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REACTIONS

FROM THE AMERICAN NUCLEAR SOCIETY TO TEACHERS INTERESTED IN THE NUCLEAR SCIENCES

Radioactive Waste from Nature

Oklo: Nature's Fission Reactor

The first nuclear chain reaction controlled by humankind took place Dec. 2, 1942, in the squash courts under the west stands of Stagg Field at the University of Chicago. The anticipation and excitement associated with that event was high. That first controlled reaction marked a turning point in humankind's understanding and use of nuclear science and technology.

But, a nuclear chain reaction took place long before that — over 1.5 billion years ago. It was in a uranium deposit near Oklo, Gabon, Africa.

Nature provided the right combination of circumstances. The uranium deposit was of the right size and shape. The concentration of uranium was sufficient; the proportion of fissionable uranium-235 was high enough. Water was present to serve as a moderator.

As fission occurred, the uranium deposit warmed. The water turned to steam and escaped from the ore deposit. The fission reaction slowed and eventually stopped. The "reactor" cooled. Then, as water again trickled down into the deposit, it served as a moderator and the fission reaction began again. The natural fission chain reaction continued off and on for hundreds of thousands of years.

Why doesn't this happen in nature today? The proportion of fissionable uranium-235 isn't high enough. Why is that? Because, in the intervening time (more than 1.5 billion years), enough half-lives have passed that the proportion of fissionable uranium in natural deposits is too low for chain reactions to take place. Today, we must enrich the uranium.

How do we know about this ancient natural reactor? Did it leave behind radioactive waste? Can our knowledge of Oklo help us with today's decision-making about radioactive waste?

To learn the answers to these and other questions, visit http://www.ans.org/pi/np/oklo/ ■

Next Issue to be Web-Only

E-Mail Notification Offered

The next issue of REACTIONS will be a web-only edition. We will send registered readers an e-mail notification when the issue is available on-line. Have you registered?

Getting registered is easy. Visit http://www.ans.org/pi/teachers/reactions/. Click on "Register for REACTIONS Email Notification" and follow the directions. At that same address, you will find copies of recent REACTIONS issues.

Future issues of REACTIONS will alternate between print and web-only editions. We plan to mail a print version twice a year (September and February) with two additional web-only issues (November and April/May). ■

Expanding quest for quark-gluon plasma

RHIC Begins Full-Energy Collisions

Researchers at the U.S. Department of Energy's Brookhaven National Laboratory have moved to a new level in their search for the hard-to-find quark-gluon plasma. They have resumed operation of the Relativistic Heavy Ion Collider (RHIC), bringing it up to full collision energy.

The initial run of the RHIC produced some interesting results, as we reported in our January issue (a web-only edition).

During the first experimental run last year, ions collided at a maximum energy of 65 billion electron volts (GeV) per nucleon. At the conclusion of that run, researchers upgraded the detectors used in the experiment and expanded the amount of computing capacity available to analyze the results. Now, the collisions will have a maximum energy of 100 GeV per nucleon.

Higher energy collisions will result in higher temperatures, enhancing the chances that the quarks and gluons can escape from inside protons and neutrons. The current run of RHIC expected to last four times as long as the initial run in 2000. ■

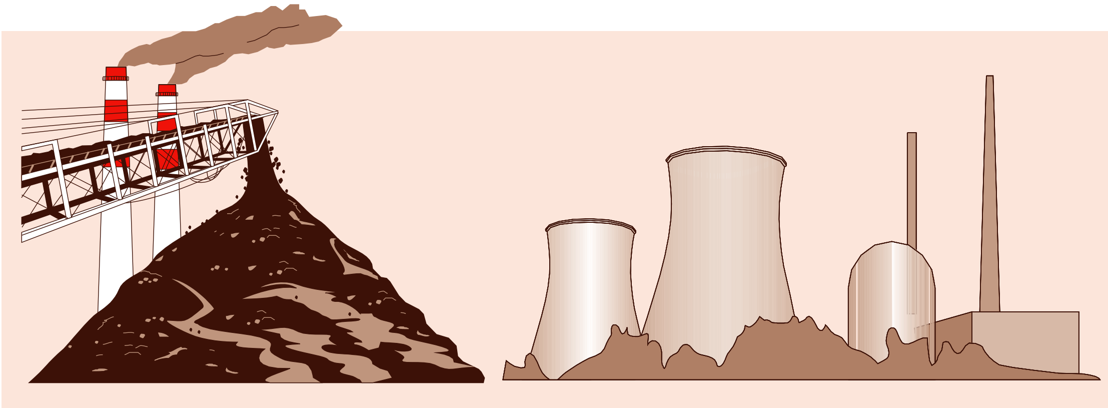
A spectacular gold-gold collision at the maximum RHIC energy as seen by the Phobos detector. Phobos consists of a cylindrical array of silicon detectors and two spectrometer arms surrounding the interaction region where the gold nuclei collide. The dots show the locations where silicon was struck by the thousands of produced particles. The lines are reconstructed trajectories of some of those particles.

