Department of Energy
Washington, DC 20545

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Dr. Judith L. Bostock
Nucler Energy Branch
Office of Management and Budget
NEOB, Room 8002
726 Jackson Place, N.W.
Washington, DC 20503

Dear Dr. Bostock:

Enclosed, as per your telephone request, is a copy of the (British) National Radiological Protection Board report, "An Assessment of the Radiological Impact of the Windscale Reactor Fire, October 1957," by M. J. Crick and G .S. Linsley, NRPB-R135, November 1982. Also, for further information is a copy of an editorial "Accident at Windscale," from the British Medical Journal, November 16, 1957, pp. 1166-1168.

Please let me know if we can be of any further assistance.

Sincerely,

J S Robertson

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Enclosures:

cc: C. DeLisi, ER-70
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Nevertheless, in spite of this observation, the moon has been thought to possess a tenuous atmosphere of about the same density as that of the earth at the level where meteors are destroyed by friction; although the density at this height is less than one-millionth of that at sea level.[3] Some optical evidence suggests that the moon's atmosphere is about as dense as this, in which case any visitors to its surface would at least be free from celestial bombardment, whatever other difficulties they might have to cope with. But even that hope now seems to have gone, for radio astronomers at Cambridge[4] have concluded, from watching a celestial radio source being eclipsed by the moon, that its atmospheric density cannot be more than one million-millionth of that at sea level on the earth; and this would stop no meteors.

In any case, the first arrivals on the moon will have to go about in space suits until they can put up some sort of airtight shelter. Space-suit designs vary between two extremes. On the one hand we have those often depicted in illustrated science fiction, which fit the female form so closely that essential "vital statistics" are in no way concealed. Unfortunately, experience has shown that, when this kind of suit is adequately inflated, the four limbs tend to become splayed out at right angles to each other so rigidly that no effort can move them. On the other hand, we have the opinion of F. Haber, of the Space Medicine Department of the U.S. Air Force, who believes that, "If humans want to work in the vacuum outside their space ships, they must do it in solid-walled cylinders, each provided with elaborate air-conditioning apparatus. If they want to walk on the surface of the moon they will have to do the work with metal arms and hands like the remotely controlled manipulators used by atomic scientists."[5] As to airtight living quarters, it has been suggested[6] that oxygen to fill them could be extracted from iron or aluminium oxides in the moon's crust. A municipal engineer,[7] who proposed rigid buildings with a double roof as protection against extremes of temperature, was criticized on the ground that a sort of plastic balloon, kept rigid by internal pressure and placed in a cave to guard against meteors, would be as effective; but he replied that he liked his game of darts and would hate having to dive for a space suit whenever he missed the board.

Many are the motives for wanting to go to the moon. The geologists would like to settle the age-long controversy whether all those innumerable craters were formed by meteoric bombardment or by volcanic action; the astronomers want to set up their telescopes where no atmospheric unsteadiness will blur their optical images; the meteorologists want to watch the earth's weather in their never-ending search for some method of accurate forecasting; Sir John Hunt has heard that the lunar mountains rise to 40,000 feet, and is anxious to have a go.[8] And finally there are the nationalists whose object is to plant their country's flag there, forgetting that a flag is a severely functional piece of apparatus designed for "waving proudly in the breeze." On the moon they will find no breeze for it to wave in.

THE WILLINK REPORT

It was stated in Monday's newspapers that the Willink Committee report will be published by the end of this week, but it had not reached this *Journal* by the time we went to press. A correspondent in the *Sunday Times* of November 10 appears to know what is in the report, for he began his letter thus, "How disturbing to members of professions to learn that the Willink Committee has recommended restricting future entry into medical schools. Will the rot spread?" According to the Political Correspondent of *The Times*,[1] "It is expected that the report will make recommendations for the control of the entry of student doctors into the medical schools, on the basis of long-term estimates of the number of medical practitioners who will be needed in Britain and the Commonwealth." If these forecasts are correct, then the recommendation of the Willink Committee will be contrary to the views of the medical profession as expressed in the evidence given by the B.M.A. and by its Scottish Committee, summaries of which are published in this week's *Supplement*. If it is true that the Willink Committee is advocating a numerical limit on the entry of medical students on the basis of predicting something which is almost unpredictable—that is, the future medical needs of this country—one possible explanation would be that such a recommendation is related not so much to medical needs as to the cost of the Service.

ACCIDENT AT WINDSCALE

A report on the accident at Windscale,[2] published as a White Paper[3] last week, shows that no harm to anyone's health is to be expected, though it points to certain shortcomings in organization. An operation for the controlled release of Wigner energy, which is a routine procedure in uranium-graphite piles, was being carried

[1] *The Times*, November 11.

