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WILLIAM H. SMITH, OF EAST CLEVELAND, OHIO, ASSIGNOR TO ELECTRO METALLURGICAL COMPANY, A CORPORATION OF WEST VIRGINIA.

ALLOY FOR HIGH-TEMPERATURE USE.

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To all whom it may concern:

Be it known that I, WILLIAM H. SMITH, a citizen of the United States, residing at East Cleveland, in the county of Cuyahoga and State of Ohio, have invented a certain new and useful Improvement in Alloys for High-Temperature Uses, of which the following is a full, clear, and exact description.

This invention relates to high-temperature resisting devices and alloys for making the same. It relates particularly to the devices employed in the heat-treating of metals which devices are frequently made in the form of muffles, boxes or containers for the reception of small parts, although equally applicable to the construction of sides, walls, doors, floors and pipes of furnaces, and to the construction of rails, cars, trams, conveyors or the like devices movable in or through a heated space for the conveyance of the substances to be treated. Such treatment is of many different kinds, such as tempering, annealing, cementation, carbonization, case-hardening, crystal-growth, etc., and ordinarily necessitates a maintenance of the work for a considerable time at temperatures up to 1,000° or 1,200° C. with intermediate coolings while the containers or furnaces are being emptied and refilled. Common iron and steel will withstand this treatment only a short time, the boxes, containers or other parts being promptly oxidized, warped, cracked, and disintegrated. Certain alloys, notably those containing a preponderance of nickel combined with a considerable amount of chromium, have been developed which serve these purposes with great success, but offer the disadvantage of extremely high price owing to the great intrinsic value of the raw materials and the expense of refining them and separating out the undesirable ingredients with which they occur in nature. The object of the present invention is the provision of an alloy for use in the above named purposes which shall possess a sufficient resistance to the severe conditions of use for most commercial purposes while being composed of much cheaper ingredients, and capable of being made from ordinary commercial materials without expensive treatments and refinings.

My improved alloy can be made conveniently by melting together iron; an alloy consisting largely or entirely of the elements iron, zirconium and silicon; and ferrochrome.

I have successfully prepared the alloy from the above named ingredients, which, in a specific example, had the following compositions:

The iron was a very pure variety known as "rivet stock," and contained about 0.20% to 0.24% of carbon, and only traces of silicon, phosphorous and sulphur.

The zirconium alloy was of the following approximate composition:

	Per cent.
Zr	30
Si	47
Fe	18
Ti	3

This alloy was practically free from carbon.

The ferrochrome contained chromium, about 60%; iron, about 36%; and silicon and carbon, each about 2%.

With ingredients of the composition given above, the charge melted down to produce the alloy may contain up to 25% of the ferrochrome, and 2 to 8% of the zirconium alloy, with the balance iron. A preferred alloy is made by using 20% of the ferrochrome and 8% of the zirconium alloy.

My improved alloy is preferably made in the electric furnace by first melting the requisite amount of iron, and adding thereto the zirconium alloy together with the ferrochrome in case the latter is used. The alloy melts readily, pours freely and produces uniform fine-grained castings in a sand-mold. Ordinary dampness of the sand does not impede the casting operation. The resulting casting can be ground, drilled, turned, or otherwise machined, the hardness depending largely upon the amount of carbon present. Machining appears to be possible with any amount of carbon less than about .60 per cent. The alloy can also be made by the crucible process but in case graphite crucibles are employed, it is necessary to reduce the amount of ferrochrome in order to compensate for the amount of carbon which will be dissolved from the crucible walls. This can be effected either by using carbon-free ferrochrome (as made, for example, by the alumino-thermic or Goldschmidt process) or by omitting the

ferrochrome entirely. The alloy of iron and zirconium omitting ferrochrome is perfectly satisfactory for many purposes although my observation is that 8% to 14% of chromium improves its quality and its behavior at high temperature. I do not advocate the employment of more than about 20% of ferrochrome of carbon content comparable with that given in the example above because the carbon content thereof will make the resulting alloy too hard. If pure carbon-free ferrochrome were employed a larger quantity could be employed without incurring this disadvantage, but the price would be raised unnecessarily. Also I do not advocate the use of any amount of chromium lying between 0% and about 8%. Unless the proportion of chromium in the resulting alloy is at least about 8% its effect in the high temperature uses contemplated is very small, but amounts between about 8% and 14% are noticeably beneficial.

