TC-1385
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ALTERNATIVE FUEL CYCLE EVALUATION PROGRAM

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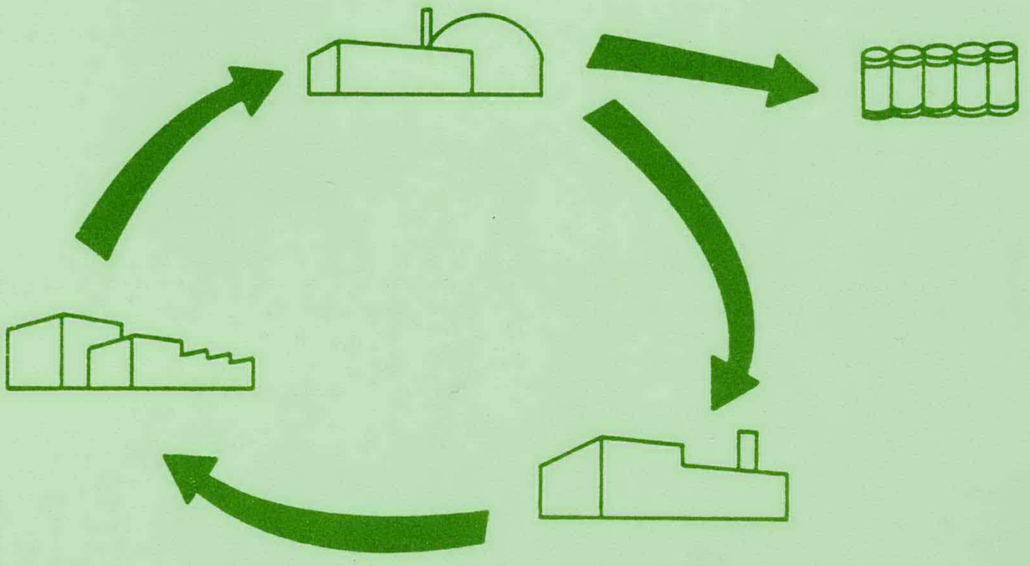
INTERNATIONAL FUEL SERVICE CENTER EVALUATION



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PREPARED FOR

THE NUCLEAR FUEL CYCLE PROGRAMS BRANCH
DIVISION OF NUCLEAR POWER DEVELOPMENT, U.S. DEPARTMENT OF ENERGY

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November 1979

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ALTERNATIVE FUEL CYCLE EVALUATION PROGRAM

INTERNATIONAL FUEL SERVICE CENTER EVALUATION

ABSTRACT

This Alternative Fuel Cycle Evaluation Program (AFCEP) study presents the technical, economic and social aspects of the International Fuel Service Center (IFSC) as an institutional approach to nuclear fuel cycle development and is provided in support of the Nonproliferation Alternative Systems Assessment Program (NASAP). Four types of IFSCs are described and evaluated in terms of three different twenty-year nuclear growth scenarios. Capital costs for each IFSC and comparable dispersed facility costs are discussed. Finally, the possible impact of each scenario and IFSC on the environmental and socio-economic structure is examined.

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INTERNATIONAL FUEL SERVICE CENTER EVALUATION

1.0 INTRODUCTION

One scenario for deployment of a nuclear fuel cycle under consideration assumes the application of the International Fuel Service Center (IFSC) concept. This concept considers grouping fuel cycle facilities such as those for storage and/or controlled utilization of recycle spent fuel (i.e., reprocessing, refabrication, and/or reactors) into a common, heavily safeguarded site.

Establishment of a safeguarded and secure International Fuel Service Center (IFSC) that would include facilities for storage and controlled utilization of recycle spent fuel would allow all necessary operations to be performed within the confines of the IFSC area. Availability of fissile material (^{233}U, ^{235}U, or Pu) outside the IFSC would be limited, since the dispersed reactors would be based on low enriched uranium, denatured uranium/thorium or spiked uranium/plutonium fuel cycles.

The collocation of related nuclear facilities has been addressed in both national and international studies of large regional energy centers or nuclear parks; and, most recently, the IFSC concept has been examined as a possible institutional deterrent to nuclear proliferation. These studies have included: NRC, Nuclear Energy Center Site Study, (NUREG-001), 1975; International Atomic Energy Agency, Regional Nuclear Energy Centers, 1977; Rockefeller Foundation, International Cooperation on Breeder Reactors, May 1978; DOE-NASAP, Preliminary Safety and Environmental Information Document, (PSEID), January 1979; American Nuclear Society, Executive Conference on Energy Parks, April 1977; Battelle Northwest Laboratories, The Hanford Nuclear Energy Center - An Interim Conceptual Study, (BNWL-1925), June 1975; Hanford Engineering Development Laboratory, Alternative Fuel Cycle Evaluation Program (AFCEP) Final Report, Volume II, Fuel Cycle Characterization Study, (TC-1550), November 1979; (TC-1222-2); Exxon Nuclear Company, Report for Evaluations of Reprocessing Configuration for a Nuclear Energy Center, October 1978; and, Burns and Roe Industrial Services Corporation, International Fuel Service Center Study, May 1979. Detailed discussions on the philosophy and concepts of International Fuel Service Centers are to be found in the above reports and in additional material cited in the Bibliography.

This AFCEP study presents the technical, economic, safeguards, environmental and social aspects of four types of IFSCs:

Type A - Long-term spent fuel storage only (30-year storage).

Type B - Spent fuel storage, reprocessing, and fabrication.

Type C - Spent fuel storage, reprocessing, fabrication, and onsite plutonium burner reactors.

Type D - Spent fuel storage, reprocessing, fabrication and onsite plutonium breeder reactors.

Reference Case - Dispersed facilities

Three growth scenarios were considered for each IFSC type. The growth scenarios were not intended to represent an exact description of the electrical growth patterns that may be experienced by a particular country or region of the world. Rather, they were selected as being growth scenarios that may span the electrical energy growth pattern of that country or region. Each scenario begins in the year 1980 and continues to the year 2000. Identifications used are low growth, increasing growth and uniform growth. All reactors constructed to satisfy power needs are assumed to have a production capability of 1000 MWe.

Capital costs for fuel fabrication plants, spent fuel reprocessing plants, away-from-reactor storage facilities, onsite reactors and site common facilities were discussed. When multiple facilities of like type were required, cost savings were allowed for sharing of equipment and some components. Capital costs were not tabulated for offsite facilities.

Environmental considerations were analyzed for the IFSC concept relative to dispersed facilities. Three areas of potential interest evaluated for IFSCs included hydrological considerations, meteorological effects, and potential radiological consequences to the public.

Social issues pertaining to the four types of IFSCs were analyzed. The relationship of the issues (as determined by public opinion polling and by prediction of socioeconomic impacts at surrogate sites) to public acceptance of each IFSC type was explored.

This study was a cooperative effort by personnel from Argonne National Laboratory (ANL), Battelle Human Affairs Research Center (Battelle-HARC), and Hanford Engineering Development Laboratory (HEDL) for the Alternative Fuel Cycle Evaluation Program (AFCEP) and the Nonproliferation Alternative Systems Assessment Program (NASAP).

2.0 SUMMARY

IFSCs were examined as an institutional factor which might provide greater proliferation resistance than dispersed deployment for nuclear fuel cycles, including those involving recycle, by limiting access to fissile material. The major findings of this study are summarized below.

- The capital costs associated with constructing IFSCs for the scenarios considered range from $0.17 to $49.2 billion 1979 dollars. Annual operating costs range from $12 million to $1.9 billion 1979 dollars.

- When compared to separate facilities at dispersed sites, an IFSC may realize cost savings through use of common facilities. Discounted cash flow analysis of the IFSC concept compared to identical dispersed facilities for the uniform-growth scenario indicate potential IFSC cost savings of between 190 and 880 million dollars (Type-A and Type-D, respectively).

- The self-contained IFSC concept minimizes the opportunity for nuclear material diversion by minimizing transportation and reducing the offsite availability of fissile materials.

- Health, safety and pollution concerns will probably have more impact on public acceptance of an IFSC than the perceived benefits of nonproliferation.

- A properly planned and located IFSC could result in a lower integrated population radiological dose for a given energy-production level than multiple dispersed sites.

- For a fixed investment, concentration of nuclear facilities at an IFSC would permit improved physical security compared to individual dispersed sites.

3.0 FACILITY DESCRIPTIONS

Implementation of the IFSC concept by a country or group of countries could be accomplished with many combinations of the various fuel cycle facilities. Descriptions of the four unique combinations are presented in Section 3.2 of this report and may be considered to be reasonably typical of possible combinations.

The fuel cycle facilities contained within an IFSC are found in Section 3.3 of this report and include description and costs for fuel fabrication, fuel storage, and fuel reprocessing facilities.

The current deployment pattern that has evolved for the siting of nuclear facilities within the United States and in other countries provides the basis for describing a reference dispersed facility case. That description provides a reference for comparison with the development of the International Fuel Service Center concepts.

3.1 DISPERSED FACILITIES

The reference case reflects principally the siting of facilities as currently practiced in the United States and most other countries. Light water reactors operating with either low enriched uranium (LWR-LEU) or uranium-plutonium mixed oxide (LWR-MOX) fuels are dispersed widely according to siting requirements of individual power generation entities and as approved by appropriate regulatory authorities. Individual sites may contain from one to four reactors.

For reference, it is assumed that each reactor has a power generation capability of 1000 MWe. Fresh fuel is shipped to the reactor site from a fabrication plant that is located independently from other fuel cycle facilities needed to close the cycle. Annual refueling is assumed.

For purposes of this study, spent fuel is stored onsite under water for six to twelve months. Sufficient capacity is provided for at least one and one-third cores. The fuel in heavily shielded casks is then shipped by rail or truck to a reprocessing plant or storage facility that is sited independently from the reactor and the fabrication plant.

The reprocessing plant receives the spent fuel shipments and stores the fuel in water-filled pools. The capacity of the plant is a typical 5 MT/day, and the fuel storage pool has a capacity of six months' worth of throughput. Processing is performed by solvent extraction yielding separated and decontaminated uranium and plutonium nitrates, as well as waste streams containing fission products at several radiation levels (high, intermediate, and low).

Facilities are provided for converting the uranium nitrate to uranium hexafluoride, and the plutonium nitrate to plutonium oxide. Storage facilities for these products are also provided. The uranium hexafluoride is shipped to an independently located enrichment plant; the plutonium oxide is shipped to a fabrication plant dedicated to the production of plutonium-uranium fuels.

Liquid waste streams are treated for recovery and recycle of nitric acid and water. Concentrated fission-product-containing liquids are then converted to solid, with possible incorporation into glass for final disposal.

3.2 TYPES OF INTERNATIONAL FUEL SERVICE CENTERS (IFSC)

3.2.1 Type-A IFSC

The Type-A IFSC has as its primary purpose the long-term storage of spent fuel. For the purpose of this study, long-term storage is defined as a 30-year time period, equivalent in duration to the plant life for the fuel reprocessing plant. This time period is considered to be sufficiently long for a decision to be reached as to eventual disposition of the fuel after that time period has passed.

The use of this type of fuel service center assumes that LWRs are sited in a dispersed manner and that discharged fuel is not reprocessed. Hence, no recycling of plutonium occurs. Facilities for fabricating low enriched uranium fuel for the LWRs are also dispersed. The focus for this case is the storage of spent fuel at the Type-A Fuel Service Center, and not the dispersed facilities.

Spent fuel is shipped to the facility where it is packaged appropriately, if required, and stored. This IFSC consists of modular facilities (see Figure 1). Each module has a storage capacity of 5000 MT of spent fuel and is able to accomodate shipments at a rate of 1500 MT/year. All modules would be located within the same secure area.

Operation of the IFSC may create liquid and solid wastes that contain low levels of radioactivity. The liquid wastes will be either concentrated and incorporated into solids, or passed through ion-exchange resins to concentrate the activity in the resin. Resulting solids are combined with other solid wastes, compacted as necessary, and transported to a burial site for low-level wastes. Airborne materials are treated for removal of particulates by passage through HEPA filters.

Because the spent fuel contains plutonium, the physical security measures for the service center are equivalent to those required by the Nuclear Regulatory Commission for reprocessing and plutonium fabrication plants. Such measures include provision for security zones formed by the erection of double barriers, the establishment of material access and vital areas, and controls over personnel and vehicle access. A material control system monitors the quantity and locations of all spent fuel in the center.

