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Process Development and Growth of Non-Ferrous Metals Production The Role of Pilot Plants

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European Metallurgical Conference
EMC 2009
June 28 - July 1, Innsbruck, Austria

AGENDA

1. Introduction
2. Growth of world non-ferrous metals production
   - How growth can be achieved?
3. The role of Piloting in satisfying capacity demands
   - Development of new technology
   - How processes in current use were piloted and developed?
   - The scale of piloting.
4. The place of piloting in the non-ferrous industry
   - Features of pilot plant operations – some case histories
   - Ingredients of a successful pilot plant campaign

INTRODUCTION

- **Why to write about pilot plants?**
- **Well, I am sure most of you knows Philip Mackey!**
- **(Sorry Arthur and Sorry Gerardo!).. He loves piloting!**
- **What my colleagues observed in the last year**
  - **A significant number of plants being closed (**Talvivaara, Finland; Morenci, USA; Ravensthorpe and Hismelt in Australia)
- **And they asked themselves:**
  - were each of the above plants thoroughly tested and piloted before commercialization?
  - What was the role of piloting in these mining/metallurgy news stories?
- **And the Answer was:** We do not know…but will be interesting to have a look at some historical patterns of successful process plant development

The world of metals…..

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The world of metals….a critical component in society

After current declines, it is projected that a period of growth will resume.

It is projected that both copper and nickel requirements are likely to grow at about 4-6% annually.

For copper, this requires of the order of an extra 800,000 tpy of refined copper, while for nickel this growth requires of the order of 75,000 tpy of finished nickel.

Growth can be achieved by..

- **Organic growth**
  - **Duplication and expansion of established processes and facilities.**
  - **Known, predictable, but subject to suitable raw material supply (as regards both quality and quantity)**

Size of copper smelters since 1900

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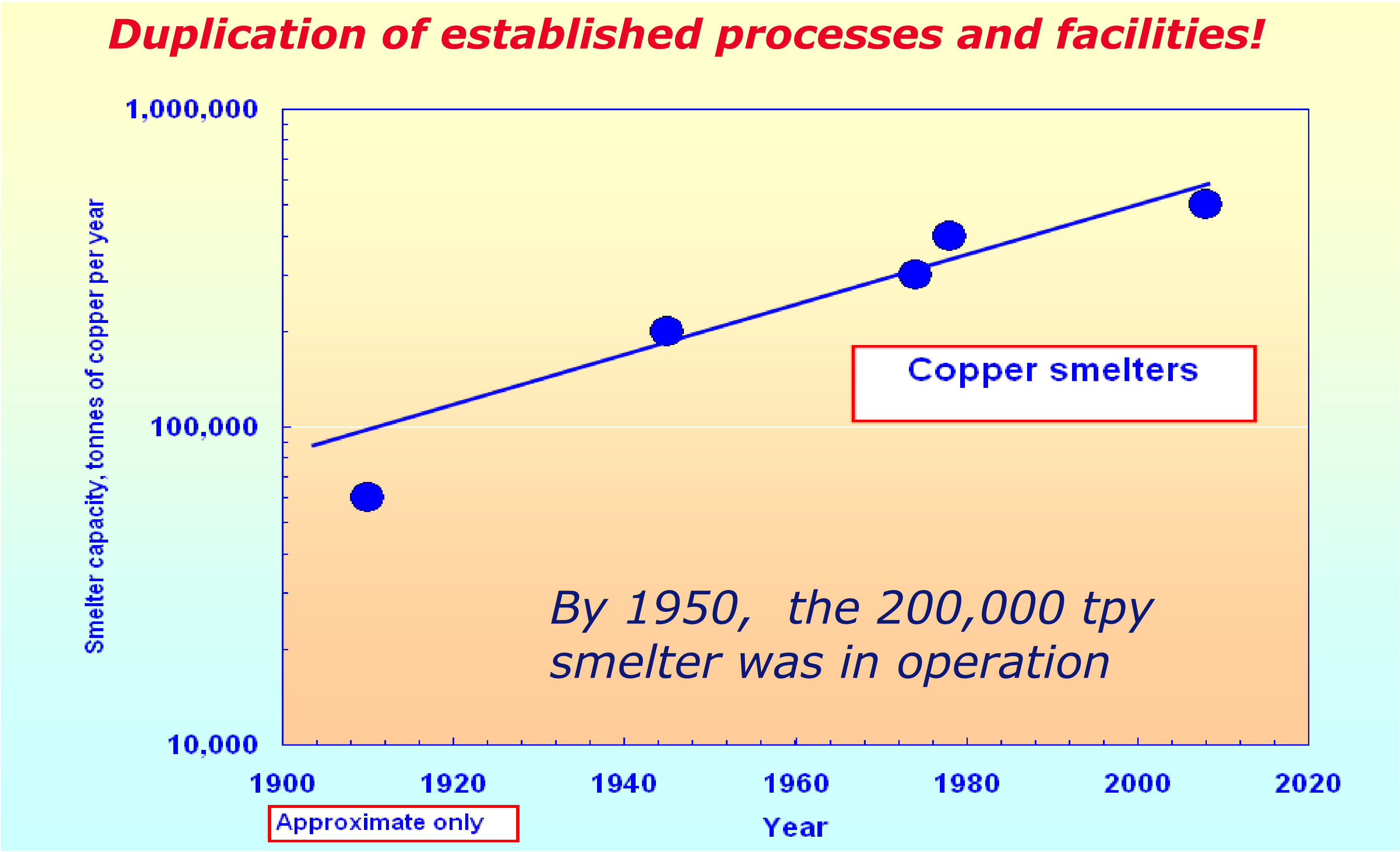
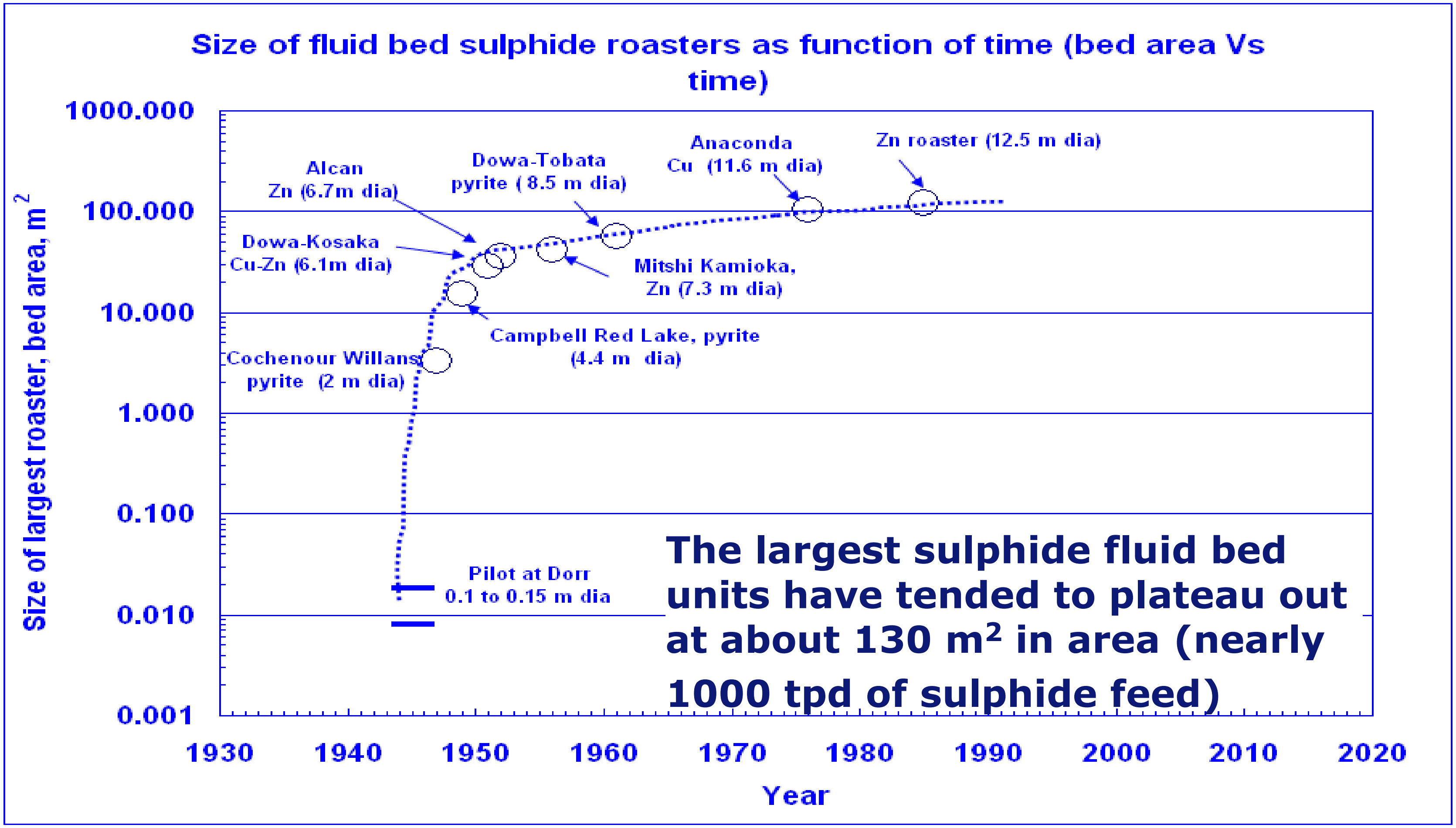


