Proceedings of the 15th International Symposium on the Packaging and Transportation of Radioactive Materials PATRAM 2007 October 21-26, 2007, Miami, Florida, USA

WHAT SHOULD RAM (RADIOACTIVE MATERIAL) TRANSPORTATION ECONOMICS BE GOVERNED BY?

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ABSTRACT

There is no simple and/or single approach to RAM transportation economics. The diversity of situations, depending on the materials transported, their quantities, the transportation modes needed and the countries concerned, makes it difficult to define a model of how economics of RAM transportation work.

However, some specificities can be noticed that apply to most of them:

- Frequently, if not always, transportation is economically only a part of a deal involving one or another activity of the nuclear fuel cycle from mining uranium to reprocessing used fuel and/or disposing of final waste. The value added by transportation generally represents a small part of the added value at each step.
- The buyer of a RAM transport generally includes it in the product or service he is trading and may be only interested in the most rapid, cheapest and safest way to transport.
- On the supplier side, rapid, cheap and safe are conflicting factors and the balance of these aspects usually may result in a sophisticated optimization applied to equipment and operations.

Of course, national and international regulations and standards play a key role in determining the optimum which is then an economic optimum with regulation constraints. These constraints are more stringent in the back-end of the fuel cycle and heavily influence the dedicated "transport system" to be developed. In the front end, a more open and competitive market is observed. Both cases are analyzed, pointing out the necessity and the global benefit of always minimizing the risks of transportation related to industrial operation and general public and media concern.

This paper comments the new approach of optimizing transport security developed within the AREVA group (and described in another paper) as a new global optimum, including economics.

INTRODUCTION

You could hardly find a field in the present world's economy that would not include a transportation component. Whenever we buy a product, we pay for the product itself of course, but we also pay for the transport which brought the product close to us.
Lots of examples show that transport can rarely be considered as an economic activity by itself, but often appears, on the opposite, as an integral part of the economy of the transported product. At the same time, the economic weight of a transportation component can be extremely diverse from one product to another. Several reasons can explain this:

- The physical or chemical properties of the product itself (specific hazards, fragility, perishable nature…) may impose various constraints on the transportation activity, such as compliance with specific regulations or the need for dedicated and sometimes sophisticated and expensive means of transportation. Radioactive material transports are a good example of this.
- The particular features of the "spatial matrix", describing the links between production and delivery locations, will shape the mode (or mix of modes) to be used, distances to be covered and eventually costs to be borne. The economy of radishes, which grow everywhere, will be less impacted by transports than, say, bananas or pineapples which grow specifically near the equator,
- Along with the product characteristics, different industrial production systems may impact transportation means and methods. In the present globalized world, each industrial field has developed its own configuration, integrating both production and transports. A globally centralized production will imply numerous international transports, but will fully take advantage of economies of scale. Regional productions, serving regional markets will minimize transportation costs. A "specialized" regional production will benefit from comparative regional advantages such as industrial synergies or lower manpower costs.

Regarding economics and whatever the actual weight of the transportation component is, one thing applies in most cases: transport costs appear as a marginal part in the overall cost of the product. What is saved there can be considered as producing either an additional financial benefit or an increased competitiveness in the market. Therefore a pressure generally exists to minimize transportation costs by all available means. This is the reason why, for instance, oil pipeline diameters have grown to over 32 inches, why some oil tankers are so big and why numerous old ships under "flags of convenience" still transport so much oil with an underpaid crew. Some adverse consequences of the latter fact are known to everybody, and we probably should bear them in mind when speaking of safety concerns in our own field!

