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JAPANESE METALLURGICAL SPECIFICATIONS IRON AND STEEL, SPECIAL STEELS SPECIAL NON-FERROUS ALLOYS

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SUMMARY

JAPANESE METALLURGICAL SPECIFICATIONS
IRON AND STEEL, SPECIAL STEELS, SPECIAL NON-FERROUS ALLOYS

This report contains tabulations of some of the more important metal lurgical specifications used in the Japanese Navy, including iron and steel, special steels and special non-ferrous metals. Principal critical alloying elements were nickel, molybdenum and tungsten. The substitute alloys developed did not approximate the prewar variety as closely as did the NE steels in the United States.

The critical metal-saving alloys were developed for special case-hardened parts, special structural steel, high-speed steel, non-magnetic wire rope, aircraft armor plate, ball bearing steel, non-ferrous alloy piston and cylinder head castings, special casting alloys, carbon steel, stainless steel cannon-ball steel, fish-torpedo steel, and others as indicated in the tables of this report.

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REFERENCES

Location of Target:

Yawata Technical Research Institute, YAWATA.

Navy Technical Bureau (Air).

Navy Technical Bureau (Ships).

Japanese Personnel Assisting in Gathering Documents:

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Comdr. Kazuma KOTO, IJN, Navy Technical Bureau (Air)

Capt. I. IWATA, IJN, Navy Technical Bureau (Supply)

Taiji IYOKU, Yawata Technical Research Institute, YAWATA.

Kanichiro TACHIBANA, Head of Control Section, Yawata Iron and Steel Company, Ltd.

Japanese Personnel Interviewed:

Capt. Ochito OHIRA (20 years experience as Naval Engineer; very capable).

Comdr. Kozuma KOTO (13 years technical experience; very capable).

Capt. I. IWATA, IJN, (no technical experience; substituted for a demobilized technical man).

Taiji IYOKU (30 years research experience; very able).

Kanichiro TACHIBANA (no technical experience).

LIST OF ENCLOSURES

(Charts of Common Iron and Steels - Prewar and Wartime Specifications - Physical and Chemical Properties)

(A) Carbon Steel (Prewar)

(B) Ni-Cr Steel (Prewar)

(C) Ni Steel (Prewar)

(D) Case-Hardening Steel (Prewar)

(E) Stainless Steel (Prewar)

(F) Cannon-Ball Steel (Prewar)

(G) Torpedo Steel (Prewar)

(H) Carbon Steel (Wartime)

(I) Ni-Cr Steel (Wartime)

(J) Ni Steel (Wartime)

(K) Case-Hardening Steel (Wartime)

(L) Stainless Steel (Wartime)

(M) Cannon-Ball Steel (Wartime)

(N) Torpedo Steel (Wartime)

(O) Armor and Shell Steel (Wartime)

INTRODUCTION

Severe shortages of metals, particularly nickel and cobalt, forced the Japanese to invent alloys without these elements: some were serviceable substitutes and the special alloys listed in the following reports are examples of these substitutes. In the more common iron and steel alloys both the prewar and emergency types are shown.

THE REPORT

PART I. SPECIAL STEELS

1. Since the principal metallic shortage of the Japanese was nickel, the first substitute steels to be examined are the nickel-conserving type. The composition of this series is listed in Table I and the physical properties in Table II.

TABLE I

NICKEL CONSERVING SPECIAL STEEL - CHEMICAL COMPOSITION

Use	Name	C	Si	Mn	P	S	Ni	Cr	Mo	W
Case Hardened Parts	Cr-Mo Steel (A107)	0.17~0.23	<0.35	0.70~1.0	<0.030	<0.030		1.0~1.5	0.20~0.40	
	Cr-Ni-Mo Steel (A108)	0.14~0.20	<0.40	<0.60	<0.030	<0.030	1.8~2.0	1.8~2.3	0.20~0.40	
Special Structural Steel	Low Cr-Mn-Mo Steel (A224) 1 2 3 4	0.30~0.37	<0.35	0.50~0.80	<0.030	<0.030		1.0~1.5	0.15~0.25	
	High Cr-Mn-Mo Steel (A225) 1 2	0.24~0.34	<0.40	0.60~1.0	<0.030	<0.030		2.3~2.7	0.20~0.40	
	Low Cr-Ni-Mo Steel (A226) 1 2 3	0.26~0.34	<0.40	<0.80	<0.030	<0.030	1.8~2.3	1.8~2.3	0.20~0.40	
Case Hardened Parts	High Cr-Ni-Mo Steel (A227)	0.25~0.30	<0.40	0.80~1.50	<0.030	<0.030	1.5~2.0	2.5~3.5	0.20~0.40	
	Cr-Ni-Mn-Mo Steel (A228)	0.15~0.22	<0.40	0.80~1.20	<0.030	<0.030	1.8~2.3	1.8~2.3	0.30~0.60	

