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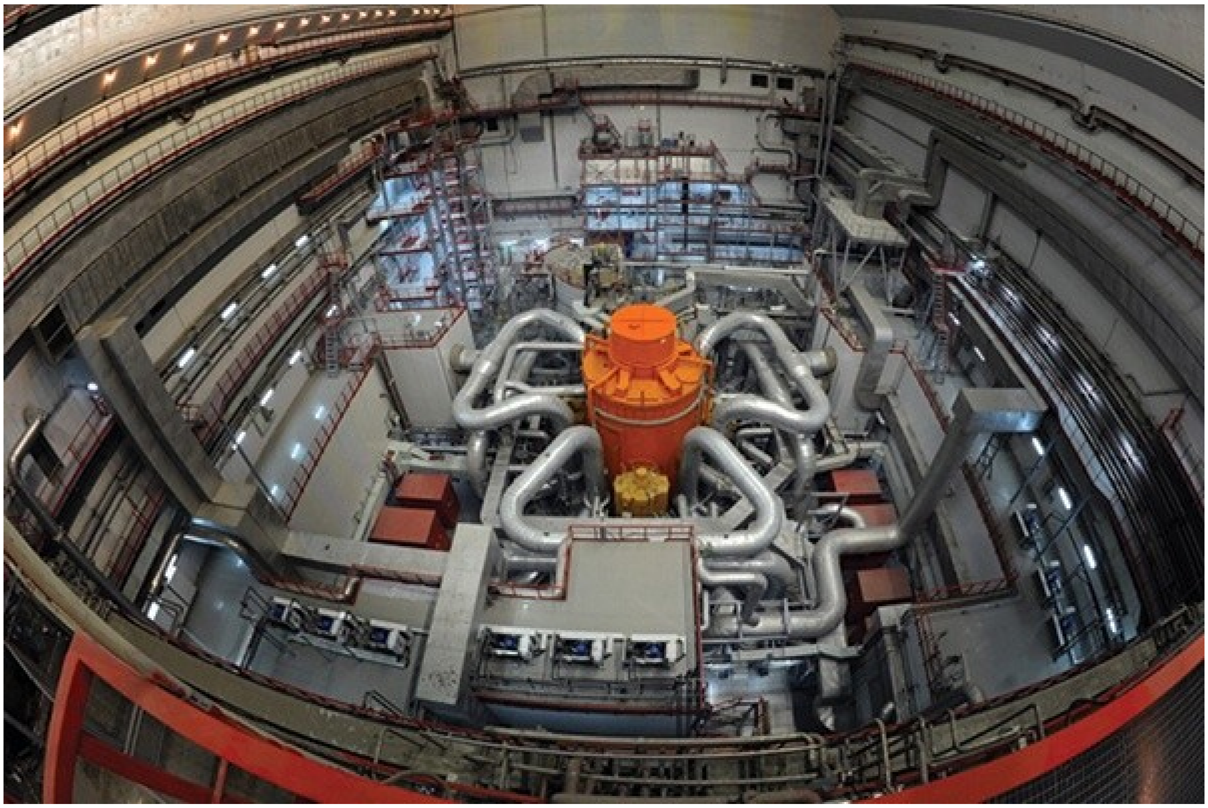
General Comment

See attached file(s)

Attachments

The case for not building large numbers of Sodium Cooled Fast SMR Reactors2

The case for not building large numbers of Sodium Cooled Fast SMR Reactors
Robert Steinhaus, former Engineering Dept Field Test Div at Lawrence Livermore National Laboratory (1974-2008)



I am not really all that thrilled about seeing large numbers of Sodium Cooled Fast SMR Reactors built while creating for the first time in history a commercial market for Plutonium start up fuel. We should be trying to build the safest nuclear reactors we know how to design. **Sodium is an inferior coolant from the standpoint of safety** relative to Molten Salts (or water).

While others will disagree, I feel that the intrinsic safety of Sodium Cooled Fast Reactors (SFRs) like the IFR, Terrapower TWR, the Russian BN-800 and the GE S-Prism is not good enough to go forward with building additional SFR reactors using sodium coolant.

If you are talking about a worldwide large scale building program involving the construction of large number of reactors (like 10,000 one GWe reactors to produce 10 Terawatts of additional power to give everyone on the planet fair access to high quality energy), then the safety of the reactor design selected becomes a paramount consideration. While individual SFR reactors like the INL/Argonne EBR-2 have run for 30 years with excellent operators and engineering controls - producing very few safety incidents, this is not the general experience with SFRs (about half of the SFRs historically built have had their operational lifetimes prematurely cuts short, decades before engineered end of life, by accidents and safety incidents).

Safety Concern -
Sodium Cooled Fast Reactors contain a lot of reactive sodium coolant.
The French Superphenix used 5500 metric tons of sodium (3300 tons in the primary reactor vessel) for a 1.2 GWe reactor - exact figures have not so far been provided for other mature SFR designs like GE PRISM or BN-800. External safety reviewers trying to access SFR safety must resort to scaling the Superphenix numbers when trying to guess SFR safety characteristics given the reticence of current SFR designers to reveal to the public and decision makers the numbers that would allow fair and accurate analysis of the potential hazard of their SFR designs.