3.2.2 Type-B IFSC

A Type-B IFSC includes spent fuel reprocessing and recycle fuel refabrication facilities to supply offsite, dispersed LWRs. The LWRs may operate either with virgin low enriched uranium fuel (LWR-LEU), or with spiked

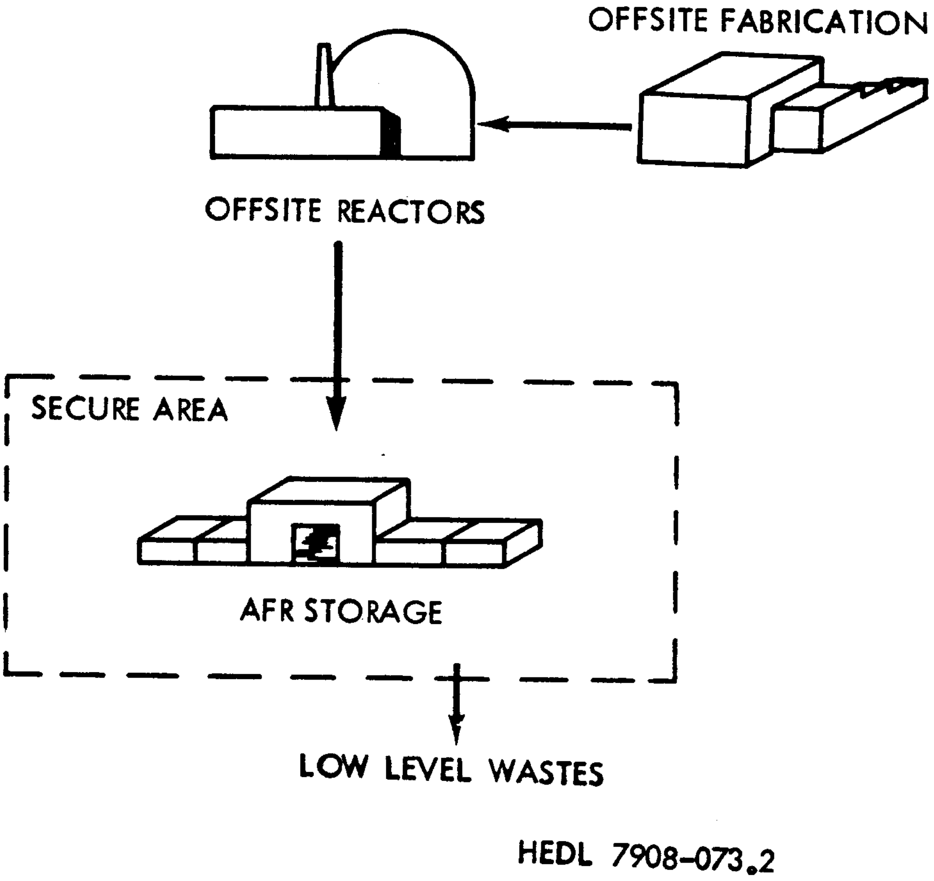

FIGURE 1. Major Facilities Within a Type-A IFSC Module.

recycle uranium-plutonium fuel (LWR-MOX). The former is fabricated offsite at a dispersed facility. Only recycle fuel is fabricated within the fuel service center. This type of IFSC provides in the fuel service module the capability to store spent fuel from all reactors which it services, six months after the fuel has been removed from the reactor. In addition, it provides the capability to reprocess and to refabricate the fissionable fuel recovered during reprocessing into fuel for use in offsite power reactors. Figure 2 graphically displays the major facilities within the Type-B IFSC.

This IFSC provides a waste processing facility that handles the waste generated in both the fuel reprocessing and fuel fabrication areas. The waste is converted into a form which is stored onsite for 5 years or less and is shipped to offsite permanent and ultimate disposal.

The handling of offgases and liquid and solid wastes is similar to that described for the dispersed facility.

Shipments to and from the Type-B IFSC consist of the following: spent fuel from the offsite reactors to the facility; shipments from the facility include recycle MOX fuel and fresh denatured fuel to the reactors; high-level waste, in the form of solid glass monoliths, to geologic disposal; and low-level solid wastes to a low-level waste burial facility.

Physical security measures are applied to the fuel service center as a whole, as well as to the individual facilities within the center. These measures are equivalent to those required by the Nuclear Regulatory Commission (NRC). The entire center is protected by double barriers that create an isolation zone that is instrumented and monitored for suspicious movements. In addition, barriers are installed around each facility. Material-access and vital areas are established as part of the security system; also established is an access-control system for personnel and vehicles. Material-control systems similar to those described for the dispersed sites are operative within each facility.

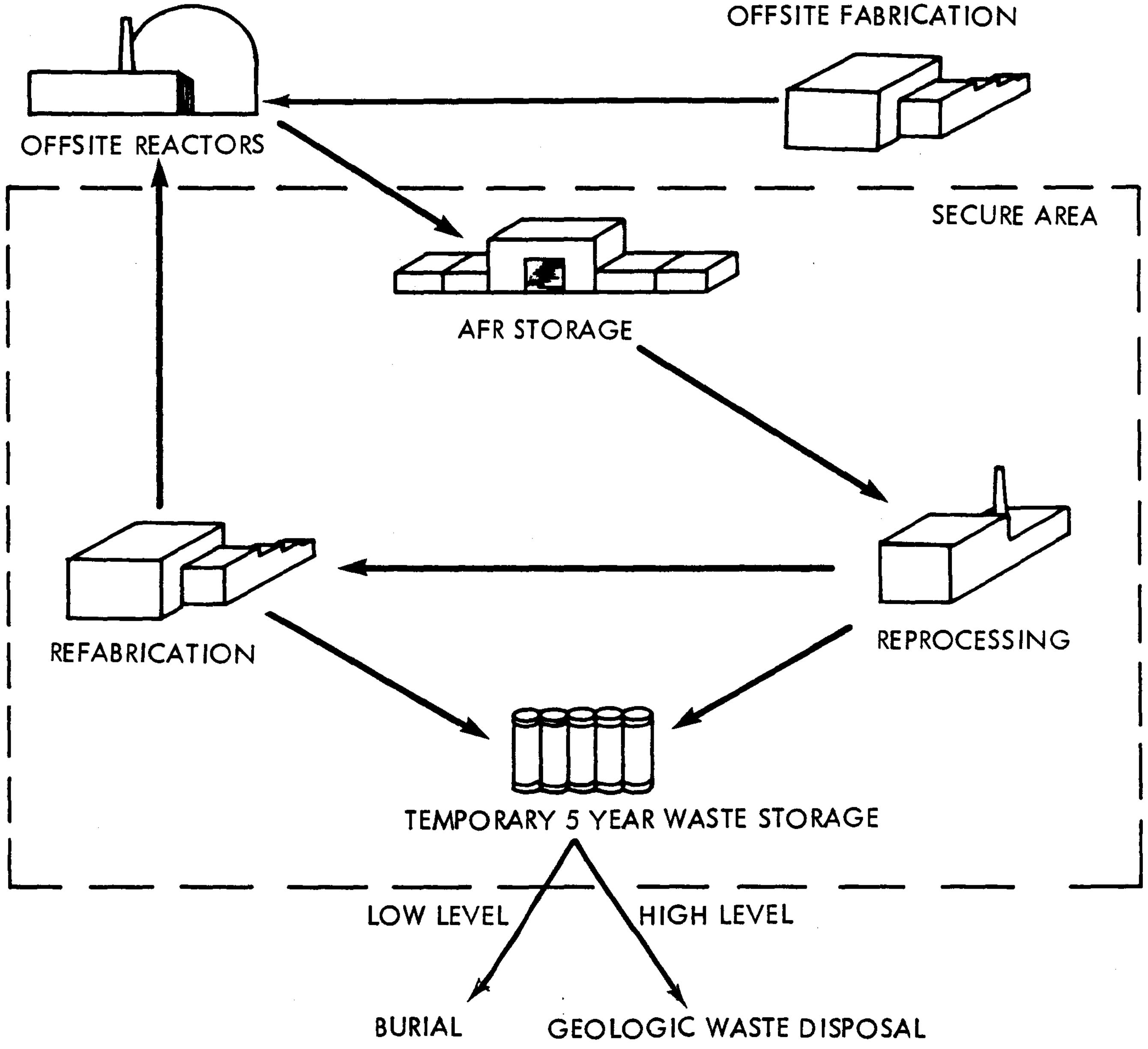

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FIGURE 2. Major Facilities Within a Type-B IFSC Module.

3.2.3 Type-C IFSC

The Type-C fuel service center contains reprocessing and refabrication facilities plus power reactors fueled with plutonium-thorium fuel. The onsite reactors (LWR-Pu/Th) burn plutonium and produce ^{233}U. Dispersed offsite reactors are fueled with low enriched uranium (LWR-LEU) or denatured uranium and thorium (LWR-DU/Th). The offsite reactors burn ^{233}U or ^{235}U and produce plutonium. Figure 3 graphically displays the major facilities for a Type-C IFSC.

The processing facilities are equipped to accommodate fuels from both onsite and offsite reactors. The fissile products from reprocessing are ^{233}U, ^{235}U, and Pu. ^{233}U and ^{235}U, diluted with appropriate amounts of ^{238}U, are shipped to offsite fabrication facilities that service the offsite reactors. The onsite fabrication facility produces plutonium-thorium fuel for the onsite reactors. Thus, no fresh fuel containing plutonium leaves the fuel service center. However, plutonium is present outside the center in the form of spent fuel from the offsite reactors.

A waste processing facility similar to that described for the Type-B center is also provided for the Type-C center. Physical security measures are similar to those described for the Type-B fuel service center.

The material-control system and the handling of offgases and liquid and solid wastes are similar to that described for the dispersed facility.

Shipments to and from the Type-C IFSC consist of the following: spent fuel from the offsite reactors to the facility; shipments from the facility include fissile uranium (^{233}U and ^{235}U) diluted with ^{238}U, in the form of oxides, to dispersed offsite fabrication facilities; high-level waste, in the form of solid glass monoliths, to geologic disposal; and low-level solid wastes to a low-level waste burial facility.

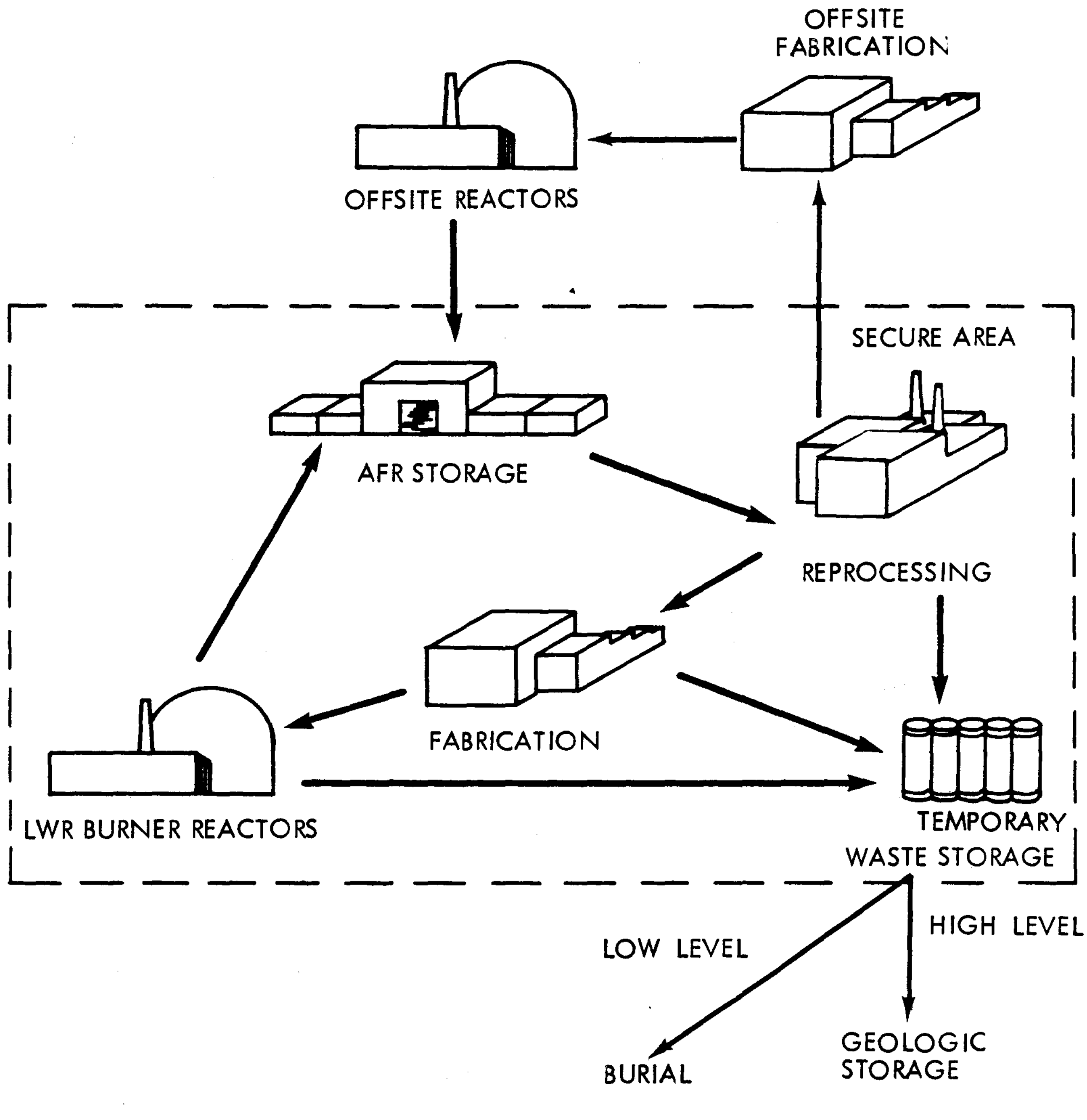

FIGURE 3. Major Facilities Within a Type-C IFSC Module.

3.2.4 Type-D IFSC

The Type-D fuel service center, as shown in Figure 4, contains reprocessing and fabrication facilities plus breeder reactors fueled with plutonium and thorium (LMFBR-Pu/Th). The onsite breeder reactors burn plutonium and produce ^{233}U. Dispersed offsite reactors are fueled with low enriched uranium (LWR-LEU) or denatured uranium and thorium (LWR-DU/Th). The offsite reactors burn ^{233}U or ^{235}U and produce plutonium.

