Recovery of Vanadium from Oil Fly Ash

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Benefits of Metal Recycling

Energy conservation

- Secondary source of metal does not require mineral processing steps which usually consume a huge amount of energy.
- Using recycled metals reduces the energy consumption by 92% for aluminum, 90% for copper, and 56% for steel.

Resource conservation

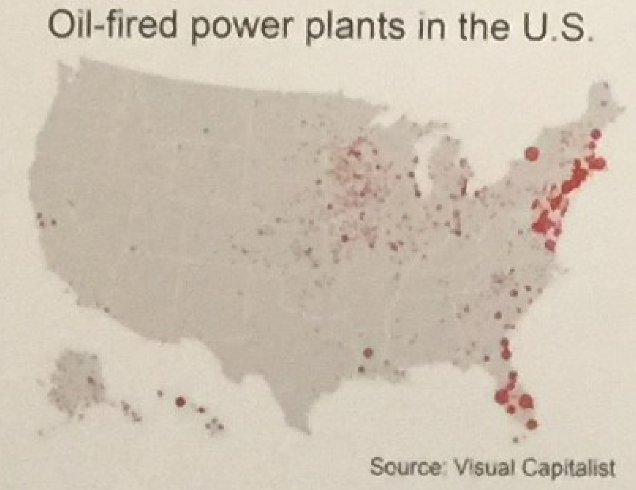
- Metal ore in the Earth crust is limited.
- Recycling a pound of aluminum conserves four pounds of bauxite ore.
- Recycling a ton of steel conserves 2,500 pounds of iron ore and 1,400 pounds of coal, and 120 pounds of limestone.

Environmental benefits

- Using scrap metals instead of ores reduces the mining wastes generation.

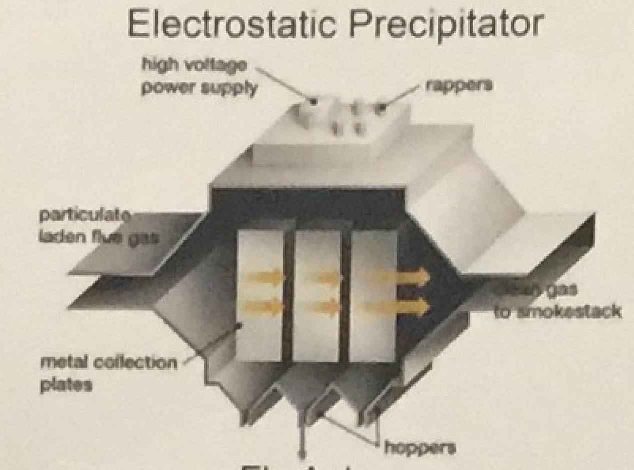
What is the Oil Fly Ash?

Oil-fired power plants in the U.S.