Sodium Safety -
Sodium reacts exothermically with liquid water or steam to generate sodium hydroxide and hydrogen:

$Na + H_2O \rightarrow NaOH + 1/2H_2 + heat$
Heat of reaction: ~ 162kJ/mole-Na
(around 7.05MJ/kg-Na)

Hydrogen tends to accumulate in the roof area of a reactor containment building and if the conditions are right, hydrogen air mixtures can detonate. The range over which hydrogen can detonate in air is from 18.3 to 59 percent by volume.

Reference – G. Manzini and F. Parozzi "Sodium Safety"

(Intrinsically safer nuclear technology exits - it is safer to use nice thermal spectrum MSRs and DMSRs to burn up waste and produce power in the majority of instances as these reactors are not capable of producing a similar magnitude nuclear accident)

The natural isotope of sodium is Na-23. It represents 100% of sodium in nature and 100% of the initial isotopic inventory in SFR coolant prior to first reactor startup operation. Fission fast neutrons easily neutron activate Na-23 into highly radioactive Na-24 with a half life of 15 hours. As a SFR reactor operates, Na-24 builds up in the 5000 tons per GWe of sodium coolant producing many thousands of tons of highly radioactive Na-24 coolant. In a hydrogen explosive accident that breeches reactor containment or in a sodium metal fire, the huge radioactive inventory of Na-24 neutron activated coolant can be released into the environment.

Na-24 activity, which gives rise to a requirement for protection against gamma radiation, reaches a level of nearly 10^{12} Bq/Kg of sodium.

Table 4.3 shows generation of activation products of sodium during five years of irradiation.

	1300 (Days)	1400 (Days)	1500 (Days)	1600 (Days)	1700 (Days)	1800 (Days)
Na24	9.896E+11	9.851E+11	9.826E+11	9.815E+11	9.814E+11	**9.820E+11**
Na22	1.453E+07	1.452E+07	1.452E+07	1.451E+04	1.451E+04	**1.451E+07**

Table 4.3 Selected Nuclides with High Activity Rates after 5 Years Irradiation (Bq/Kg)

The chemical energy in Sodium found in SFRs is greater than any other current reactor family.
SFRs used for waste burning will hold a greater radiological inventory than any reactor that has yet operated on planet earth.

When you combine the largest chemical stored energy which can be released in a sodium metal fire - hydrogen explosion with the largest radiological inventory of fission products and fissile fuel - you have the potential for a large and very serious nuclear accident.

I am not anxious to see 10,000 BN-800 reactors operating on earth when the historical safety record to date for this type of reactor indicates that this SFR reactor class has frequently suffered serious reactor operational life ending accidents.

In a large SFR reactor like the BN-800, Na-24 activity gradually rises over months of operation to reach ultimate equilibrium level of nearly 10^12 Bq/Kg of sodium

(This is a BIG number for radioactive activity in the event of a possible sodium fire-hydrogen detonation explosive accident that breaches reactor containment and forcefully drives neutron activated Na-24 coolant, reactor fuel and fission products into the environment)

Why not select better and intrinsically safer nuclear technology than the SFRs to bring about a more desirable (and safer) nuclear future?

THE ULTIMATE SAFE (U.S.) REACTOR

By Uri Gat and Sylvia R. Daugherty

http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/17/045/17045126.pdf

The Ultimate Safe (U.S.) Molten Salt Reactor is a reactor that eliminates the traditional safety concerns of nuclear fission reactors. The U.S. MSR reactor has an insignificant source term and no reasonable criticality accident.

Furthermore, the negligible residual after-heat in the reactor renders its shutdown capability comparable or superior to conventional power sources in that no actions or precautions are required following a shutdown of power.

Molten salt reactors - safety options galore

by Dr. Uri Gat and H.L. Dodds

[Molten salt reactors - safety options galore (Conference)]

MSR reactors can be designed optimized for safety - making them simple and safe designs with low excess reactivity, low fission product inventory, and small source term. These, in turn, make a criticality accident unlikely and reduce the severity of a loss of coolant to where they are no longer severe accidents. A meltdown is not an accident for a reactor that uses molten salt coolant-fuel. The molten salts are stable, non-reactive and efficient heat transfer media that operate at high temperatures and at low pressures and are highly compatible with selected structural materials. All these features reduce the chance of serious nuclear accidents.

The reality is that everyone in the SFR camp exclusively discusses the EBR2 reactor when discussing SFR safety. EBR-2 did have a good safety record (but there were over 30 safety incidents at EBR-2 during the reactor's operational life; mostly small sodium fires). SFR advocates choose not to discuss the history of operation of SFR reactors as a class (or admit to the historical fact that half of the Sodium Cooled Reactors built have had to close decades before engineered end-of-life as the result of a safety incident or accident).

