

Sept. 18, 1956

W. W. DYRKACZ ET AL

2,763,547

CAST ALLOYS

Filed June 9, 1955

2 Sheets-Sheet 1

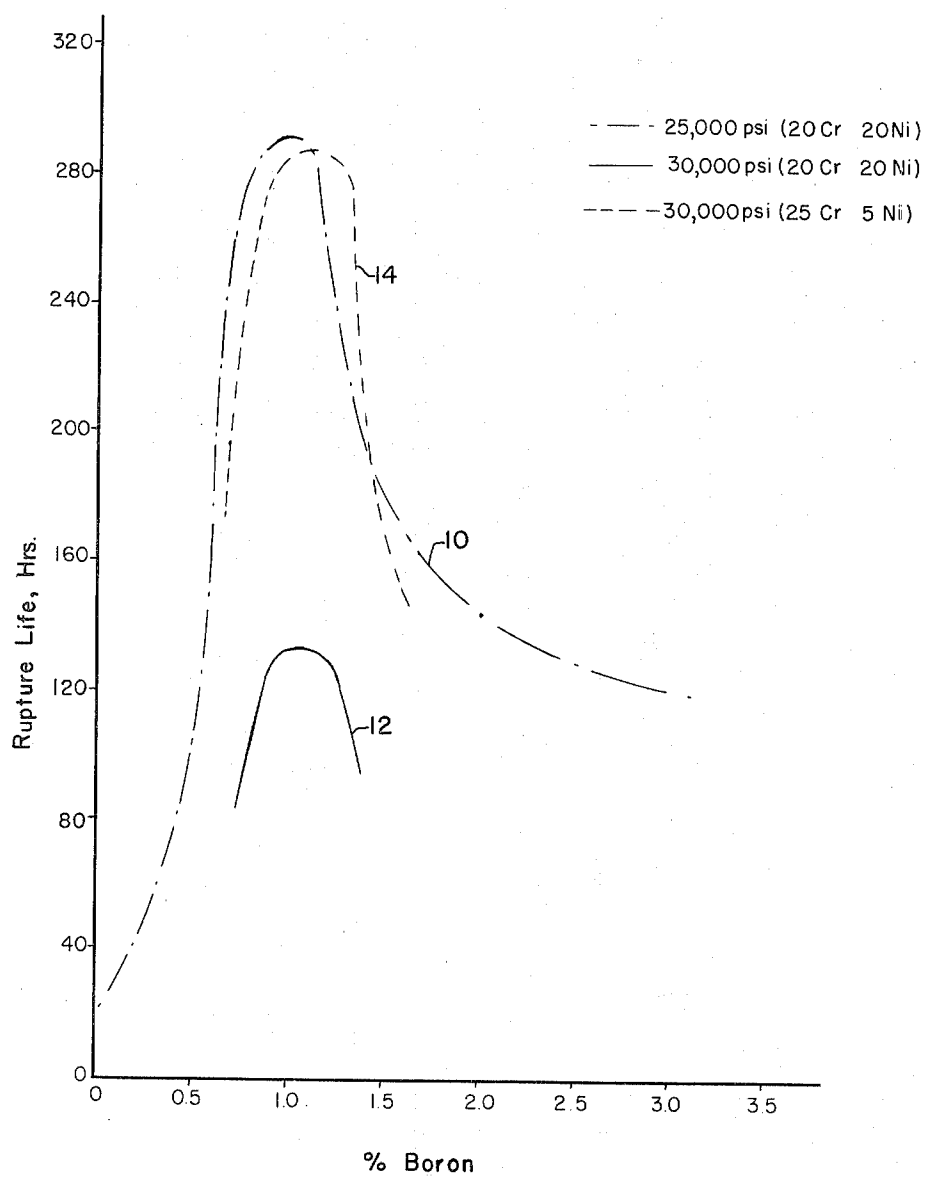


Fig. 1

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2 Sheets-Sheet 2

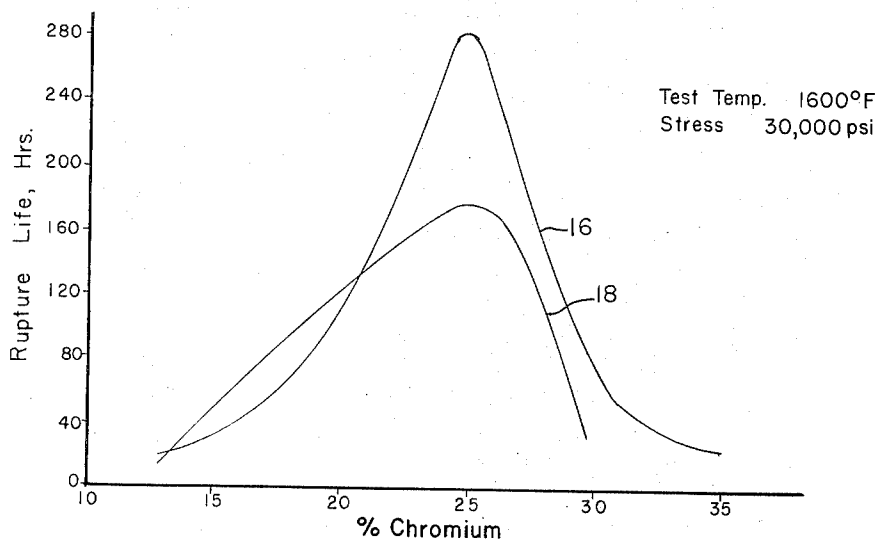


Fig. 2

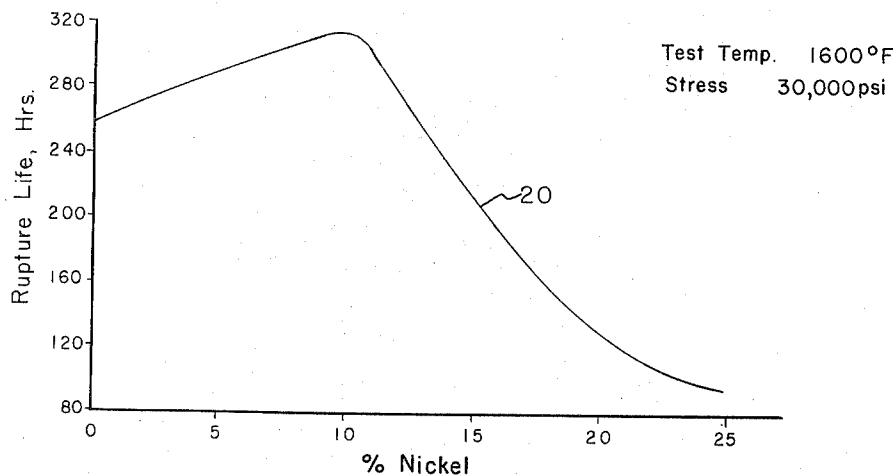


Fig. 3

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CAST ALLOYS

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Application June 9, 1955, Serial No. 514,344

5 Claims. (Cl. 75-171)

This invention relates to cast alloys, and in particular to cast austenitic alloys having high rupture strength at elevated temperatures.

This application is a continuation-in-part of our co-pending application Serial No. 423,142 filed April 14, 1954, now abandoned.

Alloys containing in excess of 9% cobalt, from about 12% to about 22% chromium, about 10% to about 30% nickel, about 2% to about 6% each of molybdenum, tungsten and columbium, about 0.1% to 0.70% carbon and the balance substantially iron, have been known as evidenced by Patent No. 2,397,034 issued March 19, 1946, to G. Mohling. An alloy of such composition is widely used in the wrought form by the industry and is known to the trade as S-816 alloy. Such alloy has good physical characteristics in the wrought condition at temperatures in the neighborhood of 1500° F., but is too weak for satisfactory application for use at temperatures in excess of 1500° F. and in particular at temperatures of 1600° F. to 1700° F.

An object of this invention is to produce a cast austenitic alloy having high rupture strength at elevated temperatures of 1500° F. to 1700° F.

Another object of this invention is to produce a cast alloy having a rupture life in excess of 200 hours at an elevated temperature of 1600° F. and a stress of 25,000 p. s. i., together with good rupture ductility.

A further object of this invention is to produce a cast article of manufacture from an austenitic alloy of 0.10% to 0.70% carbon, 30.0% to 70.0% cobalt, 18.0% to 30.0% chromium, up to 22.0% nickel, 2.0% to 6.0% molybdenum, 2.0% to 6.0% tungsten, 2.0% to 6.0% of metals selected from the group consisting of columbium and tantalum, 0.60% to 1.30% boron and not more than 7.0% iron with incidental impurities, and which will have a long rupture life at elevated temperatures of 1500° F. to 1700° F.