Source: Visual Capitalist

Electrostatic Precipitator



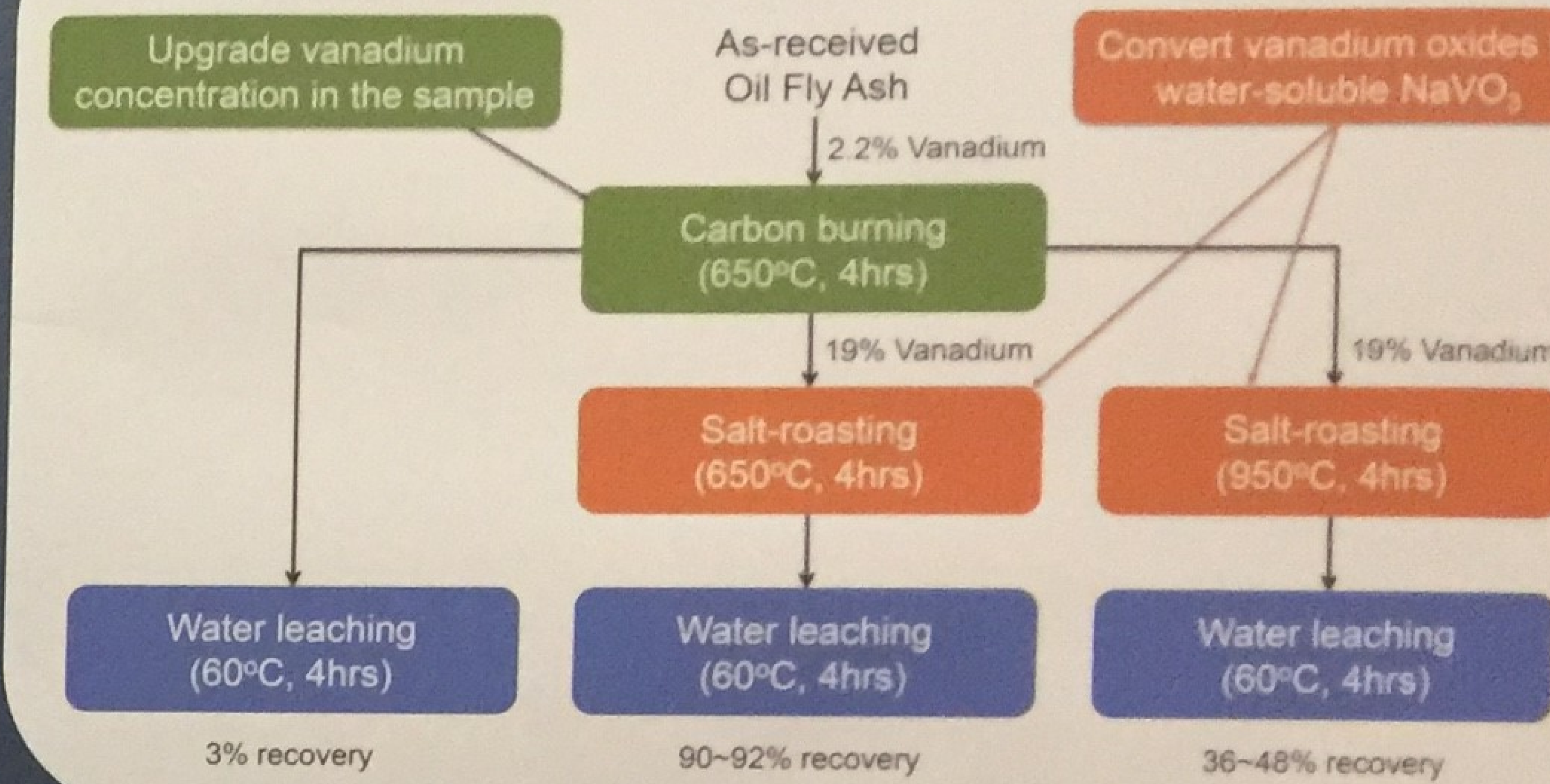
- Produce 1% of the total U.S. electricity generation in 2015.
- Consume 29,545 thousand barrels of petroleum liquids and 4,088 thousand tons of petroleum coke as the fuel.

Fly Ash

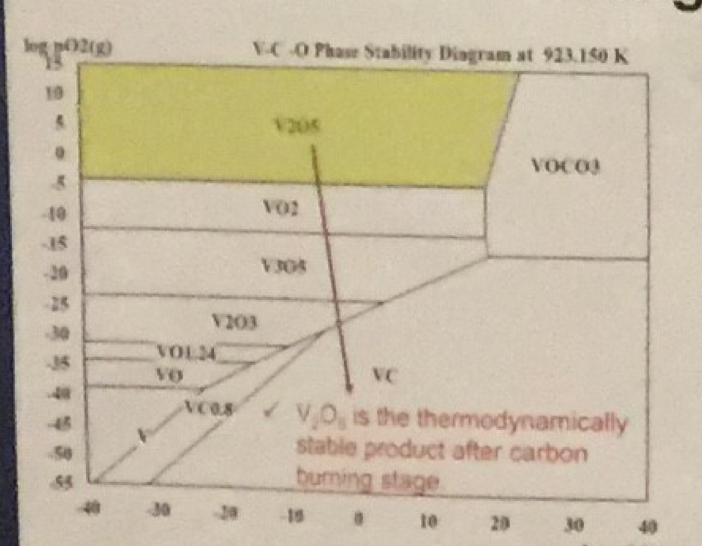
- Fine dust generated during the combustion of fossil fuel.
- Oil fly ash contains a huge amount of unburned carbon and some vanadium.

✓ Use the oil fly ash as a secondary source of Vanadium.

Proposed Flowsheet of Vanadium Recovery



Thermodynamic Analyses of Carbon Burning and Salt-roasting



V-C-O phase stability diagram at 650°C

Reaction equations during the salt-roasting:

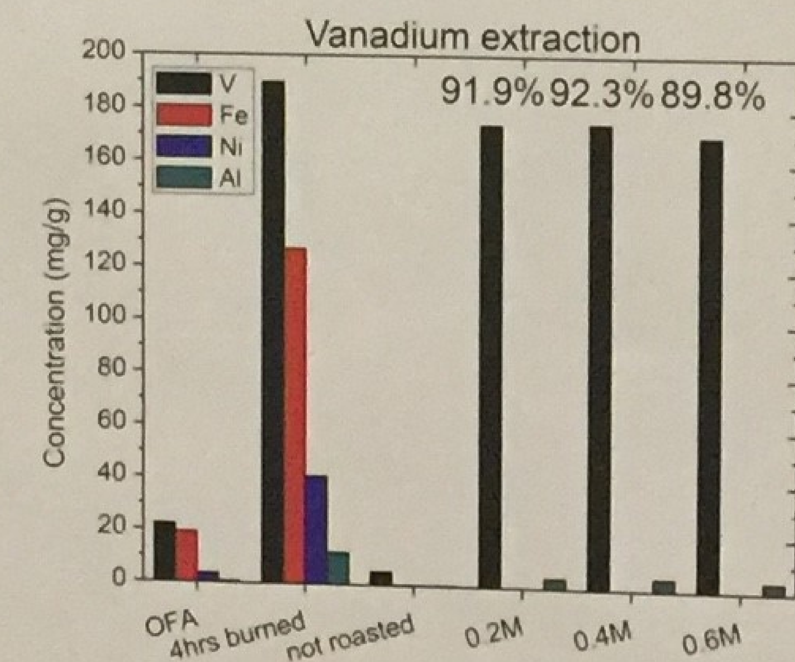
$V_2O_5 + Na_2CO_3 = 2NaVO_3 + CO_2(g)$
$\Delta G^o = -38.682$ kcal at 650°C

$V_2O_3 + Na_2CO_3 + 1/2O_2(g) = 2NaVO_3 + CO(g)$
$\Delta G^o = -32.749$ kcal at 650°C

$V_2O_3 + Na_2CO_3 + O_2(g) = 2NaVO_3 + CO_2(g)$
$\Delta G^o = -81.090$ kcal at 650°C

✓ The formation of $NaVO_3$ from vanadium oxides is thermodynamically favorable at 650°C.

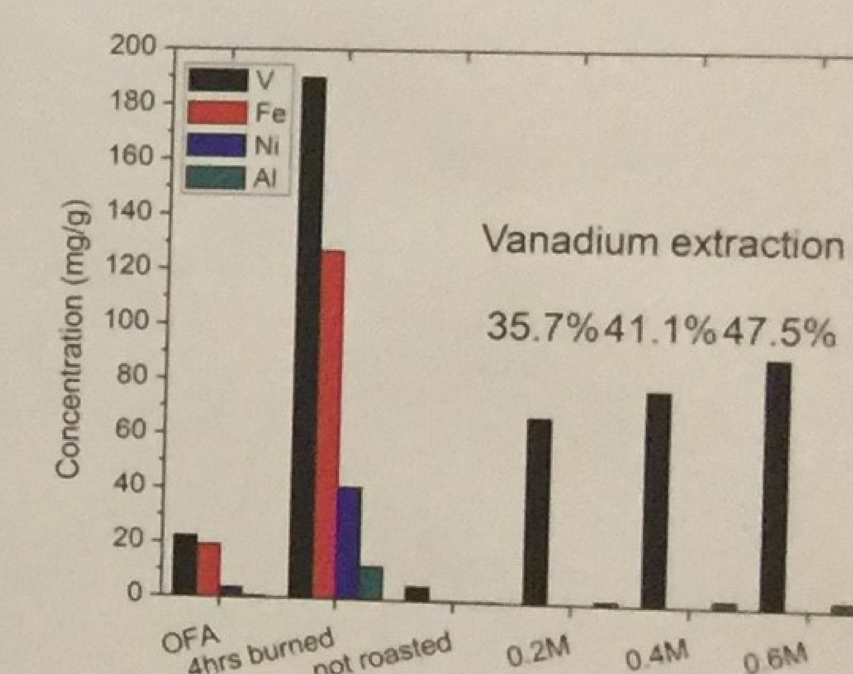
Salt-roasting & Water Leaching



Roasting: 650°C with Na_2CO_3, Leaching: 60°C water

No product melting → Vanadium extraction 91.9% at 0.2M Na_2CO_3

Salt-roasting & Water Leaching



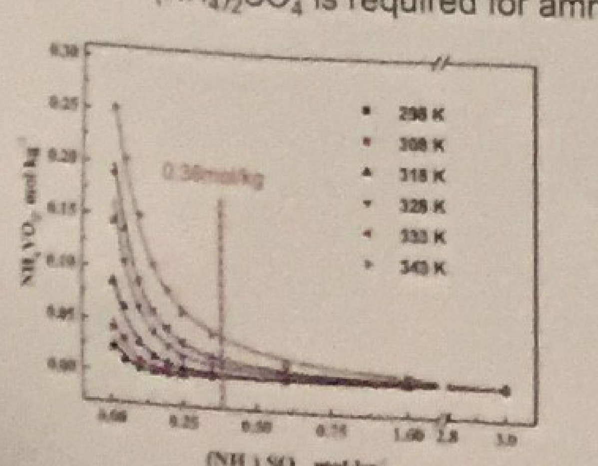
Roasting: 950°C with Na_2CO_3, Leaching: 60°C water

