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UNITED STATES GOVERNMENT

Memorandum

107038

TO : Files

DATE: April 19, 1968

THRU: John R. Totter, Director
Division of Biology and Medicine

FROM : H. D. Bruner, M.D., Assistant Director for
Medical and Health Research
Division of Biology and Medicine

SUBJECT: CONFERENCE WITH DANISH REPRESENTATIVES IN PENTAGON, MARCH 18-19, TO FOLLOW UP ON BROKEN ARROW/CRESTED ICE PROJECT, THULE BASE, GREENLAND (JANUARY 21, 1968)

ADMHR:HDB

The official list of participants is given on Attachment I. A number of people on Dr. Walske's staff participated at one time or another.

Mr. Hans Koch and Dr. Walske shared the chair as they did at Copenhagen; everything moved effortlessly with a great deal of cordiality. Mr. Koch indicated that the Danish government had appointed the following committee with himself as chairman to coordinate all efforts to evaluate the situation at Thule and undertake whatever further measures are considered necessary. /H. Koch, Chairman; J. Koch; H. Lassen (absent); H. L. Gjørup; C. F. Jacobsen; and E. J. Henningsen./ The memo of understanding signed by Mr. Koch therefore has an official connotation.

At the first session on March 18, General Hunziker, Dr. Gjørup, and Dr. Langham reported on progress in the cleanup and on data obtained since the Copenhagen meeting this time last month. With the advent of daylight, General Hunziker has been able to put large numbers of men on the ice to carry out shoulder-to-shoulder search of the ice for pieces of metal. The weather has held good and now the ice is considered to have been satisfactorily cleared of metal. He was also able to get moderately heavy road equipment onto the ice to scrape up the heavily contaminated area (defined by LRL's Fidler meters) corresponding in general to the 500 x 2000 foot blackened-streak and roughly the southern half of the cracked ice area. The scrapings, about 230,000 cubic feet, have been transported to the shore and stored in 65 empty steel tanks; this material is still frozen.

The blackened area is no longer discernable. Surface surveys suggest that possibly 10 to 100 gallons of JP-4 fuel and 350 grams of ^{239}Pu are still left in the ice. If 30% of this Pu remains suspended within the JP-4 layer, something like 100 grams of Pu might eventually spread on the shoreline; however, if agitation breaks down 80% of the emulsion, then perhaps only 20 grams would reach the shore. In any case, General Hunziker proposes to patrol the shores for metal pieces of the

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airplane, oil, and contamination. While he considers his work largely to be completed, there are still incomplete aspects such as work by the Geodetic survey, current measurements in the bay (it is about three miles/hour on the bottom beneath the crash point), storing the collected snow and ice under controlled conditions, arranging for eventual transport of all contamination to the U. S., etc.

Some 186 cores have been taken from the ice according to a specific pattern which concentrated on the black streak and the cracked ice area. The radioactivity is associated with the carbon-oil layer, although some black areas have distinctly lower levels of Pu than others. Since layers of activity are found at odd angles and positions in the vertical cores from the cracked area, it is reasoned that the ice in this area must have been fractured, blocks upended and hurled about whereupon they froze again in odd angles and positions.

As of March 1, 83% of the total Pu on the ice, as estimated from contour lines defined by the Fidler meter, had been removed; if only the black streak area and the southern half of the cracked ice area are considered then about 93% has been removed. The point is that the jumble of ice blocks in the northern half of the cracked ice area has prevented use of the scraper equipment. Not all the contamination is on the surface of the ice in this area, but no JP-4 or Pu has been found on the parts of the ice cores in contact with the sea water.

The highest levels on the meters observed in the earliest surveys were in the range of 450 to 500 mg/m^2; the highest residual value now is about 200 mg/m^2 with most being 5 mg/m^2 or less.

