PROCEEDINGS OF THE 18th

IECEC '83

INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE

VOLUME

1

OF 5 VOLUMES

THERMAL ENERGY SYSTEMS

18th INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE

PROCEEDINGS
IN 5 VOLUMES

VOLUME 1
THERMAL ENERGY SYSTEMS

"Energy for the Marketplace"

SHERATON-TWIN TOWERS
ORLANDO, FLORIDA

Intersociety Energy Conversion Engineering Conference

PURPOSE:

To reduce the overlapping and duplicative effort of the sponsoring societies in the field of advanced or non-conventional energy conversion. This conference is concerned with the engineering and application aspects of non-conventional energy conversion systems and devices as opposed to the details that are presented at various specialist conferences. Papers are screened for technical competence, clarity and brevity.

ORGANIZATION:

A standing IECEC Steering Committee consisting of two members from each society coordinates all conference activities. Each year a society (this year AIChE) sponsors the conference. Session Organizers are appointed by the General Chairman and the Program Chairman. Session Organizers invite abstracts and receive abstracts from a general solicitation through the Program Chairman. Within limits set by the General and the Program Chairman the Session Organizers are responsible for the content of their sessions and appoint appropriate Session Chairmen.

SPONSORING SOCIETIES:

American Institute of Chemical Engineers
(1976 Conference)

American Nuclear Society
(1977 Conference, Washington, D.C.)

Society of Automotive Engineers
(1978 Conference, San Diego, CA)

American Chemical Society
(1979 Conference, Boston, MA)

American Institute of Aeronautics and Astronautics
(1980 Conference, Seattle, WA)

American Society of Mechanical Engineers
(1981 Conference)

Institute of Electrical and Electronic Engineers
(1982 Conference)

Volume 1 — Pages 1-416

Volume 2 — Pages 417-930

Volume 3 — Pages 931-1440

Volume 4 — Pages 1441-1996

Volume 5 — Pages 1997-2444

ISBN 0-8169-0253-4
Published by the American Institute of Chemical Engineers
345 East 47 Street
New York, New York 10017

Responsibility for the contents rests upon the authors and not upon the AIChE, any sponsoring Society, or any society member.
Abstacting is permitted with mention of source.

Additional copies may be purchased from the AIChE.

Printed in U.S.A.

Copyright © 1983 by the American Institute of Chemical Engineers

Message from the General Chairman

Today throughout the world, there has been a de-emphasis in energy conversion projects simply to satisfy government requirements, and a realization that energy conversion must make sense in the marketplace. We as engineers, must consider how our projects are eventually going to be used, and how they will be eventually incorporated into products that people will buy and use.

For the last 18 years, the Intersociety Energy Conversion Engineering Conference (IECEC) has been a marketplace for ideas for potential products. Here, gathered together in one meeting, are the latest reports on technologies of diverse natures which will eventually compete for the marketplace. If your product is electricity for instance, you can evaluate the state of technology of several different types of heat engines, such as Stirling, Brayton Cycle, Rankine Cycle to operate different types of electric generators. You can see how photovoltaics, thermonics, and thermoelectric, MHD, and possibly other methods are doing in the direct conversion area. You can determine how wind energy, tidal energy, ocean thermal energy might fit into your needs. Possibly a new type of energy conversion will be discussed which you have never heard of before. As a marketplace for ideas, the Intersociety Energy Conversion Engineering Conference is ideal.

The utility of having one meeting for all use-related energy conversion technologies was recognized by the major engineering societies and related professional societies back in 1966. The result is the organization of the IECEC, to eliminate duplication of separately sponsored meetings. Each year, one of the sponsoring societies takes its turn to supervise and run this Conference. This year, the society is AIChE. The continuity of this Conference is provided by a Steering Committee composed of two representatives of each of the societies. The intent of the IECEC is to avoid subjects that are appropriate for established conferences on conventional power systems. It also intends to compliment all the specialist conferences that are meetings of experts in a limited area of energy conversion.

Orlando is an attractive vacation spot, and the meeting is scheduled before school starts. Therefore, we have not scheduled any late afternoon or evening activities at the conference, so that you may attend many of the internationally known attractions with your family or associates.

Since this meeting fulfills world-wide needs to learn how to do more with less by means of improved energy conversion, it has grown into an important international meeting. Particularly, we have important contributions from Europe and Japan in many technical areas. This year, the Japan Society of Mechanical Engineers is becoming one of the co-operating societies who help sponsor the IECEC. These co-operating societies do not take turns sponsoring one of the meetings, but do support the meetings with publicity to their members and do receive the privilege of registering at a reduced rate. However, whether you are a member of a sponsoring group or not, I am glad you were able to attend and partake of this meeting. If you are here as a specialist, we hope you will be interested to some degree in the whole field in energy conversion.

W. R. Martini
General Chairman

Message from the Program Chairman

This year's conference is the 18th in the series. Reflection on the changing national energy interests and priorities reveals that the energy conversion field has evolved from one of strong orientation toward military and aerospace applications to one of greater breadth that recognizes a wide spectrum of terrestrial and private-sector requirements. This shift has brought with it greater concern for the economics of the marketplace. Hence this year's theme "Energy for the Marketplace."

Superimposed on the shift discussed above is the present federal policy of emphasis on longer-range R&D, coupled with a de-emphasis of government-funded demonstration and commercialization projects. These added constraints have placed new and difficult challenges before the energy conversion engineering field. It is in this new atmosphere of difficult financial and policy constraints that we present the 18th IECEC.