An event display showing particles emerging from collisions and striking the pad chamber detectors and Time-of-Flight detectors in the two "central" arms of PHENIX, one of RHIC's large experiments. Several hundred particle tracks are seen which indicate the collision vertex at the center of the image. Photos courtesy of Brookhaven National Laboratory.

Additional information and images are available at http://www.bnl.gov/bnlweb/pubaf/pr/bnlpr071801.htm

Choosing the Fuel for New Power Plants

by E. Michael Blake



Energy has become a hot topic this year, because of electricity outages in California and the Bush Administration's push to develop new sources. There may indeed be a new energy crisis — and it didn't happen overnight.

The few power plants built in the United States over the past two decades have barely replaced the retirement of plants too old to keep working. With the country's population growing, and its prosperity known to be linked closely to growth in electricity use, a power supply that doesn't grow can't meet our expected needs. Conservation and efficiency have helped stretch the supply, but there are limits to what they can contribute. If more electricity is needed, the debate may have to begin again on which fuel is preferable for new plants.

What about hydro and alternative sources?

Hydropower is available only where there's lots of falling water, and while the fuel is essentially free, dams often lead to undesirable environmental effects. Geothermal energy is available in even fewer locations, and in unpredictable quantities. Solar and wind power need, respectively, bright sun and high winds, and even then the power output is small. The largest operating solar power plant, in Southern California, can produce at most 10 electrical megawatts (MWe) of power. Groups of windmills can generate a little more than that, but suffer frequent breakdowns and can endanger wildlife.

A new "base-load"* power plant would be expected to generate about 1000 MWe, which is enough to meet the overall needs of a population of about 500,000. To meet this need we can choose uranium-fueled nuclear power or fossil-fuel combustion power.

Fossil Fuel Options

In the latter group we'll only consider coal. There have been many petroleum crises over the past thirty years, and the oil that is available is still in great demand by the millions of motor vehicles now on the road. Similarly, natural gas — though "clean"-burning and used for plants that help meet electricity demand during peak periods — is the main fuel for home heating in the United States, and a sudden emphasis on gas-fired electricity would put a greater strain on supply, and effectively raise the cost of hot water and winter comfort.

Coal and Uranium Have Focused Uses

Coal and uranium, however, have only one large-scale use: generating electricity. The "coking" coal used in steelmaking is not the same variety as the coal used for power plants, and natural gas long ago replaced coal as a home heating fuel. There are industrial, medical, and scientific uses for uranium, but the amount required is minuscule compared to uranium's use as a power plant fuel. Neither coal nor uranium would become scarce, even if their use were to increase steadily for a century or more.

Getting 1000 MWe from Coal and Uranium

We expect our power plant to operate at an average of 75 percent of full power. Let's look at what each kind of plant would need, and the effects it would have, for one year.

Quantities of Fuel

A coal plant would need about 3 million tons of coal, and if the plant is not near a coal mine, the final fuel cost would include transportation. That much coal would fill about 28,000 hopper cars. Shipping 500 miles by rail would use up about 3.7 million gallons of diesel fuel, which would cost more than $5 million. Once the coal is at the plant, it can remain there as is, until it's needed.

Uranium must go through some processing, but the system is well-established and has operated smoothly and safely for decades. Uranium ore is first refined to an oxide, then converted chemically to a gas so that it can be "enriched" (raising the concentration of the fissionable isotope of uranium, so that it can release energy in the light-water reactors used in the United States), then converted back to a solid and fabricated into fuel elements in assemblies designed to release energy smoothly and keep the fuel confined. About seven tons of finished uranium fuel elements would produce the same amount of electricity that 3 million tons of coal would produce.