Size of fluid bed sulphide roasters as function of time

Expansion of established processes and facilities!



The largest sulphide fluid bed units have tended to plateau out at about 130 m² in area (nearly 1000 tpd of sulphide feed)

Growth can be achieved by..

- **Technological development**
  - **Creative and innovative ways to convert different feeds into saleable commodities.**
  - **Risky, but can provide investors with a leading edge technology and important cost reductions.**
  - **The risk must be managed**
    - **Piloting plays a crucial role.**

Growth by Technological Innovation

The drivers for new technologies include:

- **New ways to process complex or lower grade materials economically**
- **Environmental considerations**
- **Improved control**
- **Increased productivity**
- **Lower unit costs**
- **Elimination of batch processes**

New technology needs to be proven

Some Facts About Technological Evolution in the Non-Ferrous Industries

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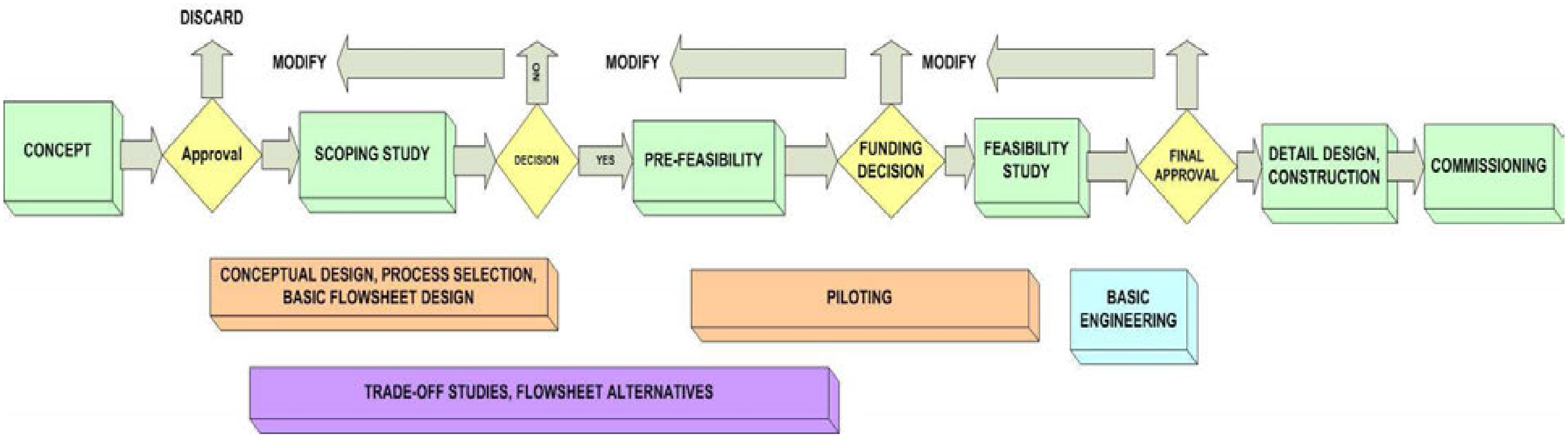
- All the currently established technologies in use in copper and nickel extraction today are relatively recent
- Over 80% of copper smelters use flash or bath smelting, both unknown or conceptual just 50 years ago.
- All current nickel extraction uses processes developed in the last 4 decades, some in the last 2!