Dr. Gjørup collected 121 samples of snow or earth from selected points downwind of the impact and fire column and from the adjacent coast lines or islands where birds or seals might be found. (See map on file and data.) His values range from zero to 3.8 $\mu gm/m^2$ with an average of 0.4 $\mu g/m^2$. The total cumulative amount of Pu for the ice surfaces surrounding black streak and impact comes to about 10 curies; the highest concentrations were found on the south shore near Narssarsuk. If there had been people at Narssarsuk, the maximal inhaled amount of Pu would have been about 0.05 μc per person.

Other samples collected up to 10 to 15 km downwind from the streak, to the west in the direction of the open water in Baffin Strait, showed very low amounts of Pu; this activity could be the result of drifting snow or the dispersion created by the fire column, but the former mechanism seems more likely. These Pu levels, however, are close to those resulting from deposition from weapons tests.

Langham has analyzed only 20 snow samples but his data agree with Gjørup's. Both find a tendency for higher levels to be on Saunders Island. They agree within a factor of 10; they considered this to be very good in view of the statistics of sample collection.

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Gjørup found only trace amounts of Pu (1.5 pCi/gm) in sea water collected from 9 points along the bottom (see map on file). Two showed positive values, 0.0016 and 0.00016 μgm/liter, but contamination is suspected. Snails and sea worms from the bottom were negative for Pu and plankton showed trace amounts. A sledge dog used on the ice and killed in a fight had 0.001 pCi/gm in the liver and 0.3 pCi total activity in its feces; the lung had none. Two foxes showed 1 pCi and 100 pCi respectively in the total gut contents, but nothing in the lungs.

Fitzpatrick reported that the nasal swabs and urines of men working on the ice were negative for Pu.

Langham then described his reconstruction of what must have taken place as the plane came in. His concept was based on the ice cores mentioned above and on infrared and other kinds of photographs reprocessed to get maximum contrast. These made it evident that the cracked ice area is circular and about 650 feet in diameter. The northern half has a much more uneven surface as a result of ice blocks frozen into various odd positions. This cracked ice area did not seem to be 650 feet in diameter when I walked over it in all directions because only the above blocks of ice about 150 feet in diameter could be identified as abnormal by a man on foot. But the photographs brought out clearly the concentric circular fracture lines that must have refrozen very quickly.

There is also clear photographic evidence of a linear streak crossing this cracked area and Langham postulated that if the plane came in at a 15° tangent to the ice with the left wing tip 60° from the horizontal, he then could account for the pattern of break-up and scattering of fuel and engine parts just prior to the contact of the nose with the ice that set off the high explosive in the weapons.

The high explosive of the weapons detonated beneath the main fuel tanks and hence the amount of fuel in the center of the cracked ice area is minimal. The very high explosive force of the weapons would account for the reticular arrangement of fracture lines and distorted ice blocks. He also postulated that one weapon exploded first and its shock wave then set off the other three. It seems likely that the explosion disintegrated the Pu and alloy, and surrounded as they were by fuel tanks, etc., this metal ought to be impacted on and into the surfaces of one side of many, but not all, pieces of wreckage metal; this is what was found.

The JP-4 fuel seems to have played a special role in the distribution of the Pu. First, it seems to have provided a filter or catchment for Pu that otherwise did not impact onto some other surface. Second, the burning fuel was the means of dispersal-dilution of Pu over a fairly large number of square kilometers beyond the immediate area of the crash. Probably 70% of the fuel burned. And finally, the remaining unburned fuel by virtue of its surface tension properties has continued to influence the distribution of the Pu and other debris. By its coating action the fuel has caused (helped?) Pu to adhere to bits of metal, rubber, nylon,

plastic, fiberglass, carbon, etc. These do adhere to one another, and they probably minimized the distribution of the Pu over the surface of the ice. Where sufficient residual carbon mixed with this debris there resulted the black streak or "scar"; without the carbon a slightly discolored, unnatural crinkly sort of "ice" formed in this -15° to -40° cold.

