Re: Mook's quote about nuclear being a "low grade heat". Is it true?

Source: http://sci.tech−archive.net/Archive/sci.energy/2004−06/0767.html

---

From: william mook (*william.mook_at_mokindustries.com*)
Date: 06/13/04

```
Date: 13 Jun 2004 07:41:37 −0700
```

bri1600bv@hotmail.com (brianb) wrote in message
news:<68a6629.0406121259.3e1fbe37@posting.google.com>...
> *Back in the day, costs were not assigned to things that we would find*
> *necessary today. But EVEN WITH THOSE COSTS NOT ACCOUNTED FOR −*
> *NUCLEAR POWER WAS 2 TO 3 TIMES AS EXPENSIVE AS FOSSIL FUELS. That's*
> *what killed the nuclear age more than anything else. No one could*
> *figure out to make things cheap enough. Nuclear energy produced by a*
> *nuclear pile with 3% or enrichment, is a low grade heat! Especially*
> *when compared to heat engines that worked with combustion of fossil*
> *fuels. This reduces temperature differences and overall *capital**
> *efficiencies. If you assumed improvements that increased capital*
> *efficiencies of nuclear power plants, you could apply them to fossil*
> *fuel heat engines, and they'd INCREASE THE DISPARITY − NOT DECREASE*
> *IT. This sensitivity analysis killed Johnson's dream. That's because*
> *a fundamental driver or ROI and cost of living in an industrial*
> *economy is the cost of energy. Subsidies that promote the use of*
> *inefficient energy sources like nuclear (and at present solar) −*
> *exacerbate the problem and don't solve it.*
>
> −−−−−−−−−−−−−−−−−−
> *Is the above quote true that nuclear energy is a "low grade heat"? I*
> *vaguely remember from thermo that efficiency is related to temperature*
> *differentials. Is that what he is talking about?*

That's precisely one of the things I'm talking about certainly. While it is possible to create very hot, and therefore very efficient nuclear powered heat engines, its not possible to do so safely. So, practical nuclear energy is constrained to low efficiencies. Check it out;

http://hyperphysics.phy−astr.gsu.edu/hbase/thermo/carnot.html

(Th − Tc) / Th = Carnot Efficency.

With all temps in absolute temperature − degrees from absolute zero − if we deal with celsius the absolute temperature is measured in degrees Kelvin, or K. The freezing point of water is 0C = 273K. Room temp is 72F = 22C, so that's 298K, so a slightly warm room is 300K...

So, if Tc = room temp (which is about 300K) we can compute ideal efficiencies − which can never be exceeded − knowing Th (hot temperature);

Th	Tc	Efficiency
373	300	19.5% − Boiling water
400	300	25.0%
500	300	40.0%
750	300	60.0%
1,000	300	70.0%
2,000	300	85.0%

This is one measure. Another is power density per unit area of reactor, per unit mass of reactor, and so forth...

Any introductory course in nuclear power plant design will go into all of these factors. Its a bit much though to recount all of it completely in an online posting.

>
> *How exactly does his PV solar concentrator work anyway. It sounds*
> *interesting.*

The cost of solar energy relates to the power available in sunlight, the cost of converting that power to useful form and the efficiency with which the conversion is done.

The amount of power arriving per square meter at the surface of the earth on a clear day is around 1,000 watts. That's about 1 and a quarter horsepower per square yard.

The cost of silicon runs around $1,550 per square meter $1,300 per square yard.

The efficiency of silicon solar cells is no more than 20% so, the useful power out when the sun shines is 200 watts electrical per square meter. This means that the cost of solar collectors will be around $7.75 per watt. Fill factor losses and other costs make this more like $8 per watt!

Since silicon is a mature technology that stands behind the consumer electronics revolution, don't look for vast improvements there. Gradual improvement is occurring and will continue. But rapid breakthroughs are not forthcoming. Although over time, prices are expected to drop gradually to below $1 per watt, just by improving the cost efficiency of silicon production.

Special tricks, like buying surplus silicon at a discount can reduce these costs to $4 per watt, but their impact is limited for any large−scale producer of solar panels. That's because only limited amounts of materials can be acquired in this way.

What is needed is a way to get silicon or to operate at vastly higher power densities. Then costs can drop. This is easily achieved through concentrating sunlight with a parabolic mirror.

