IMPACT ON FUEL CYCLE COSTS OF CONVERSION TO LOW ENRICHED URANIUM FUELS

KEVIN ALLDRED, NIGEL MOTE
International Nuclear Enterprise Group, LLC
322 Kent Road, New Milford, CT 06776, USA

ABSTRACT

Strenuous efforts are being made worldwide to convert research reactors to use LEU fuels instead of HEU fuels, in particular by USDOE's GTRI program. Considerable progress has been made with more than fifty reactors converted as of the date of this paper, and many more expected to do so in the next several years. The number of reactors converted is now sufficient for meaningful statistics relating to the conversion process to be compiled and analyzed.

One of the key issues for the operators of research reactors planning or considering conversion of their reactors is the impact on operating costs, and in particular on fuel cycle costs.

This paper examines the experience to date with reactor conversion and compares fuel cycle costs before and after conversion. Key items affecting fuel cycle cost are analyzed to provide an informative empirical guide that will be useful to guide decision making during the conversion process.

1. Introduction

Strenuous efforts are being made worldwide to convert research reactors to use low-enriched uranium (LEU) fuels instead of highly-enriched uranium (HEU) fuels, in particular by the USDOE's GTRI program. Considerable progress has been made with more than fifty reactors converted as of the date of this paper, and many more expected to do so in the next several years.

A critical issue for reactors that undergo LEU conversion is to maintain the performance of the reactor, by changing to new fuel types with higher uranium densities, by reconfiguring the core and so on. The discussion, as evidenced by the papers presented at the RRFM and RERTR Annual Meetings, etc., focuses on the impact of conversion on the technical and safety parameters of the reactor, with particular attention paid to maintaining neutron flux density. As an example, the recent paper by Glaser [1] took as its reference the INFCE criterion that "any loss in the overall reactor performance" such as flux per unit power "should not be more than marginal".

Little attention is paid in the published papers, however, to the impact of conversion on the economics of reactor operation, even though this is clearly important to reactor sustainability after conversion. The decisions made during the conversion process will potentially shape the economics of reactor operation through the impact they have on both the cost and revenue aspects. Issues such as the cost of fuel acquisition and spent fuel management, and operating parameters such as the cycle length, impact the operating costs, while changes in neutron flux densities and irradiation facilities may change the functional capability and potential revenue generating capability of the reactor

Economic sustainability is a major challenge for many research reactors worldwide. In a funding climate where direct governmental support for many facilities is diminishing, all

changes and new activities have to be evaluated in terms of their impact on the economic future of the reactor. In that context, a systematic evaluation of the potential impact on the economics of operation would be a logical part of the planning for the conversion of a reactor to use LEU fuels, with the results of that evaluation taken into account in the development of the criteria for fuel design and other decisions. This would help to mitigate any negative economic impact.

The published literature provides little insight into the impact of conversion on the economics of operation, and each reactor operator must construct its own framework for such an assessment. An understanding of whether, and how, reactor conversion has affected operating costs of those reactors that have already converted, or are at advanced stages in the planning for conversion, will help inform those reactor managers that are currently considering conversion. The purpose of this study, therefore, was to provide an initial examination of the impact on the economics of operation of converting a research reactor to use LEU fuels, and from that examination to determine whether any general patterns are evident in the conversion projects to date.

2. Framework for the Economic Analysis

The current study project began with anecdotal evidence that, at least in some cases, the special fuel designs required for reactor conversion were more expensive to fabricate than the HEU fuels used prior to reactor conversion, and that the fuel fabrication costs had not been formally included in the conversion decision making.

In order to provide a more comprehensive view of the economic impact, a questionnaire was developed and combined with a telephone survey to elicit information about the impact of conversion on reactor operations and the costs of operation. This was supported by a literature search, primarily from papers to RERTR and RRFM Annual Meetings.

