REPORT NO. 320/8

SOME PROPERTIES OF HIGH TENSILE STEEL

by

M. F. Christensen

July 6, 1936

WATERTOWN ARSENAL

WATERTOWN, MASS.

F. A. Form No. 34. Frankford Arsenal—6-3-36—1000

W.A. REPORT No. 320/8

(1)

Rock Island Arsenal Laboratory

REPORT NO. 34-2201 A

SUBJECT Some Properties of High Tensile Steel.

AUTHOR M. P. Christensen

DATE July 6, 1936.
Refer to Report 34-2201, Revised as of March 26, 1936. (Material Specifications for Welded Steel Cartridge Cases.)

SF AT 5

55 RIA—6-29-36—500 sets of 7

ROCK ISLAND ARSENAL LABORATORY REPORT

OF

DATE 7-6-36

SOME PROPERTIES OF HIGH TENSILE STEEL

.B. NO. 24-2201A

SPEC. NO.

M. NO.

EX. O.

FINDINGS

1. This investigation shows that the so-called High Tensile steels offer many advantages over Structural Nickel steel for Ordnance applications.

2. Laboratory and shop tests together with actual production experience indicate that three of these High Tensile steels have unusual merits. These steels are U. S. S. Cor-Ten, Republic Double Strength and Alan Wood 70-90.

3. The attractive properties offered by these steels are: excellent weldability, good forming quality, high working strength, high ductility and toughness, freedom from air hardening properties and a minimum content of strategic material.

4. Some of the objectionable characteristics are: relatively poor procurement, patented compositions, and U. S. S. Cor-Ten and Republic Double Strength are relatively high priced, though cheaper than Structural Nickel composition. The Alan Wood 70-90 is a very low alloy steel having a price comparable with that of Structural Carbon steel.

5. Even though the surface finish of these several steels is not excellent it is so much better than Structural Nickel steel that it becomes highly advantageous in Ordnance construction.

6. The Alan Wood's 70-90 composition is produced by a balance of metallurgical properties such that the air quenching effect inherent in the chemical composition is compensated to a large degree by the relief of cold rolling stresses adjacent to the welded zone with the result that the over-all strength of the welded plate is uniform.

7. Corrosion studies over a period of a year indicate that these steels offer no practical advantage with respect to corrosion over that of Structural Nickel steel or even Low Carbon steel sheet material.

8. This factor of corrosion must be considered from two divergent standpoints: (1) How quickly a given steel will show corrosion when exposed to the atmosphere, and (2) when unprotected which steel will remain in useful service the longest.

9. For Ordnance applications there is no corrosion resisting low alloy steel and if material is to have a reasonable life expectancy protective coatings must be used. It is found that the so-called High Tensile steels corrode more rapidly during the earlier stages of the exposure than do the plain carbon and nickel steel types, but it is found that the corrosion is more generally distributed in the case of High Tensile steel with the result that failure of plates over a long period of time is not manifest in "spots" as is the case in the plain carbon and nickel steels.

10. A procurement survey shows that there are about twelve High Tensile compositions available in the United States. today. A specification prepared at Rock Island Arsenal under the designation of RIXS-71B, restricts this procurement to three steels because of a restriction in the percentage of nickel in the composition. This restriction was made in an effort to control the amount of strategic material present in the High Tensile sheet, since no advantage was to be gained over that of the Structural Nickel in this respect if the nickel were permitted to rise to the 3.5% figure.

11. This specification has been revised to make it commercial in every respect and especially in respect to tolerances. Procurement under the specification has secured High Tensile material at a substantial saving to the Government.

RECOMMENDATIONS

1. It is recommended that High Tensile steel procured under the attached tentative specification be used to replace Structural Nickel steel in Ordnance construction where welding and forming quality is of paramount importance. This recommendation is made in the interest of greater fabrication facility, lower immediate cost to the Government, and in the interest of strategic independence.

2. It is recommended that this specification be used in the procurement in this class of material and that it be

adopted as a tentative specification after the usual manner.

3. It is recommended that all sheet steels for Ordnance application be considered as non-resistant to corrosion and that proper steps be taken to insure the integrity of this material by frequent use of paint or other proper protective coatings.

4. It is recommended that the High Tensile type of sheet be used to replace SD-1035, now specified on a great many Ordnance Department drawings. This recommendation is made in the interest of the greater facility of procurement especially in some units where a heat treatment is contemplated or where greater stiffness is desired.

5. It is recommended that greater use be made of Low Carbon Cold Rolled sheet and strip where only moderate strength but good weldability and high forming quality is necessary.

6. It is recommended that the specifications for sheet, strip, and plate be revised with a view to bringing them up to date with respect to manufacturing technique, commercial tolerances and commercial designations; particular reference is made to United States Army Specifications 57-136A and 57- 14A.

7. It is recommended that the specification of Copper in Low Carbon sheet material be deleted, since Copper's contribution to corrosion resistance is doubtful and since Copper is fast becoming a random cyclic element in American made steels. Its presence in amounts varying from .09 -.18% makes it unnecessary as a specification factor.

AUTHORITY

Pursuant to instructions to O.O. file 473.86/949, requesting an investigation of U. S. S. Cor-Ten steel for use in the Light Caisson, T5, and as a substitute for nickel steel in the fabrication in mobile artillery, this study is submitted as a supplement to Rock Island Arsenal Laboratory Report 34-2201, covering related sheet steel used in the manufacture of cartridge storage cases, M5A1, and in immediate response to O.O. 472.12/4501, this report and the appended tentative specification for High Tensile sheet steel is forwarded for comment and approval.

METHOD OF INVESTIGATION

Preliminary studies were conducted on samples procured from the several manufactures of the following products: U. S. S. Cor-Ten, U. S. S. Man-Ten, Republic Double Strength Grade No. 1 Republic Double Strength Grade 1a; Alan Wood 70-90 and Yoloy manufactured by the Youngstown Sheet and Tube Company. These sample materials were compared with Structural Nickel steel procured under U. S. Army Specification 57-114A. The investigation included the study of the following factors: Forming Quality, Physical-Chemical Properties, Weldability, Procurement and Price, togetherwwith Corrosion Resistance to outdoor exposure over a period of more than one year. Through private communications other material was investigated and qualitative results concerning this material were used for comparison with those actually studied in this report.

After sufficient material had been procured for the preparation of a specification, Specification RIAS-71 was drafted and pursuant to instructions in O. O. file No. 473.16/949, material for Carriage Limbers, T3E3, and thirty Light Caissons, T5, was procured under this specification and fabrication from the High Tensile material was studied in its progress through Rock Island Arsenal shops. This method of procedure served a practical check on the finding of the laboratory and made possible the further important comparison of the several properties of this material with Structural Nickel steel, which has been the standard of fabrication of Ordnance Materiel for a number of years.

In the course of the investigation it was found that no uniformity existed, either among manufacturers or among purchasers of sheet steel products as to the specification of surface finish and in an effort to prevent the offering of inferior material by unscrupulous purveyors, a series of finish standards have been prepared at Rock Island Arsenal. These have been in use for three months in the procurement of all sheet steel products with marked success. Samples of these finish standards are appended hereto. They are used in the Arsenal's procurement in the following manner: samples of the several finishes are filed with the usual purveyors of sheet material, contracts and purchase orders make reference by number to the finish desired.