The processing facilities are equipped to accommodate fuels from both onsite and offsite reactors. The fissile products are ^{233}U, ^{235}U, and Pu. ^{233}U and ^{235}U, diluted with appropriate amounts of ^{238}U, are shipped to offsite fabrication facilities that service the offsite reactors. The onsite fabrication facility produces only plutonium-thorium fuel for the onsite reactors. Thus, no fresh fuel containing plutonium leaves the fuel service center. However, plutonium is present outside the center in the form of spent fuel from the offsite reactor. A waste processing facility, similar to that described for the Type-B center, is also provided for the Type-D center. Shipments, physical security measures, and material-control systems are the same as for the Type-B Center.

The handling of offgases and liquid and solid wastes is similar to that described for the dispersed facilities.

3.3 FACILITY DESCRIPTION AND COSTS

Generalized descriptions for each of the major facilities that may be located within the IFSC are contained in this section. The base capital and operating costs for fuel fabrication and reprocessing facilities are based on the costs estimated by the AFCEP Fuel Cycle Characterization Study. The costs used were those available June 1979 and were based on NASAP core designs, with review by DOE. Cost data for the nominal 1500 MT/yr reprocessing and 500 MT/yr fabrication plants used in the AFCEP study were scaled to reflect costs for the plant sizes considered appropriate for each IFSC and growth

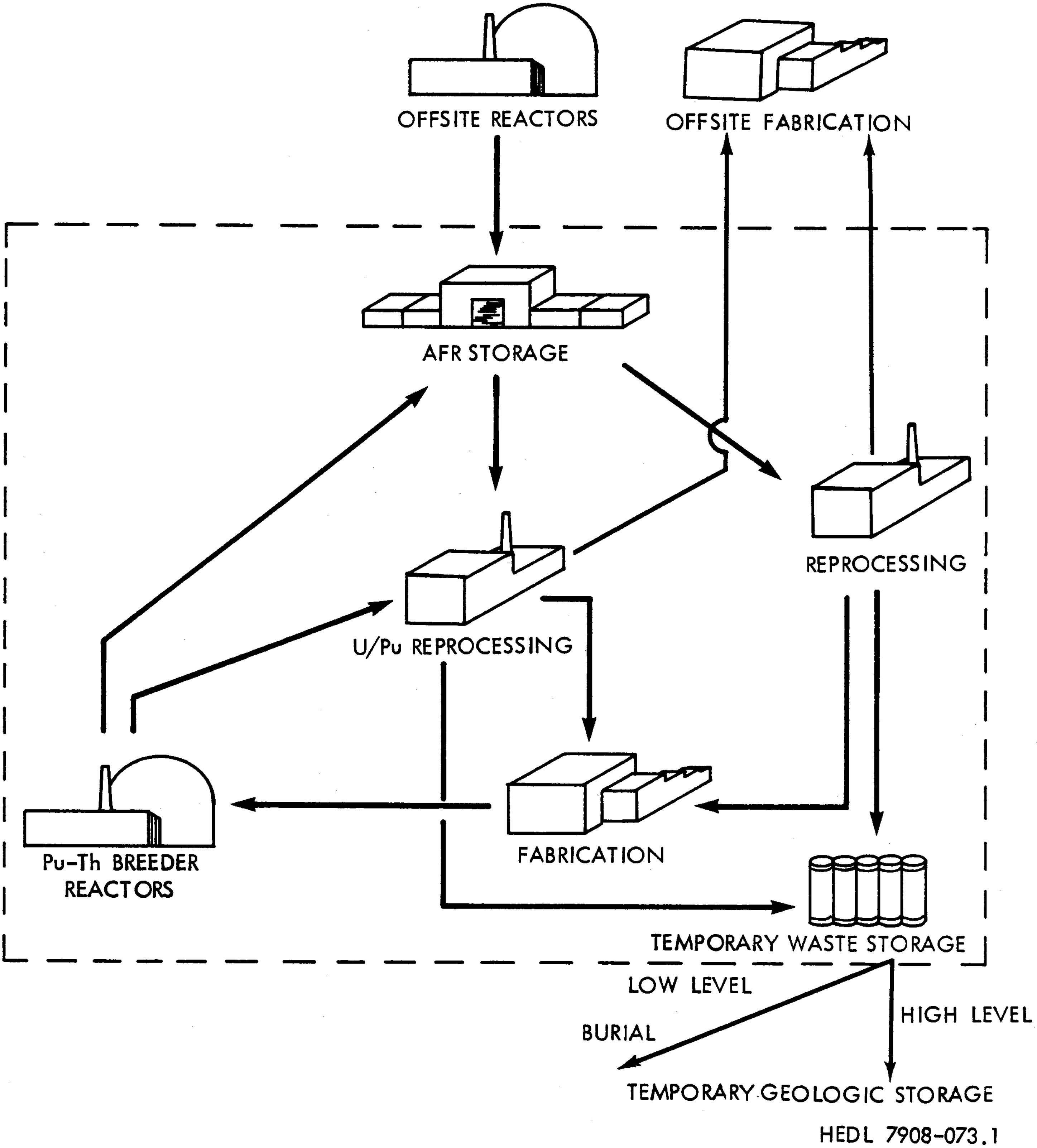

FIGURE 4. Major Facilities Within a Type-D IFSC Module.

scenario. The scaling factor formula from the ORNL TM-6522(13) document was used, as recommended, to scale from the base NASAP cost data to the appropriate size required for this report. Also as recommended in ORNL TM-6522, scaling factors of 0.35 were used for capital and operating costs of reprocessing plants, 0.75 for Type-B IFSC fabrication, 0.8 for Type-C and -D IFSC fabrication, and 0.8 for fabrication plant operating costs. The capital costs for all types of facilities include interest during construction (IDC), but do not include any other indirect or financing costs.

3.3.1 Reprocessing Plants

Two types of reprocessing plants were analyzed. The first type uses the conventional PUREX process to reprocess spent fuel from LWR-LEU type reactors and LWR-MOX reactors. The second type uses the THOREX process to reprocess spent fuel from the LWR-Pu/Th type reactors, the LWR-DU/Th type reactors, and the blanket and core assemblies from the LMFBR Pu/Th/Th/Th reactor.

3.3.1.1 PUREX-Type Plant

The spent fuel reprocessing plant includes facilities for handling spent fuel on an interim basis, for reprocessing, for conversion of uranium to UF_6, and for conversion of plutonium to an oxide. Included are facilities for the following: treatment of gaseous, liquid and solid wastes; their incorporation into glass or cement; and interim storage of solidified wastes prior to their transfer to a Federal repository for long-term storage.

The limit on ^{235}U concentration in spent fuel is imposed by the uranium conversion facility design. Plutonium conversion capacity is scaled on the assumption that 20% of the spent fuel received is recycled MOX fuel that is blended with uranium from spent fuel to obtain an average plutonium concentration of about 3 percent. A higher concentration would require a reduced throughput.

For a 1500 MT/year plant, the capital cost for the lead plant was assumed by AFCEP to range between $900-1600 million, and between $800-1400 million for the mature plant. For analysis of Types B & C IFSCs, mean values of $1250 and $1100 million for the lead and mature plants, respectively, were used for computational purposes. Capital costs were scaled to represent the appropriate size of plant.

Operating costs for lead plants were assumed to be approximately 20% higher than for mature plants. AFCEP studies indicated a range of $40-60 million per year; the mean value of $50 million per year was assumed as a base operating cost.

A total elapsed time of 12 years was assumed for the licensing, design and construction of LWR reprocessing plants. The total capital cost was distributed over the 12-year period using a typical S curve. The capital cost expenditure over the 12-year period was assigned the distribution shown in Table 1. Similarly, for the reference reprocessing plant, the labor force shown in Table 2 was assigned over the 6-year period of actual construction.

To determine the labor force requirements associated with constructing LWR reprocessing plants with capacities other than the 1500 MT/yr reference plant, a scaling proportionality was assumed:

$$\text{Labor Force }(x) = \text{Labor Force }(y) \times \frac{\text{cost }(x)}{\text{cost }(y)} .$$

The LWR reprocessing plant was assumed to operate at an average plant capacity factor of 33 percent for the first year of operation. During the second year of operation, a plant capacity factor of 67 percent was assumed; and, during subsequent years, a 100-percent capacity factor was assigned for the 300 days of normal operation. A work force of 1750 was assigned for operating the reference LWR reprocessing plant.

TABLE 1

REFERENCE REPROCESSING PLANT
CAPITAL COST EXPENDITURE FACTORS

Construction* Year	Factor
1	.05
2	.07
3	.05
4	.04
5	.02
6	.02
7	.03
8	.14
9	.23
10	.17
11	.13
12	.05

*Includes time for licensing, design and construction

TABLE 2

REFERENCE REPROCESSING PLANT
LABOR FORCE REQUIREMENTS

Construction Year	Construction Labor Force
7	90
8	1621
9	2650
10	1904
11	377
12	150

3.3.1.2 Thorex-Type Plant

DU/Th LWRs and thorium-blanketed breeder reactors are used in the cases considered herein. Spent fuel is reprocessed using the Thorex process in a plant that includes facilities for handling spent fuel on an interim basis, for separating the ^{233}U, thorium, and plutonium, and for converting the thorium and uranium nitrate into an oxide powder for storage. The reprocessing plant also contains facilities to handle the gaseous, liquid and solid wastes, to incorporate them into glass or cement, and to store the solidified wastes on an interim basis prior to their transfer to a Federal repository.

The nominal size of Pu/Th reprocessing plant was assumed to be 1500 MT/yr. A lead plant capital cost of 4.0 billion dollars was assigned to the construction of the facility. Capital costs were estimated by AFCEP to range from 2900 to 4000 million dollars. Since this is a combination of two plants (Pu/Th and DU/Th LWRs), the high end of the range was used. A 12-year design, licensing and construction period was assigned for building the facility. A scaling factor of .35 was used to scale the reference 1500 MT/yr reprocessing plant to the required plant size.

The total capital cost was distributed over the 12-year period using the cost expenditure factors shown in Table 1. Labor force requirements were scaled using the base data shown in Table 2, weighted with respect to an appropriate ratio of capital cost. That is,

$$\text{Labor Force } (x) = \text{Labor Force } (y) \times \frac{\text{cost } (x)}{\text{cost } (y)} \ .$$

The ground rules and costs associated with operating the Pu/Th reprocessing plant were assumed to be the same as were specified for the Pu/U reprocessing plant. Operation of the reprocessing plant was assumed to occur the year following the completion of construction. The first year's operation was limited to an average plant capacity factor of 33 percent. The second year's operation was limited to an average plant capacity factor of 67 percent.

During the third year, design capacity was achieved. An annual operating cost of 100 million dollars and a maximum work force of 2600 was assigned during the period in which the 1500 MT/year reprocessing plant was operating at full capacity.

3.3.2 Fuel Fabrication Plants

Two types of fuel fabrication plants were analyzed. A fabrication plant was designed to fabricate either LWR mixed uranium-plutonium oxide (MOX) fuel using coprocessed feed spiked with a high-gamma emitter or the Pu/Th-type LWR fuel. A second type of fabrication plant was designed to fabricate LMFBR-type fuel. The LMFBR considered in this study used a Pu/Th core with thorium radial and axial blankets.

3.3.2.1 LWR Fuel Fabrication Plant

A fabrication module size of 200 MT/yr was selected for the fabrication of LWR-type fuel. The denatured fuels are manufactured in a totally remote type facility. The LWR fuel fabrication facility was considered a "stand-alone" plant in which feed materials are received from the reprocessing plant. Fabrication of the fuel in such a facility is accomplished using the conventional dry press sinter process, with the feed adjusted to produce either a MOX "spiked" fuel or a "denatured" ^{233}U/Th fuel. Contaminated scrap material is processed internally, and wastes are concentrated and packed for disposal.

For Type-B and Type-C IFSCs, capital costs for fuel fabrication plants ranged from 447 to 372 million dollars for lead and mature facilities, respectively. The costs were assumed to be the same for Type-B and -C IFSCs due to the similarity in fabrication requirements for U/Pu spiked fuel and Pu/Th fuel.

The fabrication facility was assumed to begin operation the year following the completion of construction. Schedules and time tables (timing of facility) were adjusted to allow for this condition. Production at full capacity was considered feasible during the first year of operation, although in none of the cases was this required. To operate the fabrication plant a labor force of 150 was assigned. The annual operating expenses ranged from 26 million for a mature plant to 31 million dollars for a lead plant.

3.3.2.2 LMFBR Fuel Fabrication Plant

The process required to fabricate LMFBR fuel is similar to that required for LWR Pu/Th-type fuel. The facilities are designed to allow for the radiotoxicity of the materials used in fabrication. The fabrication facility is designed to fabricate the fuel core as well as both radial and axial blanket assemblies.

A fabrication module size of 200 MT/yr was selected for the fabrication of LMFBR fuels. A capital cost of 696 million dollars was assigned to the construction of the LMFBR fuel fabrication facility. A construction period of 6 years was assumed. The total capital cost was distributed over the period of construction using a typical S curve and the factors provided in Table 3. The construction labor force requirements were assumed to be the same for the construction of both the LMFBR and the LWR fabrication facilities (Table 4).

