International Nuclear Fuel Cycle Evaluation

INFCE

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ECONOMIC EVALUATION OF REPROCESSING

INTERNATIONAL NUCLEAR FUEL CYCLE EVALUATION

WORKING GROUP 4: Reprocessing, Plutonium Handling, Recycle

Sub Group 4A: Reprocessing

Note by W Marshall

The attached paper entitled, "Economic Evaluation of Reprocessing" has been seen by Dr Tamiya and he is sympathetic to it but there has been insufficient time for the two of us to confer together carefully and therefore it seems best to issue it, in this form from one of us only, as an item for first discussion in Working Group 4A in Vienna 29 November.

W Marshall

INTERNATIONAL NUCLEAR FUEL CYCLE EVALUATION

WORKING GROUP 4: Reprocessing, Plutonium Handling, Recycle

Sub Group 4A: Reprocessing

Economic Evaluation of Reprocessing

Discussion Paper By Dr Marshall

Task 6 of Group 4A is difficult because, to quote Dr Hebel, "We keep talking past one another rather than to one another". Therefore, at our meeting on the 19/20 September we agreed it would be helpful to prepare a parametric study of the economics of reprocessing and thermal reactor recycle, taking into account some necessary but arbitrary figures for breeder reactors in the future. We asked the Technical Secretariat to prepare the outline of such a parametric study and they therefore will be doing that for a future meeting. In addition, however, it seems worthwhile to draw together those parts of our discussions which are relevant so as to expose points where, I believe, we have different judgements.

I must stress that this paper is only a first discussion paper and all the proposals in it should be regarded as tentative. It is an attempt to gather together all views which have been expressed, to me or Dr Tamiya, formally or informally, and present them in a common language which obliges each of us to acknowledge the different judgements made by other delegates. The starting point for this discussion is the simple observation that an economic evaluation of reprocessing must give primary consideration to the use of the end product, namely uranium (available for recycle to the enrichment plant) and plutonium (available for recycle, either to thermal reactors or to fast reactors). We also need to look at reprocessing from an environmental point of view but that, for the time being, we will regard as a separate issue. It follows that an economic evaluation of reprocessing must consider the value of thermal recycle of plutonium and the value of fast reactors and this must be done from an immediate commercial point of view and from a strategic point of view which takes account of resource utilisation arguments.

The main factors which affect our economic assessment have been expressed as

(a) The future national and world needs for nuclear power.

(b) The future availability and price of uranium ore worldwide and to each nation individually

(c) The cost of reprocessing

(d) The cost of fabricating plutonium bearing thermal reactor fuel and its economic benefit

(e) The capital cost of breeder reactors and the costs of the fuel cycle necessary to sustain them

(f) The necessity for long lead times to develop and introduce any new energy technology

(g) The influence of environmental and non-proliferation considerations on the economic assessment.

We have spent a good deal of time discussing the factors (a) and (b) and we are in the difficulty that we regard them as important for our own discussions but the prime responsibility of Group 1, with support from Group 3. In our discussions, therefore, we are obliged to treat these factors as parameters - at least we are obliged to do that at the present stage of the INFCE exercise. At first sight, this is a grave disadvantage to our discussions but I would now like to suggest that we can avoid that disadvantage and assist our own deliberations by the following proposal.

From the discussions we have had so far, I believe a number of delegates are broadly in agreement with factors (a) and (b) but there do remain some differences of opinion between us and I have noticed that those differences mostly centre on timescales. We have, I believe, agreed that if fission power is to make a longterm contribution to energy supply, then breeder reactors are necessary, but we have not agreed on the timescale on which this is likely. We are agreed, I believe, that the price of uranium ore is likely to increase in the future but we are not agreed upon how rapidly that will happen. For these reasons, I suggest that, for our immediate discussions, we abandon the use of time as an independent variable and, by so doing, relegate to Group 1 some very important and probably controversial discussions. I further suggest that we use the uranium ore price to any particular nation as an independent parameter in which to express our judgements. Generally speaking, therefore, low prices for uranium ore will be associated with the short term situation and high prices for uranium ore will be associated with the distant future.

