Evolution of ALS Technology

Enrico Cappellini – General Manager

IKOI S.p.a.

04/08/2023

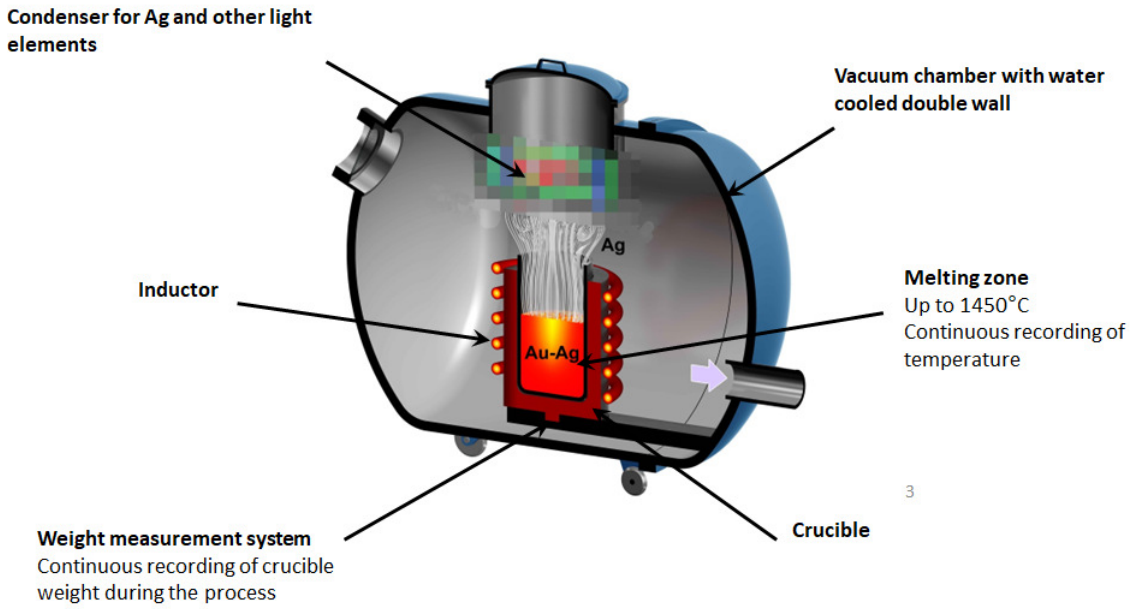
What is an ALS –Acidless Separation® Systems

- ALS is a pre-refining process to remove silver from Au/Ag/Cu alloys using vacuum distillation technology.
- It is used to reduce silver content on Au/Ag/Cu alloys, in order to make the resulting gold based alloy suitable for treatment in the subsequent final refining step (like Wohlwill gold electrolysis OR Aqua Regia that is limited in % of Silver content).

Metal Vacuum Distillation and condensation

- An alloy with silver content 1 to 90% is loaded into a graphite crucible.
- Vacuum is created.
- The graphite crucible is heated and the process of vacuum distillation is performed.
- Silver from the vapour phase condenses as solid metal particles on the cooled condenser.

By an **appropriate choice of temperature and vacuum conditions**, different metals can be distilled from the melt separately.



The vapor pressure of metallic elements

- The literature provides table giving vapor pressure data as a function of temperature, following the simplified Clausius-Clapeyron relation :

$$\ln p = A - B/T$$

- ALS will work at around 10^{-2} - 10^{-3} mbar and from 1300°C up to 1450°C.
- For these conditions, we can see that :
- The evaporation temperature for Zn, Pb, Se, Te, Sb, Bi is lower than for Ag
- The evaporation temperature for Ni, Fe, Pd, Pt is higher than for Au

