No. 8419

UNITED STATES OF AMERICA
and
SAUDI ARABIA

Exchange of notes (with appendices) constituting an agreement concerning construction of a water desalting and electric power plant. Jidda, 11 and 19 November 1965

Official texts of the notes and appendix I : English and Arabic.

Official text of appendix II : English.

Registered by the United States of America on 1 December 1966.

ÉTATS-UNIS D'AMÉRIQUE
et
ARABIE SAOUDITE

Échange de notes (avec appendices) constituant un accord relatif à la construction d'une installation de dessalement de l'eau et de production d'énergie électrique. Djeddah, 11 et 19 novembre 1965

Textes officiels des notes et de l'appendice I : anglais et arabe.

Texte officiel de l'appendice II : anglais.

Enregistré par les États-Unis d'Amérique le 1er décembre 1966.

No. 8419. EXCHANGE OF NOTES CONSTITUTING AN AGREEMENT[1] BETWEEN THE UNITED STATES OF AMERICA AND SAUDI ARABIA CONCERNING CONSTRUCTION OF A WATER DESALTING AND ELECTRIC POWER PLANT. JIDDA, 11 AND 19 NOVEMBER 1965

I

The American Chargé d'Affaires ad interim
to the Saudi Arabian Deputy Minister of Foreign Affairs

EMBASSY OF THE UNITED STATES OF AMERICA

No. 362

Jidda, November 11, 1965

Excellency :

I have the honor to refer to recent discussions concerning the plans of the Saudi Arabian Government to construct a water desalting and electric power plant in the Jidda area.

I have been instructed by my Government to confirm that, pursuant to the request of the Saudi Arabian Government and subject to the provisions hereof, the United States Government shall assume responsibility for negotiating contracts on behalf of the Saudi Arabian Government with a United States firm or firms for the architectural and engineering study and design, and with all qualified firms for supply of equipment, construction, installation, and initial operations of the project. The installations and their operation shall be based generally on the report of June 1964, submitted to the Saudi Arabian Government by Stewart L. Udall, Secretary of the Interior, entitled "Preliminary Appraisal Report on Combination Sea Water Desalting and Electric Power Plant for Jidda, Saudi Arabia", a copy of which is appended hereto (Appendix I).[2] Contracts shall be awarded by the United States Government on behalf of the Saudi Arabian Government after solicitation of proposals from firms to be selected by the United States Department of the Interior subject to Saudi Arabian Government approval. The Department of the Interior, through its Office of Saline Water, shall be responsible for United States Governuent functions except when otherwise noted in this Agreement. The Department of the Interior shall utilize its contracting procedures and contract forms with such modifications or adaptations as it in its discretion deems desirable.

The obligations undertaken by the United States Government and the United States Department of the Interior are understood to be subject ot the following terms and conditions :

[1] Came into force on 19 November 1965 by the exchange of the said notes.
[2] See p. 41 of this volume.

1. (*a*) In the interest of allowing the work undertaken by the Department of the Interior to proceed as expeditiously as possible, the Saudi Arabian Government shall establish within thirty (30) days after its acceptance of the terms of this note an irrevocable letter of credit to cover the entire estimated cost of the project to be paid by the Saudi Arabian Government, in the amount of Fourteen Million Dollars ($14,000,000). The project's estimated cost includes the expense of site selection and preconstruction planning, design, plans and specifications, construction, installation, initial operations, training of Saudi Arabian personnel, and completion of documentary. The estimated cost also includes the expenses of the Department of the Interior with the exception of (1) salaries of employees of the Department assigned to the project, (2) cost of providing an architectural and engineering study and design for the desalting plant, and (3) field supervision of the construction of the desalting plant.

(*b*) The letter of credit shall be payable through a bank in the United States and shall be in the form attached hereto as Appendix II [1] or in the approved format of the issuing bank. The Department of the Interior will draw upon the letter of credit by the submission of demand drafts on the paying bank for obligations actually incurred by the Department of the Interior. The Department of the Interior will provide at three-month intervals to the Saudi Arabian Government an accounting of the funds so expended, in such format and detail as may be mutually agreed upon by the Department of the Interior and the Saudi Arabian Government. The Saudi Arabian Government shall be advised of the amount of unexpended balances remaining upon final completion of and accounting for the work involved.

(*c*) Appeals in disputes arising out of contracts of the United States Government made in furtherance of this Agreement shall be heard and decided, pursuant to the "Disputes" clause contained in such contracts, by the Secretary of the Interior through the Department of the Interior Board of Contract Appeals. The Saudi Arabian Government agrees to make such additional funds available as may be necessary to cover the payment of successful claims.

2. (*a*) The Saudi Arabian Government shall make available in a timely manner, consistent with construction phasing, all lands, easements, and rights-of-way required for the entire project. In addition, the Saudi Arabian Government shall timely construct necessary access roads to the plant site, fuel supply lines and facilities, fresh water lines, pumping stations and reservoirs and electric transmission and distribution lines and substations, in accordance with the design of the project.

(*b*) The Saudi Arabian Government shall make arrangements for fuel of the type for which the project is designed in adequate quantity and of adequate quality for use in connection with the construction, testing, and initial operation of the project.

(*c*) The Saudi Arabian Government shall also furnish, and the Department of the Interior will accept, personnel of the Saudi Arabian Government, to observe the initial operation of the project ; and such personnel shall be trained by or at the direction of the Department of the Interior as competent plant operators and maintenance employees. The number and kinds of such personnel and their training location shall be mutually determined.

3. (*a*) Personnel of the Department of the Interior, when in residence in the Kingdom of Saudi Arabia as special representatives of the Department pursuant to this Agree-

[1] See p. 69 of this volume.

ment, will be entitled to the same privileges and immunities as personnel of comparable rank and status of the Embassy of the United States of America in the Kingdom of Saudi Arabia.

