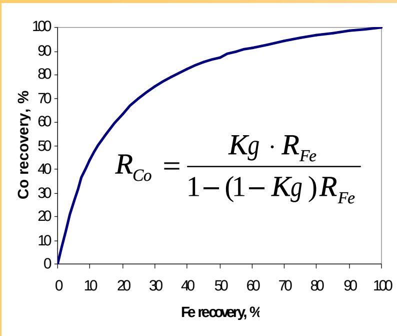
Recovery of base metals and PGMs in a DC alloy-smelting furnace



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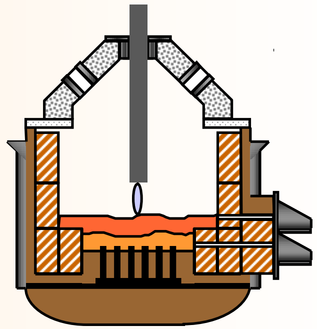
Introduction

- Reductive alloy smelting using carbon as a reducing agent:
  - Chromite smelting
  - Nickel laterite smelting
  - Recovery of base metals from slags
  - Collection of PGMs in iron alloys



- Amount of alloy increases with carbon addition
- Recovery of valuable metals is related to the recovery of iron

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Equilibrium description

CoO + Fe = Co + FeO

$$K = \frac{a_{Co} \cdot a_{FeO}}{a_{CoO} \cdot a_{Fe}} \quad [1]$$

$$K = \frac{g_{Co} x_{Co} \cdot g_{FeO} x_{FeO}}{g_{CoO} x_{CoO} \cdot g_{Fe} x_{Fe}} \quad [2]$$

$$Kg = \frac{n_{Co} \cdot n_{FeO}}{n_{CoO} \cdot n_{Fe}} \quad [3]$$

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Mass balance equations

$$n_{Co} = n_{Co}^{0} + n_{CoO}^{0} - n_{CoO} \qquad [4]$$

$$n_{Fe} = n_{Fe}^{0} + n_{FeO}^{0} - n_{FeO} \qquad [5]$$

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Definition of recovery

$$R_{Co} \equiv \frac{n_{Co}}{n_{Co}^{0} + n_{CoO}^{0}} \qquad [6]$$

$$R_{Fe} \equiv \frac{n_{Fe}}{n_{Fe}^{0} + n_{FeO}^{0}} \qquad [7]$$

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Kg Recovery Equation

$$Kg = \frac{R_{Co}(1 - R_{Fe})}{R_{Fe}(1 - R_{Co})} \qquad [8]$$

$$R_{Co} = \frac{Kg \cdot R_{Fe}}{1 - (1 - Kg)R_{Fe}}$$

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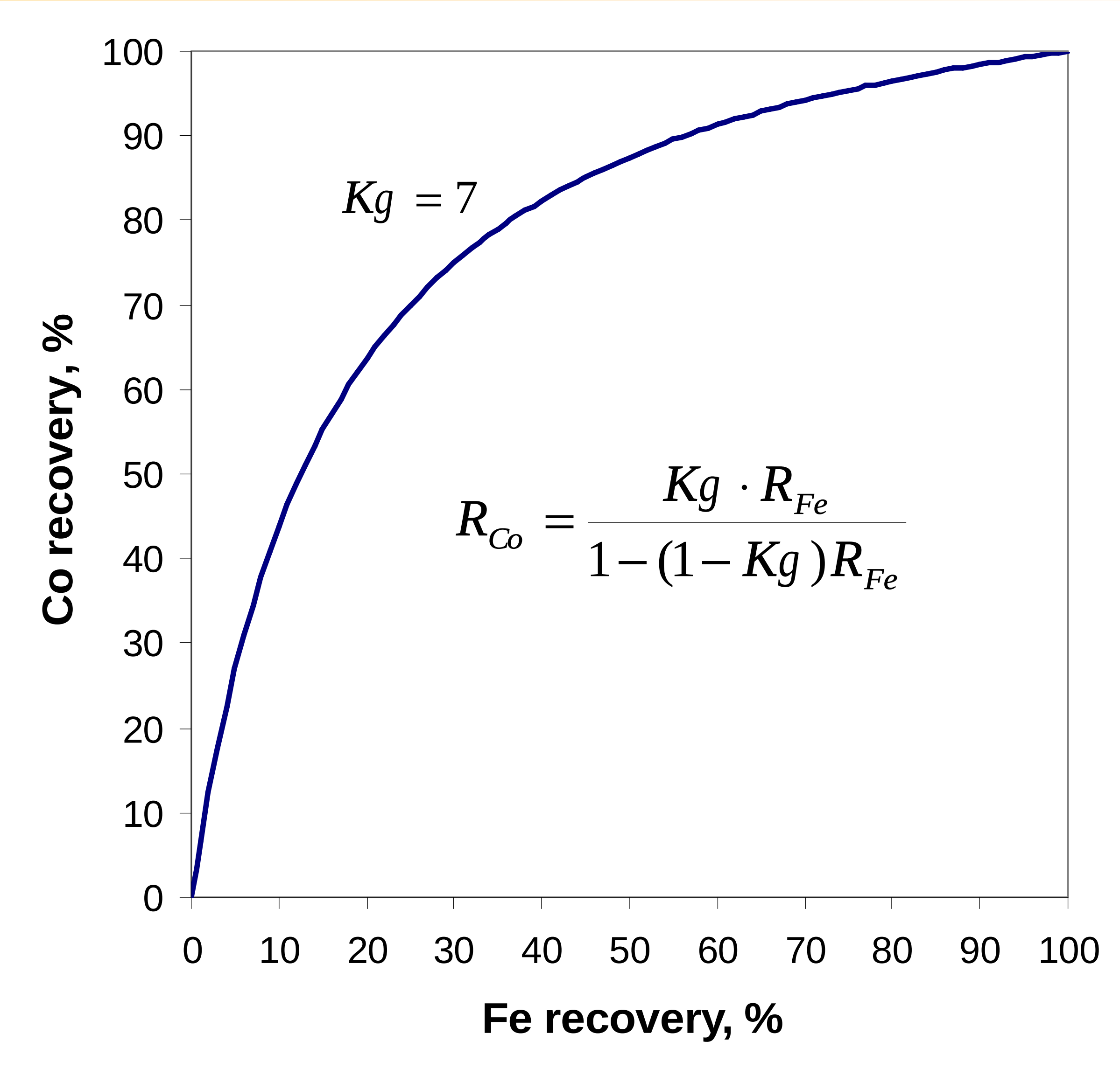
Co versus Fe Recovery