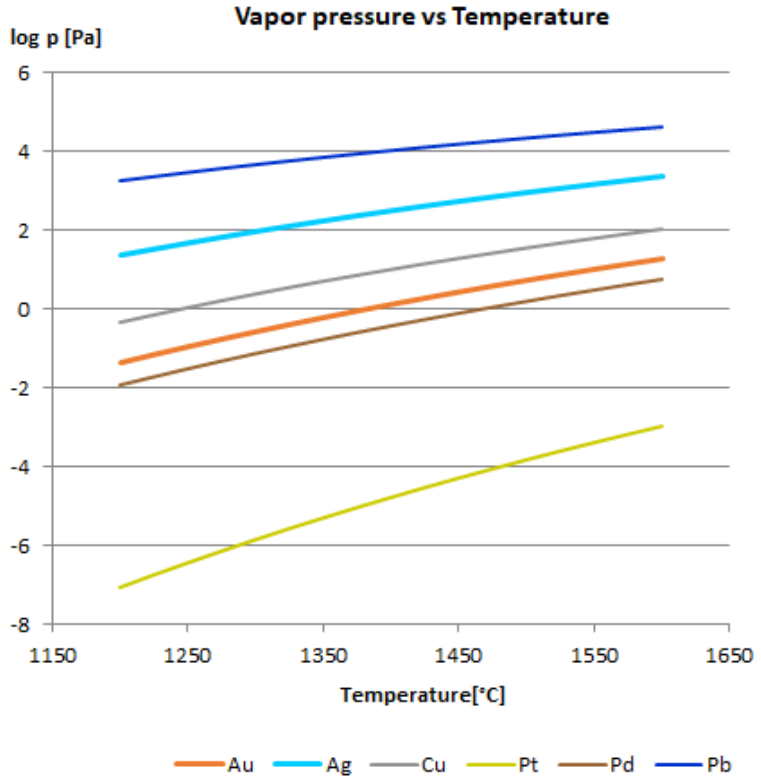
Selectivity of the evaporation

Empirical rule to evaluate the selectivity in the separation process :

$$K = \frac{P_1(T)}{P_2(T)} \frac{x_1(T)}{1 - x_1(T)} > 100$$

p1=vapor pressure of most volatile element
p2=vapor pressure of less volatile element
X1=molar fraction of the most volatile element

As an example for :
Au 70% Ag 30% at T=1'350°C
$K = \sim 150$



But note that when the molar fraction of the most volatile element tends to zero, then the K value strongly decreases. As a consequence the selectivity decreases when the molar fraction of a particular element becomes low

Theoretical evaporation rate

Ideal rate of evaporation as a function of temperature per unit area is given by Langmuir's equation :

$$\dot{m} = \frac{p_v}{\sqrt{2\pi MRT}}$$

M = molar mass of the element
R = ideal gas constant
T = absolute temperature
Pv = vapor pressure of the element

Example :