When such areas are removed, by scraping or by cores, and allowed to melt, the JP-4 floats to the surface bringing with it the above small bits of stuff and most of the Pu. It is not a true emulsifying agent because shaking will cause much of the stuff to settle out, especially the larger bits. But in general the fuel does tend to segregate the Pu (really PuO_2) away from the water. In general, 70 to 75% of the Pu will settle out after a time. Track counts by autoradiography of the fines recovered from this semi-emulsion gave mean diameters for the Pu particles of 2 μ with range of 0.1 μ to 100 μ. The Danes had also done this and they were very pleased to have arrived at the same numbers.

Some pieces of the wreckage with adherent Pu lost about 50% of their Pu when merely dunked in sea water two or three times. For the most part, however, the curve of removal resembled a Langmuir isotherm. Eighty percent was released from aluminum after some 40 hours in sea water agitated gently so as to simulate wave motion; only 30% was released from steel surfaces in 40 hours. The gradual but steady release of Pu assures that high concentrations will not develop locally from metal that may get into the bay and that the metal will eventually be no hazard.

Langham then gave some estimates which the Danes carefully noted, translated into the units they use, and agreed to with evident pleasure:

1. On the basis of cores, there are 300 to 350 gms of Pu (1.9 to 2.1 curies) in the cracked ice area, mostly in its central parts. Now that the streak and southern part of the area has been scraped, the residuum is in the northern half of the circle where the tumbled blocks are. (Danish estimate was 320 grams.)

2. On the basis of cores and the Fidler meter, there were about 3190 gms (200 curies) of Pu inside the blackened area; all but 1% (31 grams, 2 curies) has been removed. (The Danes had estimated 1600 grams but agreed with our figures and further said the residuum was a negligible amount. They indicated they would be happy with this residuum if they could be sure there were no small, local, very hot spots left on the ice.) The accuracy of the above figures depends on the calibration of the Fidler meter and the contour lines. It was agreed that the figure of 3180 $\pm$ 20% (3700 to 2500) gms is reasonable.

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3. These numbers fall short of the theoretical amount of Pu in the four weapons. Where is the rest? Some must be on the airplane metal now being packaged for shipment to the United States for burial. There will be no attempt to recover this. Some has been spread far and wide by the fire column and/or wind-drifted snow. Some may have gotten into the bay at the time of explosion, either directly or by attachment to pieces of plane which sank to the bottom. Some has been recovered directly. It appears unlikely that we shall ever get a precise inventory.

Mr. Olson (Lawrence Radiation Laboratory) said he had melted some cores in garbage cans at Thule. He found that 30% of the Pu floats, but this reduces to about 18% with time. However, the fraction which floats is proportional to the amount of "gunk" and carbon present. The Danes agreed.

Mr. Gjørup (Danish Atomic Energy Commission), as noted above, has made extensive samplings of cores, snow and earth for ^{239}Pu and ^{3}H. He reported that if a sample from the crushed area had no Pu, it also had no ^{3}H. Where the ice had a clean, hard surface, there was no ^{3}H--"the vast majority of the ^{3}H has been taken away by the clean-up procedure." The concentration in the streak area after clean-up was in the range of 10^{-5} μCi/cc. He estimated that there may have been 3000 Ci of ^{3}H in the black streak, and 10 Ci in the cracked area. Possibly 330 Ci are left on the ice. /The MPC for ^{3}H for industrial workers over a 40 hour week is 0.03 uCi/cc of water; this equals $3x10^{7}$ Ci/km^3 and 0.03 Ci/m^3. Use a value of one-thirtieth of 0.03 Ci/m^3 for intake of tritium in water by the general population over the 168 hour week. One gram $^{3}H = 9.8x10^{3}$ Ci and 1 Ci of $^{3}H = 1.02x10^{-4}$ grams./

There was general agreement on our side that Gjorup's figures for ^{3}H were reasonable.