NUCLEAR FUEL CYCLE BACK-END TRANSPORTS

These transports deserve a special part of the discussion undertaken here. Because of what happens in the reactor, unloaded used fuel contains huge amounts of radioactivity that are not comparable with what was handled before loading. Since the beginning of commercial nuclear power, safety concerns have been largely addressed by the international nuclear community. This has resulted in a consistent set of recommendations and regulations, applied in each country's legislation and covering all kinds of RAM handling and transportation. There is no need to mention how stringent they are when high activity (Bq) and/or high specific activity (Bq/g) are

involved, like it is the case in the back-end. At the same time, non-proliferation concerns have put another burden on nuclear fuel cycle activities, which results, for transportation, in both physical protection and information classification requirements. Again, this applies to back-end material with greater constraints.
These aspects suggest that guaranteeing safety and physical protection, by complying with the related regulations, will leave, in the back-end, little room for economic and market laws to actually apply. A range of additional arguments can confirm that safety and security are here really governing factors:

- Because the non-proliferation regime is the result of, and depends on, international treaties, agreements and organizations, public authorities in each country are very much involved in authorizing and monitoring all transports of sensitive nuclear materials. In particular, no operator can proceed with such transports, unless duly agreed and authorized by national authorities, which generally does not extend to other countries. As a result, very few specialized actors operate in this market, thus limiting competition.
- Furthermore, for the time being, with the exception of Sweden, only countries engaged in a closed fuel cycle policy, operating or using used fuel treatment facilities, have been implementing back-end transports on a significant scale. As shown on Fig1, this represents only a limited part of the fuel discharged from LWR reactors.

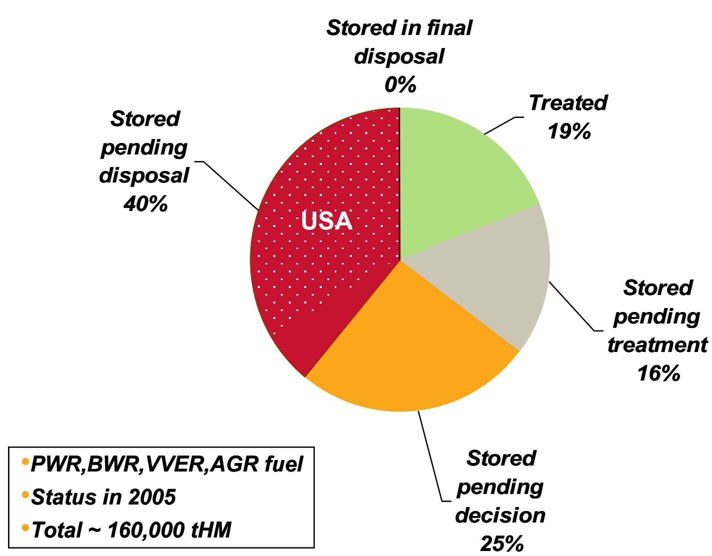

Figure 1. Current back-end policy break-down

- On the other hand, it must be noted that spent fuel transportation market is far from having reached its potential size, as all the unloaded fuel will have to be eventually transported either to a final repository (open fuel cycle) or to a treatment facility (closed fuel cycle, probably including more and more recycling in future fast neutron reactors). So, in the medium to long term, back-end transports will altogether involve the accumulated used fuel pending disposal or decision (some 130 000 tons of Heavy Metal as of today), plus some 7 000 tHM/year arising currently from existing reactors, plus the additional used fuel resulting from the "nuclear renaissance". As a result, sooner or later, this market is likely to increase worldwide tenfold or more, including national transports where and when domestic treatment plants or repositories are available, but also international transports where international solutions are implemented.

- While more actors will probably be involved in such a situation, the structure of the activity will follow the model of what has been implemented with success for four decades in France, where over 30 000 tHM in used fuel have been transported to the La Hague facility, with an outstanding safety record. This example and the related experience have shown that this activity cannot be limited to simply commissioning transports and handling used fuel on industrial sites. It has been necessary to develop and operate a comprehensive "Transport System" involving both "hardware" in terms of dedicated transport equipment (casks, heavy haul trailers, specific railcars) and inter-modal or interface facilities, but also some "software", i.e. specific activities with their own expertise, tools or even workshops and facilities (packaging design and licensing, packaging and other equipment maintenance, tracking systems and crisis management tools).

