IMPROVEMENTS IN PROCESS TECHNOLOGY FOR URANIUM METAL PRODUCTION

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The Cirus and Dhruva research reactors in Trombay use metallic uranium fuel. These requirements have been met by nuclear grade uranium ingots produced at Uranium Metal Plant. The plant operated continuously from 1959 to 1980 when an expansion programme was undertaken. The experience gained since re-commissioning is discussed in the light of recent international developments in process technology. Short-term measures for improvements in existing plant as well as long-term development trends are discussed.

I. INTRODUCTION.

The production of nuclear grade metallic uranium for use as fuel for the research reactors in Trombay began at Uranium Metal Plant in 1959. The plant capacity was expanded by 1983 to meet the additional demand of fuel for Dhruva reactor. The plant has supplied the entire initial charge and periodic replenishments required, including the second charge for modified fuel assemblies.

Expansion of capacity is based on increase in number of process equipment of similar capacity as the original plant and increase in number of batch operations per equipment. Design assumes continuous operation, 24 hours a day and 300 days in a year. This strategy was adopted in the interests of high equipment reliability based on experience and due to constraints of time and space.

The only major process change adopted in the expanded plant was the use of magnesio-thermic reduction of UF_4 in place of calcio-thermic reduction. This change was necessitated as the calcium metal was not indigenously available and supplies from foreign parties were uncertain. During expansion, a decision was also taken to replace pulse columns by mixer-settlers for solvent extraction. Both these changes were carried out based on the limited inhouse experience. The overall process flowsheet is shown in Figure 1.

The plant has over the years, been required to meet increasingly stringent standards of nuclear and industrial safety. The chemicals used are very corrosive and toxic, similar chemical plants elsewhere have been scrapped and re-built(2).

II. OPERATING EXPERIENCE

The plant after completion of expansion was commissioned in 1983. Since them continuous efforts were made for optimisation and stream-lining, backed by laboratory and plant-scale R&D work. Experience has shown following constraints.

a. High level of labour intensive operations involving large number of low volume batches through long sequence of processing steps.

b. Multiplicity of equipment increasing the maintenance load to an extent where existing resources are inadequate, with a consequent fall in equipment availability.

c. Irregular supply of critical inputs.

d. Unexpected technical constraints in the process changes incorporated during expansion.

e. Need to meet new safety standards laid down by regulatory authorities.

The details of these constraints and the improvements in process technology for over-coming them by short-term measures are described activity-wise below.

2.1 Dissolution: Charging of feed materials into dissolution tanks manually has been problematic. Scrap oxide powder dissolution can lead to NOx evolution. Mechanical addition by a hopper with vibratory feeder at reduced rate (30 Kg/hr) has been found necessary. Scrubbing medium has been changed from water to 1% alkali to ensure that effluent NOx level is below TLV limit of 15 ppm. A pneumatic transfer system for yellow cake has been installed under testing. No suitable equipment for safe dissolution of turnings of metallic uranium has been found. Turnings dissolution been found unacceptable , as the incineration facilities at AFD are being augmented to meet the load from UMP .

2.2 Solvent Extraction: Major problem faced is build-up of siliceous crud in extraction mixer-settler. The feed solution after dissolution and filteration in presses contains over 0.5 g/l of SiO_2, while mixer-settlers need clear solution with less than 50 mg/l of suspended solids. Crud build-up necessitates frequent shut down for labour-intensive drainage and clean-up. A decision is now taken to install a slurry-extractor system similar to N.F.C. design(3). The efficiency of stripping mixer-settler and solvent processing units have been found to be lower due to solvent'aging'. Larger units are now under fabrication.

2.3 Raffinate Disposal: With the installation of slurry extractor, the load on raffinate filteration will increase. Besides there is need to replace labour-intensive filter presses. A rotary drum filter or a mechanised press will be installed, with drumming station to handle 500 l/hr of 10% solids.

2.4 ADU Precipitation: Due to space constraints, the precipitation is carried out in 3 tanks in batches of 50 kg each. Filteration by vacuum nutsche filter is labour-intensive time consuming (8 hrs.) operation. An automatic batching device with pH control needs development. Belt filters of the Pannevis or Hindustan Dorr Oliver type and mechanised nutsche filters have been evaluated. Tests are also planned on a centrifuge also. Simultaneously with filteration, a mechanised calcination equipment with closed drumming station is also being considered.