- *Kg* can be calculated from equilibrium constant and activity coefficients, or fitted empirically

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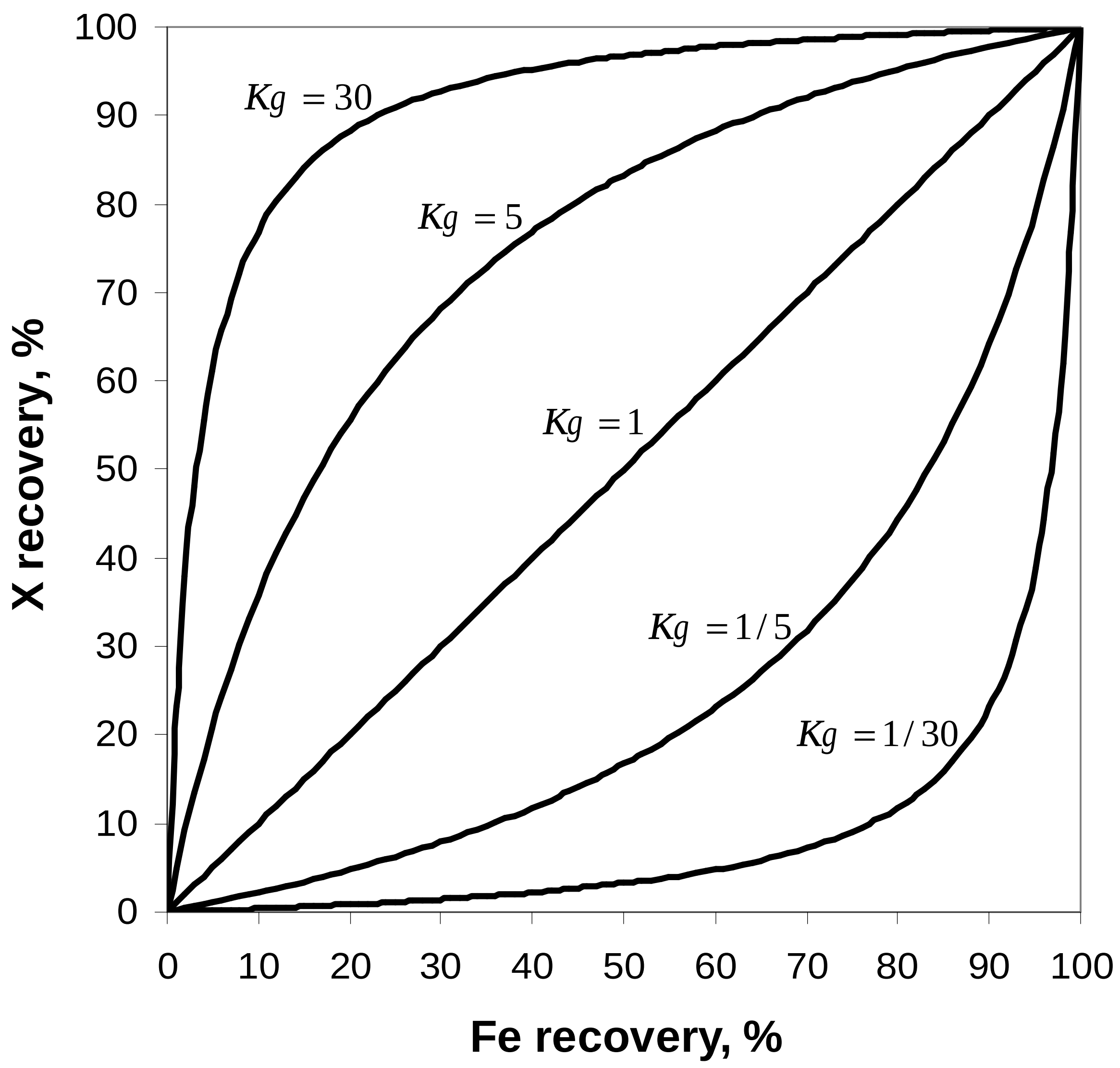
Shape of recovery curve, and values of *Kg*



