

November 7, 1960

ATOMIC ENERGY COMMISSION

U.S. COOPERATION WITH INDIA IN THE FIELD OF ATOMIC POWER

Note by the Secretary

The General Manager has requested that the attached report by the Director of International Affairs be circulated for consideration by the Commission at an early date.

W. B. McCool
Secretary

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ATOMIC ENERGY COMMISSION

U.S. COOPERATION WITH INDIA IN THE
FIELD OF ATOMIC POWER

Report to the General Manager by the
Director, Division of International Affairs

THE PROBLEM

1. To consider an AEC position for discussions with Dr. Bhabha, Chairman, Indian AEC, on or about November 18, 1960.

SUMMARY

2. Dr. H. J. Bhabha plans to visit AEC Headquarters on or about November 18, 1960 for further discussions on India's atomic power plans. During discussions at the IAEA Fourth General Conference in Vienna, he indicated he would like to receive the AEC Technical Team's conclusions (Appendix "C" to AEC 337/24), as the result of their visit to India in March 1960, to determine if they confirm the conclusions set forth in the Memorandum of Record (AEC 337/14) prepared during Dr. Bhabha's visit to Washington in November 1959. Receipt of the Team's conclusions would enable him to pursue further, within the Government of India, the question of including a modest, enriched uranium fueled power reactor - probably a 75 MWe project for the New Delhi area - in the Indian atomic power program.

3. At Meeting 1645 on August 18, the Commission discussed AEC 337/24, the principal recommendation of which was that the Commission support the AEC Technical Team's conclusions that a modest, enriched uranium-fueled nuclear power program was technically feasible and economically within reason. As a result

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of these discussions, it was decided that the Chairman would offer to discuss this subject further with Dr. Bhabha, possibly during the Fourth IAEA General Conference. Possible interest of the Indians in a 20 MWe reactor - in lieu of a 75 MWe plant - was also to be discussed. A subsequent staff analysis (AEC 337/25) recommended that we should continue to support a 75 MWe project rather than one of smaller size.

4. As indicated in paragraph 4 of AEC 337/24, the AEC Technical Team concluded that the over-all economics of nuclear power reactors at selected locations in India are, as claimed by Dr. Bhabha and as set forth in the Memorandum of Record, nearly competitive with conventional power plants at those locations. The Team also concluded that India has the technical capability to undertake a modest nuclear power program under the limitations noted in the report, and that India could successfully operate an enriched uranium reactor of 75 MW electrical capacity, but that the design and construction of the reactor should be undertaken only by a qualified U.S. contractor with undivided responsibility. It also concluded that the higher capital costs of nuclear plants and the fact that foreign exchange would probably have to be expended for fuel, represented a serious deterrent to the use of nuclear power in India.

5. The staff believes Dr. Bhabha's request for the Team's conclusions to be reasonable, and recommends that the attached letter (Appendix "A") be given to him during his visit on November 18. The frank statements included in the conclusions regarding nuclear power development in India might result in adoption by Bhabha of a more cautious approach in certain areas of his program planning. Prior to formal transmittal of the letter,

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however, Bhabha should be given the opportunity of stating any objections he might have to the conclusions.

6. A recent mission to India by representatives of the International Bank for Reconstruction and Development, in connection with India's Five-Year Plan, questioned some of the assumptions used by the Indian AEC in calculating nuclear power costs in India, and concluded, specifically, that in the Bombay area nuclear energy would be more costly than energy generated from a conventional plant. Although the International Bank for Reconstruction and Development report was particularly critical of atomic power in the Bombay area because of their view that coastal shipping could reduce the cost of coal in this area, IBRD officials with whom the report was discussed conceded that atomic power might be feasible in selective cases, including that proposed for the New Delhi area. As a result of the IBRD's findings, conclusions (1) and (3) of the AEC team's report have been modified somewhat, but the AEC's teams conclusions remain otherwise unchanged. A report on discussions with the Bank's officials, which has been prepared by the Division of Reactor Development, is attached as Appendix "B".

