

UNITED STATES PATENT OFFICE

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METHOD OF PRODUCING ALUMINUM AND ALUMINUM ALLOYS

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The production of aluminum thermally by way of reduction of aluminum oxide has been a failure heretofore for the reason that aluminum evaporates at the reducing temperature. The present invention shows a new way of producing metallic aluminum from aluminum oxide and materials containing the same in a practically satisfactory manner. The invention therefore consists in lowering the pressure of the aluminum the reducing process by the addition of substances of a higher boiling point and separating in the obtained alloy the said substances from the aluminum by a combined separating and distilling process.

It has been suggested heretofore to produce aluminum thermally by reducing the same in the presence of a metal of a higher boiling point f. i. silicium, iron and distilling the same off from the thus produced alloy. The silicium-alloys, which are obtained in this way without excessive evaporation of aluminum however contain such a low percentage of aluminum—for instance 66% of aluminum to 33% of silicium—that the aluminum cannot be practically recovered therefrom by way of distillation, because the necessary distilling temperature and the required vacuum are too high. This idea, however, can be practically carried out according to the present invention wherein the alloy is enriched in aluminum between the thermic production of the aluminum alloy and the distilling process.

The invention comprises the following steps:

1. In the process of reducing the aluminum oxide containing charge, f. i. bauxite a metal which has a higher boiling point than aluminum f. i. silicium is added or produced simultaneously with the aluminum, the amount of the added metal being such that, on the one hand evaporation of aluminum is practically prevented thereby and on the other hand the following measures can be carried out.
2. The aluminum alloy—subsequently termed “crude-alloy”—is cooled down to a temperature, at which at least the main amount of metal added or produced along with the aluminum solidifies primarily, so that the same can be separated in any suitable mechanical way, from the eutectic alloy which remains in liquid state and shall be subsequently termed “rich alloy”.
3. The rich alloy is subjected to distillation with the aid of a suitable vacuum and the distilled off aluminum is recovered upon solidification as pure metal; the residue of the distilling operation is added again in the course of the above described steps.
4. The crude alloy is produced electrothermically. In most cases not only a certain minimum load, as generally in electrothermic reduction processes, but also a current density is necessary for that purpose which is largely in excess of the hitherto usual density. The application of such a higher current density for producing high percentage aluminum alloys generally and not only in accordance with the hereinbefore stated invention is supposed and claimed to be an independent invention of its own.

Useful aluminum alloys have been found to be such containing Fe or Si or both Fe and Si; but the possibility of using other alloys is not precluded.

An iron-aluminum alloy according to the present invention must practically contain at least about 70% of Al, since in the operation according to 2, not metallic Fe but FeAl_3 with 59% of Al and 41% of Fe or any similarly composed alloy which still contains some iron, will solidify therefrom. Al-Si alloys, however, are still useful in case of a low Al content, because pure Si will primarily solidify therefrom if at least 12% of Si are contained therein. For this reason clay and kaolin may be used with advantage

for recovering aluminum therefrom according to the present invention. Alloys containing both Fe and Si are to be considered in case of employing bauxites, which contain just as much Fe_2O_3 as SiO_2 . The ordinary red bauxites, which nowadays are generally used for producing aluminum oxide, according to the Bayer method, however, must be freed from most of the Fe_2O_3 contained therein before they can be used in the process according to the present invention. This can be best done by a partial reduction in the electrical furnace so as to form corundum, without the necessity of keeping the Al_2O_3 content beyond 90%. From such corundum both an iron aluminum alloy and a silicium aluminum alloy just as described, can be produced by a smelting operation.

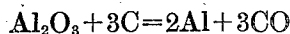
With reference to 2. The crude alloy is allowed to cool down slowly and maintained at a temperature, which exceeds the eutectic temperature as little as possible, that is practically at 600°C . if the alloy contains Fe or Si or both. The primarily solidifying body or alloy is separated from the liquid eutectic alloy in any appropriate manner. If the former is Al_3Fe or a compound which still contains some Si, the same will sink to the bottom and the rich alloy can be separated therefrom by decantation; if however the former is Si only, the same cannot be separated from the rich alloy except by compression or by a centrifuging operation. The art of centrifuging semi-liquid alloys is universally known and in the present case any suitable apparatus may be used for the purpose wherein the temperature can be kept practically constant, that is to say, at about 600°C . as above intimated.