This situation was found necessary due to the fact that many purveyors offered Structural Nickel steel which had been so scaled as to interfere with fabrication operations. No verbal description seemed to impress several manufacturers with the same idea as to the quality of finish desired. The extensive scale common on the surface of Structural Nickel steel interfered with shearing, welding and flame cutting operations, and particularly with forming operations. Since the adoption of the finish standard for Structural Nickel steel (HIA finish No. 1) fabrication has been greatly facilitated and the quality of the welds in this class of material has been greatly improved.

The corrosion studies were conducted in the following manner: small sample specimens of the several High Tensile steels, Structural Nickel steel and the usual Low Carbon Sheet products were prepared in such a manner that a small equal area of the specimen was polished to microscopic perfection such that no scratches remained on the sample at 500 diameter magnification.

These samples were then placed on an outdoor exposure rack, one set being left on the rack for a period of thirty days between examinations, the other set being observed after each rainstorm. The steels were then rated according to their position in the series as indicated by the degree and extent of corrosion after the period of exposure mentioned.

In the case of the short time exposure specimens, it was found that High Tensile types of steel corroded more rapidly and more extensively than did the plain carbon and Structural Nickel steel products. But the long time exposure samples indicated that while corrosion progressed more rapidly at the beginning in the High Tensile steels, it was not localized and they, therefore, maintain their integrity for a longer period of time than did the Structural Nickel or plain carbon products.

This method of investigation of the corrosion properties of the several steels was highly satisfactory, principally because of its reproduceability. Each steel started from the same initial condition of polish and finish, and any corrosion changes may be therefore interpreted as being representative of the steels. The short time specimens were polished after each exposure to the weather, that is, each rainstorm became a distinct corrosion observation.

DATA AND OBSERVATIONS

The data and observations presented in this report must of necessity include a great deal of qualitative information. This particular investigation does not lend itself readily to quantitative determinations and a great many of the conclusions with respect to each of the steels studied must be based upon the opinions of those individuals who have had experience in working with the material. This is especially true of shop tests, since it is very difficult to get practical fabricators to place numerical values upon the properties which they consider desirable in a given class of material.

TABLE I shows a comparison of the chemistry of the several steels studied together with certain other steels of the High Tensile type manufactured in the United States.

TABLE II shows a comparison of the physical properties of these several steels.

TABLE III shows a set of average physicals as determined on the sheets procured for the fabrication of Carriage Limbers T3E3 and the Light Caissons, E5.

TABLE IV shows the relative standing of the steels on the basis of forming quality.

TABLE V shows this relative standing from the standpoint of weldability.

TABLE VI rates the steels according to their corrosion resistance, both as determined by the short time atmospheric exposure tests and by the long time weathering procedure.

TABLE VII shows a comparison of the prices and delivery intervals and the minimum quantities necessary to secure these prices and deliveries.

TABLE VIII places the steels in order of their strategic dependence, that is, the steel containing the most strategic material is placed at the top of the list and the steel containing the least is at the bottom. In evaluating the relative weights to be assigned to the several strategic elements the 1932 IMPORT-EXPORT, PRODUCTION-CONSUMPTION statistics, as reported by the Bureau of Foreign and Domestic Commerce, and by the United States Bureau of Mines Yearbook, have been determined and used in the following manner:

The known domestic production of a given strategic is added to the known importation of that element during the period used for the evaluation (1932). This sum less the total domestic exportation yields a net figure for domestic consumption of that strategic material. The ratio of the Net Consumption to the total Domestic Production is taken as the strategic factor. An example is cited in Table IX, showing the method of arriving at these relative weighted factors.

By this method of analysis Chromium is considered more strategic than either Manganese or Nickel. Whether this be a true picture of the situation or not it is one way of arriving at an otherwise difficult determination and is offered here for what it is worth.

TABLE X shows a further comparison of price and availability based upon gage extras and quantity discounts.

These figures are taken from actual bids on Circular Advertisements issued from this Arsenal during the past year.

TABLE XI shows a comparison of some of the properties of other High Tensile alloys manufactured in this country and abroad. This table was secured from the Iron Age of February 27, 1936.

TABLE XII shows the Hardness Distribution and "... EFFECT" in welded plates of the several High Tensile materials studied.

CONCLUSIONS AND DISCUSSION

A study of the several tables and the facts here observed convince us that the High Tensile steels offer a definite improvement over Structural Nickel steel as a material for Ordnance construction. It must also be concluded from the corrosion studies here presented that none of the sheet steel products offer true corrosion resistance, and that if the integrity of Ordnance materiel, fabricated from these steels is to be maintained, frequent applications of protective coatings will be necessary. This is no innovation since it has been the practice for a great many years. It is here urged that the fact be recognized so that the ultimate adoption of High Tensile steels will not be postulated upon the expectancy of improved corrosion resistance with a resulting reduction of maintainance attention.

Most of the High Tensile steels do not have to be stress relieved after welding but it is of course recommended that this better practice be continued. The stress relieving temperature will depend upon the composition of the alloy in question, but in most cases it will be the same as for Structural Nickel steel, except in the case of heat treated structures, when the stress relieving temperature will be limited by the tempering temperature of the initial treated sheet or plate.

It must be mentioned that there is some restriction as to the size availability of these steels, but this limitation has a great deal more to do with the quantity ordered than it does with any physical limitation imposed by the steel itself, since all the compositions here studied are capable of being rolled in the widths and thicknesses common to other structural compositions.

High Tensile steel should not be used in extremely deep drawing operations. Forming quality here discussed has reference to 180° Flat cold bends and drawing and cupping operations not in excess of three inches on a ten-inch diameter.

Before contemplating any severe drawing or cupping operation the design should be submitted to the steel manufacturer for his comment and recommendation. If such deep drawing quality is essential, then it is believed that the best interests of the Government would be served by not restricting the physical property requirements too closely. Most manufacturers will assume the responsibility of meeting deep drawing requirements but will not at the same time assume the burden of meeting physical property requirements unless those requirements are consistent with the ductility and stiffness necessary for the production of the drawing or cupping quality.

Thus far no limitation has been discovered affecting the weldability of these High Tensile steels. There is a decided need for more specific information as to the proper electrodes and technique to be used in fabricating this class of material, but it must be said generally that any electrode which will satisfactorily weld Nickel steel will also satisfactorily weld these High Tensile steels.

It has been found at this Arsenal that the soft washed electrode, having a light oxide coating offers many advantages in the fabrication of these special steels, yielding a weld which, when finished, has had its physical properties improved slightly by the diffusion of the alloying elements from the High Tensile base material into the bead from the alloy deficient soft electrode. The whole question of electrodes is one of super-imposed complexity, a complexity due almost entirely to the continued use and recognition of BRAND NAMES adopted by the electrode manufacturers to designate their particular product. Until the facts about electrodes and coatings can be set down in a restrictive specification this problem will persist. The situation is analogous to the tool steel situation at the close of the World War when Brand Names, rather than compositions and properties, were the chief specification factors of the day. Government procurement is particularly open to abuse if a specification delineating the composition and properties expected in the material is not available for the control of procurement. A great many unqualified bidders quote on Government circulars, offering an inferior product at a lower price.

