FD 203/58-PET

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS
MINES BRANCH

OTTAWA

FUELS DIVISION

TECHNICAL MEMORANDUM 203/58-PET

NOTES ON MEETING CONCERNED WITH A PROPOSED THERMONUCLEAR TEST IN ATHABASCA BITUMINOUS SANDS

Prepared by W.H. Norrish

Technical Editing by Dr. D.S. Montgomery

November 1957

MW

Notes on a meeting convened at Ottawa, October 31, 1958 by Dr. John Convey, Director of the Mines Branch, Department of Mines and Technical Surveys, to consider the problems associated with the use of Thermonuclear Devices for the extraction of oil from the Athabasca Bituminous Sands.

Attendance

Dr. John Convey	Chairman
Dr. G.W. Johnson	University of California
Dr. W.J. Frank	University of California
Mr. M.L. Natland	Richfield Oil Corp.
Mr. David Guntert	Richfield Oil Corp.
Mr. G.W. Lade	Richfield Oil Corp.
Mr. Sam Stewart	Richfield Oil Corp.
Dr. G.W. Govier	Oil & Gas Cons. Board (Alberta)
Mr. A.F. Manyluk	Oil & Gas Cons. Board (Alberta)
Mr. D.R. Craig	Oil & Gas Cons. Board (Alberta)
Mr. G.M. Jarvis	Atomic Energy Control Board
Dr. G.C. Laurence	Atomic Energy of Canada Limited
Mr. A.K. Longair	Defence Research Board
Mr. J.C. Langley	External Affairs Department
Dr. J.M. Harrison	Geological Survey of Canada
Dr. J.F. Caley	Geological Survey of Canada
Mr. J. Richer	Mines & Technical Surveys Dept.
Mr. A. Ignatieff	Mines & Technical Surveys Dept.
Dr. D.S. Montgomery	Mines & Technical Surveys Dept.
Mr. W.H. Norrish	Mines & Technical Surveys Dept.

INTRODUCTION

The Director of the Mines Branch welcomed the guests and associates whose names are recorded in the attendance list. It was then emphasized that the Mines Branch had a profound interest in new mining techniques and methods of recovering mineral resources which are difficult or impossible to exploit by conventional methods. The purpose of the meeting was clearly stated as to acquaint most of the interested parties in government circles with the technical aspects of underground nuclear explosions. The political and international implications of conducting underground nuclear explosions would be specifically excluded from the discussion.

The Director then asked Mr. David Guntert of the Richfield Oil Corporation to introduce Dr. Gerald W. Johnson. After receiving his Ph.D degree Dr. Johnson taught at Washington State College, before joining the staff of the Brookhaven National Laboratory to work on neutron physics. Since 1951 Dr. Johnson has been studying the effects of nuclear explosions, first for the Department of Defence in Washington, D.C., and more recently at Livermore where he is Test Division Leader. Dr. Harold Brown is the associate director of the University of California's Radiation Laboratory at Livermore, Cal., and it is he who is responsible for the design of the thermonuclear devices. Dr. Johnson is in charge of conducting the field tests and of designing the field experiments.

In his introduction Mr. Guntert stressed the importance which his company attached to the Plowshare program of the United States Atomic Energy Commission, and stated that few people could speak with as much authority on this interesting program as Dr. Johnson.

DR. G.W. JOHNSON

In the United States the peaceful uses of nuclear explosions are being actively explored under the Plowshare program of the Atomic Energy Commission, by a group at the Livermore branch of the University of California Radiation Laboratory. A careful review of the costs of thermonuclear devices of the fission type involving U235 showed little promise of commercial application because of the relatively high cost. However hydrogen bombs of the fusion type employing deuterium as fuel did appear to be commercially attractive for making large scale excavations. The advantages of the hydrogen bomb are that it is now known how to burn heavy hydrogen, i.e. deuterium, with good efficiency, and this substance is a relatively cheap fuel - available the world over in virtually unlimited supply. The United Kingdom and the U.S.S.R. are trying to accomplish the burning under controlled conditions in machines, and basically the U.S.A. has the same objective, but at present it is only known how to combine deuterium explosively*. The advantages of the deuterium reaction for the accomplishment of peaceful objectives are as follows:

1. Cheapness and abundance of deuterium
2. The deuterium reaction does not yield radioactive

* See bottom of Page 2.

products, though high energy neutrons liberated yield radioactive elements if captured by suitable atoms. This is referred to as induced radioactivity.

