An Annotated Bibliography of Propellant Processing Methods

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Dr. Cutler has specialized in space resources research for many years, with special emphasis on oxygen reduction methods. He has been retained to write a comprehensive review of these methods, detailing advantages and disadvantages, listing byproducts, and presenting recommendations. As the first step, an extensive outline was prepared, and the portion of this outline covering product manufacture was selected as the initial goal. A working version of this section follows:

Products

I. Propellant
  A. Oxidizer
    1. Oxygen
      a. Production from lunar materials
        i. Slagging carbothermal
          - of ilmenite
          - of olivine
          - in integrated polyelement processes
        ii. Subsolidus reduction
          - ilmenite with H_2 or C
          - olinite with H_2 or C
        iii. Plasma processes
          - with $H^{\bullet}/H_2$ + $FeO{\cdot}XO_2$
          - with $Cl^{\bullet}/Cl_2$ + $FeO{\cdot}XO_2$
        iv. Slog electrolysis
          - bulk soil
          - mineral separates
          - with fluxes (Kesterk, EMEC)
      b. Production from asteroidal/Phobos/Deimos meet?
        i. Water splitting
          - electrolysis
          - photolysis
          - thermolysis
        ii. CO_2 processing
          - solid state electrolysis
          - carbonate? melt electrolysis
        iii. Oxide reductions, e.g., FeO + $(CH_2)_n$
      c. Production on Mars surface--variants of processes above

2. Peroxide
   a. H_2O_2 via Na_2O_2
   b. Direct $H_2 + O_2$
   c. Electrochemical means from O_2
   d. Water partial oxidation
3. Nitrogeneous oxidizers
   a. Organic N → NH_3
   b. Organic N → N_2
   c. N_2 → NH_3
   d. Organic N → NO
   e. NH_3 → $NO + H_2O$
   f. NO → NO_2
   g. $NO_2 + H_2O$ → HNO_3
   h. N_2O_4
   i. RFNA

B. Fuels
   a. Hydrogen
      i. From lunar soil
      ii. From asteroidal materials via hydrocarbons
      iii. Various routes from water (see above)
   b. Hydrocarbons
      i. Direct from asteroids phobos and demo
      ii. Reformed from initial pyrolyzate
      iii. Fischer-Tropsch synthesis from $CO + H_2O$
      iv. From CH_3OH
   c. Oxygenates--alcohols, ethers, etc.
      i. Methanol from $CO + H_2$
      ii. Higher alcohols from $CO + H_2$
      iii. Hydrocarbons → oxygenates
   d. Hydrocarbon--hydrogen mixtures
      (solubility of H_2 in various materials)
   e. Metals
      i. Al
      ii. Mg } see metal production below
      iii. Ca
   f. Metal/liquid mixtures

g. Nitrogeneous fuels

i. Ammonia (see above)

ii. Hydrazines from ammonia

- Cl_2 process
- O_2 process
- organo substituted hydrazines

C. Thermal propellants

1. Hydrogen (see above)
2. Ammonia (see above)
3. Hydrozine (see above)
4. Others

D. Elecric propellants

1. Calcium and potassium
2. Compounds--Cl_2, SO_3, etc.

E. Mars propellants

1. Hydrogen peroxide (see above)
2. Hydrozine (see above)
3. Fuel/oxidizer solutions
   a. Hydrocarbon--oxygen
   b. Peroxide/alcohol or peroxide/hydrocarbon
4. Metal/sulfur propellants (MgS, CaS)

II. Structural Materials

A. Metallic

1. Ferrous (Fe, Ni, Co)
   a. Fe--steel
      i. From magnetic collection
      ii. From subsolidus reduction
      iii. From slogging
   b. Iron alloys
      i. Imported alloying additions
      ii. Local source
   c. Forming and heat treating
      i. Forging
      ii. Casting
      iii. Machining
      iv. Carboxyl deposition

2. Non-ferrous metals
   a. Aluminum
      i. Winning
         - carbochlorination
         - plasma chlorination
         - fluorination
         - integrated processes
      ii. Forming
         - cast
         - roll
         - forge
         - machine
      iii. Alloying additions
         - local source--Mg, Mn
         - imported--Zn, Cu
   b. Magnesium
      i. Winning
         - carbothermal
         - salt electrolysis
         - plasma processing
      ii. Generation of MgO feed
      iii. Forming (as for aluminum)
      iv. Alloying additions
3. Vacuum refining
   a. Advantages and effects on properties
   b. Effect on local environment
4. Tool materials
   a. Tool steels--composition and properties
   b. Titanium carbide tool materials--cobalt bonded
      i. Cobalt source
      ii. Other binders
5. Brazes and solders
   a. Aluminum, magnesium, and calcium as vacuum brazes

B. Non-metallic
   1. Bricks
      a. Morter bound
      b. Cut stone

c. Sintered

d. Slogged and cast

i. Glass

ii. Ceramic

2. Bogs

a. Wire

b. Glass

3. Beams and pillars

a. Fused soil

b. Sintered

c. Mortered

d. Packed form

4. Fibers--glass

5. Refractories

a. Graphite

b. Magnetite and CaO

c. CaS and MgS

d. Cr_2O_3

e. Titanium oxides

6. Cements

7. Inorganic Polymers

8. Sulfur

III. Explosives

A. Fuel/oxidizer explosives

1. Fuel/H_2O_2

a. Organic

b. Metallic

2. NH_4NO_3 + fuel

B. Nitrates from oxygenated organics and nitric acid