Will China convert existing coal plants to nuclear using HTR-PM reactors?

http://atomicinsights.com/will-china-convert-existing-coal-plants-nuclear-using-htr-pm-reactors/

November 21, 2016 By Rod Adams 10 Comments

It would be a huge benefit to the earth's atmosphere if China, India, Brazil and the US could reduce direct coal burning while still making use of much of the capital that they have invested in building coal fired power plants. It would make an even larger difference in reducing air pollution in the areas downwind of the coal stations.

Converting coal-burning supercritical steam plants to nuclear power plants by replacing the furnaces and boilers with high temperature gas cooled reactors might become a routine power plant improvement in the relatively near future. The High Temperature Reactor – Power Module (HTR-PM) project is aimed at demonstrating the feasibility of this evolutionary concept.

At the recent High Temperature Reactor 2016 (HTR2016), held in Las Vegas, NV, Prof. Zhang Zuoyi, Director of China's Institute of Nuclear and New Energy Technologies (INET), briefed his colleagues in the international community of high temperature gas reactor enthusiasts on the current status of the HTR-PM. That project is one of the more intriguing clean air projects underway in the world today.

The end of Zhang Zuoyi's brief resulted in a sustained round of clapping; there were even a few hoots from the attending scientists and engineers that would have been more expected at a football match. (Most attendees at this talk were not from the US, the word "match" is intentional.)

Some of the audience members were able to trace their involvement and excitement about HTRs back more than 40 years to hands-on experience in the construction and operation of the Peach Bottom 1 nuclear plant, a project that was planned, constructed and operated in the US during the period from 1958 – 1978. The attendees were nearly unanimous in their appreciation of the fact that someone, somewhere was building commercial plants using the technology they had been working on for so long.

Target Market

China's HTR-PM project is squarely aimed at being a cost-effective solution that will virtually eliminate air pollution and CO2 production from selected units of China's large installed base of modern 600 MWe supercritical coal plants.

This is not a “pie-in-the-sky” long range plan to eventually replace those built facilities and leave idle capital rotting away. Instead, it is a deployment program with the first of a kind commercial demonstration approaching construction completion and commercial operation by mid to late 2018. Major parts of the machinery will be able to be merged into the existing infrastructure.

Schedule

The commercial operation date is six to nine months later than scheduled when construction began, but Prof. Zhang Zuoyi proudly explained that the HTR-PM first-of-a-kind delays were much shorter than the 3-4 year delays that have plagued the EPR and AP1000 construction projects in their country.

The current critical path item is the completion of the steam generators — one for each of the two reactors. The shells and internals have been completed, but the final stages of attaching the piping to the thick-walled, large diameter pressure vessels will delay site delivery until sometime close to the middle of 2017.

Development Challenges

Zhang Zuoyi gave an excellent overview of the design and testing challenges that the project has faced and overcome. Nearly every item on the list of critical steps for design and testing had been completed.

For example, the development effort included building four different prototypes for the helium circulators. The primary design included magnetic bearings, but the developers knew that they were well past the size limits of proven uses of magnetic bearings so they had a couple of fall back designs. They did not want the project to fail because of failure to deliver on a single component.

In another example, the reactor pressure vessels weigh in at 600 tons, making the act of installing them a very heavy lift that exceeded previously existing capabilities.

The learning that has been gained during the challenging task of construction and component manufacturing and the learning that will be gained during the operation of a plant that uses two nuclear heated boilers to power a single steam turbine will form a solid foundation for the next step.

As operational experience is gained with the first unit, the developers will be building more boilers and installing them in configurations of six to twelve boilers providing steam to a single steam turbine.

One of the items that was learned during construction of the lead unit was that the plant footprint could be reduced by about 50% by arranging the boilers in circles with three boilers in each circle instead of lining them all up side by side.