3. It is possible under the right conditions to trap the neutrons by boron or a boron containing mineral such as colemanite to yield non-radioactive substances.

Possible Applications of Thermonuclear Reactions

The thermonuclear reactions indicate the greatest future promise is in large scale operations such as:

1. Large excavations - harbours, canals, reservoirs, etc.
2. The generation of thermal power
3. The recovery of oil from shales and sands
4. Disruption of low grade ore for recovery of values by leaching
5. Ground water control and storage
6. Production of radioisotopes

Experimental Portion of the Plowshare Program

So far all the experimental work has been performed with atomic bombs rather than hydrogen bombs. In September 1957 the first underground nuclear explosion was set off. This involved a nuclear charge equivalent to 1700 tons of TNT, which was placed 900 feet below the surface of a mesa in Nevada (Rainier, Operation Plumbbob). The most recent series of nuclear tests in (Yucca Flat) Nevada, ending on the eve of the Geneva negotiations that look to the cessation of tests, included five underground shots in the energy-release range from 100 to 20,000 tons.

These were conducted at the following depths

Power	Scale depth	Actual depth
1 Kt*	650'	800'
1 Kt	200'	100'
20 Kt	300'	864'
5 Kt	450'	830'

* Note: 1 Kt=1000 tons of TNT

The scale depth was based on the Rainier experiment, and represents the depth at which the burial would be equivalent to the Rainier experiment. This was calculated from the following formula,

$$\text{Scale Depth} = \frac{\text{Actual Depth}}{(1.7)^{1/3}} (\text{Power in Kt})^{1/3}$$

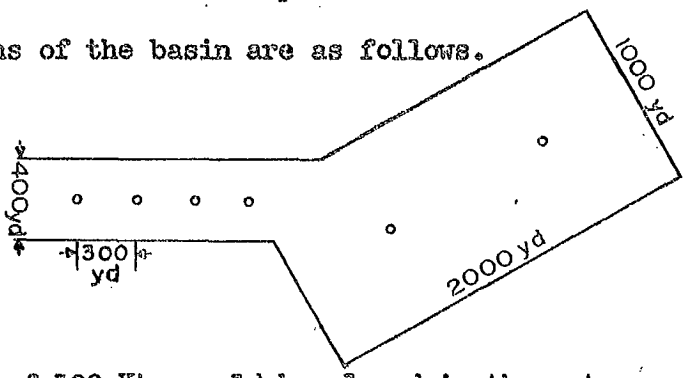
* [The only method known at present of initiating the deuterium fusion is by using an atom bomb. Edit.]

The last shot was 20 Kt and nothing was observed to come out of the tunnel. There was a very slight breakthrough: a cloud of dust was sent up to an altitude of 1000 feet. The calculated safe scale depth for containment is 450 feet. At a scale depth of 200 feet there would be breakthrough but the activity would be less than 1%. The activity fell to a level which would permit excavation after five days with excavating equipment. The recent explosions were all in the same material, - tuff, as the Rainier, Operation Plumbbob, and nothing was discovered which would cast any doubts on the results of these experiments. So far United States experience has been in only two types of terrain - coral saturated with sea water and tuff; however, the indications are that approximately 3,000 feet would contain a 1 megaton (1,000,000 ton) bomb. The results of the Rainier, Operation Plumbbob, are still being studied and will be freely given out. No detailed analysis of the current five tests is available yet, but it is the intention to have the projects conducted under Operation Plowshare international in scope, that is open to observers from all over the world.

Projected Experiments of the Plowshare Program

A detailed study is being made of a project to create a harbour in Alaska by way of demonstration and experiment some time in 1960.

The dimensions of the basin are as follows.



Four charges of 100 Kt. would be placed in the entrance canal at 300 yard centres buried to a depth of fifty feet. This should produce a canal 400 yards wide and 1200 yards in length. The main basin would be produced by two megaton bombs buried at a depth of 150 feet. All the charges are to be fired simultaneously to blow the rock clear. It is anticipated that there will be no fireball. In this experiment as much deuterium will be burnt as possible, and to further minimize the radioactivity a boron blanket of colemanite would be used. The cost is estimated at $5,000,000 to $6,000,000 as compared with $50,000,000 by conventional mining methods. This yields a cost advantage of 10:1. For larger excavations in the order of 75 to 100 million cu. yds., the cost advantage would be in the order of 30:1 to 40:1*

* [There are probably very few places in the world where 100 million cu. yards could be thrown into the air without enormous damage to property. Probably in most civilized areas an attempt would be made to break the ground and excavate by conventional methods. - Edit.]