Other objects of this invention will become apparent from the following description when taken in conjunction with the accompanying drawings in which:

Figure 1 is a graph, the curves of which illustrate the effect of the boron content on the rupture life of alloys of this invention at an elevated temperature of 1600° F. under different load conditions;

Fig. 2 is a graph, the curves of which illustrate the effect of chromium on the rupture life of alloys of this invention having two different nickel contents; and

Fig. 3 is a graph, the curve of which illustrates the effect of the nickel content on the rupture life of the alloy of this invention at an elevated temperature of 1600° F. under a load of 30,000 p. s. i.

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In practicing this invention boron is employed in critical amounts with the other alloying elements in balanced relationship to thereby enable the production of a cast alloy which, in the cast form, will have a rupture strength at 1600° F. which is equal to or better than the rupture strength of the alloy of the Mohling Patent No. 2,397,034 in the wrought condition at a temperature of only 1500° F. In producing the cast alloy of this invention it has been found that the amount of boron is critical and that the chromium and nickel contents must be closely controlled in order to obtain maximum rupture life at elevated temperatures of 1500° F. to 1700° F. under conditions of stress.

The cast austenitic alloy of this invention will be better understood by reference to the following table in which is listed the broad range of composition, a preferred range of composition and an optimum composition.

TABLE I

Element	Broad Range, Percent by Wt.	Preferred Range, Percent by Wt.	Optimum, Percent by Wt.
C	0.10-0.70	0.32-0.52	0.4
Mn	2.0 max.	0.5-1.5	1.0
Si	1.0 max.	1.20-0.60	0.4
Co	30.0-70.0	40.0-60.0	53.0
Cr	18.0-30.0	22.5-27.5	25.0
Ni	0.-22.0	0.-12.5	5.0
Mo	2.0-6.0	3.5-5.5	4.0
W	2.0-6.0	3.5-5.5	4.0
Cb+Ta	2.0-6.0	3.5-5.5	4.0
B	0.60-1.30	0.8-1.20	1.0
Fe	7.0 max.	5.0 max.	Bal.

The alloys of Table I may also contain incidental impurities such as sulfur and phosphorus in amounts up to 0.05% maximum, but such impurities are preferably maintained at not more than 0.03%.

In producing the alloys of this invention it was also found that the carbon, chromium and nickel contents were somewhat critical with respect to their effect on the rupture life of the cast alloy at elevated temperatures. It has also been found to be essential to maintain the boron content within a definite range to obtain the outstanding results to be disclosed hereinafter. Thus, while the inclusion of boron in amounts up to about 3.25% has a beneficial effect and improves the rupture life of the cast alloy at elevated temperatures with respect to similar alloys free from boron but in the wrought form and precipitation hardened, in order that the cast alloy of this invention will have a rupture life at 1600° F. as long as or better than the rupture life of an identical boron-free wrought and precipitation hardened alloy at a temperature of 1500° F., the boron content must be maintained in the range of 0.6% to 1.30% and preferably in the range of 0.8% to 1.20%.

As illustrative of the critical nature of the boron content of the cast alloy of this invention, reference may be had to the following table in which a number of alloys and their compositions are listed and which were made in perfecting this invention and in demonstrating the effect of boron:

TABLE II

Alloy Number	C	Mn	Si	Cr	Ni	Fe	W	Mo	Cb	Ta	B
F-383-----	.41	1.45	.46	20.30	19.88	1.76	4.03	4.33	2.66	1.10	0
F-494-----	.42	.94	.66	20.20	20.07	2.32	3.99	3.90	2.76	1.34	0
F-365-----	.44	1.20	.53	20.20	20.47	2.50	4.0	4.28	2.35	1.50	0.082
F-366-----	.41	1.18	.64	20.26	20.55	2.97	3.89	3.87	2.49	1.54	.18
F-384-----	.44	1.29	.63	20.32	19.92	3.27	3.96	4.36	3.19	1.25	.40
F-419-----	.38	1.04	.39	20.24	20.46	1.96	3.92	4.05	2.77	1.00	.53
F-385-----	.42	1.29	.80	20.12	20.18	4.52	4.00	4.40	3.05	1.28	.54
F-415-----	.42	1.05	.50	20.04	20.52	2.28	3.97	4.11	2.75	.82	.54
F-420-----	.39	1.14	.32	20.50	19.94	2.22	3.95	4.11	2.57	1.10	.62
F-386B-----	.46	1.33	.80	20.12	19.90	5.1	4.40	5.30	2.72	1.25	.75
F-386-----	.43	.51	.65	20.06	19.88	5.6	4.13	4.48	2.87	1.36	.78
F-387-----	.44	1.25	.80	19.94	19.90	6.31	3.96	4.13	2.92	1.34	.89
F-424-----	.41	1.13	.50	19.97	20.06	2.28	3.63	3.98	3.01	1.39	.93
F-402-----	.40	1.20	.45	19.94	20.33	1.96	4.00	3.94	2.28	1.20	1.36
F-403-----	.38	1.01	.55	19.92	19.99	2.24	3.93	4.11	2.78	1.53	1.83
F-441-----	.45	.87	.56	20.20	20.33	2.76	3.97	3.38	2.54	1.30	2.52
F-442-----	.47	1.00	.66	20.06	19.68	3.07	2.85	3.56	3.07	1.68	3.22

The alloys of Table II are representative of an alloy having a nominal composition of 0.40% carbon, 1.0% manganese, 0.40% silicon, 20.0% chromium, 20.0% nickel, 4.0% molybdenum, 4.0% tungsten, 4.0% columbium plus tantalum, not more than 7.0% iron and the balance cobalt except that as indicated in Table II, the boron contents range from 0% up to 3.22% for the different alloys. When the cast alloys of Table II were tested at elevated temperatures of 1500° F., 1600° F. and 1700° F. under specified stress conditions, the following results were obtained:

of this invention having a boron content of from 0.6% to 1.30% have a rupture life at 1600° F. under a stress of 25,000 p. s. i. in excess of 200 hours, the maximum rupture life being obtained where the boron content is in the neighborhood of about 1.0%.

The same effect of the boron is found at elevated temperatures of 1600° F. when the stress is increased to 30,000 p. s. i. and the boron content ranges from 0.6% to 1.30% with the nominal composition given hereinbefore. Likewise, when the nominal composition is changed to a 25% chromium, 5% nickel composition,

TABLE III

Effect of Boron on Rupture Properties of Cast Alloy

Heat	B	1500° F.—35,000 p. s. i.			1600° F.—25,000 p. s. i.			1700° F.—18,000 p. s. i.		
		Rupture Time (Hr.)	Elong. (Per-cent)	Red. of Area (Per-cent)	Rupture Time (Hr.)	Elong. (Per-cent)	Red. of Area (Per-cent)	Rupture Time (Hr.)	Elong. (Per-cent)	Red. of Area (Per-cent)
F-383-----	0	-----	-----	-----	21	29.1	50.1	-----	-----	-----
F-494-----	0	-----	-----	-----	15	33.0	34.9	14	24.5	40.0
F-365-----	.08	34	20.6	35.0	30	18.6	50.5	22	29.1	48.0
F-366-----	.18	34	17.0	41.0	43	23.6	50.0	31	30.1	64.3
F-384-----	.41	65	18.6	38.8	71	25.6	46.0	54	26.6	44.5
F-419-----	.53	254	10.1	22.3	186	14.2	26.3	82	20.0	36.6
F-385-----	.54	131	12.3	25.8	191	12.3	26.6	70	24.6	48.3
F-415-----	.54	226	13.2	23.8	96	16.2	39.3	-----	-----	-----
F-420-----	.62	268	10.1	18.2	181	10.1	22.4	-----	-----	-----
F-386B-----	.73	133	19.6	26.4	230	12.9	18.1	74	20.7	36.9
F-386-----	.78	524	8.5	17.7	319	10.5	21.8	253	12.2	23.4
F-387-----	.89	231	10.8	27.1	252	15.3	20.2	157	17.6	24.4
F-424-----	.93	541	9.2	15.3	267	12.8	23.1	138	14.2	22.3
F-402-----	1.36	437	4.8	9.9	172	4.9	8.3	62	6.2	9.3
F-403-----	1.83	376	1.9	4.6	159	3.0	7.7	65	4.3	8.5
F-441-----	2.52	298	4.3	5.8	127	4.5	4.6	52	8.1	5.4
F-442-----	3.22	236	1.0	0.8	117	2.2	2.1	39	1.0	1.5