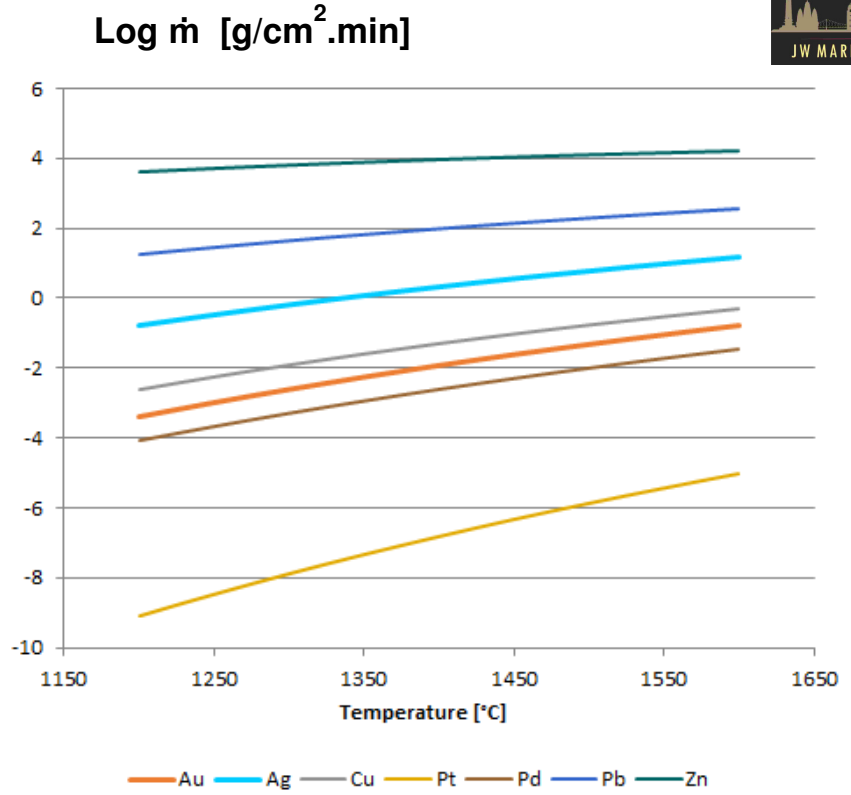
T = 1'350 °C

Crucible diameter = 20 cm

ṁ Ag = 315 g/min

ṁ Au = 1.6 g/min

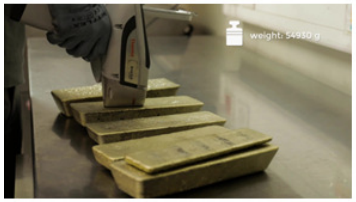
ṁ Cu = 10 g/min



ALS- AcidLess Separation® in Major Refineries worldwide

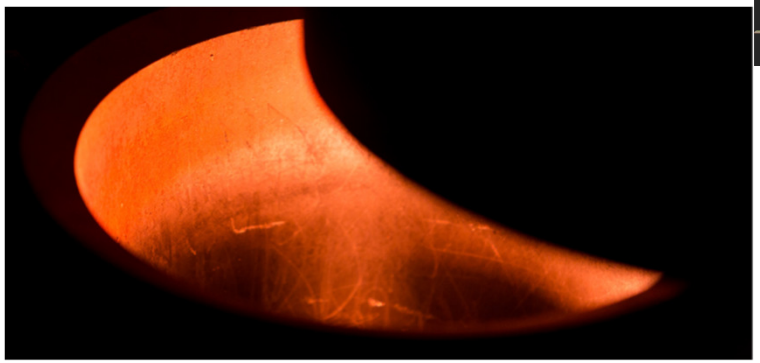
Dorè from mining with high silver content is commonly processed with ALS – AcidLess separation before final refining to obtain 9999 Au.

The process is very **sustainable, cost effective** and in line with the latest **ESG requirement** to **reduce the impact on the environment and improve working conditions.**



Evolution of ALS Technology

The same technology has been successfully tested in other applications, such as high purity silver distillation, Rhodium alloys concentration process and PGM recovery from low grade alloys.



The next step is to apply the experience of vacuum distillation to create a product suitable for Jewellery alloys:

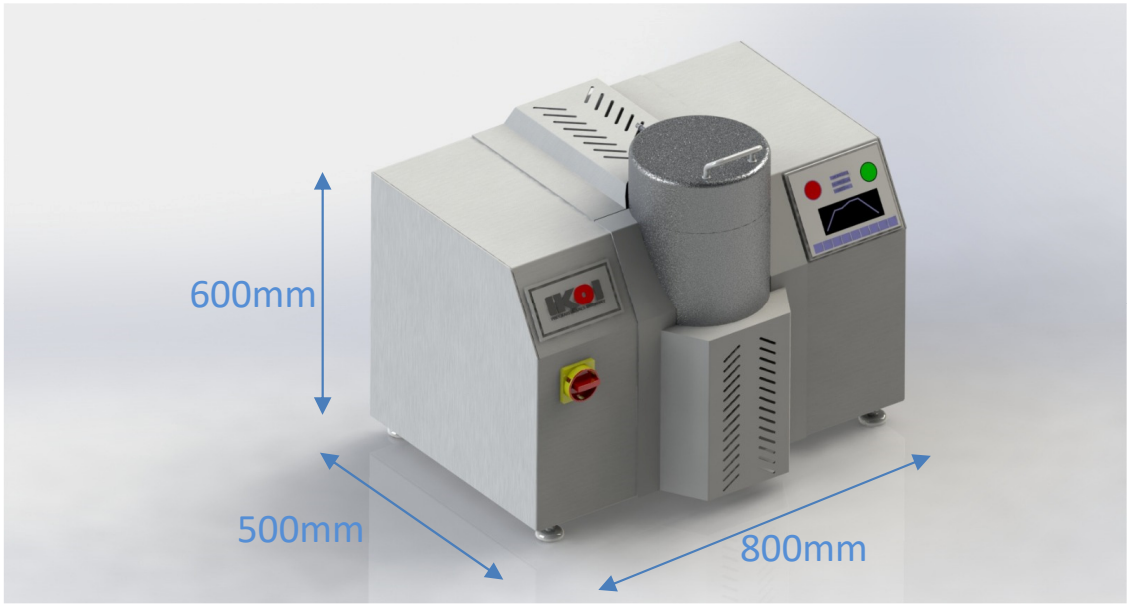
18 karat
14 karat
9 karat

Vacuum Distillation Unit for 1 kg batch: Main features

1 kg batch (pre-melted)
Compact benchtop design
Single condenser (patented)
Water cooled chamber
Pure Graphite crucible
Simple HMI system
ALS-AcidLess separation technology

