The mystery of the missing neutrinos

The search for solar neutrinos in a South Dakota gold mine has turned up fewer than theory predicts

by Dietrick E. Thomsen

Stars are the natural domain of nuclear physics. In them elements are manufactured by fusing light nuclei into heavy ones. Thus is produced the energy that stars give off, and in the various interactions the elusive particles called neutrinos are formed.

The existence of the neutrino was postulated to balance the energy equations of nuclear beta decay. Physicists had seen that a number of atomic nuclei decayed radioactively by changing a neutron to a proton and emitting an electron in the process.

But there seemed to be some energy lost, and according to a most basic law of physics, conservation of energy, that should not happen. The neutrino was postulated to make up that deficiency. It had to be without electric charge since charges balance in beta decay, and it had to have very little interaction with other matter since no direct evidence of its existence was then available. Twenty-five years after it was postulated, the neutrino was finally directly observed in 1953.

The sun is our nearest and most representative star and the only one from which there is a reasonable hope of recording many neutrinos. An experiment to detect solar neutrinos has been under way for some time in the Homestake gold mine at Lead, S.D., by a group of physicists from Brookhaven National Laboratory. Recent results, described by Dr. Raymond Davis Jr. at the meeting of the American Physical Society in Seattle in late August, show fewer solar neutrinos than there ought to be. This, he says, is a mystery that at present no one can explain to the satisfaction of all the different kinds of specialists involved.

Because neutrinos are so unlikely to interact with other matter, a very large detector is necessary. The one in the Homestake mine is a tank containing 100,000 gallons of the dry cleaning fluid perchloroethylene (C_2Cl_4). The fluid was chosen for its high chlorine content and relatively low cost. The arrival of a neutrino in the detector may convert a nucleus of chlorine to one of radioactive argon 37. In any 50 days of observation the experimenters expected about 25 argon 37 atoms to be produced in the Homestake tank.

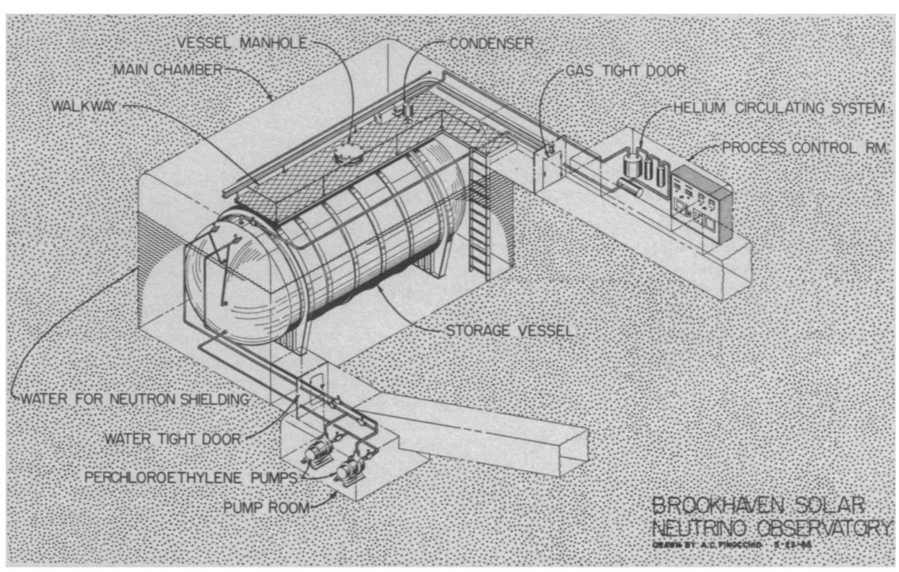
Argon is chemically inert, and therefore when it is formed, it is not chemically bound as its parent chlorine is. It is merely in solution in the perchloroethylene. It can be removed by circulating helium through the liquid. The argon 37 is then absorbed by a charcoal trap, and the trap is placed in a proportional counter.

An argon 37 nucleus decays by capturing an electron from its own atom. This produces a readjustment of electrons that results in emission of an electron with 2.8 kilo-electron-volts energy. This is what the counter looks for.