The critical nature of the boron content between 0.6% and 1.30% is evident from the rupture life recorded under the test conditions in Table III. The effect of the boron on the rupture life of the alloys listed in Table III as tested at 1600° F. under a stress of 25,000 p. s. i. is graphically illustrated by curve 10 of Fig. 1 of the drawings. As is evident from the results given in Table III and the graphic illustration of curve 10, the alloys

the same unusual peaking effect in the rupture life as tested at 1600° F. under a stress of 30,000 p. s. i. is found, as the boron content varies from 0.6% to 1.30% and in particular from 0.8% to 1.2%. Such alloys are listed in the following table, it being noted that alloys F-666 through F-669 are of the 25% chromium, 5% nickel nominal composition, whereas alloys F-568, F-386 and F-596 are of the 20% chromium, 20% nickel nominal composition,

TABLE IV

Alloy No.	C	Mn	Si	Cr	Ni	Fe	W	Mo	Cb	Ta	B
F-666	.36	.82	.63	25.36	5.24	2.25	3.93	4.07	2.81	1.20	.69
F-667	.44	.92	.64	25.48	4.72	2.32	3.98	4.22	2.78	1.06	.98
F-668	.45	.97	.70	25.48	5.26	3.35	3.98	4.00	2.80	1.39	1.27
F-669	.40	.92	.68	25.64	4.84	4.70	4.31	4.14	2.86	1.10	1.44
F-386	.43	.51	.65	20.06	19.88	5.60	4.13	4.48	2.87	1.36	.78
F-596	.43	.97	.89	20.48	20.31	2.39	4.02	4.05	2.94	1.30	.91
F-568	.41	1.15	.71	20.10	20.01	2.52	4.24	3.93	2.88	1.48	1.18

As in the case of the alloys of Table II, the balance of the compositions of the alloys of Table IV is cobalt with incidental impurities.

When the cast alloys of Table IV were tested at 1600° F. under 30,000 p. s. i. stress conditions, the following results were obtained:

TABLE V

Rupture properties at 1600° F. and 30,000 p. s. i.

Alloy No.	Boron	Hours	Percent Elong.	Percent R. A.
F-666	.69	194	20.5	51.0
F-667	.98	283	11.0	18.8
F-668	1.27	273.	6.0	9.5
F-669	1.44	163	6.7	18.9
F-386	.78	94	11.5	22.4
F-596	.91	128	16.0	22.2
F-568	1.18	130	10.5	17.4

The critical nature of the boron content on the rupture life of the alloys of Table IV as tested at 1600° F. and 30,000 p. s. i. is definitely noted from the results recorded

in Table V and is graphically illustrated by curves 12 and 14 of Fig. 1. In Fig. 1 curve 12 represents the effect of the boron content on the alloys of this invention having the nominal 20% chromium, 20% nickel content illustrated by alloys F-386, F-596 and F-568, whereas curve 14 represents the effect of the boron content on the rupture life of alloys F-666 through F-669 having the nominal 25% chromium, 5% nickel content. As illustrated, outstanding rupture life under conditions of test are obtained where the boron content ranges from 0.6% to 1.30% and in particular from 0.8 to 1.2%.

As stated hereinbefore, the chromium and nickel contents of the cast alloy of this invention are also somewhat critical when taken in conjunction with the boron content. In order to illustrate this critical effect of the chromium and nickel contents, a series of alloys having a nominal 0.9% boron content were made and in which the chromium content was varied from about 10% to about 35% for different nickel contents ranging from 0% to 30% in increments of about 5%. These alloys are listed in the following table, it being understood that the balance of the alloys is cobalt with incidental impurities:

TABLE VI

Alloy No.	C	Mn	Si	Cr	Ni	Fe	W	Mo	Cb	Ta	B
F-570	.44	.99	.65	15.54	0	6.20	3.65	4.02	2.20	1.34	.96
F-569	.39	1.02	.86	19.96	0	6.33	4.36	4.14	2.79	1.68	.94
F-630	.41	.78	.36	25.28	0	6.07	4.12	4.00	2.72	1.49	.96
F-618	.43	1.03	.24	30.88	0	6.37	3.95	4.18	2.96	1.48	.94
F-635	.47	.99	.68	35.52	0	6.41	3.82	4.00	2.82	.91	.91
F-586	.43	.92	.50	13.64	4.83	2.71	3.99	4.35	2.70	1.25	.92
F-619	.47	1.13	.56	20.08	4.94	2.21	4.04	4.20	2.79	1.44	1.01
F-667	.44	.92	.64	25.48	4.72	2.32	3.98	4.22	2.78	1.06	.98
F-634	.43	.97	.69	30.24	5.15	2.28	4.06	4.39	3.04	1.25	.92
F-588	.42	.98	.66	34.42	5.44	2.29	3.67	3.84	2.90	1.10	.87
F-587	.35	.99	.59	10.84	10.05	1.94	4.08	3.92	2.45	1.34	1.05
F-585	.43	1.01	.62	13.58	9.64	2.27	3.97	4.37	2.97	1.34	.98
F-631	.41	.78	.46	20.12	10.31	2.41	3.89	4.18	3.08	1.39	.85
F-670	.41	.94	.64	25.32	9.99	2.32	4.17	4.00	2.70	1.01	.87
F-620	.44	1.01	.84	30.64	9.97	2.03	4.01	4.52	2.78	1.44	.96
F-636	.42	1.13	.60	34.73	9.75	2.40	4.04	4.06	2.92	.91	.85
F-584	.43	1.14	.72	13.58	14.69	2.38	3.88	4.25	3.09	1.34	.94
F-632	.42	.83	.54	20.32	15.09	2.21	2.39	4.06	2.84	1.44	.94
F-641	.39	1.29	.68	25.00	14.92	2.26	4.11	4.15	2.51	1.25	.94
F-616	.41	1.06	.82	30.36	15.07	2.80	4.27	4.06	2.74	1.48	.76
F-637	.42	.99	.66	35.84	14.70	2.33	3.98	4.18	2.84	.87	.85
F-583	.42	.93	.68	13.60	19.98	2.07	3.89	4.31	2.87	1.25	.94
F-596	.43	.97	.89	20.48	20.31	2.39	4.02	4.05	2.94	1.30	.91
F-629	.41	.85	.46	25.50	18.41	2.28	5.00	4.00	2.86	1.20	.85
F-617	.41	1.06	.83	29.63	20.34	2.47	4.05	4.00	2.82	1.44	.89
F-589	.40	1.03	.26	13.85	24.82	2.07	3.64	4.35	3.12	1.44	.85
F-641	.41	1.10	.42	19.71	25.06	2.44	3.90	4.06	3.28	1.53	.84
F-640	.45	.97	.66	25.68	25.15	2.47	3.81	4.33	2.72	1.30	.91
F-639	.40	.99	.91	29.99	24.68	2.22	4.04	4.33	2.09	1.10	.87
F-638	.38	.92	.82	30.03	29.83	2.15	4.06	4.36	2.84	1.15	.87
F-501	.22	1.10	.80	20.03	19.45	2.28	4.11	4.05	2.30	1.72	.82
F-596	.43	.97	.89	20.48	20.31	2.39	4.02	4.05	2.94	1.30	.91
F-502	.61	1.03	.70	19.79	20.21	2.13	3.97	4.22	2.32	1.72	.83
F-503	.82	1.10	.80	19.84	19.86	1.90	4.69	4.05	2.63	1.82	.92
F-504	1.02	1.06	.73	19.96	20.12	1.90	3.97	3.93	2.55	1.91	.80
F-505	1.18	.90	.80	19.76	20.15	1.90	4.00	3.88	2.63	1.68	.82
F-506	1.41	.99	.90	19.44	19.86	1.80	3.92	3.88	3.15	1.72	.83

When the cast alloys of Table IV were tested at 1500° F., 1600° F. and 1700° F. under different load conditions, the following results were obtained:

being based on the test results given in Table VII for the series of the nominal 20% nickel alloys. The curves 16 and 18 are clearly illustrative of the outstanding results

TABLE VII
Effect of chromium and nickel on rupture properties
of cast alloys containing 0.9 boron

