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Uranium Enrichment by Centrifuge in Japan

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1. INTRODUCTION

Particular attention has been paid to the growing demand for nuclear power by the authorities in many countries in re-examining their nuclear power programs. Since the primary source of nuclear power by the end of this century will be from the present generation of light water reactors, a substantial growth in supply of slightly enriched uranium should be secured through the intensified expansion of enrichment capacity. The nuclear power programs and the shares of various reactor types are the most important of the determining factors in forecasting the enrichment demand. The long term forecasts are also affected by the factors of the flowsheet in nuclear fuel cycle such as the timing and rate of the introduction of plutonium recycling and tails assay of enrichment plants. According to the broad anticipation of enriched uranium supply and demand in non-communist countries presented by various organizations, still remaining uncertainties, there will be no serious shortage up to 1988.

The separative work demand in Japan for the period ahead to the year 2000, estimated to be 5,400 t SWU/y in 1985 and 14,000 t SWU/y in 2000, will be satisfied with some allowance through the enrichment service contracts with the ERDA and the EURODIF. If the stockpile cumulated during the early stage of this period can be put to deferred use, additional supply will be required in the later half of 1980's.

The basic policy in Japan depending upon the producing countries for uranium supply has been investigated by the Atomic Energy Commision(AEC) with concluding such long term programs as the security of supply through 1) the Atomic Energy Agreement between Japan and the United States, 2) the active anticipation in planned international enrichment projects, and 3) the further independent development of enrichment technology. This policy is still accepted as a most opportune scheme in meeting the separative work demand in Japan.

2. RESEARCH AND DEVELOPMENT OF URANIUM ENRICHMENT TECHNOLOGY

The frontier work on uranium enrichment technology using gas centrifuge process in Japan was initiated in 1959 at the

Institute of Physical and Chemical Research and the Atomic Fuel Corporation(AFC), original of the present Power Reactor and Nuclear Fuel Development Corporation(PNC), although there had been some early works limited only to theoretical interest in 1949. Thereafter the PNC has conducted extensive research and development of the centrifuge process with the aid of academies and industries since the AEC's designation of this activity as a national project in 1973. Cumulative governmential investment to this project now amounts to ¥ 35 billion. Progress so far has been good and more recent technology has established a basis to move into the next phase. As a consequence of this success, the country decided to start the construction work of a pilot plant providing a total capacity of 50 t SWU/y from 1977.

2.1 Historical

The activities of this field in Japan may be divided into four periods when focusing our attention to the development of centrifugal machines. In the first period ranging from 1959 to 1971, various ideas were proposed and their embodiments were attempted by repeating constructions and tests within poor conditions of only very limited rotor materials and thus limited rotation speed. Basic works were also carried out to get a close relationship between theory and experiments and to clarify better operational conditions.

It was in the second period that, based on the experience in the first period, conceptual designs were made for various centrifuges considered to be acceptable for practical use and then the first prototype model was completed after repetitive construction-modification cycles. In this period a significant portion of our effort was devoted to attaining a stable rotation of centrifuges in high peripheral speed. In this sense we developed short bowl-subcritical centrifuges and tried to upraise their rotation speed as high as possible within permissible limits of the material strength. Through these repeated improvement and the accumulation of experimental data of isotope separation tests, an agreement became close between theory and experiments. The separative efficiency of higher than 50% could be achieved in this period.

In the third period, partially overlapping the second period, we developed the centrifuges of high performance, aiming further increase in separative power by increasing the length of rotors on the basis of our experience in the development of short bowl-subcritical centrifuges. Systematic and intensified research and development of the fabrication technology of a structually favored long rotor yielded a remakable success in developing long bowl-supercritical centrifuges. It has been also confirmed even by experimental way that the mechanism of the separation of isotopes in the long bowl-supercritical centrifuge, even when a different means of feed and withdrwal is used, is quite similar to that in the short bowl-subcritical centrifuge and that the smae analytical procedure can be applied to designing the long bowl-supercritical machine. As a consequence of these, the improvement of separative power could be achieved without serious difficulties.