Advocates for the modern SFRs and safer nuclear omit to mention that Argonne/INL spent two years preparing for the EBR-2 safety demonstration and assigned an entire engineering group to the task of ensuring that the safety demonstration tests went swimmingly and without a hitch. Fortunately, the test went well with VIPs watching and cameras rolling; but these are not typical conditions for a real-life safety test when it matters (graveyard shift, new inexperienced operators, etc.).

Problems with finding a reliable supply of startup Plutonium fuel for fast reactors like the BN-800

At the request of the Clinton Administration and under the supervision of former DOE Secretary Hazel O'Leary, the US has destroyed its former capacity to supply Plutonium in grade suitable for startup of SFRs. The only current supplier of startup Plutonium for SFRs is Russia. Selling SFRs anywhere in the world establishes a technical and political dependency on Russia, which may in the future have different geopolitical objectives than the West.

Building and selling fast neutron spectrum SFRs also creates overnight a commercial market for Plutonium fuel. This has never before existed on earth and has some not insignificant geo-political and nuclear security implications.

While nations that seek nuclear weapons would prefer weapons-grade material, reactor-grade plutonium could also power an explosive chain reaction. During the long irradiation time in a typical commercial power plant, plutonium continues to absorb neutrons, transforming the ideal bomb material plutonium-239 (Pu-239) into other isotopes, including Pu-240, Pu-241, and Pu-242. Weapons-grade plutonium contains less than 6 percent of Pu-240 and much smaller percentages of Pu-238, Pu-241, and Pu-242.

The non-ideal isotopes are such because they emit more neutrons through spontaneous fission and release more heat than Pu-239. These effects can complicate weapons design. Although the greater heat emissions from reactor-grade material would complicate the engineering of the weapon, this problem is entirely surmountable. In 1962, the United States reportedly detonated an explosive device made from plutonium that was less than weapons-grade; however, the exact isotopic composition still remains classified and has not been openly published.

The SFR community routinely blows off the following two reports regarding proliferation risks posed by reactor grade Plutonium. These reports are produced by America's most respected senior nuclear designers in the weapons complex (we just do not have any better or more reliable authorities available) without any justification other than they find the reports unhelpful.

Explosive Properties of Reactor-Grade Plutonium

J. Carson Mark

https://www.princeton.edu/sgs/publications/sgs/archive/17-2-3-Mark-vonHip-Lyman.pdf

Dr. J. Carson Mark became the leader of the Theoretical Division at the Los Alamos National Laboratory in 1947, a position he held until 1973.

Reactor-Grade Plutonium Can be used to Make Powerful and

Reliable Nuclear Weapons: Separated plutonium in the fuel

cycle must be protected as if it were nuclear weapons.

By Richard L. Garwin(l)

http://fas.org/rlg/980826-pu.htm

Graph showing the buildup of Na-24 isotope in sodium coolant over the period of 5 years.

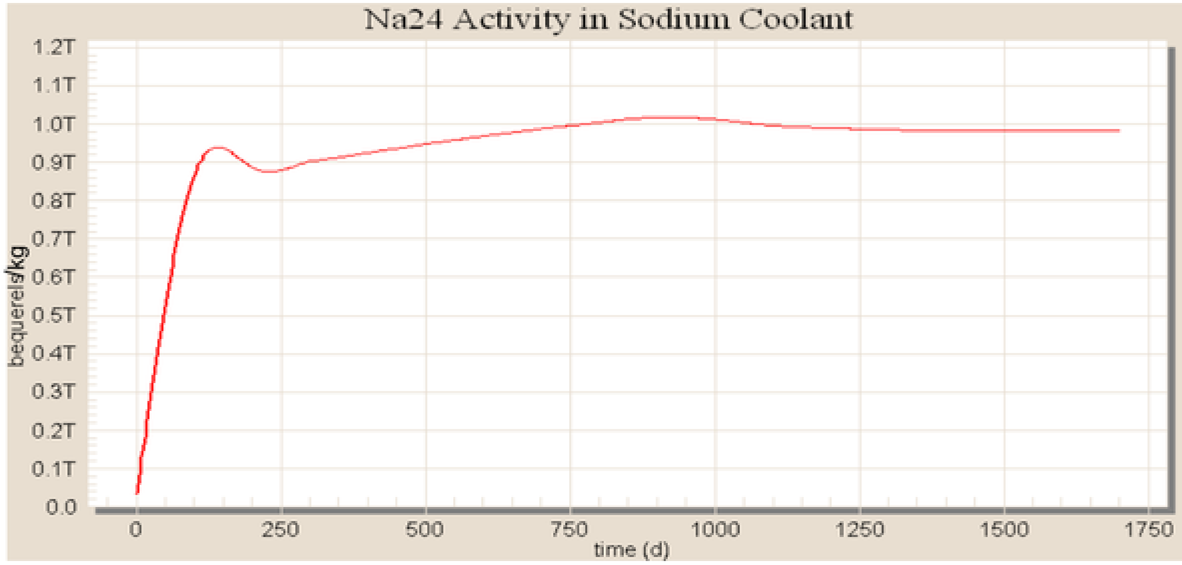


Figure 4.13 Na-24 Activity in Sodium Coolant (Bq/Kg)