Alloy No.	Cr	1500° F.—45,000 p. s. i.			1600° F.—30,000 p. s. i.			1700° F.—20,000 p. s. i.		
		Rupture Time (Hr.)	Elong. (Per-cent)	Red. of Area (Per-cent)	Rupture Time (Hr.)	Elong. (Per-cent)	Red. of Area (Per-cent)	Rupture Time (Hr.)	Elong. (Per-cent)	Red. of Area (Per-cent)
0% Ni Alloys										
F-570--	15.54	12	11.2	29.2	31	12.0	21.8	20	17.1	51
F-569--	19.96	28	13.3	34.7	41	11.3	30.0	29	27	58
F-630--	25.28	130	10.7	13.4	257	11.6	31.8	253	17.5	33.2
F-618--	30.88	32	9	12.2	30	14	24.6	33	12.2	55.7
F-635--	35.52	38	7.5	10.7	18	15.3	31.6	8	38.4	54.5
5% Ni Alloys										
F-586--	13.64	17	9.9	11.5	17	13	26.8	16	23	34.3
F-619--	20.08	19	17	17.2	116	17	21	93	17	27
F-667--	25.84	329	9.3	15.2	283	11	18.8	220	11.4	21.1
F-634--	30.24	45	9.9	12.7	70	13	27.8	35	8.2	35
F-588--	34.42	24	15	33	27	18	52.2	15	28	41.7
10% Ni Alloys										
F-587--	10.84	4	6.5	7.8	8	10	12.2	5	16.5	34
F-585--	13.58	6	7.4	20	17	12	31.6	18	23.5	35
F-631--	20.12	83	9.2	17.4	120	8.4	11.6	89	19	37
F-670--	25.32	201	11.6	11.5	314	14.5	29.1	156	10.5	28.3
F-620--	30.64	37	12.1	16	59	16	36.4	32	12.4	50.6
F-636--	34.73	15	4	2.2	16	8.2	11.4	8	21.8	34.2
15% Ni Alloys										
F-584--	13.58	11	7	10	18	17	21.8	16	14.5	22.3
F-632--	20.32	109	9.8	11.4	166	8.5	19.6	101	11	22.8
F-541--	25.00	106	12	16	174	12.2	24.0	131	16.5	35.2
F-616--	30.36	13	9.2	18	30	12	29.1	50	22	36.9
F-637--	35.84	8	5.9	8.5	10	13.5	20.8	9	24	32.2
20% Ni Alloys										
F-583--	13.60	6	9.1	14.3	14	13.5	20.1	9	11.8	20.7
F-596--	20.48	76	8.7	20.3	128	16	22.2	89	14.5	30.4
F-629--	25.50	80	16	33.5	177	13.5	26.7	249	17.5	26
F-617--	29.63	9	11.6	19.5	34	20.5	23.5	15	29	36.2
25% Ni Alloys										
F-589--	13.85	7	7.5	10	19	11.9	23.5	9	18	31.3
F-641--	19.71	27	8.9	15.2	113	13.5	19.3	83	17.5	29.6
F-640--	25.68	73	11.1	16.7	96	18	15.8	107	14.5	25.8
F-639--	29.99	9	8.1	13.7	21	13	18	28	20.5	31
30% Ni Alloy										
F-638--	30.03	4	9.6	18.0	15	14.5	26.4	14	29.5	31.0

As is evident from the test data given for the alloys of Table VI and reported in Table VII, the rupture life when tested at 1600° F. and 30,000 p. s. i. was a maximum in all cases at about 25% chromium as the nickel varied from 0% to 22%, it being noted that as the nickel also increased therefrom to 25% and 30%, such higher nickel contents had a detrimental effect on the rupture life. From the different tests conducted it became apparent that a maximum of about 22% nickel is the most that can be tolerated in the alloy of this invention and still obtain a good rupture life.

Referring to Fig. 2 of the drawing, the effect of the chromium content for two different levels of nickel content on the rupture life of the cast alloys made and tested is graphically illustrated. In Fig. 2, curve 16 represents the effect of the chromium content as it varies from about 13% to 35% on the rupture life of the cast alloy containing about 5% nickel as tested at 1600° F. and 30,000 p. s. i., such curve being based on the test results given in Table VII for the series of the nominal 5% nickel alloys. Curve 18 is a similar curve in that it graphically illustrates the effect of the chromium content on the rupture life of the cast alloy containing about 20% nickel as tested at 1600° F. and 30,000 p. s. i., such curve

obtained in rupture life where the chromium ranges from 18% to 30% and demonstrate that the optimum content of the chromium should be at about 25%.