7. The Department of State has now concluded that it will support the financing of a 75 MWe power reactor in the New Delhi area if India wishes to include such a project as a regular item in its Third Five-Year Plan (Bhabha originally asked that any financial assistance be "over and above" normal U.S. aid to India). State's proposed support, which has been approved, in principle, by Under Secretary Dillon, is subject, however, to the Commission's conclusion that the undertaking of a 75 MW reactor project of proven design by India is technically feasible and that its economics are reasonably in line with those estimated by the U.S. technical team. The offer of financial assistance will also

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require the concurrence of the Treasury Department, the Development Loan Fund, and the Export-Import Bank, which would be sought only after AEC action. A proposed cable to Ambassador Bunker, which has been drafted by State, is attached as Appendix "C".

8. As reported in AEC 337/26, India recently issued invitations to bid on its proposed 300 MWe atomic power plant. Since India's plans for this plant were delayed for several months and because of the reported foreign exchange difficulties in India, it may be the only atomic power project India will undertake to construct under the Third Five-Year Plan. Furthermore, since India has indicated interest in receiving bids on enriched as well as natural uranium fueled reactors for this plant it is possible the U.S. will be approached to consider Development Loan Fund or Export-Import Bank loans for the 300 MWe rather than the 75 MWe project. The staff believes, however, that the Indian's interest in constructing the larger, 300 MWe, project should not be encouraged, and that a forthcoming attitude on assisting a 75 MWe project might enhance the possibility of their constructing a 75 MWe plant instead of the 300 MWe project. However, if the Indians do proceed with a 300 MWe plant, as an alternative to a 75 MWe plant, the U.S. should be prepared to consider assistance for this project. No disclosure of State's decision regarding proposed assistance for a 75 MWe project should, of course, be made to Bhabha, pending clearance by the Treasury Department, Development Loan Fund and Export-Import Bank.

9. With respect to safeguards, Bhabha has indicated India would accept, in principle, safeguards for enriched fuel obtained from the U.S. under a suitable formula which has not as yet been revealed. India has declared its unwillingness, however, to

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accept safeguards for any reactors (fueled with either enriched or natural uranium), natural uranium, or other significant equipment. Acceptance of the Indian position in excluding reactors from safeguards would undermine the U.S. safeguards position, as well as that of the U.K., for, although, theoretically, safeguards attached only to enriched fuel would adequately cover any reactor in which the fuel was used, it is possible India might wish to purchase only a reactor from the U.K., utilizing natural uranium obtained elsewhere without safeguards. In light of the above, it would be desirable to elicit from Bhabha, during his visit, further details on the safeguards India would be willing to accept on an enriched uranium-fueled plant. In this connection, the staff believes that if Bhabha is assured that the U.S. had concluded that a modest enriched nuclear power program in India was feasible, based on economic and technical grounds, and was prepared to move ahead with assistance, it would greatly enhance the possibility of our satisfactorily resolving the safeguards problems with India.

STAFF JUDGMENTS

10. The Division of Reactor Development and the Office of the General Counsel concur in the recommendation of this paper. The Office of Public Information concurs in recommendation "e".

RECOMMENDATION

11. The General Manager recommends that the Atomic Energy Commission:

a. Approve the conclusions reached by the AEC Team as set forth in the Annex to Appendix "A";

b. Note that a letter such as Appendix "A" will be given to Dr. Bhabha during the course of his visit to AEC Headquarters on or about November 18, 1960;

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c. Note that a letter such as Appendix "D" will be sent to the Department of State;

d. Note that a letter such as Appendix "E" will be sent to the JCAE;

e. Note that a public announcement is not appropriate at this time.

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APPENDIX "A"

DRAFT LETTER TO DR. BHABHA FROM THE CHAIRMAN

1. I am very pleased to enclose herewith a summary of the conclusions reached by the Commission's team, which visited India from February 29 to March 18, 1960, on the technical and economic feasibility of nuclear power in India in the near future. As you know, the visit was undertaken as a consequence of the proposals advanced by you during your visit to the United States in November 1959, and of the subsequent visit by Commissioner John S. Graham to India in December 1959.

2. As I am sure you realize, the limitations inherent in any study of the type undertaken by the team are self-evident. In the final analysis, only a detailed engineering study of a specialized project to be constructed at a specified location, would provide a precise and conclusive answer to the question of the economics of a power reactor to be constructed in India.