These people bid on Government business chiefly because they know that the awards must be based upon price and because it affords them a certain amount of advertising script in that they are able to say to their commercial customers that they have furnished a government establishment with their product. No mention is made, of course, of how satisfactory that material might have been.

It is urged that a specification for welding rods and electrodes is decidedly needed in the Ordnance Department and it is believed that Watertown Arsenal with its facilities for metallurgical research could make a valuable contribution in this direction. The problem is a big one and its solution would undoubtedly be expensive but worth while.

Respectfully submitted,

Mitchell P. Christensen

Mitchell P. Christensen.

A. C. Hanson

Approved
Civilian in Charge of
Research.

[signature]

Approved
Officer in Charge of
Laboratory.

TABL

CHEMICAL COMPOSITION
LOW ALLOY HIGH T

	Brand Name	Manufacturer	C%	Mn%
1.	Nickel*	Several	.25/.45	.60/.90
2.	Cor-Ten*	U. S. Steel Corporation	.10 Max.	.10/.30
3.	Man-Ten*	U. S. Steel Corporation	.35 Max.	1.25/1.70
4.	Sil-Ten	U. S. Steel Corporation	.40 Max.	.60/.90
5.	Yoloy (Low)*	Youngstown Sheet & Tube Co.	.10 Max.	.10/.30
6.	Yoloy (High)	Youngstown Sheet & Tube Co.	.25 Max.	.60/.90
7.	Republic Double Strength #1*	Republic Steel Corporation	.12 Max.	.40/1.00
8.	Republic Double Strength #1A*	Republic Steel Corporation	.30 Max.	.40/1.00
9.	Allan Wood 70-90*	Allan Wood Steel Company	.10/.25	.50/.75
10.	Armco High Tensile	American Rolling Mills Co.	.30/.45	.70/.90
11.	Mayari High Tensile	Bethlehem Steel Corporation	.10/.15	.60/.90
12.	Hi-Steel	Inland Steel Company	.10 Max.	.30/.60
13.	Cromansil	Granite City Steel Company	.25 Max.	1.15/1.30
14.	Jal-Ten	Jones & Laughlin Steel Co.	.35 Max.	1.25/1.75

*Steels investigated at Rock Island Arsenal; for actual % studied see Table IA.

TABLE I

AL COMPOSITIONS OF AMERICAN MADE
ALLOY HIGH TENSILE STEELS

Mn%	Si%	P%	S%	Ni%	Cr%	Cu%	Mo%
.60/.90	.15/.30	.02/.04	.03/.05	3.00/3.75	Trace	Trace	Trace
.10/.30	.50/1.00	.10/.20	.05 Max.	Trace	.50/1.50	.30/.50	No
1.25/1.70	.15/.30	.02/.04	.03/.05	Trace	No	.20/.50	No
.60/.90	.20/.40	.02/.04	.03/.05	Trace	No	.05/.50	No
.10/.30	.20 Max.	.02/.04	.03/.05	.75/1.50	No	.80/1.00	No
.60/.90	.20 Max.	.02/.04	.03/.05	1.50/2.50	No	.75/1.25	No
.40/1.00	.20 Max.	.02/.04	.03/.05	.40/.60	No	.50/1.80	.20 [illegible]
.40/1.00	.20 Max.	.02/.04	.03/.05	.40/.60	No	.50/1.80	.30 [illegible]
.50/.75	.25 Max.	.10 Max.	.03/.05	.15/.25	.15/.25	.30/.50	Trace [illegible]
.70/.90	.05/.15	.02/.04	.03/.05	No	No	.20/.30	No
.60/.90	.30/.50	.03/.05	.03/.05	.30/.50	.80/1.00	.30/.50	No
.30/.60	.15 Max.	.05/.15	.03 Max.	.40/.60	No	.75/1.25	No
1.15/1.30	.60/.90	.02/.04	.03/.05	No	.25/.50	.50 Max.	No
1.25/1.75	.30 Max.	.02/.04	.03/.05	No	No	.30/.50	No

IA.

12

	Cu%	Cr%	Mo%	V%
75	Trace	Trace	Trace	Trace
	.50/1.50	.30/.50	No	No
	No	.20/.50	No	No
	No	.05/.50	No	No
0	No	.50/1.00	No	No
50	No	.75/1.25	No	No
	No	.50/1.80	.20 Max.	No
	No	.50/1.80	.50 Max.	No
	.15/.25	[illegible]	Trace .50	Trace
	No	.20/.30	No	No
	.80/1.00	.30/.50	No	No
	No	.75/1.25	No	No
	.25/.50	.50 Max.	No	No
	No	.30/.50	No	No

TABLE 1A

ACTUAL CHEMICAL COMPOSITION OF HIGH TENSILE
STEELS STUDIED AT ROCK ISLAND ARSENAL

Brand	Lot	Manufacturer	C%	Mn%	Si%	P%	S%	Ni%	Cr%	Cu%	Mo%	V%
Nickel	#1	Bethlehem Steel Company	.27	.67	.21	.036	.041	3.32	No	Trace	No	No
Nickel	#2	Inland Steel Company	.42	.69	.26	.020	.026	3.55	No	.05	No	No
Cor-Ten	#1	United States Steel Corp.	.10	.17	.65	.16	.037	No	1.12	.43	No	No
Cor-Ten	#2	United States Steel Corp.	.09	.25	.58	.16	.025	No	1.36	.47	No	No
Cor-Ten	#3	United States Steel Corp.	.10	.19	.69	.18	.031	No	1.27	.39	No	No
Man-Ten	#1	United States Steel Corp.	.26	1.56	.19	.031	.021	No	No	.20	No	No
Yoloy	#1	Youngstown Sheet & Tube	.08	.41	.17	.022	.030	2.23	No	1.06	No	No
R.D.S.#1	#1	Republic Steel Corporation	.11	.75	.21	.019	.026	.65	No	1.31	.16	No
R.D.S.#1A	#1	Republic Steel Corp.	.24	.82	.17	.021	.032	.74	No	1.33	.23	No
AW YO-90	#1	Alan Wood Steel Company	.19	.51	.11	.080	.025	.39	.06	.48	No	No
AW YO-90	#2	Alan Wood Steel Company	.16	.63	.14	.061	.019	.27	.04	.53	No	No
AW YO-90	#3	Alan Wood Steel Company	.18	.57	.16	.072	.031	.23	.08	.39	No	No

TABLE II

PHYSICAL PROPERTIES OF AMERICAN MADE LOW ALLOY HIGH TENSILE STEELS

	Brand Name	Manufacturer	Yield Stren Lbs. Per Square
1.	Nickel*	Several	50,000 to 60,0
2.	Cor-Ten*	U. S. Steel Corporation	50,000 to 60,0
3.	Man-Ten*	U. S. Steel Corporation	55,000 to 65,0
4.	Sil-Ten	U. S. Steel Corporation	45,000 to 50,0
5.	Yoloy (Low)*	Youngstown Sheet & Tube Co.	55,000 to 65,0
6.	Yoloy (High)	Youngstown Sheet & Tube Co.	65,000 to 75,0
7.	Republic Double Strength #1*	Republic Steel Corporation	55,000 to 65,0
8.	Republic Double Strength #1A*	Republic Steel Corporation	65,000 to 75,0
9.	Allan Wood 70-90*	Allan Wood Steel Company	55,000 to 65,0
10.	Armco High Tensile	American Rolling Mills Co.	55,000 to 65,0
11.	Mayari High Tensile	Bethlehem Steel Corporation	45,000 to 50,0
12.	Hi-Steel	Inland Steel Company	60,000 to 70,0
13.	Cromansil	Granite City Steel Company	50,000 to 60,0
14.	Jal-Ten	Jones & Laughlin Steel Co.	45,000 to 50,0