The last period from 1976 to the present includes two courses of activities. One is essentially on the line drawn by the rotor fabrication technology established on a success in the third period. Further lengthened rotor may be expected to lead proportionally increased separative power. Moreover the research is taking place on new materials suitable to much faster rotation with a bright prospect. Another activity is our challenge to assembling an epoch-making centrifuge with much more increase of dimensions as well as rotating speed, aiming a drastic improvement of the separative power. This is carried out through the reappraisal of each of the machine components. However the decision to employ such a newly devised model as a pilot plant machine should be made not only by its performance in separative power but by the costs required. Thus an effort is also made to reduce the fabrication costs by the mass production of major components and the reduction of the casing weight.

2.2 Safety and reliability tests of gas centrifuges

Since some magnitude of air leakage may cause serious damage to an enrichment plant using gas centrifuge process, particular attention must be paid to this matter. It is unlikely that all the centrifuges in a plant may be operated without any trouble for a long term, because they rotate at much higher rotation speed than usual rotary machines. For these few years extensive tests have been repeated for the verification of the system integrity and for the investigation of the influence of shocks and vibrations caused by the trouble of neighboring centrifuges. As a result of these tests, a structurally favored centrifuge can be properly designed at present, although it has been difficult to catch up every probable case because of its phenomenological complexity. Moreover, we have developed a device which is effective in surpressing the propagation of troubles in the case of the leakage of air into an enrichment plant.

Because of the unique condition that Japan is located in a frequent earthquake zone, the earthquake resistivity of centrifuges is a particularly important problem to be solved. Extensive tests made under various seismological conditions dictate that both sub- and supercritical centrifuges have sufficient earthquake resistivity against the degree of seismic intensity of up to some hundred gal. Since a great deal of centrifuges are to be operated in an enrichment plant, their life time and reliability are also important. The life test has already been under way on centrifuges to be employed as a pilot plant machine as well as on individual major machine components. An improvement has been achieved to a great extent on rotors and bearings which are the most important components determining the life time and reliability. However further long term test with a large number of centrifuges is necessary for the critical appraisal of their life time and reliability. It is our expectation in this sense that this verification will be properly made in the planned pilot plant.

2.3 Cascade tests

Two experimental cascades, C-1 and C-2, were constructed for extensive cascade tests. The operations of C-1 and C-2 cascades were initiated in 1974 and in 1975, respectively. Naturally the operation experience and the knowledge about the characteristics of both ideal and step cascades obtained from these experimental cascades will be put to significant use in designing the planned pilot plant. Leakage tests were also made on these cascades to investigate the influence. An effective way against this kind of trouble was obtained through these cascade tests.

2.4 Industrial status

Before 1969, only one company engaged in manufacturing centrifuges. Thereafter, in reply to our request, several companies started to participate in this business and an uncompromising improvement was made on the contract procedures. The introduction of a competition principle leads a rapid progress of the manufacturing technology. It is our understanding that the industry is ready for the construction of a commercial plant capable of competing in the world market in 1980's.

3. FUTURE PLAN AFTER THE PILOT PLANT

The construction work of a pilot plant using gas centrifuge process in Japan will, as already mentioned in the introduction, start in 1977 and it will be in partial operation in 1979. After appraising the result of this pilot plant, the construction of a demonstration plant will be expected in the early 1980's. Continuing successive expansion of this demonstration plant, the first commercial plant providing a total capacity of few thousand t SWU/y will be in full operation in the later 1980's. The construction sequence and process facility startup will be phased so as to balance construction works and to minimize interference with process startup. Thereafter, the expansion of enrichment capacity will be principally dependent upon the demand.

4. CONSIDERATION ON THE INDUSTRIALIZATION

As a preparatory activity for the near future, we have made feasibility studies and economic analyses on a commercial plant. It is a unique facet of a uranium enrichment business that this business requires an enormous plant investment and operation cost, while the SWU price, a sole source of return in this business, is controlled within certain limits by the international situation of politic affairs as well as so called price adjustment in relation to the world market price. Thus, there exists big problem when the industry engages in this business on a private economy basis. The total capital turnover, defined as the ratio of gross sales to gross capital invested, is quite low and very close to those in the electric power, gas, and iron and steel industries in agreement with the Garret's analysis. Since the total capital turnover reflects the nature of the enterprise, this uniquely low value may render the uranium enrichment enterprise among these national key industries. Therefore, who and how manages and finances the enrichment enterprise becomes a very important problem to be solved in connection with big investment required and the taking over of accompanying risk.