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out at the time the accident occurred. A standard pile consists of a large block of graphite somewhat larger than a house, with hundreds of cylindrical holes passing from one side to the other, parallel to the ground. Cartridges composed of uranium and uranium oxide contained in a case of aluminium or zirconium alloy are inserted into the centre of the pile through the holes at one side, and, when expended, are pushed out from the other by fresh cartridges similarly inserted. The surrounding graphite is known as the moderator and slows down the neutron emission from the uranium to a suitable level. This results in some of the atoms of carbon becoming displaced from stable to unstable positions, thus increasing the internal energy of the graphite. E. P. Wigner[4,5] postulated that this would occur, and the phenomenon is known as the Wigner effect. The Wigner effect is progressive and can result in a spontaneous release of energy. This occurred in the Windscale pile in 1952. Artificial heating of the graphite under controlled conditions causes a reversal of the Wigner effect, and this operation, which had been successfully accomplished on eight previous occasions, was in progress when the accident occurred.

Controlled release of stored Wigner energy is accomplished by shutting off the air cooling systems which are normally in operation and allowing the temperature of the pile to rise. The progress of the operation is assessed by observation of the temperatures which are recorded by thermocouples, but on this occasion, owing partly to lack of adequate knowledge of the Wigner effect at the time the pile was built, unduly high temperatures were being attained at points in the graphite where thermocouples were not installed. The physicist in charge of the operation, handicapped by insufficient data and inadequate instructions for the procedure, repeated the heating process too soon and too quickly, causing failure of the uranium cartridges and oxidation of the uranium. On October 9 it was realized that the graphite temperature readings were unusually high, and the cooler fans were turned on intermittently. Early on the next day meters in the chimney recorded increased radioactivity, but the levels were considered to be within normal limits. The fans were turned on again, and again the measured radioactivity increased. As a result of these observations the operators concluded that one or more uranium cartridges had failed. Special apparatus is installed to assist in the detection of burst cartridges, but on this occasion the scanning gear was found to be jammed, although it had been recently repaired. It was necessary therefore to arrange for visual inspection through the pile face, and four channels revealed cartridges at red heat. Because the cartridges were distorted by the heat it was not possible to eject them in the normal way through the opposite face of the graphite pile, and the fire was therefore localized by removing a number of neighbouring cartridges. Carbon dioxide foam was applied but failed to reduce the temperature, and it was decided then to use water to quench the fire. This was begun at 8.55 a.m. on October 11, adequate measures having been taken to ensure the safety of the staff, and continued for 24 hours, at the end of which time the pile was cold. Although the Committee of Inquiry was unable to endorse the conclusion that the observed temperature recordings indicated the need for a second heating, it agreed that both the instrumentation in the pile and the instructions to the physicist were inadequate. The Atomic Energy Authority has accepted full responsibility for the accident and is determined to do all it can to avoid a similar occurrence elsewhere.

As to the measures taken to deal with the consequences of the accident, the committee appointed by the Medical Research Council agreed that these were essentially right, and, once they were brought fully into play, were applied decisively and were adequate to prevent ill effects. The International Commission on Radiological Protection[6] has recommended a maximum permissible exposure for life for any fission products which may be inhaled of 10^{-9} μc per c.c. For prolonged exposure this value should be divided by 10, but for short periods of exposure, similar to those occurring as a result of this accident, may be multiplied by 10. If 10^{-9} μc per c.c. is considered to be one unit, then the air contamination over the factory site from the afternoon of October 10 to midday October 11 varied between 2 and 10 units. All measures necessary to safeguard the members of the emergency squad working on the damaged pile were taken, and no cases of severe excessive exposure occurred. The accepted permissible dose of radiation in any 13-week period is 3 r. For the relevant 13-week period including the accident the 3 r maximum was exceeded by only 14 workers, and the highest recorded level was 4.66 r. These findings were checked and found to be accurate by personal emergency recording equipment used during the accident. In accordance with standard practice these workmen have been removed from further radiation risk and will not resume until it is safe to do so. No worker was detained for special treatment, and in only one case was there any difficulty in decontaminating hands and heads of exposed persons. Suitable protection was provided for this workman when he returned to his home, and the decontamination was completed next day. The procedure is strict and the monitoring sensitive, so that no risk remains for this man or for the persons with whom he comes into contact.

Some anxiety was felt by members of the public who thought that the risk from inhalation of radioactive materials outside the works might be significant. Measurements made on the hair and clothing of persons who cycled in the vicinity show that, even if they neither washed nor changed their clothes in ten days, the exposure would still have been negligible. As previously stated in these columns,[2] the main potential hazard was from absorption of radioiodine. The report con-

[2] *Brit. med. J.*, 1957, **2**, 991.
[3] *Accident at Windscale No. 1 Pile on October 10*, H.M.S.O., Cmd. 302, 1957. See summary in *Journal* at p. 1171.
[4] Wigner, E. P., quoted by Burton, M., and Neubert, T. J., *J. appl. Phys.*, 1956, **27**, 557.
[5] —— *U.S. Atomic Energy Commission Report*, C.P. 387, 1942.
[6] *Brit. J. Radiol.*, 1955, Suppl. 6.

firms this view and states that, except for the need to check periodically the content of strontium-90 in the milk of cattle grazed on certain specified areas, no risk exists from either radiostrontium or radiocaesium as a result of the accident. Having agreed that absorption of radioiodine constituted the main hazard, the committee has presented data which indicate that no harmful effects are likely to result either to plant personnel or to members of the public. A thyroid iodine survey has been made among workers and among local inhabitants round the works. The International Commission on Radiological Protection recommended a level of 0.1 μc for safe continuous and constant activity in the adult thyroid. The highest thyroid activity recorded among the staff is 0.5 μc and among the local population 0.28 μc in a child. These levels are well within the permissible level for short exposure, which is accepted as ten times the recommended level of 0.1 μc for prolonged exposure.

