5. ITER oriented issues-2 (etc.)

5.1 The Production of Beryllium Ingots for ITER Program at "Ulba Metallogocal Plant"

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The study analyzes the possibilities of utilization beryllium ingots produced at UMZ for the purposes of ITER program. The results of comparative analysis of specification requirements to S-65 grade chemical compound and statistic data on UMZ beryllium ingots impurities content are presented. It has been demonstrated that beryllium industrial ingots produced at UMZ can be used for a production of powders and billets conforming the requirements of ITER specification. Beryllium ingots production flow chart, description of basic process equipment, the layout of metallurgical production upgrade, the results of such upgrade implementation are complimentary data to this study. The study is illustrated with explanatory drawings.

As is well-known, beryllium of S-65 and DShG-200 grades has been approved as basic structural beryllium grades for ITER [1]. Beryllium DShG-200 was being produced at UMZ in the 70^{th} ...80^{th}. The source beryllium for this grade was obtained by vacuum distillation that predetermined the low content of metallic impurities in this material. At present the production of beryllium by vacuum distillation has been suspended and its activation is not being scheduled. The production of this grade material at the other plants will require significant financial expenditures and most probably can turn to be economically unprofitable.

Due to that beryllium of S-65 grade remains to be the base material for ITER. The main distinguishing feature of this grade is its high purity in comparison to the known S-200 grade and to structural beryllium grades produced at UMZ and in China.

Nevertheless, UMZ intends to participate in ITER program as the supplier of starting beryllium in ingots for the production of powders and S-65 grade billets.

As it was already mentioned during the previous Work Shops on ITER, UMZ beryllium productions just as Brush Wellman beryllium production are the productions of a complete cycle [2]. Beryllium production process starts from the conversion of ore raw material to beryllium hydroxide and is completed by production of beryllium ready products. Beryllium ingots manufactured at UMZ are used as starting material for production of powders and billets of structural application. Ingots are being produced at UMZ using the well-known method of beryllium fluoride thermal reduction by magnesium [3]. The flow sheet of process is shown at fig. 1.

The process starts with beryllium hydroxide dissolving in ammonium fluoride and obtaining ammonium fluoro-beryllate (AFB). Solution of ammonium fluoro-beryllate subjects to removal of such impurities as iron, manganese, aluminum, calcium, cooper, nickel, chromium. After that the solution is steamed to obtain ammonium fluoro-beryllate crystals. AFB crystals are separated from mother water in centrifuge. AFB crystals than are fed into 200-liters induction furnace with graphite crucible to run thermal decomposition at the temperature 900-950^{0}C. Beryllium fluorides melt poured out through the bottom drain hole into a water-cooled vibration mould lined with graphite. Waste gases are purified by a system of process recovery followed by obtaining ammonium fluoride solution (bifluoride), which goes back to the process and is used for producing ammonium fluoro-beryllate. After beryllium fluoride is cooled down, it is crushed and sent to magnesium thermal reduction stage. The process is carried out in induction furnace of 200 liters in volume with graphite crucibles under the temperature 1350-1400^{0}C. After beryllium passes the reduction reaction and reaction products are melted, it is poured out into a cast-iron mould (Fig.2).