3. If you have any questions regarding the team's conclusions, we should be glad to discuss them with you.

Summary of USAEC Team's Conclusions Following
its Visit to India, February 29 to March 18, 1960

1. The Indian requirement for nuclear power in the long run appears reasonably certain. Barring a major slowdown in Indian economic development and a serious reversal in the technological improvement advances seen for nuclear power, it is expected that nuclear plants should fulfill important needs for power in selected regions of India over the next 20 years.
2. In the immediate future, enriched uranium nuclear power plants can be installed at a few selected points in India to yield power costs that are within the range of conventional power generation at the same sites. The attached tables reflect the estimated costs of conventional and atomic power plants in the Bombay and New Delhi areas.
3. The most attractive site for immediate nuclear power installation in India is the Bombay-Ahmedabad area. This area is distant (up to 900 miles) from adequate coal fields, and already has exhausted its hydro power reserves, and has a large and rapidly growing demand fed by an extensive grid. It is recognized that this situation could change if relatively inexpensive ways (such as coastal shipping) could be found to transport Indian coal to the area.
4. The next most attractive site for nuclear power installation in India is the Delhi area. This area is also quite distant (about 600 miles) from coal, and has a substantial interconnected load with rapid load growth. Although the Delhi system is interconnected with the Bhakra power plant, the overall system load growth will permit operation of a nuclear plant at high load factor. Overall nuclear power costs at this site should be close to conventional costs from thermal stations.
5. Nuclear power plants involve an initial higher capital cost than conventional plants. Under present circumstances in India, nearly all of this difference would be in the form of foreign exchange.
6. Operating costs for nuclear plants would involve a substantial foreign exchange outlay as long as fuel fabrication and reprocessing were performed outside of India. For enriched plants, there would be a continuing outlay of foreign exchange for burn-up of enriched material, unless at some unforeseeable future date, such plants were operated with U-233 or some other fissionable material which might become available to India.

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7. India has the technical capability (with appropriate specialized training for personnel) to safely and effectively operate a nuclear power plant, to provide construction labor and all but the highest levels of construction supervision. Under present conditions, design, procurement and erection of a nuclear plant should be the responsibility of a competent U.S. firm with undivided authority.

8. India has a rapidly growing industrial capability which should enable it to supply various components for nuclear power plants beyond those built in the immediate future.

9. Fabrication of at least the initial charge of fuel elements should be undertaken in the United States. However, India has the capability and resources to undertake fuel fabrication at an early date, under initial U.S. supervision.

10. Fuel reprocessing should initially be undertaken outside India, either in the U.S. or possibly in the EUROCHEMIC facility. India could build and operate a fuel reprocessing plant under initial close U.S. supervision, but it would probably be economically undesirable for it to do so until the installed reactor capacity in India reaches about 1,000,000 kw. If India undertakes the construction of a processing plant for natural uranium, it should make provision for the processing of slightly enriched uranium in the same plant.

11. The India atomic energy program would profit substantially from the experience gained through participation in the design and construction, and through operation of an enriched reactor of 75 MW capacity. It would also gain greatly from the sense of direction in its program imparted by such an undertaking.

12. The original Indian conception to accumulate U-233, (thus enabling use of their thorium reserves), through preliminary stages of plutonium production in natural uranium, and U-233 production from plutonium in thermal converters would not permit the establishment of a self-sustaining thorium - U-233 cycle. Full utilization of thorium by India will require an initial step utilizing enriched uranium with thorium, and/or the development of economic and effective breeders.

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TABLE I

COSTS OF THERMAL POWER STATIONS - INDIA

<u>CAPITAL COST</u>	<u>\$180/KWE</u> to	<u>\$220/KWE</u>
<u>Power Cost</u>	<u>Mills/kwh</u>	<u>Mills/kwh</u>
I. Fixed Charges		
A. Int. & Dep. (4.5% + 2.4%)	1.78	2.20
B. Operation & Maintenance	.38	.38
	<u>2.16</u>	<u>2.58</u>
II. Fuel Costs		
at \$8.50/ton (representative of New Delhi area)	4.58	4.58
at \$9.50/ton (representative of Bombay area)	5.47	5.47
Total Power Cost		
Fuel at \$8.50/ton (New Delhi area)	<u>7.01</u>	<u>7.46</u>
Fuel at \$9.50/ton (Bombay area)	7.63	8.05
Over-all eff.	29.6% <u>1/</u>	
Load Factor	80%	
Station Consumpt.	6%	

1/ Probably high due to poor quality coal. Current average about 22%.