2.5 Conversion of UO3 to UF4: Reduction of UO3 to UO2 and its subsequent conversion to UF4 is carried out in 125 mm rotary tubular furnaces. At each stage powder transfer is manual, in batches of 50 kg, and feed rate is low 5-6 kg/hr. At such low rates mechanical feeders do not perform satisfactorily, especially since the powder is fine and cohesive - not grannular and free-flowing. The HF gas is highly corrosive and toxic. Seal life is low, about two weeks, when the original bellow-seal design is used with split bearing. Now an improved seal with integral bearing has been designed and life doubled. In addition repair time has been reduced. While the space does not permit installation of one bigger furnace, efforts are directed at better maintenance, more spares and operating control.

2.6 Magnesio-thermic-Reduction: Experience has shown that cycle times are longer (48 hrs.), break-down is more frequent, slag processing is more complex and ingot quality poorer than estimated. Efforts have been made and ingot size successfully increased from 60 kg to 200 kg. Other measures include (a) installation of integrated slag processing facility in a new location. (b) provision of additional furnace, lining stand, blender cum dryer, and discharging stand. (c) dust collection system, (d) automatic reaction completion indicator (e) mechanical handling of ingots and (f) inproved maintainence procedures for instruments and equipment.

2.7 Ingot Machining: Quality of slag metal separation by magnesio-thermy is not as good as by calcio-thermy. This requires higher production as well as additional operation of ingot machining. Machining generates metal turnings which have to be recycled. These factors were not considered earlier, and the plant production is now constrained. As a long term solution requires an additional melting facility for direct ingot melting under argon pressure, prior to fuel fabrication, is now under consideration.

2.8 Instrumentation: The need for instrumentation has grown with expansion. A centralised instrumentation station with automatic data logging, analysis and alarm indication is being set-up. An automatic control system for the slurry extractor is under development. This strategy of selective instrumentation and control has been adopted since retro-fitting modern computer control system to entire plant will not only be exhorbitant, but also not feasible. Some of the instrumentation, such as phase ratio indicator for extraction and r-indicator for magnesio-thermy, needs R&D work. Bulk of the instruments are however routine e.g. flow monitors, temp. monitors and will be installed shortly.

III. FUTURE DEVELOPMENTS

Improvements in process technology in existing plant are limited by available space, existing lay-out, and the need to continue production without interruption. However, in the longrun, major improvements aught to be incorporated since fuel for the reactors is to be produced for decade. Moreover alternative uses of metal, such as in AVLIS process, have to be borne in mind. Assessment of existing technology with reference to international developments, indicates following areas of work:

3.1 Continuous dissolution: This is a widely accepted practice in plants abroad (4) (5) and ensures continuous uniform feed to the wet plant. The existing slurry-extractor design has a solvent inventory 5-10 times that of mixer-settler. Development of a more compact extractor is needed.

3.2 UO3 Production: The ADU route yields a powder of low tap density (2.3 g/cm) poor flow ability and inconsistant reactivity. General practice for magnesio-thermy is to use powder obtained by de-nitration, whcih is more dense (3-3.5 g/cc) and granular (4)(5). The ADU derived powder is not amenable to mechanised handling unless cake is extruded (6). The granular UO3, by comparison, can be readily conveyed mechanically. Hence denitration route for UO3 production will need investigation.

3.3 UF4 Production: A combined (or integrated) system for reduction and hydrofluorination needs to be developed to avoid intermediate transfer of pyro-phoric UO2. This will also enable improved HF economy. Designing such a system will solve many of the production problems.

3.4 Metal Production: High density pelletised charge with hard refractory liner in a top loading furnace has been proven to be a safer and better method of metal production. While some work is started in UMP it needs considerable R&D input.

3.5 Effluent Treatment: A wet process for UF4 production needs to be developed for utilising the large amount of aqueous HF generated during hydrofluorination of UO2. Denitration route of UO3 production need be developed to reduce nitrate effluent.

