Material safeguards

One of the more important technical safeguarding measures is material accounting or balancing, which in short consists of periodically checking if no material has been diverted. This is rather trivial for an isolated amount of matter, like in a nuclear power plant or a storage facility. But when dealing with a continuous process like reprocessing or MOX fuel manufacturing, in which the material changes its form and composition, this becomes a very difficult, if not impossible, task. A plant needs to be shut down in order to make up a material balance and since this is not very compatible with commercial goals it is only done once a year under IAEA safeguards. We will now merely focus on the plutonium reprocessing system.

Plutonium safeguards goals

The general goal of the IAEA safeguards is **"the timely detection of diversion of fissile materials for non-peaceful uses"**. This is not real prevention, since diversion can only be detected afterwards. The IAEA is no police, they merely monitor and report to the UN if necessary. In practice, the safeguards are to be stimuli towards "good behaviour" rather than a control regime. This should become clear in the rest of this section, and it has more or less been stated by several IAEA representatives too. And let's be honest, everyone knows that the real "police", if any, in this field would be the CIA.

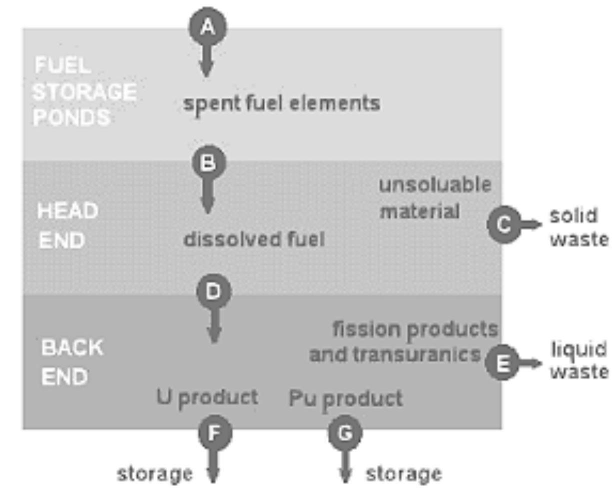
Because of the ambiguous nature of the Non Proliferation Treaty (NPT) on several levels, non nuclear weapons member states are obliged to accept IAEA safeguards, while the nuclear weapon states are formally obliged to nothing. The British THORP plant, for example, is subject to safeguards on a voluntary base. The French UPs are not, or at least not at any moment in any part the complex. It is therefore important to remember that safeguards can only prevent **horizontal** proliferation. They cannot prevent an acknowledged nuclear weapon state from expanding its nuclear arsenal. It is interesting to define the safeguards' objective a little more precisely (focussed on plutonium):

- Let's start with **"non peaceful uses"**. This implies that there must be some kind of evidence of a bomb being or to be built, before they can state that something's wrong. The IAEA cannot prevent you from building and "exploiting" your own reprocessing plant. This is a direct consequence of the fairly empty NPT text.
- **"Timely detection"** means **four weeks**, since this is the shortest **conversion time** the IAEA considers possible to build a nuclear bomb, starting with plutonium oxyde, nitrate or even metallic plutonium. Numerous specialists, however, claim that if everything is well prepared (be it by a "bad" state or some group) it might well take only a few days. Moreover, since industrial reprocessing and MOX plants only make up their full plutonium statistics **once a year**, the timely detection part is very weak for it cannot meet its own definition here. Since any state can withdraw from the NPT on a **three months** notice, it is clear that even within the NPT framework states can produce their own plutonium and leave the treaty whenever it suits them.
- **"Fissile material"** obviously means nothing without a quantification, and the so-called **significant quantity is 8 kg for plutonium**. Why? I haven't got a clue. If they mean that this is the smallest amount of plutonium (heavy metal weight) needed to build a nuke, they have been proven wrong at many occasions by scientists and even Los Alamos specialists. You can read more about plutonium bombs and critical masses in the section <u>about plutonium bombs</u>. For a plutonium storage bunker or so, 8 kg or less is a reasonable safeguarding goal. But for reprocessing and MOX plants, the material throughput is high enough to have numerous significant quantities missing on the account just because of adding up measuring errors.

At this point the conclusion that the material safeguards system in reality fails its objectives is already very hard to discard. For the sake of avoiding unproductive technocratic definition discussions (although there is enough evidence to silence the plutonium lobby) and also because it is interesting to see what huge amounts of plutonium can disappear under IAEA safeguards without any consequence, the rest of this section will be devoted to the IAEA's model using a statistical test.

Material balancing

Figure 1: Reprocessing material balancing areas



In figure 1, you can see the three material balancing areas (MBAs) in a reprocessing complex. If you browsed through the section that gives you a look at La Hague, this will be simple to comprehend. Every point where the plutonium changes its physical form (or when fuel compounds are split up) is a key point for measuring.