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TABLE II

POWER COSTS FOR A 75 MWE FWR
CONSTRUCTED IN INDIA

<u>Construction Cost</u>	\$29,925,000	\$399/KW
Primary Loop - U.S.	17,682,000	
India Rs	7,567,000	
Other Foreign Exchange	4,825,000	
<u>Fixed Charges @ 80% L.F.</u>		<u>Mills/KWH</u>
Int. & Dep. (7.7%)		4.38
Operation & Maintenance		.50
Total Fixed Charges		4.88
<u>Fuel Costs - U.S. Costs</u>		
Fabrication @ \$90/Kg of UO ₂	1.19	
Shipping	.20	
Depletion - 13,000 MWD/ton	2.13	
Reprocessing	.40	
Pu credit at \$12/gm	-.82	
Lease Charge 4 1/2%	.50	
Total Fuel Costs	3.60	3.60
TOTAL POWER COST		8.48

TABLE II-A

ALTERNATE FUEL COST
(TABLE FOR MIN. U.S. FOREIGN EXCHANGE)

<u>Fuel Costs - U.S. Charges 1/</u>	<u>Mills/KWH</u>
Fabrication @ \$90/Kg of UO ₂	0
Shipping	0
Depletion - 13,000 MWD/ton	2.13
Reprocessing	0
Pu credit at \$12/gm	-.82
Lease Charge 4 1/2%	.50
	1.81 2/

- 1/ If India did fuel fabrication, reprocessing
- 2/ Becomes 2.63 mills/kwh if India retains Pu produced.

Basis

Sp. Power 16 MWT/MTU	
Initial Enrichment	3.1%
Final Enrichment	2.1%
Thermal Eff.	31%

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APPENDIX "D"

DRAFT LETTER TO THE SECRETARY OF STATE

1. You may recall that as a result of proposals advanced by Dr. H. J. Bhabha, Chairman, Indian AEC, in November 1959 regarding possible U.S. assistance for the installation of atomic power reactors in India, and of the subsequent visit by Commissioner John S. Graham to India in December 1959, the Commission sent a technical team to India in February and March 1960 to examine the technical and economic feasibility of an atomic power program for that country.

2. Enclosed herewith is a copy of a letter to Dr. Bhabha which informs him of the conclusions reached by the Commission's team as a result of their visit. The Commission is in agreement with these conclusions.

3. You will note that the team concluded that India has the technical capability to undertake a modest nuclear power program under certain limitations. It was concluded that India could successfully operate an enriched uranium reactor of 75 mw electrical capacity, but that the design and construction of the reactor should be undertaken only by a qualified U.S. contractor or contractors with undivided responsibility for the job. The team further concluded that the overall economics of nuclear power reactors at selected locations in India are, as claimed by Dr. Bhabha, nearly competitive with conventional power plants at those locations. The higher capital costs of nuclear power plants, however, and the fact that at least initially their fueling costs would be almost wholly a foreign exchange item, represents a serious deterrent to their use in India.

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APPENDIX "E"

Draft Letter to the Chairman, JCAE

1. Enclosed for the information of the Committee is a report of the U.S. technical team which visited India for the purpose of learning in greater depth about India's plans for nuclear power and its capabilities for carrying out a nuclear power program. The Committee was advised of this visit in a letter from the General Manager of February 10, 1960.

2. The team concluded that India has the technical capability to undertake a modest nuclear power program under the limitations noted in the report, a copy of which is attached. It was concluded that India could successfully operate an enriched uranium reactor of 75 MW electrical capacity, but that the design and construction of the reactor should be undertaken by a qualified U.S. contractor with undivided responsibility for the job. The team further concluded that the overall economics of nuclear power reactors at selected locations in India are as claimed by Dr. Bhabha, nearly competitive with conventional power plants at those locations. The higher capital costs of nuclear power plants, however, and the fact that at least initially their fueling costs would be almost wholly a foreign exchange item, represents a serious deterrent to their use in India.

3. The Commission plans to inform Dr. Bhabha, Chairman, Indian AEC, of the Team's conclusions, which the Commission endorses, during the course of a visit by Dr. Bhabha to Washington on or about November 16, 1960. The Department of State is also being informed of the Commission's support of the Team's conclusions.

4. The attached report has been designated Official Use Only since the information which it contains concerning India's plans for nuclear power, and the status of their consideration within the Indian Government, is regarded as privileged information by the Indian Government.

