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Literature Survey on Construction Cost Estimation of Hot Cell Facility

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1. Introduction

One of the non-reactor facilities, the hot cell facility, faces a challenge in obtaining reliable reference and baseline data for construction cost estimation compared to nuclear power plants(NPPs). This difficulty arises not only from the relatively limited construction experience available for hot cells as compared to NPPs, but also because the design, configuration, and dimension of each hot cell are all different depending on its development background, purpose, and materials handled. Hence, for the hot cell facility, establishing a generalized model for cost estimation is not easy due to the inconsistencies and estimating issue of construction costs for hot cell facilities remains an active engineering research topic both domestically and internationally.

In this study, we preliminarily survey literatures on construction cost estimation of hot-cell facility at the initial stage of design to make foundational data of future development of domestic hot-cell facility.

2. A Cost Estimating Example of Mu*STAR ADSR Fuel Conversion Facility

Globally, it has been not easy to find literature regarding the construction cost estimation of hot cell facilities. Among the collected publications, one is a cost estimation report on a fuel conversion facility of Mu*STAR ADSR published by ORNL(Oak Ridge Nat. Lab.)[1]. Mu*STAR ADSR(Acc.-Driven Subcritical Reactor), one of the subcritical reactor models which requires external neutron source, has been designed to use fluoride salt-based fuel conversed from LWR spent nuclear fuel.

Construction cost estimation of the fuel conversion facility was performed by physical dimension method and based on three practical examples of hot-cell facility: DTS(Dry Transfer Sys.), SPL(Sample Prep. Lab), FMEF(Fuel & Mat. Exam. Facility) and one expert advisory, as shown in Table 1.

Assuming the area of the hot cell facility is between that of the SPL and FMEF, the construction cost for the fuel conversion facility is estimated to have a range from a minimum of \$100 million to a maximum of \$1 billion based on the unit cost(total facility area costs) of the reference hot cell facilities, between \$2,000 and \$20,000 per square foot. Particularly, expert insights suggest that recent construction costs for hot cell facilities are nearing \$20,000 per square foot, indicating that domestic hot cell facility construction costs may also reflect high total facility area costs. As a result, since construction costs will vary depending on the design and size of the hot cell, if we conservatively assume that future domestic hot cell facilities have an intermediate area and total facility area cost between the SPL and FMEF, it is carefully necessary to select the unit cost(facility area cost) by considering design, dimension, configuration of the hot cell facility.

3. Cost Estimating Studies on Reprocessing Facility Constructions

As other relevant studies, research on cost estimation for reprocessing facilities, which can be considered similar to hot cell facilities, can be found. The surveyed research literature estimated the construction costs of reprocessing facilities based on the scaling factor method, which can be expressed as follows.

$$Cost_{new} = Cost_{past}\left(\frac{Capacity_{new}}{Capacity_{past}}\right)^{n},$$

where n is a scaling factor(SF). Haire argued that for aqueous reprocessing facilities, a SF of 0.1 is appropriate for small processing capacities, while a SF of 0.9 is suitable for large processing capacities[2, 3].

In addition, Carter also suggested that a SF is quietly low for small processing capacities, based on the fact that there was almost no increase in construction cost even though design of electrochemical reprocessing facility was modified(21.3 MT/y → 70 MT/y)[4].

Although these two arguments might seem invalid by engineering intuition, as they contradict the established economical notion that facility capacity and unit production cost are inversely related, they may be reasonable because hot cell facilities are often designed with over-specifications to ensure safety and conservatism. Therefore, it is believed that both studies provide significant implications in the field of facility design and cost estimation and they need more baseline data and reviews for the result verification, as they present important results that challenge conventional engineering intuition and insights.

Meanwhile, Bunn reported that if the reprocessing capacity of a hypothetical facility is between half as big and twice as big as an existing facility, a SF of 1.0 is used and a SF in the range of 0.6-0.7 is used when the scale ratio is highly larger but less than 50[5]. Also, he used a

Table 1. Recent studies on construction cost estimation of hot-cell facility

No	Publisher (or Researcher)	Year	Facility	Features & Conclusions
1	ORNL[1]	2019	DTS (Dry Transfer Sys.)	● hot-cell area: 8,300 ft^2 ● hot-cell area cost: 11,000 $\$/ft^2$
2			SPL (Sample Prep. Lab)	● hot-cell area(total facility area): 900 ft^2(43,500 ft^2) ● hot-cell area cost: 83,000 $\$/ft^2$ ● total facility area cost: 2,000 $\$/ft^2$
3			FMEF (Fuel & Mat. Exam. Facility)	● hot-cell area(total facility area): 9,000 ft^2(215,000 ft^2) ● hot-cell area cost: 65,000 $\$/ft^2$ ● total facility area cost: 3,000 $\$/ft^2$
4			SRNL Advisory	● total facility area cost: 20,000 $\$/ft^2$
5	DOE (Haire M. J.)[2,3]	2003	Aqueous reprocessing facility	● SF for reprocessing facility of small capacity: 0.1 ● SF for reprocessing facility of large capacity: 0.9 ● Limitation: cannot apply to the medium capacity
6	DOE (Carter J. T.)[4]	2010	Electrochemical reprocessing facility	● modifications of facility design (21.3 MT/y → 70 MT/y) cannot affect cost rising because of the small reprocessing capacity. (SF for reprocessing facility of small capacity is close to zero) ● similar with Harie's conclusion
7	M. Bunn[5]	2016	Aqueous reprocessing facility	● SF ($\times 0.5 \leq$ reprocessing capa. $< \times 2.0$): 1.0 ● SF ($\times 2.0 <$ reprocessing capa. $< \times 50$): 0.6-0.7 ● Based on 50 MT/y facility, SF of 800 MT/y facility, 0.85, is applied as a practical estimation example

SF of 0.85 in practical case of cost estimation for 800 MT/y facility based on 50 MT/y facility.

Consequently, all three studies suggest that a SF greater than 0.6 should be used for estimating the construction costs of the high-capacity facilities, and it is considered that more reference and baseline data be needed for verification.

4. Conclusions

In this paper, we preliminarily survey literatures on construction cost estimation of hot-cell facility at the initial stage of design to make foundational data of future development of domestic hot-cell facility. For the construction cost estimation, it was founded that physical dimension method and scaling factor method were utilized.

In study result based on physical dimension method, although the cost range between 2,000 $\$/ft^2$ and 20,000 $\$/ft^2$ is too broad, being tenfold, and the accuracy of the figures may vary significantly due to domestic conditions, we obtained important baseline data for construction cost estimation of the hot-cell facility.

Also, in study result based on scaling factor method, we can find a new engineering insight for utilization and baseline range of SF depending on capacity of the reprocessing facility.

However, overall, the number of reference sources is not only insufficient, but also results of both the physical dimension and scaling factor methods show a wide range of values, making it difficult to use them as reliable and valid foundational data. Thus, it is highly considered necessary to develop more detailed and specific strategy, framework, methodology for the construction cost estimation suited to domestic conditions (e.g. development purposes and concepts of hot cell facility, phase of design, *etc*).

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