Waste Products

In one year, our coal plant would emit about 40,000 tons of sulfur dioxide, about 20,000 tons of nitrogen oxides, and a variety of non-combustible minerals that are included in the coal (such as mercury). "Scrubbers" can be attached to the smokestacks — at extra cost — to trap these emissions, but some fractions still escape. Also, no amount of scrubbing can alter the fact that this is combustion, which always produces carbon dioxide. Our coal plant would release as a by-product about 1.5 million tons of carbon dioxide in a year. Because carbon dioxide in the atmosphere contributes to the "greenhouse effect," trapping in the atmosphere heat from the sun that might otherwise radiate back into outer space, it is believed that large-scale combustion all over the world is leading to global warming, which could have disastrous environmental effects.

At our nuclear plant, power is produced without combustion, through the fissioning of uranium atoms — releasing no carbon dioxide, sulfur dioxide, nitrogen oxides, or mineral effluents. What is left is the water that transferred heat from the fuel to the generating equipment, and the spent nuclear fuel, and both are still contained within the reactor's pressure boundary. The radioactive material

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*"Base load" is the term used by electric utilities to mean the steady electricity supply produced to meet the minimum electricity demand from customers. A "base load" power plant is a plant that provides this steady supply, at any time of day, for months on end. A "peaking" plant would operate only during times of peak demand, perhaps for a few hours a day.

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Choosing the Fuel...

produced by fission is kept in the system, and eventually filtered out. Once it is used up, the fuel is removed from the reactor, cooled for a few years in a secured water pool at the reactor site, and finally sealed in casks that confine all radioactive material and lingering radiation.

Storing Waste

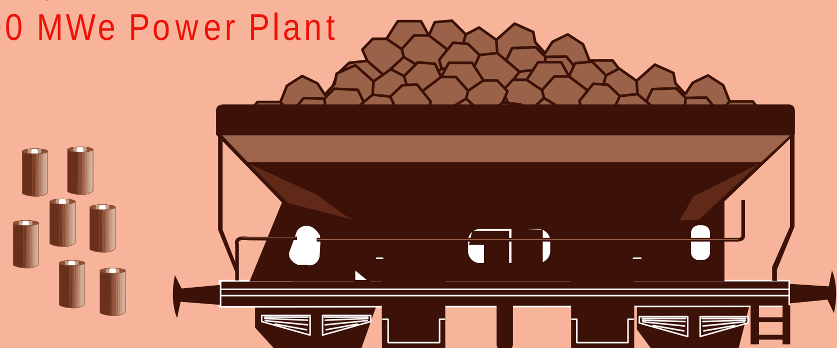
The federal government is committed to creating a site for final disposal of all power plant nuclear fuel, but there has been no significant progress to date. In the meantime, spent fuel casks continue to be stored at reactor sites. Although it is a burden for plant operators to keep track of spent fuel, it is feasible for every nuclear plant site to store all of the spent fuel it will generate during its operating life.

Everyday operation of our nuclear plant generates what is considered low-level radioactive waste, including the resins used to remove fission products from reactor water. This material, like radioactive byproducts from medicine, industry, and other sectors, can be disposed of in licensed low-level waste facilities, which are engineered to prevent the escape of radioactive material to the environment.

The 1000 MWe nuclear plant would generate less than 100 cubic metres of low-level waste requiring offsite disposal. The 1000 MWe coal plant, however, would generate thousands of cubic meters of ash and other non-gaseous wastes (the exact amount would depend greatly on the coal and the plant).

Meanwhile, the next time a utility elects to build a nuclear power plant, it will embark on a new regime for construction, regulation, and operation that has been on the books for several years, but never tried. The Nuclear Regulatory Commission has approved the basic designs of a number of standardized advanced fission reactor plants, so that licensing can concentrate on a single process, largely concerning site-specific issues. The new plant designs are expected to be more cost-effective and efficient. The new process should make it possible to build a nuclear plant almost as quickly as a coal plant. ■

Fuel for 1000 MWe Power Plant



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Project 66 – Activity

Classroom Role Play — A "Mock" Public Hearing

Deciding About Construction of a Power Plant

Making a decision about whether to build a power plant of any type in a specific location can be a complicated undertaking which brings out diverse opinions and powerful emotions. Setting up a classroom role play to simulate a public hearing on the plan could be an effective way to sensitize your students to the many points of view and the tough tasks involved.

✓ Many groups have a stake in such a decision – and widely differing points of view. Structure the role play activity around the interests of these different groups.

