Re: CANDU reactor questions

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- *From*: "Alessandro" <miaposta_42@xxxxxxxx>
- *Date*: Fri, 22 May 2009 21:36:40 +0200

"Paul Ciszek" <nospam@xxxxxxxxxx> ha scritto nel messaggio
news:gv6lng$i4$1@xxxxxxxxxxxxxxxxxxxx

> In article <qVzRl.23132$Ux.12232@xxxxxxxxxxxxxxxxxxxxx>,
> Alessandro <miaposta_42@xxxxxxxx> wrote:
>
> > "Paul Ciszek" <nospam@xxxxxxxxxx> ha scritto nel messaggio
> > news:gv6bjt$b2h$1@xxxxxxxxxxxxxxxxxxxx
> >
> > > 2) While CANDU reactors make better use of U−235 than
> > > the American fuel
> > > cycle does, it sounds like, unless they are being fed
> > > recovered
> > > plutonium from elsewhere (such as dismantled nuclear
> > > weapons) they
> > > are essentially limited by the amount of U−235 available,
> > > which we
> > > can't really afford to think of as inexhaustable.
> >
> > Of course, there is no unlimited raw material in the earth, but today the
> > uranium market price is dirty cheap (~ one $ per oil barrel equivalent)
> > and
> > we are plenty of the fuel at a cost of x10 or x20 that, of course with
> > anyway an enormous return of the energy invested in mining. Today, the
> > need
> > for reprocessing is mainly ecological, not economic, because we get rid of
> > transuranics (which have very long hal life) waste
>
> I thought I once saw a comparison of how long the world could meet its
> energy needs using various fuel sources in which a U−235−only fuel cycle
> didn't last that much longer than fossil fuels.

These aren't *all* uranium reserves, because they consider, as usual, only low cost uranium resources, typically less than 130 $/kg of uranium mined (corresponding, indeed, to only one $ per oil barrel equivalent), but with nuclear electricity you can use uranium (even with current nuclear technology, no thorium or breeders) at ten times that cost with negligible escalation in nuclear kWh cost; of course, there is a market price for uranium where breeders (and thorium breeders) become more economic than current nuclear technologies

> > 1) This business about "burning" "higher actinides"−−do
> > they mean
> > getting useful energy by *fissioning* assorted stray synthetic
> > elements that turn up in reactor waste? I thought that
> > designing
> > a self−sustaining reaction around the "good stuff" like
> > U−235,
> > Pu−239, or Th−233 was hard enough, and that most of those
> > other
> > by−products like Am−241 just hurt a fission reaction. How
> > does
> > one "burn" "higher actinides" at a net energy profit?
>
> Because actinides/transuranics behave themself like fissile elements
> (including uranium 235), i.e.
> if we burn them we produce enormous quantity of energy, in the range of
> more
> than 3 tonn of coal equivalent per single gram of them

> Again: I thought only a few isotopes could be made to fission on demand, and the rest, like Americium−241, actually *interfered* with useful fission.

Only with current nuclear technologies (using slow/thermal neutrons) transuranics elements like americium tends to build−up and not fission, this doesn't happen in reactors using fast (or simply "faster") neutron reactor technology, like the integral fast reactors (IFR) or molten salts reactors (MSR or LFTR). Pratically, they destroy *all* nuclear "waste" converting them in useful energy (and fission products with half lifes mainly of only years or tens of years) − pratically, we can produce all the world electricity needs for several millenia, only consuming the uranium and nuclear waste *still produced* and today stored somewhere in the planet, with no need of single gram of new uranium to mine
http://en.wikipedia.org/wiki/Integral_Fast_Reactor
http://www.theoildrum.com/node/5002

"....Our nuclear technology still has faults:

a.. it uses only a fraction of the energy in the uranium we mine,
b.. it leaves much more waste than is necessary, and
c.. it presents proliferation hazards that could be avoided.
We should do better, and we can.
The USA has developed technologies to address all of these problems, and then mothballed them. The failure to develop our capabilities was not technical, but political, and came mostly from within your own party. This is another luxury we can no longer afford. These should go back on the front burner as soon as humanly possible.

The neglected technologies are:

a.. The molten−salt reactor (MSR)
b.. The Integral Fast Reactor (IFR)
These two technologies have several very valuable properties in common:

1.. They reprocess their fuel at the reactor site.
2.. Because of the on−site reprocessing, there is no storage of spent fuel.
3.. Also because of this, the volume of waste is minuscule; the waste from a reactor's entire lifetime can be stored on−site and not removed until decommissioning.
4.. They can use roughly 100 times as much of the raw fuel material as today's reactors.
A ton of raw nuclear fuel (uranium or thorium) can make approximately one gigawatt−year of electric power in an MSR or IFR. The total electric power needs of the USA could be satisfied by less than 500 tons per year of either, and a great deal of this could come from material already mined or even designated as "waste". Because of these properties, the MSR and IFR are potential solutions to both the USA's energy difficulties and the nuclear waste problem.

The Molten−Salt Reactor (MSR)
The Molten−Salt Reactor was originally developed for nuclear aircraft, but it was later tested as an alternative to water−cooled reactors. An experimental reactor at Oak Ridge National Laboratory was tested using three different fuels: enriched uranium−235, plutonium and uranium−233 (bred from thorium). It ran well on all of them. The final run was intended to gather data to evaluate the feasibility of a thorium−uranium fuel cycle, and was apparently successful.

