened and Tempered.			
	Shock.			Static Tests.
	$v = 7·75$	$v = 6·63$	$v = 4 65$	
Circular Notch 8.m.m. dia....	23·8	...	...	...
,, ,, 4.m.m. dia....	24·5	26·1	23·7	27·5
,, ,, 3.m.m. dia....	...	...	...	...

It will be seen from the above table that the effect of the speed of the shock is very small, with notches rounded at the bottom. In regard to the shape of the notch, the figures show that the resilience increases as the radius at the bottom of the notch increases. Also that while the velocity of shock, form of notch, etc., modify the absolute values obtained for the resiliency, they do not appear to affect sensibly the relative values for the resiliency of many metals. Mesnager also points out that with circular notches the value of the resiliency is due to the work of bending and breaking, and that these two periods cannot be separated, as the bending of some portion of a test piece is going on while others are breaking. With sharp-angled notches, the work of bending, although not entirely eliminated, is reduced considerably. Hence, sharp-angled notches should be used in scientific tests. In commercial tests where the results may have to be repeated as a check, he considers circular notches are preferable to triangular.

If a specimen of soft steel is notched on its under side, and polished so as to show the distribution of the strain lines in the depth, then subjected to partial bending, the strain lines consist of the interposition of two elementary deformations, one of swelling, the other of a depression, fig. 13.

The depression E F G B H is nearly an ellipse, the swelling is a portion of the ellipse, having the same major-axis. The two ellipses have the portions A G B H, in common, and thus the two deformations are in part neutralised. Rupture takes place along the synclinal lines G F and H E.

In fragile steel, fig. 14, the ellipse caused by the compression or swelling is reduced to nearly nothing, and the rupture is made downwards by tension following the line A K, fig. 14, and the rupture is effected abruptly with a

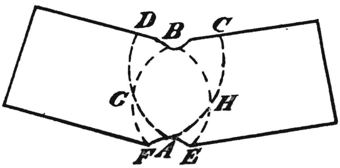

FIG. 13.

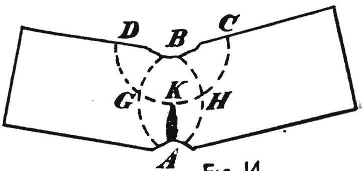

FIG. 14.

small expense of work. If the point K is near A, the metal will not be weak, if it goes towards B, the metal will be weaker the nearer it is to B. Thus the prominence of the swelling and the position of the point K, are important factors in this determination of the fragility of a specimen.

TABLE II.

TRANSVERSE DROP TESTS.

Weight of hammer, eq. 40lb. Distance apart of supports eq. 4.8in.

Description.	Section at Centre.		Height of drop. Metres.	No. of blows required to produce fracture.	Total deflection up to last blow before fracture.	Average deflection per blow. Inches.	Work done in fracturing in metre-lbs.	Work done in fracturing in feet-lbs.	Remarks.
	Br'adth m.m.	Depth m.m.							
3 pr cent. Nicke' Steel	20	10	0.3	5	0.50	0.125	60	196.8	
" "	"	"	"	5	0.50	0.125	60	196.8	
6 pr cent. Nickel Steel	"	"	"	7	0.57	0.092	80	262.5	
Crucible Steel ..	"	"	"	3	0.15	0.150	24	78 7	
Axle	"	"	"	4	0.42	0.135	48	157 4	
Tyre	"	"	"	2	0.12	0.125	24	78.7	
3 pr cent. Nickel Steel	"	"	0.15	9	0.57	0.054	54	177 0	
6 pr cent. Nickel "	"	"	"	15	0.73	0.039	90	295.3	
Crucible .. "	"	"	"	3	0.15	0.078	18	59.0	
Axle .. .. "	"	"	"	8	0.47	0.060	48	157.4	
Tyre .. .. "	"	"	"	4	0.15	0.052	24	78.7	
3 pr cent. Nickel "	30	15	1.00	5	0.35	0.087	200	656.2	
" " "	"	"	0.50	10	0.35	0.039	200	656 2	Halves, still connected
6 pr cent. Nickel "	"	"	1.00	7	0.56	0.085	280	919 3	" " "
" " "	"	"	0.50	18	0.86	0.040	360	1180.0	
Crucible .. "	"	"	1.00	3	0.25	0.125	120	394.0	
" " "	"	"	0 50	7	0.30	0 050	140	459.5	
Axle .. .. "	"	"	1.00	6	0.62	0.124	240	787.0	
" " "	"	"	0.50	12	0.58	0.053	240	787.0	
Tyre .. .. "	"	"	1.00	3	0.20	0.100	120	394.0	
Tyre .. .. "	"	"	0.50	8	0.20	0.059	120	394.0	

TRANSVERSE DROP TESTS.