The fabrication facility was assumed to begin operation the year following the completion of construction. Similar to the LWR fabrication facility, full capacity was allowed, but never required, during the first year of operation. To operate the LMFBR fabrication facility, a labor force of 150 and a constant operating cost of 67 million dollars per year were assumed.

TABLE 3

REFERENCE FABRICATION PLANT CAPITAL COST EXPENDITURE FACTORS

Construction Year	Factor
1	.02
2	.24
3	.38
4	.28
5	.06
6	.02

TABLE 4

REFERENCE 200 MT/Yr LWR FABRICATION PLANT LABOR FORCE REQUIREMENTS

Year	Construction Labor Force
1	17
2	306
3	500
4	206
5	71
6	28

3.3.3 Reactor Types

Although the various scenarios considered in this study involve the use of several different types of reactors, only two types of reactors are located within the IFSC. For the Type-C fuel service center, a plutonium-burning LWR is located within the center; and, for the Type-D fuel service center, an LMFBR is located onsite.

The total capital cost associated with constructing a plutonium-burning LWR was set at to 755 million dollars. This cost was distributed over a 9-year period of construction using the factors provided in Table 5. The associated construction-force requirements are tabulated in Table 6.

The total capital cost assigned to constructing the LMFBR used in the Type-D fuel service center was set at 1.05 billion dollars. The cost was distributed over the 9-year construction period using the data provided in Table 5. The construction force required to construct an LMFBR is shown in Table 6.

The above costs were used for the first (lead) LWR and LMFBR within the fuel service center. Cost savings of approximately 20% were applied to the

TABLE 5

CAPITAL COST EXPENDITURE FACTORS
1000 MWe PU BURNING LWR OR LMFBR

Construction Year	Factor
1	.01
2	.03
3	.06
4	.11
5	.19
6	.25
7	.20
8	.10
9	.05

TABLE 6

LABOR REQUIREMENTS
1000 MWe PU BURNING LWR OR LMFBR

Construction Year	Construction Labor
1	296
2	533
3	1185
4	1422
5	1108
6	758
7	367
8	172
9	83

second and subsequent reactors within the IFSC, resulting from continuity of construction, standardization, modularization, and shared fuel facilities.

3.3.4 Away-from-Reactor (AFR) Storage Basin

The away-from-reactor spent fuel storage basin was designed to store spent fuel in a water-filled, stainless-steel-lined concrete basin. The facility would have an initial storage capacity of 5000 metric tons of spent fuel and would be capable of receiving 1500 metric tons of spent fuel per year.

The facility would be designed to receive, handle, decontaminate and reship spent fuel casks; to remove irradiated fuel from casks; to place the fuel in a storage basin; and to control the quality of the water.

The total capital cost of the facility is estimated at 270 million dollars. A 5-year period of construction is assumed. The estimated labor force required during the construction period is provided in Table 7.

TABLE 7

REFERENCE 5000 MT AFR STORAGE FACILITY
LABOR FORCE REQUIREMENTS

Year	Construction Labor
1	51
2	130
3	1100
4	810
5	530

Operation of the facility is assumed to begin the year following completion of construction. It is estimated that a work force of 215 would be required to operate the facility. An annual operating cost of 16-20 million dollars was assigned for the operation of the plant.

3.3.5 Site Common Facilities

The development of an IFSC provides an opportunity for combining certain facilities required for each component of the IFSC. Such shared facilities, referred to as site common facilities, include, but are not limited to the following: security, radioactive waste treatment, communications, utility services, cafeterias, dispensaries, and service buildings.

When compared to separate facilities at dispersed sites, common facilities would probably produce cost savings attributable to shortening of plant construction times, economies of scale and elimination of duplicate facilities. Savings would also result from sharing administration and service buildings, electric plant equipment, certain site and yardwork items, site development work, and licensing (PSAR, FSAR) efforts.

Several studies show that capital cost savings may result when nuclear facilities are concentrated at a common site. Possible savings in capital cost for a fuel cycle facility center, as opposed to dispersed siting, range from 2 to 8%, as reported in NUREG-0001, <u>Nuclear Energy Center Site Survey</u>. WASH 1288, <u>Evaluation of Nuclear Energy Centers</u>, reports estimated cost savings of 5 to 10% of capital-cost of reactor plants due to continuity of construction and modularization. The NASAP(4) study on fuel cycle facilities reports that substantial capital-cost benefits can be realized with large power IFSCs. The IAEA Study Project Report on Regional Nuclear Fuel Cycle Centers(2) mentions that significant economic savings can be obtained in the capital-cost component of an international fuel service center when compared to the alternatives of smaller national facilities.

For this study, a savings in capital cost was assumed to be 8%. However, the extent of any savings is subject to the uncertainty of possible future changes in technology, government policy, and power demand. Due to uncertainty in labor force requirements for a large facility complex, no credit was taken for potential operating cost savings.

4.0 GROWTH SCENARIOS

Three nuclear power growth scenarios were analyzed for comparative purposes: low growth, increasing growth and uniform growth. The scenarios span developmental patterns that may be experienced in various regions of the world over a 20-year period beginning with the year 1980. (A region could be an entire country, a portion of a country, or a combination thereof.) For purposes of this study, all reactors constructed to satisfy power needs were assumed to have a production capability of 1000 MWe.

4.1 LOW-GROWTH SCENARIO

In this scenario, a total of 10 reactors is placed in operation over the 20-year period. It is assumed that no reactors exist at the start of the period, that the first reactor will be placed in operation at the beginning of the first year (1980), and that an additional reactor will be placed in operation every two years thereafter. The sequence is shown in Table 8.

4.2 INCREASING-GROWTH SCENARIO

This scenario assumes a total of 120 reactors will be in operation at the end of the 20th year (1999). It is further assumed that four reactors are already in operation at the beginning of the first year. Two reactors are added each year, beginning with the first, for seven years; four reactors are added in each of the following three years; six are added in each of the next five years; and, finally, twelve are added each year for the balance of the period. To determine the total of stored fuel (needed for making a judgment as to when and how large a fuel reprocessing plant should be introduced into the system), the four reactors operating in the first year (1980) were assumed to have been introduced in increments of two each year; i.e., no reactors were operating in 1977, two in 1978, and four in 1979. The sequence is shown in Table 8.

TABLE 8

REACTOR INTRODUCTION RATE

		LOW GROWTH		INCREASING GROWTH		UNIFORM GROWTH	
No.	Year Calendar	Reactors Started*	Total Reactors Operating	Reactors Started*	Total Reactors Operating	Reactors Started*	Total Reactors Operating
-2	1977				0	1	1
-1	1978			2	2	7	8
0	1979			2	4	7	15
1	1980	1	1	2	6	7	22
2	1981		1	2	8	7	29
3	1982	1	2	2	10	7	36
4	1983		2	2	12	7	43
5	1984	1	3	2	14	7	50
6	1985		3	2	16	7	57
7	1986	1	4	2	18	7	64
8	1987		4	4	22	7	71
9	1988	1	6	4	26	7	78
10	1989		5	4	30	7	85
11	1990	1	6	6	36	7	92
12	1991		6	6	42	7	99
13	1992	1	7	6	48	7	106
14	1993		7	6	54	7	113
15	1994	1	8	6	60	7	120
16	1995		8	12	72	7	127
17	1996	1	9	12	84	7	134
18	1997		9	12	96	7	141
19	1998	1	10	12	108	7	148
20	1999		10	12	120	7	155

---

*At beginning of year shown

4.3 UNIFORM-GROWTH SCENARIO

In this scenario, a total of 155 reactors is assumed to be in operation at the end of the 20th year (1999). It is further assumed that 15 reactors are already in operation at the beginning of the first year. Seven reactors are added to the system each year for the entire period. For estimating total fuel in storage, it was assumed that no reactors were operating in the year 1976, one in 1977, eight in 1978, and fifteen in 1979. The sequence is shown in Table 8.

5.0 IFSC DEVELOPMENT AND COSTS

5.1 GROWTH PATTERNS AND IMPLICATIONS

Previous chapters have described the four variations of the IFCS concept used in this report and the nuclear fuel cycle facilities that may be found within each center. The growth scenarios provide the setting for the development of each IFSC and may be considered reasonably typical of various regions or areas and the span of probable electrical energy growth rates.

5.1.1 Type-A IFSC Development

The primary purpose of the Type-A IFSC is to provide storage of spent fuel for approximately 30 years. Spent fuel may be shipped to the AFR after a 6 to 12 months' residence time in the spent fuel storage pool at the reactor site. The growth scenarios are assumed to span 20 years as previously discussed. No new facilities are introduced after this time.

5.1.1.1 Low-Growth Scenario

Spent fuel from the dispersed LWR-LEU reactors is shipped to the single IFSC for interim storage. The rate of accumulation of fuel increases as the numbers of reactors in the system increases. Accumulations at the end of the 10th and 20th years are 751 and 2748 MT, respectively. The rate of receipt in the 20th year is 249 MT.

5.1.1.2 Increasing-Growth Scenario

Accumulations of spent fuel discharged are 4208 and 22,213 MT after the 10th and 20th years, respectively. Receipts in the 20th year are about 3000 MT. Storage modules having a capacity of 5000 MT are built for this scenario, with the initial module in operation by the 5th year. Additional modules are needed in the 15th, 19th, 22nd, 23rd, and 24th years.

5.1.1.3 Uniform-Growth Scenario

Accumulation of spent fuel discharges are about 14,000 and 35,000 MT after the 10th and 20th years, respectively. Receipts in the 20th year are about 3900 MT.

A total of eight storage modules is needed at the end of the period. They are introduced as required, with the initial module in operation by the 5th year.

5.1.2 Type-B IFSC Development

Type-B IFSCs contain facilities for reprocessing fuels from dispersed LWR-LEU and LWR-MOX reactors, and for fabricating LWR-MOX fuels. With this type center, reprocessing facilities can be sized according to considerations that would be used if the facilities were dispersed; unlike the Types-C and -D centers, there are no further constraints. The dates of the beginning of processing and the size of the facilities needed are given in Table 9.

5.1.2.1 Low-Growth Scenario

This scenario provides for the introduction of three LWR-MOX reactors during the study period. The remaining seven are LWR-LEU reactors; no LWR-DU/Th reactors are introduced. The reprocessing plant begins operation at the beginning of 1993 (the 14th study year).

Interim storage of discharged fuel reaches a maximum of 1051 MT during the 12th year and decreases to about 500 MT at the end of the period. Plutonium in storage reaches a maximum of about 4400 kg in the 18th year.

TABLE 9

SUMMARY OF IFSCs AND REPROCESSING NEEDS

Type Center	Growth Scenario	No. of IFSCs Started	Capacity of Reprocessing, MT/Yr LWR-LEU	 Pu Fuels*	 LWR-DU/Th
B	Low	1	300 (13)**	150 (17)**	---
C	Low	1	300 (13)	56.6 (20)	40.2 (20)
D	Low	1	300 (13)	57.2 (19)	140.4 (20)
B	Increasing	1	3000 (15)	1500 (18)	---
C	Increasing	1	1500 (13)	283 (17)	201 (20)
		1	1500 (18)	283 (20)	201 (20)
D	Increasing	2	750 (13)	143 (18)	351 (20)
		1	750 (13)	143 (20)	351 (20)
B	Uniform	1	3000 (13)	1500 (16)	---
C	Uniform	2	1500 (13)	283 (17)	201 (20)
		1	1500 (17)	283 (20)	201 (20)
D	Uniform	4	750 (13)	143 (18)	351 (20)
		2	750 (17)	143 (20)	351 (20)

---

*For Type-B Center: LWR-MOX Fuel
For Type-C Center: LWR-Pu/Th Fuel
For Type-D Center: LMFBR-Pu/Th Fuel

**Year started shown in parentheses

5.1.2.2 Increasing-Growth Scenario

This scenario provides for the introduction of 25 LWR-MOXs by the 20th year. The balance, 95 reactors, are LWR-LEU. No LWR DU/Th reactors are introduced (see Table 9).

Interim storage of discharged fuel reaches a maximum of 8700 MT in the 14th year and decreases to about 5600 MT at the end of the period. Plutonium in storage reaches a peak of about 22,000 kg in the 20th year.

5.1.2.3 Uniform-Growth Scenario

The number of LWR-MOX reactors introduced is 34. The balance, 121 reactors, are LWR-LEU. No LWR-DU/Th reactors are introduced (see Table 10).

Interim storage of discharged fuel reaches a maximum of nearly 21,000 MT in the 18th year and decreases to 18,000 MT in the 20th year. Plutonium in storage reaches a peak of 44,000 kg in the 20th year.

5.1.3 Type-C IFSC Development

Type-C IFSCs contain processing facilities for all reactors and fabrication facilities for LWR-Pu/Th reactors, plus plutonium-burning reactors (LWR-Pu/Th). The processing plant size for LWR-LEU reactors at a single IFSC site is limited to 1500 MT/year by the number of onsite reactors considered reasonable. The corresponding processing capacity for LWR-Pu/Th fuels at system equilibrium is 300 MT/year, which is sufficient to support ten LWR-Pu/Th reactors. For high system growth rates requiring greater processing capacities, multiple IFSCs are needed. For the increasing- and uniform-growth scenarios, two and three centers, respectively, are needed in the study.