TABLE II

HEAT TREATMENT & PHYSICAL PROPERTIES OF NICKEL CONSERVING SPECIAL STEELS

Use	Name		Normalize Temp.°C	Annealing Temp.°C	Quenching I °C	Temperature II °C	Tempering Temp.	Yield Point Kg/mm²	Tensile Strength Kg/mm²	Elongation %	Reduction of Area %	Impact Value KgM/Cm²	Brinell Hardness	Effective Diameter mm
Case Hardened Parts	Cr-Mo Steel (A107)		850~920	850 F.C.	850~920 in oil	800~850 in water	100~200	>80	>100	>15	>40	>16		
	Cr-Ni-Mo Steel (A108)		850~920	850 F.C.	850~920 in oil	780~850 in oil	100~200	>90	>110	>12	>40	>7		
Special Structural Steel	Low Cr-Mn-Mo Steel (A224)	1	830~880	850 F.C.	830~880 in oil		600~700	>70	>90	>18	>50	>9	262~321	<60
		2	830~880	850 F.C.	830~880 in oil		500~600	>80	>100	>15	>45	>7	285~363	<50
		3	830~880	850 F.C.	830~880 in oil		450~550	>95	>115	>12	>40	>5	331~401	<50
		4	830~880	850 F.C.	830~880 in oil		350~450	>115	>135	>7	>20	>3	375~429	<30
	High Cr-Mn-Mo Steel (A225)	1	850~920	700 A.C.	850~920 in oil		550~650	>80	100	>15	>40	>7	285~363	<120
		2	850~920	700 A.C.	850~920 in oil		500~600		>120	>10	>40	>4	331~401	<100
	Low Cr-Ni-Mo Steel (A226)	1	820~900	650 A.C.	820~900 in oil		550~670	>80	>100	>17	>40	>8	285~363	<150
		2	820~900	650 A.C.	820~900 in oil		530~630	>95	>115	>15	>40	>6	331~401	<150
		3	820~900	650 A.C.	820~900 in oil		950~550	>115	>130	>10	>30	>4	363~429	<100
Case Hardened Parts	High Cr-Ni-Mo Steel (A227)		850~910	700	850~910 in air		200		>160	>7	>25	>5	444~534	<150
	Cr-Ni-Mn-Mo Steel (A228)		850~920	650	850~920 in air		200	>100	>120	>13	>40	>8	341~415	<150

F.C. - Furnace Cool A.C. - Air Cool

2. Molybdenum was used in the nickel-conserving series but eventually became a secondary shortage itself. The molybdenum-conserving series is shown in Table III for chemical composition and Table IV for heat physical properties.

TABLE III

CHEMICAL COMPOSITION OF MOLYBDENUM CONSERVING SPECIAL STEEL

Use	Name	C	Si	Mn	P	S	Ni	Cr	Mo	W
Case Hardened Parts	Cr-W Steel (A137)	0.17~0.23	⟨0.35	0.70~1.00	⟨0.030	⟨0.030		1.0~1.5		0.4~0.8
	Cr-Ni-W Steel (A138)	0.14~0.20	⟨0.40	⟨0.60	⟨0.030	⟨0.030	1.8~2.3	1.8~2.3		0.4~0.8 (A.C)
	Cr-Al Nitriding Steel (A131)	0.35~0.45	⟨0.50	⟨0.60	⟨0.030	⟨0.030		1.4~1.7		0.6~1.0
Special Structural Steel	75 Kg. Si-Mn-Cr Steel (A232) 1 2 3	0.25~0.35	⟨0.7~1.0	0.7~1.0	⟨0.030	⟨0.030		0.7~1.0		
	90 Kg. Si-Mn-Cr Steel (A234) 1 2 3 4	0.33~0.40	⟨0.30~0.80	0.8~1.2	⟨0.030	⟨0.030		0.80~1.2		
	High Cr-Ni-W Steel (A237)	0.25~0.35	⟨0.40	0.8~1.5	⟨0.030	⟨0.030	1.5~2.0	2.5~3.5		0.4~0.8
	Cr-Ni-Mn-W Steel (A238)	0.15~0.22	⟨0.40	0.8~1.5	⟨0.030	⟨0.030	1.8~2.3	1.8~2.3		0.7~1.1

TABLE IV

HEAT TREATMENT AND PHYSICAL PROPERTIES OF MOLYBDENUM CONSERVING SPECIAL STEEL

Use	Name	Normalizing Temp. °C	Annealing Temp. °C	Quenching °C I	Temperature °C II	Tempering Temp. °C	Yield Point Kg/mm²	Tensile Strength Kg/mm²	Elongation %	Reduction of Area %	Impact Value Kgm/cm²	Brinell Hardness	Effective Diameter mm
Case Hardening Steel	Cr-W Steel (A137)	850~920	700 A.C.	850~820 in water	800 870 in water	100~200	>80	>100	>15	>40	>6		
	Cr-Ni-W Steel (A138)	850~920	700 A.C.	800~880 in oil	780 850 in oil	100~200	>90	>110	>12	>40	>7		
	Cr-Al Nitriding Steel (A131)	880~980	750 A.C.	88~980 in oil		700	>70	>85	>15	>50	>10		
Structural Special Steel	75 kg. Si-Mn-Cr Steel (A232)	850~900	850 F.C.	850~900 in oil or water		550~650	>60	>75	>20	>50	>10	212~277	⟨50
		850~900	850 F.C.	850~900 in oil or water		450~550	>75	>95	>13	>40	>6	269~341	⟨30
		850~900	850 F.C.	850~900 in oil or water		350~450	>90	>115	> 8	>35	>4	331~388	⟨30
	90 kg. Si-Mn-Cr Steel (A234)	850~900	850 F.C.	850~900 in oil or water		600~680	>70	> 90	>18	>50	>7	262~321	⟨60
		850~900	850 F.C.	900 in oil or water		450~600	>95	>115	>12	>40	>4	331~401	⟨50
		850~900	850 F.C.	850~900 in oil or water		450~600	>95	>115	>12	>40	>4	375~429	⟨40
		850~900	850 F.C.	850~900 in oil or water		350~500	>115	>135	> 7	>20	>3	375~429	⟨30
	High Cr-Ni-W Steel (A237)	850~910	700 A.C.	850~910 in air or oil		200		>160	> 7	>25	>5	444~534	⟨150
	Cr-Ni-Mn-W Steel (A238)	850~920	650 A.C.	850~920 in air or oil		200	>100	>120	>13	>40	>6	341~415	⟨100

Air Cool - A.C. Furnace Cool - F.C.

