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AN INVESTIGATION OF 18 NiCoMo (300)

MAR-AGING STEEL FORGINGS

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REPORT NO: FZM-2608
DATE: 10 MAY 1962

AN INVESTIGATION OF 18
NiCoMo (300) MAR-AGING
STEEL FORGINGS

OBJECTIVE:

To completely evaluate new high strength steels for use in critical applications, such as aircraft landing gears.

SCOPE:

To determine the mechanical properties of candidate alloys when used in heavy forged sections.

Testing to include:

1. Notch Toughness

Notch toughness testing of fatigue cracked, centrally notched specimens ($K_t = 17$) at R.T. and -65°F taken from 4" x 12" billets.

2. Heat Treat Response

Heat treat response tests to determine effects of aging temperature and time and grain direction within forging on F_{tu} , F_{ty} , R.A., $\%e$, and F_{tnu} ($K_t = 6.5$).

3. Fatigue

Fatigue properties in longitudinal and transverse directions tested in axial tension-tension fatigue. SN curves will be developed for stress concentration factors of 1 and 2.

4. Low Cycle Fatigue

Low cycle - high stress fatigue tests will be conducted to obtain failures between 0 and 100 cycles. The effect of environment will be studied.

5. Stress Corrosion

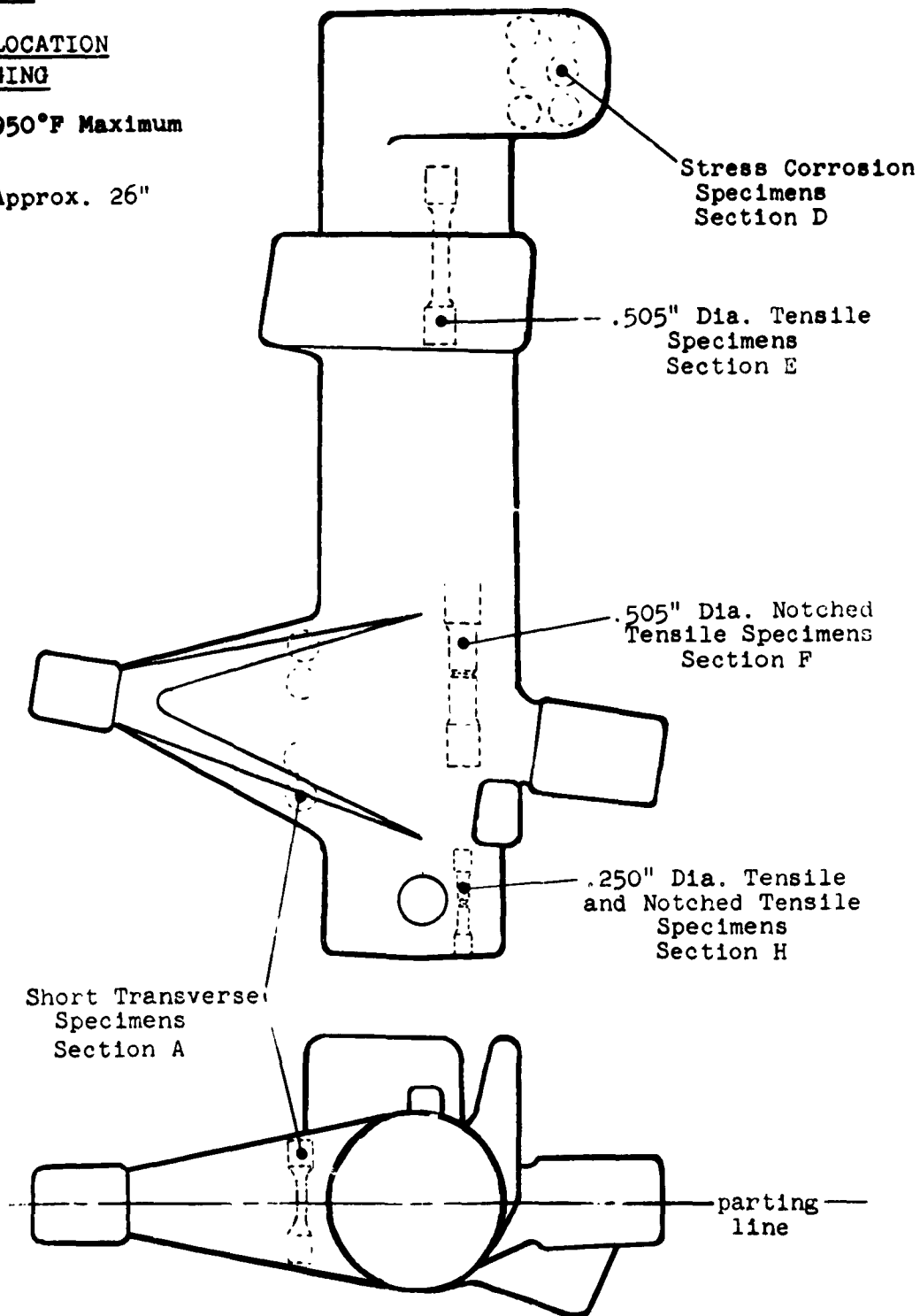
Stress corrosion data will be generated on axial loaded specimens using an alternate immersion 5% salt water solution-air test. Both smooth round specimens (short transverse direction) and sheet specimens cut from the long transverse direction of the 4" x 12" billet will be tested. A fatigue notch .030" long will be produced in one face of the sheet specimens to provide stress concentration.