$$R_{Co} = \frac{Kg \cdot R_{Fe}}{1-(1-Kg)R_{Fe}}$$

- *Kg* = 1 represents Fe
- Most 'noble' at top left

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Application to cobalt recovery from slag

- Cobalt present as CoO in slag
- Need more than settling
- Oxides reduced by Fe, forming FeO
- Carbonaceous reductant
- Temperature between 1500 and 1600°C
- Aim to selectively reduce Co in preference to Fe

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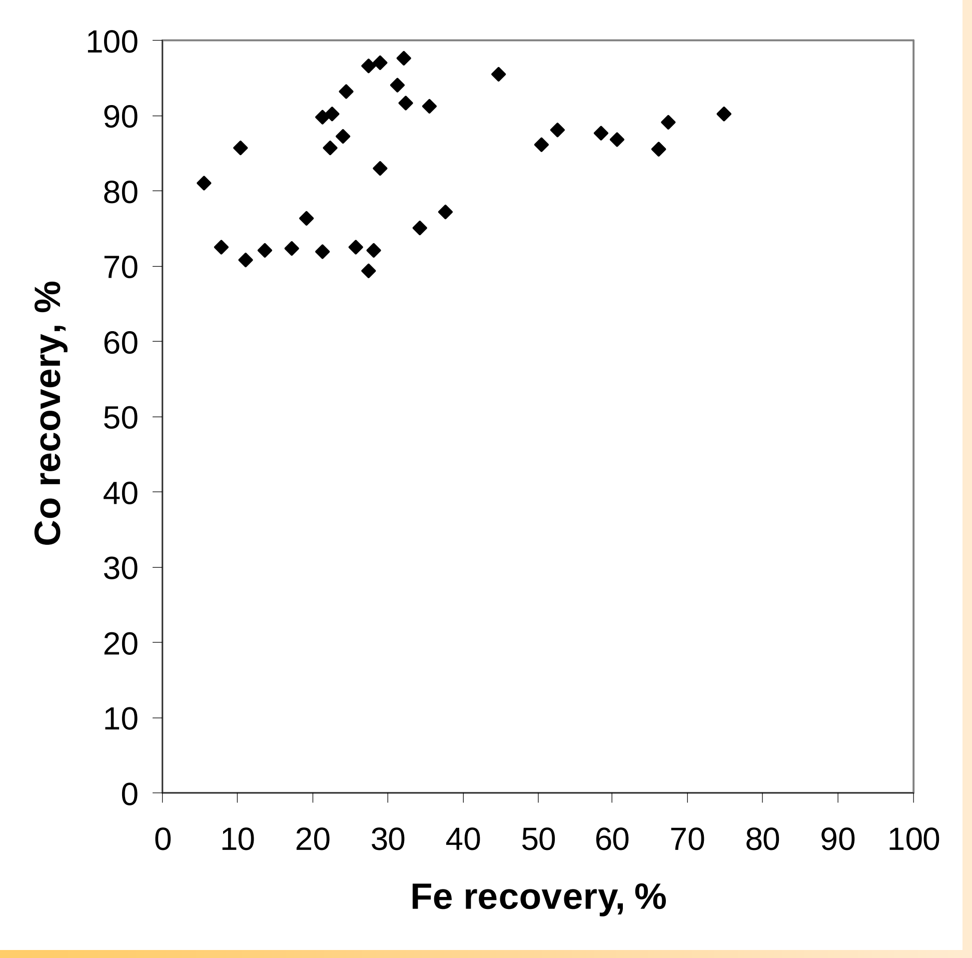
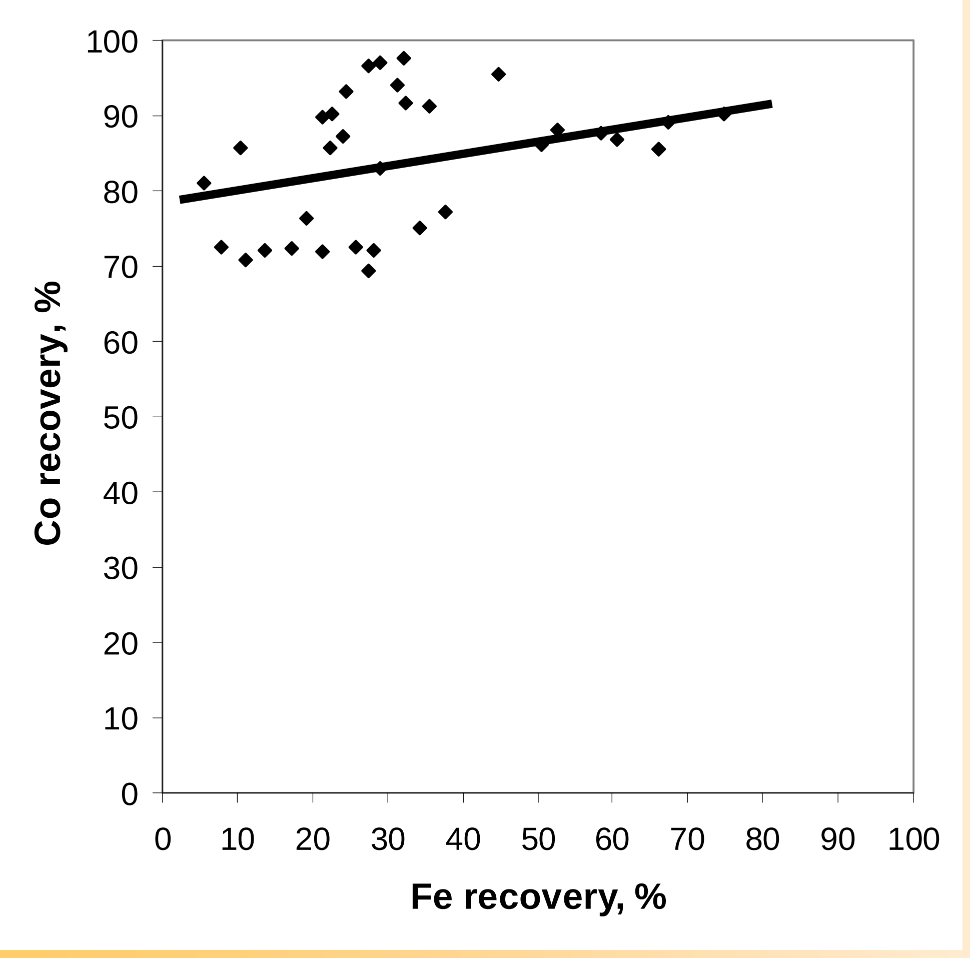
Recovery of cobalt from copper reverberatory furnace slag