The Place for Piloting in Typical Projects:



An example: Development of the ISAMILL technology

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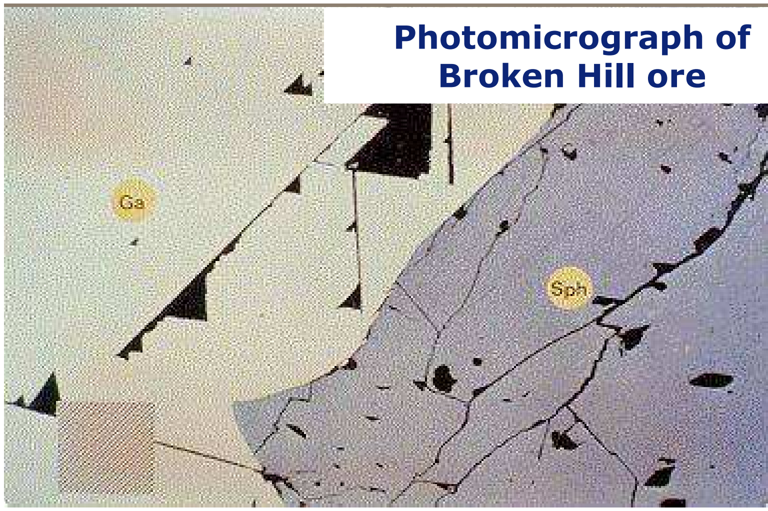
- **The basic need:**
  - A new approach to turn the huge McArthur River zinc-lead deposit from an interesting assemblage of minerals into an ore body (1991).

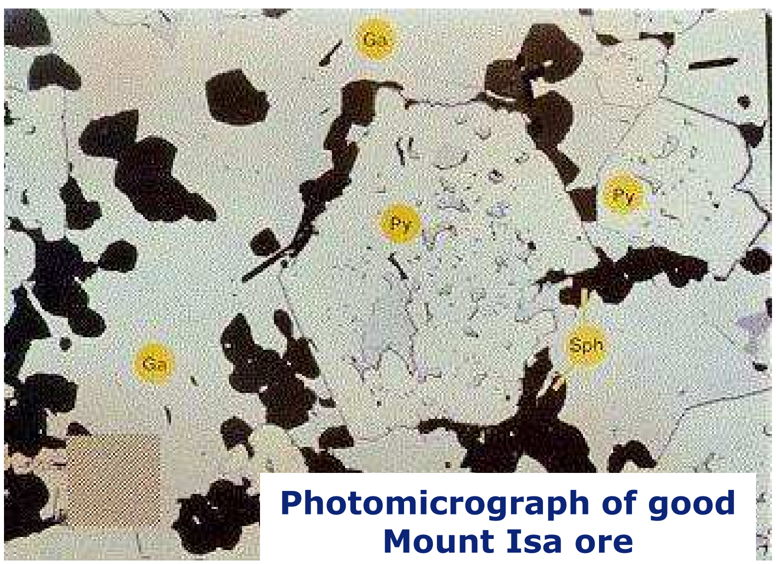
- **The key issue:**
  - The fine nature of the minerals with complex intergrowths of pyrite, sphalerite and galena

How to treat this fine material?

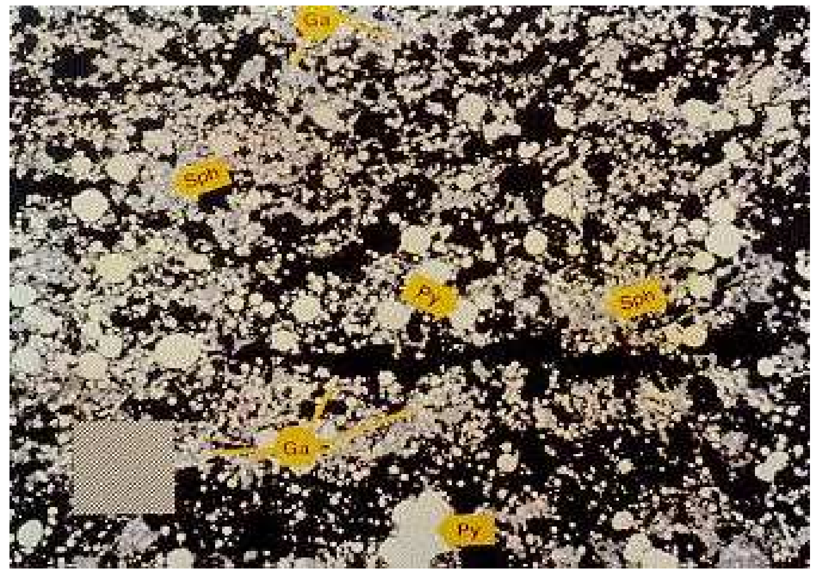
Photomicrograph of Broken Hill ore



Photomicrograph of good Mount Isa ore



Photomicrograph of McArthur River ore



- **Differences in the Size of Galena Crystals**
- **Fine Grinding Required**

The Sweet innovation

- The Innovation
  - After looking to conventional grinding and flotation applications or even hydrometallurgical options…the sweet answer was:
    - Technological transfer of the Bead Mill from the paint and chocolate industry to the mineral processing industry
    - This innovation was well tested on today is established and recognized technology