FIGURE 1

SPECIMEN LOCATION
IN FORGING

Forged at 1950°F Maximum

Length - Approx. 26"



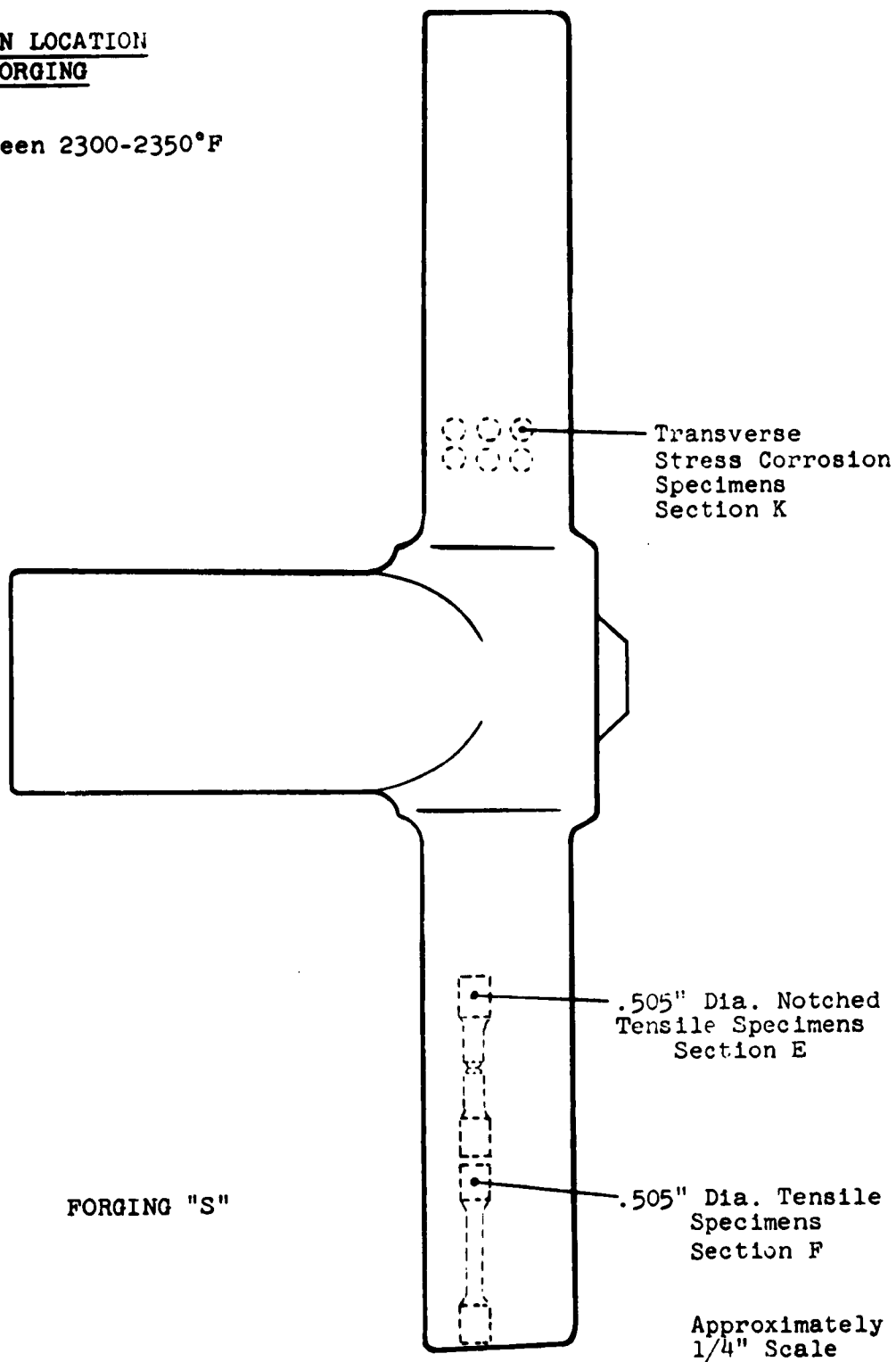
FORGING "W"