Safety and physical protection concerns have thus given shape to what has become a back-end transport industrial activity. At the same time, it must be acknowledged that opposite forces apply to the economic side of this activity:

- There is a general trend of globally improving safety features in design and operation. This is constantly discussed with Safety Authorities during licensing procedures. At the same time, nuclear utilities tend to extract more and more value from the nuclear fuel they use: longer campaigns and higher burn-up require higher enrichment of fresh fuel and produce increased radioactivity of used fuel. These two aspects induce a trend in increasing transportation costs.
- On the other hand, an important part of the transportation costs is devoted to the required dedicated equipment and its operation (typically 50%). This is where optimization can take place by e.g. economically improving designs, adjusting maintenance operations and mastering logistics.

All in all, the operation of a mature "Transport System", as it is in France, proves to serve the implemented recycling policy with a cost-effectiveness which is probably comparable with what happens in other energy sectors, such as oil or gas industry where transports are reported to represent 5 to 10% of the added value.

NUCLEAR FUEL CYCLE FRONT-END TRANSPORTS

The arguments showing the importance and the economic impact of safety and physical protection concerns for the back-end transports, while not disappearing, lose much of their strength in the front-end. Much lower radioactivity, along with reduced proliferation sensitivity, allows for simpler, industrial type, packaging which can be transported by common, non-dedicated transportation equipment.

On the other hand, front-end transports involve much larger volumes, first because all reactors in operation worldwide need to be supplied with fuel, but also because several steps of transformation before supplying reactors usually imply transportation of intermediate materials. Regarding LW Reactors, when 1 kgU as enriched UO_2 is loaded in the reactor, coming from a

fabrication facility, 1 kgU as enriched UF6 has been transported from an enrichment plant, 7 to 10 kgU have traveled there as natural UF6 from a conversion plant and the same amount came to the conversion plant as uranium concentrates from the mine. Annually, some 100 000 tHM in various forms are transported throughout the world. No need to insist on the specific "Spatial Matrices" and industrial features for each step: mines are principally located in Australia, Canada, Africa, and emerging in Kazakhstan, conversion plants are in North America, Russia, France and still in Great Britain, enrichment facilities essentially in the USA, Western Europe and Russia, while fabrication plants are more distributed worldwide but usually need "just in time" deliveries in order to optimize reactor operation.
So, with its own characteristics, the front-end transportation market can function like a common open market, with normal competition among numerous actors. While the final customers are obviously the utilities that are using uranium in their reactors, the actual buyers of transportation services are commonly providers of fuel cycle industrial services, including traders. As a result, what has been mentioned about incentives to minimize transportation costs applies here to each step of the front-end fuel cycle. Remembering the oil transportation case, it should be verified that there is no detrimental effect on the nuclear industry as a whole. Two aspects can be pointed out in this respect:

- Front-end transports economic weight appears as very small compared to the added value at practically every step, so price pressure on transports should be correctly balanced against their quality, reliability and dependability.
- Other risks, beyond safety concerns, have to be considered and dealt with: principally industrial risks in order to secure smooth and continuous industrial operation and public acceptance risks because maintaining media, local politicians and general public confidence is of paramount importance.

Front-end transports economic weight

Front-end transports economic impact has always been recognized as limited, but it must be noted that in the current situation of climbing prices for natural uranium, this is particularly true. In order to give an idea, an evaluation has been made, based on a set of assumptions concerning current and foreseeable prices for front-end fuel cycle steps and an estimation of related transportation costs. The results are presented on the charts Fig2 and Fig3.