With reference to 3. For the purpose of distilling of the pure metal from the rich alloy, the same furnace and the same working method as commonly applied in the art of electrothermically refining crude zinc may be used with the sole difference that a vacuum must be provided in the present case. The height of the required vacuum depends upon the distilling temperature—the same increases as the temperature decreases—and upon the limit up to which the aluminum shall be distilled off. The vacuum necessarily must be the higher the more the distillation residue is desired to be free of Al. If, for example, a rich alloy containing 87% of aluminum and 13% of silicium, is to be distilled so that the residue will contain 2 parts of Al and 13 parts of Si or 87% of Si and 13% of Al, an initial vacuum of 87 mm. Hg will be necessary at 1475°C . and a final vacuum of 13 mm. Hg.

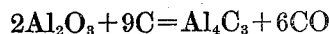
With reference to 4. In electrothermic reduction processes such as for manufacturing calcium carbide, ferro-silicium and so on, the electrodes are usually loaded with 4 to 6 amperes to the square centimetre. Such a

current density is sufficient in cases, where a natural aluminous silicate such as clay or an artificial silicate such as a mixture of Al_2O_3 and SiO_2 is intended to be melted down for the production of a crude alloy containing Si, because such silicates act as a resistance even if they are in molten condition. Thus the energy density required for the reduction exists in the furnace.

If, however, Al_2O_3 alone or simultaneously with other oxides, SiO_2 excepted, for instance with Fe_2O_3 , are to be reduced and the usual current density of 4 to 6 amperes by the square centimetre is applied, only part of the Al_2O_3 under treatment will be reduced to Al, while another part thereof combines to form aluminum carbide and still another part remains unreduced. Thus the reaction does not completely run according to the equation.



but partially takes place in accordance with the formula



This is the reason why by electrothermic reduction processes as hitherto practiced—with the exception of Si compounds—only Al alloys containing not more than 40% of Al could be produced, which cannot be used in the operation under 2. In order to produce alloys which can be utilized according to the present invention the energy density in the furnace must be increased and as Al_2O_3 alone or mixed with other oxides— SiO_2 excepted—is a conductor when in molten condition, this cannot be done except by increasing the current density. The degree to which the same is to be increased, depends upon the total load of the electrode. In the manufacture of alloys, which are high in Al contents the lowest loading limit is about 1000 kilowatt and at such a load of 1000 kilowatt a current density of 10 to 12 amperes by the square centimetre shall be applied in accordance with the present invention, except in cases where a natural or artificial aluminous silicate is to be reduced.

I will now proceed to describe my invention more in detail by way of a few examples, wherein various raw materials are employed.

1. Clay and kaolin contain so much SiO_2 that upon reduction a crude alloy having a sufficiently low proportion of aluminum is formed, so that a considerable loss in Al by way of evaporation cannot occur. As always Si primarily solidifies in an Al-Si alloy of such a character, the resulting crude alloy contains on the other hand, so much Al that the operation according to 2 is possible. Consequently the carbon required for the reducing purpose only is to be added, but no further additions are made. As ashes are not injurious in any way coke-dross may be used for the reducing purpose which prefer-

ably is to be mixed with the clay in any suitable kneading machine or the like. The resistance of the charge is still increased thereby. As clay even in molten condition is in itself a resistance, the usual current density of 4 to 6 amperes by the square centimetre is applied. The crude alloy is transferred while still in liquid condition to a flame-furnace which preferably is constructed and arranged to form a liquation furnace, so as to have, for instance a slanting bottom. In the furnace the crude alloy is allowed to cool down slowly and then kept at a constant temperature of, for instance 600° C. Silicium crystallizes in needle form, which are distributed throughout the whole molten mass, while Fe in the form of a Si-containing AlFe compound sinks to the bottom together with all of the Ti in the form of Al_4Ti . The molten mass in the furnace is in a viscous or semi-liquid state and is subjected to a pressing or a centrifuging action. The rich alloy running off contains in both cases about 12% of Si some Fe and Ti. The same is subsequently melted down in an electrically heated distilling furnace and the Al contained in the molten mass recovered by distillation. The residue of the distilling process is returned to the liquation furnace. The residue of the pressing or centrifuging operation from the upper portion of the liquation furnace is impure metallic silicium, which can be purified by a treatment with acid, the residue from the lower portion is ferro-aluminum containing Si and Ti. Both must be recovered as by-products; the latter, however, amounts to a small proportion only.

