AQUEOUS PROCESSING OF LUNAR REGOLITH FOR IN-SITU PRODUCTION OF STRUCTURAL MATERIALS AND FUELS; W.N. Agosto, Lunar Industries, Inc., P.O. Box 590004, Houston, TX 77259-0004

The lunar production of 1000 metric tons (MT) per year of oxygen by aqueous hydrofluoric acid (HF) leaching of basaltic soil of Apollo 12 composition can co-produce the following products:

Table 1. Coproducts of a Lunar Based Plant Producing 1000 MT of Lunar Oxygen/yr by the HF Leach Process (MT) (1,2)

Aluminum		180
Silicon		710
Iron		560
Magnesium		150
Titanium		50
Alumina	(Al_2O_3)	340
Silica	(SiO_2)	765
Titania	(TiO_2)	80
Calcium Silicate	(Ca_2SiO_4)	545

The mass of such a plant, excluding power facilities, is estimated at 50 MT with a volume of 50 m^3 and power consumption of 4.2 megawatts. Deployment would require 15 to 20 person-hours EVA and about one person-week IVA. Mean time before shutdown was estimated at 100 hours with 20 hour recovery and consequent 80% availability. The plant would operate about 7000 hours per year.

Accordingly, a lunar HF plant could produce over 80 times its mass in oxygen, metal, and pure oxide product during the first year of operation while recycling all reagents. By contrast, the best dry process that provides the same lunar oxygen production rate, i.e., molten fluoride salt electrolysis of highland anorthite (3), would co-produce 850 MT of silicon-aluminum composite, 150 MT of aluminum, and 500 MT of calcium oxide, with power requirements comparable to the HF process, and with a combined plant and reagent mass of 450 MT, excluding power facilities and radiators. Thus, as is typical of proposed dry processes, total annual output product is limited in variety compared with the aqueous process and is no more than a few times the mass of the installation.

Existing commercial chemical plants that process 1,000,000 short tons per year by aqueous processes are highly automated and employ about 220 people around the clock which is equivalent to just over 12 person-tons per day. For 4500 MT per year of lunar products (the approximate sum of coproducts and oxygen in Table 1), about 1.3 person-years of labor would be required on the moon. These are estimates derived from a very mature industry, and it is likely that HF processing could be made even less labor intensive in lunar operations.

The major caveats to such a lunar process are water abundance and complexity of the flow sheet as well as reagent and water recovery. With respect to complexity, the process is very flexible and can be trimmed, expanded, or scaled to any product mix or volume over wide limits. Besides, flow sheet complexity is nothing new in the chemical industry. What is most advantageous to lunar venue is the potential for almost total automation of the process to extract virtually every major and most minor lunar surface elements in production quantities, with the possible exception of solar wind gases.

As for water availability, it is our opinion that any permanent lunar industrial operation will require water. Indeed, large scale lunar industrialization and attendant colonization would require abundant water which will almost certainly be at least 89% lunar derived. Likewise, water recycling will be required over the whole range of lunar operations and would not be unique to the HF process.

In addition, recovery of fluoroacids is well precedented in industrial operations. HF is routinely recycled in large quantities in the petrochemical industry, albeit in anyhydrous form. And there are many processes for recovery of halogen acids in aqueous systems (4,5). Accordingly, water on the moon can be conserved as a permanent tool to extract virtually all of the lunar elements or oxides as needed.

In addition to the many space industrial and structural applications of the coproducts in Table 1, metals produced by the HF process can be used as rocket fuel. Estimated specific impulses of aluminum (283 sec), magnesium (267 sec), and silicon (272 sec) assuming rocket combustion at 1000 psi, an expansion ratio of 50, and LOX/metal ratios of 2 to 3 are ample for transportation in cislunar space and other low to moderate gravity wells in the solar system. Magnesium may be especially appropriate as rocket fuel because it vaporizes at 1090^{o}C, well below its combustion temperature (6,7).

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