Unit Throughputs Used Throughout a Typical Process Development Cycle

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Typical Process Development Cycle

Development Phase	Unit throughput
Laboratory testing	<0.01
Mini-plant testing	0.01 to 0.1
Pilot testing	1.0
First commercial plant	8 to 10*

*For flash and bath smelting processes. Scale up for fluid bed roasters, kilns and electric furnaces tends to be higher (>20)

Pilot Plant Testing of Non-Ferrous Metallurgical Processes

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Examples of successfully developed processes presently used for nickel and copper production

<u>COPPER</u>

<u>Copper (sulphides)</u>

- **Flash smelting (Outotec and Vale Inco)**
- **Bath smelting (El Teniente, Noranda, TSL (ISASMELT, Ausmelt), Mitsubishi, Vanyukov)**

<u>Copper (Oxides)</u>

- **Heap leaching, bio-leaching**

<u>NICKEL</u>

<u>Nickel (sulphides)</u>

- **Electric furnace smelting (with/without fluid bed roasting)**
- **Flash smelting**

<u>Nickel (laterites)</u>

- **Rotary kiln-electric furnace**
- **Shaft furnace-electric furnace**
- **Blast furnace including nickel pig iron**
- **Caron process, HPAL processes, other**

Development of Current Processes In Use Today – The Role of Piloting - I

A study of the historical pattern of development of current flash and bath smelting processes used for copper and nickel was carried out by the present authors, in particular the laboratory and pilot testing phases.

This study revealed the following trends as regards the first commercial plant that was built in each case.

Development of Current Processes In Use Today – The Role of Piloting - II

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1. Each process was thoroughly tested and well-piloted (during the period 1950s to 1990s)
2. Typically pilot campaigns ran from 0.5 to 2+ years
3. Typically it took the first commercial plant from 1 to 2 years to reach “Design Throughput” (a “Type 2” or “Type 3” start-up)
4. Normally for non-ferrous smelting, the capacity of the first commercial plant was sized 8-10 times the capacity of the pilot plant (2^{nd} and 3^{rd} generation plants are now sized much larger). The scale-up adopted for fluid bed roasters was much larger (>50-100 times).

These results are illustrated in the following bar charts

Development of Current Processes In Use Today – The Role of Piloting - III

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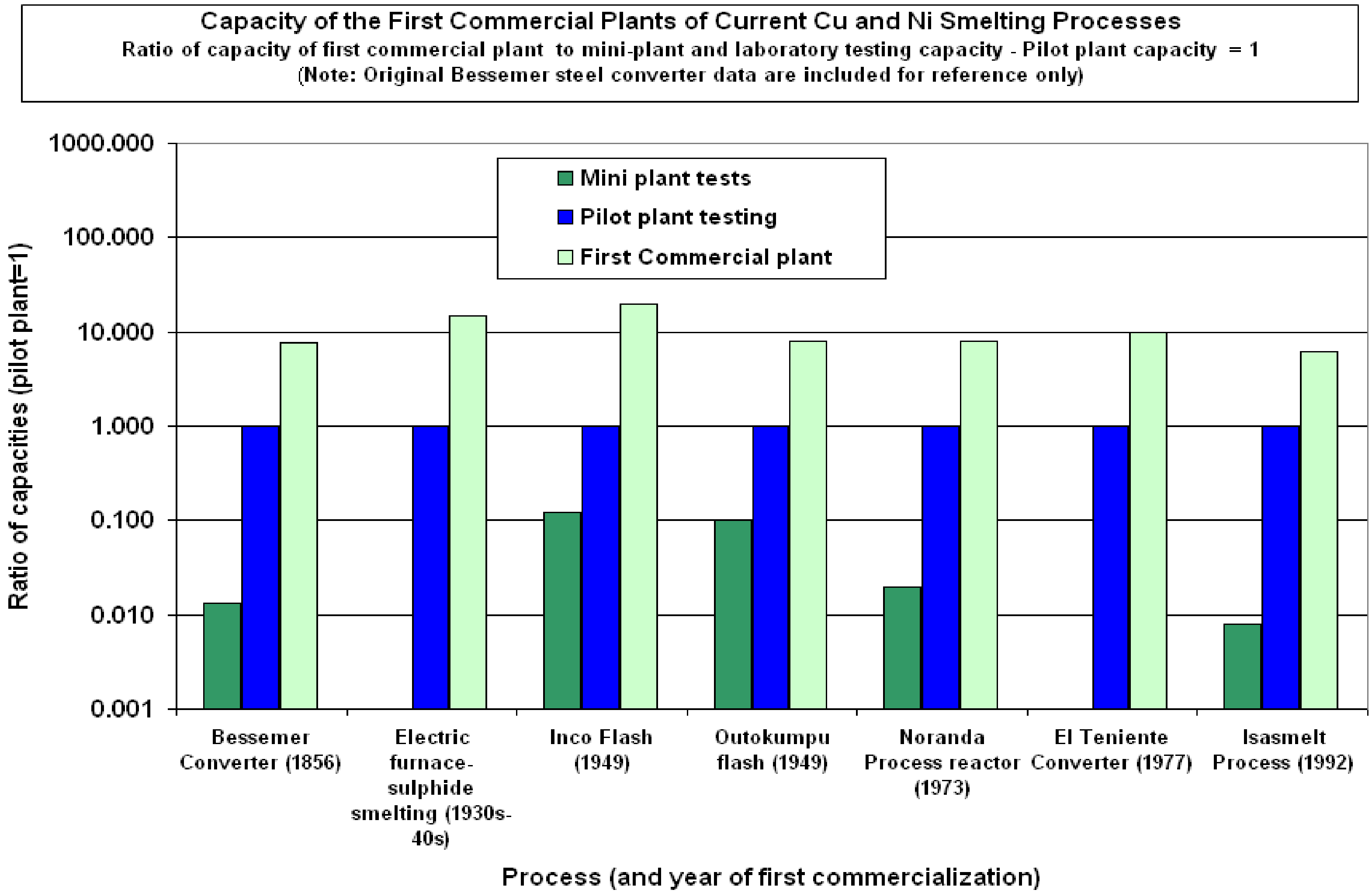