The program in this Proceedings shows the areas of current interest, many of which lie in the private sector. I think that the spectrum of topics represents a healthy balance among the technical fields, and among the potential markets. Some of them are in healthy competition; others complement one another. Frank McLarnon and I hope that you find this program interesting and informative. Thank you for joining us for a successful 18th IECEC.

Elton J. Cairns
Technical Program Chairman

此为试读，需要完整PDF请访问：www.ertongbook.com

Table of Contents

VOLUME I—THERMAL ENERGY SYSTEMS

Nuclear Power

839001

THE NUCLEAR FUEL CYCLE

DESPERATELY IN NEED OF FRONT END ALIGNMENT

George White, Jr., President
M. Jerry Reaves, Vice President

NUEXCO

The front end of the nuclear fuel cycle which includes uranium supply, conversion of U3O8 to UF6 and enrichment of UF6, is characterized by excess capacity, excess production, growing inventories and price weakness. Excess capacity resulted from uncritical acceptance by suppliers of overly optimistic utility plans for nuclear growth. Cancellation and deferrals of nuclear plans led to reductions in forecast demand just as the new production capacity was coming on line to meet the high levels of demand forecast earlier.

The unique and conservative nature of the utilities as business entities and the unique, sole-end-use character of uranium and its related fuel cycle services suggest that the markets for these materials and services will differ from those of other fuels. An international market is foreseen, marked by continuing boom-bust cycles.

INTRODUCTION

The front end of the nuclear fuel cycle is characterized by excess productive capacity, excess production, growing inventories and, not surprisingly, price weakness. These characteristics apply to the principal fuel commodity, uranium, as well as to its related services conversion and enrichment.

While similar statements could perhaps be made about oxide conversion and fuel fabrication capacity, and about zirconium, pressure vessels, and turbine generators, these areas are outside Nuexco's field of expertise. Our field is the front end of the fuel cycle: in uranium, conversion of U3O8 in UF6 and enrichment services.

Who is Nuexco and why am I qualified to speak here today? Nuexco was founded in 1968 by two veterans of the nuclear industry: George White and Payne Kibbe. As the first general manager of General Electric's Atomic Power Equipment Division, George pioneered GE's entry into the commercial nuclear market in the late 1950s and early 1960s. Payne was an early player in the uranium game in the western U.S., and was President of Atlas Corporation, a long time, and still active, uranium production company.

From this small start, Nuexco has grown into a worldwide organization. Our headquarters are in Menlo Park, California and we have offices in Stamford, Connecticut, in Atlanta, Georgia, and in Ferney Voltaire, France (just outside Geneva). We also retain a complex of representatives and special consultants to provide coverage in all uranium producing and consuming areas, including Australia, Korea, Japan, Taiwan, South Africa, Niger and Gabon.

Our business activities fall into three major categories:

1. We are publishers. We have put out a monthly report on the nuclear fuel industry since 1968. This report comments on supply and demand, recent transactions, price trends. It includes the Nuexco Exchange Value which is generally viewed as being the spot market price for uranium. We also publish values for the secondary markets for conversion and enrichment.

2. We are consultants. We develop analysis and studies on supply and demand, prices, procurement, marketing and inventory strategies as well as assorted other topics. We work on both a custom and multi-client basis.

3. Finally, we are brokers of fuel cycle materials and services. We believe we are the largest broker in the world, having participated in transactions involving more than 200 million pounds of U3O8 and millions of Kgs of conversion and enrichment services.

The title of this paper and my opening remarks suggest that the front end of the fuel cycle is in a mess. And indeed it is. Using 1982 WOCA (World Outside Communist Areas) data, the situation looks like this.

URANIUM

Uranium mines and mills currently in place have the capacity to turn out approximately 150 million pounds U3O8 annually. This figure will increase by 12 million pounds with the mid-1983 commissioning of the Key Lake mill in Saskatchewan. These numbers are, of course, subject to some variation based on the grade of the ore mined and milled. Within geologic limits, grade can and will be adjusted based on mine/mill economics, prices and contracted delivery commitments.

Actual production during 1982 was only 106 million pounds, most of which was produced to meet delivery obligations under contracts executed in prior years. Actual uranium consumption during 1982, however, was only 63 million pounds and will not approach 100 million pounds until 1987 or 1988 at the earliest.

Thus, we have an industry capable of making 150 million pounds, which is actually making 106 million pounds when only 63 million pounds were actually needed. The difference between production and consumption (some 43 million pounds) was added to inventory bringing total inventory to more than 400 million pounds, or equivalent to nearly 6 years forward usage. Someone, somewhere is holding that inventory with all the attendant carrying charges. Compare this with 90-day inventories of oil or 120 day coal stockpiles.

Over capacity and overproduction when combined with numerous cancellations and deferrals of nuclear units have had predictable results. Utilities became sellers of excess or unneeded inventories, in competition with primary producers. Prices broke sharply lower declining from $40 per pound U3O8 in early 1980 to a low of $17 by mid-1982 before recovering somewhat to $22.25 by March 1983.

While spot prices have strengthened of late, they are still well below the levels necessary to justify new production ventures, and it seems likely that, rather than large new ventures, the first beneficiaries of any sustained price recovery will be production operations that had previously been shut in. However, any sustainable price recovery cannot predate the completion of liquidation and redistribution of excess inventories.