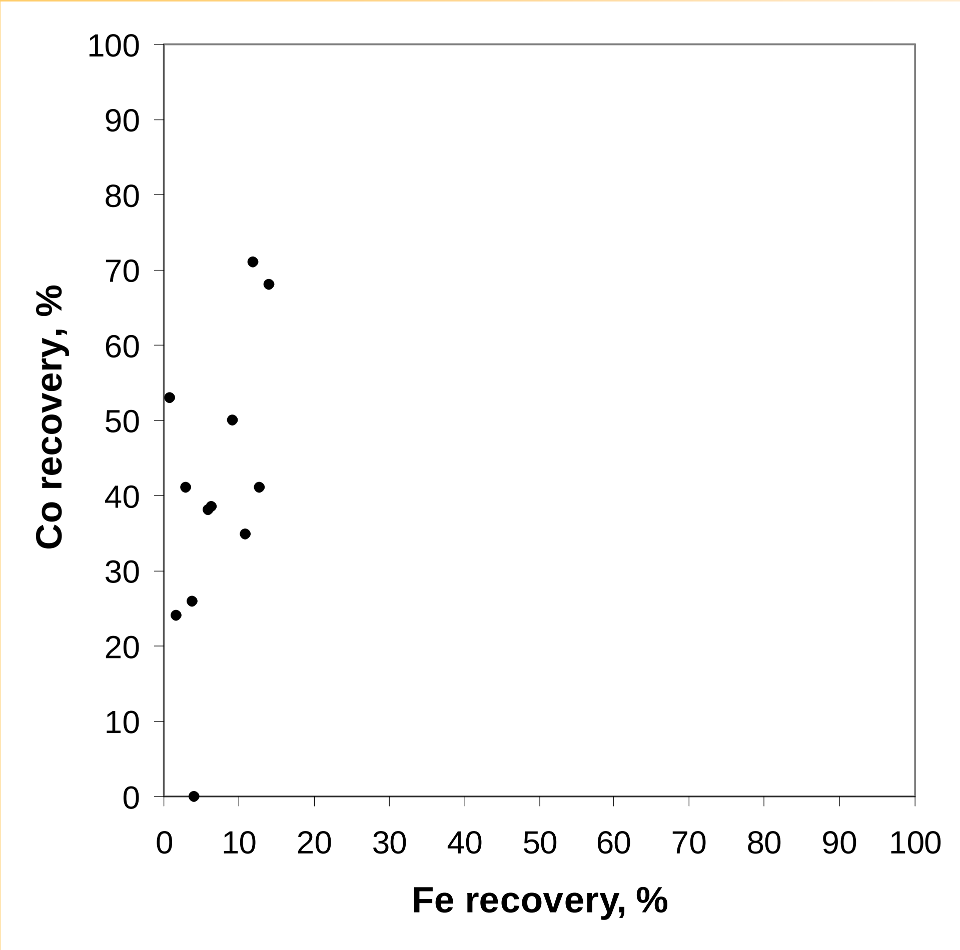
- A fair degree of scatter
- Wide range of experimental conditions
- Analytical uncertainties