Molten−salt reactors have a number of advantages over today's water−cooled technology:

1.. They cannot suffer a meltdown, because the fuel is already molten. If the cooling systems are shut off, the reactors shut down through their essential physics; they are inherently safe.
2.. They cannot explode, because they run well below the boiling point of the salts and require no pressure vessels. This also makes their components

relatively lightweight and easy to manufacture.
3.. They can run at relatively high temperatures, which increases their efficiency and makes the heat usable for many industrial purposes.
4.. They can remove fission wastes continuously, so there is never a danger from "afterheat" when a reactor is shut down.
5.. The extracted wastes are relatively pure rather than containing large amounts of unused fuel, so their bulk is comparatively tiny. The wastes can be made ready for permanent disposal right at the reactor site. Fuel cannot be diverted for weapons because it never leaves the reactor building.
6.. They can be started up with plutonium from spent nuclear fuel or reclaimed weapons material, and can destroy this fuel while breeding new fuel from thorium.
7.. The physics of breeding thorium to uranium creates uranium−232 as well as uranium−233, which is not a difficulty for power production but makes the material unsuitable for use in weapons. Even more so than light−water reactors, molten−salt thorium breeders do not pose a risk of nuclear weapons proliferation.
According to recent news, the USA has approximately 900,000 tons of high−grade thorium reserves. This is approximately 2000 years of supplies at current rates of electric consumption, or hundreds of years if thorium was substituted for all fossil fuel. Lower−grade thorium resources include coal ash.

In addition to reactors using molten fluoride salts, it appears to be possible to make fast−breeder reactors using molten chloride salts. This has not yet been tested, but it probably should be.

The Integral Fast Reactor (IFR)
The IFR is another promising technology nixed by partisan politics. A prototype reactor was killed by a Democratic congress in 1994, despite test results showing great potential. Fifteen years have now passed, fifteen lost years. It's time to go back to it.

The IFR is similar in some ways to the Molten Salt Reactor. It can convert nearly 100% of the raw fuel (uranium in this case) to useful energy; it reprocesses fuel at the reactor; it produces tiny amounts of waste pre−packaged for disposal; the fuel processing does not separate weapons−grade components; and the fuel from the reactor is always too radioactive to be safe to divert.

Unlike Light Water Reactors which use fuel as ceramic (oxide) pellets and the Molten Salt Reactor which uses salt mixtures, the IFR's fuel is metallic. This fuel is cast into rods and cooled by liquid metal. Both liquid sodium and lead−bismuth alloy have been suggested as coolants. Like the MSR, the IFR operates at atmospheric pressure and requires no large metal forgings. The last design tested was also proven to be passively safe.

The IFR may seem redundant if we have MSRs, but it has proven capabilities that MSRs do not, capabilities that we need:

1.. It is a fast−neutron reactor, so it can "burn" troublesome isotopes of plutonium and americium rather than leaving them as a disposal problem.
2.. It can turn stocks of uranium to fuel, even the uranium in spent PWR fuel.
3.. Because of this, it can ultimately eliminate the entire stock of nuclear fuel piled up at present and past nuclear plants.
4.. It can also convert our entire stock of Depleted Uranium (DU) to fuel.
It may be possible to make a fast−neutron reactor using molten salts, but the fuel chemistry and other details have not been tested; the IFR has. The IFR needs to be taken to full−scale test ASAP, so that our big nuclear waste problem can be turned into a small, short−lived one.

The Consequences of Breeders
Between the two technologies of the MSR and IFR, the USA's entire inventory of spent nuclear fuel (43,000 tons of uranium as of 2002), depleted uranium (roughly 6 times as much) and thorium (900,000 tons of reserves) become available as domestic fuel reserves. The entire electric demand of the USA could be met with roughly 500 tons per year of this; the entire energy needs of the USA would take perhaps 1500 tons. We could export both clean, no−carbon power generators and the fuel to run them. If we are looking to save the world from climate change, we have to grab these opportunities with both hands... "

>>> 2) Supposedly you can load a CANDU−variant with Thorium−233 and someone else's waste Plutonium, and get a self−sustaining reaction. Once you start doing that, can you keep it going with Thorium, or do you need a continuous supply of someone else's Plutonium?

>> No, besides of course economics considerations, with a Candu reactor and a thorium cycle (that's physically impossible to do with natural or enriched uranium cycle) you can produce at least slightly more fissile from the thorium blanket (i.e. uranium 233) than the plutonium you consume. The following feeds are enterily composed of uranium 233 and thorium, no new plutonium need at all

> So, once India gets their reactors going, they can get by on nothing but fresh Thorium? Sweet.

That's right, moreover they are going to produce for a single tonn of thorium about 100 times more the electricity than from one tonn of uranium in current reactors, i.e. several TWh per tonn of natural thorium, instead 40−50 GWh per tonn of natural uranium mined

>> Actually, today the French don't *breed* any fuel, don't make confusion between
>> simply reprocessing, allowing of course some fuel savings, and breeding that
>> means you can produce more fisssile fuel than that you consumed, that's
>> possible only with 1) plutonium sodium (or metal) cooled fast breeders or 2)
>> thorium cycle with slow neutrons, that means even with current nuclear technology
>> Again, the problem is mainly costs, if we want a self sustained (breeding)
>> fuel cycle we have to reprocess the spent fuel many times and, at least with
>> a solid fuel approach, this is very costly and complex (for the
>> infrastructures we should need).

> So, are you saying that a minority of France's nuclear power comes from
> fissioning Plutonium?

Without fast breeders, we can achieve with plutonium/uranium recycle in LWR
only some savings, but not so much

> Oh, one more question:
>
> Is the Plutonium−238 that the US prefers for radiothermal generators
> specifically a by−product of nuclear weapons production? That is,
> if a nation were actively re−processing civilian reactor fuel and
> making use of the Plutonium, would it be able to make the occasional
> Pu−238 RTG?

I'm not an expert here, but I don't think a simple chemical separation is
not sufficient to extract Pu−238 from a typical LWR waste stream, a
different process of production/separation is needed, I guess (honestly, I don't
know how)

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