He then presented and discussed the data which he had developed from snow samples collected on the shore, on the islands, and on wide traverses away from the streak (v.s.). These data and the map are on file. Most were below 1 pCi/cm^2 (0.01 uCi/m^2); the highest value, 40 pCi/cm^2 of Pu (0.4 uCi/m^2), was south of the streak close to the shore and in general the higher values were to the west and south as might be expected from the prevailing winds blowing snow westward and southward. The islands where the birds nest were low or zero. Narssarsuk on the south coast and back into its ravine seemed to have an average level higher than the rest. He estimated that there might be 10 curies spread out on the ice and land exclusive of the streak. There was no alpha activity in the lake from which the Base water supply is taken. /16 curies of ^{239}Pu = 1 gram/

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In the afternoon a number of subjects of a technical or logistic nature were discussed. There were no difficulties in reaching agreements, which next day, Tuesday, became items on the "Gentlemen's Agreement" document, Attachment III. For example, General Hunziker noted it was easy to decontaminate completely the trucks and heavy snow removal equipment, but it was hard to remove the Pu that was embedded in small cuts on the tires--Would it be satisfactory to use 450 c/m on the standard α-counter as the limit for use of those tires on the base? Dr. Gjørup made some calculations and said, "Yes." And so it went.

Six other items are of interest:

1) The area enclosed by the 60 $\mu g/m^2$ line as determined by the Fidler instrument will be roped off and prohibited to the Greenlanders until the ice melts and/or goes out into the strait.

2) Langham repeated that the plane must have come in at a 15° angle to the surface with the left wing 60° down. The nose of the plane is fragile and only 0.8 G is required to crush it up against the leading edge of the wing; 3 G is needed to crush the wing assembly. Hence, he deduced that the wing touched and pulled the nose down. It crumpled, the bomb shakles broke, and one set off the other three. The explosion blew downward and rearward and as the bomb bay doors are very thin, relatively "clean" Pu was blown against the ice of the cracked area, particularly its south half. Momentum kept the heavy pieces of the plane going forward and hence some might be free of contamination, especially if protected by a blanket of metal, plastic, and fuel.

3) Did part of the plane go through the ice? There were a few desultory guesses, but no one had sound reasons for either view. However, if the mass of the wing and central fuselage is given a value of 1, the anterior part of the plane has a value of 0.001 with the tail section 0.0001. The tail has aerodynamic properties and tends to go sailing off on its own. What happened to it?

4) Well-frozen ice with an undisturbed surface has a surface tension as high as steel and would retain all Pu impacted on it. The north half of the crushed area is almost free of Pu; the south half was very active.

5) Possibly the remaining Pu and fuel could be immobilized by putting carbonized-sand (an oil-getter used by the Navy and available from Navy stores) on the cleaned-up area. This will retain heat from the sun, help the underlying ice to melt, and drop the getter plus oil and Pu to the bottom. General Hunziker agreed to carry out an experiment to see if it might work; if it does, this will be applied to the streak.

6) The Danes felt that from now on it was not necessary to make a lot of duplicate samples of snow, plankton, animal material, etc. They would do all that they felt was necessary for monitoring surveillance. Would this be all right with the U. S. scientists? We agreed that it would.

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The Air Force will provide logistic support for the Danes. Dr. Vibe, their mammalogist, will do the sampling in the bay. Dr. Martin-Hensen, their fisheries expert, will carry on a survey of whether fish migrating southward (if any) have Pu in them. They intend to maintain a flexible approach to take care of unexpected findings. They saw no need to sample the dust or the earth on the southern headlands.

Their reasons for this low-key insistence on the above monitoring-surveillance were given privately as having to do with the native Greenlanders' outlook on logic. Their approach was: If we declare the bay to be suitable for hunting and travel, then we can't mount a big investigative program with foreigners in evidence for the Greenlander will say, "Is the bay safe or is it not? What you say and do are different!" The Greenlander, however, will understand if we sort of casually check out a seal or two, etc.