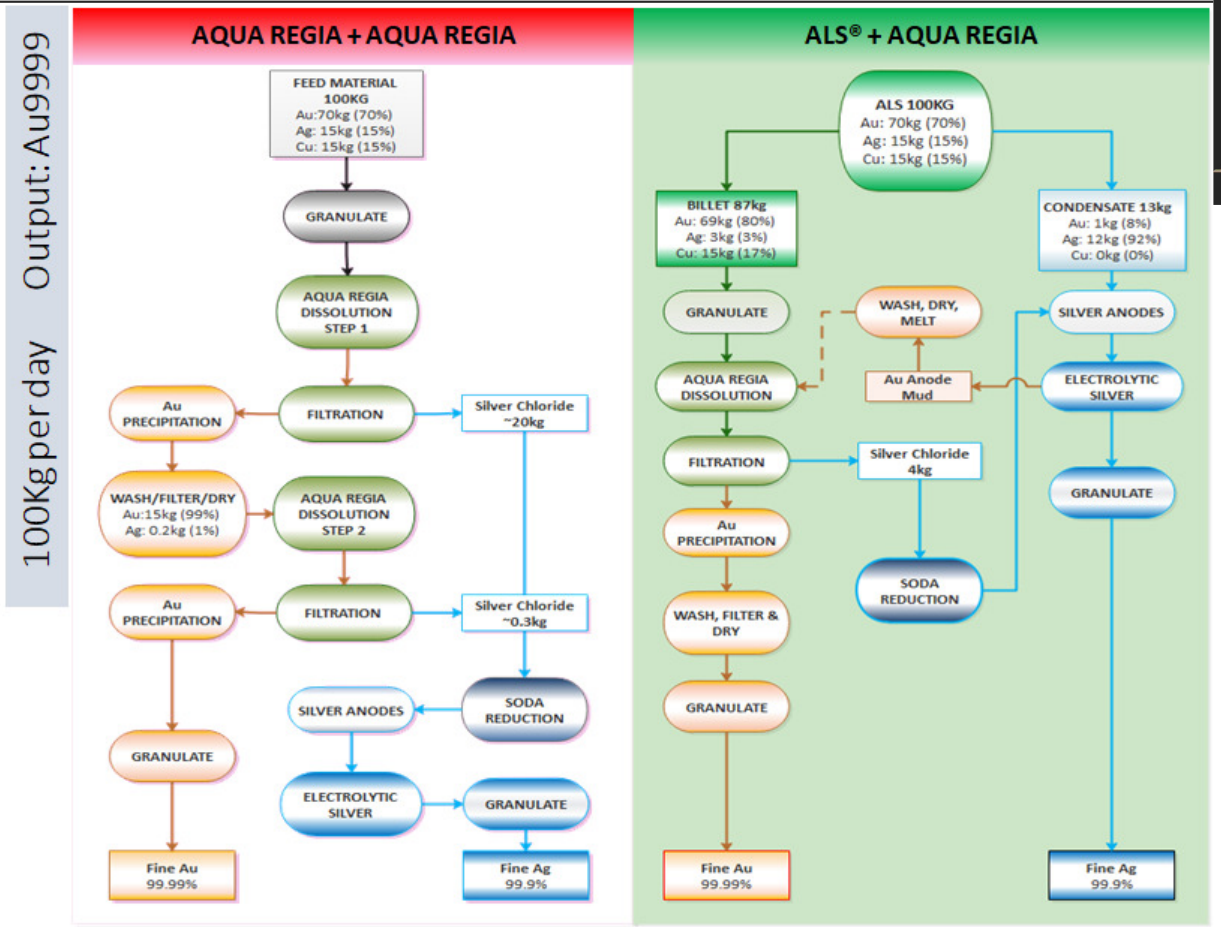
Vacuum Distillation Unit for 1 kg batch: Benefit

Cost competitive
Simple to use and maintain
Low Opex
Fast silver separation time
Easy to recover gold and silver
No need for specialized technicians
No metal losses
No effluent
No fumes
Green and sustainable technology



Process Comparison for 18 karat alloy (casting trees)

Typical process for 18 karat alloy refining (Jewellery scrap), compared to the alternative process introducing ALS technology



Benefits of Vacuum distillation process for Karat Gold:

1. Lower inventory as gold is available faster
2. Lower Opex
3. Lower gold loss
4. Less effluent per oz of gold recovered
5. Less cost per oz of silver recovered
6. Better metal control
7. Easy in-house solution for jewellery refining

Thank you!

Q & A session