SEVERAL REMARKS ON THE FUEL CYCLE ECONOMY

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ABSTRACT

Present paper deals with some aspects influencing significantly cost of nuclear fuel and possibilities of its usage in optimal fuel cycle technology. Our discussion is focused on the phase of fuel procurement that means financial parts of the contract as well as its technical Appendices. Typically the fuel fabrication price is taken as the main economy indicator; nevertheless also many other financial and technical features of the contract must be taken into account in order to reach the best price of electricity sold into public energy grid. Our experience from several international tenders shows that the consistent complex of commercial and technical parameters of the contract is necessary to achieve optimal economic results and prepare proper conditions for advanced fuel cycle technology. Among those essential characteristics are payment conditions and schedule and extent of vendor's services and assistance to the operator. Very important role play also technical parameters, as safety and operational limits, influencing loading pattern quality and operating flexibility. Obviously also a level of operator's fuel cycle technology is a crucial point that is necessary for usage of technical quality of the fuel at the power plant.
The final electricity price, produced by the plant, and uranium consumption are the only objective criteria to evaluate economic level of the fuel contract and the fuel cycle at all.

INTRODUCTION

The fuel cycle cost is one of substantial parts of the NPP economy. As far as a fuel management is concerned there are two essential areas influencing its economic features. The first one represents the fuel procurement (or a front-end price) and the second one is the fuel management technology. Of course, also back-end expenses are significant. Nevertheless back-end strategies are in most cases based on the "wait-and-see" policy and back-end financing is thus usually solved through special funds. Even there is ongoing discussion about the spent fuel: is it a dangerous and troublesome waste or a promising source of energy? From that reason we have decided not to include the back-end problems into the present discussion and focus only on the fuel procurement and selected technical/organizational aspects plying important role in the framework of the fuel management technology. Both of them have to be treated as commercial and technical challenges.

The base and framework for that phase is a contract with the vendor comprising prices of fuel and materials as well as conditions and extent of vendor's supply and services. There are different types of contracts – they may be typical fabrication agreements or more complex ones comprising procurement/providing of nuclear materials and different extent of service/assistance involvement of the vendor. Nuclear fuel leasing agreements are somewhat specific so that they will not also be included into our topic.
Main components of the total fuel price are the following:

a) nuclear materials (including enrichment)
b) fabrication and transport
c) services and assistance to the NPP

The first item is usually result of the commercial strategy (and smartness) of the fuel user. In addition to that there are specific rules and regulations for nuclear material and pre-fabrication service procurement in the European Union. For that reason we would like to concentrate on the fabrication type of the contract, that means fabrication and vendor services.
The most popular and visible feature of the commercial part of the contract is the net fabrication price. Nevertheless that is only a part of the contractor's expenses. Very important contribution to the final fuel price play conditions of the delivery and a regime of payments. Also a general schedule, which includes leading times of material/by-product procurement and delivery as well as the production process itself, may have a significant impact on the price. The NPP operators as a rule use credits to finance their fuel and material purchases and thus direct payments and taxes are the final sum of money that the NPP operator is due to pay. In other words a time-transformed value of money has to be evaluated very carefully.
Let us now give a simple example. In some contracts the customer pays after delivery. In contradiction to that other contracts need partial payments in advance. The last is not a cheap practice (to the customer).
Very specific but at the same time extremely difficult task represents a problem of a long-time price development. Quite unpredictable is a course of nuclear material price. We dare say that nobody would expect uranium prices going up so dramatically during last few years. The long-term uranium contracts versus spot-market purchases are permanent tasks of a procurement art. In addition to that there are problems with the long-time fabrication price escalation (escalation formula) and, of course, setting the zero (reference) date.

FUEL FEATURES AND LIMITS

It is obvious that safety limits are key parameters for licensing while operating limits define framework for a quality and flexibility (that is also economy) of the fuel cycle. Theoretically the fuel user may have a choice between more conservative limits or less margin-containing limits. Of course his decision concerning a way he will adopt must be consistent with his technical ability to utilize the more promising limits, in other words the customer has to evaluate which parameter margins he can afford.
If both (more allowable limits and operator's technical ability) are consistent and applicable at the NPP, it enables to design better core patterns and operate the plant in modes that are more favorable from the point of the energy grid requirements (including the load-follow modes). The possibility to design the very low leakage cores improves the NPP economy and at the

same time helps to suppress the pressure-vessel irradiation damage. Higher NPP operating flexibility also means potentially higher prices of electricity sold during peaking regimes.
On the other hand the limits defined by the fuel vendor must be reasonable. Concerning that point the CEZ company has for a long time adopted useful practice that the fuel vendor is responsible for the first core design when a new or modified fuel is being implemented. In that way the vendor (through his own core design) gives evidence that his limits are realistic and achievable.
Among warranties providing by the vendor, the warranty of achieving rated reactor power is of a special importance. If the following loading patterns, after the first one performed by the vendor, are not designed by him, a reliable procedure how to verify the reactor power must be agreed between the parties.
Speaking about the fuel management technology, also methodology and procedures of performing core design and its safety assessment (RSAC) has to be mentioned. Especially all inaccuracies or parameter-errors need special attention. It is necessary to correlate their interpretation with the methodology used. The last is very important for both the fuel licensing as well as for the core design and subsequent safety assessment.