Recovery of cobalt from copper reverberatory furnace slag



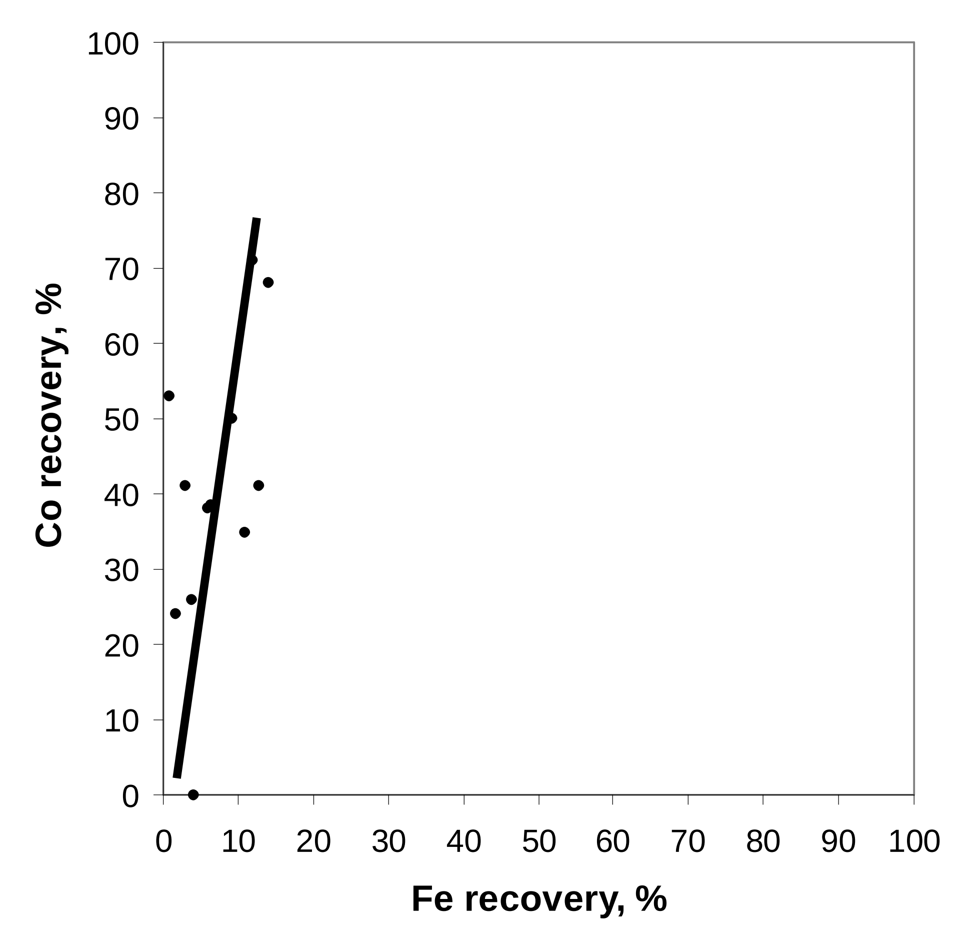
- Perhaps a straight line?

Recovery of cobalt from flash furnace slag



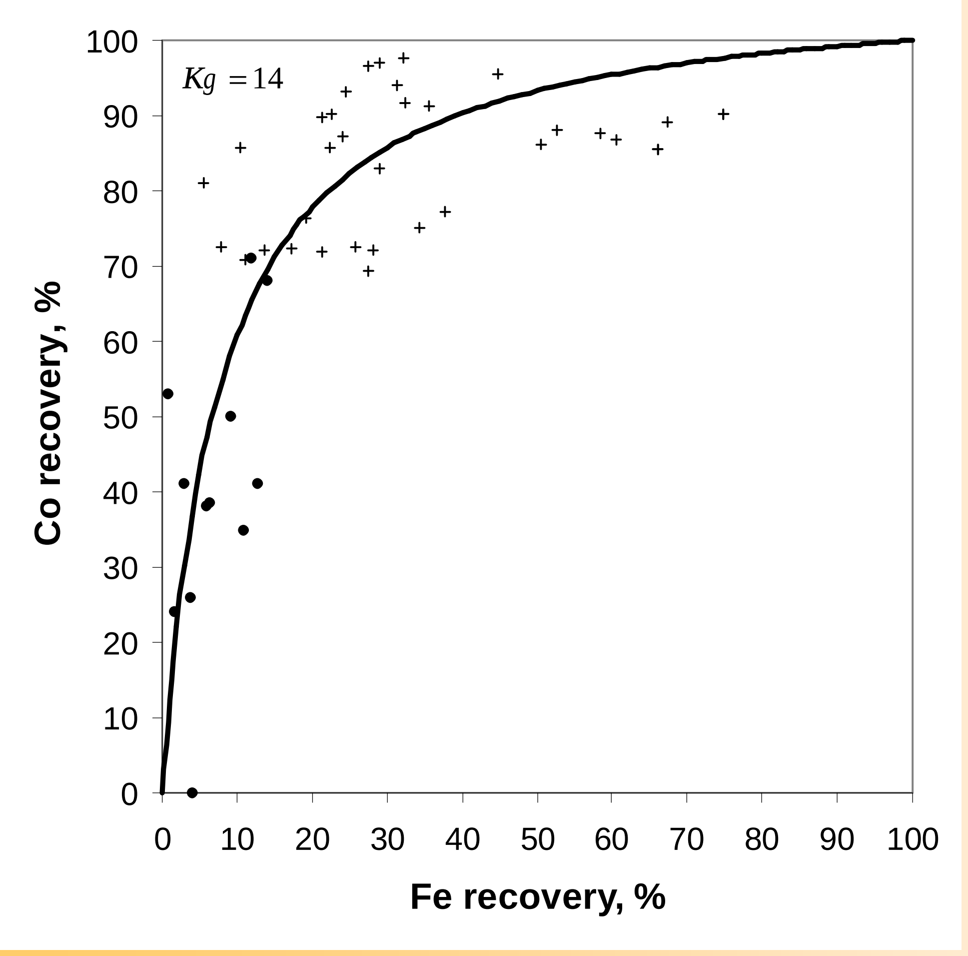
- Set of data with only small amounts of reduction
- Low recoveries