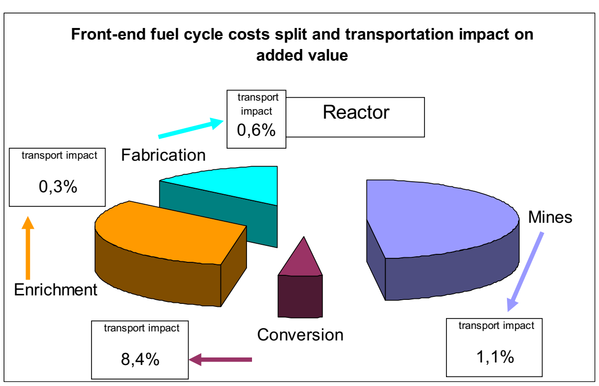

Figure 2. Break-down for 50$/lb U3O8

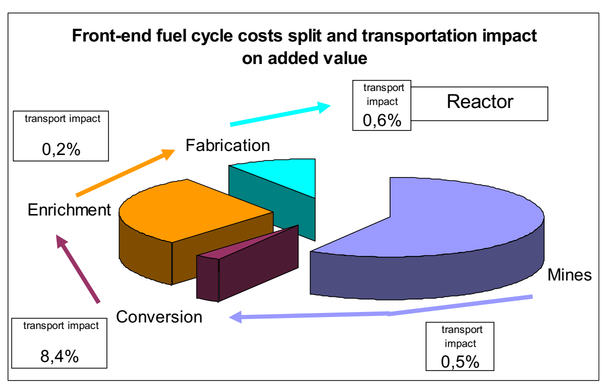

Figure 3. Break-down for 100$/lbU3O8

Two levels have been selected for U3O8 and enrichment costs: 50 $/lb associated with 100$/SWU and 100$/lb associated with 120$/SWU. Typical current costs for the other steps

have been retained. Transportation costs have been evaluated trying to maximize them: a German utility has been imagined buying natural uranium in Australia, conversion in Canada, enrichment in Western Europe and fabrication in Sweden (example cited in 2005 WNA Report). The obtained picture speaks for itself: the global transportation impact, in this worst-case example, is close to 1% for 50$/lbU3O8. The imaginary utility could have saved the equivalent of all the transportation costs by buying natural uranium at 49 instead of 50$/lbU3O8. The figures are even more impressive if a 100$/lbU3O8 cost is allowed for, showing a global impact of only 0.7%.
The conclusion at this point is that the economic pressure to gain on transportation costs will provide negligible results probably not worth the possible additional risks it might induce.

Beyond safety regulations risk analysis

Even if this has to be constantly evaluated, we probably can admit that present transporters of front-end materials are all serious and thoroughly comply with all safety recommendations and regulations. But is this enough? As an example, the chart in Fig4 gives a qualitative image of what is the result of safety requirements for transportation packaging.

