Aug. 30, 1949. V. T. MALCOLM 2,480,151

METAL ALLOY

Filed Dec. 23, 1946 2 Sheets-Sheet 1

Fig. 1.

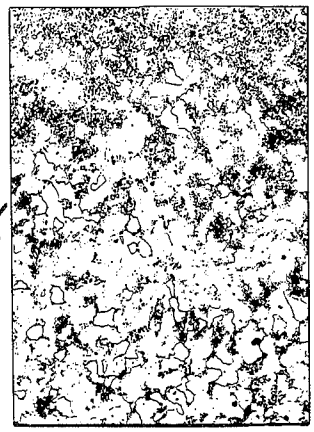


Fig. 2.

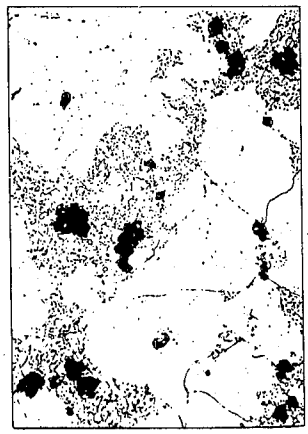


Fig. 3.



Fig. 4.



Fig. 5.

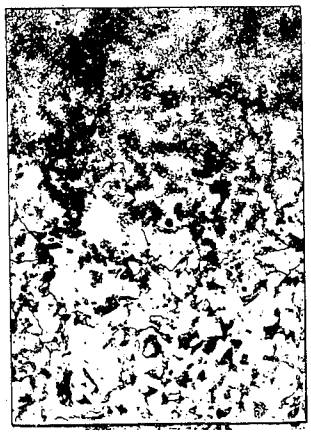
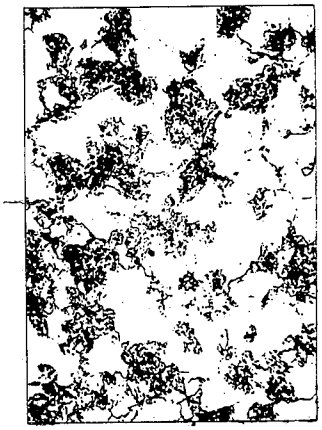


Fig. 6.



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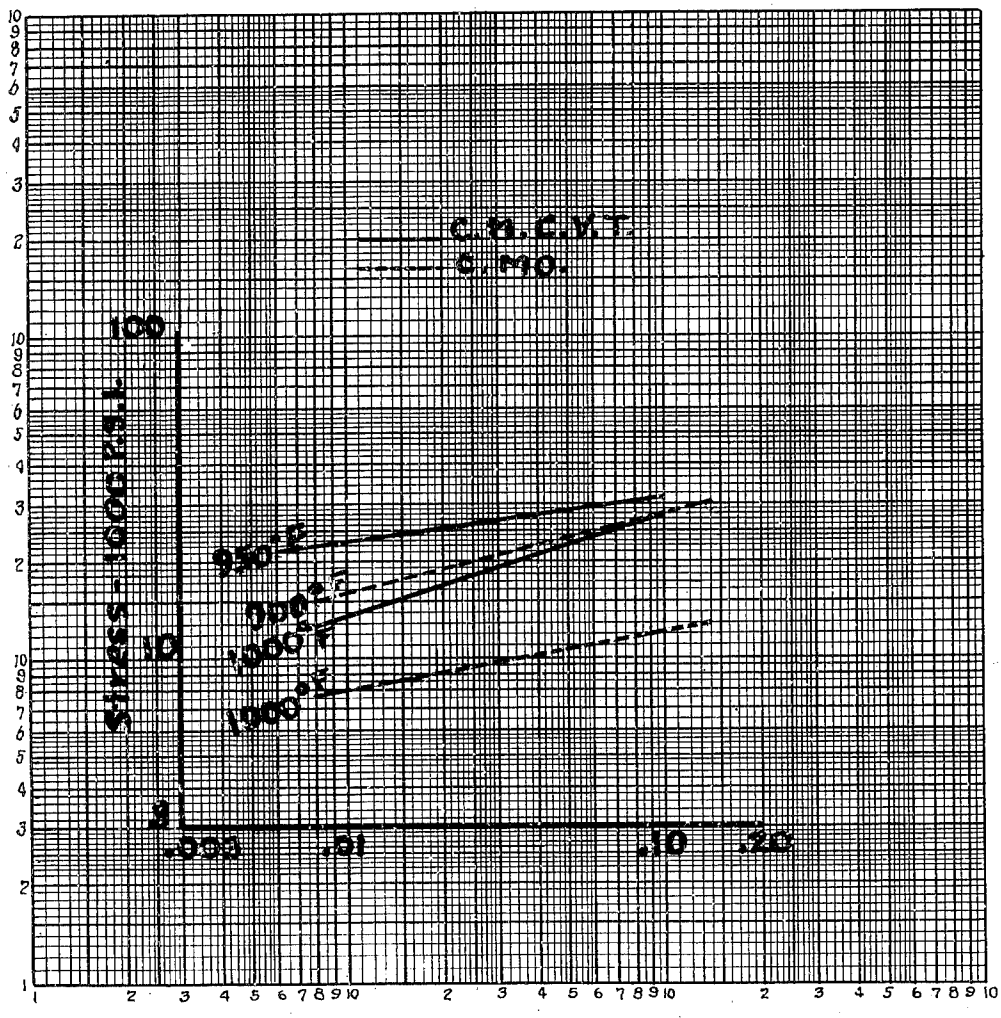