Recovery of cobalt from flash furnace slag



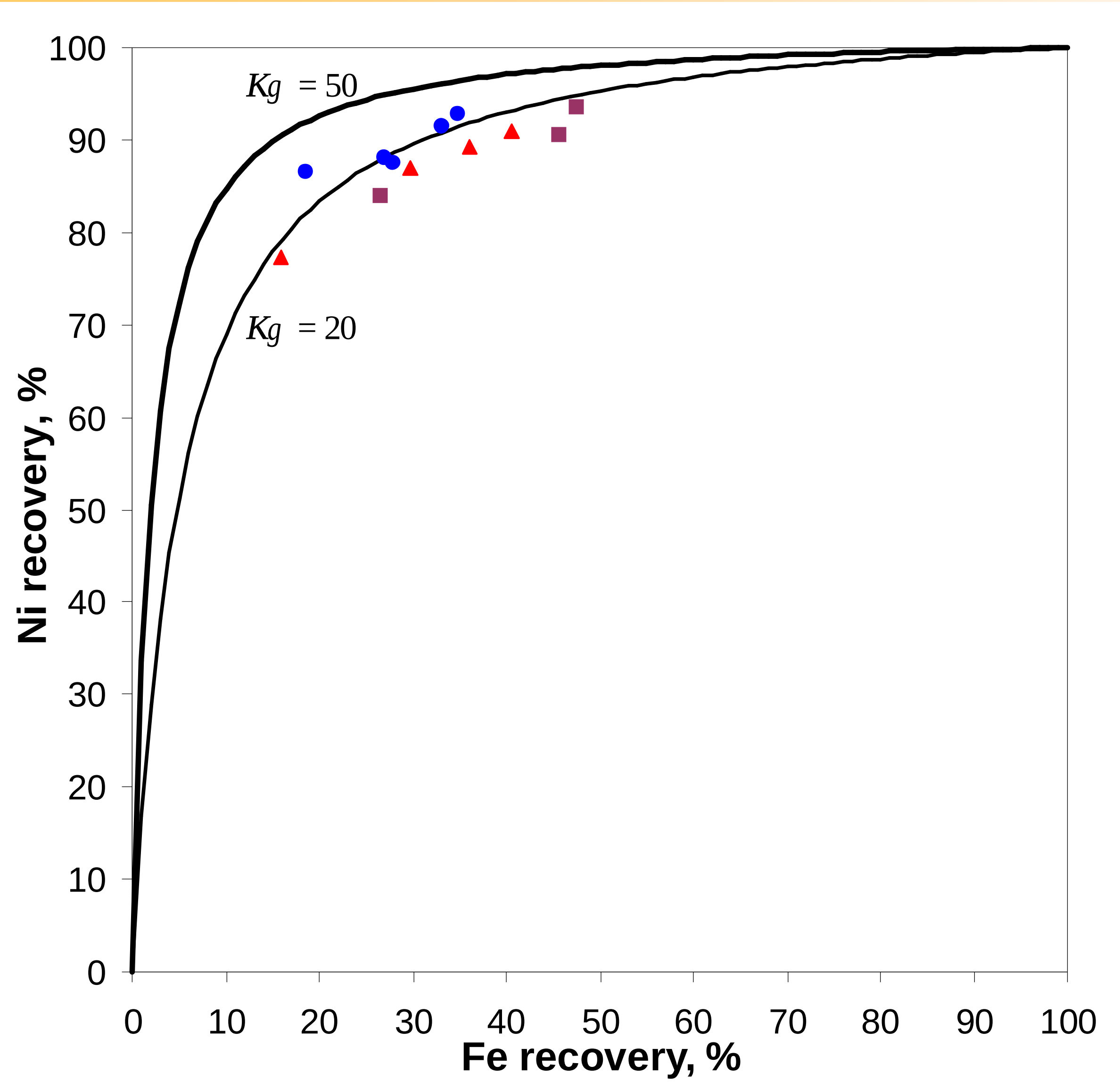
- Set of data with only small amounts of reduction
- Low recoveries
- Perhaps another straight line?