3. Tungsten, although relatively plentiful at the beginning of the war, in time became a critical material. Table V lists the composition of a tungsten-conserving series and Table VI the heat treatment and physical properties of the series. Tables VII and VIII give the pertinent data on a special low tungsten tool steel.

TABLE V

CHEMICAL COMPOSITION OF TUNGSTEN-CONSERVING SPECIAL STEEL

Use	Name	C	Si	Mn	P	S	Ni	Cr
Case Hardened Parts	Cr Steel (A147)	0.17~0.23	⟨0.35	0.70~1.00	⟨0.030	⟨0.030		1.0~1.5
	Cr-Ni Steel (148)	0.14~0.20	⟨0.40	⟨0.60	⟨0.030	⟨0.030	1.8~2.3	1.8~2.3
Structural Steel	High Cr-Ni Steel (A247)	0.25~0.35	⟨0.40	0.8 ~1.5	⟨0.030	⟨0.030	1.5~2.0	2.5~3.5
	Cr-Ni-Mn Steel (A248)	0.15~0.22	⟨0.40	0.8 ~1.2	⟨0.030	⟨0.030	1.8~2.3	1.8~2.3

TABLE VI

HEAT TREATMENT AND PHYSICAL PROPERTIES OF TUNGSTEN-CONSERVING SPECIAL STEEL

Use	Name	Normalising Temp. °C	Annealing Temp. °C	Quenching I °C	Temperature II °C	Tempering Temp. °C	Yield Point Kg/mm²	Tensile Strength Kg/mm²	Elongation %	Reduction of Area %	Impact Value Kgm/cm²	Brinell Hardness	Elective Diameter mm
Case Hardened Parts	Cr-Steel (A147)	850~920	700 A.C.	850~920 in water	800~870 in water	100~200	>80	>100	>15	>40	>6		
	Cr-Ni Steel (148)	850~920	700 A.C.	850~920 in oil	780~850 in oil	100~200	>90	>110	>12	>40	>7		
Structural Steel	Cr-Ni Steel (A247)	850~910	700 A.C.	850~910 in air		200		>160	>7	>45	>5	444~534	⟨150
	Cr-Ni-Mn (A248)	850~920	650 A.C.	850~920 in air		200	>100	>120	>13	>40	>6	341~415	⟨100

TABLE VII

COMPOSITION OF TUNGSTEN-CONSERVING HIGH SPEED STEEL

Specification No.	C	Si	Mn	P	S	Cr	W	V	Co
A821	0.65~0.90	⟨0.35	⟨0.50	⟨0.035	⟨0.035	3.5~4.5	9~12	1.3~1.8	
A822	0.65~0.90	⟨0.35	⟨0.50	⟨0.035	⟨0.035	3.5~4.5	10~13	1.3~1.8	3.4~4.0

TABLE VIII

HEAT TREATMENT AND HARDNESS OF TUNGSTEN CONSERVING HIGH SPEED STEEL

Specification Number	Annealing Temperature °C	Quenching Temperature °C	Tempering Temperature °C	Hardness at Annealed State Brinnell	Rockwell No. at Quenched and Tempered State	Forging Ratio
A821	850~880 F.C.	1240~1290	550~580	⟨248	>62	>9
A822	850~880 F.C.	1240~1290	560~590	⟨269	>63	>9

4. Aircraft armor and non-magnetic wire rope are metallurgical specialities on which considerable alloying materials were expended. These items are charted in Tables IX, X and XI.

TABLE IX

NON-MAGNETIC WIRE ROPE - CHEMICAL COMPOSITION

Name	C	Si	Mn	Ni	Cr	Dia. of Wire mm	Tensile Strength Kg/mm^2	Breaking Torsion (D X 100 length)
Non-Magnetic Wire Rope	0.10~0.20	<0.50	4.0~6.0	9.0~11.0	17.0~19.0	0.33	>135	>5

TABLE I

CHEMICAL COMPOSITION OF ARMOR PLATE FOR AIRCRAFT

	Specification Number	C	Si	Mn	P	S	Ni	Cr	Mo	Thickness of Plate mm
Armor Plate	B601	0.35~0.40	<0.35	0.8~1.0	<0.030	<0.030	2.5~3.5	1.5~2.0	0.40~0.60	3.0, 4.0, 5.0, 6.0
	B602	0.18~0.25	0.6~1.0	0.8~1.2	<0.030	<0.030		1.0~1.5		8.0, 12.0
	B603	0.23~0.30	0.6~1.0	0.8~1.2	<0.030	<0.030		1.0~1.5		16.0

TABLE XI

HEAT TREATMENT AND PHYSICAL PROPERTIES OF ARMOR PLATE FOR AIRCRAFT

	Specification Number	Normalizing Temp. °C	Annealing Temp. °C	Quenching Temp. °C	Tempering Temp. °C	Tensile Strength Kg/mm^2	Elongation %	Impact Value Kgm/cm^2	Hardness			Hardness at Case Hardened
									R.C.	V.H.N.	B.H.N.	B.H.N.
Armor Plate	(B601)	850~900	700	850~900	100~180	>190	>6		48~54	510~550	500~560	
	(B631)	850~900	700	850~900	100~200	>140	>8	>7		390~435	375~415	>570
		850~900	700	850~900	100~200	>150	>5	>5		435~474	415~461	>570