In regard to oil shales, some thought is being given to this question by the United States Bureau of Mines, but the exact status of this project was not given. It was estimated that one megaton bomb would break 50,000,000 tons of rock and release 25 million barrels of oil. With these remarks Mr. Johnson closed his address.

MR. M.L. NATLAND

Mr. Natland of the production staff of the Richfield Oil Corporation then addressed the group and presented a series of slides which explained visually the content of the report entitled "The Use of Nuclear Energy to Effect in Situ Recovery from the McMurray Oil Sands of Alberta, Canada" by M.L. Natland. This proposed method for the recovery of oil from the bituminous sands refers only to those locations where there is a relatively heavy overburden of the order of 800 to 1000 feet and conventional methods of recovery would be out of the question for economic reasons. The Richfield Oil Company has rights on areas of this character, and is anxious to know whether this type of area should be abandoned or retained. An atomic experiment, in the company's view, would enable a decision to be made on this question.

The reasons why the Athabasca bituminous sands are particularly suitable from the point of view of conducting an experiment were stated to be:

1. There is no surface culture, and the region is essentially uninhabited
2. There is railroad access
3. The mineral rights are held by one agency
4. The bituminous sands are sufficiently thick to permit the heat and blast effects to operate on a substantial quantity of oil.

The reasons why Canada and North America should show more concern in establishing their hydrocarbon reserves was stated to be that the bargains for crude oil in the Middle East were becoming less and less favourable from the American point of view. Formerly the producing country and the refiner divided the profits 50%/50%. The Japanese have complicated the situation by offering 75%:25%. The steady deterioration of the Middle East situation suggests that North America should take some prompt steps to liberate itself from this stranglehold.

Returning specifically to the Athabasca bituminous sands it was stated that the projected test site is 64 miles south of McMurray in an area where there is no population. The oil sand was stated to be of the order of 170 - 180 feet in thickness including the barren layers or a thickness of 120 feet net of saturated bituminous sand. The overburden was estimated to be 1000 feet, and it was proposed to fire the atomic blast slightly below the bituminous sand bed at a depth from the surface of the order of 1200 feet. The experimental charge was visualized as being about the same size as involved in the Rainier tests, whereas if this was successful the full scale operation would require

explosions of the order of 10 Kt. The principle of oil removal from the sand was the dissipation of heat through the oil sand, raising its temperature from 0° to 100°C. It was stated that a 25° to 60°C rise would be sufficient to bring the viscosity of the oil to that of water*. In this fluid condition the oil was visualized as draining to a central cavity where it would be pumped to the surface. The estimated recovery from one shot was 900,000 barrels worth $2,700,000 at $3 per barrel.**

Mr. Natland spoke of the Athabasca oil resources as 300 billion barrels or 60% of the proven reserves of the free world. Development would have a great strategic advantage considering the transportation: 17,000 miles from Abadan around the Cape to Liverpool or 8,300 miles via Suez as against 3,500 miles from the Athabasca area.

Discussion Period (Mr. Ignatieff, temporarily chairman)

Mr. Longair expressed great concern at the release of high energy neutrons which would yield a considerable amount of induced radioactivity. Dr. Johnson and Dr. Frank agreed, but stated that the quantities of colemanite required to blanket the reaction were reasonable and that there was no need to take too pessimistic a view of this problem. Dr. Johnson mentioned that a very small proportion of the energy was dissipitated in the form of a seismic wave (0.5%). The shock wave through the rock was converted into heat in the course of time and this was the mechanism by which the strata were heated. Very little heating occurred by thermal conductivity through the rock mass. The diffusion of heat by thermal conductivity has been very slow at Rainier even after 13 months. This fact is considered to be promising from the point of using underground explosions as a source of thermal power. Dr. Johnson stated that regarding the Athabasca bituminous sand project, the U.S. Atomic Energy Commission would have to be satisfied regarding the usefulness, practicability and safety before they would consider the execution of any experiment. Laboratory studies would be necessary to clarify many points. Mr. Natland interjected that a sample of Athabasca oil is now at Oak Ridge for laboratory studies and tests. Up to the present time it was stated there has been no evidence of induced radioactivity of long half life.

Dr. Johnson mentioned that before submitting a project to the U.S. Atomic Energy Commission, the Livermore group liked to be able to demonstrate that the use of nuclear energy was of the order of ten times

* [There would seem to be an error of the order of 100 in this statement. - Edit.]