The tank is placed 4,850 feet underground to minimize the effects of particles other than neutrinos. Still it must contend with argon 37 produced by mu mesons from cosmic rays and by slow neutrons from radioactivity in the surrounding rock. One of the gases produced by underground nuclear explosions is argon 37, so the experimenters must also take account of possible increases in atmospheric argon 37 accidentally released by underground tests. One-quarter cubic centimeter of atmospheric argon somehow gets into the tank per 100,000 gallons of liquid.

Mu-meson production of argon 37 is measured by placing small tank cars of perchloroethylene at various levels in the mine and comparing the amounts of argon 37 in them. Slow-neutron production is measured by placing a known neutron source at the large tank. Lately a water shield has been built to filter out the slow neutrons.

Atmospheric argon 37 is more difficult to estimate since few systematic observations of it have been made (argon comprises about one percent of the atmosphere, and most of that is non-



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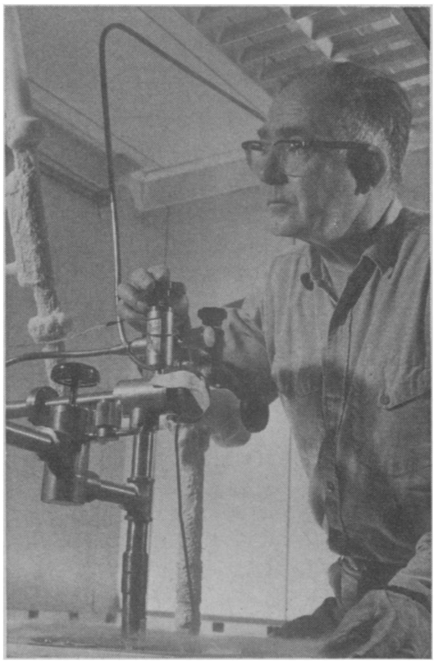
100,000 gallons of cleaning fluid records about one neutrino in three days.



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Davis: Can the boron 8 be wrong?

radioactive argon 40). Dr. Davis thinks that nuclear explosions may have influenced one of the three experimental runs so far analyzed. It showed much more argon 37 than the other two, and the Americans, Russians and Chinese all exploded tests at the time. Dr. Davis wishes that the three governments would give him advance notice of tests, but he expresses little hope of ever getting the information.

When all the background is subtracted, argon 37 atoms attributable to solar neutrinos amount to about 0.34 ± 0.30 atom per day. Thus they are detecting on the average only about one neutrino arrival every three days instead of the one every two days they expected. Though the statistics are still poor, Dr. Davis declares that there is a definite discrepancy between theory and experiment. No one knows why.

"Suppose there is something wrong with the boron 8," he suggests. According to theory, beta decay of boron 8 nuclei is supposed to be the main contributor of the solar neutrinos that the Brookhaven experiment is able to detect, and boron 8 is thus the main candidate for blame if something is wrong. But so far no one is willing to admit that it could be off.

People who make theoretical models of nuclear processes in the sun insist that their numbers and proportions are correct. Nuclear physicists, who have repeatedly measured the cross sections for the various interactions involved, insist that the numbers they supply to the theorists are accurate. Dr. Davis and his colleagues are sure that their experiment is virtually flawless. For the moment the discrepancy is a mystery to which no one can supply the key. □

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INJECTABLE SOLUTIONS AND ADDITIVES: Compatibilities, Incompatabilities, Routes of Administration—Thomas J. Fowler—Springer Pub. Co., 1971, 32 p., paper, $3.25; wall chart, paper, $3. Brings together widely dispersed information and presents it in conveniently tabulated and chart form.

THE MODERNIZED METRIC SYSTEM: The International System of Units (SI) and its Relationship to U.S. Customary Units—National Bureau of Standards—GPO (NBS-SP 304), 1971, 29"x45" chart, paper, 50¢. Wall chart, depicts and defines the six base units of measuring length, time, mass, temperature, electric current and luminous intensi y.

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