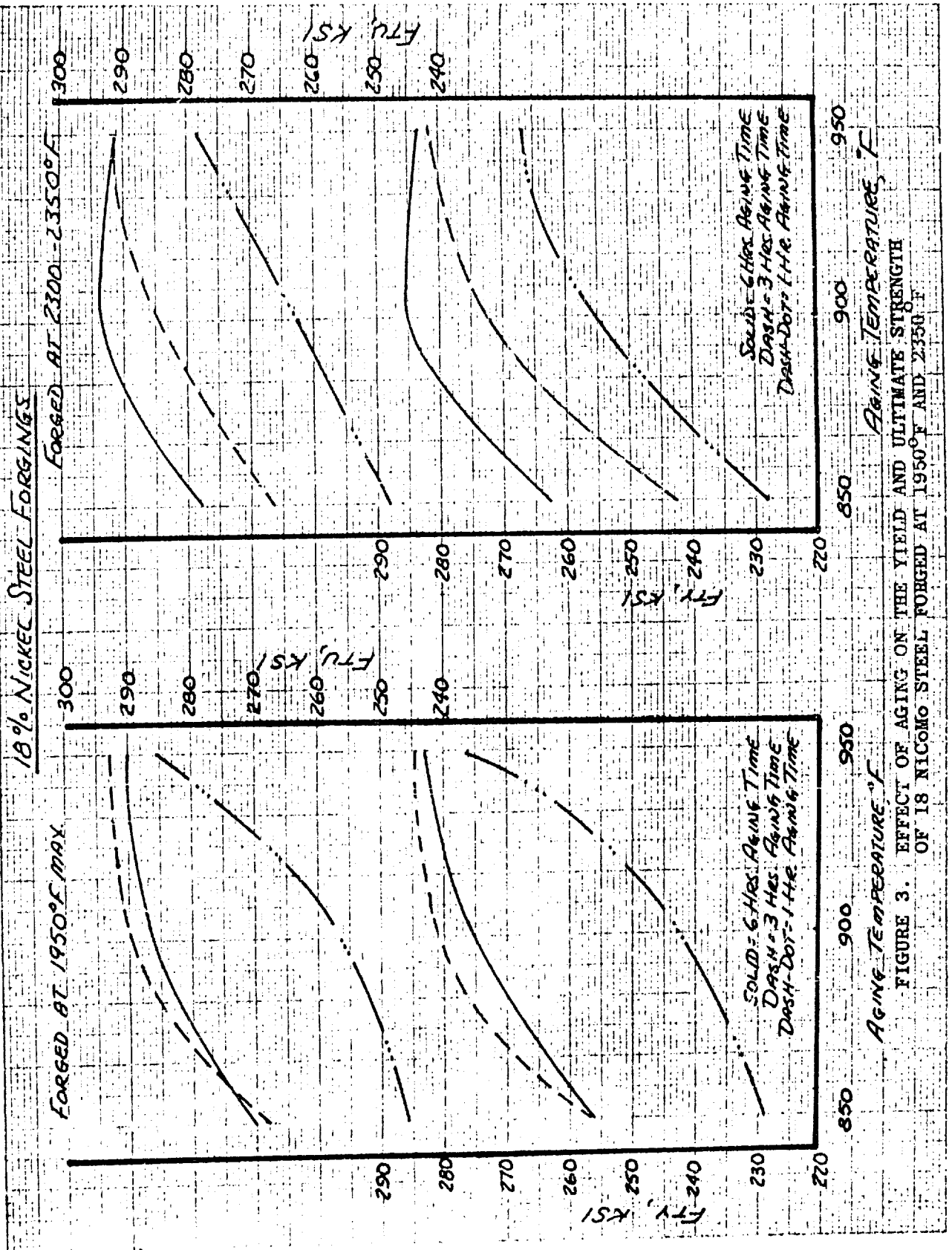
Approx. 1/4"
Scale

FIGURE 2

SPECIMEN LOCATION
IN FORGING

Forged between 2300-2350°F





18% NICKEL STEEL FORGINGS

SOLID = 6 HRS. AGING TIME

DASH = 3 HRS AGAIN: TIME

DASH-DOT = 1 Hr. Aging Time