The dates of the beginning of processing and the size of the facilities needed for each IFSC site are given in Table 9.

TABLE 10

REACTOR MIX IN YEAR 2000 AS FUNCTION OF TYPE OF CENTER AND GROWTH SCENARIO

	TYPE IFSC		
	Type-B	Type-C	Type-D
LOW GROWTH			
LWR-LEU	7	8	8
LWR-Pu/Th*	-	2	-
LMFBR-Pu/Th*	-	-	2
LWR-MOX	3	-	-
LWR-DU/Th	-	0	0
TOTALS	10 (1)**	10 (1)	10 (1)
INCREASING GROWTH			
LWR-LEU	95	105	100
LWR-Pu/Th*	--	14	--
LMFBR-Pu/Th*	--	--	17
LWR-MOX	25	--	--
LWR-DU/Th	--	1	3
TOTALS	120 (1)	120 (2)	120 (3)
UNIFORM GROWTH			
LWR-LEU	121	128	119
LWR-Pu/Th*	--	25	--
LMFBR-Pu/Th*	--	--	35
LWR-MOX	34	--	--
LWR-DU/Th	--	2	1
TOTALS	155 (1)	155 (3)	155 (6)

---

*Onsite reactors; all others dispersed.

**Numbers in parentheses are number of IFSCs.

5.1.3.1 Low-Growth Scenario

Two of the ten reactors at the end of the period are LWR-Pu/Th reactors; the balance are LWR-LEU. No LWR-DU/Th reactors are introduced (see Table 10). One IFSC module is needed.

Interim storage of discharged fuel reaches a maximum of 1051 MT in the 12th year and decreases to 472 MT at the end of the period. Maximum fissile plutonium in storage is 4400 kg in the 18th year. Uranium-233 in storage is 918 kg by the 20th year.

5.1.3.2 Increasing-Growth Scenario

Of the 120 reactors in the system at the end of the period, 14 are LWR-Pu/Th and one is an LWR-DU/Th (see Table 10). Of the 14 onsite reactors, 9 are in the first IFSC established, with 5 being in the second IFSC.

Interim storage of discharged fuel reaches a maximum of about 6400 MT in site 1, (13th year) and 3400 MT in site 2 (17th year). Corresponding maximum values for fissile plutonium are 12,400 kg (20th year) for site 1, and 10,000 kg (20th year) for site 2. The stockpile of uranium-233 in denatured form is 2900 kg.

5.1.3.3 Uniform-Growth Scenario

Of the 155 reactors, 25 are LWR-Pu/Th and two are LWR-DU/Th (see Table 10). The onsite reactors are distributed over three separate sites: 9 each at two sites, and 7 at a third.

Interim spent fuel storage maximums are 9700, 9700, and 6500 MT for the three sites, respectively.

Corresponding maximums for fissile plutonium storage are 13,000, 13,000, and 10,500 kg, respectively, for the three sites. The stockpile of uranium-233 in denatured form is 5700 kg.

5.1.4 Type-D IFSC Development

A Type-D IFSC differs from the Type-C only in that the onsite plutonium burning reactors are LMFBR-Pu/Th rather than LWR-Pu/Th reactors. The reprocessing plant size for LWR-LEU reactors at a single IFSC site is limited to 750 MT/year by the number of reactors considered reasonable. The corresponding processing capacity for LMFBR-Pu/Th fuels is 150 MT/year, which is sufficient to support 11 LMFBR-Pu/Th reactors. For high system growth rates requiring greater processing capacities, multiple IFSCs are needed. For the increasing- and uniform-growth scenarios, three and six IFSCs, respectively, are needed in this study.

The dates of the beginning of processing and the size of the facilities needed for each IFSC site are given in Table 9.

5.1.4.1 Low-Growth Scenario

Two of the ten reactors at the end of the period are LMFBR-Pu/Th reactors; the balance are LWR-LEU. No LWR-DU/Th reactors are introduced (see Table 10). One IFSC module is needed.

Interim storage of spent fuel reaches a maximum of 1051 MT in year 12 and decreases to 377 MT at the end of the period. Maximum fissile plutonium in storage is 4500 kg at the end of the 20th year. Uranium-233 in the stockpile is 1800 kg.

5.1.4.2 Increasing-Growth Scenario

A total of three IFSCs is needed. Seventeen LMFBR-Pu/Th reactors are introduced: six in each of two sites, and five in the third. Three LWR-DU/Th reactors are introduced; the balance are LWR-LEU reactors (see Table 10).

Interim spent fuel storage maximums are 3200 MT (13th year) for two sites, and 2100 MT (14th year) for the third. Maximum fissile plutonium in storage is 8300 kg (20th year) for two sites, and 7500 kg (20th year) for the third. Uranium-233 in storage is 6400 kg.

5.1.4.3 Uniform-Growth Scenario

A total of six IFSCs is needed. Thirty-five LMFBR-Pu/Th reactors are introduced: seven each in four sites, four at the fifth site, and three at the sixth. One LWR-DU/Th is introduced. The balance are LWR-LEU reactors (see Table 10).

Interim storage of spent fuel reaches a maximum of 5000 MT (14th year) at four of the sites, and 3000 MT (17th year) at the two remaining sites. Corresponding maximums for fissile plutonium are 7800 kg (18th year) at four sites, and 7000 kg (20th year) and 6200 kg (19th year) at the fourth and fifth sites, respectively. Uranium-233 in storage is nearly 18,000 kg.

5.2 COSTS OF CONSTRUCTION AND OPERATION

The costs associated with construction and operation of IFSCs were developed, for each IFSC type and for each growth scenario, from the foregoing description of IFSC growth patterns. Costs were considered only for onsite facilities in IFSCs. Details of the costs for construction and operation which were assumed for individual facilities were given in Chapter 3. Costs for each case were developed from year-by-year summations of capital cost expenditures and annual operating costs; manpower requirement for construction and operation of the facilities were also tracked on a year-by-year basis. Construction and operating costs are in constant 1979 dollars.

Table 11 shows a summary, for all IFSC types and all growth scenarios, of total capital costs for each case over the 20-year study period, and of operating costs and operating manpower during the final year of that period. The year 20 data are presented only to indicate a one-time picture of the employment and operating cost levels.

TABLE 11

SCENARIO COST COMPARISON SUMMARY

Facility Description	Growth Scenario	Capital Costs* ($\$10^9$)	Year 20 Annual Operation Costs* ($\$10^6$)	Year 20 Manpower Required
Type-A IFSC				
AFR	Low	0.17	12	130
	Increasing	0.77	52	595
	Uniform	1.90	130	1380
Type-B IFSC				
AFR Reprocessing Fabrication Waste	Low	1.23	85	950
	Increasing	3.56	225	3682
	Uniform	5.66	369	6164
Type-C IFSC				
AFR Reprocessing Fabrication Waste Pu Burners	Low	2.93	149	1150
	Increasing	13.93	968	6972
	Uniform	23.15	1345	10,858
Type-D IFSC				
AFR Reprocessing Fabrication Waste Pu Breeders	Low	5.11	238	1550
	Increasing	21.86	914	8213
	Uniform	49.23	1966	16,529

---

*All dollar values are constant 1979 dollars.

5.2.1 Type-A IFSC

The only onsite operating facilities in a Type-A IFSC are away-from-reactor (AFR) spent fuel storage and temporary waste storage facilities.

For the low-growth scenario, only a single AFR facility of 2500 MT capacity is in operation by the 20th year. However, a second storage facility is required to be in operation in the 23rd year; early construction costs of this facility enter the problem during the 19th and 20th years. Total construction costs for this case are $170 million; the maximum construction force is 600 people, with the peak occurring in the second year. Operating costs in the 20th year total $12 million, and the estimated operating force is 130.

In the increasing-growth scenario, considerably more fuel storage is involved. For this case, three 5000-MT storage modules are operating in the 20th year, and three additional units of the same size are under construction. Capital construction costs total $900 million, and the construction force peaks at 1000 in the year "zero" (the year before "start" of the study period). It drops to zero in year 3, picks up again in the year 10, peaks twice at 800, goes to a high of 840 in the 19th year, and then slowly increases from the 21st year on (following the end of the study period). Operating costs for this case are $52 million in the 20th year, with an operating manpower of 595 in that year.

For the uniform-growth scenario, the Type-A IFSC requires eight 5000-MT storage modules to be in operation by the 20th year; three more are in construction. Capital costs for this case total $1.9 billion; the labor force increases to 1490 by that year, representing the peak for the study period. Operating costs in the 20th year are $130 million, and the operating force is 1380.

5.2.2 Type-B IFSC

The Type-B IFSC receives spent fuel from LWR-LEU reactors, reprocesses the fuel, and refabricates spiked mixed-oxide fuels for use offsite.

For the low-growth case, facility requirements for the 20-year study period consist of a 2500-MT storage basin, a 300 MT per year LWR fuel reprocessing plant, and a 200 MT per year refabrication facility for spiked mixed-oxide fuel. Capital costs total $1.23 billion. The construction force peaks at 1334 in the 9th year of the study period. In the 20th year, annual operation costs total $85 million, and the operating staff is 950.

For the increasing-growth scenario, the facilities include the following: two 5000-MT storage modules, a reprocessing plant of 3000-MT capacity (placed in operation in the 16th year), a second plant in construction at the end of the study period, and four 200-MT fabrication plants in operation by the end of the study period. Capital costs for this scenario total $3.56 billion; construction manpower peaks at 3500 in the 12th year. Operating costs in the 20th year total $225 million, and the operating staff is 3682.

In the uniform-growth scenario, four 5000-MT AFR storage modules are required, along with two 3000 MT per year reprocessing plants and six 200 MT per year refabrication plants. Additional refabrication capacity is under construction at the end of the study period. Capital costs total $5.66 billion for this case; the peak construction manpower is 3000 in the 11th year. Operating costs are $369 million in the 20th year, with an operating staff of 6164.

5.2.3 Types-C and -D IFSCs

Types-C and -D fuel service centers entail the utilization of onsite reactors for consumption of plutonium. In the Type-C center, these reactors are fueled with mixed plutonium and thorium oxides; for the Type-D center, plutonium-fueled LMFBRs are used. In either case, the onsite reactors generate ^{233}U, which is then denatured and shipped offsite for fabrication and use in denatured uranium-thorium fueled reactors. For this study an assumption limited the number of reactors at a single site to 10 LWRs (Type-C) or 7 LMFBRs (Type-D). For these cases, multiple IFSCs were assumed. A complete IFSC, with its full complement of fuel cycle facilities, constitutes a module which is then replicated at the next site development. These modules and their associated cost and manpower data are described in Table 12. Manpower requirements for construction and operation of these modules are shown in Figures 5 and 6. The total manpower requirements for a given growth scenario depend on the number of modules completed (shown in Table 9).

For the low-growth scenario, the first IFSC module is not completed, for either the Type-C or Type-D IFSC, during the 20-year study period. For the Type-C case, the partially completed site contains one 2500-MT fuel storage facility, one 300 MT per year reprocessing plant, one 200 MT per year fabrication plant, and two LWRs in operation. Capital costs for this case are \$3.92 billion; operating costs in the 20th year are \$121 million, and the operating manpower in that year is 1150.

The Type-D case under low growth is similar to the Type-C except for the addition of a 150 MT per year reprocessing plant for LMFBR fuel, and the use of two LMFBRs rather than LWRs. Capital costs for this case total \$5.11 billion. Operating costs in the 20th year are \$149 million, with a staff of 1550.

In the increasing-growth scenario, the Type-C case utilizes two site modules completed except for six reactors not yet on line by the 20th year. Capital costs for this case are \$13.93 billion; 20th-year operating costs are \$968 million, and an operating staff of 6972 is required.

For Type-D, three IFSC modules are completed, except for four LMFBRs. Capital costs are \$21.86 billion; 20th-year operating costs are \$914 million, and the staff is 8213.

TABLE 12

COST BREAKDOWN BY COMPONENT FOR BASIC IFSC MODULES

BASIC TYPE-C MODULE

Component	Size	Cap. Cost (Billion)	Annual Operating Cost (Million)	Operating Manpower Requirement
Pu/U-LWR Reprocessing Plant	1500 MT/yr	1.25	60	1750
Pu/Th-LWR Reprocessing Plant	300 MT/yr	1.19	48	670
Pu/Th-LWR Fabrication	200 MT/yr	.45	31	150
AFR	5000 MT	.27	20	216
Reactors - Lead	1000 MWe	.75	25	100
Subsequent	1000 MWe	.61	25	100

BASIC TYPE-D MODULE

Pu/U-LWR Reprocessing Plant	750 MT/yr	.98	47	1155
Pu/Th-LMFBR Reprocessing Plant	150 MT/yr	1.79	54	650
Pu-Th/Th/Th LMFBR Fabrication	200 MT/yr	.70	67	150
AFR	5000 MT	.27	20	216
Reactors - Lead	1000 MWe	1.06	25	100
Subsequent	1000 MWe	.85	25	100

NOTE: Reactor costs are for each plant in the module.