** [The figure of $3.00 per barrel presumably is a hypothetical figure based on possible future conditions as a realistic present day figure would be of the order of $1.00 per barrel - Edit.]

cheaper than using conventional methods. So far there only appeared to be an economic advantage of 2 to 4 in favour of the use of nuclear energy associated with the exploitation of the bituminous sands.

Dr. Johnson stated that the United States AEC would like to develop a relationship on the technical level in these applications with an organization in Canada similarly concerned. The U.S.A.E.C. is volunteering its services by supplying all the results of "Plowshare" that are being co-ordinated by the University of California. Irrespective of the oil sand proposal Dr. Johnson said that he would like to see easy lines of communication established between the U.S.A.E.C. and the Canadians who might be concerned. A suggestion was made by Mr. Natland that the Department of Mines and Technical Surveys should receive and distribute the Plowshare reports and Dr. Convey agreed to this proposal.

Motion Picture.

The morning session concluded with showing of the film "Industrial Applications of Nuclear Energy prepared by the Livermore Radiation Laboratory for the Geneva Conference 1958".

AFTERNOON SESSION

Dr. Convey invited discussion at a meeting in the Chateau Laurier, and this carried on for about two hours. A few members present at the morning session were not present and Mr. Langley left in the middle of the afternoon session. Dr. Laurence was asked if he had any questions.

Dr. Laurence made the point that unless it could be demonstrated that the scheme of recovery of oil from the sand could be shown to be technically feasible, with a high degree of certainty, and that there was a definite need for this approach to the problem, the Canadian A.E.C.L. would not look with much favour on an experiment of this nature. The principal causes for concern stem from the radiation hazard which assumes various forms. First of all there is the question of the radioactive contamination of the oil arising from fine glass particles becoming suspended in the oil. There is also the question of the production of induced radioactivity, such as carbon 14, and the conversion of trace elements in the oil to radioactive species. The production of radioactive strontium from the strontium in the Devonian limestone is also a serious matter. There will have to be obtained assurance that all fission products are incorporated in the glass. The caving of the fractured chimney would tend to pulverize the glass. The caving of the roof to the surface would release krypton, zenon, argon, etc., which might pose a hazard. The spread of radioactivity would have to be considered particularly as there is no large land reservation area set aside as in Nevada.

Mr. Natland enlarged on the proposed Richfield experiment. The scheme being considered was to drill a hole large enough to admit a nuclear device and probably back fill with sand. Probably an area of three sections by one section (3 sq. miles) would be set aside. Around the charge hole, a checkerboard array of probe holes would be set out, in which thermocouples and other devices might be placed. The charge

would be set off by remote control and the heat would be allowed to permeate the bituminous sand, cracking the oil and reducing its viscosity so that it would move under the action of gravity to a central collecting point. The principal flash from the fireball would be intense gamma radiation which would not induce radioactivity of nickel and other trace metals.

Dr. Johnson. If the U.S. Atomic Energy Commission had anything to do with this project there would be a careful design of the experiment by the Livermore staff of the Radiation Laboratory of the University of California. Geological and other information would have to be supplied to the U.S.A.E.C. to show that there was no possibility of contaminating the water in any natural drainage system. The weapons group and the design group would make calculations and a structural model would be prepared to find out where the neutrons would go. If the explosion was located at the contact between the Devonian limestone and the bituminous sand, a large amount of silica would be present and it is believed that most of the radioactivity would be incorporated in the calcium and magnesium silicates.

In regard to strontium, the chimney effect, and breakout, some information could be gained by experiment. A technical group should determine the safe depth (not the operating group). Geological information would have to be secured about the extent and rate of movement of underground waters. The Rainier explosion would not have been allowed, had water been present. This was because no one would have guessed that almost all the radioactivity would be confined to the glass. It was expected that radioactivity would be distributed throughout the crushed zone but actually none was found. This crushed cone portion of the Rainier experiment is still undergoing study. Samples are being taken of gases and water, but so far the radioactivity has been at a rather low level.

In regard to population hazard the experiment should be so designed that if a breakthrough occurred there would not be any hazard; conditions such as wind velocity and direction would be considered. Under the conditions of the experiment it would be surprising if any radioactivity would be found beyond a few miles. The experiment in the Athabasca region with a 1.7 Kt. bomb 1000 ft. below the surface cannot be compared with the 40 Kt. bomb mounted on a 700 foot tower that was fired in Nevada, yielding fall out for 120 miles.