✓ Assign each student to take on the role of an individual or a role in a group. Allow some time for students to investigate the concerns and questions that might be important to their "assigned roles." Then, bring the students together at a mock "public hearing" conducted by a group such as the zoning board or the city council. Let each person play a role in the event, voicing questions, opinions and concerns. Someone must chair the hearing (mayor or chairman of zoning board) so that everyone gets to participate.

✓ You may want to structure the specific nature of the "power plant proposal" by creating a hypothetical situation that bears similarities to your own community. Or, you may wish to make it more generic. In general, however, presume there is a proposal to build a new power plant near an existing community. The company planning to build can be identified either as a well-known local utility or as an independent company which will construct an electricity generation plant and sell the power to a local utility company.

✓ Assign students to a variety of roles or groups (power company reps, local government, community residents, interest groups, business people, etc.)*.

Continued next page

Scholarships Offered for Nuclear Studies

ANS offers a variety of scholarships for U.S. college students who are pursuing degrees in nuclear science, nuclear engineering, or a nuclear-related field.

While most ANS undergraduate scholarships (as many as 21) are for students who have completed two years of studies, four scholarships are awarded to students entering their sophomore year. ANS also offers up to 29 scholarships for full-time graduate students in nuclear fields.

In addition, as many as eight scholarships are available to undergraduate or graduate students with greater than average financial need. Qualified high school seniors are eligible to apply for these scholarships.

Additional information is available at http://www.ans.org/pi/careers/ ■

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✓ Coach the students to think about how each person or group would view the construction of a power plant.

- What concerns would they have because of their role? How would a new plant impact property value? What would that mean to government officials? What about the impact on property owners or real estate investors?
- How would the new plant impact the environment, rare species, wetlands, air quality, public health? Would different groups have different views about this? What might those views be?
- Would the presence of a new power plant impact population, school attendance, costs of operating community services, etc? Would it bring additional traffic? What other impacts might it have? Would the community have to spend money to expand services? Will population changes affect the "character" of the community? Will it affect appearance or desirability of the community?
- Will opinions and concerns of various groups and individuals depend upon whether the proposal is to use coal, gas, or nuclear for the power source? How will these factors influence their opinions? What can each group do to influence others?

✓ Have the students research appropriate information, questions and concerns in advance. Convene the "mock" hearing. Conclude the session by discussing some of the things students may have learned from the experience.

*For additional ideas about types of groups to include, click here.

Teacher Workshops Scheduled

Teacher Workshops conducted by ANS and other organizations provide an opportunity to expand your knowledge and skills in teaching about nuclear science and technology.

ANS will conduct an introductory (75-minute) workshop, "Detecting Radiation in Our Radioactive World," at each of the three NSTA Regional Conventions this fall. The conventions are scheduled in Salt Lake City, Utah, October 25-27; Columbus, OH, November 8-10; and Memphis, TN, December 6-8. These workshops do not require advance registration, but they are limited to seating capacity of each room.

ANS will hold a full-day workshop in the Reno, Nevada area on Saturday, November 10. This event will provide greater depth of information and more opportunities for hands-on classroom activities. Advance registration will be required for this event.

Other workshops are being scheduled by utilities, universities and local sections of ANS. For the latest list and more information, visit http://www.ans.org/pi/teachers/workshops/schedule.cgi

The schedule is updated as new events are added, so check the site periodically. ■

New Career Brochure Available

A new ANS brochure highlights some of the exciting career opportunities for graduates with degrees in nuclear science and technology. Medical science, energy and environment are just some of the application fields mentioned in the text.

This new, full-color brochure is appropriate for high school students, their parents, teachers, and guidance counselors. It provides samples of career choices in several major fields where nuclear science and technology are utilized. In addition, the brochure offers tips about preparing for a career in nuclear science.

The brochure is available on the ANS web site. Visit http://www.ans.org/pi/ and click on "Nuclear Careers/Scholarships." ■

Did you read the June issue of REACTIONS?

Articles included:

- demand exceeds supply of nuclear engineers
- how-to tips for using cloud chambers in your classroom
- useful web sites (energy, radiation, physics topics)
- nuclear science and technology facilitates research in other fields

Available ONLY at http://www.ans.org/pi/teachers/reactions/ ■

For additional information about nuclear careers, see the June 2001 issue of REACTIONS. The cover story explains that demand for nuclear engineering graduates exceeds the supply. Related resources are found on the second page of that issue. ■

GO!