The titanium which in this case enters as an impurity of the zirconium has a beneficial scavenging effect and is probably all employed in this way and it is doubtful whether it occurs in the metallic form in the resulting alloy. Likewise a considerable part of the zirconium is consumed in the process though generally a small percentage remains in the finished alloy and I prefer to employ enough of the same to accomplish this.

In any event it is necessary that phosphorus and sulphur be restricted to the least possible limits.

It may be assumed that the finished alloy will contain everything which was present in the charge, and nothing else, and on this basis the composition of the alloy resulting from the melting of any given charge may be computed. It is well known to those skilled in the art, however, that the above assumption is never strictly true when the alloy is prepared under ordinary conditions, for certain constituents tend to oxidize and slag off during the process, while other materials, notably carbon and iron, are practically always taken up by the alloy from crucibles and other utensils. In addition, chemical analyses are only accurate within certain limits, and in the case of some chemical elements the analytical figures are subject to considerable error, especially where the element to be estimated occurs only in small amount in the material under analysis.

Nevertheless, the composition of the ultimate alloy can be calculated from the composition of the charge with sufficient accuracy for many purposes. The tabulation below will illustrate the accuracy which can be attained in this way.

Materials quite close in composition to the iron, zirconium alloy and ferrochrome referred to above, were made up into four charges, as follows:

	A.	B.	C.	D.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Zirconium alloy	8	2	8	2
Ferrochrome	20	20	13	13
Iron	72	78	79	85

The relation between the calculated compositions of the final alloy and the actual analytical figures is shown by the following table:

	A.		B.		C.		D.	
	Calc.	Found.	Calc.	Found.	Calc.	Found.	Calc.	Found.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fe	80.0	81.82	84.6	84.04	85.0	87.38	90.5	94.36
Si	3.5	4.30	1.08	2.13	3.4	3.08	0.93	0.47
C	0.25	0.56	0.25	0.64	0.15	0.81	0.15	0.22
Cr	13.2	12.30	13.2	13.00	7.9	7.96	7.9	
Zr	3.1	0.68	0.7	0.16	3.2	0.38	0.7	0.20
Ti	0.24	0.15	0.06	0.03	0.25	0.12	0.06	0.03

From the tabulation above, it will be noted that a large proportion of the zirconium present in the charge fails to enter the final alloy, but that even when only 2% of the zirconium alloy is present in the charge, zirconium is found in the final alloy.

Charge A corresponds closely to my preferred charge and the composition of the resulting alloy is indicated by the analytical figures.

It will be understood that other ingredients, especially such as frequently or ordinarily occur with and are employed in the metallurgy of the named ingredients can be added without departing from my inventive idea, and generally that I do not restrict myself to the exact compositions or proportions or substances herein mentioned except as the same are recited in the claims hereto annexed or rendered necessary by the prior state of the art.

Having thus described my invention, what I claim is:—

1. An alloy containing 8% to 15% of chromium, at least 2.5% of silicon, and a fraction of one per cent of zirconium, with the balance principally iron.

2. An alloy containing 8% to 15% of chromium, at least 3% of silicon, and a small amount of zirconium, with the balance principally iron.

3. An alloy containing at least 3% of silicon, and a smaller percentage of zirconium, with the balance principally iron.

4. An alloy containing 12% to 15% of chromium, at least 3% of silicon, and a small amount of zirconium, with the balance principally iron.

5. An alloy containing at least 3% of silicon, at least 70% of iron, and 12% to

15% of chromium, said alloy being such as can be made by melting under the conditions herein described, a charge comprising ferrochrome, pure iron, and 2% to 8% of an iron-zirconium-silicon alloy containing more silicon than zirconium.

6. An alloy containing about 80% of iron, more than 3% of silicon, 12% to 15% of chromium, and a fraction of one per cent of zirconium.

In testimony whereof, I hereunto affix my signature.

WILLIAM H. SMITH.