5. We shall keep the Joint Committee informed of any further significant developments on this subject.

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APPENDIX "B"

STAFF ANALYSIS OF THE INTERNATIONAL BANK FOR RECON-
STRUCTION AND DEVELOPMENT'S CONCLUSIONS OF
MISSION TO INDIA

1. The International Bank for Reconstruction and Development prepared an internal report in August, 1960, as the result of the Bank's mission to India earlier in the year to study India's Third Five-Year Plan. Among other subjects, a comprehensive picture of the electric power requirements was presented. A rather pessimistic view of India's nuclear plan for 300 MWe from two natural uranium reactors in the Bombay area was expressed. The Bank's team questioned the validity of several assumptions of the Indian AEC (which also were generally accepted by the AEC team):

a. "They (the Indian AEC) assumed the thermal efficiency of coal burning plants will be only 29%, whereas modern steam plants should be able to achieve 35%."

b. "They assume an interest rate of 4-1/2%. If a higher rate of interest were taken as reflecting the true scarcity of capital in India, the cost comparison would be greatly to the disadvantage of nuclear power."

c. "A load factor of 80% has been assumed, which is more than can reasonably be expected under Indian conditions."

2. During the week of October 24, 1960, representatives of the Division of Reactor Development met with the authors of the IBRD report. These discussions brought out the following points:

a. In the Bank's judgment India is not a "fuel scarce" country and the high coal prices in Bombay are largely due to the lengthy rail shipment required. However, if plans for coastal shipping are carried out (at moderate cost) coal could be delivered cheaply to many coastal ports, such as Bombay, and a great burden on the railroads would be relieved.

b. The staff members of the Bank felt there were many other more critical areas than nuclear power competing for whatever loans the Bank could make available.

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3. The Bank's officials agreed, however, with the AEC team's estimated costs for a 75 MWe PWR in the New Delhi area and stated that the comparison with a thermal plant appeared valid. (There is no alternative to shipping coal by rail in this area.) The only change they suggested was to use a 6% cost of money in the comparison with the thermal plant instead of the 4-1/2% used. This adjustment increases the differential by only .3 mills. The estimated cost would be 9.3 mills/kwh from the nuclear plant as compared to 8.5 mills/kwh for a conventional plant.

4. During the meetings the question of the current thermal efficiency of India's conventional plants was discussed. It was agreed that this factor hinged on the amount of ash reportedly present in Indian coal. At the present time with ash contents of 26% to greater than 40%, ash must be blown out frequently which results in large heat losses. This in turn limits efficiency to 30% or less. While the Bank officials agreed that this represents the current situation, they stated that the coal quality would improve as deeper coal seams were mined (The surface coal currently being mined having the higher ash content.). For this reason, they felt that thermal efficiency could be expected to be higher (to 35%) some time in the future.

5. The load factor - assumed to be 80% - is believed realistic for the specific case of the New Delhi area reactor. This was confirmed by the AEC team in discussions with the Indian Water & Power Resources Board. There is little question, however, that as India's power capacity is expanded lower load factors will result.

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APPENDIX "C"

DRAFT TELEGRAM

TO Amembassy NEW DELHI
RPTD INFO Amconsul BOMBAY

1. You are authorized to approach Prime Minister or other appropriate Indian official to state U.S. readiness consider credit assistance for a 75 MW enriched uranium reactor in the New Delhi area if India wishes include such project in Third Plan in view findings joint AEC team following its visit to India in March.

2. Type assistance we believe would be given serious consideration might include financing part or all foreign exchange component initial capital costs and portion of fuel costs, i.e. fuel inventory. We estimate foreign exchange component to be approximately \$22,500,000 and fuel inventory about \$5,800,000. Annual fuel charges, which we estimate to be about \$2,000,000 would have to be paid for in dollars although India might reduce these charges considerably at later date by doing its own reprocessing and fuel fabrication. AEC team estimated power cost 75 MW reactor would be about 8.5 mills per kwh as opposed to 7.5 for thermal plant, but such preliminary estimate does not repeat not preclude possibility that charges for nuclear plant would be higher.

3. You should state further that U.S. will continue to insist on safeguards applied either through the IAEA or bilaterally.

4. Recommend you also state U.S. believes India would be placing us at disadvantage if it used general Soviet credit for reactor project, with its attendant propaganda advantages, while regular U.S. loan assistance was applied to conventional projects with less popular appeal.