Due to variations in grade, depth, location and geologic environment average cost data means little in the uranium business. Suffice to say, however, that $22 prices (in 1983 dollars) will not long sustain uranium production worldwide.

CONVERSION

Turning next to conversion, we see a somewhat similar situation. There are five major WOCA converters: Kerr-McGee and Allied in the United States, Eldorado in Canada, BNFL in England and Comurhex in France. Combined they currently have the annual capacity to convert nearly 120 million pounds of U3O8 into UF6. By 1985, as a consequence of almost completed expansions, this capacity will be in excess of 140 million pounds U3O8 annually. However, as noted earlier, the need in 1982 was only for 63 million pounds. The cancellations and deferrals of nuclear plants which led to the liquidation of uranium inventory have impacted dramatically on the conversion market. Much of the excess uranium inventory which is for sale is in the form of UF6. However, most buyers prefer to purchase U3O8. Hence a transaction called the deconversion swap was developed. UF6 is swapped for U3O8 plus dollars, with the dollars representing the value of the conversion service. This market is characterized by few buyers and many sellers. Not surprisingly, prices of secondary market conversion prices have been driven down to levels well below prices charged by the primary convertors. Primary conversion prices approximate $3 per pound U. During the past year, the secondary market conversion price has fluctuated between $1.00 and $1.50 per pound U.

ENRICHMENT

Finally, there is the enrichment area. Here the principal WOCA suppliers number only three: U.S. DOE, the tripartite English-Dutch-German Urenco project and the multi-national, French-led Eurodif project. The USSR does sell some swu into the WOCA market and development projects in Brazil, South Africa and Japan provide small quantities, but the total quantity from these other sources is not really significant. The principal suppliers have the current capability, at a 0.20 tails assay and 3.0% product assay, to enrich 130 million pounds U3O8. Again, we see supply capability nearly twice current consumption rates. And again we have seen the development of a secondary market to dispose of excess enrichment. Prices are discounted as much as 30% from those charged by primary suppliers.

How did this sorry state of affairs come to pass. It certainly wasn't intentional. Rather it was the result of a complex of economic, political, technical and social factors. Permitting myself 20/20 hindsight, it is clear that the nuclear option was oversold. Nuclear power is neither as cheap, nor as simple as was promised. Nor was the public reaction to nuclear properly gauged. On the other hand, the nuclear fathers were aware of Murphy's law. They knew nothing is as easy as it looks. They knew that if something could go wrong it would go wrong and at the worst possible time. However, no reasonable person would have guessed that construction times would treble from 4 to 12 years, and that actual costs would increase by up to 600 percent.

Thus, the starting point is an unrealistic level of nuclear ordering worldwide in the late 1960s and the early 1970s. At this point, it is important to remember that utilities are particular and unique business organizations. They are regulated monopolies. Their charter is to provide reliable service at the lowest possible rates consistent with a regulated rate of return sufficient to attract investment capital. When nuclear appeared the cheapest, it was ordered.

As more and more nuclear plants were ordered, the industrial infrastructure responded and commitments were made to enlarge existing facilities and build new ones. It rippled throughout the industry--more uranium development, more conversion capacity, more enrichment capacity, etc. etc. Again, in hindsight, one can observe that the suppliers were uncritical in their acceptance of these utility plans. Rather, with scarcely a look backward, they plunged ahead. Serious problems arose including, in no particular order of importance: Environmental concerns, the Arab oil embargo, record high interest rates, escalating costs, conservation, economic distress, reduced load growth and finally, as the piece de resistance, the Three Mile Island incident. Incredibly however, as these problems began to surface and, multiplied and compounded, there was still hardly a look backward; investment continued to pour in and capacity continued to grow, even as the market for these products and services was shrinking rapidly.

Returning for a moment to the utilities, risk aversion, translates into conservatism. As nuclear plants were ordered, the utilities became concerned about adequate supplies of fuel and services needed to run these plants. So they contracted for uranium, conversion and enrichment in quantities and on schedules to meet the most optimistic outcome. Too much, too soon might not be desirable, but, for a utility, too little or too late is totally unacceptable.

In the best of cases, because some delays are inevitable, this meant taking and paying for materials and services before they were needed. In the worst cases, cancellation of entire nuclear programs, it meant taking and paying for material and services for which there was no requirement at all. All utilities find themselves involved in a web of interlocking contractual commitments. One orders a reactor in 1972 for startup in 1980. You contract with General Electric for fuel fabrication services to meet that schedule. In order to provide enriched uranium to General Electric on a timely basis, you conclude an enrichment contract with U.S. DOE--a very long-term contract--30 years--with prohibitively expensive financial penalties for cancellation or and late delivery. In order to meet your enrichment contract schedule, you have to contract for timely delivery of uranium and conversion services. Voila, everything is locked into place. Then your reactor is delayed until 1986, or worse canceled altogether. In those days no one ever bothered with a force majeure provision that contemplated such events, and a uranium producer who has borrowed millions from his friendly banker in order to develop his mine on the basis of your long-term supply agreement is not apt to release you from your obligation to take and pay.

Thus, secondary markets develop as utilities dump unneeded material and services. The reality of the new market has started to sink in. Producers and their bankers have become more skeptical. U.S. uranium production which exceeded 43 million pounds U_3O_8 in 1980, will likely be less than 16 million pounds in 1983. Various Australian and Canadian projects have been deferred. DOE plans for increased enrichment capacity are being scaled back in size and delayed. The real arbiter is price and price is now performing its classic economic function.