I suggest that we can hope to reach factual agreement on items (c) and (d). Item (e) gives us a further difficulty because the costs of breeder reactors clearly influence the value of plutonium and, therefore, the value of reprocessing which is of interest to us. However, breeders are the prime responsibility of Group 5. Once again, therefore, we must treat fast reactor economics as a parameter which, in our own discussions, we leave undetermined. At first sight, one might think that the appropriate parameter to choose would be the capital cost of a breeder reactor at, say, 1000 MW electrical. To do just that, however, would ignore those points of view which argue that the costs of the fuel cycle of breeder reactors will be substantial, which may or may not be the case, and presumably Group 5 will address that issue. For our immediate discussions, therefore, I suggest we use a parameter which I shall call "the fast reactor premium" defined in the following way.

(1) Choose an arbitrary reference point for uranium price at 25$ per lb

(2) Calculate the cost of electricity in $ per kW using an LWR reactor with a once-through fuel cycle

(3) Using the same financial rules, calculate the cost of producing electricity from a fast reactor

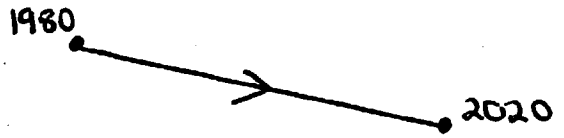
(4) The fast reactor premium is then defined as the difference between items 3 and 2.

In short, the fast reactor premium is the extra cost of producing electricity using fast reactors relative to using LWRs supplied by uranium ore at 25$ per lb.

Using these two parameters we are, therefore, able to describe the economics of once-through thermal recycle and fast breeders in a two dimensional parameter space as shown in Figure 1 and as described in some detail in the long footnote

to that diagram. I would hope to get agreement (±15%) between delegates about the position of the boundary lines between the areas of preferred choices. Since the cost of electricity from fast reactors is independent of the uranium ore price, and since the cost of electricty from a LMR is linearly dependent upon the uranium ore price, it follows that the boundary line between the once-through cyle and fast reactors must be a straight line with a slope which we can probably agree on without too much discussion. Furthermore, since the choice between the once-through cycle and the thermal recycle of plutonium is independent of fast reactor costs, that must be a vertical line on the graph. It follows also that the possibility of thermal recycle slightly delays the economic attraction of fast reactors. We ought to be able to get agreement to this graph because it is non-controversial but I do not think we can get agreement to the re-interpretation of the horizontal axis as time and re-interpretation of the vertical axis as fast reactor capital cost.

I mentioned earlier that, in our discussions so far, we have a consensus that if fission power is to make an indefinite contribution to our energy needs, then breeders will be required. There are, however, different views on the cost of breeders (and the timescale by which they might be available). I have, therefore, superimposed on Figure 1 my own tentative interpretation of the views of some hypothetical delegates. Of course, every delegate has an opportunity to make his own choice and I have put in my own tentative interpretations entirely for illustrative purposes. For each example, I have put in two points like this



to represent my understanding of their possible judgements. This arrow contains three pieces of information. It represents the delegate's opinion of what the price of uranium will be in the year 2020 and it also represents his opinion of the extra cost of fast reactors now and how that will decrease with repetitive ordering in the future.

From these few examples it is clear why some countries put a high economic value on reprocessing - because it is an essential preliminary to either thermal reactor recycle or fast breeder reactors and they judge that one or other of these will be economic and soon.

The simple diagram of Figure 1 must be supplemented by three additional factors which have emerged from our discussions. First, the position of the boundaries varies with the scale of the nuclear power programme. The paper from Egypt argued that a developing country will need to use plutonium fuel but could not afford the cost of independently setting up fuel cycle services. The IAEA paper on multinational fuel cycle centres made the same point. Therefore, unless we can agree to mutual dependence and co-operation, the diagram facing developing countries will look different and give them less options.

Second, we must remember the long lead times required for those technologies. Most countries plan a forty year life for a reactor and achieve a ten year construction time. A utility placing an order for a reactor is, therefore, looking ahead half a century. Over that timescale, conventional economics, which discounts at about 10% a year, is not the only assessment technique we need. The timescale for a government is necessarily even longer than for a utility because most governments accept the responsibility of setting up the options for their utilities. Therefore, a government's attention is concentrated on the research, development and demonstration of a technology; and for nuclear technology that will typically take one, two or even three decades.

Third, we must remember that each government will, or ought to, make sure that its chosen strategy is robust. Therefore, each must examine explicitly or implicitly, the "regret" they would experience if their present judgement turns out to be incorrect.

In the discussion we have had, collectively and privately, I have noticed the danger of "talking past one another" because the three factors listed above are not given proper recognition. In particular, too many discussions are simply a reiteration of strongly held views about the future (ie of the Figure 1 type). Furthermore, there is great danger of misunderstandings arising about (i) plans to set up options and (ii) plans to set up large scale commercial exploitation. Several countries might choose to stress the importance of thermal reactor recycle or fast breeders and appear to be in direct conflict with those which argued that both were premature. The conflict is not actually so sharp.