*Steels investigated at Rock Island Arsenal. For actual physical properties see Table

Yield Strength Lbs. Per Square Inch	Ultimate Strength Lbs. Per Square Inch	Elongation in 2" %	Hard Rockwe
50,000 to 60,000	85,000 to 100,000	25 to 20	85-95
50,000 to 60,000	75,000 to 85,000	26 to 21	75-85
55,000 to 65,000	80,000 to 90,000	24 to 19	80-90
45,000 to 50,000	85,000 to 95,000	22 to 18	85-95
55,000 to 65,000	70,000 to 80,000	[illegible]2 to 28	75-85
65,000 to 75,000	85,000 to 100,000	28 to 22	85-95
55,000 to 65,000	75,000 to 85,000	28 to 25	75-85
65,000 to 75,000	90,000 to 100,000	22 to 18	85-95
55,000 to 65,000	70,000 to 80,000	30 to 20	65-75
55,000 to 65,000	80,000 to 90,000	28 to 20	80-90
45,000 to 50,000	70,000 to 80,000	20 to 15	65-75
60,000 to 70,000	80,000 to 90,000	25 to 20	80-90
50,000 to 60,000	70,000 to 80,000	30 to 20	65-75
45,000 to 50,000	80,000 to 90,000	20 to 15	80-90

perties see Table IIA.

2

...ation in 2" %	Hardness Rockwell "B"	Bend Test
... to 20	85-95	180° One Thickness
... to 21	75-85	180° On Itself
... to 19	80-90	180° One Thickness
... to 18	85-95	180° One Thickness
... to 28	75-85	180° On Itself
... to 22	85-95	180° Two Thicknesses
... to 25	75-85	180° One Thickness
... to 18	85-95	180° Two Thicknessos
... to 20	65-75	180° on Itself
... to 20	80-90	180° One Thickness
... to 15	65-75	180° On Itself
... to 20	80-90	180° Ŏm Itself
... to 20	65-75	180° On Itself
... to 15	80-90	180° One Thickness

TABLE IIA

ACTUAL PHYSICAL PROPERTIES OF HIGH
TENSILE STEELS STUDIED AT ROCK ISLAND ARSENAL

Brand	Lot	Manufacturer	Yield Strength Lbs. Per Square Inch	Ultimate S[…] Lbs. Per S[…]
Nickel	#1	Bethlehem Steel Company	54,700	87,700
Nickel	#2	Inland Steel Company	62,400	99,100
Cor-Ten	#1	U. S. Steel Corp.	68,900	87,600
Cor-Ten	#2	U. S. Steel Corp.	65,400	65,300
Cor-Ten	#3	U. S. Steel Corp.	67,200	64,100
Man-Ten	#1	U. S. Steel Corp.	71,000	91,200
Yoloy	#1	Youngstown Sheet & Tube	58,100	71,300
R.D.S. #1	#1	Republic Steel Corp.	54,500	78,300
R.D.S. #1A	#1	Republic Steel Corp.	76,500	90,6[…]
AW 70-90	#1	Alan Wood Steel Co.	57,700	76,2[…]
AW 70-90	#2	Alan Wood Steel Co.	63,440	79,7[…]
AW 70-90	#3	Alan Wood Steel Co.	56,180	69,0[…]

All tests reported are on samples from material less than .250 inches thick and the thinnest sheet tested was .050 inches thick. Thin sheets will show higher hardness and ultimate strength but the yield strengths are quite consistant in all gages up to .250 inches.

Ultimate Strength Lbs. Per Square Inch	Elongations in 2"	Hardness Rockwell "B"	Bend Test -
87,700	25.4	86	90° Sharp -
99,100	21.5	91	90° Sharp -
87,600	25.7	86	180° On Its
85,300	23.6	84	180° On Its
84,100	22.3	83	180° On Its
91,200	24.6	87	90° Sharp -
71,300	31.3	66	180° On Its
78,300	29.6	84	180° On Its
90,680	17.5	92	90° Sharp -
76,200	28.5	68	180° On Its
79,720	21.5	71	180° On Its
69,000	26.0	64	180° On Its

...hes thick
...s will show
...e quite con-

2

Rockwell "B"	Bend Test - 1/8" Sheets
86	90° Sharp - 180° One Thickness
91	90° Sharp - 180° One Thickness
66	180° On Itself
84	180° On Itself
85	180° On Itself
87	90° Sharp - 180° One Thickness
66	180° On Itself
84	180° On Itself
92	90° Sharp - 180° Two Thicknesses
68	180° On Itself
71	180° On Itself
64	180° On Itself

TABLE III

AVERAGE PHYSICALS OF SHEETS USED IN
LIMBERS 75M3 & CAISSONS 75 X.O. 4710*

Thickness	Range	No. Tested	Yield Strength Lbs. Per Sq. Inch	Ultimate Strength Lbs. Per Sq. Inch	Elongation in 2"	Elongation in 8"
.0625	High	1	64,950	79,870	20.5	
.0625	Low	1	55,780	69,080	28.0	
.0625	Mean	57	59,900	75,000	23.7	
.093	High	1	62,400	80,070	25.0	
.093	Low	1	51,600	66,170	23.0	
.093	Mean	24	58,000	74,700	30.6	
.125	High	1	58,300	79,120		21.0
.125	Low	1	50,610	67,780		26.0
.125	Mean	4	54,200	72,900		23.5
.156	High	1	61,560	76,150		20.0
.156	Low	1	52,550	68,620		23.0
.156	Mean	9	54,900	73,000		21.9
.187	High	1	60,780	78,880		25.0
.187	Low	1	54,280	72,590		25.0
.187	Mean	12	58,300	75,250		21.9

*Material Allan Wood 70-90 Type "B".

TABLE IV

RELATIVE FORMING QUALITY

Brand	1/8" - 180° Flat Bend	1/8" - 90° Sharp Bend	1/8" - 180° Bend One Thickness	1/8" - 180° Bend Two Thicknesses
Allan Wood 70-90	Passed	Passed	Passed	Passed
Cor-Ten	Passed	Passed	Passed	Passed
R. D. S. #1	Passed	Passed	Passed	Passed
Yoloy	Passed	Passed	Passed	Passed
Man-Ten	Failed	Passed	Passed	Passed
Nickel (Low)	Failed	Passed	Failed	Passed
R. D. S. #1A	Failed	Failed	Failed	Passed
Nickel (High)	Failed	Failed	Failed	Passed

1/8" Stiffness by Spring Back-Least Stiff First	1/4" Shearing Order By Separation Depth-Best First
Allan Wood 70-90	1/64" Depth AW 70-90
Cor-Ten	1/32" Depth R.D.S. #1
Yoloy	1/32" Depth Yoloy
R. D. S. #1	3/64" Depth Cor-Ten
Low Nickel	5/64" Depth Man-Ten
Man-Ten	7/64" R. D. S. #1A
R. D. S. #1A	7/64" Depth Nickel (Low)
High Nickel	9/64" Depth Nickel (High)

Remarks: Stiffness was determined by the least deflection of a 6" x 1" x 1/8" Cantilever beam, resulting in a permanent set.