IV. CONCLUSION

The process technology used for metal production is proven and well established. However technological improvements are required to reduce labour-intensive operations, increase scale of operation, reduce maintenance improve personnel and machine safety and increase producitivity. Many of these changes can be incorporated only when better lay-out can be made in new space. Meanwhile measures for improved production under existing constraints have been identified and action taken for implementation.

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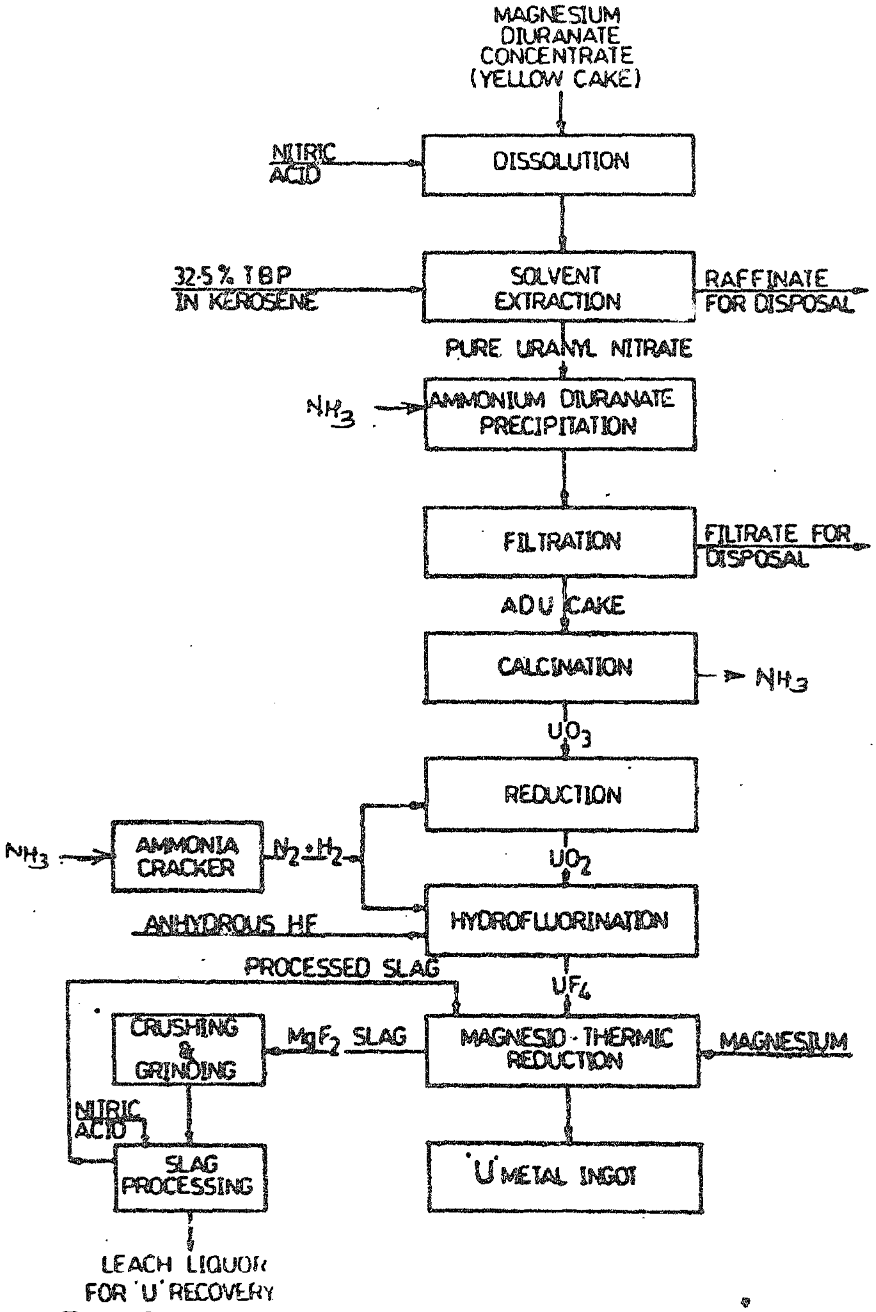

Fig.1.- FLOW SHEET FOR URANIUM METAL PRODUCTION

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