In brief, it appears that the Danes intend to minimize the hazards-monitoring-surveillance aspects of the bay and dismiss them from public view. Nothing definitive was said about tritium; it, too, will receive the same low key treatment. (E.g., Gjørup and I compared ^{3}H figures: The MPC for ^{3}H for a radiation worker ingesting his usual intake of water during 40 hours per week is 0.03 μCi/ml or 3×10^{7} Ci/km^{3}. Assume 200,000 Ci of tritium was on/in the ice: Then $3 \times 10^{7} / 2 \times 10^{5}$ 1.5×10^{2} or a factor of safety of 150 for a radiation worker if the 200,000 Ci were confined to only one cubic kilometer of bay water. He said there cannot possibly be a hazard and dismissed it.) /The bay has a volume of about 50 km^{3}, the ^{3}H released was less than 2×10^{5} Ci, and much of that went up in the initial fire column as $^{3}H_2$ or ^{3}HOH./

Hence, in the most pleasant way possible, the Danes officially gave us to understand that they considered the surveillance in behalf of the Greenlanders and Danish soil their problem and they proposed to take care of it. This was also said personally to me in various ways by different members of the team whom by now I can regard as personal friends.

Attachments:
Participants in the Conference on the
Thule Accident Cleanup, 18-19 March, 1968
The Pentagon - Room 4E871
Gentlemen's Agreement
Thule Environmental Investigation Program
Summer of 1968

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Attachment I

PARTICIPANTS IN THE CONFERENCE ON THE THULE ACCIDENT CLEANUP
18 - 19 March 1968
The Pentagon - Room 4E871

Danish Visitors

Mr. Hans H. Koch	Permanent Undersecretary of State, Chairman, Executive Committee, Danish AEC
Professor Jørgen Koch	University of Copenhagen, Consultant to Danish National Health Service
Dr. H. L. Gjørup	Head, Health Physics, Riso
Dr. Eigen Juel Henningsen	Deputy Director-General Danish National Health Service
Dr. C. F. Jacobsen	Assistant Director, Riso
Mr. G. Vigh	Secretary, Danish AEC
Mr. Anker Hansen	Scientific Counselor to Danish Embassy

U. S. Participants

Dr. Carl Walske	Assistant to the Secretary of Defense (Atomic Energy)
Major General Richard O. Hunziker	Deputy Chief of Staff for Materiel, Strategic Air Command; Chief, SAC Disaster Control Team
Dr. Gerald F. Tape	Commissioner, USAEC
Major General Otto J. Glasser	Assistant Deputy Chief of Staff for Research and Development, USAF
Dr. Wright H. Langham	Leader, Bio-Medical Research, Los Alamos Scientific Laboratory
Mr. Herbert M. Parker	Battelle Memorial Institute, Pacific Northwest Laboratory
Dr. H. D. Bruner	Assistant Director, Division of Biology and Medicine, USAEC

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Major Joseph S. Pizzuto	Health Physicist; Secretary, USAF Radioisotope Committee
Brigadier General Albert J. Bowley	Commander, 45th Air Division, SAC; President, Eighth Air Force Aircraft Accident Investigation Team
Colonel Chester A. Hockett	Deputy Director of Munitions, Strategic Air Command; Executive Officer, SAC Disaster Control Team
Mr. James L. Olsen	Lawrence Radiation Laboratory, Livermore, California
Colonel Jack C. Fitzpatrick	United States Army, DASA
Colonel Oscar J. Sundstrom	Chief, Nuclear Branch, Directorate of Supply and Services, USAF
Mr. Frank Tucker	Scandinavian Affairs, U. S. State Department

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Attachment II

This document records the "gentlemen's agreements" reached during the Danish/US meeting of 18-19 March in Washington and is supplementary to the similar document written in Copenhagen on 16 February, 1968.