As to the future, I would offer three observations which are based on Nuexco's long experience in the fuel cycle game.

1. Excess capacity and excess inventory is bad enough, but these inventories have continued to grow as production continues to be greater than consumption.

   The development of these excess inventories exert, in turn, enormous financial strain on the inventory holders, which, in turn, leads to inventory liquidation. Such liquidation has led to a collapse of uranium spot prices and the development of severely discounted markets for conversion and enrichment services.

One is inescapably led to the conclusion that prices will be weak, and buyers will dominate the market until the inventory liquidation is complete or, to say it another way, until the inventory has moved from weak hands to strong hands.

Furthermore, it is clear that production rates must and will, in time, be more nearly rationalized with consumption rates. We have seen the beginning of this rationalization. The bold plans to produce more uranium, more conversion and more swu, ran head first into the reality that there simply weren't enough buyers. Quite correctly most of these plans have been canceled or deferred.

2. Secondly, I would offer the opinion that the nuclear fuel market will be characterized by a unending series of boom-bust cycles. My reasoning is based on the fundamental nature of the utility charter; which, as noted earlier, is reliable service at the lowest possible rates consistent with a regulated rate of return sufficient to attract investment capital. If only five words could be used to describe utility business philosophy, I would choose the words "conscious policy of risk aversion." This is not intended to be critical of utilities, but merely a statement of the way things are and must be. I personally prefer cheap electricity. However, I prefer expensive electricity to no electricity at all.

As also noted earlier, too much, too soon may not be desirable, but it is preferable to too little or too late. Too much, too soon dictates excess productive capacity, be it in uranium, conversion or enrichment. Excess capacity and inventory build-up lead to price weakness. Price weakness is followed by a dimunition of new capital investment, then later by utility concerns of future shortages, then later by higher prices and so on.

It has been said that those who don't learn from history are bound to repeat it. In this case, however, the utilities cannot be blamed. It is a condition of their existence.

Before those of you with doctorates in economics rise to debate me, I would remind you that uranium is a unique commodity. It has but one use. It is, insofar as buyers are concerned, totally price inelastic. There will never be a real demand pull situation in uranium. The best that sellers can ever hope for is a perception of future shortage, to increase prices. Classic economic theory must be recalibrated to take account of both the unique nature of uranium as well as the unique nature of its user group.

3. A third conclusion relates to the inter-nationalization of the market. U.S. uranium is flowing to Europe, Taiwan, Korea and Japan. Canada, South Africa, Australia, Namibia and Niger also ship to customers around the world. U.S. utilities contract for conversion in Canada and Europe as well as the U.S. Europeans, Japanese, Taiwanese, Koreans and others buy conversion in the U.S., France, Canada, and the United Kingdom. The development of the secondary conversion market has added to this mix.

In the enrichment area, the monopolistic position of DOE is a thing of the past. Eurodif and Urenco have captured significant market share. The assignment and sale of SWU in the secondary market have become an enormous business crossing international boundaries with ease.

It is truly a world market. Embargoes and cartels, government sponsored or otherwise, designed to regulate commerce are doomed to fail as are legislative attempts made in the name of non-proliferation. The efforts of the U. S. government in this area are the clearest demonstration of just how counter-productive such efforts can be. The dominant U.S. enrichment position has been lost; the U.S. is no longer viewed as a credible enrichment supplier and South Africa, Brazil and others are moving as rapidly as possible to create indigenous enrichment capacity. That's not what I would call a very effective non-prolifer ation policy.

In the commercial area, Australia's uranium floor price policy provided Canada a once in a lifetime oppor-

此为试读，需要完整PDF请访问：www.ertongbook.com

tunity to sweep the market for two years. My thought here is simple--if I may borrow a term from Wall Street, "Don't fight the tape, you'll get killed."

In closing I would observe that the previous comments suggest a very complex market in which the financial stakes are enormous. Four hundred million pounds of excess U3O8 at $25 per pound represent a capital investment of $10 billion. At 15% the carrying cost alone is $1.5 billion annually. If conversion and SWU are added, we are talking of waste, in my relatively small industry, of more than $3.0 billion annually.

Consider a European seller of enriched product which is physically located in Europe. Before the transaction is fully concluded, it may involve a Japanese buying SWU through a de-enrichment swap, followed by a U.S. utility purchasing the conversion component via a location and a de-conversion swap, followed by a Canadian producer purchasing the U3O8, after a nationality swap, for delivery at a U.S. converter to a European buyer. This is not a flight of fancy. Such tansactions do occur.

These are complicated deals requiring technical skills, commercial savy, regulatory knowledge, timing and a fair measure of good luck. The market is not likely to settle down. Rather it is likely to be more volatile and increasingly complex. It will be impossible to judge if you are a planner, but a lot of fun if you enjoy commerce.

839002

LWR REPROCESSING - CURRENT STATUS OF MAJOR PROGRAMS

R.E. Brooksbank
R.J. Sloat
R.O. Sandberg

Bechtel National, Inc.
Nuclear Fuel Operations

ABSTRACT

Despite the near-term oversupply of uranium concentrate and the sharp decline in uranium prices, a number of major nations are nevertheless proceeding with plans for commercial-scale reprocessing of spent reactor fuel. This paper presents an overview of the world-wide status of light water reactor fuel reprocessing, discussing both operational experience in existing facilities and plans for expanding reprocessing capacity.