The figure is probably pretty self-explanatory. It does contain an important lesson though: *process losses* are generally known and measured, these have nothing to do with the amount of material unaccounted for (MUF). Most importantly, these two quantities do not equal one another. Unforeseen process losses (like leakage) can be an *explanation* for a positive MUF though, but that is very different from assuming that they different expressions for the same thing.

Material Unaccounted For (MUF)

Figure 2: MUF definition

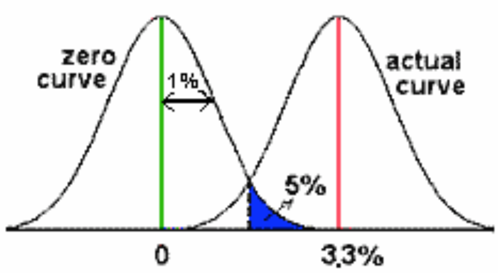
$$\text{MUF} = \text{START INVENTORY} - \text{END INVENTORY} + \underbrace{\sum \text{IN}}_{\text{dissolution measurements}} - \underbrace{\sum \text{OUT}}_{\text{end product measurements}}$$

By definition, the MUF equals the end inventory (what is in the plant at the end of the balancing period) minus the beginning inventory plus the difference between all material that has gone into the plant and all material that has gone out. These are sums of measurements for all in and out batches of material. A positive MUF might mean that there has been an unforeseen process loss, or that plutonium has been diverted, or nothing at all but merely resulting from stacking unavoidable measurement errors. Hence the statistical uncertainty has to be ruled out to a high degree, before substantial diversion evidence can be drawn from mass shortage.

The statistical uncertainty due to stacking measurement errors can be modeled by a normal distribution (Gaussian curve) around the measured MUF and the zero MUF expectation value. The width of such a curve is determined by the standard deviation (when properly normalized, the SD equals the distance from the center to the steepest point of the curve where its derivative would be at its max). The sharper the peak, the less uncertainty there is due to inaccurate measurements. The IAEA model contains three crucial statistical parameters, which have been chosen as follows:

- The standard deviation (SD) is set to 1% of throughput.
- The detection probability must at least be 95%.
- The false alarm probability must not exceed 5%.

Figure 3: IAEA MUF decision limit



Since the normal distribution is a probability distribution, the area underneath such a curve should measure 100% (luckily there are tables which can be used to derive a probability for any interval, or vice versa).

Please don't assume that a 95% detection probability and a 5% false alarm probability are linked like 95% + 5% = 100% as symmetry might suggest. Both are necessary parameters to "cut off" the Gaussian curves, since these are mathematically defined for an infinite interval. But the first refers to the zero MUF curve

meaning that for an anomaly at least 95% of the zero curve area should not be overlapped by the actual MUF curve. And the second refers to the actual curve, meaning that for an alarm at least 95% of the actual curve area should not be overlapped by the expected zero curve. Both are no more than opportunistically chosen reliability criteria and because of symmetry both cut off the Gaussian curves at a 1.65 SDs distance from the center to the right and the left respectively, in case of a positive MUF (vice versa for a negative MUF).

Thus, the maximum MUF which has to be tolerated can become 3.3 SDs or 3.3 % of the plutonium throughput. Since the Cogema UPs have an annual throughput of some 8000 kg plutonium, both can have a maximum MUF of about 265 kg, or 33 significant quantities. BNFL's THORP could even reach 50 significant quantities. This means that a dazzling amount of **some 925 kg of plutonium could get "lost" annually in the European commercial reprocessing industry** within the IAEA safeguarding system!

Could this be made less? Of course it could. The best improvement while maintaining the statistical parameters choices would be shorter balancing periods. This would be a significant commercial disadvantage for the industry, and is therefore not accepted. The industry is even backed up by article 4 of the NPT, which explicitly states that the industry's commercial purposes may not be hindered by safeguards. This painfully shows how unimportant non-proliferation really is to the nuclear lobby. One might also sharpen the statistical criteria, but there are several obstacles to this. Most importantly, there is a great cash shortage. Also, numerous false alarm calls would further decrease the public's trust in the IAEA.

All this shows that the IAEA safeguarding system in fact has little relevance for preventing proliferation due to political and financial reasons. And one should not forget that reprocessing and MOX plants are essentially most vulnerable for plutonium diversion. Yet, many European politicians would say that I'm exaggerating when stating that when it comes down to it, the safeguards system fails in every aspect and that a consistent non-proliferation policy simply implies a plutonium economy ban. Obviously, what they really mean is that one should take a "pragmatic" approach, and just accept the situation. Well, I don't think so.