Shearing order was determined by measuring the granular separation fracture with a 15-Power Brinell microscope, reporting the separation depth to the nearest 1/64".

R. S. Ransom (Welding and Structural Steel Departments) states: "Material known as High Strength Steel, shears, fabricates and forms much more readily than Structural Nickel Steel usually specified for this work". Reference X.O. 4710.

TABLE V

RELATIVE WELDABILITY OF LOW
ALLOY HIGH TENSILE STEELS .187 INCH PLATE

Order Based Upon Ratio of Weld to Parent Metal	Remarks
AW 70-90 73,150/76,200 equals .96	W. W. Ransom states:
R.D.S. #1 72,500/78,300 equals .92	"In regard to welding, great strides are being made in the industry toward a development of electrodes for the material" (High Strength Steel).
Yoloy 62,900/71,500 equals .88	
Cor-Ten 64,200/87,400 equals .74	"At present, it can be said that this material is slightly easier to weld than Structural Nickel Steel and in the near future, it is to be expected that electrodes will be available with which High Strength Steels may be welded as readily as Structural Carbon Steel."
Man-Ten 65,100/91,200 equals .71	
R.D.S. #1A 64,200/90,680 equals .71	
Low Nickel 60,200/87,700 equals .69	"Therefore, from the shop standpoint, the adoption of this material is highly desirable in that there is much less wear and tear on tools and equipment, and intricately shaped parts can be hot formed at a lower temperature and there is less breakage of the parts."
High Nickel 67,800/99,100 equals .68	

TABLE VI

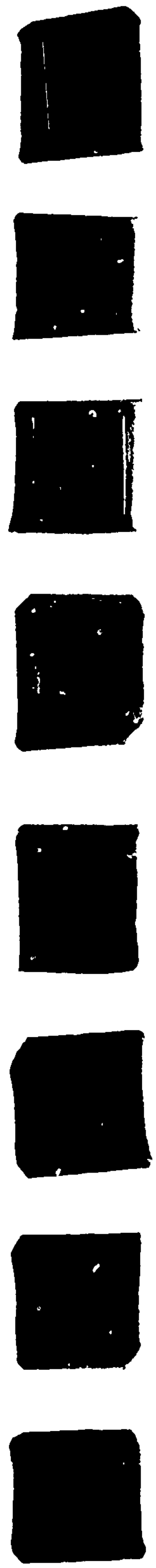
RELATIVE CORROSION RESISTANCE OF BOTH PLAIN CARBON AND HIGH TENSILE STEELS STUDIED AT ROCK ISLAND ARSENAL

	*Short Time Exposure 1/2" Square Specimens - Polished Metallographically Average of 19 tests except as noted		*Long Time Exposure Test 2" x 3" Macro-Polished Plates One Year Except as Noted	
1.	Weirton Cold Rolled (.10% C)	1.	R.D.S. #1	9 months
2.	Republic Hot Rolled (.17%C)	2.	Yoloy	5 months
3.	Weirton Hot Rolled (.24C and .24 Cu)	3.	Cor-Ten	
4.	Nickel Steel (High Carbon)	4.	R.D.S #1A	5 months
5.	Nickel Steel (Low Carbon) (11 tests)	5.	Man-Ten	
6.	Alan Wood 70-90 (11 tests)	6.	Cold Rolled (.24C & .22 Cu)	
7.	R.D.S. #1	7.	Nickel Steel (High Carbon)	
8.	R.D.S. #1A (5 tests)	8.	Nickel Steel (Low Carbon)	
9.	Cor-Ten	9.	Allan Wood 70-90	(5 months)
10.	Yoloy (5 tests)	10.	Weirton Cold Rolled (.10C)	
11.	Cold Rolled (.24 C & .22 Cu)	11.	Weirton Hot Rolled (.24C & .24 Cu)	
12.	Man-Ten	12.	Republic Hot Rolled (.17C)	

*Least Corroded First: See Plates A and B immediately following Table VI.
Note 1: For Composition and properties of the Carbon Steels see Lab. Report 34-2201.

ROCK ISLAND ARSENAL

531-40505, August 19, 1935
Comparative Corrosion Tests.



Man-Ten

Cold Rolled
(.24 C + .22 Cu)

Cor-Ten

Republic Double
Strength #1

Nickel Steel
(High Carbon)

Weirton Hot Rolled
(.24 C + .24 Cu)

Republic Hot Rolled
(.17 C)

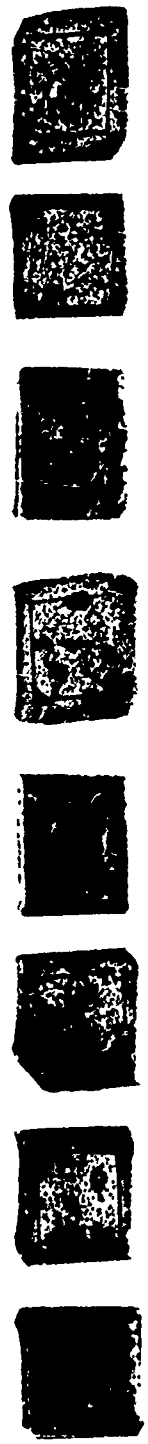
Weirton Cold Rolled
(.10 C)

Short Time Corrosion Specimens
1/2" Square Comparison Areas
AS POLISHED BEFORE RAIN EXPOSURE
August 19, 1935

Plate 531-40505-A

ROCK ISLAND ARSENAL

531-40506, August 19, 1935
Comparative Corrosion Tests



Man-Ten

Cold Rolled
(.24 C + .22 Cu)

Cor-Ten

R. D. S. #1

Nickel Steel
(High Carbon)

Weirton Hot Rolled
(.24 C + .24 Cu)

Republic Hot Rolled
(.17 C)

Weirton Cold Rolled
(.10 C)

Short Time Corrosion Test
Typically Corroded Polished Specimens
After 1-1/2 Hours Exposure to Rain
On Outdoor Rack August 19, 1935

Plate 531-40506-B

TABLE VII

PRICES, DELIVERIES AND MINIMUM QUANTITIES
BASED ON .125 INCH SHEET FOR COMPARISON

	$ per 100 lbs.	Delivery	Minimum Quantity	Sheet Thickness
Alan Wood 70-90	4.18	21 days	2,000 lbs.	1/8"
R.D.S. #1	5.93	28 days	2,000 lbs.	1/8"
R.D.S. #1A	5.93	28 days	2,000 lbs.	1/8"
[illegible]-Ten	4.83	60 days	2,000 lbs.	1/8"
Man-Ten	4.83	60 days	2,000 lbs.	1/8"
Structural Nickel*	12.78	5 days	1,000 lbs.	1/8"
Yoloy	5.43	45 days	2,000 lbs.	1/8"
Structural Carbon	3.23	5 days	1,000 lbs.	1/8"

*3/16" Structural Nickel is priced at $6.75; this situation reflects adversely against 1/8" Structural Nickel sheet. Note: Prices are those obtained on Circular Ads under Ord. Dept. Tentative Spec. AXS-71B. Structural Carbon and Structural Nickel prices are based on United States Army Specification 57-114A.