Fig. 7.

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METAL ALLOY

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Application December 23, 1946, Serial No. 717,855

3 Claims. (Cl. 75—126)

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This invention relates to improvements in metal alloys and is directed more particularly to steel alloys.

The principal object of the invention is the provision of a steel alloy which is adapted to withstand certain deteriorating influences and reactions caused by high pressures and high temperatures, particularly if the alloy is to be welded. That is to say, super-heated steam at a pressure within the range of from 600 to 4000 pounds per square inch and at temperature between 900 and 1100 degrees Fahrenheit has certain deteriorating influences and reactions on prior art carbon molybdenum steels which according to this invention are obviated as will hereinafter appear from the following description.

With the foregoing and various other novel features and advantages and other objects of my invention as will become more apparent as the description proceeds, the invention consists in certain novel features of construction and in the combination and arrangement of parts as will be hereinafter more particularly pointed out in the claims hereunto annexed and more fully described and referred to in connection with the accompanying drawings wherein:

Figs. 1 to 6 inclusive are reproductions of photomicrographs of steels at 100 and 500 magnifications respectively to explain the novel features of the invention; and

Fig. 7 is a reproduction of a chart showing the creep rate of steels to explain the novel features of the invention.

Referring now to the drawings more in detail, the invention will be fully described.

What of late has become known as "graphitization" has been the cause of considerable concern in the operation of major steam generating stations using steel pipe, valves, fittings and other apparatus at high pressures and temperatures within the range of 900–1100° F. This is due to the failure by fracture or brittleness of certain specified carbon molybdenum steels corresponding to a chemical composition of:

Carbon	.05–.35
Manganese	.70 max.
Phosphorus	.05 max.
Sulphur	.06 max.
Silicon	.60 max.
Molybdenum	.40–.60

These failures have been very definitely caused by excessive local "graphitization." Examinations of many steam lines throughout the country have revealed instances of local "graphitization"

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to the extent that this type of deterioration has become of grave concern to the entire power industry.

Carbon molybdenum steel of the above composition has heretofore been recognized in the steam industry as a valuable material to withstand high pressures and high temperatures in central stations due to its strength and toughness, and especially due to its excellent creep resistance under elevated temperatures within the range of 900–1100° F. However, due to the excessive local "graphitization" which has taken place with the consequent danger of premature failure, newer types of steel having more stable characteristics are necessary.