Obtaining statistically comparable data presented some difficulty. For example, in the case of fuel acquisition, direct comparison of pre-conversion and post conversion costs was often not feasible because of the rapid changes in the international market prices for enriched uranium, the irregular, infrequent purchases of HEU fuel prior to conversion and, in certain cases, the commercial confidentiality of information. In addition, it is not universally safe to assume that HEU fuel would have continued to be routinely available under the preexisting terms and conditions had the reactor not been converted.

Information that was easier to collect included issues such as changes to the operating cycle length, re-configuration of the core, changes in reactor power level and changes in spent fuel discharges.

The questionnaire and the telephone survey were designed to cover all the main issues noted above, as well as to solicit other items of importance to the respondent reactor managers. The data was tabulated to allow comparisons and conclusions to be drawn, without compromising any of the proprietary information in the individual responses.

3. Results of the Analysis

1. Most reactor operators surveyed did not use explicit economic optimization criteria during planning for conversion, see Figure 1. Those that did were primarily those with a strong commercial focus, for example [2].

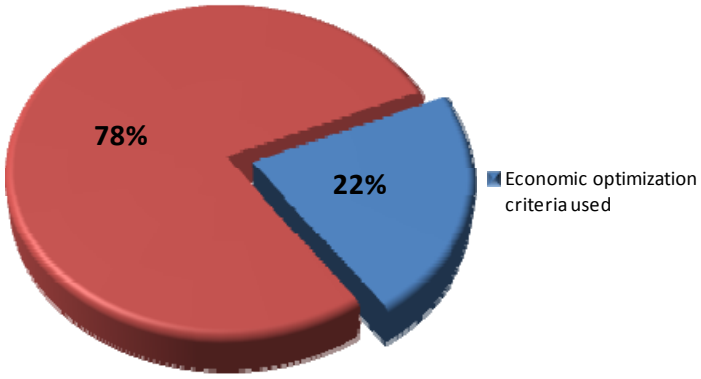

Figure 1: Use of Economic Optimization Criteria during Conversion

2. Increased operational costs were reported only by those reactors that refuel during normal operations. Smaller reactors (< 0.5MW) reported little or no requirement to purchase or dispose of fuel post conversion, and therefore no quantifiable impact on operating costs following conversion. In all cases surveyed, these smaller reactors were able to maintain the neutron flux densities, shut down margins, and other technical parameters needed to fulfill their mission, and so are not vulnerable to changes in income as a consequence of LEU conversion.

3. Similarly, those reactors that are primarily involved in activities that are not sensitive to the exact flux provided, for example, teaching or geochronology, were not sensitive to the potential reduction in flux and this was, thus, not a “flux penalty”.

4. For the larger reactors, there were no trends or rules that applied to all. Differences between facilities dominated the analysis, even for reactors that use similar fuel types.

5. Although an unavoidable reduction in flux density is often discussed as a likely consequence of conversion to LEU fuels, this was not supported by the data. As many reactors maintained their neutron flux density as suffered reduced neutron flux densities, see **Figure 2**.

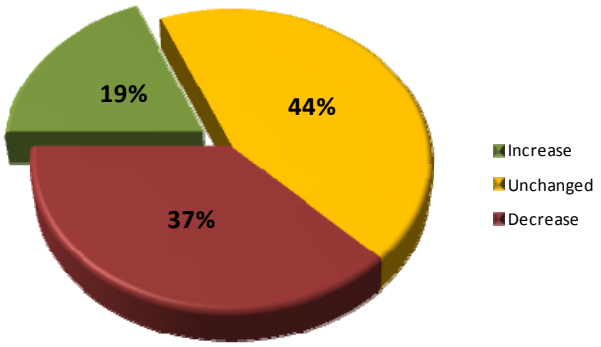

Figure 2: Change in Neutron Flux Density Following Conversion

6. In certain cases a reduction in neutron flux density as a consequence of conversion was dismissed as insignificant by the reactor manager. In others, an increase in reactor power has been used or proposed to maintain the neutron flux densities

required for the reactor's planned activities. The planners for the SAFARI reactor, for example, have restating the criteria for conversion in terms that include "limited loss (preferably none) in the maximum production capacity", and "no increase in the fuel cost per production unit" [2]. These observations suggest that preserving neutron flux density per unit power is less relevant in today's context than preserving the capability to execute a strategic plan or reactor mission.