A country actively planning <u>for</u> thermal reactor recycle may not actually do it on a large scale and, in fact, would not do it at all if the price of uranium remained low enough; but it judges that it is important to have that option available if needed. A country actively arguing <u>against</u> thermal reactor recycle probably has uranium reserves or breeder technology so that that option is not important. Both are actually minimising their possible "regret" even if they do not explicitly say so.

We should also be careful to acknowledge that, for the next two decades, the world nuclear community will be very close to operating only on the once-through cycle because, by the turn of the century, the numbers of large operating reprocessing plants or fast breeders are bound to be small and the quantity of electricity produced by thermal reactor recycle will be a small percentage of the total.

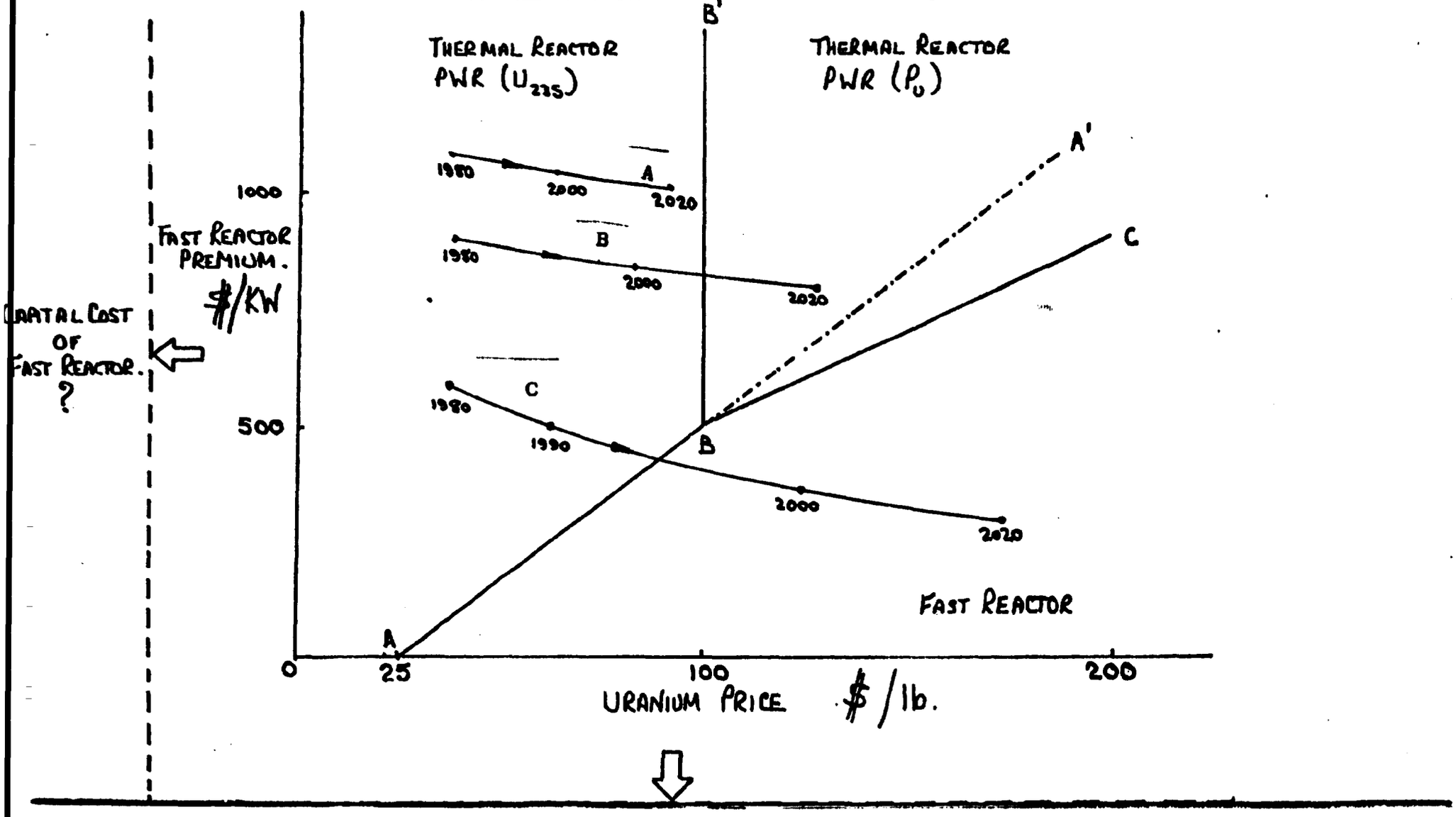
For all these reasons, I would like delegates to consider the following procedure for our discussions of "economic assessment".