The following tests were made by means of the impact testing machine, shown in fig. 1, using a number of blows, and the results are recorded in Table II. The total work done in producing fracture per unit of volume expresses the relative resistance of the materials to suddenly-applied loads. All the qualities of steel were the best of their kind respectively.

STATICAL CROSS BENDING TESTS.

The results recorded in Table III. show the resistance of notched bars, similar to those recorded in Table II., but subjected to a gradually-applied load. The work of rupture is obtained from the stress-strain diagram; and is much greater than that obtained in the impact tests.

TABLE III.
CROSS BENDING TESTS.

Specimens identical with the smaller specimens used in Impact Cross Breaking Tests. Cross Section at centre

Description.	Yield Point from diagram. Lbs.	Load at Rupture. Lbs.	Total deflection before Rupture. Inches.	Work done in Rupturing from diagram. Inch-lbs.	Work done in Rupturing, similar specimens, by Impact. Inch-lbs.
Axle Steel... ...	2,400	4,280	·55	5,462	1890
,, ,, ...	2,000	4,000	·37	4,377	
Tyre Steel ...	2,400	3,850	·25	3,375	945
,, ,, ...	2,250	3,850	·25	3,430	

The results obtained in the ordinary statical tension tests for the various qualities of steel tested by impact recorded in Tables II., III., V., and VI., are as follows:—

Tyre Steel.—Tensile strength, 50 tons per square inch; elastic limit, 27 tons per square inch; elongation on 8 in., inches, 22 per cent.

Axle Steel.—Tensile strength, 36 tons per square inch; elastic limit, 22 tons per square inch; elongation on 8 in. 22 per cent.

TABLE IV.

Description.	Original Dimensions. Dia. inches.	Original Dimensions. Area. sq. ins.	Stress in Pounds. Total.	Stress in Pounds. Per sq. inch.	Stress in Tons per sq. inch.	Limit of Elasticity, tons per sq. inch.	Ratio of Limit to Break.	Contracted Dimensions. Dia. inches.	Contracted Dimensions. Area. sq. in.	Contraction of Area, per cent.	Elongations, measured after fracture. On 6"	Elongations, measured after fracture. On 3"	Local Elongations.	General Elongation, per cent.	Co-efficient of Quality.	Revolutions before testing.
Nickel Steel containing approximately 6 per cent. of Nickel, Mild	.625	.3068	22,800	74,320	33.18	23.4	71.9	.334	.0876	71 1	15.6	10.5	.54	17.0	5.6	...
	,,	,,	22.900	74.640	33.32	22 5	67.7	.340	.09079	70 4	16.75	10.8	.485	19.9	6.7	...
	,,	,,	22.750	74,150	33.10	22.5	68.1	.337	.08919	70.9	15.0	10.2	.54	16.0	5.3	...
	,,	,,	22,820	74.370	33 20	22.9	69.2	.337	.08919	70.8	15.48	10.5	.52	17.6	5.9	...
	,,	,,	22,550	73.500	32 81	20 3	62.1	.345	.09482	69.1	15.8	10.0	.42	19.3	6.3	20,200
	,,	,,	22,500	73 340	32.74	20.3	62.1	.345	.09412	69.1	16.0	...	.08	25.3	8.3	14 350
	,,	,,	This specimen broke in the Alternating Machine.							...	...	8.4	...	...	...	27,650
Ditto, Medium	.625	.3068	31,250	101,860	45.47	30 6	67.2	.427	.1432	53.3	11.6	8.0	.41	12.0	5.5	...
	,,	,,	31,000	101.050	45.11	30.6	67.8	.400	.1257	59 0	12.6	8.4	.42	14.0	6.3	...
	,,	,,	30.750	100 240	44.75	30 6	68.6	.385	.1164	62.0	13.0	8.7	.44	14.3	6.3	...
	,,	,,	31,000	01,050	45 11	30 6	67.8	.404	.1280	58 1	12.4	8.4	.43	13.4	6.0	...
	,,	,,	31 250	101 860	45 47	32 0	70 4	.396	.1232	60.0	13.6	8.8	.40	16.0	7.3	20 800
	,,	,,	31,250	101.860	45 47	31.7	69.9	.407	.1301	57.6	12.0	8.2	.44	12.6	5.7	13,8' 0
	,,	,,	31,250	101,860	45 47	28.1	61.7	.393	.1213	60.4	12.7	8.6	.45	13.6	6.2	29,050
Ditto, Hard	.625	.3068	37,400	121,900	54 42	38 6	70 9	.480	.18095	41.0	9.6	6.6	.36	10.0	5.4	...
	.624	30582	36.750	120.170	53 64	38.6	72.4	.480	.18095	40.8	9.3	6.4	.35	9.6	5.1	...
	.625	.3068	37,580	122,500	54.68	39 2	74.5	.479	.18019	41.2	9.4	6.4	.34	10.0	5.5	...
	,,	,,	37,243	121,520	54 25	38 7	72.6	.480	.18070	41 0	9.4	6.5	.35	9.9	5.3	...
	,,	,,	37.750	123,050	54 93	38 7	70.4	.471	.17417	43.2	9.2	6.1	.30	10.3	5.7	15,050
	,,	,,	36 275	118,240	52 78	37 8	71.6	.433	.14705	52.0	9.1	6.7	.43	8.0	4.2	28,450
	,,	,,	36,275	118,240	52 78	37.0	70.3	.472	.17490	42.9	9.0	6.2	.34	9.6	5.1	15,500
											On 5"	On 2½"				
Ditto	0.745	.4359	56,200	129 000	57.6	40 9	71.0	.620	.3019	30,7	0.80	0.44	0.08	14.4	8.2	*
	0.745	.4359	54,200	124,500	65.6	44 2	79.0	.570	.2551	41 4	0.85	0.57	0.29	11.2	6.2	†