5. A chromium-tungsten type steel was used for ball-bearings as examined in Tables XII and XIII.

TABLE XII

CHEMICAL COMPOSITION OF BALL BEARING STEEL

Name	Specification Number	C	Si	Mn	P	S	Cr	W
Cr-W Steel	(A511)	0.50~0.65	0.80~1.0	<0.70	<0.030	<0.030	6.7~8.0	6.7~8.0
Low Cr-W Steel	(A513)	0.55~0.65	0.7~0.90	<0.70	<0.035	<0.035	5.5~6.5	3.0~3.5

TABLE XIII

HEAT TREATMENT AND PHYSICAL PROPERTIES OF BALL-BEARING STEEL

Name	Specification Number	Annealing Temp. °C	Quenching Temp. °C	Tempering Temp. °C	Yield Point Kg/mm^2	Tensile Strength Kg/mm^2	Elongation %	Reduction of Area %	Hardness R.C.
Cr-W Steel	(A511)	900~950 Furnace Cool	1100~1200 Air Cool	500 Air Cool	>30	>70	>10	>20	
Low CR-W Steel	(A513)		1000~1050 Air Cool	530~550 Air Cool					>50

PART II. NON-FERROUS ALLOYS

1. This shortage of alloying elements also made itself felt in the non-ferrous field, particularly that of the high-strength light alloys. Tables XIV and XV show high strength casting and forging materials. Table XVI gives the physical and chemical properties of a series of high-strength sheet materials while Table XVII shows a special high strength casting alloy.

TABLE XIV

CHEMICAL COMPOSITION & PHYSICAL PROPERTIES OF NICKEL CONSERVING HIGH STRENGTH LIGHT ALLOY

Use	Spec. No.	Cu	Mg	Mn	Si	Fe	Ni	Tensile Strength Kg/mm²	Elongation %	Hardness Brinell	Annealing Temp.	Quenching Temp.	Tempering Temp.
Piston	C 312	0.5~1.3	0.8~1.5		11.5~13.5	<0.8	0.5~1.3	>35	>2	>110		550°C W.C.	160°C
	C 313	2.5~3.5	1.0~2.0	0.2~0.4	0.6~1.0	<0.8		>30	>5	>90		500~530°C W.C.	200°C
Cylinder Head Casting	C 505	3.5~4.5	1.0~2.0		<0.8	<0.8	1.5~2.5	>20			350°C A.C.		
								>28		95	350°C A.C.	500~520°C W.C. or A.C.	200°C
	C 507	3.5~4.5	1.0~2.0	0.2~0.5	<1.0	<0.8		>18					
								>25		90	400°C A.C.	490~510°C W.C. or A.C.	200°C

TABLE XV

CHEMICAL COMPOSITION & PHYSICAL PROPERTIES LIGHT ALLOY CASTINGS

Specification Number	Tensile Strength Kg/mm²	Elongation %	Brinell Hardness	Quenching Temp.	Tempering Temp.	Cu	Mg	Mn	Si	Fe	Zn
C 502	>16	>2				3.5~4.5	<0.2		4.0~5.0	<0.8	
	>28	>1	90	500°C W.C.	150°C						
C 512	>14					2.0~4.5	<1.5		3.0~6.0	<1.5	<1.5
	>24		>90	500°C W.C.	170°C						
C 504	>18	>3					0.3~0.8	0.3~0.8	8.0~10.0	<0.8	
	>25	>2	95	520°C O.C.	170°C						
C 514	>15					<4.0	<1.5	<0.8	6.0~10.0	<1.0	
	>20		>90	520°C O.C.	170°C						
C 602	>16	>2				3.5~4.5			4.0~5.0	<1.5	<1.0
C 612	>14					2.0~4.5	<1.5		3.0~6.0	<2.0	<1.5
		>10						(Fe <2.0%)	(Si Fe <10%)		
		>10						(Fe <2.0%)	(Si Fe <10%)		

O.C. - Oil Cool W.C. - Water Cool

TABLE XVI

CHEMICAL COMPOSITION & PHYSICAL PROPERTIES HIGH STRENGTH SHEET MATERIAL

Specification Number	Heat Treat	Diameter of Thickness mm	Yield Point Kg/mm²	Tensile Strength Kg/mm²	El. %	Annealing Temp. °C	Quenching Temp. °C	Tempering Temp. °C	Cu	Mg	Mn	Si	Fe	Zn	Cr	Al
C267	H.D.H.	<3.0	>27	>40	>8		400~440 W.C.		0.8	1.5~2.5	0.3~0.8	0.5	<0.6	5.0~5.8	0.1~0.4	
		<3.0	>28	>43	>8		400~440 W.C.	110~130 x 24H	0.8	1.5~2.5	0.3~0.8	0.5	<0.6	5.0~5.8	0.1~0.4	
	H.D.T.	<3.0	>45	>50	>6		400~440 W.C.	110~130 x 24H	0.8	1.5~2.5	0.3~0.8	0.5	<0.6	5.0~5.8	0.1~0.4	
		<3.0	>48	>53	>6		400~440 W.C.	110~130 x 24H	0.8	1.5~2.5	0.3~0.8	0.5	<0.6	5.0~5.8	0.1~0.4	
C262	S.D.H.	<3.0	>27	>40	>12		490~500 W.C.		3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			
		<3.0	>28	>43	>12		490~500 W.C.		3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6	5.0~5.8	0.1~0.4	
C222	S.D.O.	<0.4	25	>25	>12	360 A.C.			3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			
		0.4~6.0	25	>25	>15	360 A.C.			3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			Bal
		6.0~10.0	25	>25	>12	360 A.C.			3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			
	S.D.H.	<0.4	27	>42	>12				3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			
		0.4~2.0	28	>43	>14		490~500 W.C.		3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			
		2.0~6.0	28	>44	>15		490~500 W.C.		3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			Bal
		6.0~10.0	28	>44	>12		490~500 W.C.		3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			
		10.0~25.7	27	>43	>12		490~500 W.C.		3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			
	S.D.R.	<0.4	31	>43	>18		490~500 W.C.		3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			Bal
		0.4~2.0	32	>44	>10		490~500 W.C.		3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			
		2.0~6.0	33	>45	>12		490~500 W.C.		3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			
		6.0~10.0	33	>45	>12		490~500 W.C.		3.8~4.8	1.2~1.8	0.4~1.0	<0.5	<0.6			
C282	H.D.		The Same with S.D.			360 A.C.	490~510 W.C.		4.0~4.8	0.6~1.2	0.6~1.0	0.6 1.0	<0.8			R