TABLE VIII
RELATIVE STRATEGIC DEPENDENCE

Most Strategic First	Strategic Weight
Cor-Ten (Cr and Mn)	681*
Nickel Steel (Ni and Mn)	156
Yoley (Ni and Mn)	94
AW 70-90(Cr, Ni and Mn)	46
RDS #1A(Ni and Mn)	35
RDS #1 (Ni and Mn)	32
Man-Ten(Manganese)	10

TABLE IX
STRATEGIC FACTORS

Sample Calculations: Chromium

1932 Production of Chromium in U.S. was 0.2 Metric Tons
1932 Importation of Chromium into U.S. was 90.6 Metric Tons
1932 Exportation of Chromium from U.S. was None
1932 Consumption of Chromium in U.S. was 90.8 Metric Tons

Therefore, the Strategic Factor for Chromium is:

$$\frac{90.6 - 0.2}{0.2} = 453$$

Similarly:

Nickel $\frac{8.4}{.2} = 42$

Manganese $\frac{133}{18} = 7.4$

Tungsten $\frac{4.6}{1.0} = 4.6$

*Thus, the Strategic Weight of Cor-Ten Steel is:

Cr % times Cr factor plus Mn % times Mn factor

Or:

$1.50 \times 453 = 679$

$.30 \times 7.4 = 2$

Strategic Weight 681

TABLE X

PRICES BASED ON GAGE DIFFERENCES
PER 100 POUNDS

Thickness	Allen wood 70-90	H.D.S. #1	Cor-Ten	Str. Nickel	Str. Carbon
1/16	$ 4.03	$ 5.23	$ 4.78	$ 6.97	$ 3.23
3/32	3.98	5.03	4.78	5.78	2.88
1/8	4.18	5.93	4.83	12.78	3.23
5/32	3.78	4.83	4.43	5.78	2.65
3/16	3.78	4.73	4.43	5.78	2.88
1/4	3.58	4.68	4.37	5.68	2.78

All prices based upon quantities in excess of 10,000 pounds but less than 20,000 pounds.

		Chemical Composition in Per Cent									Strength, Lb. per Sq. In.	Strength, Lb. per Sq. In.	in 8 In. Per Cent	Izod Ft.-Lb.	Charpy
		C	Si	Mn	P	Cu	Cr	Ni	Mo	V					
1	Ordinary Structural Cu-Bearing	0.20	...	0.40–0.60	0.04‡	0.20		...	...	...	25-30,000	50-60,000	25-30	...	25–35
2	High-Carbon	0.40–0.45	...	0.40–0.60	0.04‡	...	...	...	...	...	45,000	80-90,000	18-20	...	15-20
3	Nickel	0.40 0.45			...		...	3.25–3.50	...	...	50-60,000	85-100,000	18-20	40	
4	Mayari	0.40			...	...	0.50 0.75	1.25		...	50,000	85,000	19		
5	Ni-Mn	0.30	0.20	1.0		...		2-2.5			65,000	100,000	19	..	
6	Nickel	0.20	0.20	0.60	0.04‡			2-2.5			55,000	80,000	20-25	65	
7	Copper (Lorig)	0.10				1.0					55,000	76,000	25*†	..	
8	Copper (Nehl)	0.12				0.85				...	45-50,000	65-68,000	25	..	
9	Copper (Brupil)	0.16				1.0				...	50,000	70,000	26	..	
10	Copper (Hayward & Johnston)	0.05				0.85					60,000	70,000	25*		
11	Copper, pptn.-hardened (Smith & Palmer)	0.10			...	1.0					80,000	90,000	20*	..	
12	Yoloy	0.06				1.0		2.0			55,000	65,000	32*		
		0.22				1.0		2.0			85,000	90-96,000	27*		25
		0.24	0.20	0.67	0.05	1.0		2.0			60,000	80,000	27		50
13	Hi-Steel (Inland)	0.10	0.15	0.50	0.10	1.0		0.50			55-65,000	75-85,000	22		
14	Alan Wood	0.27	0.01	0.45	0.10	0.45					75,000	90,000	14-20		
15	Phos (Hunt)	0.09	0.01	0.40	0.50						50,000	80,000	23	(Very Low)	
16	Phos (d'Amico)	0.14			0.24						57,000	78,000	22	(Low)	21
17	Cu-P (Lorig & Krause)	0.07	0.02	0.47	0.26	1.4					65,000	80,000	27*	..	
18	Republic	0.22		0.75	...	1.2		0.75	0.16		70,000	90,000	20*	50	
	Dbl. Strength	0.08		0.70		1.4		0.75	0.11		65,000	74,000	21	76	
19	G.H.R.	0.12–0.25	0.50‡	1.0–1.2		0.35			0.15–0.25						
20	Corten	0.10	0.50–1.0	0.10–0.30	0.10–0.20	0.30–0.50	0.50–1.50				50-60,000	65-75,000	23	60	
21	Chromador (Haigh)	0.26	0.11	0.74	...	0.31	0.90				57,000	92,000	22		
	(Roberts)	0.22		0.80	...	0.30	0.90				52,000	85-100,000	17		
22	Union Baustahl	0.15	0.25	0.80	...	0.50–0.60	0.40								
		0.12	0.20	0.70	...	0.60	0.40	...			50-60,000	70-85,000	20-25		10-15**
		0.25	0.50	1.0		1.0	0.60								
		0.19	0.32	0.86	...	0.61	0.40								
23	Cromansil	0.06	0.87	1.12			0.25	...			54,000	71,000	31	61	
		0.16	0.76	1.34		††	0.47				62,000	91,000	26		
		0.21	0.72	1.17			0.47				50,000	92,000	30	36	
24	Krupp	0.12	0.30	1.2		0.30					55-60,000	80-85,000	20-28		
		0.25	0.50	1.6		0.40									
25	Lauchhammer	0.12	0.50	0.90		0.30					(Meets German specifications for Stahl 52)				
		0.25	0.70	1.1		0.60									
26	Common German Steel 52	0.12	0.40	0.75		0.25		...			(Meets German specifications for Stahl 52)				
		0.25	1.1	0.90		0.60									
27	Manten	0.23	0.23	1.40		0.20		...	...		65-70,000	88-98,000	19-20	..	
27a	Jalten	0.35 max.	0.30	1.25–1.75		0.40 min.					50,000	80,000	20	50	
28	Silten	0.40	0.20–0.30	0.70–0.90	...	0.20					45,000	80-95,000	24		
29	Delaware River Bridge	0.34	0.22	0.57							46,500	82-87,000	20-25	..	
		0.42	0.24	0.58											
30	Mauretania 1907	0.21	0.29	0.96							52,500	90,500	25		
		0.27	1.12	0.72							62,500	90,000	25-30		
											67,000	106,000			
31	Recent U. S. Navy	0.18	0.25	1.45		0.30				0.18	50,000	80,000	30		
32	Freund (1935)	0.14	1.06	0.57		0.18	0.09				56,500	76,000	25		
33	Low C-Mn (Lang 1911)	0.10	0.31	1.27		0.15					54,500	71,500	28	..	

*In 2 in.
**Charpy, mkg. per sq. cm.
†Normalized.
††0.50 per cent copper may also be present.
‡‡Molybdenum present, content as needed.
‡Maximum content; this element is usually less than this amount.