Regarding krypton, zenon and daughters - cesium 137, etc., some things are known. In the case of small shots, some krypton and zenon got into the tunnel. Samples were taken after the recent shots and information will be available for the designing of a safe experiment. The Chairman of the U.S.A.E.C. was concerned over whether the shots could trigger an earthquake, but careful energy studies convinced him otherwise.

Discussion on procedures: Dr. Laurence anticipated that many questions would be asked as in the case of the construction of a reactor of similar output. There would be a need to convince Canadians regarding the glass shell, etc. He suggested there should be a detailed proposal

as for a reactor, covering all precautions and hazards, for study by the Atomic Energy Control Board and Canadian authorities. There would need to be a lot of preparatory work and he thought laboratory studies could help to develop feasibility. He raised the question of using dynamite for some information. (Dr. Johnson expressed the view that the use of dynamite could provide some information on shattering and seismic effects, but could not produce the thermal gradients required).

Dr. Laurence later expanded his thoughts in regard to the "reactor plan of approach", mentioning that A.E.C.B. has an advisory safety committee and when application was made this committee could get in touch with the applicant for a statement, then could invite the applicant and the province affected for discussion. The committee could consider recommending action: 1. A license to construct 2. After another look, authorization to operate.

Dr. Johnson saw no need to contemplate a 3-year study, but to get anywhere a schedule and plan of study would be needed. If Canada is interested, the U.S.A. would get into the study and the Athabasca proposal is considered very interesting. But Canada should initiate, take the lead, and the U.S.A. would come into the study if invited. There should be no illusions - it would be a tough study. The U.S.A. almost certainly would first do: 1. An oil shale experiment; 2. A salt experiment re thermal power. Limestone study was already coming into the plans and there may be a test in the second year. He referred to the intention to set off a blast of high explosive in a block of salt to study velocity and the manner of propagation of shock wave. There was the same idea for oil shales. Answering Dr. Montgomery, Dr. Johnson thought the subjects of carbon 14 and sulphur could be tackled in laboratory studies.

Dr. Govier dealt with the attitude of the Alberta Government and of the Oil and Gas Conservation Board. It is Alberta policy to lease tracts to companies interested in developing processes. A good deal of thought has been given to the Richfield application and the approach was from the standpoint of whether approval could be given to an experiment; no attempt is being made to consider the economic merit of this experiment. He thought the Alberta Government would be prepared to give approval if the Conservation Board was satisfied that there would be no hazards. Assurances were needed: (a) that there would be no surface breakthrough; (b) that the radioactive products would be confined in insoluble slag; (c) that no contamination of oil sands or water or from gases would occur; (d) that there would be no contamination of the Grand Rapids sand above or in the underlying Devonian limestone. Apart from such considerations, the Alberta Government, he thought, would welcome a test experiment and he thought would like to see the Federal Government undertake a study. He saw no emergency but if the test is to be carried out at all the machinery should be set up and the question is how to get assurances as Alberta has not the facilities to make an assessment. He thought that with proper study a safe experiment could be designed and agreed that the northern part of Alberta should be a safe place for such an experiment.

Mr. Jarvis expressed the view that the A.E.C.B. would have veto

power; that the Board would be interested in the proposed study; that federal approval would not give any right to operate.

Dr. Govier referred to two kinds of technical forecasting: (a) feasibility regarding economic recovery of oil; (b) regarding safety, including contamination. The latter study was the underlying need. It would be the responsibility of the Province to issue a license to conduct an experiment (to operate).

Dr. Harrison thought a geological study would require three years.

Dr. Convey replying to a query by Mr. Jarvis, thought it would be logical for the Department of Mines and Technical Surveys to initiate a group study. This would need Cabinet approval and A.E.C.B. approval of personnel. There would be need to establish liaison with Dr. Johnson's group. He thought much information would be available from the U.S.A. in a year. He saw need for a study of geology. The first exercise needed would be a very thorough look at the proposal.

Dr. Johnson remarked in regard to aquifers that experiments could be done to see whether contamination, if it occurred, would be hazardous. The study should be of the worst conditions.

Mr. Natland suggested that Richfield could probably get information on aquifers from drilling.

Dr. Montgomery sought information about the size of task force required for a study, to which Dr. Johnson replied giving a figure of 80 for the salt study (on the matter of storing heat in suitable formation and utilizing it for power).

QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1958