A.C. - Air Cool W.C. - Water Cool SD - Plate

TABLE XVII

SPECIAL CASTING ALLOY (HIGH STRENGTH) - CHEMICAL COMPOSITION

Specification Number	Hardness H-V	Annealing Temp.	Quenching Temp.	Tempering Temp.	Cu	Mg	Sn	Al
4701	40	200°C A.C.			2.0~3.0		7.0~9.0	<02 bal.
4702	60 110	300°C A.C.	500°C quickly cool	200°C	3.5~4.5	1.0~2.0	2.0~4.0	<02 bal.

2. The more common types of iron and steel for shipbuilding purposes are shown in specification form in Enclosures (A) to (O). In most cases both the prewar and emergency types are shown.

3. To summarize, the Japanese were critically short of nickel and cobalt and had to use substitute alloys. Molybdenum was substituted until it became a secondary critical item, and tungsten, too, was eventually in short supply. Japanese shortages were much more severe, however, than those which made the "NE" series of steels necessary in the United States, and the substitute alloys were proportionally inferior.

ENCLOSURE (A)

Carbon Steel - Prewar										
Kind	Mark	C	Si	Mn.	P	S	Cr.	Breaking Point Kg/mm²	Elong-ation %	Bending Angle
No.1	A 15	.11~.15	.05~.30	.3~.7	<.03	<.03	<.15	34~40	90 B +1.5L	180
No.2	A 20	.16~.20	.05~.30	.3~.7	<.03	<.03	<.15	39~45	90 B +1.5L	180
No.3	A 25	.21~.25	.05~.30	.3~.7	<.03	<.03	<.15	44~50	90 B +1.5L	180
No.4	A 30	.26~.30	.05~.30	.3~.7	<.03	<.03	<.15	49~55	90 B +1.5L	180
No.5	A 35	.31~.35	.05~.30	.3~.7	<.03	<.03	<.15	54~60	90 B +1.5L	180
No.6	A 40	.36~.40	.05~.30	.3~.7	<.03	<.03	<.15	60~70	90 B +1.5L	180
For Forging	A 45	.41~.45	.05~.30	.3~.7	<.03	<.03	<.15			
For Forging	A 50	.46~.50	.05~.30	.3~.7	<.03	<.03	<.15			
High Carbon Steel	A 55	.51~.55	.05~.30	.3~.7	<.03	<.03	<.15			
	A 60	.56~.60	.05~.30	.3~.7	<.03	<.03	<.15			
	A 65	.61~.65	.05~.30	.3~.7	<.03	<.03	<.15			
	A 70	.66~.70	.05~.30	.3~.7	<.03	<.03	<.15			
No.1	SF34				Acid <.055 Basic <.045	<.050 <.050		34~40	90 B +1.5L	180
No.2	SF39					<.050		39~45	90 B +1.5L	180
No.3	SF44					<.050		44~50	90 B +1.5L	180
No.4	SF49					<.050		49~55	90 B +1.5L	180
No.5	SF54					<.050		54~60	90 B +1.5L	180
No.6	SF60					<.050		60~70	90 B +1.5L	180

ENCLOSURE (B)