Increasing Value Of Existing Infrastructure

In some cases, these nuclear boiler installations will be part of entirely new power stations. The more intriguing aspect of the concept, however, is the fact that the high temperature atomic boilers produce steam conditions that are identical to the design conditions for a large series of modern, 600 MWe steam plants that currently use coal as the heat source.

During the question and answer period, Prof. Zhang Zuoyi responded to my questions by confirming that some of the pebble-bed atomic boilers will be installed as replacement heat sources for existing steam plants. Those installations will be able to take advantage of the switchyards, the installed transmission networks, the cooling water systems, the sites and in some cases the entire steam plant including the steam turbine.

The priority for replacing coal boilers with nuclear boilers will be at power plants in areas with major pollution problems. Those plants are often located very close to population centers; that reality is one of the reasons that China has invested in developing reactors that can be tested and proven to be safe.

The HTR-PM modules can withstand complete loss of pressurization and helium flow without a forced shutdown and still not release enough radioactive materials to exceed the very conservative dose limits in place today.

Cost And Value

The overall cost of this first of a kind nuclear plant will be in the neighborhood of $5000.00/kw of capacity. That number is based on signed and mostly executed contracts, not early estimates. It is about twice the initially expected cost. According to Zhang Zuoyi, 35% of the increased cost could be attributed to higher material and component costs that initially budgeted, 31% of the increase was due to increases in labor costs — which Zhang Zuoyi noted were rising rapidly in China — and the remainder due to the increased costs associated with the project delays.

Zhang Zuoyi described the techniques that will be applied to lower the costs; he expects them to soon approach the $2,000 to $2,500 / kw capacity range.

The value proposition of these clean replacement boilers, however, will be more than just economical electricity. The real payoff will be the ability to enjoy the fruits of economic development without as much difficulty in merely taking a breath.

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About Rod Adams

Atomic energy expert with small nuclear plant operating and design experience. Financial, strategic, and political analyst. Former submarine Engineer Officer. Founder, Adams Atomic Engines, Inc. Host and producer, The Atomic Show Podcast. Resume available here.

Please subscribe to the Atomic Show RSS feed.

Comments

1. RTK42C says

   November 21, 2016 at 12:09 PM

   Rod,

   Can you elaborate on the techniques / ideas that Prof. Zhang Zuoyi has to cut the cost in half and how long it will take to achieve that cost reduction? For the sake of comparison, did he happen to mention the cost of power production in China (so we could make a statement such as “the 2000-2500 $/kw of capacity using a HTR-PM is X times the cost of capacity for the coal unit it is replacing”)?

   Reply

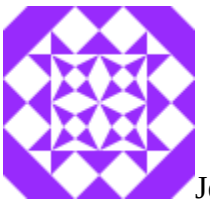
-  Rod Adams says

  November 21, 2016 at 2:06 PM

  @RTK42C

  Prof. Zhang Zuoyi is no longer an academic who freely shares everything he knows. He is now a businessman who understands that some information is too valuable to share for free. Specific costs, supply chain details and cost reduction strategies are among the closest hold topics for commercial enterprises.

  Reply

  -  Jeff S says

    November 21, 2016 at 3:41 PM

    Well, seeing as he *did* give out that specific cost for the first-of-a-kind build, it seems like that should at least be possible to compare to the costs for coal in China? Or are the coal costs closely guarded secreets?

    Reply

    -  Benjamin Haas says

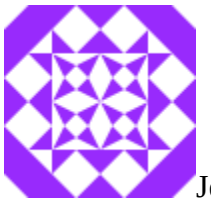
      November 21, 2016 at 7:54 PM

      A few years ago, I found article an article titled, “Economic potential of modular reactor nuclear power
      plants based on the Chinese HTR-PM project”, with Zuoyi Zhang as a co-author. The paper can still be found on line

and might be behind a paywall now, but I still have the full text.

In that paper, their FOAK estimates are over twice that of a series built PWR, with the target dropping to about parity. The main cost driver for the FOAK are the pressure vessel, reactor internals, and steam supply equipment. In my opinion, their plan for dropping that cost is through economy of scale of those parts.