Attention is directed toward developments in the major nuclear power nations, including France, Japan, the UK and the Federal Republic of Germany. The outlook for reprocessing in the United States is featured, focusing primarily on the prospects for initiating operation of the Barnwell Nuclear Fuel Plant. The likely impact of the Nuclear Waste Policy Act of 1982 is considered, as well as emerging trends in Government reprocessing policy.

INTRODUCTION

From the outset of the nuclear power program it was recognized and generally accepted that fuel discharged from reactors utilizing enriched fuels should ultimately be reprocessed to recover residual uranium and plutonium energy values. Reprocessing was considered essential to the long-term viability of the nuclear option to extend the limited supply of economically recoverable uranium resources.

Growing concern over the potential risks of nuclear proliferation associated with widespread use of separated plutonium led the U.S. Government in the mid-1970's to reconsider the desirability of closing the uranium-plutonium fuel cycle. The International Fuel Cycle Evaluation (INFCE) undertaken in 1977-1980 by 66 nations and five international organizations, however, reconfirmed the need for reprocessing and breeder reactors where necessary to ensure energy supply security, provided that these activities are carried out under stringent international nuclear safeguards. With the exception of the United States, the major nuclear nations of the world therefore continued to proceed expeditiously with plans to construct commercial-scale reprocessing facilities.

This paper presents an overview of the status of light water reactor (LWR) fuel reprocessing programs worldwide, discussing both operational experience and progress toward expansion of reprocessing capacity. Current prospects for resuming commercial reprocessing in the U.S. are highlighted.

GENERAL OVERVIEW OF REPROCESSING PLANTS

Following the initial demonstration of the Purex process in the pilot-scale facilities at the Oak Ridge National Laboratory in 1952, the majority of reprocessing plants built subsequently throughout the world have utilized this well-proven technology. Approximately 380 (1) plant-years of operational experience have been accumulated to date in reprocessing plants, providing a sound basis for closing the fuel cycle.

Table 1 presents an overview of the status of reprocessing plant projects throughout the world.

Table 1

STATUS OF WORLD WIDE REPROCESSING PLANT EFFORTS

Nation	Type Plant Planned or Operated		
	Commercial	Military	Pilot-Scale
Argentina			X
Belgium	X		
Brazil	X		
France*	X	X	X
Germany*	X		X
India*	X		X
Italy			X
Japan*	X		X
Pakistan			X
UK*	X	X	X
U.S.*	X	X	X
USSR*	X	X	X

*Fast Breeder Programs in Progress

France, the United Kingdom, the USSR and the U.S. have operated plants which have reprocessed large quantities of fuel in connection with their commercial, military and pilot scale programs and valuable experience has been gained. Belgium, Japan and India have operated small scale pilot and/or demonstration facilities which have reprocessed commercial reactor fuels. These facilities serve a dual function which includes both the development of reprocessing technology within the host nation and provide a means for recovery of plutonium and uranium to close the nuclear fuel cycle. Seven nations also have active programs to develop reprocessing technology for fast breeder reactor fuels since these fuels are significantly different than LWR fuels. Since the development status of the FBR cycle will be reviewed in a separate paper, it will not be covered here.

FOREIGN REPROCESSING PROGRAMS

Because of time constraints, it will not be possible to cover all of the foreign reprocessing programs. The discussion is primarily focused, therefore, on the activities in France, the United Kingdom, Japan and West Germany which have major commercial-scale programs for reprocessing LWR fuels. The U.S., UK and France have literally reprocessed tens of thousands of tons of spent metallic fuels as part of their defense programs. This experience has provided a sound technological basis for reprocessing the oxide fuels characteristic of today's LWR's. Through February 1983, the quantity of oxide fuels processed in the Western world amounts to approximately 1,255 tons of uranium, broken down as follows:

Table 2

OXIDE FUELS PROCESSED (2)(3)

Plant	Tonnes of Uranium
La Hague, France	555
Karlsruhe, FRG	120
Sellafield, UK	90
Mol, Belgium	100
Tokai, Japan	150
West Valley, USA	240
Total	1,255

Approximately 4,000 tonnes of oxide fuel have been discharged from European nuclear power plants, about 20 percent of which have been reprocessed. The rate of spent fuel discharge will continue to increase as new generating capacity goes into commercial service. As shown in Tabe 3, cumulative fuel discharged from European reactors is forecast to reach 50,000-60,000 tonnes by the year 2000.

Table 3

COMPARISON OF FUEL DISCHARGED WITH REPROCESSING PLANT CAPACITY (2)
(1000's of tonnes of heavy metal)

Year	Fuel Discharged	Five-Year Cooled Fuel	Reprocessing Plant Projected Capacity
1985	9	2-3	1.8
1990	22	8-10	8-10
1995	35-40	20-23	19-25
2000	50-60	35-44	30-42

To accommodate this load, reprocessing capacity is being expanded substantially by constructing new plants, modifying existing facilities and restarting a dormant plant. Comparing the quantity of fuel available to the projected capacity of reprocessing facilities, it appears the reprocessing capacity will be adequate.

France (2)(3)(4)(5)

France currently has the most ambitious reprocessing program in the world, processing domestic as well as foreign fuel on an industrial scale. The reprocessing plant at Marcoule (UP-1), commissioned in 1958, was initially employed to process defense fuels exclusively. In recent years, however, it has become increasingly involved in reprocessing relatively small amounts of civilian power reactor fuels. The experience gained at Marcoule and its associated experimental facilities provided the basis for the design of the reprocessing complex at La Hague.