Ni-Cr Steel Prewar																			
Kind			Mark	C	Si	Mn	P	S	Ni	Cr	Cu	Mo	Yield Point Kg/mm²	Breaking Point Kg/mm²	Elong-ation %	Contraction of Area %	Shock Value m-Kg	Hardness Brinnell
1st Class	No.1	A	SNC 60A	.25~.40	<.35	.35~.65	<.05	<.05	1.0~2.5	.3~ .9			<40	<60	<20	<45	<3.5	
		B	SNC 60B	.25~.40	<.35	.35~.65	<.035	<.035	1.0~2.5	.3~ .9			<40	<60	<20	<45	<3.5	
	No.2	A	SNC 70A	.25~.40	<.35	.35~.65	<.05	<.05	1.0~2.5	.3~ .9			<50	<70	<22	<50	<7.5	>200
		B	SNC 70B	.25~.40	<.35	.35~.65	<.035	<.035	1.0~2.5	.3~ .9			<50	<70	<22	<50	<7.5	>200
2nd Class	No.1	A	SNC 70C	.25~.40	<.35	.35~.65	<.05	<.05	2.5~3.5	.3~ .9			<50	<70	<20	<40	<3.5	
		B	SNC 70D	.25~.40	<.35	.35~.65	<.035	<.035	2.5~3.5	.3~ .9			<50	<70	<20	<40	<3.5	
	No.2	A	SNC 80A	.25~.40	<.35	.35~.65	<.05	<.05	2.5~3.5	.3~ .9			<65	<80	<18	<45	<7.5	>230
		B	SNC 80B	.25~.40	<.35	.35~.65	<.035	<.035	2.5~3.5	.3~ .9			<65	<80	<18	<45	<7.5	>230
3rd Class	No.1	A	SNC 75A	.25~.40	<.35	.35~.65	<.05	<.05	3~4	.5~1.0			<60	<75	<18	<45	<3.5	
		B	SNC 75B	.25~.40	<.35	.35~.65	<.035	<.035	3~4	.5~1.0			<60	<75	<18	<45	<3.5	
	No.2	A	SNC 90A	.25~.40	<.35	.35~.65	<.05	<.05	3~4	.5~1.0			<75	<90	<15	<40	<6.0	>260
		B	SNC 90B	.25~.40	<.35	.35~.65	<.035	<.035	3~4	.5~1.0			<75	<90	<15	<40	<6.0	>260
4th Class	No.1	A	SNC 90C	.25~.40	<.35	.35~.65	<.05	<.05	4~5	1~2			<75	<90	<12	<30	<7.5	>260
		B	SNC 90D	.25~.40	<.35	.35~.65	<.035	<.035	4~5	1~2			<75	<90	<12	<30	<7.5	>260
	No.2	A	SNC 150A	.25~.40	<.35	.35~.65	<.05	<.05	4~5	1~2				<150	<7	<25	<2.5	>420
		B	SNC 150B	.25~.40	<.35	.35~.65	<.035	<.035	4~5	1~2				<150	<7	<25	<2.5	>420
Barrel etc.			G 1	.2 ~.3	.05~.20	.3 ~.7	<.035	<.03	3~4	.6~1.0	<.20		<47	66~82	<16	<50	ft-lbs <20	>200
			G 7	.2 ~.3	.05~.20	.3 ~.7	<.035	<.03	1.5~2.0	1.0~1.5	<.20		<47	66~82	<16	<50	ft-lbs <20	>200
			G 8	.2 ~.3	.05~.20	.3 ~.7	<.035	<.03	1.5~2.0	1.0~1.5	<.20	.2~.4	<47	66~82	<16	<50	ft-lbs <20	>200

ENCLOSURE (C)

Ni Steel Prewar														
Kind		Mark	C	Si	Mn	P	S	Ni	Yield Point Kg/mm²	Breaking Point Kg/mm²	Elong-ation %	Contraction of Area %	Shock Value m-Kg	Brinnell Hardness
No.1	A	SN 65A	.3~.4	<.35	.3 .8	<.05	<.05	1.0~2.5	>38	>65	>22	>50	>4	
	B	SN 65B	.3~.4	<.35	.3 .8	<.035	<.035	1.0~2.5	>38	>65	>22	>50	>4	
No.2	A	SN 68A	.3~.4	<.35	.3 .8	<.05	<.05	2.5~3.5	>42	>68	>16	>30	>5	
	B	SN 68B	.3~.4	<.35	.3 .8	<.035	<.035	2.5~3.5	>42	>68	>16	>30	>5	
No.3	A	SN 70A	.3~.4	<.35	.3 .8	<.05	<.05	3~4	>47	>70	>16	>30	>5	>200
	B	SN 70B	.3~.4	<.35	.3 .8	<.035	<.035	3~4	>47	>70	>16	>30	>5	>200
No.4	A	SN 70C	.25~.35	<.35	.3 .8	<.05	<.05	3.5~4.5	>50	>70	>20	>40	>5	>200
	B	SN 70D	.25~.35	<.35	.3 .8	<.035	<.035	3.5~4.5	>50	>70	>20	>40	>5	>200

ENCLOSURE (D)

Steels for Case Hardening Prewar													
Kind	Mark	C	Si	Mn	P	S	Ni	Cr	Yield Point Kg/mm²	Breaking Point Kg/mm²	Elong-ation %	Contraction of Area %	Shock Value %
No.1	SH 50A	<.18	<.35	<.60	<.045	<.045			>30	>50	>20	>50	>7.5
	SH 50B	<.18	<.35	<.60	<.030	<.030			>30	>50	>20	>50	>7.5
No.2	SH 80A	<.18	<.35	<.60	<.045	<.045	2~3	<.3	>55	>80	>17	>45	>6.0
	SH 80B	<.18	<.35	<.60	<.030	<.030	2~3	<.3	>55	>80	>17	>45	>6.0
No.3	SH 90	<.15	<.35	<.60	<.030	<.030	3~4	<.5	>70	>90	>15	>45	>5.5
No.4	SH 95A	<.18	<.35	<.60	<.045	<.045	3~4	.5~1.0	>75	>95	>15	>45	>5.5
	SH 95B	<.18	<.35	<.60	<.030	<.030	3~4	.5~1.0	>75	>95	>15	>45	>5.5
No.5	SH 100	<.15	<.35	<.60	<.030	<.030	4~5	<.5	>80	>100	>12	>45	>5.0
No.6	SH 110A	<.18	<.35	<.60	<.045	<.045	4~5	.5~1.0	>90	>110	>12	>45	>5.0
	SH 110B	<.18	<.35	<.60	<.030	<.030	4~5	.5~1.0	>90	>110	>12	>45	>5.0

ENCLOSURE (E)

