ASIA PACIFIC
PRECIOUS METALS
CONFERENCE
3-5 June 2018
PARKROYAL on Beach Road, Singapore

ALS® AcidLess Separation and FCC® Flameless Casting Chamber, two new green and disruptive techonolgies for precious metals refining and bars manufacturing

Faoro Giovanni / IKOI SpA

current main product lines

FLAMELESS TUNNEL® FURNACES
(Patented Technology)

ALS® ACIDLESS SEPARATION
(Patented Technology)

FCC® FLAMELESS CASTING CHAMBER
(Patented Technology)

GOLD & SILVER CASTING MACHINES

AUTOMATIONS & ROBOTICS

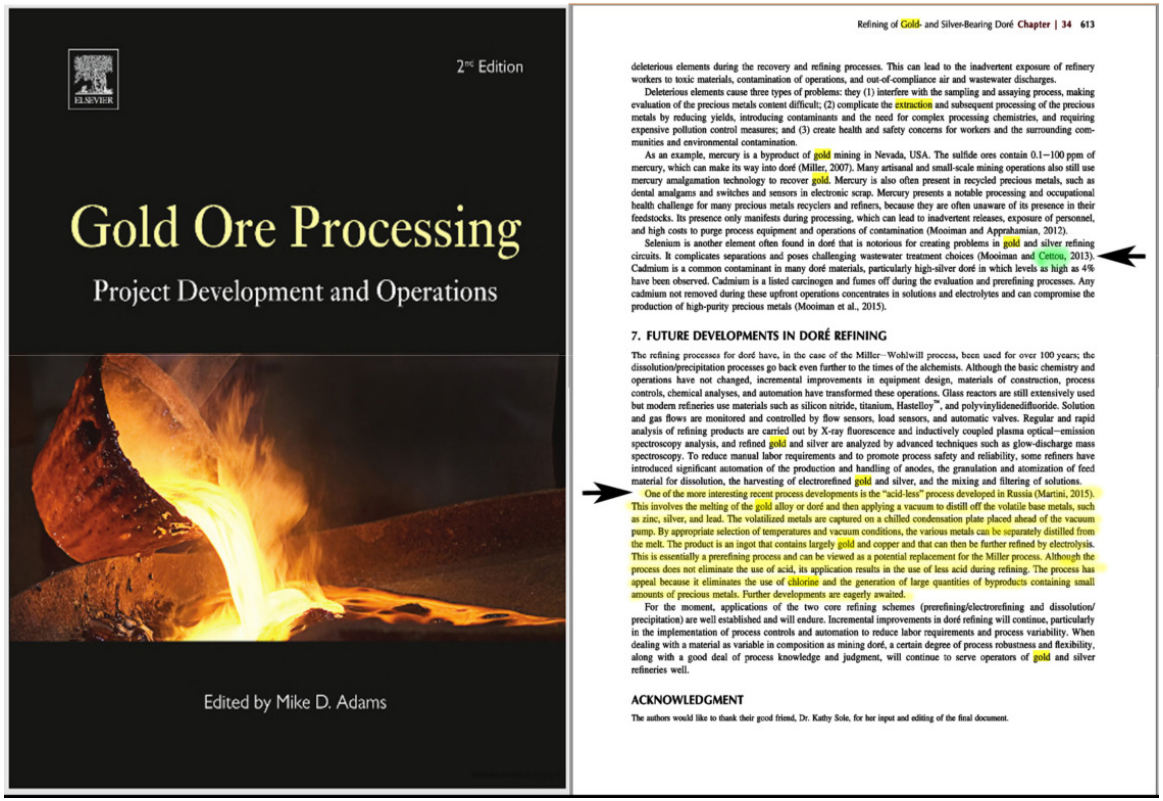
DOSING / WEIGHING MACHINES

TURN KEY PLANTS & SPECIAL PLANTS

AcidLess Separation

AcidLess Separation

- The ALS® represents a real "technological leap" forward in over 150 years of history of precious metals refining.
- Through the distillation under vacuum process, the separation of silver from gold is made avoiding the use of dangerous chemical agents
- The advantages of this new technology are enormous in terms of the yield and productivity of the plants; as confirmed in the "Gold Ore Processing" by Prof. Mike D. Adams, ALS® is defined as "one of the most interesting process innovations seen recently"



Refining of Gold- and Silver-Bearing Doré Chapter | 34 613

deleterious elements during the recovery and refining processes. This can lead to the inadvertent exposure of refinery workers to toxic materials, contamination of operations, and out-of-compliance air and wastewater discharges.

Deleterious elements cause three types of problems: they (1) interfere with the sampling and assaying process, making evaluation of the precious metals content difficult; (2) complicate the extraction and subsequent processing of the precious metals by reducing yields, introducing contaminants and the need for complex processing chemistries, and requiring expensive pollution control measures; and (3) create health and safety concerns for workers and the surrounding communities and environmental contamination.