1. The aircraft debris currently stored in sealed containers will be removed from Greenland as soon as convenient; possibly this summer, based on the availability of retrograde cargo.

2. Regarding the black area, the removal measures completed to date are considered adequate. The snow and ice which have been removed are stored in sealed metal containers and present no hazard in this state. It is agreed that the contained radioactive material will be removed from Greenland as soon as convenient. The exact approaches to be employed (i.e., concentration by filtration versus bulk removal) are to be the subject of detailed study by the U. S. Air Force. The recommended plan will be presented to both governments for approval prior to implementation.

3. The vehicles will be decontaminated to levels consistent with good health physics practices. It is agreed that less than 2×10^{-6} uc/cm^2 (450 cpm as measured by a standard swipe sample) constitute an acceptable level insofar as the tires are concerned. On the vehicle itself, a factor of 10 below this level is considered adequate.

4. The proposal to enclose the crash scene by stanchions and rope is acceptable. At an appropriate time the Danish AEC will take measures to release the hitherto restricted area for public use with the exception of this limited zone, which will continue under observation. The Danish AEC will be notified when this rope is in place.

5. It was agreed that the U. S. Air Force would implement the suggestion to treat the 2500 square meters active region of the impact area with carbon/sand to accelerate the melting of this region. This technique will be tested on similar ice as early as possible. The U. S. Air Force will also continue to evaluate measures for the physical removal of exposed radioactive ice and debris.

6. The so-called "black area" and "cracked ice area" which are estimated to contain an insignificant part of the total Pu distributed on the ice, will be left in its present state.

7. Roads and other public areas will continue to be monitored and detected contamination will be kept to levels consistent with good health physics practices.

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8. The tank farm and other restricted work areas will also be monitored and by the conclusion of operations, contamination will be reduced to levels consistent with good health physics practices.

9. The Danish AEC will conduct an ecological program as described in the attached plan with logistic support being provided by the U. S. Air Force as required.

10. The Danish AEC will conduct surveillance of the shore lines in accordance with the attached plan. The U. S. Air Force will be available to assist as required in the removal of any discovered debris.

11. The question of a possible search of the sea bottom was reserved for further study of costs and utility by the U. S. Air Force. Should such a search be undertaken, the results would be made available to the Danish AEC.

12. As a general policy, any of the above plans is subject to modification based on new evidence as it is collected.

13. Major policy questions will continue to be decided on the basis of Washington/Copenhagen agreement. Minor policy and detailed operational decisions will be made jointly at Thule.

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Attachment III.

Risø, March 14, 1968

Thule Environmental Investigation Program
Summer of 1968
(To be carried out by the Danes)

1. Samples for Plutonium Analysis

Samples will be collected of the following primary media: sea water, sea bottom, zooplankton and mussels. These samples will be collected in two zones, zone I enclosed by a circle with its center at the site of impact and radius 1 km, and zone II comprising Bylot Sund and Wolstenholme Fjord.

In zone I the following numbers of samples will be taken: 4 sea water samples, 10 bottom samples, 4 plankton samples and 12 mussel samples.

In zone II will be taken: 12 sea water samples, 12 bottom samples, 12 plankton samples and 12 mussel samples.

In addition the following secondary samples will be collected from the area as a whole:

9 samples of seals' faeces (walrus, bearded seal and harp seal)
9 samples of birds' faeces (common eider, long-tailed duck, little auk)
6 samples of wing snail
3 samples of seaweed
3 samples of lichen (from Narssarssuk)
5 samples of eiderdown
3 samples of fish (polar cod).

2. Survey of Coast Lines

The coast from Uvdle to Cap Athol and the coasts of Saunders Island, Wolstenholme Island, Eider Islands and Dalrymple Rock will be searched for debris. A suitable procedure has to be established.

Further surveys (e.g., of the northern coast of Wolstenholme Fjord) will depend on the wind conditions following the ice melting.

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