Pilot Plant Testing
Noranda Process Reactor

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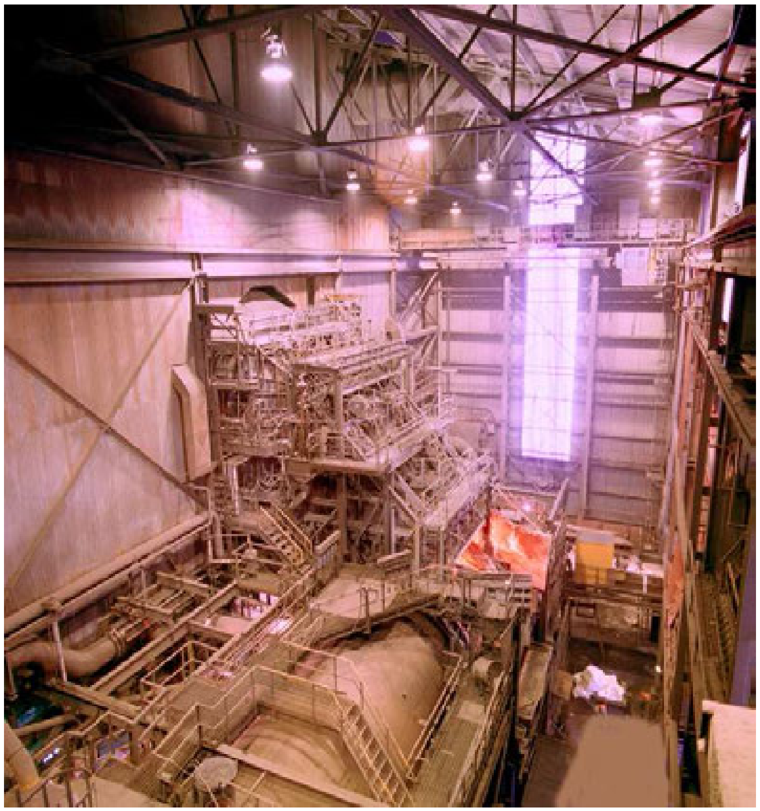

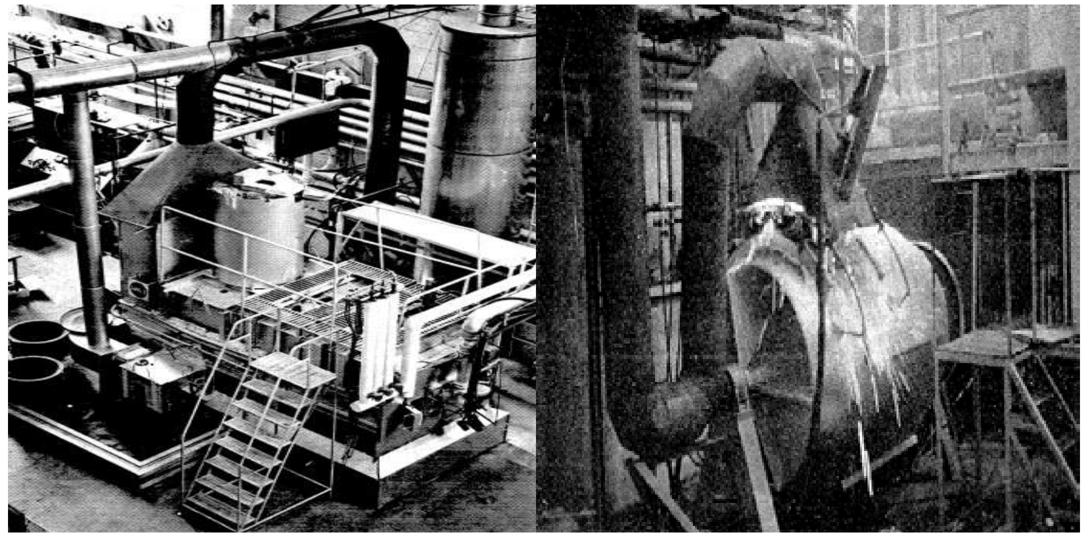

Types of early semi-pilot units (~ 2 tpd) used to test initial Noranda Process concept

800 tpd first commercial plant

Pilot Plant Testing ISASMELT™

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ISASMELT™ pilot plant (1983-1988)

Cu ISASMELT™ Demonstration plant (1987-1991)

Development of Current Processes In Use Today – The Role of Piloting - IV

The first testing and commercialization of the following processes:

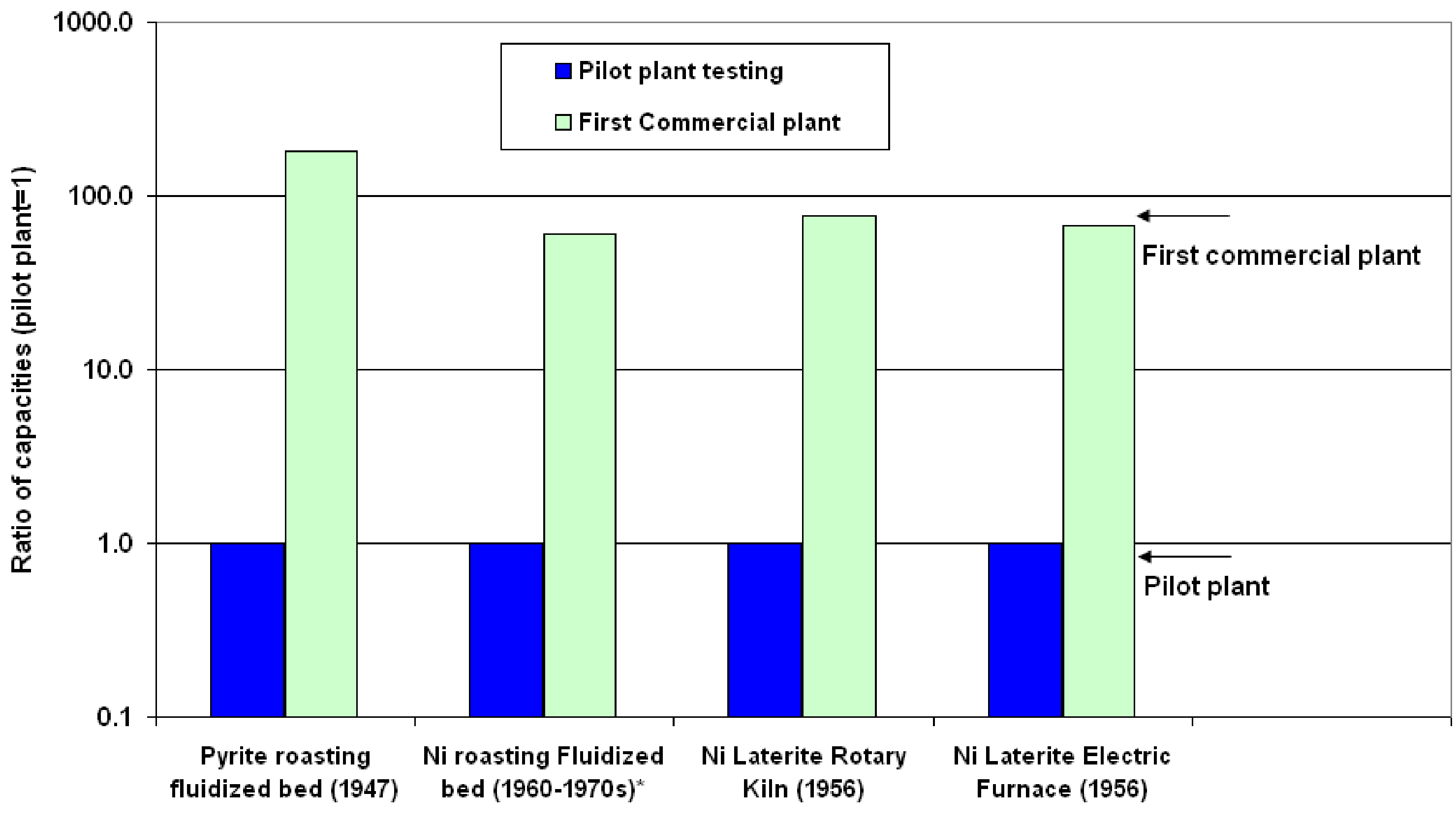
- Fluid bed roaster (for pyrite)
- Rotary kiln for nickel laterite reduction
- Electric furnace (for nickel laterite)

The original "pilot testing" of the above processes was on a fairly small scale, typically a 0.1-0.15 m (4 to 6 -inch) diameter roaster was initially used, and for the electric furnace, test work was carried out on a 200 kW unit.

The scale-up to the first commercial units was in some cases over 100 times, refer following bar chart

Development of Current Processes In Use Today – The role of piloting - V

Capacity of the First Commercial Plants of Current roasting and Ni Smelting Processes
Ratio of capacity of first commercial plant to mini-plant and laboratory testing capacity - Pilot plant capacity = 1



* Roaster at Sudbury smelter

Pilot Plant Testing
Fluidized Bed Operations

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0.15 m dia. pilot fluidized bed
at XPS (nominal 10 to 50 kg/hr)

6 m dia. fluidized bed
nominal 40 tph of concentrate

Development of Current Processes In Use Today – The role of piloting - VI

Plants today are much larger than the first commercial plants

For new technology areas, there would be a large scale-up factor from "pilot scale" to typical current large plant sizes.

Typically, a new commercial plant based on already tested and commercialized technology is patterned after that at an existing facility. Piloting for new feed or with new components is desirable

The new plant is often for a higher capacity than existing plants

Material handling effectiveness and good process knowledge becomes key.

Classification of projects by T. McNulty (1998)

Four types of project start-up curves considered:

Type 1: Mature technology, used elsewhere

Type 2: Prototype technology, incomplete pilot testing

Type 3: As Type 2 but with limited piloting and/or feed variability

Type 4: As Type 2 but more complex flowsheet

McNulty Project Classification

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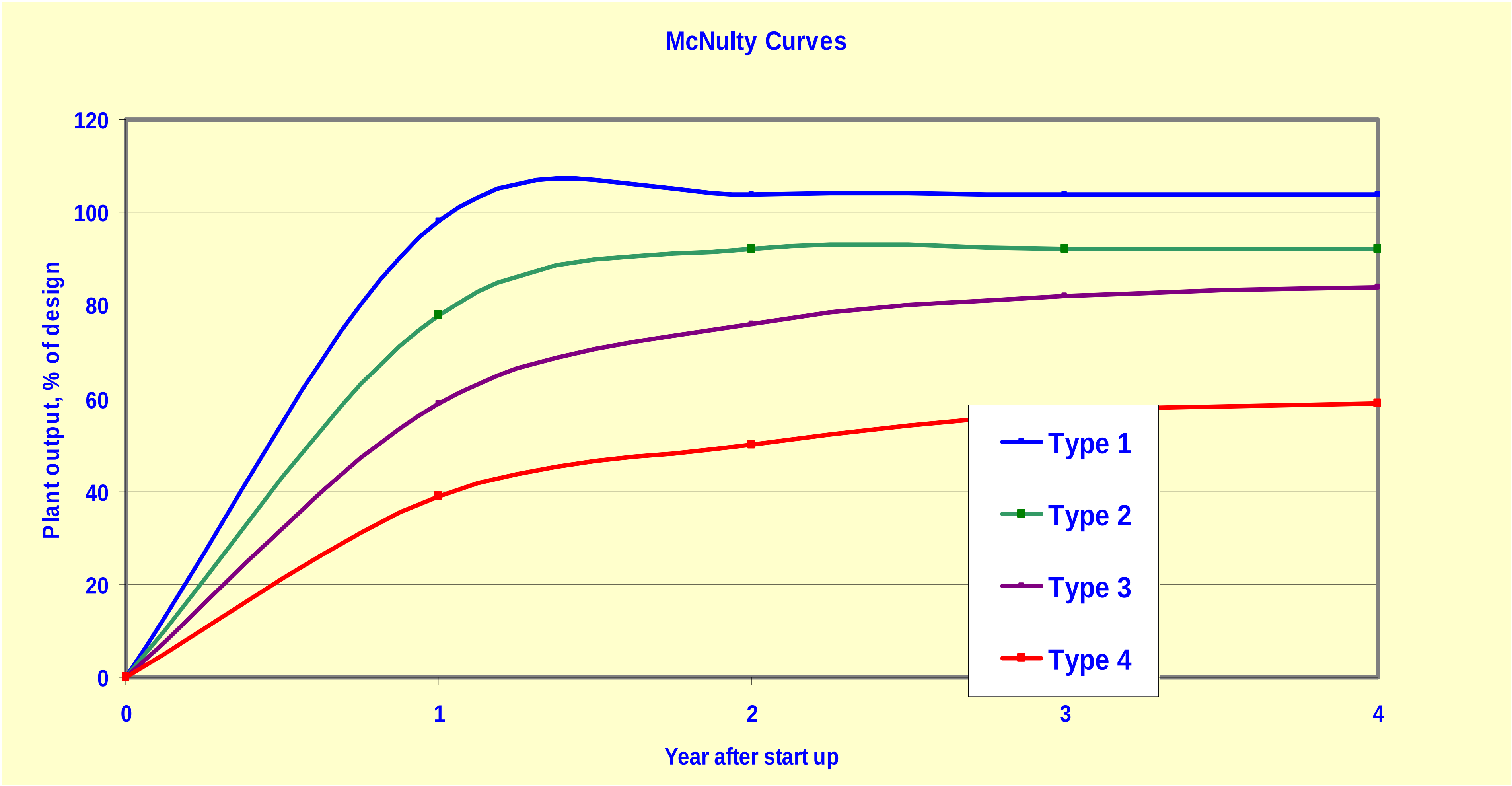

Piloting and Commercial Success

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Features of pilot plant operations
Some recent case histories:

1 Hartley Platinum AC Furnace:

(“Conventional“Ni-Cu sulphide feed, electric furnace/converters)

Piloting - None, assumed to be similar to previous

Commercial success -none

Duration of first campaign - 3 weeks

Current Status - Inoperative

2 Chambishi Metals DC furnace (Cobalt from reverb slag)

Piloting -Extensive lab testing, 3 weeks piloting,

Commercial success - Moderate success considering technical novelty

Duration of first campaign – 6 weeks

Current status – Ran ~ 8 years, shut down Dec. 2008, due to high production costs, low metal prices

Chambishi Metals - DC Arc furnace for cobalt from slag

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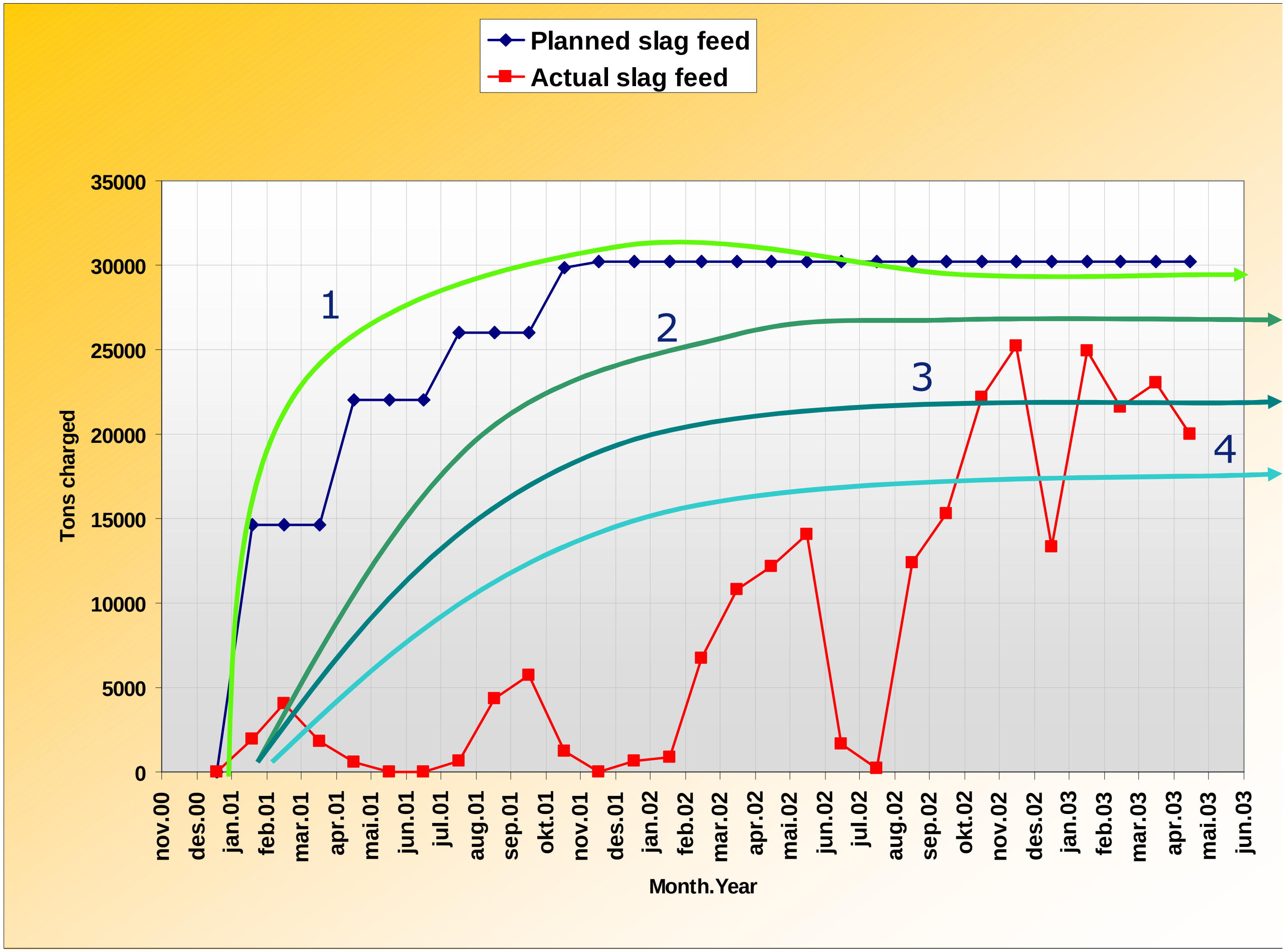
A novel process for a novel material: 1st commercial plant.