* Tested in an oil bath at a temperature of 505 per cent. F. † Tested in the ordinary way.

NOTE.—The extreme fibre stress in all the rotating tests was 54,085lbs. per square inch. Bending Moment $= M$, $f =$ intensity of fibre stress, $r =$ radius of specimen $= \cdot 3125''$. $f = \frac{My}{I} = \frac{M}{.775403}$ 54,085.

Crucible Steel.—Tensile strength, 36 tons per square inch; elastic limit, 19 tons per square inch; elongation on 8 inches, 25 per cent.

Three per cent. Nickel Steel.—Tensile strength, 45 tons per square inch; elastic limit, 30 tons per square inch; elongation on 8 inches, 18 per cent.

Six per cent. Nickel Steel.—The results of tension tests of this steel are fully recorded in Table IV.

Impact Tension Tests.—The great difficulty in these tests is the determination of the actual impact absorbed by the test piece. It is usual to make tests on standard bars, $l = 11.3 \sqrt{a}$, and to calculate the volume of the test piece on the cylindrical portion only. To obtain results which are comparable, it is necessary to use identical apparatus, sections and dimensions under identical conditions. The total impact of a number of blows of definite specific impact may be used as the quality factor, or the specific impact which will just fracture the piece with one blow. The following results were obtained by the author on various qualities of steel*, using the machine, fig. 1, dia. of specimen, eq. 0.3 inch; length of parallel portion eq. 3 inches; volume of parallel portion eq. 0.212 cu. ins; height of drop, 0.5 metres (20 inches). The extensions after each blow were measured with a cathetometre.

TABLE V.

Weight of hammer eq. 79 lb.

Description.	No. of Blows.	Total Extension up to last blow before fracture. inches.	Total Extension measured after fracture, inches.	Mean Extension per blow, inches.	Total Extension per cent. on 3 in. after fracture.	Work done in fracturing piece in feet-lbs.	Specific Impact in feet-lbs. per cubic inch.
Crucible Steel ..	6	0.756	..	0.151	..	787	3712
" "	7	0 681	0.90	0.113	30.0	918	4330
" "	7	0.796	0.90	0.133	3.00	918	4330
3 pr cent, Nickel Steel..	8	0.645	0.80	0.092	26.6	1049	4938
" " "	6	0 640	0.70	0.128	23.3	787	3712
" " "	6	0.880	0.90	0.126	30.0	787	3712
6 pr cent. Nickel Steel..	6	0.592	0.70	0.118	23.3	787	3712
" " "	7	0.664	0.75	0.110	25.0	918	4330
Axle Steel, cut from axle	7	0.916	1.00	0.153	33.3	918	4330
" " "	7	0.872	1.00	0.145	33.3	911	4330
Tyre Steel, cut from tyre	8	0.656	0.70	0.094	23.0	1049	4938
" " "	8	0.692	..	0.099	..	1049	4938

The following experiments were made on various sizes of test pieces, with a hammer weighing 122.5 lb., the length of the test pieces over which the elongations were measured was 6 inches.