As an example, mercury is a byproduct of gold mining in Nevada, USA. The sulfide ores contain 0.1–100 ppm of mercury, which can make its way into doré (Miller, 2007). Many artisanal and small-scale mining operations also still use mercury amalgamation technology to recover gold. Mercury is also often present in recycled precious metals, such as dental amalgams and switches and sensors in electronic scrap. Mercury presents a notable processing and occupational health challenge for many precious metals recyclers and refiners, because they are often unaware of its presence in their feedstocks. Its presence only manifests during processing, which can lead to inadvertent releases, exposure of personnel, and high costs to purge process equipment and operations of contamination (Mooiman and Apprahamian, 2012).

Selenium is another element often found in doré that is notorious for creating problems in gold and silver refining circuits. It complicates separations and poses challenging wastewater treatment choices (Mooiman and Cettou, 2013). Cadmium is a common contaminant in many doré materials, particularly high-silver doré in which levels as high as 4% have been observed. Cadmium is a listed carcinogen and fumes off during the evaluation and prerefining processes. Any cadmium not removed during these upfront operations concentrates in solutions and electrolytes and can compromise the production of high-purity precious metals (Mooiman et al., 2015).

7. FUTURE DEVELOPMENTS IN DORÉ REFINING

The refining processes for doré have, in the case of the Miller–Wohlwill process, been used for over 100 years; the dissolution/precipitation processes go back even further to the times of the alchemists. Although the basic chemistry and operations have not changed, incremental improvements in equipment design, materials of construction, process controls, chemical analyses, and automation have transformed these operations. Glass reactors are still extensively used but modern refineries use materials such as silicon nitride, titanium, Hastelloy™, and polyvinylidenedifluoride. Solution and gas flows are monitored and controlled by flow sensors, load sensors, and automatic valves. Regular and rapid analysis of refining products are carried out by X-ray fluorescence and inductively coupled plasma optical–emission spectroscopy analysis, and refined gold and silver are analyzed by advanced techniques such as glow-discharge mass spectroscopy. To reduce manual labor requirements and to promote process safety and reliability, some refiners have introduced significant automation of the production and handling of anodes, the granulation and atomization of feed material for dissolution, the harvesting of electrorefined gold and silver, and the mixing and filtering of solutions.

One of the more interesting recent process developments is the "acid-less" process developed in Russia (Martini, 2015). This involves the melting of the gold alloy or doré and then applying a vacuum to distill off the volatile base metals, such as zinc, silver, and lead. The volatilized metals are captured on a chilled condensation plate placed ahead of the vacuum pump. By appropriate selection of temperatures and vacuum conditions, the various metals can be separately distilled from the melt. The product is an ingot that contains largely gold and copper and that can then be further refined by electrolysis. This is essentially a prerefining process and can be viewed as a potential replacement for the Miller process. Although the process does not eliminate the use of acid, its application results in the use of less acid during refining. The process has appeal because it eliminates the use of chlorine and the generation of large quantities of byproducts containing small amounts of precious metals. Further developments are eagerly awaited.

For the moment, applications of the two core refining schemes (prerefining/electrorefining and dissolution/precipitation) are well established and will endure. Incremental improvements in doré refining will continue, particularly in the implementation of process controls and automation to reduce labor requirements and process variability. When dealing with a material as variable in composition as mining doré, a certain degree of process robustness and flexibility, along with a good deal of process knowledge and judgment, will continue to serve operators of gold and silver refineries well.

ACKNOWLEDGMENT
The authors would like to thank their good friend, Dr. Kathy Sole, for her input and editing of the final document.

AcidLess Separation

- The ALS® plant was presented 2 years ago, with a publication in the Alchemist magazine of LBMA.


LBMA

Alchemist

The London Bullion Market Association ISSUE 79 October 2015

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ALCHEMIST ISSUE SEVENTY NINE

Acidless Separation: New Technology for Refining Gold and Silver

By Giovanni Faoro, Chief Executive Officer, IKOI Srl

The Acidless Separation® (ALS) project originates from a collaboration between IKOI Srl and Ekaterinburg Non-Ferrous Metals Processing Plant (EZ-OCM). The need for a 'green' process for precious metal refiners gave the two companies the idea of developing and patenting a new refining process and a new plant, starting from the process that had been used for many years at EZ-OCM. Over the past two years, IKOI has developed the process and the plant, and now the technology is ready to be used by refiners all over the world.

Background of the refining processes

Refiners currently use several refining processes to refine gold and silver, and in particular to separate these two precious metals. All these processes for separating gold and silver use acids or hazardous chemicals.

The most well-known 'crude' process is Metal Chlorination (Miller process), which is applied to a vast range of alloys and is used by many companies. The Miller process has many disadvantages; for example, it requires many

A second option is to proceed directly with the Electrolysis procedure, but this type of refining process is only advantageous if the input gold alloy contains at least 80% to 85% of gold, otherwise the direct electrolysis procedure can prove very time consuming.

If the gold alloy does not contain the right proportions of gold and silver, then more silver needs to be added to obtain the optimum composition of the gold alloy. Electrolysis, like the Miller process, also incurs high operating costs for the disposal of hazardous materials and involves long precious metal recovery times, in this case, not from the sludge but from the solutions and the anodes.