Therefore, the principal object of this invention is to provide a steel which is free from the deteriorating effect of "graphitization" caused by instability of the carbide structure which at the same time has higher physical properties and better creep resistance within the temperature range of 900–1100° F. than the previously known steel. A complete study has been necessary in order to determine carbide forming elements which would maintain their structural stability within the 900–1100° temperature range.

It has long been recognized that the Fe_3C type of carbide found in the prior steel is not a stable phase, and that if given a sufficient time at a temperature within the 900–1100° F. range it will decompose with the formation of graphite. Evidence has been found of structural instability of the carbon molybdenum steels referred to within this temperature range and as a result of these findings research has been carried out which resulted in the more stable type of steel hereof.

In the carbon molybdenum steel, previously referred to, the carbides cannot be entirely considered to be of the nature of Fe_3C, which is known to be metastable with respect to graphite, but may also contain molybdenum in solution in the ferrite; and in a given steel of this composition different types of carbides may be expected to exist at different temperatures or after different times at a constant temperature and more than one type may coexist under certain conditions of time, temperature and stress.

Aluminum is nearly always added to carbon molybdenum steels as a deoxidizing agent and reacts above the critical point in such a manner that the carbides form a homogeneous, probably colloidal solution, which persists until the critical point is reached. And as the gamma iron goes over to the alpha state in which the carbides are only slightly soluble, the precipitated carbides

assume the form of thin plates characteristic of normal pearlite. It is believed that by the addition of the aluminum it will bring about the flocculation or coalescence of the carbides before transformation takes place or during the critical period, therefore denoting one of primary causes for graphitization.

Residual aluminum, as aluminum oxide, according to investigation, has no effect on graphitization in carbon molybdenum steel but has great bearing on the production of sound steel castings free from "hot tears" etc., while metallic or acid soluble aluminum induces "graphitization" without any advantage to the steel making practice.

It is, therefore, necessary in the manufacture of cast steels to add a certain quantity of aluminum in order to obtain good castings but the aluminum addition must be so adjusted that the residual quantity must be under .05 and remain mostly in the oxide form, and may be brought about by the judicious addition of carbide forming alloys which increase the structural stability of this type of steel.

Chromium, vanadium or titanium, each of which when added in certain quantities to carbon molybdenum steel, are known to produce a more stable carbide when the steel is used within the temperature range of 900–1100° F., and due to this increased stability will improve the resistance of the steel to "graphitization" but in order to obtain the maximum resistance to graphitization it is necessary to add certain amounts of chromium, vanadium and titanium in the proper combination to carbon molybdenum steel and at the same time exercise the judicious use of aluminum as a deoxidizing agent.

Therefor according to this invention I provide a new steel having the following chemical composition:

Carbon	.05–.35
Manganese	.70 max.
Phosphorus	0.5 max.
Sulphur	.06 max.
Silicon	.60 max.
Molybdenum	.40–.60
Chromium	.40–.70
Vanadium	.10–.20
Titanium	.005–.05
Aluminum	.05 max.

It is also of importance that special care be given to methods of heat treatment of steels, and a great part of the research on the steels investigated was determined by X-ray diffraction, metallography, micro-radiography and with sensitive dilatometers. Experimental work followed by practical applications provided sufficient data so that previous heat treatments of the steel could be modified with definite improvement and the ideal structure for stability obtained.

I have discovered that a heat treatment consisting of the following steps will result in a steel having the desired ideal structure:

Homogenize at 1750° F.—6 hours
Normalize at 1650° F.—½'' per hour of thickness of heaviest section of metal
Temper at 1300–1325° F.—½'' per hour of thickness of metal

In the tempering operation, the cooling should be very slow between the 1300° to 1000° range and may be accelerated from the lower temperature.

The previous heat treatments used as a standard in the treatment of carbon molybdenum steel was to normalize at 1650° F., followed by a temperating treatment at 1200° F. and slowly cooled.