The statical tension tests of this steel are recorded in Table IV.

TABLE VI.

Description.	Diameter in inches.	Volume in cubic inches.	No. of Blows.	Height of Drop. Average in feet.	Mean Extension per blow, measured on 3 inch.	Mean Extension per blow, measured on 6 inch.	Work done in breaking the bar, in feet-lbs.	Specific Impact in feet-lbs. per cubic inch.
6.1 pr cent. Nickel Steel, Mild ..	.625	1.8408	6	9·84	0.256	0.350	6831	3705
6.1 pr cent. Nickel Steel, Hard ..	.625	1.8408	6	9 84	0 138	0.183	7232	3929
6.1 pr cent. Nickel Steel, Mild ..	.400	0.7539	2	8 20	0.350	0.750	2009	2668
,, ,, ,, ,,	.400	0.7539	2	9 84	0.500	0.750	2411	3197
,, ,, ,, ,,	.400	0.7539	1	10.18	..	1.200	1247	1654
,, ,, ,, ,,	.400	0.7539	1	10.18	..	0.820	1240	1658
,, ,, ,, ,,	.300	0.4242	1	8 20	..	..	1005	2369
6.1 pr cent. Nickel Steel, Medium	.300	0.4242	1	7 54	0.580	..	924	2177
,, ,, ,, ,,	.300	0.4212	1	6 56	0.660	..	804	1895
,, ,, ,, ,,	.300	0.4242	1	4 92	0.620	..	603	1421
,, ,, ,, ,,	.300	0.4242	2	3.28	0.320	..	804	1895
,, ,, ,, ,,	.300	0.4242	1	4.10	0.550	..	603	1183
6.1 pr cent. Nickel Steel, Hard ..	.300	0.4212	1	3.62	0.450	..	442	1086

Comparing the results given in the Table No. V., with those given in Table No. VI., it will be seen that in order to obtain results which may be compared with each other, it is necesasry to keep all the conditions constant, which is accomplished by preparing all the specimens of the same, form and dimensions and testing them in the same machine under precisely the same conditions, such as the weight of the hammer, height of drop, and equal intervals of time between each drop; the specific impacts in ft., lb. per cubic inch will then represent the relative resistances to shock of the materials tested.

The following results, Tables VII. to X., were obtained by Mr. A. Morrison, B.E., Junior Demonstrator in Engineering, in connection with his thesis on Impact Tests, and supply useful information on tests of notched bars with the Charpy and the Guillery impact machines.

In the impact tension tests with the Charpy machine, the method is superior to that illustrated in Fig. 2, as the energy of rupture is more accurately determined, and the effect of the oscillating weight is more direct in consequence of the absence of the intermediate piece which receives the blow in Fig. 2.

It will be observed that some of the steel recorded in Tables Nos. VII. to X., give low results, although they all gave satisfactory results in the statical tension tests, for strength and ductility; impact tests of this character bring out the homogeniety of the material in a very decided manner.

Mr. Morrison also observed that in nearly all the fractures obtained in the impact tests with notched bars, there was a distinctly visible crystalline structure graded in size, from near the notch being very fine in grain, and gradually increasing in coarseness towards the compression side of the test piece. The rapid alternation of stress due to the shifting of the neutral axis away from the notch during the proces of rupture, accounts for the appearance of the fractured surface.

TABLE VII.