The final process that we wish to analyse is Dissolution-Precipitation, such as in the process with aqua regia, which has the same disadvantages as the Electrolysis process except that the significant investment in metals is not necessary for this process.

The main advantage of Acidless Separation® (ALS) over the processes discussed above is its 'green' philosophy. In fact, ALS requires no chemicals, for example acids, chlorine or other hazardous materials, and it has zero emissions. Another advantage of this technology is its universal application, as the ALS process removes the limitations imposed by the composition of the input alloy.

"In 2013, a meeting between IKOI and EZ-OCM gave rise to the idea of developing, patenting and marketing the ALS technology, starting from the technology that had already been in use in the EZ-OCM plants since the 1990s."

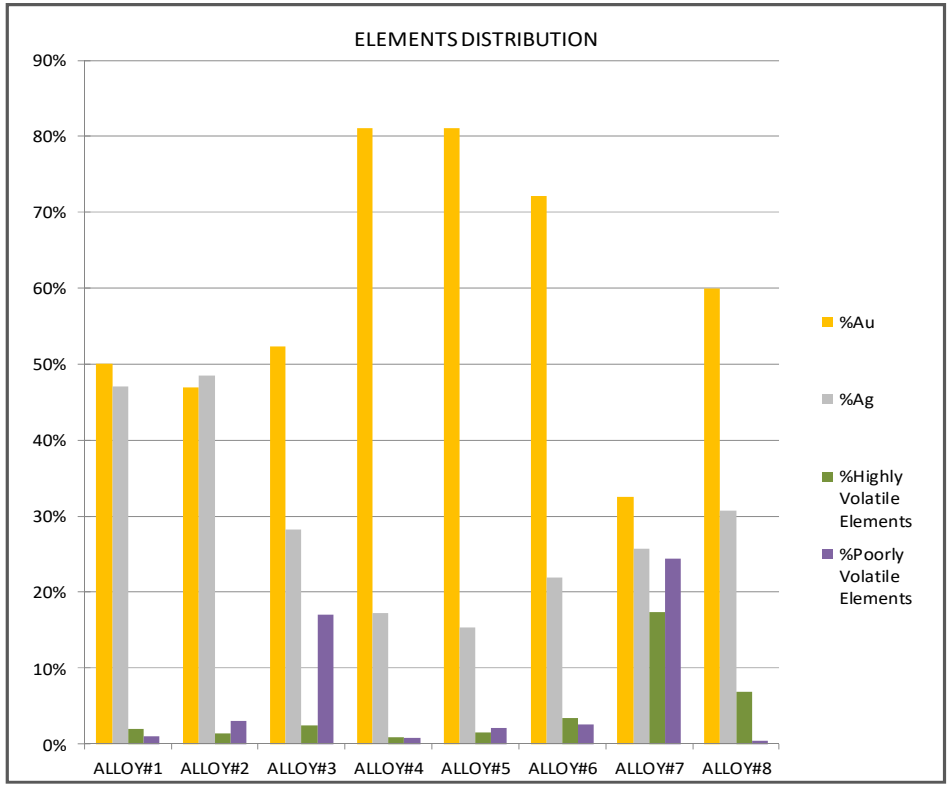
The Acidless Separation® machine is also quick and easy to use. It is a fully automatic

- Since then, 5 ALS® plants have already been installed and are currently in operation in the largest international PMs refineries.

AcidLess Separation

Summary overview of the performance of the Acid-Less Separation technology as pre-refining step

ALLOY	Type	Kg Batch	%Au	%Ag	%Highly Volatile Elements	%Poorly Volatile Elements	Ag YIELD	Au YIELD
ALLOY #1	Very rich in Silver	58.7	50,02%	47,02%	1,94%	1,02%	94,7%	98,79%
ALLOY #2	Very rich in Silver	56.5	47,00%	48,50%	1,40%	3,10%	99,5%	97,68%
ALLOY #3	Rich in Silver	52.9	52,30%	28,23%	2,50%	16,97%	98,4%	98,53%
ALLOY #4	Rich in Gold	58.9	81,04%	17,30%	0,90%	0,76%	96,9%	97,44%
ALLOY #5	Rich in Gold	44.1	81,10%	15,30%	1,50%	2,10%	70,9%	99,54%
ALLOY #6	Rich in Silver/imp.	29.1	72,08%	21,90%	3,41%	2,61%	73,2%	99,52%
ALLOY #7	Hi impurities cont.	30.8	32,54%	25,70%	17,40%	24,36%	88,7%	99,65%
ALLOY #8	Rich in Ag/Hi imp.	101.5	59,95%	30,73%	6,88%	0,44%	88,7%	99,05%



AcidLess Separation

ALS® Acid-Less Separation technology advantages

SPEED OF PROCESS
Much shorter than chemical processes

EASY TO OPERATE
With exception of loading and unloading, the process is fully automatized

SAFE AND SECURE
It is a batchwise process, taking place in a fully confined environmnent