Clearly if we focus light to a point with a dish (or a line using a trough) we can increase power density 10x, 100x, 1,000x, (although line concentrators are limited by optics to 208x solar intensity, and dish concentrators are similarly limited to about 40,000x solar intensity) and even more to obtain costs (for silicon) that is 1/10th, 1/100th, 1/1,000th, and less. So, by concentrating sunlight we can reduce costs to $0.78 per watt, or $0.08 per watt,or 8/10th cent per watt, or less.

Now, anyone who has taken a solid state physics course in college may recall that in experiment three in the course they illuminated a photocell with a variable light source and plotted the current produced. Anyone who did well in the course will be quick to say that at around 2x solar intensity the power peaked at about 1.5x full solar current, AND THEN DROPPED! They will recall that this illustrated that solar cells suffer from parasitic losses when illuminated at high intensity. You actually get less power out at high intensities of illumination than you do at one solar because of these parasitic losses. So, they conclude, along with everyone else, that you can't do what I've just proposed to dramatically reduce solar power costs. In fact,if you add the cost of the concentrator and tracker to make this system work, costs could actually increase. And they're right! With conventional photocells you can't concentrate the light to reduce costs.

Well, lets look at parasitic losses then. What are they exactly? And can you get around them?

To answer these questions we need a little undertanding of what happens in a solar cell.

A solar cell is a version of a photo diode. A diode is a device that lets current run in one direction and not the other. A solar cell is set up to produce a forward current when its illuminated and the diode maintains the electrical potential of this forward current so that it is available to an external load, powering it.

But, there is also a dark current. If you illuminate a solar cell and put it in the dark, without a load, the electrical potential will gradually fade away. That's becaus a 'dark current' exists. This dark current is the leakage of current opposite the forward current and it is proportional to the temperature of the junction. Increase the temperature and the dark current increases by the same proportion, robbing current from the forward current, reducing efficiency. This relationship is so accurate folks use silicon diodes to make thermostats and electronic thermometers by injecting a known current and measuring how much is lost across the diode.

So what's this have to do with parasitic losses? Well, heat increases the dark current. This robs the forward current of power. Now, here's the kicker. The forward current all by itself heats the junction! That's because the junction has a resistance. This means the junction disappates power heating it when current flows. This is proportional to current squared times resistance.

So, now we know enough to calculate the result of experiment two in your solid state physics course! The voltage of a solar cell is given by its structure and composition. The current is proportional to light intensity. The temperature of the junction is proportional to the current squared times resistance − and the dark current is proportional to the temperature times a factor. So the complete equation looks like this;

Pout = FORWARD CURRENT − DARK CURRENT

Pout = Factor1 * Intensity − Factor2 * Resistance * Itensity ^2

The factors are just constants related to the materials involved and their method of assembly. The important thing to see is that as light intensity grows the forward current increases as expected, but the dark current grows faster, and eventually overtakes the forward current no matter what.

In typical solar cells this occurs around 2x solar intensity. Which makes it dandy for a simple experiment.

But, by changing the internal resistance of the solar cell (as in Swanson's SUNPOWER cells) you can change the speed with which the dark current grows with intensity and change the location of the peak. Or, by changing the VOLTAGE of the cell by making a certain type of multi−junction stack(as in Sater's PHOTOVOLT cells and others) you can change the rate of growth and the location of the peak as well. Combining both ideas,along with others related to the factors,you can do extremely well!

How far can you go in this direction? We've tested cells in our equipment that are capable of producing output some 3,000x that observed at 1 solar intensity! We are currently working on cells that operate at 5,000x solar intensity and higher! We have as a goal to achieve solar cells that operate at 15,000x solar intensity.

This dramatically reduces the cost of silicon in a solar cell − so that the costs of the mirrors, trackers, heat sinks, and other stuff −

dominate.

As each factor comes to the top of the cost list, we have addressed it, very successfully. Today we have 48 patents underway related to all aspects of making the original concept of high−intensity photocell operation work cost efficiently. We even found that large forward currents and low dark currents can be manipulated at high intensities so that efficiencies are actually increased from handbook values.