No.	Description.	Method.	Notch.		Specimen.				Energy of Rupture.		Angle of Rupture.	Remarks.
			Width.	Depth.	Length.	Breadth	Depth at Notch.	Section of Rupture.	Total.	Per sq. cm.		
			mm.	mm.	mm.	mm.	mm.	sq. cm.	kg.m.	k.gm.	0°	
1	Bessemer Steel ...	Guillery	2.00	1.99	60.0	9.94	7.94	0.790	22.5	28.49	..	Characteristic fibrous fracture.
2	" "	"	"	2.00	"	9.99	7.99	0.798	19.7	24.67	...	Very fine dark structure.
3	" "	"	"	2.02	"	9.98	7.96	0.795	21.7	27.28	...	Fine silky fracture, shows signs of cracking.
4	" "	"	"	2.04	"	9.98	7.95	0.794	24.7	31.09	...	Fine silky fibrous structure.
5	" "	"	"	2.00	"	10.00	8.00	0.800	17.75	22.19	...	Very fine dark structure, slight sign of longitudinal crack.
6	Lithgow Steel ...	"	"	2.00	"	10.00	8.00	0.800	16.00	20.00	...	Very dark colour with crystalline patch near side furthest from notch
7	Axle Steel	"	"	2.29	63.6	10.34	8.04	0.831	5.50	6.62	...	Very crystalline fracture.
8	" "	"	"	2.42	63.6	10.42	8.00	0.833	14.00	16.79	...	" " "
9	" "	"	"	2.26	63.5	10.23	7.96	0.865	17.75	20.51	...	Good clean fracture.
10	Crucible Steel ...	"	"	2.16	60.0	10.00	7.84	0.784	4.00	5.10	6.2	Crystalline fracture.
11	" "	"	"	2.22	"	"	7.78	0.778	4.00	5.14	4.7	" "
12	6 p.c. Nickel Steel	"	"	2.24	"	"	7.76	0.776	16.50	21.26	39.1	Good clean fracture.
13	" " "	"	"	2.20	"	"	7.80	0.780	16.50	21.16	28.2	" " "
14	3 p.c. Nickel Steel...	"	"	2.18	"	"	7.82	0.782	12.50	15.99	26.8	Coarse crystalline fracture.
15	" " "	"	"	2.16	"	"	7.84	0.784	12.50	15.94	26.2	" " "
16	Tyre Steel	"	"	2.18	,	"	7.82	0.782	5.40	6.91	6.1	Very coarse crystalline fracture.

NOTE.—Nos. 10 to 16 were of the same quality respectively as those recorded in Tables II., III., V. and VI.

TABLE VIII.

No.	Description.	Method.	Notch. Width.	Notch. Depth.	Specimen. Length.	Specimen. Breadth	Specimen. Depth of Notch.	Specimen. Section of Rupture.	Angle of Swing. Before	Angle of Swing. After.	Energy of Rupture. Total.	Energy of Rupture. Per sq. cm.	Angle of Rupture.	Remarks.
			mm.	mm.	mm.	mm.	mm.	sq.cm.	o	o	k.gm.	kg.m.		
17	Axle Steel, from broken axle ..	Charpy	2.00	2.11	59 6	10.04	7.94	0.797	162.5	102.5	12.11	15.19	..	Crystalline Fracture
18	Axle Steel, from broken axle ..	,,	,,	2.29	60.0	10.03	7.74	0.776	162.5	107.9	10.61	13.66	..	,, ,,
19	Axle Steel ..	,,	,,	1.92	60.0	9.94	8.02	0.797	,,	110.8	9.83	12.32	..	,, ,,
20	,, ,,	,,	,,	2.24	59 9	9 93	7.69	0.736	,,	111.7	9.59	12.57	..	,, ,,
21	,, ,,	,,	,,	2.35	63.5	10 32	7.96	0.822	162.0	109.0	10.27	12.50	..	Very crystalline fracture
22	,, ,,	,,	,,	2.41	,,	10 37	7.96	0 826	,,	105.0	11.37	13.77	..	,, ,,
23	,, ,,	,,	,,	2.52	,,	10.51	7.98	0 839	,,	150.0	1.40	1.67	..	,, ,,
24	,, ,,	,,	,,	2.00	60.0	10.00	8.00	0.800	163.4	116.0	8.54	10.67	..	Slightly Crystalline frac.
25	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	120.0	7.53	9.41	..	Very Crystalline
26	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	153.0	1.11	1.38	..	Crystalline fracture, showing absence of homogenity
27	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	155.0	0.85	1.07	..	
28	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	112.5	9.45	12.10	..	Specimens had a well-developed longitudinal crack, otherwise good fracture.
29	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	93.0	14.88	19.07	..	
30	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	127.0	5.85	7.32	..	Fractures showed decided want of homogeneity
31	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	127.0	5.85	7.32	..	
32	,, ,,	,,	,,	2.05	59.94	9.96	7.91	0.788	162.5	103.0	11.97	15.18	..	Good Fracture

TABLE IX.