Cobalt recovery from slag



- The *Kg* recovery equation covers both ranges well
- *K* = 30
- *Kg* = 13 by theory
- *Kg* = 14 by fitting

Application to ferronickel



- Ni follows the same pattern
- Data shown for three samples under different conditions, not necessarily at equilibrium
- Selection of *Kg*, 20 or 50?

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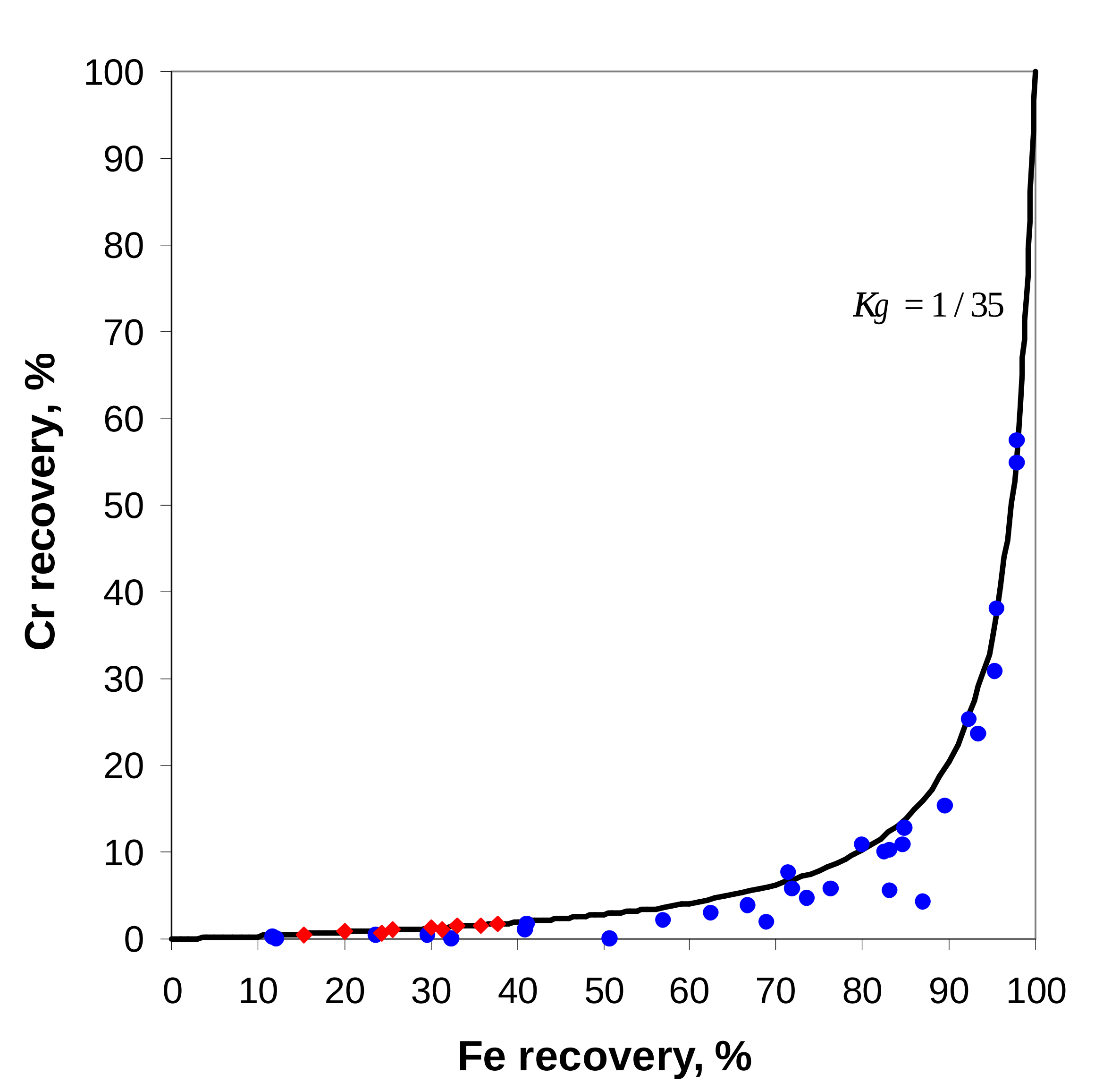
Cr in FeNi



- Cr recovery is usually very low in FeNi
- Lab tests can easily be over-reduced to make sufficient metal
- Excellent agreement with other (revert tailings) work too

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ConRoast PGM smelting

- ConRoast involves smelting low-S concentrates in a DC arc furnace and collecting valuable metals in an iron alloy
- Mintek operates a 3MW furnace that is designed to smelt up to 2000 tons per month