LESS METAL IMMOBILISATION
Only incoming feedstock is treated. There is no need to correct the alloy avoiding P.M. lock up

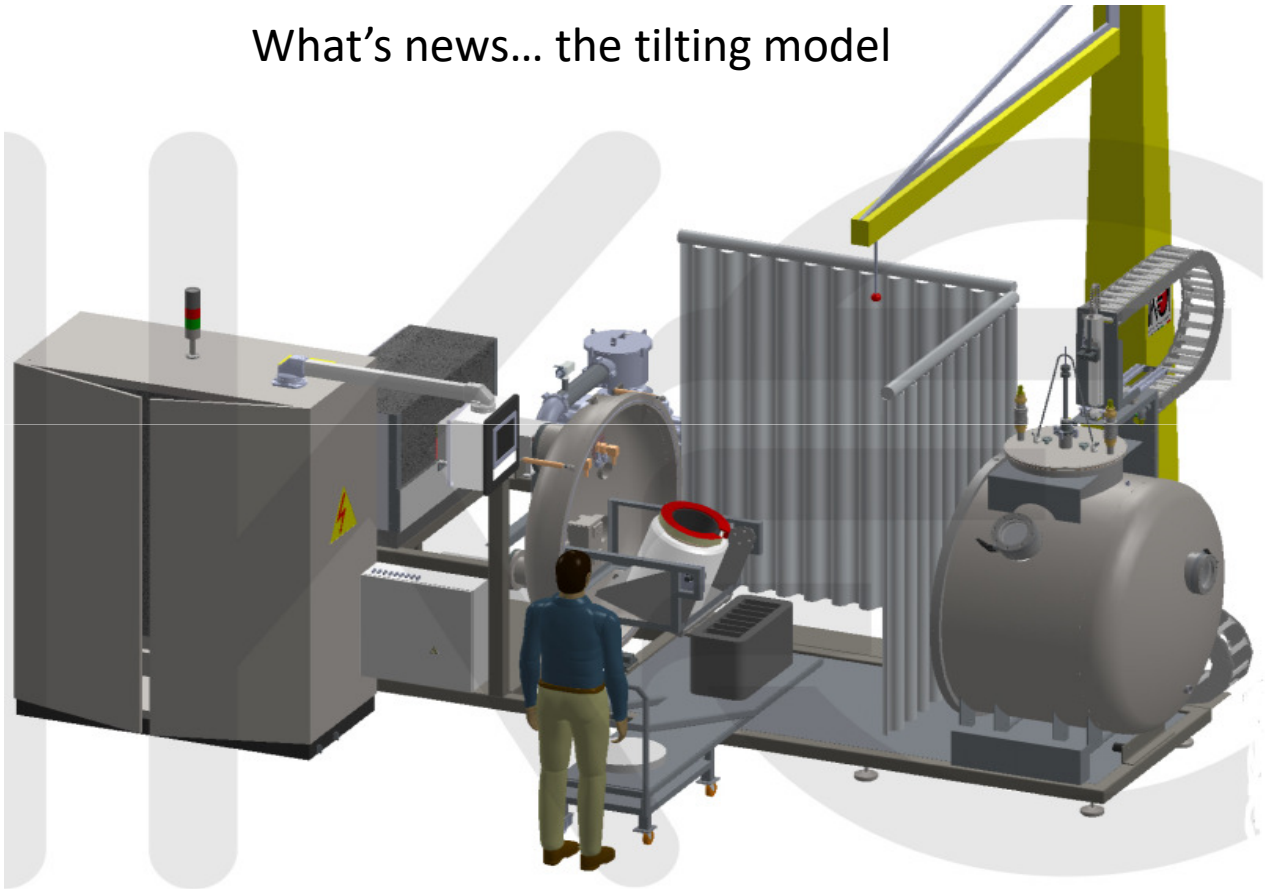
GREEN COMMITMENT
No chemicals consumption, no fume, no liquid effluent

NO METAL LOSS
There is no loss of any kind of precious material

The economic benefits declared by some customers after the use of the ALS® technology have been quantified on a prudential basis in 400÷500 thousand Euros per year.