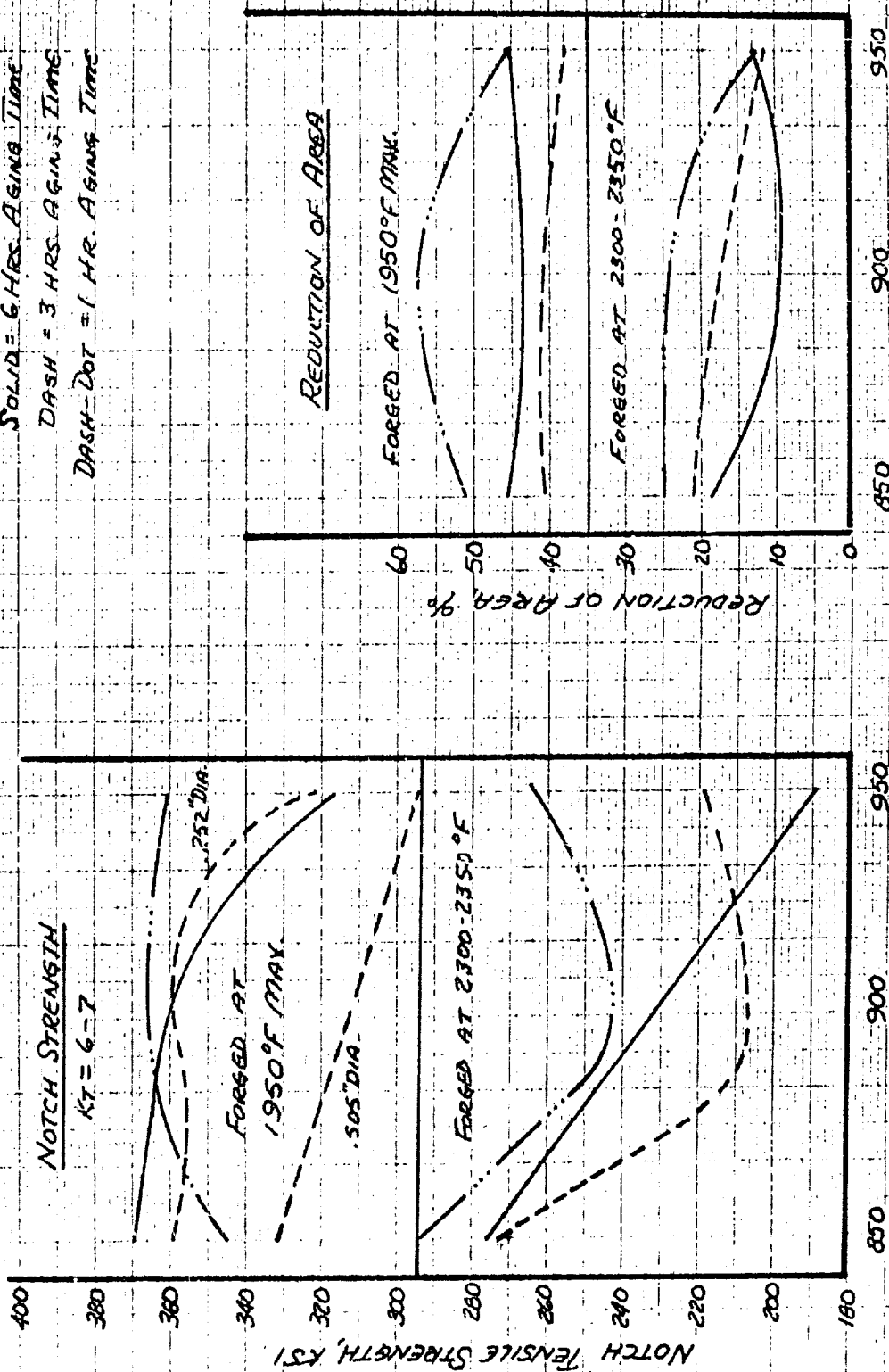


TABLE ICOMPOSITION AND FORGING PROCEDURE OF 18 NiCoMo STEEL

CHEMICAL COMPOSITION

OF 18 NI-CO-MO USED

IN FORGING PROGRAM

VENDOR: Allegheny Ludlum Steel Corporation

HEAT NUMBER: Consutrode #23992

CHEMISTRY:

Carbon	0.007
Manganese	0.02
Silicon	0.02
Phosphorus	0.004
Sulphur	0.004
Nickel	18.73
Cobalt	8.75
Molybdenum	4.92
Titanium	0.63
Aluminum	0.11
Boron	0.003

MANUFACTURING PROCEDURE ¹
FOR FORGING 18% NICKEL
IN ACCORDANCE WITH VENDOR
RECOMMENDATIONS
(W FORGINGS ONLY)

1. Cut a single multiple 9" RCS x 290#
2. Charge into a furnace operating at 1500°F and equalize
3. Heat to 1950°F at a rate of 200°F/hour and equalize
4. Forge a "blank" on flat die hammer (2 reheats necessary)
5. Transfer to a second furnace operating at 1950°F and equalize
6. Roll on an 8,000# steam hammer in one heat
7. Transfer to a third furnace operating at 1950°F and equalize
8. Finish forge on a 12,000# steam hammer. Two reheats necessary plus one flash reheat in order to hot trim flash metal.

NOTE: During finish forging, the 18% Ni was not soaked during reheats in order to prevent or at least minimize grain growth. The forging received in excess of 25% reduction during finish forging (from roller configuration to finish size). It was necessary to "flash" heat for trimming; however, the body of the forging did not exceed 1790°F. Temperature of forging after last hammer blow was approximately 1550/1675°F.

9. Air Cool after trimming.
10. Shotblast clean.

1. Information from Kropp Forge, letter DeLazaro (Kropp) to Rusk (GD/FW) dated 15 March 1962.

TABLE II
NOTCH TOUGHNESS PROPERTIES OF 18 NiCoMo (300) MAR-AGING STEEL

	Aging Temp, °F	Test Temp, °F	Crack Length at Instability	Notch Strength, Ksi		Shear %	Hardness R _c
				Gross	Nominal Net		
1.	850	RT	1.212"	59.2	91.8	99.3	51.7
2.	850	-65	-	49.8	76.5	-	52.9
3.	900	-65	-	43.4	66.9	-	53.2
4.	900	-65	-	47.8	73.9	-	53.2
5.	950	RT	1.512"	54.4	84.9	109.5	53.3
6.	950	-65	-	52.4	83.2	-	53.3

1. Specimens from 4" x 12" billet with notch in short transverse direction.
2. All specimens annealed at 1500°F and aged 3 hours at indicated temperature.
3. Fatigue cracks formed by axial tension - tension stress equivalent to 1/5 F_{ty} initially ($R = 0.1$) and propagated at 1/10 F_{ty} to 1.05" length.

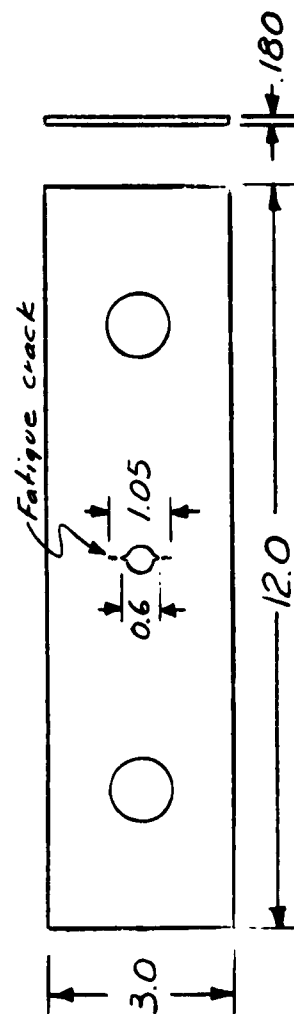


TABLE III
HEAT TREAT RESPONSE OF 18 NiCoMo STEEL FORGING "W"