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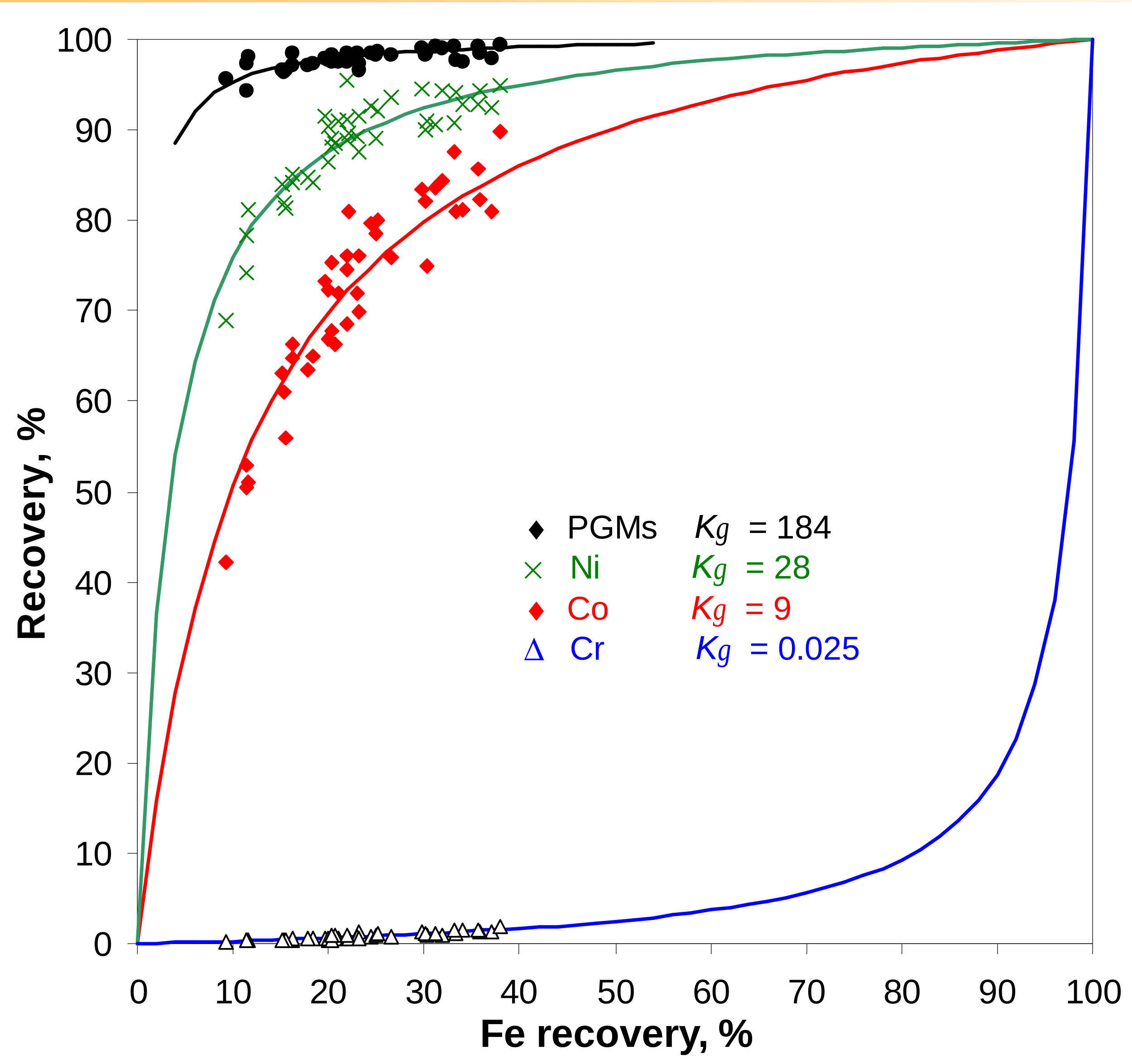
PGM smelting

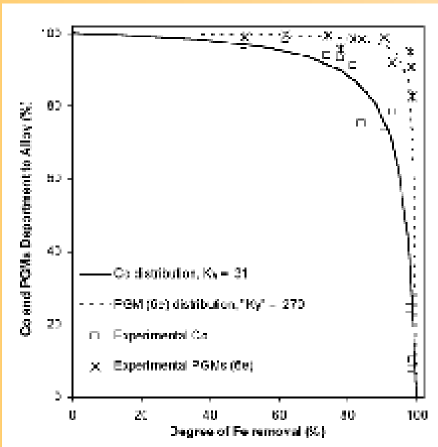
- 1.5 MW furnace
- 37 000 tons smelted over four years
- Each monthly data point represents hundreds of kg

PGM smelting



- Good reasons for using *Kg* on NiO, CoO, and CrO
- PGM behaviour can be modelled this way too (empirically)

Application to oxidative converting processes



- Reductive smelting and oxidative converting are governed by the same chemical reactions (one is the reverse of the other)
- Recovery is plotted against degree of iron removal

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Mintek's DC furnaces

http://www.mintek.co.za/Pyromet/

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