Reply

2.  Jeff S says

November 21, 2016 at 3:39 PM

While this won't save jobs in coal mining and transportation, this could save some jobs at coal power plants. I have an uncle who recently retired from working at a coal plant, and I know there was concern within the power industry at lost jobs from closing coal plants.

Granted, it's probably going to require retraining much of the staff, because nuclear technology is a bit different than coal, but these conversions could allow a lot of power plant jobs to be retained, seems like.

That would probably be welcome news to some people.

Reply

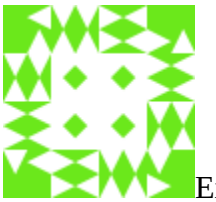
3.  Robert Parker says

November 21, 2016 at 7:30 PM

Rod,
I note the potential for hydrogen production to change the greenhouse gas emissions and global warming causation of existing steel production with this technology. Please refer to a very good paper by Viktor Sivertsson from Uppsala

University on Hydrogen production using high temperature nuclear reactors A feasibility study. In this article he compares the benefits of technologies such as high temperature electrolysis with sulphur – iodine

Reply

-  Eino says

  November 21, 2016 at 10:17 PM

  I think you are on to something. It seems like a natural that process heat for industries should quickly follow once the Chinese begin building these things. I also wonder if the plants can receive uprates. Will it be possible to run the hot gas produced by the reactor through a Brayton cycle turbine with the hot exhaust gas then used in a steam generator like a natural gas cogen.

  Necessity is the mother of invention and the Chinese have the necessity to clean up their air.

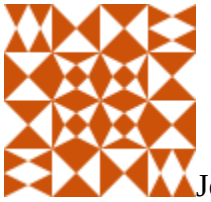
  Reply

4. David B. Benson says

   November 21, 2016 at 9:32 PM

   An alternative is a 12-pack of the forthcoming Nuscale modules @ 50 MWe apiece. Cannot reuse the steam equipment but can use the existing electrical equipment at the site. The estimated price is the same, US $5/W, and the estimated total time to mechanical completion is but 51 months from licensing.

   Reply

5.  John ONeill says

   November 22, 2016 at 3:58 AM

   These PBMRs are reminiscent of the British AGRs, which were likewise graphite moderated, gas cooled, ran at about 600 C, and were built in pairs to give coal-quality steam. Both types are too large to qualify as Small Modular Reactors. Hence maybe the decision to place them in circles, not in rows – a few of the SMR designs have a row of reactors all under one gantry crane, but these things are too big for that.
   The AGRs get about 30% better thermal efficiency than light water reactors, but have a lower burnup on the fuel. They were also designed to be refueled at full power, which proved troublesome because of vibrations in the fuel assemblies.
   The German pebble bed reactor prototype had refueling problems too, with pebbles sticking in the chute. Hopefully the Chinese have sorted this out, so they might get a higher capacity factor than light water reactors, plus perhaps two or three times a LWR's burnup by recycling pebbles back through.
   Did Prof Zhang say what enrichment the fuel will have, and what burnup they are expecting ?

   Reply

   -  Rod Adams says

     November 22, 2016 at 5:52 AM

     @John ONeill

     Yes, the HTRs have evolved from the AGR line of thinking, with design choices intended to address areas where the AGRs had issues. (It's worth noting that many of the AGR issues have been mitigated; most of them are still operating today, routinely providing about 15% of the UK's electricity.)

     AGR burnup is limited by low enrichment and by material limitations of the fuel assemblies. HTRs have TRISO coated particles designed to vastly improve fuel durability and they use higher fuel enrichments – nominally 9% fissile. (German AVR testing included all possible fissile isotopes.)

The pebble form puts the moderating graphite into the fuel element and avoids many of the problems associated with the monolithic graphite structure cracking and swelling that has limited AGR performance and projected longevity.

Fuel pebble handling systems have been refined and improved over the AVR. They still might have some operational issues, but not show stoppers.