The physical properties at room temperature of the regular carbon molybdenum steel are specified as follows:

Tensile strength, p. s. i.	70,000
Yield strength, p. s. i.	45,000
Elongation in 2'' percent	22
Reduction of area, percent	35

The physical properties of the steel of my invention are as follows:

Tensile strength, p. s. i.	80,000
Yield strength, p. s. i.	50,000
Elongation in 2'' percent	22
Reduction of area, percent	35

The creep limit of the carbon molybdenum steel at 1000° F. causing .1% creep in 100,000 hours is 8000 pounds per square inch, whereas in the steel of my invention the creep limit at 1000° F. causing .1% creep in 100,000 hours is 12,900 pounds per square inch.

The chart of Fig. 7 shows the difference in the creep limits of the two steels. In said chart C. M.-C. V. T. means Chapman carbon-molybdenum-chromium-vanadium-titanium steel of the invention and C. Mo. means the prior art regular carbon molybdenum steel.

Tests for resistance to graphitization have been carried out over long periods of time and the photomicrographs of Figs. 1 to 6 inclusive show the conditions that exist in the several steels after test at temperature. The photomicrographs are as follows:

Figs. 1 and 2 are photomicrographs of WC–1 type, A. S. T. M. A–217, at 100 and 500 magnifications respectively and discloses the existence of nodular graphite after 3000 hours at 950° F. It may be noted that graphitization is severe.

Figs. 3 and 4 are photomicrographs at 100 and 500 magnifications respectively and shows the WC–1 type with addition of .53 chromium, which is now known as WC–3 type, A. S. T. M. A–217. These photomicrographs disclose the beginning of graphitization after 5000 hours at 1000° F.

Figs. 5 and 6 are photomicrographs at 100 and 500 magnifications respectively of WC–3 type, A. S. T. M. A–217, with addition of titanium and vanadium according to this invention. No graphitization is disclosed in this type of steel after 10,000 hours at 1025° F.

In accordance with my invention and heat treatment, the steel does not show any tendency towards graphitization after 10,000 hours at 1025° F., whereas the original carbon molybdenum and modified carbon molybdenum do show this tendency even in a shorter time.

Another important feature of my invention is the control of grain size which may be kept uniform from heat to heat while at the same time the steel has excellent welding characteristics and is not brittle when properly preheated and stress relieved.

The proper preheat is 600° F. and during the welding operation this preheat should never be allowed to drop below 550° F. It is also desired that the steel be warmed up for several hours at this temperature before starting the welding operation.

The stress relief, or post heat treatment, should be carried out at a temperature of 1300° F. and never greater than 1325° F. and the time at tem-

perature should be ½'' per hour of thickness of weld after which it must be slowly cooled through the range of 1300 to 1000° F. and from the lower temperature cooling may be accelerated.

The invention may be embodied in other specific forms without departing from the essential characteristics thereof. Hence, the present embodiments are therefore to be considered in all respects merely as being illustrative and not as being restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all modifications and variations as fall within the meaning and purview and range of equivalency of the appended claims are therefore intended to be embraced therein.

What it is desired to claim and secure by Letters Patent of the United States is:

1. A machinable readily weldable carbon alloy steel consisting of in combination, between .05% and .35% carbon, no more than .70% manganese, about .60% chromium, about .55% molybdenum, about .12% vanadium, and about .03% titanium, with the balance consisting of iron and incidental impurities.

2. An alloy steel having the necessary physical properties for utilization at high pressure and at high temperatures approximating 1000 degrees Fahrenheit consisting of, between .05% and .35% carbon, about .70% manganese, about .60% chromium, about .55% molybdenum, about .12% vanadium, and about .03% titanium, with the balance consisting of iron and incidental impurities.

3. An alloy steel having a chemical composition for use with high temperature steam and adapted to resist local graphitization consisting of, between .05% and .35% carbon, about .70% manganese, about .60% chromium, about .55% molybdenum, about .12% vanadium, and about .03% titanium, with the balance consisting of iron and incidental impurities.

VINCENT T. MALCOLM.

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