AcidLess Separation

What's news… the tilting model

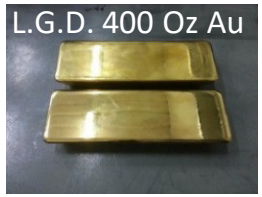


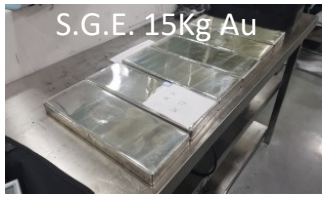
Flameless Casting Chamber system

FLAMELESS CASTING CHAMBER®

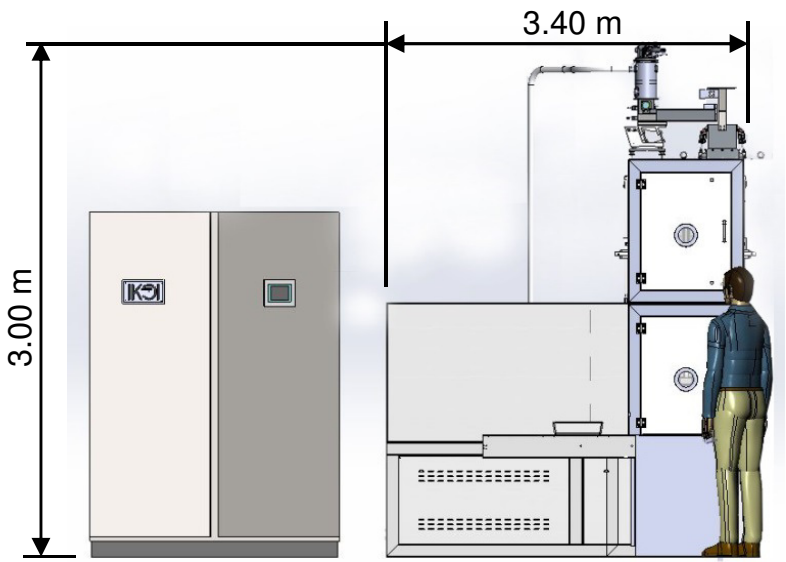
Melting & Casting Bars System

A worldwide patented technological innovation
to produce any kind of Gold & Silver banking bars
3Kg SGE, 15Kg SGE, 400 Oz LGD, 1000 Oz LGD and any others
at lower cost
saving energy up to 50%
totally **GREEN** for the environment





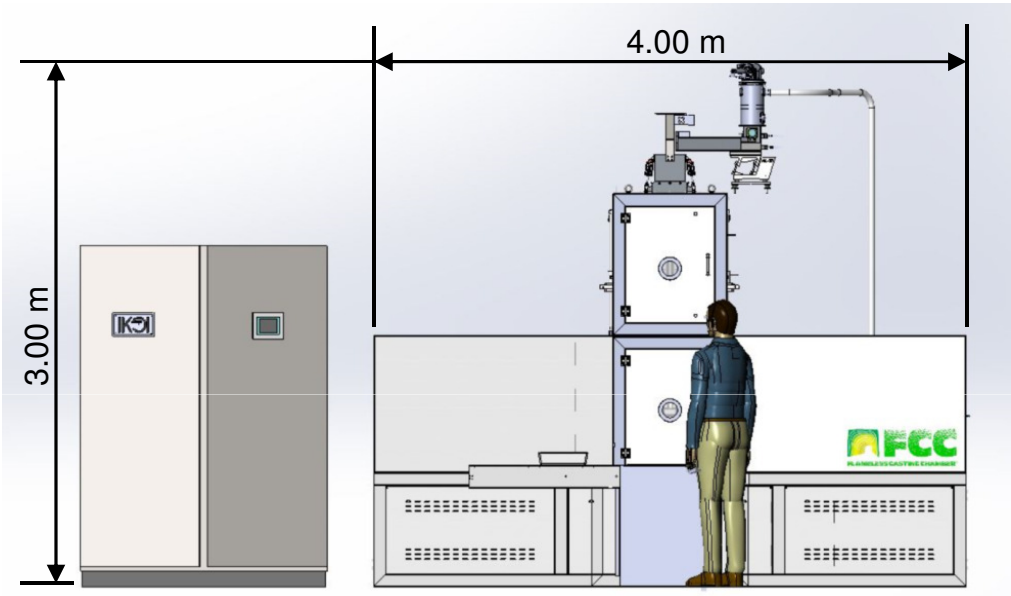
Flameless Casting Chamber system



FCC®-3 automatic system for the production up to 3 bars/h 1000 oz Ag from crystals

Bar size	Metal	Max hourly productivity (bars/h)	Max hourly productivity (Kg/h)	Max productivity per 8h shift (Ton/shift)
1000 oz London Good Delivery	Silver	3 pcs/h	~93 Kg/h	~0.75 Ton/shift
15 Kg SGE Standard	Silver	5-6 pcs/h	~75-90 Kg/h	~0.72 Ton/shift
400 oz London Good Delivery	Gold	5-6 pcs/h	~62-74 Kg/h	~0.60 Ton/shift