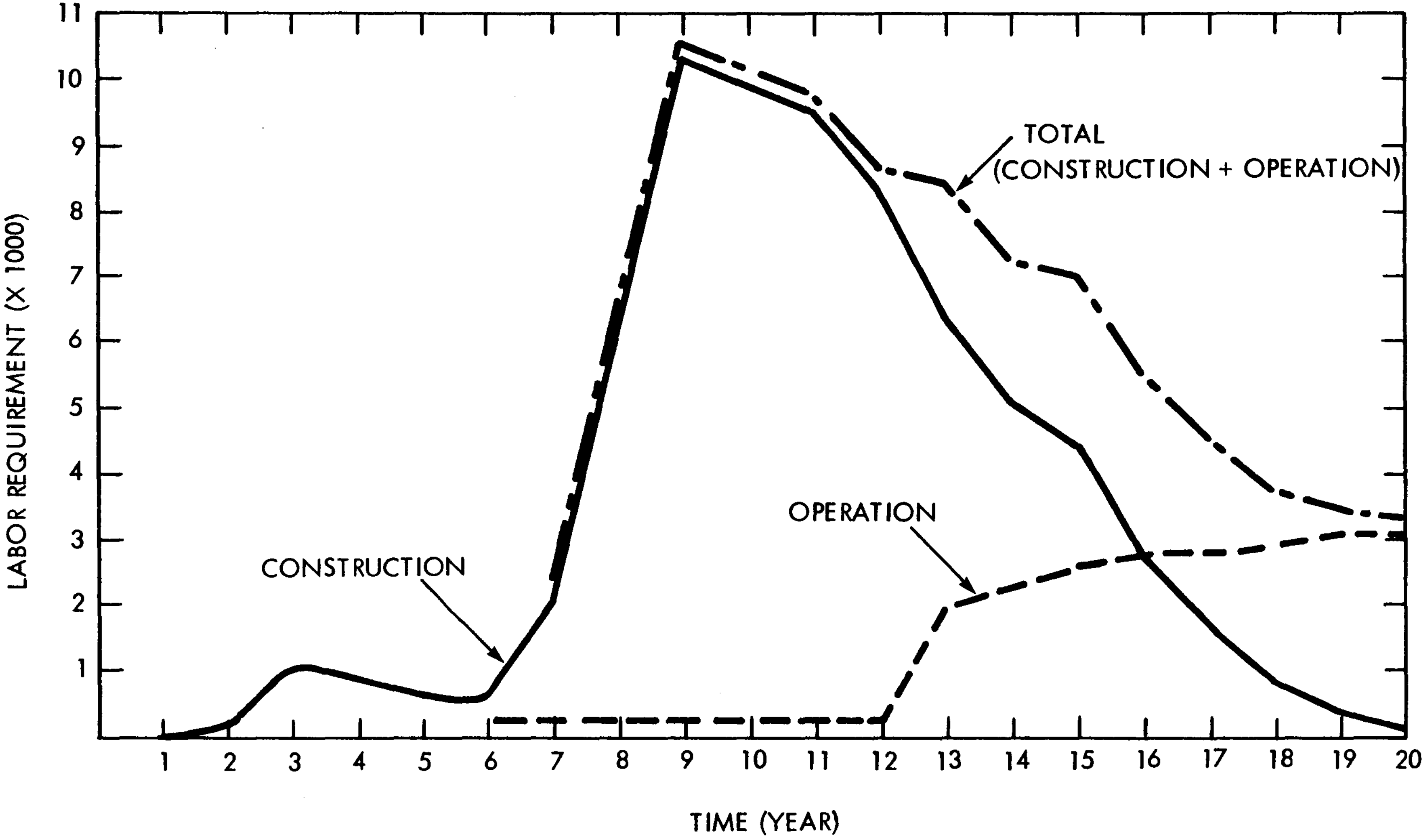

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FIGURE 5. Labor Force Requirements: Type-C Basic Module.

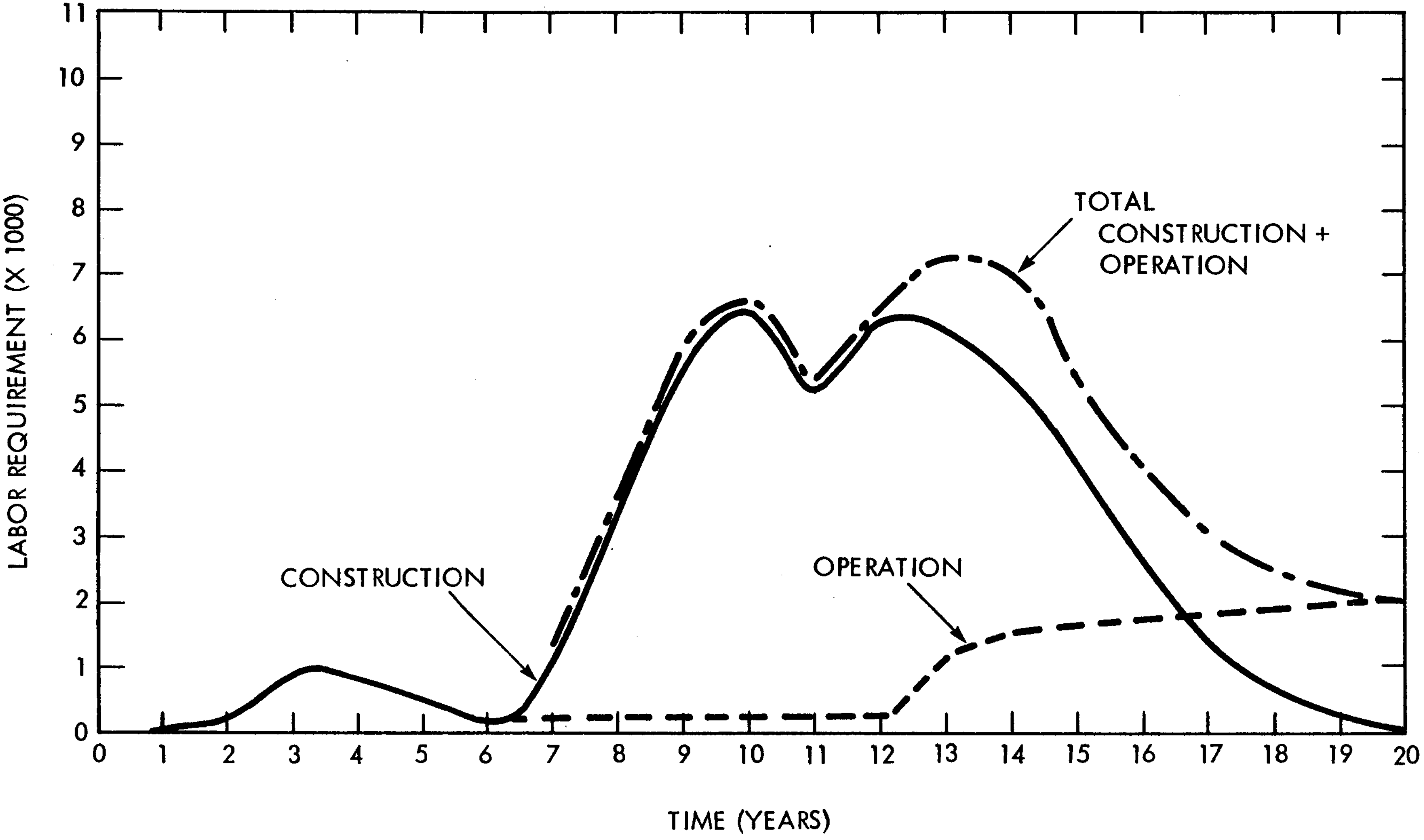

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FIGURE 6. Labor Force Requirements: Type-D Basic Module.

In the uniform-growth scenario, the Type-C IFSC complex consists of three modules, which are completed except for five LWRs. Capital costs for this case are $23.15 billion. Operating costs in the 20th year are $1.34 billion, and the operating manpower totals 10,858.

For the Type-D Case, six IFSC modules are in operation, except for seven LMFBRs, by the end of the study period. Capital costs for this case total $49.23 billion. Operating costs in the 20th year are $1.97 billion, and the required staff is 16,526.

5.3 ANALYSIS OF UNIFORM-GROWTH SCENARIO

A discounted cash flow analysis of the IFSC concepts compared to identical dispersed facilities results in the IFSC concepts having a cost advantage of between 8.3 and 13.7 percent. Considering the capital and operating cost ranges indicated in NASAP and AFCEP estimates, the certainty of the cost savings may be doubtful.

In performing the analysis a fixed charge rate of 22.6 percent was applied to the capital expenditures. Oak Ridge National Laboratory reported in the ORNL/TM-6522 document that the fixed charge rate was typical for industry financing. The rate assumes both a 65 percent equity financing and a 12 percent weighted average cost of money, and also accounts for federal and state tax rates. Fixed charge rates of 10.8 percent and 31.6 percent were computed by ORNL for government and high-risk industrial financing, respectively. The computed typical industry rate of 22.6 percent was selected as being representative of probable financing alternatives.

A discount rate of 10 percent was used to obtain the present worth (1979 dollars) of the year-by-year monetary requirements. The use of the 10 percent discount rate is required by the Office of Management and Budget (OMB) for the evaluation of government decisions concerning the initiation, renewal or expansion of all programs or projects which involve costs or benefits extending for 3 or more years. OMB Circular A-94, dated March 27, 1972 (with the May 10, 1972 revision), states this requirement.

Present-value costs were obtained for each of the 20 study years for both the IFSC concept and for the dispersed facilities. Costs incurred beyond the 20-year study period are not included in the analysis. The yearly present-value costs were summed (see Table 13) and compared to determine the possible benefit of each IFSC concept. The analysis is presented only for the uniform-growth scenario. Probable expected benefits from the increasing- and low-growth scenarios would be of lesser amount due to the fewer number of facilities required at an IFSC.

TABLE 13

COMPARISON OF PRESENT-WORTH COSTS(1)
UNIFORM-GROWTH SCENARIO
(M$)

IFSC TYPE	IFSC CONCEPT				DISPERSED FACILITIES				IFSC COST SAVINGS
	OPERATING COSTS(2)	FIXED CHARGES(2)	TOTAL	PRESENT WORTH(3)	OPERATING COSTS(2)	FIXED CHARGES(2)	TOTAL	PRESENT WORTH(3)	
A	1172.	2952.7	4124.7	1205.8	1172.	3722.1	4894.1	1398.0	192.2
B	2415.	8747.1	11162.1	2617.9	2415.	10142.9	12557.9	2950.0	332.1
C	7235	28275.4	35510.4	7158.9	7235.	31620.9	38855.9	7807.8	648.9
D	8281	42383.9	50664.9	9573.8	8281.	47268.3	55549.3	10455.7	881.9

(1) Constant 1979 dollars (in millions of dollars).

(2) Summation of the annual dollar values.

(3) Summation of the discounted annual operating costs and fixed charges.

6.0 SAFEGUARDS CONSIDERATIONS

This section is not intended to be a comprehensive analysis of all safeguard methods or possible diversion means. Rather, discussion is limited to the relatively unique advantages of an International Fuel Service Center (IFSC) compared to independently sited nuclear facilities in an international community. A complete analysis of safeguard procedures may be found in the International Atomic Energy Agency (IAEA) contributions to the International Fuel Cycle Evaluation (INFCE).

6.1 BACKGROUND

For the purposes of comparison of the safeguards requirements, two scenarios have been compared. They are 1) Type-D IFSC, in which spent fuel storage, reprocessing, refabrication and Pu-Th LMFBRs are within the center with LEU or Du/Th reactors and fabrication facilities outside; and 2) the dispersed case, in which the above facilities are all deployed in a dispersed manner.

Both options will require conventional physical security, material control, and material accountability systems, presumably using the IAEA safeguard requirements as a basis for design.

6.2 SAFEGUARDS COMPARISON

The basic differences between the IFSC concept, and the dispersed siting scenario which have an effect on safeguards requirements are:

1) There is marked reduction in the offsite movement of weapons-usable nuclear materials.

2) There is an increased ability to protect materials from diversion through a more sophisticated physical security system and a large guard force.

The concentration at a single site of functions and facilities that may be susceptible to nuclear material proliferation greatly minimizes the opportunity for diversion during transportation and reduces the offsite availability of fissile materials in either a desirable or undesirable form. For IFSC Types B, C, and D, spiked or denatured fuel assemblies and ultimate waste disposal containers are all that are shipped offsite.

By collocation of several facilities at one site, security-related cost savings and performance improvements may be realized. Security facilities are provided at each of the components within the IFSC. Also provided are additional site common security facilities such as an external barrier to surround the entire facility, including external lighting, lighting towers, TV cameras, and separate personnel and receiving/shipping portal. Common physical security features (security force, fencing, alarms, security-related facilities, access controls, secured fissile material storage) provide security-related cost savings. The colocation of facilities within an IFSC allows for the added protection of a larger security force than would be provided at any of the dispersed site facilities. Even so the total security force would be less than the sum of the forces for all the individual sites. Studies by Sandia and others have shown that the single most significant factor affecting safeguards reliability is the size of the site's security force. Essentially, given optimized physical security features and optimized response times after detection, the larger the guard force the more chance there is for successfully preventing diversion.

Process monitoring and material accountability would be required for both the IFSC and dispersed facilities. Both would also require the same offsite international support facilities, personnel and response institutions. However, for other site-related capital and operating expenses involving international interface (control centers, alarm systems, personnel), a collocated site would be less costly than a complex of dispersely sited fuel cycle facilities because of the elimination of redundancy.