Stainless Steels - Prewar																
Kind	Mark	C	Si	Mn	P	S	Ni	Cr	Inside Radius	Bending Angle	Yield Point Kg/mm²	Breaking Point Kg/mm²	Elong-ation %	Contraction of Area %	Shock Value m-Kg	Hardness Brinnell
No.1	EB_3	.25~.40	<.60	<.5	<.035	<.035	7~10	14~19	B 1.0xr	18°	>45	>75	>45	>50	>11	170~220
No.2	EB_0	<.20	<.60	<.5	<.035	<.035	<2	11~15	B 1.0xr	18°	>40	>60	>25	>40	>9	170~230
No.3 A	EB_1	.2 ~.3	<.60	<.5	<.035	<.035	<1	11~15			>50	>70	>17	>25	>3	>200
No.3 B	EB_1	.2 ~.3	<.60	<.5	<.035	<.035	<1	11~15			>60	>80	>12	>20		>250
No.4	EB_7	.3 ~.4	<.60	<.5	<.035	<.035	<1	11~15			>60	>80	>12	>20		>250
	EB_8	<.20	<.5	<.5	<.04	<.04	7~10	12~19		18°	>40	>60	>45	>50	ft-lbs 40	160~220
	EB_5	.08~.12	<.5	<.5	<.04	<.04	7 ~ 9	14~17								
	EB_2	.2 ~.3	<.3	<.2~.6	<.035	<.030	1.5~2	12~14				75~95	>18		ft-lbs >25	

ENCLOSURE (F)

Ordinary Cannon-ball Steel Prewar													
Mark	C	Si	Mn	P	S	Ni	Cr	Cu	Mo	Yield Point Kg/mm²	Breaking Point Kg/mm²	Elong-ation %	Shock Value Ft-lbs
FS_3a	.41~.45	.05~.3	.3~ .7	<.045	<.04	1.2~1.7	<.25			>50	75~100	>12	
FS_3b	.53~.58	.05~.3	.8~1.4	<.035	<.03	0~ .3	.7~1.0			>50	75~100	>12	
FS_3c	.45	.3	.5	<.045	<.04	<1.7	<1.0			>50	75~100	>12	
GA	.4 ~.5	<.35	.3~ .7	<.035	<.035	1.5~2.0	.2~ .6			>55	80~100	>12	>10
No.1	.45	<.3	.5	<.045	<.04	<1.7	<1.0			>50	75~100	>12	>10
No.2	.45	<.3	.5	<.045	<.04	<1.7	<1.0			>50	75~100	>12	>15
No.3	.45	<.3	.5	<.045	<.04	.6~1.7	.5~1.0			>55	80~100	>12	>10

ENCLOSURE (G)

Steels for Fish-Torpedo-Prewar															
Mark	C	Si	Mn	P	S	Ni	Cr	Cu	Mo	Yield Point Kg/mm²	Breaking Point Kg/mm²	Elong-ation %	Contraction of Area %	Hardness Brinnell	Shock Value Ft-lbs
W 7	.22~.30	.05~.30	.6~1.0	<.03	<.03	1.4~2.0	.9~1.3	.8~1.2	.4~.6	>100 > 95	>110 >105	>13.5 >15	>27 >30	305~385	720~722
W 8	.33~.37	.8~1.2	.8~1.2	<.035	<.035		1.0~1.3	.25	.3~.5	>100 > 95	>110 >105	>13.5 >15	>27 >30	305~385	720~722
W 9	.27~.35	<.3	.8~1.2	<.035	<.035	.8~1.2	.8~1.2	.2~ .5	.25~.45	>100 > 95	>110 >105	>13.5 >15	>27 >30		
W F	.37~.43	<.3	.8~1.2	<.035	<.035	.3~ .7	.8~1.2	<.4	.05~.25		> 95	>12		280~385	
W 3	.25~.35	.05~.30	.3~.6	<.035	<.035	2.5~3.0	.6~ .9	<.2	.3 ~ .7	>100 > 95	>110 >105	>13.5 >15	>27 >30	305~385	720~722

ENCLOSURE (H)

Carbon Steel										
Kind	Mark	C	Si	Mn	P	S	Cr	Breaking Point Kg/mm²	Elongation %	Bending Angle
No.1	SMC_1	<.10	<.35	<0.75	<.05	<.05		32~45	>33	
No.2	SMC_2	.10~.20	<.35	<0.75	<.05	<.05		38~52	>30	
No.3	SMC_3	.20~.30	<.35	<0.75	<.05	<.05		45~58	>27	
No.4	SMC_4	.30~.40	<.35	<0.75	<.05	<.05		52~66	>23	
No.5	SMC_5	.40~.50	<.35	<0.75	<.05	<.05		58~73	>20	
No.6	SMC_6	.50~.65	<.35	<0.75	<.05	<.05		66~85	>15	

ENCLOSURE (I)

Ni-Cr Steel															
Mark	C	Si	Mn	P	S	Ni	Cr	Cu	Mo	Yield Point Kg/mm^2	Breaking Point Kg/mm2	Elong-ation %	Contraction of Area %	Shock Value Ft.lbs.	Hardness Brinnell
C_1	.2~.3	.05~.2	.3~.7	<.035	<.03	3~4	.6~1.0	<.20		>47	66~82	>16	>30	>20	>200
C_7	.2~.3	.05~.2	.3~.7	<.035	<.03	1.5~2.0	1.0~1.5			>47	66~82	>16	>30	>20	>200
C_8(NCM)	.25~.35	.05~.2	.3~.7	<.035	<.03	1.5~2.0	1.0~1.5	<.20	.2~.4	>47	66~82	>16	>30	>20	>200

ENCLOSURE (J)