When the test results given in Table VII for the alloys of the optimum 25% chromium content are correlated with the different nickel contents of from 0% up to 30%, the effect of the nickel on the rupture life of the cast alloys as tested at 1600° F. under a load of 30,000 p. s. i. can be and is graphically illustrated as by curve 20 of Fig. 3 of the drawing. As clearly shown by curve 20, good results are obtained even in the absence of nickel, whereas optimum results are obtained with nickel in the range of from 5% to 12.5% and with the nickel preferably at about 10%.

In making the cast alloys of this invention it has been found desirable to maintain the carbon content within the range of 0.10% to 0.70% and preferably within the range of 0.32% to 0.52%, it being found that such carbon contents exert a maximum effect in extending the rupture life of the cast alloys of this invention. In substantially all cases it has been found that a maximum rupture life is obtained with the alloys of this invention where the carbon content is maintained at about 0.4%. This has been found to be true under different conditions of test such

as at 1500° F. under a load of 45,000 p. s. i., at 1600° F. under a load of 30,000 p. s. i. and at 1700° F. under a load of 20,000 p. s. i.

The cast alloys of this invention have outstanding rupture strength which makes possible their use as cast articles of many different shapes and sizes where a long rupture life at elevated temperatures is required. Thus the alloy of this invention can be successfully cast by precision casting methods or otherwise into the shape of turbine blades and other articles of manufacture for use in jet engines and gas turbines, and because of the high rupture strength will permit an increase in the operating temperature of such apparatus to a blade temperature in excess of 1600° F.

The alloys of this invention can be produced by standard steel mill practice and can be readily reproduced by anyone skilled in the art. In practice the alloy can be poured into small ingots or pigs which are sold directly to the producer of cast articles, or the pigs can be further melted and cast into forms such as fingers or shot which can be used by the consumer in the making of precision castings.

We claim:

1. A cast austenitic alloy consisting of 0.10% to 0.70% carbon, up to 2.0% manganese, up to 1.0% silicon, 30.0% to 70.0% cobalt, 18.0% to 30.0% chromium, up to 22.0% nickel, 2.0% to 6.0% molybdenum, 2.0% to 6.0% tungsten, 2.0 to 6.0% of metal from the group consisting of columbium and tantalum, 0.60% to 1.30% boron, and not more than 7.0% iron with incidental impurities.

2. As an article of manufacture, a casting formed from an austenitic alloy consisting of 0.10% to 0.70% carbon, up to 2.0% manganese, up to 1.0% silicon, 30.0% to 70.0% cobalt, 18.0% to 30.0% chromium, up to 22.0% nickel, 2.0% to 6.0% molybdenum, 2.0% to 6.0% tungsten, 2.0 to 6.0% of metal from the group consisting of columbium and tantalum, 0.60% to 1.30% boron, and

not more than 7.0% iron with incidental impurities, said casting being characterized by its high rupture strength at elevated temperatures of 1500° F. to 1700° F.

3. A cast austenitic alloy consisting of 0.32% to 0.52% carbon, 0.5% to 1.5% manganese, 0.20% to 0.60% silicon, 22.5% to 27.5% chromium, up to 12.5% nickel, 40.0% to 60.0% cobalt, 3.5% to 5.5% molybdenum, 3.5% to 5.5% tungsten, 3.5% to 5.5% of metal selected from the group consisting of columbium and tantalum, 0.8% to 1.2% boron, and not more than 5.0% iron with incidental impurities.

4. A cast austenitic alloy consisting of about 0.4% carbon, about 1.0% manganese, about 0.4% silicon, about 25.0% chromium, about 5.0% nickel, about 53.0% cobalt, about 4.0% molybdenum, about 4.0% tungsten, about 4.0% of metal selected from the group consisting of columbium and tantalum, about 1.0% boron and the balance iron with incidental impurities.

5. As an article of manufacture, a casting formed from an austenitic alloy consisting of 0.32% to 0.52% carbon, 0.5% to 1.5% manganese, 0.20% to 0.60% silicon, 22.5% to 27.5% chromium, up to 12.5% nickel, 40.0% to 60.0% cobalt, 3.5% to 5.5% molybdenum, 3.5% to 5.5% tungsten, 3.5% to 5.5% of metal selected from the group consisting of columbium and tantalum, 0.8% to 1.2% boron, and not more than 5.0% iron with incidental impurities, the cast article being characterized by having a rupture life of not less than about 200 hours at a temperature of 1600° F. under a stress of 25,000 p. s. i.

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