7. Some reactor operators reported increases in the fuel acquisition costs, and in the costs of fuel fabrication. As noted above, however, it is difficult to isolate the reasons for the cost increases. Infrequent purchases of fuel prior to the date of conversion mean that changes in the market cost of enriched uranium cannot be separated from the costs of fabrication at this stage of the analysis.

8. Several reactors reported an increase in fuel acquisition costs because of increased consumption of fuel assemblies, due either to a lesser duty cycle for the fuel, or to the need to increase reactor power to offset a reduction in neutron flux density. An increase in the number of fuel assemblies consumed not only increases the new fuel procurement costs, but also potentially increases the spent fuel management costs.

9. Spent fuel management costs were recognized as a very significant issue, but for several of the reactors surveyed, the true cost of spent fuel management was masked by the Foreign Research Reactor Spent Nuclear Fuel (FRRSNF) Acceptance program. For the period the FRRSNF program is in operation, many reactor operators are not exposed to increased costs of spent fuel management, either on the basis of number of fuel assemblies discharged, or because of the choice of fuel meat. However, at the end of the program, a step change in spent fuel costs is expected, with the potential to threaten reactor sustainability. One of the respondents noted that that this could become a disincentive for some reactors to convert. This observation suggests that an analysis of the spent fuel management costs would be of particular significance in planning conversion, and it also creates a strong linkage between the FRRSNF acceptance and GTRI conversion programs.

10. There was no clear picture on the impact of security costs. Although in principle, removal of all HEU from a reactor site might be expected to reduce the costs of security, this was not supported by the limited data available. In most cases, changes and upgrades in nuclear facility security standards over the past several years have masked the savings that may have resulted from conversion to LEU fuel.

11. Conversion can affect regulatory costs, with two of the respondent reactors noting that proposed increases in reactor power to offset a reduction in neutron flux density would result in additional regulatory work and potential costs.

4. Conclusions and Recommendations

Conversion to LEU fuels can significantly impact the economics of reactor operation in terms of both revenues and costs. Therefore, strategic planning and economic analysis should be integral to the planning for the conversion of a research reactor. Such an analysis would highlight issues that are potentially relevant, and provide information on how they might be optimized to reduce, or avoid, a negative economic impact. For example, at what point does a change in the flux density become economically or functionally relevant? A cost benefit analysis based on the reactor's strategic plan would show at what point a reduction in neutron flux density becomes a flux penalty, and whether it is relevant to the future sustainability of the reactor. The analysis would also quantify the level of increased cost and effort that can be tolerated when correcting the problem.

In this regard, economic *sustainability* of reactor operations according to the strategic and business plans for the reactor would be a more valuable means of determining conversion priorities than isolated technical criteria such as neutron flux density per unit power.

The current analysis should be developed further, both to improve the statistical analysis of the economic impact of LEU conversion, and to develop a mechanism and guidelines for assessing the economic impact. This would assist research reactor operators who are planning to convert their reactors to use LEU fuels to fully understand the potential impact of conversion on their operating costs and to optimize their plans to ensure sustainability.

5. References

[1] Alexander Glaser, *Performance Gain with Low-Enriched Fuel and Optimized Use of Neutrons*, The 29th International Meeting on Reduced Enrichment for Research and Test Reactors (RERTR) September 23-27, 2007, Prague, Czech Republic

[2] WE Stumpf, AP Vermaak, and G Ball *Key Considerations in the Conversion to LEU of A Mo-99 commercially producing reactor: SAFARI-1 of South Africa* 2000 International Meeting on Reduced Enrichment for Research and Test Reactors October 1 - 6, 2000 Las Vegas, Nevada, USA