The initial reprocessing facility at La Hague (UP-2), commissioned in 1966, was designed to process metallic fuel from the French gas-cooled reactors (GCR's). Since commissioning it has processed 4340 tons of GCR fuel. Between 1972 and 1976 it was modified under the High Activity Oxide (HAO) project to provide the capability to reprocess 400 MTHM/year of oxide fuels from light water reactors (LWR's).

Through February 1983 the HAO had successfully processed 555 MTHM of LWR fuels from 11 European utilities and one Japanese utility. While operating problems were encountered initially in the HAO facility, they have been largely resolved, and the experience gained has provided an excellent design base for future plants (3).

From a commercial standpoint, COGEMA's light water reactor reprocessing activities are a well-established and growing business. The French have contracted for reprocessing about 1250 MTU in the UP-2 plant. In addition, contracts have been signed with 30 separate utility companies for processing spent fuel from 70 reactors. The countries involved in these contracts include Japan, West Germany, Switzerland, Belgium, the Netherlands and Sweden and cover a total of 6,000 MTU of spent PWR and BWR fuel.

In order to meet contractual commitments for reprocessing services, additions and modifications will be made to the UP-2 plant to increase its nominal LWR reprocessing rate from 400 to 800 MTHM/year. In addition, a new reprocessing plant, UP-3, having a nameplate capacity of 800 MTU/year, is now under construction at La Hague and is scheduled to start up in 1987.

The operating performance of the reprocessing plants in France has been good despite the fact that these facilities were constructed early in the nuclear age and have been called upon to process a wide variety of LWR, gas-cooled reactor (GCR) and fast breeder fuels. In contrast to the contention of some skeptics, the safety record in these plants has been excellent and the personnel exposure associated with the processing of LWR fuels at La Hague is well below allowable exposure limits and is continuing to decrease with time.

United Kingdom (5)(6)

The United Kingdom has accumulated extensive reprocessing experience in its Sellafield (Windscale) plants, where over 20,000 tons of uranium metal fuels have been processed in the B-204 and B-205 facilities. The B-204 plant, after reprocessing defense fuels exclusively from 1952-1964, was shut down and converted to an oxide head-end facility having a theoretical annual capacity of 400 MTHM. The modified head-end included a shear-leach system and a single "Butex" solvent extraction cycle. The partially decontaminated uranium-plutonium stream from the B-204 plant was then transferred to the B-205 plant where reprocessing was completed. This plant processed approximately 90 MTHM from 1969-1973 when it was shut down following a contamination incident in the head-end facility.

British Nuclear Fuels Limited (BNFL) plans to construct storage and reprocessing facilities for irradiated oxide fuels from commercial advanced gas-cooled reactors (AGR's) and light water reactors from nuclear installations within the UK and from foreign utilities. Government authorization has been granted to construct an industrial-scale plant known as THORP (Thermal Oxide Reprocessing Plant) with a nameplate capacity of 1200 MTHM/year (to be added as two 600 MTHM/year increments). The design has not been finalized, but for planning purposes a throughput of 650 MTHM/year has been assumed with operation beginning in 1989 or 1990. Planned storage capacity at Sellafield will be increased stepwise from the present 2300 MTHM to 6000 MTHM by 1987 which is adequate to accommodate all AGR and foreign LWR oxide fuels expected to be received through 1990. It is expected that the THORP will be capable of reprocessing fuel in addition to the 6000 MTHM already committed.

Federal Republic of Germany (FRG) (5)(7)

Several years ago, adequate provision for nuclear waste management became a precondition for issuing construction permits for additional reactors in West Germany. In response to this requirement a group of 12 German utilities established the nuclear fuel reprocessing company, Deutsche Geselleschaft fur Wiederaufarbeitung von Kernbrennstoffen mbh (DWK), which was charged with the responsibility for constructing and operating spent fuel storage, fuel recycle and waste treatment facilities.

Although Germany is presently evaluating the direct disposal of spent fuels as an alternative to reprocessing, it has been actively involved with irradiated fuel reprocessing activities which include:

- The interim reprocessing of FRG irradiated fuel at the La Hague plant in France (2700 MTHM).
- The operation of the WAK pilot plant at Karlsruhe. This facility, which has a nameplate reprocessing capacity of 175 Kg/day, was on-line from 1971 to 1980 and processed 115 MTHM of spent fuel (43 MTHM from LWR fuel). From May 1980 to October 1982, the plant was shut down to replace a failed dissolver and to refurbish the head-end hot cells. The plant is now operational and is used to develop reprocessing technology for application in future German reprocessing plants.
- The design of one or two small (350 MTHM/year) commercial reprocessing plants. The first facility, planned for a 1992 startup, will use the basic Purex process and will incorporate a shear-leach head-end. DWK has applied for a construction permit for this plant which is to be located in Schwandorf, Bavaria. The Lower Saxony Government recently chose Dragahn as the most suitable site for plant number 2, which would include an option to double plant capacity if needed.