VENDOR'S SERVICES AND ASSISTANCE

The CEZ company has a wide experience with introducing new or significantly modified fuels. This practice needs a very close and good cooperation with the fuel vendor. Every such a step requires the fuel re-licensing. In-spite of the fact that the Czech institutions are widely and intensively involved in the safety analyses, anyway the proper Safety Analysis Report, required by the Czech Regulatory Authority, can not be made without a close cooperation and assistance of the vendor. That cooperation consists of several steps:

a) substantiation of the new fuel (materials and design),
b) theoretical justification of its basic features,
c) wide range of safety analyses, at least in the frame of agreed parts of the Safety Analysis Report,
d) transfer of operating experience gained with the offered fuel during its trial or routine use at other NPPs, that is organized or supported by the vendor,
e) support/assistance to implement the new fuel at the customer's NPP (procedures, personal assistance,...),
f) assistance to the fuel user during fuel licensing and first period of implementation at the plant
g) transport and handling services and assistance (including fuel shipping conditions and arrangement)

All of them may help or cause many problems to the customer or at least they may cost a pretty good sum of money. Some of them have been mentioned in the present paper.
In addition to those mentioned above there is one more very valuable item, which price is difficult to estimate, and it is vendor information service and its activity in collecting and evaluating data from other NPP operators using its fuel. Based on the contractual agreement the CEZ provides operating data to the vendor and the vendor provides feedback for his customers. This practice means that fuel-user seminars are regularly organized for Czech and Slovak NPPs.

QUALITY ASSURANCE

No doubts that high operating reliability is a crucial condition of the good operating safety and economy. Of course, any fuel contract comprises warranties - but to be realistic, it is reasonable to realize that they are more or less only means of psychological pressure towards the vendor to supply the quality product. If problems with the fuel would arise, the NPP operator's actual loses are much greater than any remedies he can obtain from the vendor. Every reactor operator thus requires the fuel with reasonable (not maximal) margin in mechanical properties up to very high burn-up levels. Methods, devices and criteria used for fuel leakage monitoring and testing during operation and after shut-down have to be discussed in details between the vendor and purchaser. The fuel warranty and operating limits must be consistent with the NPP leakage-detection facility and procedure. No wonder this issue is a real never-ending story.

The CEZ Company has very wide and very good experience with obtaining and storing the data about its fuel in use. In principle there are two databases. The first of them has been created in cooperation with the fuel producer. It keeps full information on materials (both nuclear and non nuclear) used during the whole production process. Also all fabrication steps and results of production technology tests are monitored and recorded. That practice enables (to both parties) to monitor and evaluate the production and shipping process in details and to document the features of every component as well as of the final product. Our experience during the sufficiently long period has entitled this practice and it is beyond dispute it has contributed to the high fuel quality and subsequent excellent fuel operating record. Obviously that task has cost some money but it is a necessary base for keeping the production process under clear control.

The second database stores physical data necessary for fuel accountancy and safeguard purposes coupled with detailed operating data. In that way we are able to trace and describe complex life history of any fuel assembly starting its production, through its arrival at the NPP territory up to placing it into interim spent fuel storage. They provide all necessary data when the diagnosis of the failed assembly would be done.

Generally it is possible to claim that the number of leaked fuel assemblies at the Dukovany NPP since 1985 has been lower than the typical figure in the international scale. We are convinced that this positive situation is a result of both very high fuel quality as well as careful fuel management and responsible operating.

CONCLUSIONS

Let us summarize that fuel utilization at the NPP has two main phases or approaches influencing the NPP results. The first one has just been discussed and it can be named as the commercially-technical. The next one comprises the fuel management technology at the plant and that can be indicated as technically-organizational. It is obvious that its framework has been preset in the fuel contract as we discussed above. And speaking about the NPP safety and economy we have also to comprise the problem of the service-life. One example – sufficiently lowered neutron leakage from the core implies good production economy and through suppressed pressure vessel irradiation prolongs the service life of one of non-replaceable part of the power plant. Both are achievable only with the quality and reliable fuel and properly set limits that are efficiently utilized by advanced fuel management technology.

The only objective and credible economic criterion to evaluate and compare proposals of different suppliers is the final price of produced electricity. It comprises all contract commercial and technical aspects and reflects the NPP operator technical possibility and ability. When evaluating the fuel cycle efficiency, the criterion of consumption of uranium spent for reactor production is introduced.
The fuel management technology with the stress on the core design optimization will be a topic of the next paper.