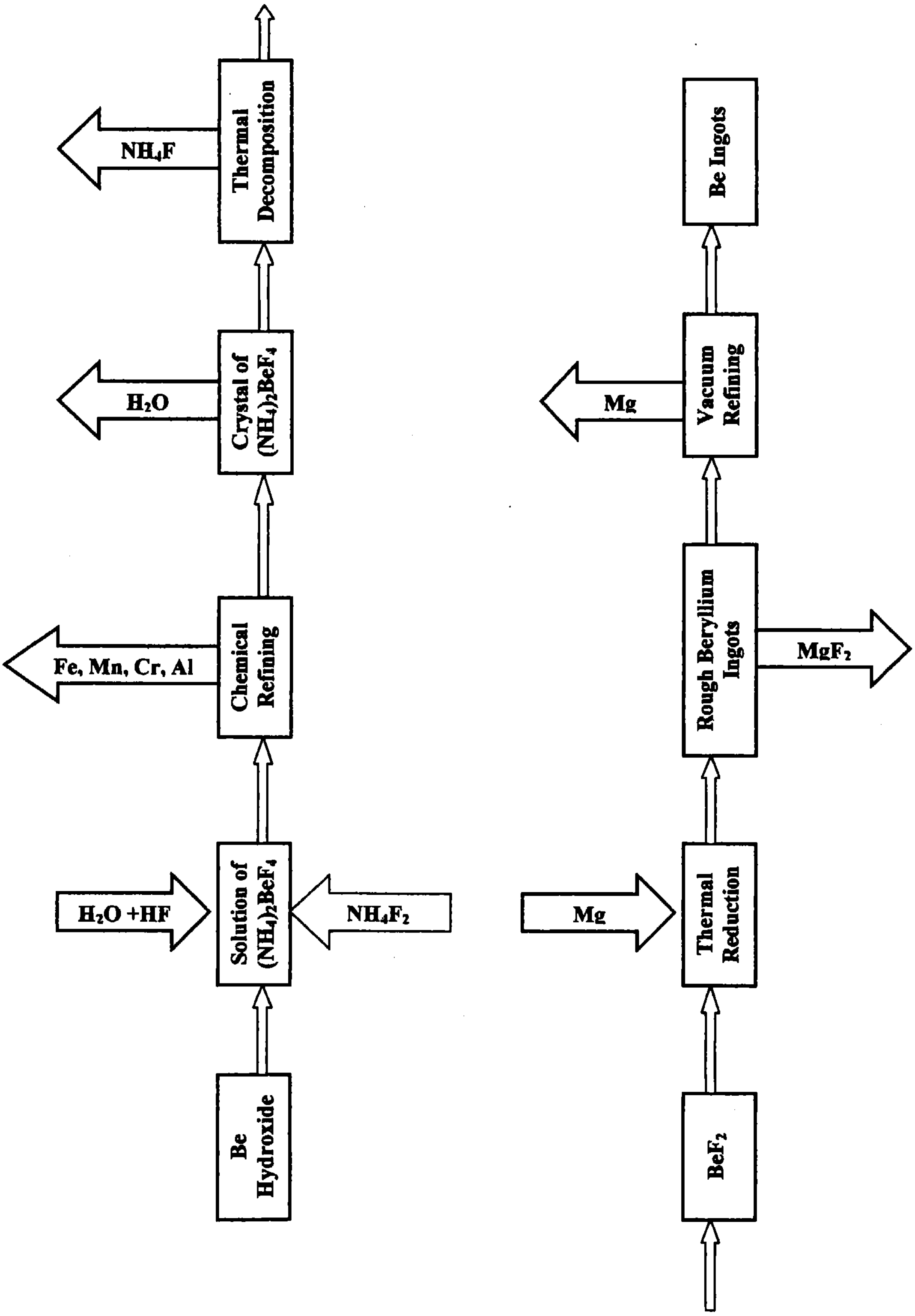

Fig. 1. Flow sheet of Be Ingots Production

Slag is poured out on a water-cooled mould lined with graphite, crushed and subjected to water leaching to separate beryllium fluoride and beryllium pebbles. Crude beryllium ingots contain some slag and up to 1-1.5% of magnesium, therefore they are further refined. The refining is carried out in vacuum induction furnaces with beryllium oxide crucibles. Crucible capacity is 20-30 liters. Beryllium is melted in argon media followed by magnesium distillation. Refined metal is poured out into cast-iron mould through casting cup with filter. Cooled ingots after they are taken out from a mould and quality tested, are stored in a warehouse (Fig.3)

Two grades of beryllium ingots of different purity are produced at UMZ using this technology (Table 1).
Ingots of B-2 grade could not be used for the production of S-65 grade beryllium powders due to the high content of iron and carbon. Ingots of B-1 grade are of relatively high purity and their chemical compound is closed to the requirements of S-65 grade, except for higher content of iron. Nevertheless, this grade ingots could be used for the production of S-65 grade powders as the average statistical content of iron in ingots does not exceed 0.075%. The average value was calculated on the basis of analysis of 300 ingots B-1 grade, produced in 2002 (Fig. 4). An analysis of ingots quality characteristics, specifically iron content been performed within the above indicated period shows a stability of ingots quality and production process (Fig.5).
B-1 grade beryllium ingots produced at UMZ have high purity corresponding to S-65 grade specification requirements. At present UMZ upgrades beryllium ingots production. The two new vacuum furnaces for beryllium refining fusion were purchased in 2002. One of the furnaces was installed and at present is under a release testing (Fig.6). New equipment will allow to increase process reliability and to provide stability of product quality.

Table 1. Chemical Composition Be Ingots and Grade S-65 of Be

Element	Content, % weight (max)			
	S-65 (specification)	Grade B-2 (specification)	Grade B-1 (specification)	Grade B-1 (fact)
Be (min)	99.0	99.0	99.5	99.6...99.75
O (BeO)	0.7 (1.0)	0.3 (0.5)	<0.05 (<0.075)	<0.05 (<0.075)
Al	0.06	0.06	0.06	0.015...0.055
C	0.1	0.12	0.1	0.05...0.09
Cr	0.04	0.08	0.06	0.02...0.036
Cu	0.04	0.04	0.02	<0.02
Fe	0.08	0.25	0.1	0.025...0.1
Mg	0.06	0.04	0.04	0.01...0.04
Mn	0.04	0.04	0.03	<0.02
Ni	0.04	0.04	0.04	0.01...0.035
Si	0.06	0.06	0.06	0.01...0.05

