The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

On the hazards of ignorance of thermodynamics

Posted by Engineer-Poet on October 7, 2008 - 8:33pm
Topic: Economics/Finance
Tags: gas turbine, molten salt reactor, nuclear, original, pebble bed modular reactor, steam turbine [list all tags]

The feasibility of non-combustion gas turbines in nuclear reactors

In a discussion about nuclear reactors, a discussion subthread about gas turbines as energy converters ended with this late-arriving statement:

> *Non-combustion gas turbines are not proven. They're mostly in pilot/research stages. You say that the conditions in non-combustion lower temp operation are more reasonable than in higher temp combustion gas turbines, but the fact that they are not commercially competing with Rankine steam cycles, even in the higher temperature regimes, should caution us not to trivialize the engineering/commercial issues.*

The one-week period for comment on the post ended before I could write a response.

What's missing from this analysis? Let me lay out the pieces:

- One can already purchase simple-cycle combustion turbines achieving 46% thermal efficiency.
- These are internal-combustion units running on open cycles, requiring neither hot-side nor cold-side heat exchangers.
- A turbine using inert gas as a working fluid is not internal combustion, by definition. The source of heat must be something outside the fluid. If the heat source is combustion, this requires a hot-side heat exchanger. This is an unnecessary capital expense.
- Preserving the inert working fluid against loss requires a cold-side heat exchanger. This is another unnecessary capital expense for a combustion system.
- Reducing the operating temperature from ~1100°C to ~800°C would also reduce the thermal efficiency. If the heat source is combustion, this increases fuel costs.

We can see from a relatively simple analysis that today's absence of inert-gas turbine generators has nothing to do with technical feasibility. It is soley a matter of economics.

How does a nuclear heat source change the economics? Comparing to the points above:

1. One cannot buy a steam turbine operating at 650°C and higher temperatures. The most feasible option for taking advantage of the high temperature of molten-salt and pebble-bed reactors is gas turbines.

2. The hot-side heat exchanger is either inherent (in a gas-cooled reactor) or required to separate the nuclear materials and the working fluid (molten-salt reactor).
3. Nuclear plants do not chemically modify the working fluid of their heat engines, so are the equivalent of "external combustion".
4. The cold-side heat exchanger is required (like the condenser in a steam turbine).
5. The reduced operating temperature is a given, set by the nuclear heat source.
6. Since the gas turbine can operate at a higher source temperature than a steam turbine and can thus achieve greater thermal efficiency, it improves the return on the capital investment in the rest of the plant. This reduces costs relative to revenue.

The thermodynamic properties of inert gases are well-understood. Designing a fractional gigawatt gas turbine to run on e.g. helium would require design changes such as gas bearings (to eliminate petroleum lubricants or water which would cause corrosion or coking in the hot side), but these have already been proven in other applications. The only reason we aren't running helium turbines today is that it would increase both capital and operating expenses. If the heat source was a high-temperature nuclear reactor, the helium turbine would generate more revenue than a steam turbine for the same capital expense in the reactor. This is why we can expect to see inert-gas turbines as part and parcel of any Pebble Bed Modular Reactor (PBMR) or Molten Salt Reactor (MSR) powerplant.