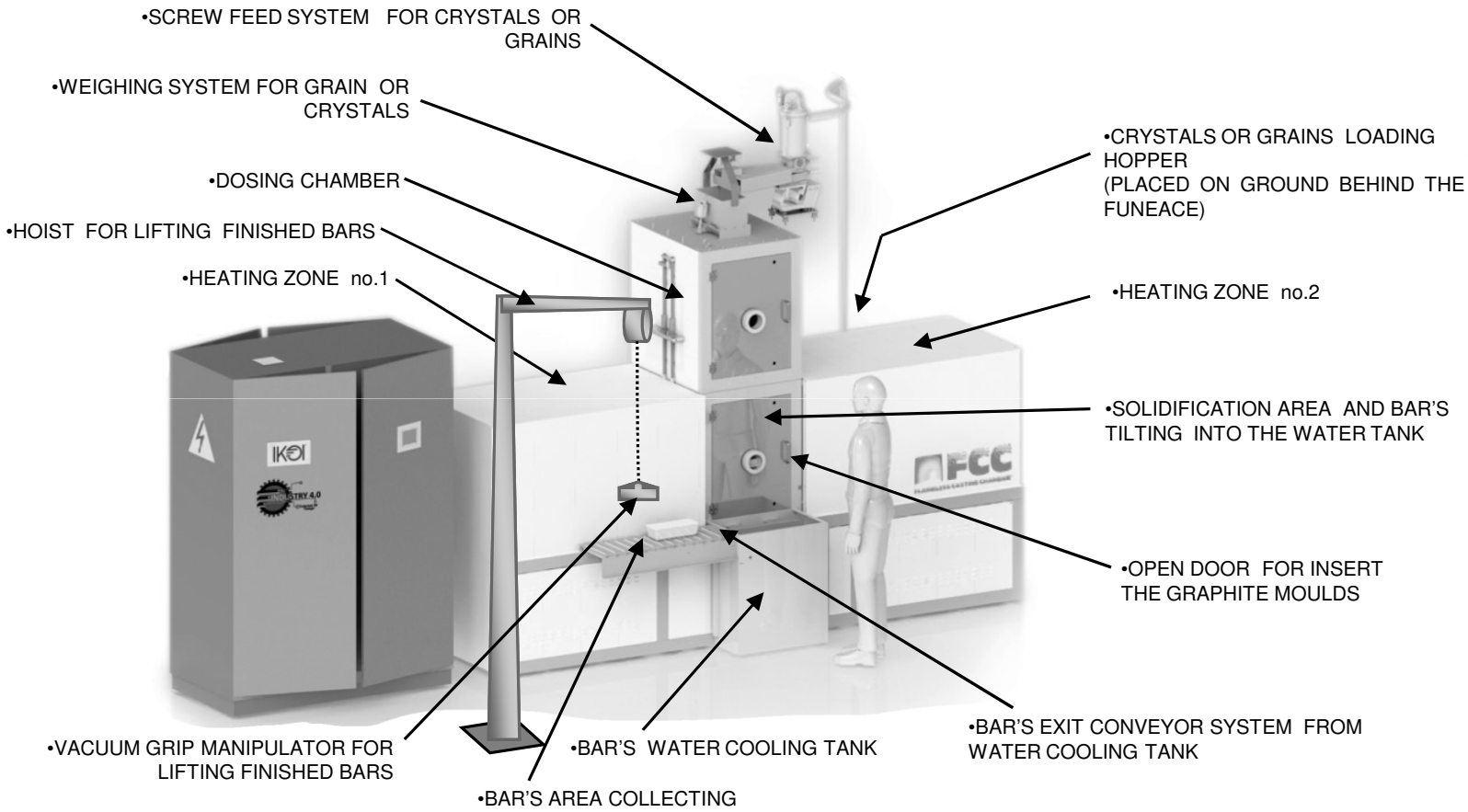
Flameless Casting Chamber system



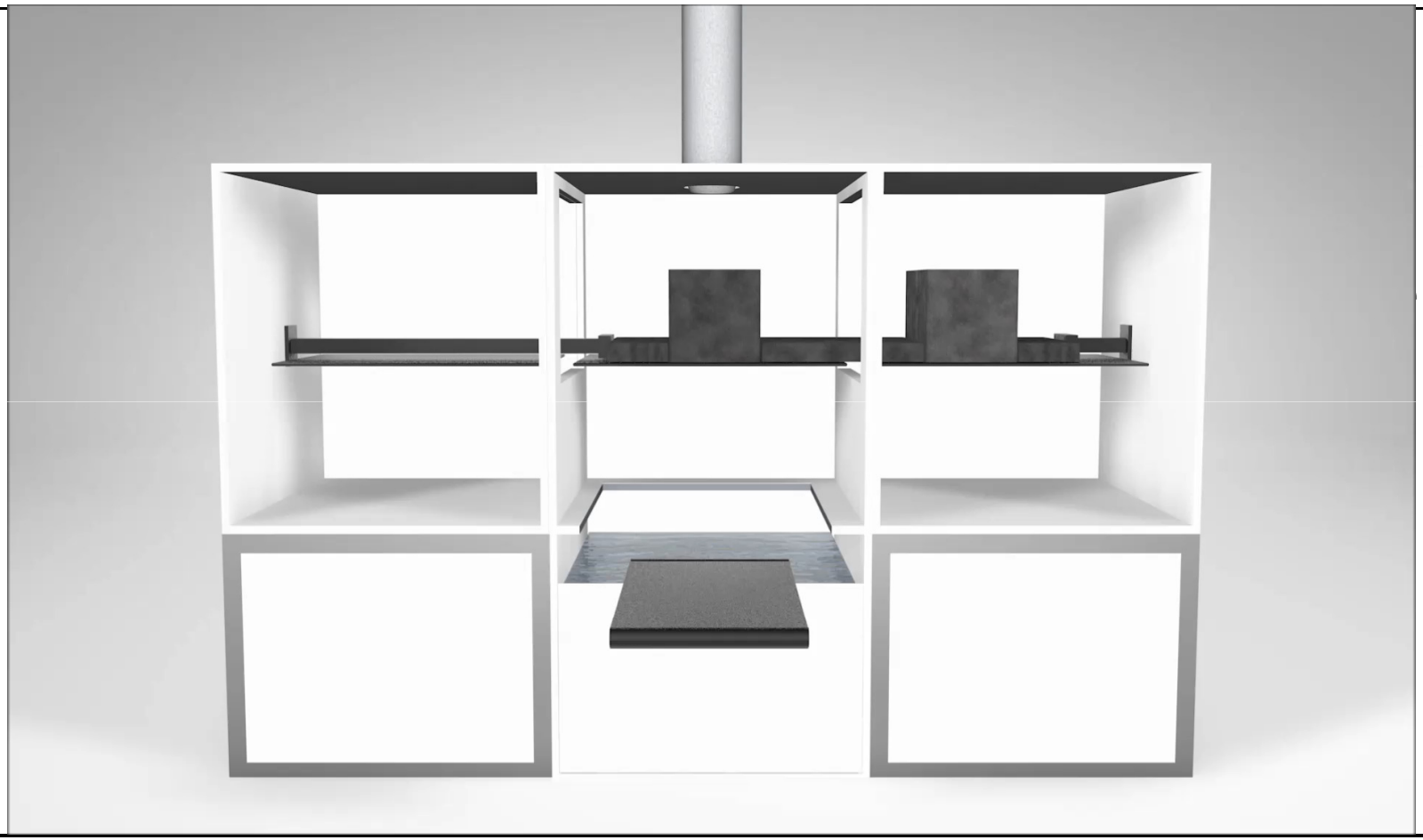
FCC®-6 automatic system for the production up to 6 bars/h 1000 oz Ag from crystals