Belgium (7)

The Eurochemic Fuel Reprocessing Plant, located in Mol, is a pilot-scale facility used to carry out research and industrial activities associated with reprocessing. Its original construction was funded by shareholders representing 13 European nations including Austria, Belgium, Denmark, France, Germany (FRG), Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and Turkey. It was designed to process magnesium and aluminum clad low-enriched uranium fuels at a rate of 0.35 MTHM day; stainless steel or zircaloy clad fuels at 0.02 MTHM/day and high-enriched uranium fuels at 0.01 MTHM/day. It operated from 1966 to 1974 and processed 180 MTHM of low-enriched uranium fuels and 30 MTHM of high-enriched uranium fuels. Upon its shutdown, the company's mission became one of preparing Eurochemic wastes for disposal and phasing out of all operations. The plant has been decontaminated and present plans call for it to be refurbished by a new company jointly owned by the state and the electric utilities for possible use in the reprocessing of non-standard fuels from test reactors. The Belgian Senate recently (March 1983) gave Eurochemic final approval to proceed with the project. It is expected to take about four years to make the modifications necessary to adapt the plant to current needs.

Italy (7)

Italy's strategy for managing irradiated fuel from its present and planned LWR nuclear stations involves interim storage until sufficient fuel has been collected to provide sustained feed for a commercial size domestic reprocessing plant. According to the national energy plan adopted in October 1981, a commercial plant should be required by about 1990 to reprocess the fuel from the 6000 MWe nuclear generating capacity planned for addition during the remainder of this decade.

Italy is presently accumulating reprocessing experience in the small scale Eurex (50-100 kg HM/day) and ITREC (15 kg HM/day) pilot plant facilities.

India (7)

India has three small reprocessing plants as part of its program to close the nuclear fuel cycle. The Trombay Reprocessing plant, which operated from 1965-1974, reprocessed natural uranium metallic fuels. This contact maintenance facility utilized the Purex process and had a capacity of 0.1 to 0.15 MTHM/day. The Tarapur Fuel Reprocessing Plant has the capability for reprocessing natural and low-enriched zircaloy clad UO_2 fuels from the Tarapur reactor at a rate of 0.5 MTHM/day. Construction was completed in 1975 on this contact maintenance plant which employs a chop-leach head end and the basic Purex process. Trial runs were completed in 1981. The Kalpakkan plant, completed in 1981, is capable of reprocessing spent fuel from the Madras Atomic Power Project reactors at Kalpakkan. The plant incorporates a separate line capable of processing fuel from India's 15 MW Fast Breeder Test Reactor.

Japan (7)(8)(9)

Because Japan has very limited domestic energy resources, it has until recently had to rely primarily upon imported oil to meet its energy needs. In order to gain energy independence, Japan launched an aggressive program dedicated to the nuclear option. In order to close the fuel cycle and minimize uranium imports, Japan has assigned the reprocessing of spent fuel a high priority. Its program includes both LWR and fast breeder reactor fuels.

In 1967, a quasi-governmental organization, the Power Reactor and Nuclear Fuel Development Corporation (PNC) was established under Japanese Atomic Energy law to develop Japan's own fast breeder and advanced thermal reactors and to carry out a development program which included all the various steps in the fuel cycle. With French assistance, the PNC constructed the first Japanese reprocessing plant at Tokai Mura from 1971 through 1974. After a series of delays due to political considerations, plant "hot" operations were started in 1977. Between startup and March 1982, this Purex-type plant which has a capacity of 0.7 MTHM/day, processed 140 MTHM and recovered approximately 700 Kg of plutonium. The Tokai plant, together with the supporting reprocessing contracts with COGEMA and BNFL, is expected to fill Japan's reprocessing requirements through this decade.

Although operations have been generally satisfactory, a series of difficulties have been experienced at Tokai. In 1978, the plant was shut down due to a leak in a heat exchanger in the acid recovery evaporator. In 1981 another leak requiring repair developed in a coil in the acid recovery fractionating column. Early in 1982 a small leak was detected in one of the plant's two dissolvers which reduced the plant capacity. On February 18 (4) of this year an additional leak was detected which caused a complete plant shutdown. A replacement dissolver is currently being fabricated and is expected to be operational in the fall of 1984. It will be located in a space designed for a spare dissolver. The experience gained by the Japanese in the operation of Tokai will greatly benefit the design of the commercial plants to follow, and make a major contribution to Japan's ultimate objective of energy independence.

To fill the reprocessing requirements beyond 1990, a new organization, Japanese Nuclear Fuel Service Company (JNFS) was created in 1980. This organization, which is supported by ten Japanese utilities and other private industries will manage the construction and operation of a second LWR reprocessing plant having a 1200 MTHM/year capacity.

STATUS OF REPROCESSING IN THE U.S.

In the 1960's and 1970's there were four major commercial projects launched by the U.S. nuclear industry to reprocess fuel from light water reactors (Table 4).

Table 4

COMPARISON OF SIGNIFICANT CHARACTERISTICS OF U.S. COMMERCIAL REPROCESSING PLANTS

	Plant			
Characteristic	NFS	MFRP	AGNS	EXXON
Capacity (t/day)	1	1	5	8
Process	Purex	"Aqua-fluor"*	Purex	Purex
History	Operated	Built	Built	Designed
Head-End Concept	Chop-Leach	Chop-Leach	Chop-Leach	Chop-Leach
Process Extractors	Pulse Columns	Pulse Columns** IX Volatility	Pulse Columns Centrifugal	Pulse Columns
Maintenance Concept	Remote Contact	Remote	Remote Contact	Remote Concept

*Service mark of General Electric Co.
**First cycle only.