2. White bauxite with a high proportion of SiO_2 encounters, when melted down by a reduction process, high losses in Al by evaporation; the resulting crude alloy, however, is well adapted for further treatment, which is to be carried out in the very same manner as above described with reference to clay and kaolin. In order to avoid losses in Al there are two ways open: either part of the metallic silicium recovered by the pressing or centrifuging operation is returned to the reduction furnace, or immediately and at once in the reduction operation SiO_2 , that is quartz, sand or even clay, is added together with the carbon required for the reducing purpose, so that right-away a crude alloy with a sufficiently low Al content will be formed. In both cases as much metallic silicium is recovered as a by-product as will correspond to the proportion of SiO_2 supplied to the reduction furnace setting aside of course all losses incident to evaporation. The application of high current densities is indispensable except in the case where in the reduction furnace an addition of clay, quartz or sand is made.

3. The same holds in case that a red bauxite containing about the same percentage of both

SiO_2 and Fe_2O_3 is to be melted down. The resulting crude alloy contains, it is true, only about 60% of Al, but nevertheless a rich alloy and subsequently the pure metal can be recovered therefrom since only part of the Al is combined with Fe. But in contradistinction to clay and white bauxite considerable amounts of ferro-aluminum containing Si and Ti are recovered in this case as a by-product besides metallic silicium. In order to avoid losses in Al by evaporation at the manufacture of the crude alloy, the first recovered amount of silicium or even of ferro-aluminum may be returned to the reduction furnace and a circulation through the liquation furnace and back may be accomplished.

4. When common red bauxite with but a low proportion of SiO_2 as hitherto generally employed for producing alumina according to the Bayer method, is melted down for reducing purposes at a high current density ferro-aluminum containing only about 60% of Al is recovered. Almost all of the Al is combined therein with Fe and practically no rich alloy and no pure metal can be recovered therefrom. As above mentioned first the Fe_2O_3 must be eliminated therefrom by partial reduction. This is accomplished by melting down the bauxite to form corundum. From the thus produced corundum aluminum can be produced in accordance with the present invention over a crude alloy with Fe or with Si.

The present invention is also utilisable for the production of silumin instead of aluminum immediately from crude materials if a crude material poor in Fe_2O_3 such as kaolin is reduced with the aid of carbon and the process is interrupted upon the production of the rich and the poor alloy. The rich alloy will then answer the requirements made in respect to the aluminum; the poor alloy is purified with acids and yields a pure silicium.

What I claim is:

1. The method of producing aluminum or its alloys from substances containing aluminum oxide consisting in subjecting said substances to a reducing smelting operation in presence of silicon, which by formation of an aluminum-silicon-alloy lowers the vapor-pressure of the aluminum, separating mechanically from this aluminum silicon alloy a rich aluminum alloy, which contains not less than about 70% Al and a poor aluminum alloy, recovering from this rich alloy pure aluminum by distillation in a vacuum, returning the residue from the distillation to the separating stage and producing from the poor aluminum alloy silicon.

2. The method of producing aluminum or its alloys from bauxite consisting in removing the iron content of the same by reduction in an electric furnace, subjecting the iron-freed material to a reducing smelting process with the addition of silicon, separating me-

chanically from the resulting aluminum-silicon-alloy an alloy rich in aluminum and separating from the latter pure aluminum by distillation.

- 5 3. The method of producing aluminum or aluminum alloys from bauxite by removing iron by reduction in an electric furnace, subjecting the iron-freed material to a reducing smelting process with the addition of a silicon
10 containing compound separating from the resulting aluminum-silicon-alloy mechanically an alloy rich in aluminum and separating from the latter metallic aluminum by distillation.

- 15 In testimony whereof I affix my signature.
WILHELM NEUMANN.

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