We should first consider the decisions facing an electricity utility at the turn of the century. What options has it available? Depending on the world and national position, what is its most economic choice? How should it spread economic risk between non-nuclear, thermal, recycle or breeder reactors? What regret is associated with each choice?

Next we should consider the decisions facing a national government between now and the turn of the century. What range of options should it set up? What commitments can it make already? What is a set of prudent decisions to provide for its best judgement of the future and the most likely variations from that?

This approach may not necessarily lead to an agreement or consensus between us but I would be grateful if delegates could consider it.

DIAGRAMATIC REPRESENTATION OF ECONOMIC FACTORS AFFECTING NUCLEAR FUEL CYCLE STRATEGY.



NOTE:- THE POSITIONS OF THE BOUNDARY LINES AA, BB, & BC AND THE VALUES SHOWN RELATED TO PARTICULAR DATES ARE ARBITRARY AND ILLUSTRATIVE ONLY

DIAGRAMMATIC REPRESENTATION OF ECONOMIC FACTORS AFFECTING NUCLEAR FUEL CYCLE STRATEGY

Footnote

The diagram attempts to provide a common basis for representing individual countries' views about the relative economics of the three main nuclear fuel cycles - the once-through thermal reactor cycle, plutonium recycle in thermal reactors, and the fast breeder reactor cycle - without the need to make speculative judgements about fast reactor capital costs or the time at which the price of uranium will reach any particular figure.

The diagram is composed of a plot of "fast reactor premium" against "uranium price" with, superimposed on this plot, three boundary lines (AA', BB' and BC) defining the areas of preferred fuel cycle choices.

"Fast Reactor Premium", on the vertical axis, is the difference between the total "present worth" cost of the fast reactor fuel cycle (capital and fuel cycle cost) and the once-through thermal reactor (PWR) fuel cycle costs, expressed in $/KW. An arbitrary reference point of $25/lb for uranium ore price is used.

"Uranium Price", on the horizontal axis, is the price in $/lb at which U_3O_8 is available to the country whose choice is to be represented on the graph, referenced to constant money values (1978 prices).

The line AA' shows how the ("present worth") costs of the once-through thermal reactor fuel cycle increase with uranium price. Therefore, for any values of uranium price and fast reactor premium which intersect below the line AA', the fast reactor cycle will be cheaper than the once-through cycle; and for any values above the line, the reverse will be true.

The line BB' illustrates that above a certain uranium price, plutonium recycle in thermal reactors will be cheaper than the once-through cycle. In the diagram an arbitrary figure of $100/lb has been illustrated, so that in the area to the right of the line BB', plutonium recycle will be cheaper than the once-through cycle.

The line BC is similar to the line AA', but takes into account the fact that the costs of plutonium recycle will be about 20% lower than the once-through fuel cycle, because of the saving in uranium used. In this case therefore, for any values of uranium price and fast reactor premium which intersect above the line BC and to the right of the line BB', plutonium recycle will be the most economic choice.

The diagram therefore falls into three areas, in each of which one of the three main fuel cycles will be the cheapest option. This shows one boundary line coming at $100 per lb and the scale of the fast reactor premium being in the range of $500 to $1000 per kilowatt. Delegates will wish to consider the figures they would prefer to show on this diagram. These particular choices have been chosen arbitrarily because they are suitable round numbers.

Plots of individual countries' views of how the fast reactor premium and the price of uranium are likely to change can then be drawn. Three possible views are illustrated, using an arbitrary notation, F,G,I,J,U,U' for individual countries:

The line marked A illustrates the view of a country which does not expect either a rapid reduction in fast reactor capital costs nor a rapid increase in the price of uranium, so that the once-through cycle will be the cheapest option for many years ahead.

The line marked B illustrates the view of a country which expects relatively high fast reactor capital costs, but substantial increase in the price of uranium, such that plutonium recycle will become the most attractive option.

The line marked C illustrates the view of a country, which had developed fast reactor technology early and expected fast reactor capital costs to decrease with time accompanied by a substantial increase in the price of uranium, so that the fast reactor fuel cycle will become the most economic choice.