AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SCIENCE

ISSN 0036-8075
18 AUGUST 1989
VOLUME 245
NUMBER 4919

■ **SCIENCE is published weekly on Friday, except the last week in December, and with an extra issue in February by the American Association for the Advancement of Science, 1333 H Street, NW, Washington, DC 20005.** Second-class postage (publication No. 484460) paid at Washington, DC, and at an additional entry. Now combined with **The Scientific Monthly®** Domestic individual membership and subscription (51 issues): $75. Domestic institutional subscription (51 issues): $120. Foreign postage extra: Canada $46, other (surface mail) $46, air mail via Amsterdam $85. First class, airmail, school-year, and student rates on request. **Single copy sales:** Current issue, $3.50; back issues, $5.00; Biotechnology issue, $6.00 (for postage and handling, add per copy $0.50 U.S., $1.00 all foreign); Guide to Biotechnology Products and Instruments, $18 (for postage and handling add per copy $1.00 U.S., $1.50 Canada, $2.00 other foreign). Bulk rates on request. **Authorization to photocopy** material for internal or personal use under circumstances not falling within the fair use provisions of the Copyright Act is granted by AAAS to libraries and other users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of $1 per copy plus $0.10 per page is paid directly to CCC, 27 Congress Street, Salem, Massachusetts 01970. The identification code for *Science* is 0036-8075/83 $1 + .10. **Change of address:** allow 6 weeks, giving old and new addresses and 11-digit account number. **Postmaster:** Send Form 3579 to *Science*, P.O. Box 1722, Riverton, NJ 08077. *Science* is indexed in the *Reader's Guide to Periodical Literature* and in several specialized indexes.

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COVER Polar view of the sun constructed from Kitt Peak magnetograms, showing magnetic flux drifting from the sunspot belt toward the negative-polarity north pole during August 1983. The poleward streams, which form a rigidly rotating spiral pattern, gradually establish a strong "topknot" polar field as the 1986 sunspot minimum approaches. See page 712. [Image created at the Naval Research Laboratory from data provided by J. W. Harvey]

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Reliability of Electric Service

On 14 June, a particularly vicious storm hit the Washington, D.C., metropolitan area. It destroyed thousands of trees; many of them fell over electrical distribution lines. In the course of minutes about 150,000 customers lost electricity.

Such experiences stimulate questions about the reliability of the electrical system as a whole. Earlier there was excessive generating capacity. Generation of electric power in the period between 1980 and 1986 rose by 1.5% per year. Utility planning was adjusted accordingly. However, for 1987–88, the average yearly increase was 4.2%.* During the first half of this year consumption rose another 3%. Accordingly, questions are now being raised about adequacy of future reserves. The situation differs from region to region, but now in the north and middle Atlantic states reserves are on the low side. The intertie system connecting utilities in Pennsylvania, New Jersey, Maryland, and the District of Columbia already this summer has been forced to reduce voltage by 5% on four occasions.

A person who is accustomed to a proper response when flicking a switch is not likely to realize the complexities of reliable operation of an electrical system and the need to have reserves to cope with contingencies. Publications of the North American Electric Reliability Council (NERC) can give one a glimpse of some of the problems. For example, a Generation Availability Report 1983–1987 presents extensive data on the reliability of the more than 4000 electric generating units that represent 91% of the installed capacity of North America.

The NERC report presents detailed figures on outages of all types of plants. Data relevant to coal-fired plants in the 600- to 799-megawatt range illustrate where failures occur. Each plant on average sustained a total of 7.7 forced outages per year due to failures in the boiler. In addition, other systems of the plant accounted for more than 5.6 forced outages per year. Partial failures also led to reduced output. Beyond that, scheduled maintenance required cessation of generation. In all, the average equivalent outage time for boiler-related reasons was 1122 hours out of an annual 8640. Other components of the plant, including the steam turbines, generators, and pollution control equipment, caused further outages totaling about 800 hours. Thus the average plant of this type was available only 78% of the time. Similar figures were noted for other fossil fuel–fired installations.

About half of the outages due to the boiler system result from leaks in boiler tubing. A 600-MW boiler has about 100,000 meters of 6.35-centimeter diameter stainless steel tubing containing about 10,000 welds. Analysis has shown that failure of the tubing occurs for at least 22 reasons—most relate to extreme conditions present in a modern boiler. A 600-MW boiler consumes 10,000 tons of coal and the oxygen from 140,000 tons of air each day. In the center of the boiler, temperatures range up to 2000°C, and the average upward velocity of the gas stream and fly ash is nearly 100 kilometers per hour. Turbulent velocities may be much greater. Near the edges of the boiler, where the water-filled tubes are located, temperatures are as high as 1600°C. In the superheater, which is at the top of the boiler, the temperature of fluid within the tubes is 500°C or more. In some installations, the fluid pressure is 270 atmospheres. Pressure in the fire side of the boiler is slightly below atmospheric. If a tiny leak occurs in the tubing, the hot reactive H_2O cuts a large hole leading to a forced outage. The tubing is also subject to hydrogen embrittlement from the inside. On the outside it is exposed to sulfur compounds, NO_x, and at times to excess oxygen. Occasionally tubing may be exposed to a reducing environment that can also cause failure. Other factors leading to failure include erosion due to impact of fly ash, stress rupture, and fatigue due to vibration.

The NERC Generating Availability Data System pinpointed boiler tube failures as a major source of forced outages. This has led to a cooperative effort involving a number of utilities. They have used extensive data concerning tubing failures. Their efforts, coordinated by the Electric Power Research Institute, have resulted in a substantial decrease in forced outages. This precedent is likely to be followed by other cooperative efforts to reduce other types of outages and thus to increase the reliability of the electric system. Complexities, however, are such that progress will be slow.—PHILIP H. ABELSON

*Department of Energy, "Monthly energy review, March 1989" (DOE/EIA-0035, Energy Information Administration, Washington, DC, 1989).