No.	Description.	Method.	Notch. Width.	Notch. Depth.	Specimen. Length.	Specimen. Breadth	Specimen. Depth of Notch.	Specimen. Section of Rupture.	Angle of Swing. Before	Angle of Swing. After.	Energy of Rupture. Total.	Energy of Rupture. Per sq cm.	Angle of Rupture.	Remarks.
			mm.	mm.	mm.	mm.	mm.	sq.cm.	0°	0°	kg.m.	kg.m.	°	
33	Axle Steel ..	Charpy	2.00	2.00	60.00	10.00	8.00	0.80	162.0	113.7	9.12	11.39	32.5	Fairly Coarse Crystalline Fracture
34	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	116.0	8.50	10.62	34.4	Fairly Coarse Crystalline Fracture
35	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	121.0	7.25	9.07	27.2	Coarse Crystalline Fracture
36	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	123.0	6.76	8.45	25.7	Coarse Crystalline Fracture
37	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	112.7	9.36	11.68	34.5	Very Fine Crystalline Fracture
38	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	115.0	8.80	10.99	31.7	Very Fine Crystalline Fracture
39	Bessemer Steel..	,,	,,	,,	,,	,,	,,	,,	,,	92.5	14.91	18.63	,,	Very Fine Dark structure, sign of longitudinal crack
40	,, ,,	,,	,,	,,	,,	,,	,,	,,	,,	103.0	11.90	14.88	,,	Very fine silky structure
41	,, ,,	,,	,,	2.01	,,	9.96	7.96	0.79	,,	96.0	12.30	15.49	,,	Fine silky structure
42	Lithgow Steel..	,,	,,	2.00	57.00	10.00	8.00	0.80	,,	93.7	14.57	18.21	,,	Fine fibrous structure

Note.—The results obtained in the ordinary tension tests of the axle-steel i Nos. 33 to 38, were very regular. The tensile strength was 36.5 tons per sq. in., and the elongation measured on 8 inches 25 per cent.

TABLE X.
IMPACT TENSION TESTS.

No.	Description.	Method.	Gauge Dimensions.			Angle of Swing.		Energy of Rupture.		Elongation on		Local Elong'n.	General Elong'n, p.c.	Total Elong'n, p.c.	Remarks.
			Length	Diam.	Volume	Before Rupt're	After Rupt're	Total.	Per cu. cm.	cm. 6.350	cm. 3.175				
			cm.	cm.	cu.cm.	0°	0°	kg.m.	kg.m.	cm.	cm.	cm.			
1	Axle Steel, from broken axle ..	Charpy	6.350	0.6350	2.0109	162.5	..	32.59	16.21	1.98	..	..	..	31.18	Test piece did not fracture.
2	Axle Steel, from broken axle ..	,,	,,	,,	,,	,,	38.0	29.05	14.46	1.90	1.36	0.82	17.01	29.92	
3	Axle Steel, from broken axle ..	,,	,,	,,	,,	,,	..	32.59	16.21	1.94	1.08	0.22	29.09	30.55	Test piece did not fracture.
4	Axle Steel, from broken axle ..	,,	,,	,,	,,	,,	..	32.59	16.21	1.94	0.98	0.22	30.24	30.55	Test piece did not fracture.
5	Axle Steel ..	,,	,,	0.6324	1.9948	,,	99.5	13.15	6.59	0.873	0.793	0.714	2.50	13.75	
6	,,	,,	,,	..	,,	,,	62.75	23.54	11.80	1.438	1.111	0.794	10.00	22.50	
7	,,	,,	,,	0.6312	1.9968	,,	21.0	31.48	15.84	1.924	1.150	0.377	25.30	30.31	
8	Bessemer Steel ..	,,	,,	0.6350	2.0109	,,	83.0	17.94	8.92	0.754	0.555	0.357	6.25	11.87	
9	,, ,,	,,	,,	,,	,,	,,	82.4	18.11	9.01	0.774	0.556	0.337	5.87	12.19	

NOTE.—Nos. 1 and 2 are from the same material as Nos. 17 and 18, Table VIII,; Nos. 5, 6 and 7 are from the same material as Nos. 21, 22 and 23 of Table VIII.

The diagram, fig. 15, illustrates the grading of the size of the crystals in the fractured surface.

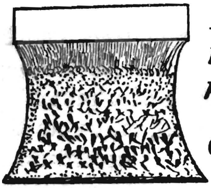

FIG. 15.

In nearly every case the crystalline structure started from a line near the notch, about one quarter the distance of the notch from the upper surface, indicating that the neutral axis is nearer to the notch than the geometrical axis of the test piece. Mesnager, by means of polarized light, and notched bars of glass, was able to render the neutral axis visible, and found that it is a wavy line passing closer to the notch than to the geometrical axis, the distance from the notch to the neutral axis being only 23 per cent. of the depth of the specimen at the notch. The effect of the notch therefore brings the neutral axis nearer to the notch than to the compresison face of the test piece.