TABLE III

WELD HARDNESS SURVEY 1/8" SHEETS

Rockwell "B" Scale	Parent Metal	Heated Zone	Weld Metal	Heated Zone	Parent Metal
Cor-Ten	88	96	82	97	87
R.D.S. #1	87	95	86	96	88
R.D.S. #1A	91	97	84	97	90
Yoloy	66	75	77	75	67
AW 70-90	71	76	74	76	70
Man-Ten	87	92	81	93	86
Nickel	92	97	78	96	95
*Hot Rolled Carbon	58	69	82	74	59

*See Rock Island Report 34-2201 for other Low Carbon steels.

Rock Island Arsenal
Tentative Specification

RIA-[illegible]
April 17, 19[illegible].

STEEL, HIGH TENSILE, FOR ORDNANCE MATERIEL
(SHEETS, PLATES AND STRIPS)

I. GENERAL SPECIFICATIONS.

1. The current issue of the following specifications in effect on the date of invitation for bids, forms part of this specification:

Federal	QQ-M-151	Metals, General Specification for Inspection of.
U. S. Army 100-2		Standard Specification for Marking Shipments.

II. GRADES, TYPES, CLASSES, ETC.

1. Grades. This specification covers one grade of HIGH TENSILE steel.

2. Types. High Tensile steel shall be of three types as specified:

Type I - Sheets.
Type II - Plates.
Type III - Strips.

Distinction between sheets, plates and strips is included in Section IV, Table I, of this specification.

3. Conditions.

a. Sheets and strips shall be furnished in the following conditions as specified:

A-1 Hot Rolled Normalized.

A-2 Hot Rolled Annealed.

A-3 Cold Rolled.

A-4 Heat Treated.

A-5 Bright Annealed.

b. Plates shall be furnished in the following conditions as specified:

B-1 Hot Rolled as Rolled.

B-2 Hot Rolled Normalized.

B-3 Hot Rolled Annealed.

B-4 Heat Treated.

Material may be pickled and/or oiled as specified; if it is desirable to have the material unoiled, it should be so stated in the purchase order. Sheets and strips secured pickled or cold rolled should be ordered oiled.

III. MATERIAL AND WORKMANSHIP.

1.(a) The ingots, slabs or billets from which the sheets, plates or strips are made shall be manufactured by the electric furnace or open hearth process.

(b) Sufficient discard shall be taken from each ingot, slab or billet to insure freedom from injurious piping and undue segregation.

(c) Unless otherwise specified, the material shall be furnished in one of the following conditions at the option of the manufacturer - A1, A2, A3 or B1, B2, B3.

2.(a) All sheets, plates and strips shall be flat, free from seams, laminations, blisters, snakes, excessive and detachable scale, or any other injurious defect, and shall have a smooth, dull finish.

(b) Material ordered pickled shall be wholly free from scale.

(c) Material may be either roller or stretcher leveled, but sheets, plates and strips (except coils) shall be commercially flat.

IV. GENERAL REQUIREMENTS.

1. The steel furnished under this specification may be of any chemical analysis, except as limited in Table II, which will produce, by proper fabrication, a material which meets the physical property requirements of Table III, and which will weld with reasonable facility by the usual technique.

2. Sheets, plates and strips are distinguished on the basis of Condition, Thickness and Width of these flat rolled products as shown in Table I.

3. <u>BIDDERS ARE REQUIRED TO STATE THE "[illegible]" CHEMICAL COMPOSITION AND CONDITION OFFERED AT THE TIME OF MAKING PROPOSALS.</u>

4. THE SUCCESSFUL CONTRACTOR SHALL FURNISH A CERTIFIED REPORT OF THE PHYSICAL AND CHEMICAL PROPERTIES OF THE MATERIAL SHIPPED IN SATISFACTION OF THE CONTRACT OR PURCHASE ORDER, AT THE TIME OF SHIPMENT.

TABLE I

Uniform Classification of
Sheets, Plates and Strips

Product	3-1/2" or Less	Wider Than 3½", Less Than 6"	Wider Than 6", Less Than 24"	24" to 48"	Wider Than 48"
Plates	None	None	0.250 Thick and up.	0.250 Thick and up.	0.1875 Thick and up.
Sheets Hot Rolled	None	None	None	0.059 Thick to 0.250	0.059 Thick to 0.1875
Sheets Hot Rolled Annealed	Less Than 0.250 Thick	Less Than 0.034 Thick	Less Than 0.059 Thick	Less Than 0.059 Thick	Less Than 0.059 Thick
Sheets Cold Rolled	12" to 24" wide Less than 0.028 Thick			All Thicknesses	
Strips Cold Rolled	Less Than 12" Wide All Thicknesses		12" to 24" 0.029 Thick and up.	None	None
Strips Hot Rolled	0.025 to 0.250	0.035 to 0.250	0.059 to 0.250	None	None

NOTE:- Material 6" and narrower, and 0.250 thick and thicker shall be ordered as bar stock.

5. Plates may be either sheared or edge rolled, but must be within the dimensional tolerances shown in paragraph V-3.

. This specification contemplates ... when specified in the contract or purchase order, drawings or sketches shall accompany the advertisement for bids.

... REQUIREMENTS.

1.(a) Chemical Composition. Steels of any chemical composition whatsoever may be furnished under this specification subject to the limitations of Table II, provided the composition furnished is within the limits stated by the contractor in his original bid.

(b) The chemical analysis reported in the CONTRACTOR'S CERTIFIED REPORT shall be made from drillings taken at least 1/4" beneath the surface of a test ingot taken during the pouring of the melt, and there shall be at least one such analysis from each melt from which the material is made.

(c) A particular chemical analysis may be specified in the contract or purchase order at the option of the procuring agency.

TABLE II

Chemical Composition

Plates	Carbon	0.35%	Maximum
	*Nickel	1.00%	"
	Sulphur	.05%	"
Sheets and Strips	Carbon	0.20%	Maximum
	*Nickel	1.00%	"
	Sulphur	.05%	"

*NOTE:- Preference will be given to steels of compositions containing the least number and quantities of strategic materials.

2.(a) Physical Properties. Steels furnished on this specification shall conform to the physical properties required in Table III.

(b) Any detail requirement not included in this specification and deemed necessary to the procurement of satisfactory HIGH TENSILE material, shall be incorporated in the contract or purchase order.

[illegible]

Plates 2" to 4" Thick	Yield Strength	- 4[illegible]/sq. in. Minimum
	Elongation 8"	- 25.0% "
	Elongation 2"	- 2[illegible] "
	Bend Test (Cold)	- 180° to [illegible] diameter of [illegible] thicknesses.
	Must be of Arc and/or Acetylene Welding [illegible]	
Plates Less than 2" Thick	Yield Strength	- 45,000# sq.in. Minimum
	Elongation 8"	- 25.0% "
	Elongation 2"	- 20.0% "
	Bend Test (Cold)	- 180° to a diameter of [illegible] thicknesses.
	Must be of Arc and/or Acetylene Welding [illegible]	
Sheets and Strips	Yield Strength	- 50,000#/sq.in. Minimum
	Elongation in 8"	- 25.0% "
	Elongation in 2"	- 18.0% "
	Bend Test (Cold)	- 180° to a diameter of 1 thickness on material 0"[illegible] to 0"250.
	Bend Test (Cold)	- 180° flat on material [illegible] thick or less.
	Must be of Arc and/or Acetylene Welding [illegible]	

NOTE:- Unless otherwise specified, elongation may be measured in either a two or eight inch gauge length.

