Effect of Scale on Capital Costs of Nuclear Fuel Reprocessing

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INTRODUCTION

The total costs for a geologic repository for the disposal of spent nuclear fuel (SNF) and high-level radioactive wastes are estimated at $31.5 billion to $42.8 billion in 2001 dollars [1]. These large costs provide an incentive to deploy technologies to extend the life of the repository or to completely avoid the need for a second repository. Compared with direct disposal of intact SNF assemblies, repository life can be greatly extended by separating the SNF into various components so that a much smaller fraction will require repository disposal. For example, cesium and strontium can be removed to lower the heat load on the repository and uranium can be removed for either reuse or alternative disposal. However, the treatment technologies must be cost-effective for overall cost savings to be realized. An important factor in the deployment of treatment technologies is the scale of the treatment facility.

BACKGROUND

Separation of the SNF into various constituents for disposal encompasses traditional reprocessing technologies with added separations processes to support both repository heat management and transmutation of long-lived transuranium and fission products. Information has recently been developed summarizing the capital cost of reprocessing SNF as a function of plant size (i.e. plant throughput) [2]. The findings outlined in Ref. 2 indicate that the usual engineering approximation that "capital costs are proportional to the *n*th power of capacity is not valid over wide ranges of plant throughput." Plants with a throughput below a few hundred metric tons of heavy metal per year (MTHM/year) show little variation in their capital costs. At very large plant sizes, the capital costs vary in one-to-one, or higher, proportionality with plant throughput, because very specialized construction methods for large equipment are required. These opposing effects on throughput vs capital cost create a middle region in which the cost per unit throughput is minimized and thus define an optimum size for the reprocessing plant.

DESCRIPTION OF THE ACTUAL WORK

Existing information on the capital costs of reprocessing plants was gleaned from the literature. Most of the available information is from cost estimates performed as part of a design effort, particularly in the United States. Because it is sensitive business information, most current reprocessing practitioners in Europe and Japan do not provide details on their costs. However, limited capital cost data based on European experience exist [3]. Some data are also available on the effect of implementing the plant as either a single-line or dual-line facility.

The available information on capital costs pertained to the period 1976 through 1991. Capital construction indexes were used to escalate these costs to those applicable at the end of CY 2002 [4]. The data were then fit to a scaling rule in which the scale factor, n, was permitted to vary linearly with the plant throughput. This provided a good fit to the data, and the empirical function was consistent with previous work [2]. The derived relationship was used to go a step further and calculate the capital cost on the basis of a unit installed cost, in dollars per kilogram of heavy metal. The unit installed cost as a function of plant throughput is illustrated in Fig. 1, which presents costs for more traditional designs. Although modern

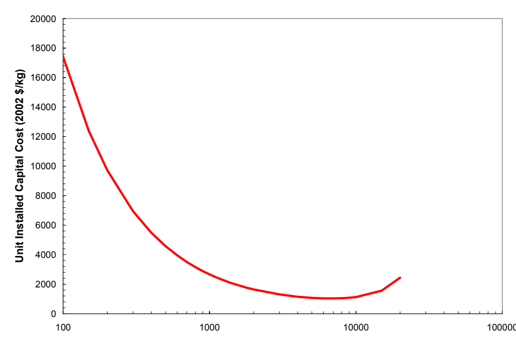

Fig. 1. Variation in unit installed cost with plant capacity for single-line plants.

designs incorporating extensive remote or robotic operations will be more expensive to build (but perhaps cheaper to operate), similar trends are expected to be applicable

RESULTS

The curve shows a broad near-minimum in unit installed cost between 2000 to 8000 MTHM/year. The optimum size for a light water reactor (LWR) spent fuel reprocessing plant is ~7000 MTHM/year. The unit installed cost of such a plant is $1040/kg (in 2002 dollars). However, the unit installed cost of a plant with a throughput capacity of 2000 MTHM/year (i.e. 2/7th of the capacity) is only ~60% higher. For plant sizes less than 1000 MTHM/year and those greater than 10,000 MTHM/year, the unit installed costs vary remarkably with changes in plant capacity. For example, the unit installed costs for 500-MTHM/year and 2000-MTHM/year plants are $4680/kg and $1645/kg, respectively, while the capital costs are $2.29B and $3.29B, respectively.

Dual-line plants are about 50% more costly than single-line plants. Their increased reliability factor may offset a significant amount of the initial larger capital cost. Associated waste processing facilities are about 30% of the cost of a single-line reprocessing plant. The capital cost of a dual-line reprocessing plant with waste treatment systems for dispositioning spent LWR fuel at the rate of 2000 MTHM/year is estimated at ~$6B. Capital recovery amortized over a 30-year period (assuming a 5% interest rate and no inflation) indicates a capital cost component of $193/kg for reprocessing at this scale.

REFERENCES

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