Ni Steel												
Kind	Mark	C	Si	Mn	P	S	Ni	Yield Point Kg/mm^2	Breaking Point Kg/mm^2	Elong-ation %	Contraction of Area %	Shock Value m-Kg
No.1	SN 65A	.3~.4	<.35	.3~.8	<.05	<.05	1.0~2.5	>38	>65	>22	>50	>4
No.3	SN 70A	.3~.4	<.35	.3~.8	<.05	<.05	3~4	>47	>70	>16	>30	>4

ENCLOSURE (K)

Steels for Case Hardening												
Kind	Mark	C	Si	Mn	P	S	Ni	Cr	Yield Point Kg/mm^2	Breaking Point Kg/mm2	Elong-ation %	Contraction of Area %	Shock Value m-Kg
No.1	SH 50	<.18	<.35	<.60	<.045	<.045			>30	>50	>20	>50	>7.5
No.2	SH 80	<.18	<.35	<.60	<.045	<.045	2~3	<.3	>55	>80	>17	>45	>6.0
No.3	SH 90	<.15	<.35	<.60	<.045	<.045	3~4	>.5	>70	>90	>15	>45	>5.5

ENCLOSURE (L)

Stainless Steel													
Kind	Mark	C	Si	Mn	P	S	Ni	Cr	Yield Point Kg/mm^2	Breaking Point Kg/mm^2	Elong-ation %	Contraction of Area %	Shock Value m-Kg	Hardness Brinnell
No.2	EB_0	<.2	<.6	<.5	<.045	<.045	<2	11~15	>40	>60	>25	>40	>9	170~200
No.3	EB_1	.2~.3	<.6	<.5	<.045	<.045	<1	11~15	>50	>70	>17	>25	>3	>200
	EB_8	<.2	<.5	<.5	<.045	<.045	7~10	12~19	>40	>60	>45	>50	ft-lb >41	160~200

ENCLOSURE (M)

Ordinary Cannon-ball Steels													
Mark	C	Si	Mn	P	S	Ni	Cr	Cu	Mo	Yield Point Kg/mm^2	Breaking Point Kg/mm^2	Elong-ation %	Shock Value Ft-lbs
No.1	.45	<.3	.5	<.045	<.04	<1.7	<1.0			≯50	75~100	>12	>10
MC	.53~.58	.05~.3	.8~1.4	<.035	<.03	<.3	.7~1.0			>50	75~100	>12	>10

ENCLOSURE (N)

Steel for Fish-Torpedo

Mark	C	Si	Mn	P	S	Ni	Cr	Cu	Mo	Yield Point Kg/mm^2	Breaking Point Kg/mm2	Elong-ation %	Contraction of Area %	Hardness Brinnell	Shock Value Ft.lbs.
V_{11}	.35	.50	1.0	<.035	<.045	1.0	1.5	<.25	.20	>100 > 95	>110 >105	>135 >105	>27 >30	305/385	>20 >22
V_9	.3 ~ .35	<.3	.8~1.2	<.035	<.045	.8~1.2	.8~1.2	.3~.6	.2 ~ .4		>110 >105	>135 >105	>27 >30	305/385	>20 >22
V_F	.37~.43	<.3	.8~1.2	<.035	<.035	.3 ~ .7	.8~1.2	<.4	.05~.25		> 95	> 12		280/385	

ENCLOSURE (O)

		Chemical composition %									Mechanical properties					
		C	Si	Mn	P	S	Ni	Cr	Cu	Mo	Yield Point Kg/mm^2	Tensile Strength Kg/mm^2	Elong-ation %	Reduction of Area %	Impact Izod Ft-lbs	Remark
Armor Plate	PLI	.43/.53	.05/.25	.30/.45	<.035	<.030	3.7/4.2	1.8/2.2	<.20		NVNC	>50	85 26%	>18	>40	Mean >30 Min >25	Thickness >75 mm
											NVNC	>45	80 8%	>19	>40	Mean >35 Min >28	75~180
											NVNC	>40	75 10%	>20	>40	Mean >35 Min >30	>180
											VC	>45	80 8%	>19	>40	Mean >33 Min >28	75~180
											VC	>40	75 10%	>20	>40	Mean >33 Min >28	>180
											VH	>45	80 8%	>19	>40	Mean >33 Min >28	75~180
											VH	>40	75 10%	>20	>40	Mean >35 Min >30	>180
	PLIO	.38/.46	.05/.25	.30/.45	<.035	<.030	2.5/3.0	.80/1.30	.90/1.30		CNC	>60	85 6%	>19	>40	Mean >35 Min >30	<75
	PLII	.30/.38	<.35	.30/.45	<.035	<.040	3.3/3.8	1.8/2.2	.25	.25/.40	MNC	>50	85 6%	>20	>40	Mean >35 Min >30	75~180
												>40	75 10%	>28	>40	Mean >40 Min >25	>180
	CNC1	.36/.44	<.35	.30/.45	<.035	<.045	1.8/2.3	1.4/1.8	.6/1.0	.1/.25		>60	80/90	>19	>40	>30	
	CNC2	.36/.44	<.35	.30/.45	<.035	<.045	1.3/1.8	1.4/1.8	.60/1.0	.1/.25		>60	80/90	>19	>40	>30	
Shell Steel	SL3	.55/.65	<.40	<.30	<.030	<.030	2.5/3.0	2.0/2.6				35/70	70/100	>10	>20		Annealed Condition
	SL4	.45/.65	<.40	<.30	<.030	<.030	3.4/4.0	6.0/1.0		.40/.80		40/70	70/110	> 8	>10		Annealed Condition
	SL6	.43/.53	<.40	8/1.2	<.030	<.030	.8/1.2	1.8/2.2		.24/.40		35/70	70/100	>10	>20		Annealed Condition

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