6.3 SAFEGUARDS COSTS

Studies have shown that substantial costs are associated with upgrading safeguards at any facility or complex of facilities. Costs of improved safeguards include:

1) Developing and implementing appropriate access use denial features into existing nuclear processes and monitoring systems

2) Adding detection and communications systems and institutional interfaces required to maintain international cognizance of the status of nuclear facilities

3) Establishing and maintaining an international institutional reponse system in the form of treaties and agreements as well as technological, economic and security forces which can be brought to bear on nonconforming host nations.

These added requirements however, would not only be associated with an IFSC, but also with any dispersely sited series of nuclear complexes providing an equivalent power-generating capability.

However, it is expected that safeguard costs for an IFSC will be somewhat lower than an equivalent independently-sited nuclear complex for the following reasons:

- Capital costs for physical security are expected to be lower due to some degree of sharing of systems between facilities at the site. Such shared systems include perimeter protection, personnel gate house, vehicle gatehouse, identification equipment, main control center, auxiliary control center, evacuation systems, materials management instrumentation computers for materials management and physical security, and SNM storage.

- Capital costs for enhancing international safeguards could be shared at an IFSC. These facilities and/or systems include onsite (international) command complex (facility) and equipment.

- Operating costs for the IFSC may be lower than the sum of the costs for several independently sited facilities because a smaller total number of security force personnel and site-related personnel interfacing with international institutions is required to achieve equivalent response capabilities and resultant protection.

The IFSC will also provide savings in those costs associated with transportation and adequate protection of the additional offsite SNM shipments associated with independently-sited nuclear power complexes.

7.0 ENVIRONMENTAL AND SOCIAL ASPECTS

The environmental considerations and social aspects were analyzed for the four types of IFSCs relative to dispersely-sited facilities.

7.1 ENVIRONMENTAL CONSIDERATIONS

Several studies have been made(2,14-17) of the environmental interfaces involved with the operation of nuclear energy parks, which resemble the more complex types of International Fuel Service Centers (IFSCs) in their composition of nuclear power plant and attendant nuclear fuel cycle facilities. From these studies three areas are of interest in the evaluation of IFSCs: 1) hydrological considerations, 2) meteorological effects, and 3) potential radiological consequences to the public.

7.1.1 Hydrological Considerations

Depending on specifics of cooling system design and local climate, a nuclear power plant of nominal 1000 MWe capacity and equipped with evaporative cooling facilities of usual design will require a cooling water supply of 20 to 30 cubic feet per second (ft^3/s). Most of this supply is consumed by evaporation in the dissipation of waste heat from the facility. An IFSC containing several such power plants will thus exhibit a considerable requirement for cooling water supply. If sites under consideration do not have the required water availability, the options available would be: 1) to reduce IFSC size or 2) to utilize cooling methods requiring less water, such as "dry" or "wet/dry" cooling tower configurations, at increased facility cost. However, several United States sites under consideration as nuclear energy centers (e.g. Hanford, Oak Ridge) appear to have adequate water supplies for full development of any IFSC scenarios considered by this study.

7.1.2 Meteorological Effects

The cumulative effects of the rejection of heat to the atmosphere from several nearby power plants, coupled with the large amounts of water vapor released to the atmosphere from these plants, have been hypothesized to result in a number of atmospheric phenomena. Under certain weather conditions, icing and/or ground fogging may occur. In addition, the envelope of moist, heated air over such a site may display several of the characteristics of the "thermal islands" which form in the air over large metropolitan areas. Effects ascribed to these phenomena include diversion of winds (with attendant smog formation), disruption of rainfall patterns, inducement of local rainfall from passing cloud formations, and the induction of thunderstorms at the periphery of the "island".

The potential effects of water utilization and atmospheric heating at IFSCs certainly merit further investigation. However, these effects are likely to be highly site-specific rather than generic. They are likely to be primarily local in nature, and they will probably tend to restrict full IFSC development or "power density" (closeness of power plant siting) at some sites rather than eliminate the sites from consideration.

7.1.3 Radiological Consequences

Several studies have been made(2,14-17) of the potential radiological consequences from operations of integrated nuclear energy centers. These centers, which consist of relatively large clusters of nuclear power plants together with supporting fuel cycle facilities, are comparable in their potential effects to International Fuel Service Centers of Types B, C, and D. Results of these studies indicate that the radiological dose to the public from a well-sited nuclear energy center (or IFSC) will not be greater than, and will probably be less than, the combined population dose from equivalent dispersely-sited facilities.

The radioactive effluents from a developed IFSC (except Type-A) will be dominated by the release from the reprocessing plant(s) in the complex. This is graphically illustrated in Table 14(14), which shows the estimated radiation dose to the public from a nuclear energy center containing power plants with 25 GWe of generating capacity, together with associated fuel fabrication, reprocessing, and waste management facilities. Table 14 also shows that the reprocessing plant contributes about 75% of the maximum dose to the individual, and about 90% of the dose to the population within a 50-mile radius of the site.

The magnitude of the estimated dose from the reprocessing plant assumed in the referenced study indicates that in a dispersed-siting situation, remote sites would be required for these facilities. However, the other facilities at the center (power plants and fabrication plants) may normally be sited closer to centers of population under dispersed-siting scenarios. The relative proximity to population centers would tend to increase the contributions to dose from those facilities. In either instance the dose to the whole body is significantly less than the 5 mrem limit prescribed by Appendix I, 10CFR50.

For example, the contributions to annual total body dose from 20 nuclear plants (25 GWe) in the energy center noted in Table 14 are 1.5 mrem to the maximum individual dose, or 53 man-rem to the population within a 50-mile radius. This amounts to 0.075 mrem and 2.7 man-rem per power plant unit. Table 15 shows, for comparison, the individual and population doses for four 2-unit nuclear power plant sites selected from among sites for which recent environmental statements are available(18,19,20,21). The doses in Table 15 exhibit a range of 1 to 2.8 mrem per plant unit for annual maximum individual dose, or 12 to 36 times that for a plant at the nuclear energy center site (although still very small and well within acceptable limits). Similarly, the 50-mile population dose per plant unit ranges from about 3 to 10 man-rem per plant unit, or 1 to 4 times that of the centralized site.

TABLE 14

ESTIMATED TOTAL RADIATION DOSES AND DOSE COMMITMENTS TO A MAXIMUM INDIVIDUAL AND THE POPULATION WITHIN 50 MILES FROM OPERATION OF AN HNEC*(14)

Organ	MOX(a)	FRP(b)	Reactors(c)	Total(d)	MOX	FRP	Reactors	Total
Maximum Individual	First-Year Dose, mrem				Fifty-Year Dose Commitment, mrem			
Total Body	4×10^{-6}	4.9	1.5	6.4	1×10^{-3}	5.1	1.5	6.6
Bone	2×10^{-4}	0.2	0.9	1.1	4×10^{-2}	0.6	1.1	1.7
GI-LLI	6×10^{-6}	4.9	1.5	6.4	6×10^{-6}	5.1	1.5	6.6
Lung	8×10^{-4}	4.9	1.5	6.4	1×10^{-3}	5.1	1.5	6.6
Thyroid (Adult)	5×10^{-7}	5.1	2.7	7.8	5×10^{-7}	5.3	2.8	8.1
Thyroid (Infant)	-	13	11	24	-	-	-	-
Population	First-Year Dose, man-rem				Fifty-Year Dose Commitment, man-rem			
Total Body	4×10^{-4}	410	53	460	0.1	430	55	490
Bone	2×10^{-2}	13	28	41	4.3	32	32	68
GI-LLI	4×10^{-4}	410	53	460	4×10^{-4}	430	55	490
Lung	8×10^{-2}	410	53	460	0.2	430	55	490
Thyroid	4×10^{-5}	430	85	520	4×10^{-5}	450	88	540

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*HNEC - Hanford Nuclear Energy Center.

(a) A 300-MT/yr MOX fuel fabrication plant.
(b) A 1500-MT/yr fuel reprocessing plant.
(c) Seven BWRs and 13 PWRs with total capacity of 25 GWe.
(d) Doses from other waste management facilities not listed are negligible.

TABLE 15

RADIATION DOSE ESTIMATES FROM SELECTED 2-UNIT NUCLEAR POWER STATIONS(18,19,20,21)

	Estimated Max Individual Dose (mrem)		Estimated Population Dose (man-rem)	
Site Location	Total Body	Thyroid	50-mile Radius	U.S. Population
Massachusetts	5.5	8.0	17	4
Illinois	2.1	ND	7	29
Tennessee	2.9	15	8	51
Ohio	5.0	12	21	92

ND = No Data

In recent years, two comprehensive studies of cumulative regional population dose resulting from operation of large numbers of nuclear facilities(16,17) considered the comparative effects of "clustered" (e.g. energy park) siting as compared to dispersed configuration. The Tennessee Valley Region(17) study summarized the effects of "clustered" siting, as shown in Figure 7. For each case shown in the figure, the dose contribution was dominated by reprocessing plant releases. All facilities in that study were referenced to the year 2000 and were assumed to be equipped with advanced effluent treatment facilities such as those that provide for the entrapment of noble gases. The indicated differences among the cases are small, but a somewhat lower dose is indicated for large clusters of facilities.

Another reduction in population dose, although small, occurs in transportation operations. It has been estimated that an annual increment of 7 man-rems accrues to the total U.S. population as a result of shipment of fuel and radioactive waste to and from an LWR power plant (e.g. 14 man-rem for a 2-unit station).(18,19,20,21) This dose increment may vary somewhat for various fuel cycles. However, the clustering of power plants and fuel cycle facilities into an IFSC can effect considerable reductions in the number of offsite fuel and waste shipments required; dose to the public will be correspondingly reduced, as compared to a dispersed-siting situation.

From comparisons of the foregoing studies and evaluations, it appears that the addition of nuclear power plants and associated fuel cycle facilities either as IFSCs or in dispersed siting configurations will result in small increments to population dose that are well within acceptable limits. However, the development of well-sited IFSCs can result in a slight reduction in population dose below that for the dispersed case.

7.2 SOCIAL ASPECTS

The purpose of this section is to identify the range of social implications that pertain to the development of the IFSC concept and to provide an analysis of some of the potential social impacts that are likely to accompany

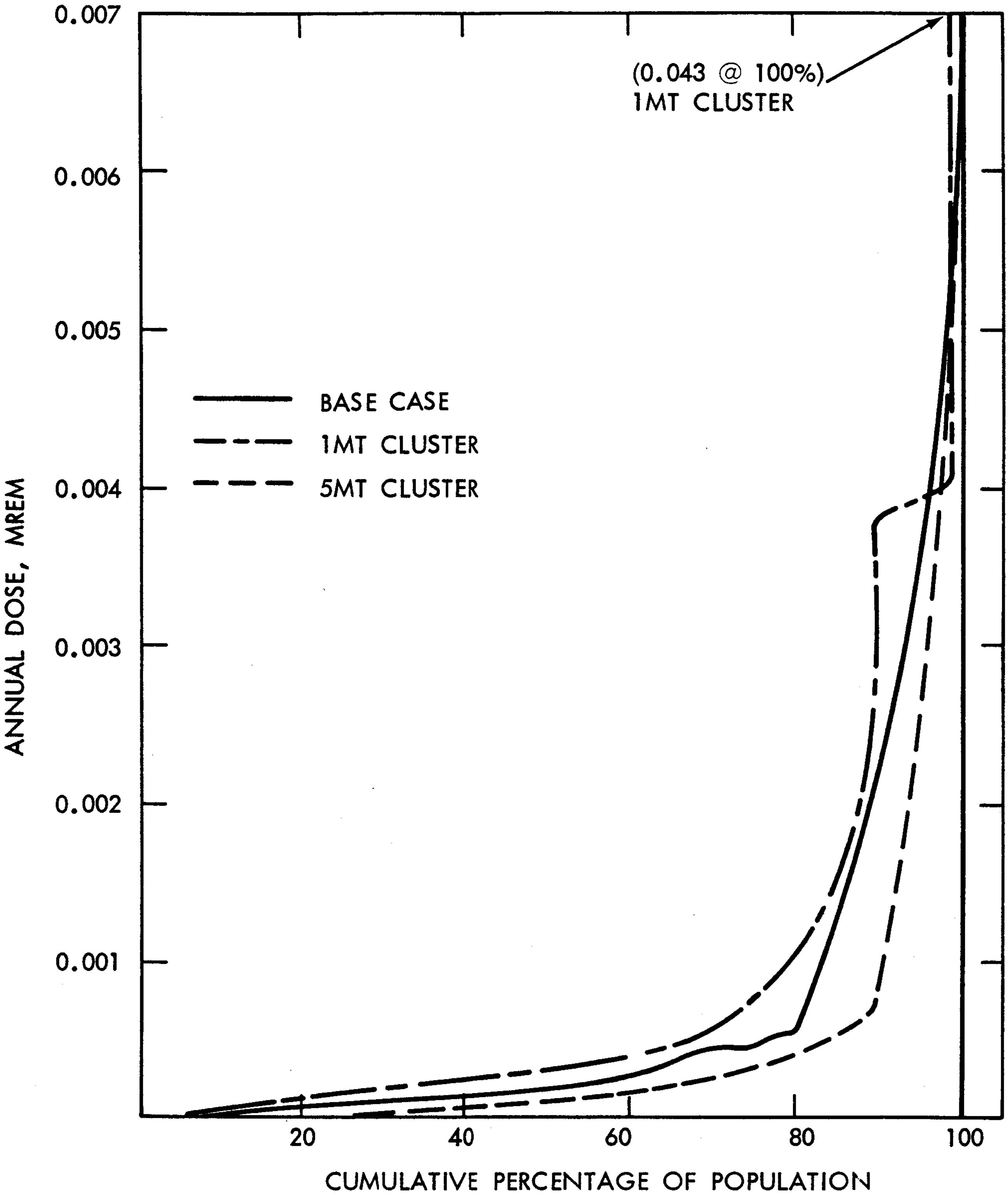

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FIGURE 7. Variation in Population Dose Distribution with Cluster Siting Assumptions.(17) (MT refers to the reprocessing plant size.)

the development of the different types of IFSCs. Because of the scarcity of relevant data, this analysis is limited to a discussion of possible public responses to this new concept and to a forecast of social and economic effects attributable to the work force requirements associated with building and operating IFSCs at two hypothetical sites. The major emphasis in this section pertains to the siting of IFSCs in the United States.