Product melting → Vanadium extraction 35.7% at 0.2M Na_2CO_3

Ammonium Metavanadate Precipitation

$2NaVO_3 + (NH_4)_2SO_4 = 2NH_4VO_3 + Na_2SO_4$ $\Delta G^o = -3.051$ kcal at 25°C

✓ $(NH_4)_2SO_4$ is required for ammonium metavanadate precipitation.



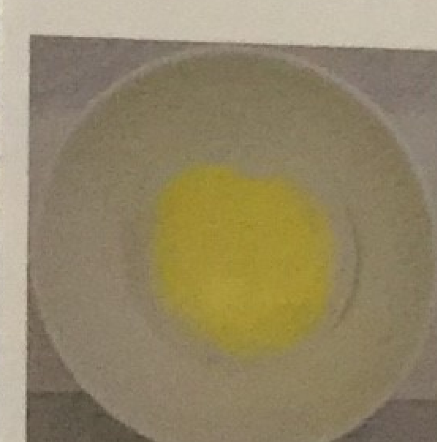
The solubility of NH_4VO_3 in the $(NH_4)_2SO_4$-H_2O system is related to the concentration of $(NH_4)_2SO_4$ and the temperature of the solution.

Temp. ↓ → NH_4VO_3 Solubility ↓

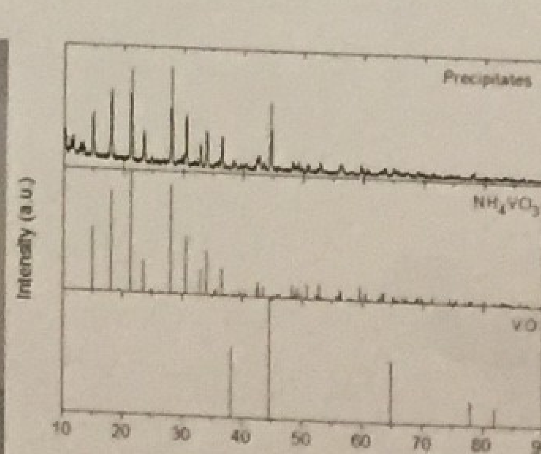
$[(NH_4)_2SO_4]$ ↑ → NH_4VO_3 Solubility ↓

AMV precipitation conditions:
Temperature: 25°C
$[(NH_4)_2SO_4]$ = 0.38 mol/L solution

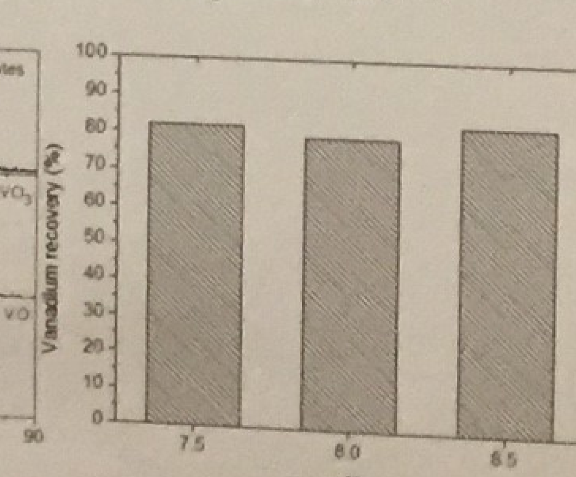
Ammonium Metavanadate Precipitation



Filtered precipitates



XRD analysis of precipitates



Vanadium recovery

✓ Chemical phases of precipitates are NH_4VO_3 and VO based on the XRD analysis.

✓ The percentage of vanadium recovery is about 80% after AMV precipitation.

Summary

Carbon burning

- Vanadium enriched product → about 19% vanadium
- Optimum carbon burning temperature → 650°C

Salt-roasting

- Produce water soluble sodium vanadate → $NaVO_3$ or $Na_2V_2O_7$
- Optimum roasting temperature → 650°C

Water leaching

- The percentage of vanadium dissolution → 92% at 60°C

Precipitation

- The percentage of vanadium recovery by precipitation → 80% at 25°C

Overall

- The percentage of overall vanadium recovery → 73.6%