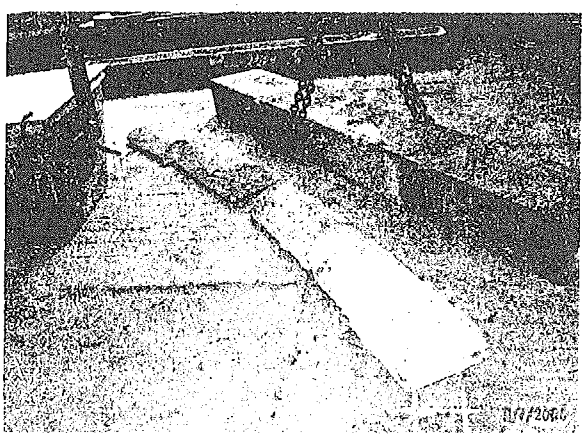

Fig. 2. Rough Be Ingots

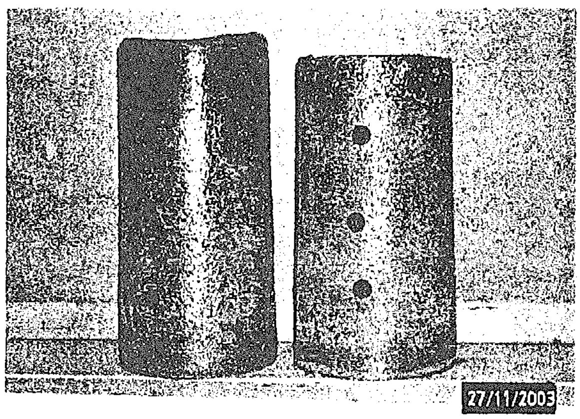

Fig. 3. Be Ingots

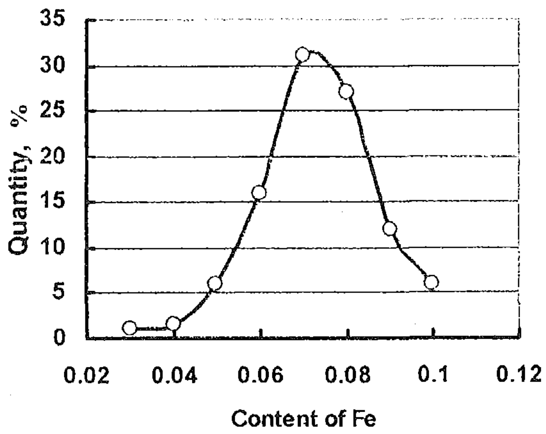

Fig. 4. Distribution Curve of Fe Content for B-1 Ingots (number of ingots - 300)

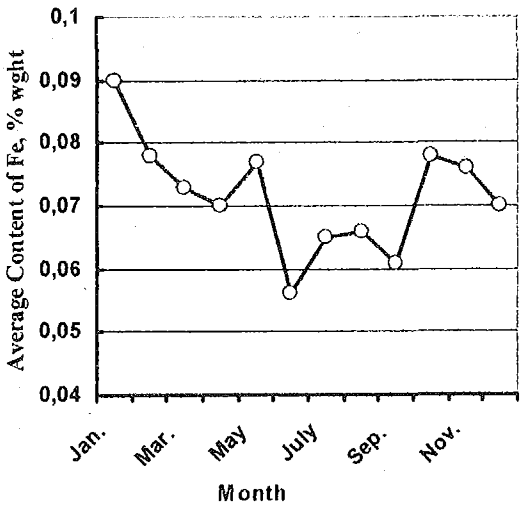

Fig. 5. Average Monthly Content of Fe in B-1 Ingots for 2002 year

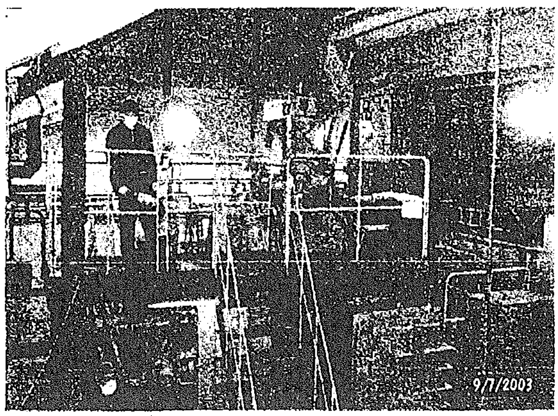

Fig. 6. New Vacuum Induction Furnace for Refining Melting

CONCLUSIONS

1. B-1 grade beryllium ingots produced at Ulba Metallurgical Plant can be used as starting material for the production of beryllium billets of S-65 grade.
2. Ulba have possibility for produce and supply requirement quantity Be ingots for ITER

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