Since the United States does not currently use many of the facilities that are to be sited within a given IFSC type (e.g., LWR plutonium burners, LMFBRs, commercial reprocessing plants or AFRs), the comparisons that will interest most people involve whether or not to site such facilities. Thus, in the following analysis, much of the focus will be on public attitudes regarding acceptance of the various facilities. This section also presents an analysis of the nature and magnitude of the stresses that facility construction and operation place on a community and will discuss the major factors--such as local labor force availability, number of new families in-migrating to the site, and demands for social services--that contribute to the creation of social and economic impacts at the local and regional level.(22) This analysis will utilize two reference sites that differ in terms of population size and density and distance to large urban centers.(23)

7.2.1 Proliferation as a Nuclear Power Issue

The major reason for pursuing the IFSC concept relates to the possible reduction of the potential for proliferation. Thus, whether a nation would be willing to host an IFSC may be partially dependent upon the salience of proliferation as a nuclear power issue in that country. This section will discuss the importance of the proliferation issue to different publics in the United States.

Although proliferation is a major concern affecting the present administration's nuclear power policies, it is not the main concern of the media coverage of nuclear power in the United States.(24,25) Health and safety issues, economic issues, and political issues all received at least twice as much news coverage as proliferation from 1972 through 1977. Lack of news coverage may explain why survey research findings on public conerns regarding proliferation are quite scanty. However, survey questions relating to the United States' export of nuclear technology do exist and do provide at least indirect evidence of proliferation concerns. These data also have implications regarding public perceptions of the United States' supplying other countries with the technology for IFSCs.

The Roper Organization, Inc. conducted representative national surveys in 1975 and 1976 asking respondents about their attitude toward selling nuclear reactors abroad while keeping in mind proliferation considerations.(26) About 45 percent of the public felt that the United States should not sell reactors abroad because of proliferation concerns, about 33 percent of the public approved of reactor sales abroad, and about 13 percent of the respondents volunteered the response that the matter depended upon which country was the buyer.

Late in 1978 Louis Harris and Associates, Inc., polled the general public and seven leadership groups (political, business, regulator, environmental, utility company, labor, and media) on nuclear power attitudes.(26) A progression of questions was asked regarding reactor sales abroad. Congruent with the Roper findings, 32 percent of the public favored the sale of reactors abroad (with no restrictions), while 54 percent opposed such a sale. The business, political, regulator, utility company, and labor leadership groups supported reactor sales abroad, while environmental and media groups opposed. However, there was strong majority agreement by the general public and by all leadership groups, except the environmental leadership group, that it was better for the United States and its allies rather than the Russians to make a reactor sale abroad if such a sale was to be made. When the same implication was made regarding a sale, but the situation pitted the United States against Japan, West Germany or France, a majority nod was given to the United States by all leadership groups except the environmental group.

If stringent safeguards were agreed to by a purchasing nation, a 54 percent majority of the general public would agree to a reactor sale abroad. Five of the leadership groups gave strong majority support to this proposal, while the media group gave plurality support and the environmental group exhibited majority opposition. It could be that the IFSC concept would be perceived by some of these publics as providing such stringent safeguards.

Respondents were also asked whether they believed that a purchasing nation could fabricate a nuclear weapon regardless of the safeguard provisions. About two-thirds of the general public felt that the safeguard provisions would not necessarily stop weapons production. A plurality to majority of all the leadership groups, except the utility company group, also felt that the safeguard provisions would not necessarily stop weapons production. A majority of the utility company leaders believed that the safeguard provision would prevent proliferation.

If the percentage of the general public who generally favored the sale of reactors abroad (32 percent) is compared to the percentage who favored reactor sales to nations who agree to safeguards (54 percent), it can be seen that safeguards do make a difference in public perceptions. Even with adequate safeguards, 31 percent of the general public opposed reactor sales abroad. Thus, somewhat in agreement with the Roper findings, it appears that about one-third of the United States public outright favors United States reactor sales abroad; about one-third of the general public outright opposes reactor sales abroad (possibly for proliferation reasons but more likely because of the general opposition to nuclear power); about one-fifth of the public is specifically concerned about the reactor sale-proliferation link to the extent that they do not favor United States reactor sales abroad without adequate safeguards provisions; and the remainder of the public has no opinion. In general, political, business, regulator, utility company, and labor leaders are less concerned about proliferation than are environmental and media leaders. Finally, in a relative sense, proliferation is not as important an issue as reactor safety, waste management, or thermal pollution for any of the different publics.

7.2.2 Type-A IFSC

The Type-A IFSC only involves spent fuel storage. Since research has shown that most of the general public is not knowledgeable about the various aspects of nuclear waste management, general beliefs about nuclear waste management technical capabilities are relevant to public acceptance of the Type-A IFSC. At this time, about 40 percent of the American public believes that the technology exists for safely storing and disposing of nuclear wastes, about 15 percent thinks that the technology will be developed within 10 years, and an additional 15 percent think that the technology will be developed within 25 years. The remaining 30 percent of the general public is unsure that a safe waste management system can ever be developed. Relatively speaking, waste management is perceived by the general public as the most serious of the nuclear power issues.(27,28) Also, a survey conducted in Washington State found much more opposition to using Hanford as a disposal site for United States' and foreign wastes compared to using Hanford as a disposal site for the United States' wastes only.(26) Thus, the intended ultimate disposition of the fuel rods stored in a Type-A IFSC will have a large bearing on public acceptance of such a facility.

Impacts associated with the construction and operation of the Type-A IFSC are not likely to be great. The construction work force peaks out at between 600 and 1000 workers in the third year of a five-year construction period. Thereafter, about 200 permanent workers remain onsite to operate the facility. Since, in general, a population influx of 10 percent or more relative to the total county population is needed to strain a community's social service capability and to produce stressful adjustments for long-time local residents, it is unlikely that the construction and operation of the Type-A IFSC would, by itself, produce severe socioeconomic consequences either locally or regionally even in a sparsely populated area of the United States.

7.2.3 Type-B IFSC

The Type-B IFSC has as its major purpose the reprocessing of spent fuel from and the fabrication of fresh recycle fuel for offsite dispersed LWRs. The major new factors in this IFSC are reprocessing, refabrication, spiking, and the use of offsite LWRs using spiked MOX fuel. While a fairly large body of survey data exists on reprocessing, nothing eixsts on fabrication and the use of MOX fuel.

The general public seems to understand the meaning of reprocessing,(29) although only a small majority of the general public believes that nuclear fuel can be recycled.(26) In a 1979 survey conducted by Louis Harris and Associates, Inc., the general public and leadership groups were asked whether they thought that spent nuclear fuel should be reprocessed or disposed of. There was solid majority support among the general public for reprocessing. Except for the environmental leadership group, all leadership groups were also very much in favor of reprocessing. Even a large majority of the media group, a leadership group typically critical of nuclear power, support reprocessing of spent fuel.

In order to examine the possible basis for attitudes toward reprocessing, respondents were asked four belief items about reprocessing spent fuel. First, there was a slight majority belief on the part of the general public and all the leadership groups, except the environmental group, that reprocessing is economically attractive. Second, there was plurality to majority support by the total public, politicians, businessmen, regulators, and utility company officials that reprocessing should be carried out because of the need for nuclear fuel. Environmentalists, labor leaders, and media officials did not believe that reprocessing was necessary for fuel supply reasons. Third, a plurality of the general public believed that terrorists and saboteurs would somehow steal reprocessed fuel and threaten the public with nuclear weapons even if safeguards were set up. Other than the environmental group, a large majority of the other leadership groups did not share this belief. Finally, a large majority of the general public and of all leadership groups, except the environmental leadership group, believed that reprocessing reduced the amount of nuclear wastes that would have to be disposed.

In summary, support for reprocessing seems to be based on the beliefs that reprocessing reduces the amount of wastes that need to be disposed and that reprocessing is economically attractive. Support seems not be be based on the belief that reprocessing is needed because of a uranium shortage. Sabotage and terrorism concerns seem small enough, in a relative sense, so as not to influence attitudes against reprocessing.

The socioeconomic impacts associated with the Type-B IFSC were analyzed in three alternative modes--low growth, uniform growth, and increasing growth. The work force requirements for the uniform growth and the increasing growth configurations are expected to place significant demands on the local service infrastructure for towns located in sparsely populated areas of the country. However, the impacts for the Type-B facility for uniform growth and increasing growth are expected to be trivial for densely populated areas of the country. The Type-B low growth IFSC is not likely to place excessive demands on local communities in either densely or sparsely populated areas of the country.

7.2.4 Type-C IFSC

There are two new major factors involved with this IFSC. First, the plutonium burner reactor is a concept that is new to and unknown to the public. Second, the idea of siting ten of these reactors on one site is different from present siting practice and moves this IFSC type close to the nuclear energy center concept.

No public survey data have been collected on the plutonium burner concept. There is little doubt, however, that plutonium is viewed by some of the public as an exceptionally dangerous material. Whether a plutonium burner reactor would be judged publicly acceptable because it uses up plutonium or whether a plutonium reactor would be judged publicly unacceptable because it uses plutonium as fuel is not known.

The second important aspect of the Type C-IFSC is the siting of ten plutonium burner reactors on a single site. To this extent, the Type-C IFSC approaches a concept that had been studied in the past under various names, including nuclear energy centers, energy parks, and power parks. Many who have studied the nuclear energy center concept believe that the single greatest barrier to the building nuclear energy centers is public acceptance, not technical issues nor political/institutional issues.(30,31) As these authors note, local public opposition is almost inevitable regarding the sites of individual reactors so that local opposition to the collocation of numerous reactors is likewise inevitable and likely to be more severe.

The purported advantages of such a concept include more reliable safeguarding of nuclear materials, a possibly higher degree of health and safety protection, reduced environmental impacts, more efficient land use, better control of radioactive wastes, and reduced construction time and costs. The purported disadvantages include electricity transmission limitations, adverse climatological effects, cooling water requirements, the possibility of common-mode failures, and the types of equity issues that occur when residents of a limited area are asked to take risks for the benefits of residents living in different area. The equity issue is compounded by the international aspect of the IFSC. Several case studies in the United States suggest that public acceptance of clustered facilities may not be widespread.(31,32,33) Public acceptance would likely be most favorable in areas that have had a long-standing relationship with nuclear power.

The socioeconomic impacts associated with the Type-C IFSC will also influence public acceptance. The Type-C IFSC is considered in three growth configurations, including low growth, uniform growth, and increasing growth. The latter two growth patterns involve the same number of workers for onsite construction activities, a mean of about 11,000 during the three heaviest years of construction. The low growth pattern involves a construction work force only about one-fifth that number.

The low growth forecast for the Type-C IFSC will produce small levels of in-migration in relatively densely populated areas. Thus, the impacts are not expected to be large. However, the Type-C IFSC sited in a relatively sparsely populated country would cause a much larger population in-migration during both construction and operation. The levels of population increase would likely exceed the ten percent rule-of-thumb judgment for impact significance. The two areas likely to be especially affected are education and crime with a projected increase in the number of major crimes likely.

For both the increasing growth scenario and the uniform growth scenario, the Type-C IFSC would require a mean construction work force of about 11,000 for the three peak years. For sparsely populated countries, this work force would produce even more severe impacts than would the low growth scenario. More densely populated countries would be able to absorb such a work force with relatively minor social impacts.

7.2.5 Type-D IFSC

The major new aspect of the Type-D IFSC is the substitution of the Pu-Th breeder reactor for the LWR burner reactor. Several surveys have been conducted to determine public familiarity with the attitudes toward breeder reactors. In 1977 the general public was somewhat unfamiliar with the breeder reactor concept--only one-third of the American public felt at least somewhat familiar with the concept.(26) A plurality of the American general public favored breeder reactor development in 1978. Regarding leadership groups, there was plurality support of the breeder reactor by the political leaders, and majority support by business leaders, regulators, utility company officials, and labor leaders. There was majority opposition to breeder reactor development by environmental leaders and by media leaders.(26)

The Type-D IFSC construction force low growth configuration peaks at 3,200 workers and the uniform and increasing growth configurations peak out at about 6,400 workers. Thus, Type-D IFSCs for all growth scenarios will probably induce significant construction phase socioeconomic impacts only at sites located in sparsely populated countries. Sites located in more densely populated countries should be able to absorb the construction phase socioeconomic impacts.

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