Pyrometallurgical testwork	Furnace size (MW)	Scale up factor
Batch-over 300 runs, no problems	0.15 to 0.25	0.1
Semi-pilot campaigns 1 week continuous operation/campaign, 3 campaigns	1.0 to 1.5	1
Pilot plant operation Cancelled to fast track commercial plant	10.0	10
Commercial operation – refractory problems surfaced	40	40

Chambishi Metals
Planned versus actual
(McNulty curves superimposed)



Chambishi Metals.
Conclusions and observations:

- What was planned to be a Type 1, but the novelty suggested Type 3, actually became a Type 4 until the design imperfections were rectified.
- The design imperfections were not revealed during batch and intermittent testing.
- The time “saved” by not performing piloting was lost in the commercial plant
- The financial impact on the project was considerable

Pilot Plant Testing of Non-Ferrous Metallurgical Processes

- Cost and time duration?

- Ingredients of a successful pilot plant campaign?

- How much piloting should be carried out?

…The " No piloting" Alternatives

- The intended commercial plant becomes the *de facto* pilot
- Learning is on an expensive full size facility
- Ultimate failure is highly likely- McNulty Type 4 start-up almost guaranteed.
- Owners, funders, shareholders unhappy, everybody loses.

The "Cost" of Piloting: Data from Actual Project

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Parameter	*Base Case*	*With Piloting*	*Without Piloting*
Feed Rate	**Type 1**	**Type 1**	**Type 1**
Metal Recoveries	**Ideal**	**Type 1**	**Type 2 (5 years)**
IRR, %	**11.8**	**11.4**	**10.3**
NPV,$ M	**141.7**	**116.2**	**26.4**

Apparent Cost of Piloting:

Δ NPV $25.5 M

Apparent Cost of not piloting: Δ NPV $115.3 M

Lost Opportunity, true cost: Δ NPV = $89.8 Million !

Key Ingredients for piloting Success

- Commitment and adequate budgeting for piloting by Company (project management)
- Sufficient representative feedstock
- Clear objectives for campaigns
- Sufficient duration to identify time-related issues (tap-hole wear, accretions etc.)
- Openness to essential modifications to deal with identified or latent issues.

Obstacles to piloting (perceived and real)

- Obtaining sufficient feed material

  Example….to produce enough copper concentrate to run a 1 week duration pilot campaign requires mining 330 tons of ore…a similar type of situation would apply for nickel developments.
- Apparent “cost” to the project, insufficient appreciation of true benefits.
- Perceived delay to project (again, benefits not understood)
- Long duration necessary to find potential operational flaws

An approach to face the obstacles
The Xstrata Experience at MIM

1. One of the most difficult steps in the commercialisation of new technologies is the financing of large-scale pilot and demonstration plants.
2. Such plants in the mining industry can cost 10s or 100s of millions of dollars.
3. One strategy: Scale up of the plants to become operating units. In this way, they paid for their own development.
4. The Lead Isasmelt and Copper Isasmelt pilot plants were profitable operations while the processes were being developed. Both pilot plants increased smelter production. In this way the paid for their own development!

Examples of Piloting facilities

Testwork and Pilot facilities

Xstrata Process Support:

- **Roasting: 2”, 4” and 6” diameter fluid beds**
- **Sintering: 12” diameter bed**
- **Calcination: Rotary kiln**
- **Smelting: 30kg batch melts**
- **Leaching: Atmospheric and Pressure leach pilot plant**
- **Mineral processing: Flotation Mini-pilot plant**
- **Crushing and Blending: sample preparation plant**

- **Supported by comprehensive thermal analysis, slag and refractory testing, mineralogical and analytical facilities**

Pilot Plant Testing of Non-Ferrous Metallurgical Processes

Concluding Comments

Piloting unearths the unexpected- The foreseen can be designed out, the un-foreseen has to be experienced before it can be dealt with.

How long to run the pilot campaign?- Until something breaks, then you fix it and run until something breaks, then you fix it and run it until…

Piloting is expensive, just as is detail design, but the real cost is small compared to the alternative of not piloting

Pilot Plant Testing of Non-Ferrous Metallurgical Processes

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Acknowledgements:

To all who have journeyed with us over almost 4 decades of exciting and interesting projects in the field of Extractive Process Metallurgy.

To all our colleagues within Xstrata, particularly at Xstrata Technology Services who man the piloting campaigns, fix the bugs and make the novel processes work

Thank you, our audience, for your interest