Bar size	Metal	Max hourly productivity (bars/h)	Max hourly productivity (Kg/h)	Max productivity per 8h shift (Ton/shift)
1000 oz London Good Delivery	Silver	6 pcs/h	~186Kg/h	~1.50 Ton/shift
15 Kg SGE Standard	Silver	10-12 pcs/h	~150-180 Kg/h	~1.45 Ton/shift
400 oz London Good Delivery	Gold	10-12 pcs/h	~124-148.8 Kg/h	~1.20 Ton/shift

Flameless Casting Chamber system



Flameless Casting Chamber system



Flameless Casting Chamber system

ADVANTAGES of the FCC®-3 system

TECHNICAL DATE FOR 1000oz G.D. BARS FROM CRYSTALS	TRADITIONAL "MELTING & CASTING" SYSTEM	NEW FLAMELESS CASTING CHAMBER® FCC®-3
Energy Consumption kW/h	90	75
Power kW (Total installed)	90	150 (50%ON, 50%OFF)
Power kW (heating)	80	150 (50%ON, 50%OFF)
Power kW (suction, moulds pre-heating, ecc)	10	0
Productivity Output	3 bars/hour	3 bars/hour
Output Actual Productivity in 8 Hours Shift	24 bars	24 bars
Safety	✖	✓
Metal Loss	✖	✓
Finished Product Quality	✖	✓
Manpower Needs	✖	✓
Energy Consuption	✖	✓