3. Permissible Variations.

(a) Sheet and Strip Thickness. The permissible variations in thickness of sheets and strips shall be shown in Tables IV, V and VI.

(b) Plate Thickness. The permissible variations in thickness of plates shall not exceed 0"010 under the thickness ordered. The variation over the ordered thickness shall not exceed the limits set by the American Steel Manufacturers Standard Practice.

(c) Plate Width and Length. The permissible variations in width and length shall not exceed 1/4" under the width or length ordered for sheared plates, nor 1/8" under the width or length ordered for rolled edge (Universal Mill) plates.

(d) Plate Camber. The permissible camber shall not exceed 1/8" in each five feet of length.

(e) Strip Camber. Permissible camber in strip shall not exceed 1/4" in each eight feet of length for strip wider than 1½", or ½" in each eight feet for strip 1½" wide or narrower.

(f) Sheet Camber. Permissible camber in sheets shall conform to Table VI.

(g) Strip Flatness. Maximum permissible bow shall be 1/2" in each eight foot of length.

TABLE IV

Permissible Thickness Variations in Sheets

Ordered Thickness - Inches	Permissible Variation from Ordered Thickness - Inches
0.250	0.016
0.249 to 0.220	0.015
0.219 to 0.190	0.014
0.189 to 0.160	0.013
0.159 to 0.140	0.012
0.139 to 0.120	0.011
0.119 to 0.100	0.010
0.099 to 0.080	0.009
0.079 to 0.070	0.008
0.069 to 0.060	0.007
0.059 to 0.050	0.006
0.049 to 0.040	0.005
0.039 to 0.030	0.004
0.029	0.003

NOTE:- The above tolerances will not apply to sheets 0.100 or thicker in widths over 60". Tolerances for such sheets shall be plus or minus 0.016.

... Unless otherwise specified in this specification, the contract or purchase order, American Steel Manufacturers commercial tolerances with respect to physical dimensions and weight shall apply.

4. Definitions.

(a) Hot Rolled Normalized material shall be air cooled from the final hot rolling temperature, or may be reheated to a temperature sufficiently above the critical range to produce grain refinement, and then be cooled freely in still air at room temperature. Such sheets shall be free from heavy scale.

(b) Hot Rolled Uniform Annealed material shall be reheated subsequent to final hot rolling to a temperature sufficiently above the critical range to produce grain refinement, and then be slowly cooled. This procedure shall be conducted in such a manner that the finished product shall have a uniform color and structure. Such sheets may be given one pass cold rolling or roller leveling to flatten.

(c) Cold Rolled Sheets.

1. Cold Rolled Sheets will be produced with a full pickled, full annealed treatment and sufficient cold rolling to produce a high degree of smoothness.

2. Cold Rolled Strip shall be produced by cold reduction and finished to a high degree of smoothness.

(d) Heat Treated material shall be slowly and uniformly heated to the correct temperature above the critical range, and then be quenched in an appropriate quenching medium.

(e) Bright Annealed material shall be annealed in such a manner that the material is unoxidized by this operation, and the finish produced prior to bright annealing shall be substantially the same after the annealing operation.

VI. METHODS OF INSPECTION AND TESTS.

1.(a) Check Analyses. Check analyses may be made by the inspector or through him by any Government Laboratory or other designated representative, and without cost to the contractor.

(b) Samples for check chemical analyses shall be taken by machining the entire cross-section of tensile test specimens.

[illegible] Number of Tests. [illegible] be made on each melt and each [illegible] for each different thickness of plate, sheet or strip.

(b) Tensile Specimen - Sheets and Strips. The tensile specimen for sheets and strips shall conform to the form and dimensions of Specimen TYPE 5, Section IV, Part [illegible], Federal Specification [illegible]-M-151.

(c) Tensile Specimen - Plates.

1. For plates under 2" in thickness, the tension test specimen shall conform to the form and dimensions of Specimen TYPE 2, Section IV, Part 5, Federal Specification [illegible]-M-151.

2. For plates 2" thick and over, the tension test specimen shall conform to the form and dimensions of TYPE 1, Section IV, Part 5, Federal Specification [illegible]-M-151.

(d) Bend Specimen - Sheets and Strips. The bend test specimen shall consist of a strip at least as wide as the strip material when this is less than 2", and for sheets and wide strip, the specimens shall be at least 2" wide; all bend specimens shall be not less than 6" long, with the edges machined parallel and rounded to not more than 1/16" radius.

(e) Bend Specimen - Plates. The bend test specimens for plate material shall be at least 1-1/2" wide with both edges machined parallel. Material thicker than 2" may be reduced to 2", but one rolled surface must be bent in the test; the edges of plate specimens shall be rounded to not more than 1/8" radius.

(f) Specimens shall be taken with the grain, i.e., in the direction of rolling, of the sheet, strip or plate. On thick plates, the specimen shall be taken from midway between the center and one surface of the plate. The inspector may take more than one tensile and one bend specimen if he so elects.

(g) Defective Specimens or specimens which break out of the gauge length shall be discarded and another substituted.

3.(a) Yield Strength - Sheets and Strips. Yield Strength of sheets and strips shall be the stress in pounds per square inch calculated for the load at which an elongation of 0.006 per inch of gauge length occurs. This elongation may be determined by the "divider method".

[illegible] from the [illegible] half of the gauge [illegible] "[illegible] method".

[illegible] Bend tests. The bend [illegible] shall [illegible] through 180° without cracking on the outside of [illegible] portion around a [illegible], the diameter of which has been fixed [illegible]

[illegible] Rejection. Material not meeting the requirements [illegible] this specification, or those of the contract or purchase order, shall be rejected and the contractor notified. Material [illegible] shows injurious defects while being fabricated, shall be rejected and the contractor notified.

VIII. [illegible]

1. Identification. All pieces, sheets or strips from the same melt or annealing heat shall be legibly stamped or tagged with the melt or heat number, or the contractor's identification number, and the manufacturer's name or brand. The identification mark shall appear in the Certified Report of Physical and Chemical Properties opposite the tabulation of these properties.

2. Invoice, packing slip or manifest of shipment shall be accompanied by the Certified Report or a copy of such report at the time of shipment. If a copy is sent with the shipment, the Certified Report shall follow at the earliest possible time.

3. Material shall be packed for shipment in accordance with commercial practice for acceptance by common and other carrier for safe transportation, at lowest cost, to the place of delivery.

4. Sheets shall be properly separated by grade and be protected against corrosion.

5. Sheets 1/16" or less in thickness shall be boxed. Sheets over 1/16" to 1/8", inclusive, shall be either boxed or crated; sheets over 1/8" shall be either bundled or wrapped.

6. Strips shall be furnished in coils when and as ordered.

7. Marking for shipment shall be in accordance with requirements of Specification 100-2.

... use of this specification for the material ... is mandatory on all procuring agencies of the Army.

NOTICE:- When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility or any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may be in any way related thereto.

NOTE:- Copies of this specification may be obtained from the Office of the Chief of Ordnance, Washington, D. C.