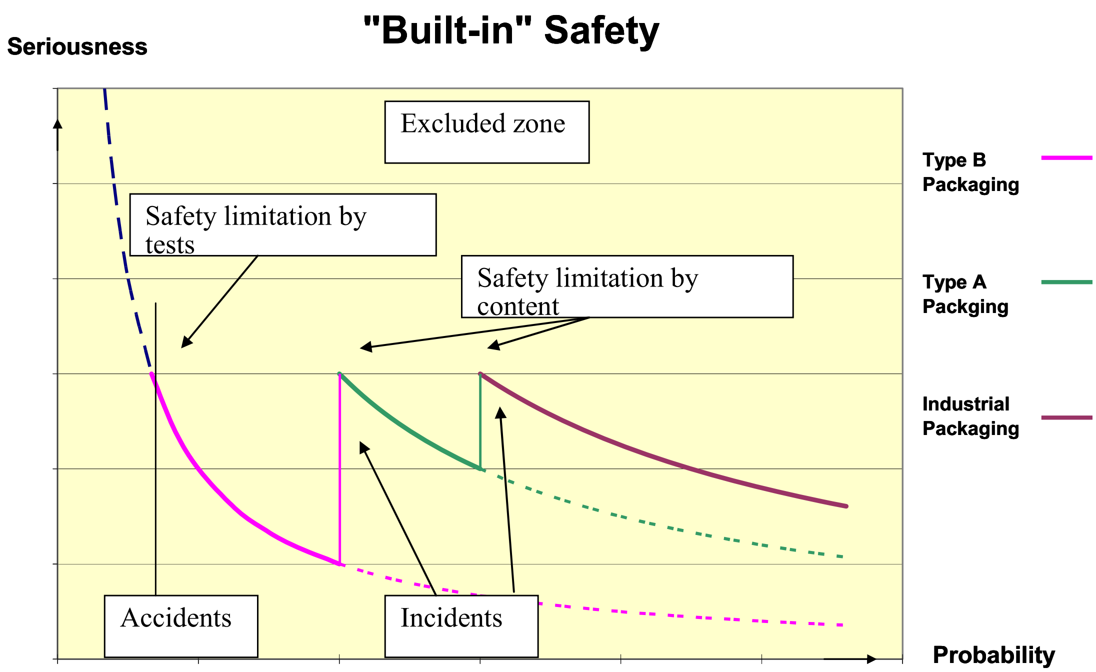

Figure4. Safety protection given by packaging

It is a usual risk-analysis chart (Seriousness – Probability) with curves representing the protection given by different types of packaging. Industrial and type A packagings, while giving less protection, are limited in safety consequences by a limitation of the content in radioactivity (in Bq and in Bq/g). Type B packagings protect from safety hazards up to the limit of accidental situations covered by the related tests they are required to withstand.
Two domains are worth mentioning:

- To the left of the accidental vertical line, beyond design events may occur. They must be dealt with by mitigation actions based on emergency preparedness and crisis management tools put in place and regularly tested during large scale drills.

- To the right of the chart, and under the protection curves, lies the domain at stake for front-end transports: the possible events to be considered here have no unacceptable safety consequences, but may have some impact as far as industrial operation or public acceptance are concerned. The effects of possibly repeated events in these fields are not to be underestimated: they may adversely affect one or another step of the nuclear fuel supply chain by, even temporarily, cutting the links, but also impact, with hardly predictable economic outcome, the nuclear industry as a whole if confidence is lost in the actor's capacity of reliably mastering nuclear transports.

In a specific endeavor, the AREVA Group has decided to fully address the necessity of effectively reducing all transport related risks, with a special attention to the front-end. A dedicated organization, described in another presentation, has been put in place, forming what can be called a global centre of excellence for safe, secure, reliable transports and qualified emergency response. The effort includes gathering human resources with definite skills and expertise, developing a specific methodology, constantly improving practices and communication by taking benefit of the feedback obtained from trainings and occurring events.
Taken as such, this effort has obviously its economic side, but it is strongly believed that possible increased expenses at this stage will largely be paid out by significant improvements and benefits relating to an increased efficiency due to sound and harmonized procedures, optimized logistics, focused sub-contractors surveillance and eventually reduced detriments from adverse transportation events. The economic optimum is very often on the side of a mastered quality.

CONCLUSIONS

Trying to answer the question in the title, the reflections in this paper have shown the discrepancy between back-end and front end RAM transportation economics. In the back-end, safety and non-proliferation requirements impose specific conditions to designing equipment and operating transports. While not leading to unbearable costs, this proves to create such essential results as "built-in" safety, intrinsic reliability and emergency response efficiency of a necessary "Transport System".
The picture is different in the front-end because less stringent requirements allow for fewer costs devoted to safety, although all related regulations remain fully complied with. For the same reason, the market is competitive and transportation costs represent a very small part of the added value, especially if increased prices for mined uranium are considered. In this context, beyond safety risk analysis shows that the lower reliability, acceptable on a strict safety level, may adversely impact the industrial operation of fuel cycle facilities or be detrimental to media and general public confidence.
As a leading Group supplying nuclear fuel cycle services at every step, as well as worldwide, AREVA acknowledges the sensitivity of all nuclear transports. In the context of its own growth, facing new challenges emerging with the nuclear renaissance, AREVA is committed to a program of actions aimed at reducing risks for all nuclear material flows it manages worldwide.