While the U.S. does not currently have a reprocessing plant in operation, reprocessing technology for plant-scale application has been extensively developed by U.S. industry.

The Nuclear Fuel Services plant at West Valley, New York, operated successfully for a period of six years (1966-1972) and reprocessed 641 tons of fuel. In order to remain competitive with large facilities expected to be constructed, the plant was shut down in 1972 to increase capacity from 1 to 3 MTHM/day. As a result of a series of new and retroactive regulations placed on the reprocessing sector by the Atomic Energy Commission, mainly in the seismic design area, the NFS owners concluded that the cost of compliance with these regulations could not be justified and decided not to reopen the plant..

General Electric constructed a 1 MTHM/day reprocessing plant at Morris, Illinois. As a result of a series of operational difficulties experienced during a lengthy "cold" testing period, the company decided not to proceed with hot operation. The difficulties were associated with the operation of a new process which represented a departure from the conventional Purex process.

A third commercial plant, built during the 1971-1975 period and owned by Allied-General Nuclear Services (AGNS), was virtually completed except for high level waste vitrification and plutonium nitrate-to-oxide conversion facilities, but was never granted an operating license. Efforts to license and operate this plant were terminated as the result of a moratorium placed on commercial reprocessing on April 7, 1977 by then President Carter in response to nuclear weapons proliferation concerns.

Exxon Nuclear was designing an eight MTHM/day reprocessing plant to be constructed in Oak Ridge, Tennessee. It was canceled, however, because of the reprocessing moratorium.

Although the four and one-half year moratorium on commercial reprocessing in the United States was lifted by President Reagan in October 1981, the legacy of this former policy continues to plague the U.S. nuclear industry. The specter of future shifts in Government nuclear policy which once again might preclude reprocessing has made launching a private reprocessing venture very difficult.

The near-term justification for reprocessing on a commercial scale is more difficult in the U.S. compared to other nations, since the U.S. has adequate reserves of economically recoverable uranium to meet foreseeable domestic demand through the turn of the century. Thus there is no threat to the security of supply. The economic justification for reprocessing at the currently depressed level of uranium prices and in the absence of a market for recovered plutonium must be evaluated by each utility individually. Utilities facing large capital investments for constructing additions to spent fuel storage capacity, and/or possessing spent fuel with relatively high enrichment levels will likely favor the reprocessing option. Utilities without storage concerns may elect to forego reprocessing until uranium prices rise.

The Nuclear Waste Policy Act of 1982 commits the Government to accept both spent fuel and high-level waste from reprocessing. Whereas the Act specifies a single 1 mill/Kwhr fee for disposal of either spent fuel or high level waste, U.S. utilities are seeking a credit for reprocessing because of the cost savings associated with the reduction in HLW volume. Spent fuel placed in a repository must be retrievable for a specified period of time. Unless a similar requirement is placed on vitrified HLW, the additional cost associated with retrievability of spent fuel will provide an additional incentive for reprocessing.

Despite the current absence of utility orders for new nuclear plants, there is little doubt that uranium and coal will fuel the bulk of the new U.S. electric generating capacity well beyond the end of this century. For nuclear power to fulfill that role at a competitive price, it will ultimately be essential to reprocess spent fuel. Reprocessing of oxide fuel must therefore be demonstrated and fully proven in the near term so that the U.S. is prepared to move forward with several plants when needed.

The only realistic first step to restore commercial reprocessing in the U.S. is to bring the nearly completed Barnwell Nuclear Fuel Plant into service. Unless this is accomplished, it appears highly unlikely that any new reprocessing projects will be initiated. A number of investigations have been performed to examine the technical, economic, and institutional/political feasibility of initiating reprocessing operations at Barnwell. The alternatives identified for preserving the reprocessing option range from temporarily mothballing the facility to moving toward full commercial operation immediately.

One of the difficulties with moving ahead with the Barnwell project is that industry has been reluctant to proceed without a strong indication that the Government can resolve the institutional/political problems, thus reducing the financial risks to an acceptable level. The Government, on the other hand, is reluctant to act prior to receiving a specific industry proposal.

To resolve this dilemma, a group of utilities and industry representatives have developed a proposal in which one scenario calls for the BNFP owners to donate the plant to the Government, which in turn leases the facility to private industry to operate it as a demonstration project. To minimize the amount of plutonium and high-level waste generated, the plant would be operated substantially below its design capacity, probably about 500 tonnes/year, and would reprocess a total of 5000 tonnes of fuel. In this mode of operation the plant would also provide sufficient Pu to meet the needs of the fast breeder program. If a satisfactory market for plutonium develops by the end of the demonstration period, plant throughput might then be increased to its full capacity of 1200-1500 MTHM/year.

Whether a sufficient number of utilities will be willing to contract for reprocessing services under this scenario is not known at this time. Similarly, whether the Government will accept ownership of the plant along with the attendant responsibilities of ownership remains an unanswered question. If the outcome is affirmative, other commercial reprocessing ventures can be expected to be launched in the early 1990's. If a Government/utility consensus cannot be reached, the U.S. is unlikely to supply commercial reprocessing services for the remainder of this century. It is expected, however, that the U.S. will continue to improve its reprocessing technology through its research and develop programs on both thermal and fast reactor fuels.

References

(1) Introductory Remarks, Brian Farrow, AIF Conference on the Nuclear Cycle, Kansas City,

此为试读,需要完整PDF请访问: www.ertongbook.com