At present we have developed solar collectors that can be mass produced for far less than current solar cells per peak watt and have an areal efficiency of 40%. This means a square meter produces 400 watts electrical and we can produce energy for less than the cost of fuels alone in conventional power plants. When you add in the cost of batteries, inverters and everything needed to make a workable power plant − we can produce baseload power for less cost than coal fired plants. When the DC output of the panels are used to drive water electrolysis hydrogen is produced at less cost per unit energy than gasoline! This means that for the first time in history, we have the ability to make massive use of solar energy on an industrial scale − and actually save money doing so!

Since the panels cost less than the enegy they produce over their lifecycle, we do not sell equipment. We sell energy!

This is a paradigm shift in the solar energy business. We're the first solar energy company that actually sells energy! And we do so cost−competitively without government subsidy or non−market support.

We are in the process of negotiating a number of contracts with companies that use large quantities of DC electricity − becuase our system offers the lowest cost method of producing energy. We are also in the process of negotiating a number of land use agreements with a companies that own land − this gives us access to over 100,000 square miles throughout the world.

100,000 square miles of land (about 1/3rd the size of Cecil Rhodes' holdings obtained from Queen Victoria) is enough land area to produce four times today's industrial energy needs entirely from sunlight.
With 4% annual growth in energy use around the world − a growth rate consistent with peaceful economic development throughout the world − we will make use of all this land within the next 35 years.

This is an important factor in evaluating the resources of a solar ENERGY company. While oil, gas and coal companies have reserves evaluated in barrels, tons or cubic feet − solar energy companies like ours are to be evaluated by their land holdings − since that is the interface with the inexhaustable solar resource we're making use of.
By this measure Mok is the largest energy company in the world, with an inexhaustible supply which we can tap cost competitively and with a capacity to meet a continuously growing world economy demand for the

next 35 years. Against this measure all other energy companies pale by comparison!

What to do with this resource? Make synthetic fuel obviously.

Hydrogen is a very interesting fuel to make. Not only can it be used in a variety of ways directly, it can be used indirectly to produce lots of interesting products.

Most interesting is the Sabatier reaction to produce methane − synthetic natural gas from carbon dioxide and hydrogen. Here, we can take CO2 from the air, or from a coking plant, or from a coal fired plant, combine the CO2 with hydrogen and make synthetic natural gas from it.

We can sell the natural gas, or we can run the natural gas through zeolite to produce synthetic liquid fuels and sell those. Australia takes large quantities of extracted natural gas and makes liquid fuels this way.

Since our methane and liquid fuels are derived from air and sunlight, we actually are converting all fossil fuel users who burn our fuels to solar energy users − giving everyone virtual solar plants − without the need to massively change infrastructure. In the process we produce clean synthetic fuels that have zero sulfers metals and other dirty secondary pollutants.

By making use of atmospheric carbon dioxide as an industrial carbon feedstcok in a solar powered fuel generation system we have closed the open ended industrial carbon cycle that has fouled our air and have the means to cost efficiently run carbon dioxide levels up or down − independent of rate of use of carbon based fuels. Ultimately, all the oil that ever was or ever will be extracted and burnt may be re−created with this solar powered system − all free of charge − except of course the capital cost and land cost associated with the operation.

With low−cost synthetic fuels chemically identical to extracted fuels,produced at lower cost than extracted fuels,we have the means to enter the market and augment our failing fuel supplies. For the US this means we have a way to create energy independence using domestic resources for the first time since US fuels faltered and gave rise to OPEC.

General global economic growth means continued exponential growth in energy use. Since extracted fuels are limited and solar fuels are unlimited we can expect solar fuels to dominate supplies within 15 years or so, even while extracted fuels are produced in as large a quantity as they can be produced from known resources.

All the carbon released is available to the solar synfuel producer as
a feedstock − free of charge! With solar energy as the resource for
the solar fuel cycle, and atmospheric carbon − all the oil formerly
and now in the wells of the major oil companies, will one day be in
the holding tanks of the solar synfuel maker, and be available to
refill the spent wells as carbon dioxide levels are steadily brought
down to natural levels.

Meanwhile, continued research will bring online more efficient ways to
bring solar energy to market. Hydrogen fuel, beamed energy, super
capacitors, super batteries, will all be developed over time to make
solar more efficient, and eventually end the age of oil and its major
effects on the environment.

This is all possible because we have solved the problem of making very
very low cost solar collectors. These collectors can be used in a
variety of ways − the most important for today's economy is the
generation of synthetic fossil fuels from carbon dioxide in the air
and sunlight.