Safeguards for Reprocessing and Enrichment Plants

Agency safeguards are entering a new phase with the coming under active safeguards for the first time of reprocessing plants in several regions of the world. This is taking place at a time when not only the safeguards aspect itself is coming under international scrutiny, but also at a time when the necessity of reprocessing plants is being called into question. Attracting less attention at the moment, but potentially of equal significance, are the enrichment plants that soon will be coming under Agency safeguards. It is not unreasonable in view of the present controversies to ask what is the significance of these reprocessing and enrichment plants, what are the problems concerning safeguards that appear to have given rise to the controversies, and how these problems are to be solved.

The question of significance is an easy one to answer. The output of these plants is material which some people consider can be used directly for military purposes, whereas the output from other plants, for instance, reactors, would require long and extensive processing before it could be used for military purposes. Like most short answers, this one is an over-simplification which requires some elaboration to make it strictly accurate. For example, the material output of a power reactor is in the form of irradiate assemblies containing plutonium which is potentially of military use if the irradiation had been within a certain range. However, to utilize this plutonium under clandestine conditions, the highly radioactive material would have to be secretly transported to a reprocessing plant and there would have to be simultaneous falsification of the reactor material accounts and the plant records. Such falsification would be difficult to conceal. The total time required to obtain useable plutonium would be many months. Diversion of material from a uranium fabrication plant making fuel for power reactors would be easier physically but strategically it would be of little value. The material, uranium oxide powder, would have to be converted to uranium hexafluoride and then processed in an enrichment plant. The implication is that a technologically advanced plant (presumably clandestine) would have to be available to the diverter intending to make military use of material from a reactor or a fabrication plant. There is a vital difference in the situation with reprocessing and enrichment plants. These plants are designed to produce plutonium or enriched uranium, so that diversion now involves only misuse of the end product, which with a little further work could perhaps be used to produce a weapon. This, however, is only true for certain modes of operation of the plants in question. Nonetheless, it is certainly true as a very simplified generalization that a reprocessing or enrichment plant does represent a significant jump in the useability of material for weapons purposes.

Reprocessing Plants

Turning to the safeguards problems of the reprocessing plant, the central question is the degree to which material can be accounted for. In this, as in any plant, the safeguards task is to ensure that "what goes in, comes out" in an identifiable form or can be otherwise accounted for. In general all other plants have a well defined input so that the problem resolves itself into one of accounting for output or in-plant inventory. The reprocessing plant is unique in that the input is less readily accounted for than the output, since it is composed of irradiated fuel rods. The composition of these rods at the time of initial receipt is only known from reactor calculations. The first objective in material accountancy control at such a plant is therefore to achieve a direct measurement of the content of the fuel. This is usually done by sampling the solution produced by dissolution of the fuel to determine its concentration, and measuring its volume in a specially calibrated accountancy tank. In the terminology of safeguards, this is a key measurement point. In this type of plant, the word key should be doubly stressed. Provided a good reliable measurement can be obtained at this very important point, the further safeguards accountancy tasks are relatively easy. The output of the plant, typically in the form of plutonium nitrate solution, similarly can be determined by concentration and volume measurements, with parallel measurements of the uranium and waste streams to correlate all data with the input. In some cases, further operations take place at the plant to convert material to the oxide form for storage. Either way the material is then usually stored for some time at the plant so that attention has to be paid to the sealing and to the physical protection of the product.

It is standard operational practice to periodically wash out the plant and to accumulate material in convenient accountancy vessels from which samples can be taken for inventory purposes. With good procedures, a material balance can therefore be struck at any required interval. Scope for a would-be diverter lies in inadequately performing these wash out procedures so that all material held up in the plant does not accumulate in the designated measurement points. Careful verification of these procedures is essential.

In principle then, the approach towards the safeguarding of a reprocessing plant is clear: careful accountancy, and verification that the procedures on which the raw data for accounts are obtained are correctly carried out. In practice, for an inspector life is not quite so straight forward, the first difficulty for anyone faced with such a plant is its complexity and the inaccessibility of much of the equipment. Since the plant is dealing with highly irradiated fuel, the early stages (in which the fuel is chopped up, dissolved in acid and the fission products separated) must all be carried out behind heavily shielded concrete walls. The measurement vessels are likewise hidden from view so that no direct observation is possible. Instead the operator or inspector must rely on indirect measurements. Liquid levels, for example, are determined by manometers or dip-tubes. The latter comprise a pair of tubes, one at the top of the vessel the other at the bottom. Air is bubbled through both tubes and the air pressure in the tubes is measured. The difference in air pressure is a measure of the height of liquid in the tank, and the reading is displayed in the plant control room. Such methods are simple and well tried but have the disadvantage, from a *verification* point of view, that they are susceptible to falsification, for example by surreptiously altering the air pressure to give false readings in the control room. Even without the problem of the shielding walls it would be difficult to acquire the necessary familiarity with the intricate maze of pipework in such a plant to be able to guarantee that such falsifications were impossible. Safeguards analyses have therefore to take into account such problems and find an approach that provides the necessary data.