Condition	Loca- tion	Grain Direc- tion	Temper Temp, °F	F _{ty} Ksi	F _{tu} Ksi	Elong. % in 4D	% R.A.	Loca- tion	F _{tnu} , Ksi	Notch Ult. Ratio	K _t
Forged at 1950°F max. .250" dia. specimens	H-1	Long.	850-1 Hr.	228.8	245.4	10.5	51.5	H-2	345.2	1.41	5.7
	-3	↓	-3 Hr.	246.4	263.6	11.0	50.1	-4	360.0	1.37	6.3
	-5	↓	-6 Hr.	255.6	269.8	9.0	45.2	-6	369.6	1.37	5.7
	H-25	Long.	900-1 Hr.	241.3	255.6	10.5	57.8	H-8	366.5	1.43	5.7
	-9	↓	-3 Hr.	261.3	278.7	9.0	44.8	-10	358.4	1.29	5.7
	-19*	↓	-3 Hr.	266.2	306.0	10.0	51.5	-20*	360.1	1.18	5.7
	-11	↓	-6 Hr.	275.1	286.0	8.0	43.8	-12	361.2	1.26	6.2
	H-13	Long.	950-1 Hr.	276.4	284.6	9.0	46.1	H-14	360.4	1.27	5.7
	-15	↓	3 Hr.	275.2	286.2	10.0	49.3	-16	323.2	1.13	5.7
	-17	↓	6 Hr.	282.4	290.1	8.0	45.2	-18	317.8	1.10	5.7
	E-1	Long.	850-3 Hr.	255.4	267.3	9.5	41.9	F-1	324.0	1.21	6.5
	-2	Long.	-3 Hr.	255.7	267.7	9.5	40.9	-2	334.8	1.25	6.2
Forged at 1950°F max. .505" dia. specimens	C-11	Long.	900-3 Hr.	269.9	281.1	10.5	44.4				
	E-3	↓	↓	285.4	292.8	8.5	38.4	F-3	316.1	1.09	6.2
	-7	↓	↓	276.4	287.0	8.0	43.3	-4	312.0	1.08	6.2
	-8	↓	↓	279.5	289.8	9.5	42.3	-5	309.4	1.07	6.2
	E-12	Long.	950-3 Hr.	283.3	291.4	8.0	35.2	F-6	293.9	1.01	6.9
	-13	Long.	-3 Hr.	283.2	293.1	9.0	40.3	-7	280.0	.96	6.5
								-8	294.3	1.01	6.9
	A-1	S. Tran.	900-3 Hr.	274.1	287.7	7.9	26.1				
	-2	↓	↓	273.6	287.7	7.9	26.9	A-3	281.8	.98	6.2
	-7	↓	↓	275.1	284.5	7.5	31.8	-4	227.9	.79	6.2

All specimens annealed 4 hours at 1500°F prior to removal from forging.

* Held at -112°F for 16 hours prior to aging.

TABLE IV
HEAT TREAT RESPONSE OF 18 NiCoMo STEEL FORGING "S"

Condition	Loca- tion	Grain Direc- tion	Temper Temp, °F	F _{ty} Ksi	F _{tu} Ksi	Elong. % in 4D	% R.A.	Loca- tion	F _{tnu} , Ksi	Notch Ult. Ratio	K _t
Forged at 2350°F max. Forging "S" .505" dia. Specimens	F- 1	Long.	850-1 Hr.	227.6	247.6	6.0	24.6	E- 1	293.9	1.19	6.9
	- 2	↓	-3 Hr.	242.6	266.2	5.0	21.2	- 2	275.8	1.04	6.2
	- 3		-6 Hr.	262.2	277.7	5.0	18.3	- 3	275.9	.99	6.9
	F- 4	Long.	900-1 Hr.	255.2	263.3	6.0	24.4	E- 4	240.7	.91	6.9
	- 5	↓	-3 Hr.	273.0	284.4	3.5	17.4	- 5	206.4	.73	6.9
	-10*	↓	-3 Hr.	269.8	280.8	3.0	11.9	-10*	271.3	.97	5.9
	- 6		-6 Hr.	285.3	294.7	3.0	9.1	- 6	232.7	.80	6.2
	F- 7	Long.	950-1 Hr.	266.8	278.4	3.0	13.3	E- 7	273.0	.98	6.2
	- 8	↓	-3 Hr.	281.3	291.9	3.0	11.2	- 8	218.5	.75	6.2
	- 9	↓	-6 Hr.	283.5	291.5	3.0	12.5	- 9	188.9	.65	6.2

All specimens annealed 4 hours at 1500°F prior to removal from forging.

* Held at -112°F for 16 hours prior to aging.

Inquiries for additional information on
this program should be addressed to

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