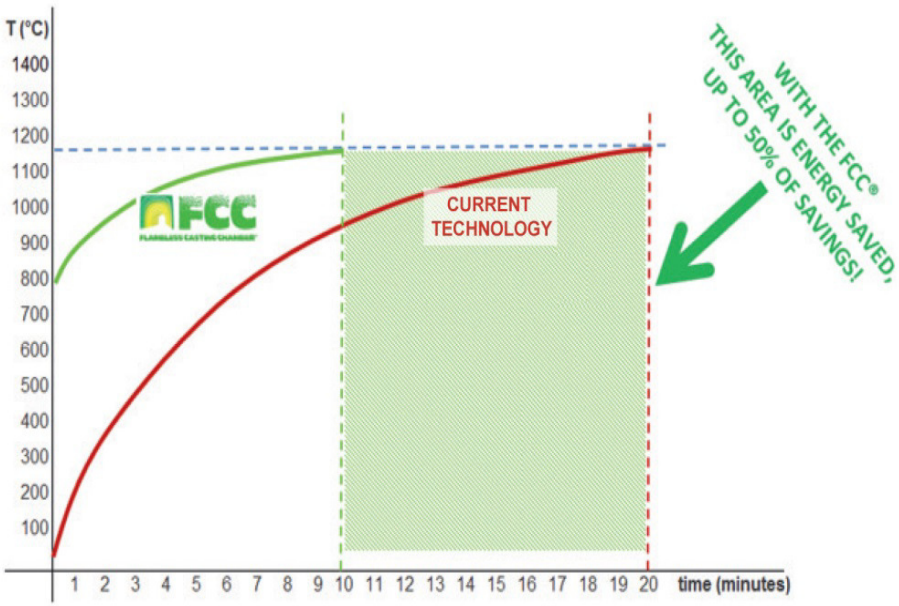
Flameless Casting Chamber system

ADVANTAGES of the FCC®-6 system

TECHNICAL DATE FOR 1000oz G.BD. BARS FROM CRYSTALS	TRADITIONAL "MELTING & CASTING" SYSTEM	NEW FLAMELESS CASTING CHAMBER® FCC®-6
Power kW (heating)	150	150
Power kW (suction, moulds pre-heating, ecc)	20	0
Power kW (Total installed)	170	150
Theoretical Productivity Output	5-6 bars/hour	6 bars/hour
Output Actual Productivity in 8 Hours Shift	40-48 bars	48 bars
Safety	✖	✓
Metal Loss	✖	✓
Finished Product Quality	✖	✓
Manpower Needs	✖	✓
Energy Consuption	✖	✓

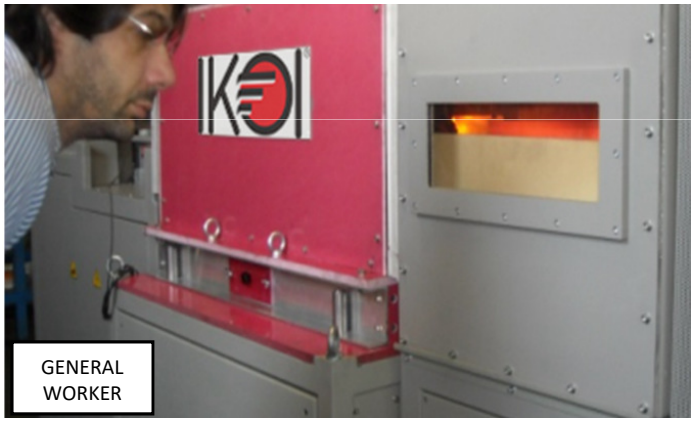
Flameless Casting Chamber system

Energy savings



Safer for the operators
GREEN for the environment

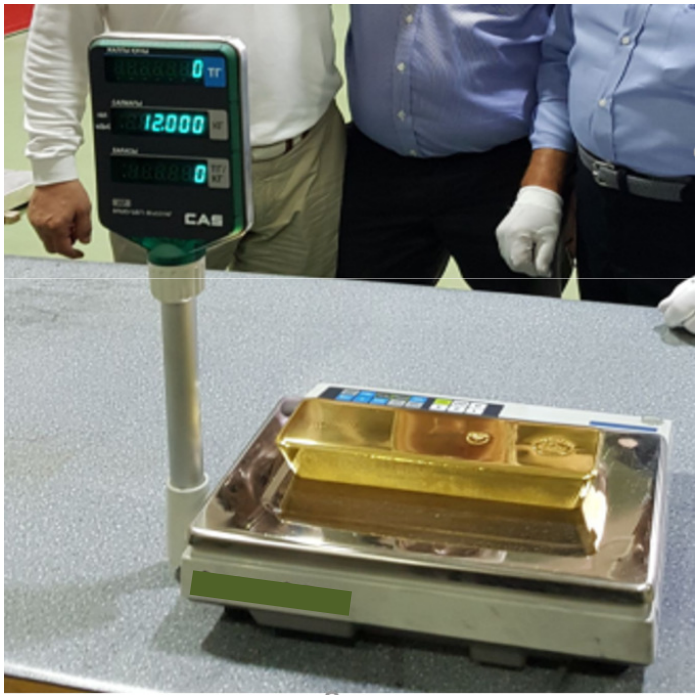
Traditional "melting & casting" system



New FCC®
Flameless Casting Chamber

Flameless Casting Chamber system

Cancels precious metal losses



Increased quality of the bars

traditional way

400 Oz gold FCC® System

traditional way

1000 Oz silver FCC® System

Flameless Casting Chamber system

ADVANTAGES SUMMARY

- ✓ Increased quality of the bars
- ✓ NO precious metal loss
- ✓ **Green** technology, respect for the environment
- ✓ Reduction on length (machine compact and high efficiency)
- ✓ Safer for the operators
- ✓ Reduction of electricity consumption
- ✓ NO radiant and convective heat loss
- ✓ Reduction of the labour time & NOT specialized skilled workers requested
- ✓ Faster production times
- ✓ LBMA accreditation for 400 Oz Au and 1.000 Oz Ag L.G.D. Bars

Flameless Casting Chamber system

PATENT PENDING

The United States of America

The Director of the United States Patent and Trademark Office

Has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this

United States Patent

Grants to the person(s) having title to this patent the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America or importing the invention into the United States of America, and if the invention is a process, of the right to exclude others from using, offering for sale or selling throughout the United States of America, or importing into the United States of America, products made by that process, for the term set forth in 35 U.S.C. 154(a)(2) or (c)(1), subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b). See the Maintenance Fee Notice on the inside of the cover.

Michelle K. Lee

Director of the United States Patent and Trademark Office

Thank you!

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PRECIOUS METALS INGENUITY
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