One approach is known as isotopic correlation. In this technique, the isotopic composition of material passing through the reprocessing plant is determined at various stages. There is a certain relationship, or correlation, between the different isotopes in nuclear fuel that has been irradiated, and this isotopic correlation can be used to characterize the nuclear material. Whereas the composition of one or two isotopes in a simple sample could be falsified, it would be virtually impossible to falsify a series of samples in such a way that the isotopic correlation would not change and be detected.

Containment and surveillance devices also can be used. For example, closed circuit television mounted to view the cell where the fuel is chopped up can ensure that no clandestine processing of diverted assemblies takes place. Seals on the storage vessels can eliminate the need for the frequent measurement of the end product, which would otherwise be required because of its high strategic value.

In attempting to summarize the situation on the safeguarding of these plants, it is difficult to avoid the alternate pitfalls of describing the problems in such detail as to make them seem insurmountable or to over-simplify to the extent that any doubts expressed appear unreasonable. Nevertheless, it is true that a reprocessing plant can be adequately safeguarded provided the following conditions are met:

1. All accountancy vessels are carefully calibrated;

2. Reliable samples can be taken of input, output and all streams leaving the plant;

3. Frequent inventories with controlled washouts are taken;

4. The output can be put under an easily checked seal or continuous surveillance.

Enrichment Plants

Fears are sometimes expressed about the possible misuse of commercial uranium enrichment plants to produce uranium or markedly higher enrichment for military purposes. For commercial purposes, such plants are designed to produce material of up to five or six percent enrichment. For military purposes, enrichment up to 93 percent has been customary. The central safeguards question in relation to this type of plant is whether the commercial plant can in some way be adapted or mis-operated to produce the high military grades in place of low commercial grades. The answer to this question to a large extent depends upon the type of plant. The centrifuge plant achieves commercial enrichment in only a few stages, but since the quantity that can be handled by each machine is small, many thousands of machines are operated in parallel at each stage to give the required throughput. A clandestine arrangement to achieve a high degree of enrichment would be to increase the number of stages by reducing the number of machines used in a stage. The choice facing the operator is large volume at low enrichment or low volume at high enrichment. The possibility of misuse therefore exists in principle for this type of plant, but there has always been debate on how practical such clandestine reconnection would be.

For the classical gas diffusion plant, the problem of readaption is much more difficult, if not impossible. The nature of the diffusion process is such that little separation is achieved at each stage, so many stages are required even for low enrichments. For military grades, there may be more than two thousand stages. On the other hand, the quantity of material handled by each unit is such that only one unit is required for each stage. The typical diffusion plant is therefore built as a cascade of units in series, starting with very large units tailing off to smaller units as higher enrichments are reached. Since each consists of a compressor and a diffusion chamber, the possibility of subdividing the early stages to equip clandestine later stages does not exist if an adequate throughput is still to be maintained.

The first enrichment plants to come under active safeguards are of the centrifuge type. The first commercial diffusion plants to be safeguarded are still under construction.

Regardless of the type of plant, a common feature influencing the safeguards approach is the extreme sensitivity of the owners to the commercial value of the design. For this reason, the basic international agreements recognized from the beginning the desire of the operator to have the plant treated as a "black-box", that is to say, a location where safeguards activities are carried out on the perimeter of sensitive areas without access to the inner workings. The safeguards approach to these plants takes account of this restriction by adopting the classical safeguards approach of careful material accountancy, adopting the philosophy that if all material entering and leaving is carefully measured and an accurate balance is struck, then it is of little concern how the internal operations are conducted. Fortunately, the typical enrichment plant has the highest standards of material accountancy of any type of nuclear plant. Both published and unpublished figures over many years operation show a remarkable precision in the material balance, and there is no reason why plants currently being designed and commissioned should not even improve upon this standard. Safeguards procedures at the plants will consist therefore of careful verification by the safeguards inspectorate of all material fed to the cascades and of all material withdrawn, both with regard to quantity and quality (enrichment). Sealing and surveillance, the inspector's two other allies, will play an important part in reducing the manpower effort required. Examination of the material balance under these circumstances not only indicates whether material is missing but also indicates the mode of operation of the plant, since a change to high enrichment output inevitably is reflected in a change in the tails and feed ratios.

This article began by referring to the current controversies over reprocessing and enrichment plants. This is not the place to go further into alternative approaches to national plants that have been proposed, such as the IAEA work on regional centres or multinational ownership. It is possible to conclude, however, that no matter what ownership or operating agreements are eventually worked out, the basic safeguards approaches outlined here will apply.