The decision to suspend distribution of milk from the Windscale area was a difficult one to make. No established tolerance for radioiodine in milk exists, but a limit of 0.39 μc per litre for milk given to infants had been suggested. The first milk analyses revealed levels up to 0.8 μc per litre, and milk distribution was stopped. After consultations between the medical and physics experts it was agreed that milk from the area should not be consumed until the levels had decreased to not more than 0.1 μc per litre. Examination of water, meat, eggs, and vegetables in the area revealed that no hazard existed in relation to ingestion of these items. The committee of the Medical Research Council expressed the opinion that the delay between recognition of the accident and the institution of an extensive and rapid milk-sampling programme throughout the area of possible risk was a weakness in the organization apparent only after the event, and that the investigations had revealed certain gaps in scientific knowledge which require early attention.

The final section of the Report outlines the differences between the Windscale plant and the more modern installations already working at Calder Hall and under construction for the electricity authorities in other parts of the country. The new piles not only have better controlling equipment but operate at a higher temperature. The latter modification will allow release of much of the Wigner energy as it is formed, so that operations to release stored energy will be required less frequently. Moreover, in the newer piles failure of a fuel cartridge would be detected immediately and the amount of radioactive material which could escape into the atmosphere would be too small to constitute a hazard. In the words of Sir Edwin Plowden, chairman of the United Kingdom Atomic Energy Authority, this accident caused disturbance and anxiety to many people. No harm to any person has resulted or is likely to result from the episode, and the devotion to duty and prompt and efficient actions of all those concerned in dealing with the accident deserve the highest praise. We should be grateful, too, to the members of the various expert committees who have produced so promptly a report which makes available to the public all the relevant facts, and interprets them for us.

LIGHTNING SHOCK

A direct hit by a lightning flash or a high-voltage electric current is almost invariably fatal. Massive holes and tears are found in the body, especially in the brain and blood vessels. But most people apparently struck by lightning seem to suffer no more than freakish damage to parts of their clothes and body. This is because the current tends to take the pathway of lowest resistance; it leaps from one low-resistance conductor to another, so that down this pathway all the energy is dissipated, leaving organs a few centimetres away unharmed. The main resistance offered by the body is in the dry skin, which is why household electric currents are so much more dangerous to the wet body. Surprisingly, the pathways followed by such currents as do traverse the body are not yet finally settled. It is thought that the energy goes mainly along blood vessels or nerves,[1] but A. W. Weeks and L. Alexander[2] considered that the whole body is a low-resistance, structureless gel, so that there is a steady potential drop along the shortest line between the points of entry and exit of the current, with uniform potential fields around. When the current passes from one hand to the other it traverses the lower cervical spinal cord, which may explain why the results of this accident often look like transverse myelitis or even disseminated sclerosis. Whatever the pathways taken, it is the nervous sytem that always seems to bear the brunt of the current, though experimentally large currents can make the heart stop or fibrillate. A condition of profound "shock" with apparent suppression of all nervous activity may last one or two hours after a heavy electrical shock, yet the persons still recover without apparent sequelae.

The precise aetiology of the massive lesions seen at necropsy in fatal cases is poorly understood. Heating effects are undoubtedly important, especially with currents such as are used for legal electrocution, in which currents of high amperage and medium voltage are applied for several minutes. Electrolysis producing gases has been suggested as causing the holes sometimes seen in the brain. Blake Pritchard[3] thought they might be due to electrostatic effects bursting apart oppositely charged portions of the body, in the same way as objects held are often flung far away from the person; but this is unlikely in view of the probably uniform potential fields in the body. The wave of compressed air produced by the discharge may also have some mechanical effects.

The surprising thing is perhaps that those who survive lightning stroke do not have more permanent and striking disabilities. Minor sequelae are frequent, and headaches and paraesthesiae seem to be the commonest effects

[1] Hughes, J. P. W., *Brit. med. J.*, 1956, 1, 852.
[2] Weeks, A. W., and Alexander, L., *J. industr. Hyg.*, 1939, **21**, 517.
[3] Pritchard, B., *Lancet*, 1934, 1, 1163.
[4] Arden, G. P., Harrison, S. H., Lister, J., and Maudsley, R. H., *Brit. med. J.*, 1956, 1, 1450.
[5] Critchley, M., *Lancet*, 1934, 1, 69.