(*b*) The Saudi Arabian Government shall bear the costs of taxes of all non-Saudi Arabian personnel of public or private organizations present in the Kingdom of Saudi Arabia to perform work in connection with this Agreement. Such taxes shall include property taxes on personal property intended for their own use, and any tariff or duty upon personal or household goods brought into the Kingdom of Saudi Arabia for the personal use of themselves and members of their families. Such reimbursement for any tariff or duty shall not apply to such personal or household goods as may be sold by any such personnel in the Kingdom of Saudi Arabia. It is further understood that whenever such personnel shall undertake work outside the limits of the project to be performed in accordance with this Agreement, they shall be subject to the regulations of the Saudi Arabian Government with respect to taxes and duties.

4. All property, material, equipment, services, and supplies brought into the Kingdom of Saudi Arabia by the Department of the Interior or its contractors to carry out the functions contemplated by this Agreement shall not be subject to import and export duties, licenses, excises, imposts, bonds, deposits, and any other charges except for services requested and rendered, provided they will be reexported upon completion of the work. Property, materials, equipment, and supplies belonging to the Department of the Interior or its contractors that do not become a part of the completed works shall remain the property of the Department of the Interior or its contractors and may at any time be removed from or disposed of in the Kingdom of Saudi Arabia free of any restrictions or any claims which may arise by virtue of such removal or disposal, provided that the duty thereon shall be paid in the event of their sale or disposal in the Kingdom of Saudi Arabia.

5. (*a*) The Saudi Arabian Government agrees that the United States Government, its officers and its employees, will be held harmless from causes of action, suits at law or equity, or from any liability or damages in any way growing out of :

(i) the performance of the functions covered by this Agreement, or

(ii) the construction, operation, and maintenance of project facilities.

(*b*) In order to effect the proper indemnification of the United States Government, its officers and its employees, as indicated in subparagraph (*a*) hereof, the Saudi Arabian Government further agrees that it will post sufficient sureties as may be mutually agreed upon with the United States Government to indemnify the United States Government for any final judgments or final decisions of administrative tribunals, which judgments or decisions require payment by the United States Government for any liability arising from the performance of the functions covered by this Agreement or from the construction, operation and maintenance of the project facilities.

6. (*a*) The United States and Saudi Arabian Governments will consult, upon request of either of them, regarding any matter relating to the terms of this Agreement, and will endeavor jointly in the spirit of cooperation and mutual trust to resolve any difficulties or misunderstandings that may arise.

(*b*) The Kingdom of Saudi Arabia shall designate an Authority to act finally for the Government of Saudi Arabia in connection with all project matters that may properly be referred to it by the Contracting Officer, who will be appointed by the Department of the

Interior and identified to the Saudi Arabian Government. The Contracting Officer shall establish and maintain constant liaison with such Authority and shall keep it constantly advised with respect to the progress of work undertaken by the Department of the Interior hereunder. It is contemplated by both Governments that the proposed project work will be in two phases, that is, the preconstruction phase and the construction and initial operation phase. The Contracting Officer shall consult with, and obtain the approval of, the Authority prior to taking any of the following actions :

(i) With respect to Phase I :

a. giving instructions to the Contractor to perform preconstruction work and preparation of plans and specifications, or to make basic alterations in performance of the contract ;

b. giving approval to the final plans and specifications to be included in the proposal to the Contractor ;

c. giving instructions to terminate the performance of the contract, in whole or in part, unless the reason for the termination notice shall be lack of funds to meet contractual commitments.

(ii) With respect to Phase II :

a. giving instructions to the Contractor to introduce changes in the design parameters of the proposed plant, or with respect to any change of a basic feature of the proposed plant ;

b. giving final acceptance to the Contractor for the completed installation ;

c. giving instructions to terminate the performance of the contract, in whole or in part, unless the reason for the termination notice shall be lack of funds to meet contractual commitments.

(*c*) The Contracting Officer shall give notice to the Authority at any time when he has reason to believe that available funds are insufficient to complete the work. The Authority shall take such action as may be required to promptly supplement the funds or to notify the Contracting Officer that no further funds shall be made available.

7. The Agreement set forth herein will be binding upon both Governments until completion and acceptance of the project and until the final accounting of all funds involved has been made. In the event of a change of circumstances, making it necessary or desirable to terminate the arrangements agreed to herein, either Government may give 60 day's notice in writing of its intention to terminate those arrangements. Thereafter, the United States and Saudi Arabian Governments shall consult together with the aim, insofar as possible, of fixing mutually satisfactory termination date and procedures. Further, insofar as possible, the termination date shall be fixed sufficiently in advance so that the Department of the Interior may make personnel and other adjustments in their operations in light of such termination.

8. Upon completion of the project, the Department of the Interior will arrange for the removal of its property and the Contractor's property as expeditiously as possible, and will deliver to the Saudi Arabian Government the project in an operable condition. For the purpose of developing data and information which may be of significance in further research and development in the field of saline water conversion, the United States, for a period of five (5) years following the completion and acceptance of the project by the Saudi Arabian Government, will inspect the project and observe its operation through

such technical and other personnel as may be required. For the same purpose the United States Government shall be allowed to examine production records for cost of operation and maintenance, and to conduct such tests as it may desire—as long as such tests do not materially interfere with normal project activities.

9. The United States and Saudi Arabian Governments agree as follows concerning the disposition of patent rights to inventions arising out of any engineering, design and development work under contracts on work on the Jidda water desalting and electric power plant. This disposition of patent rights to inventions is to meet the legal objectives of both countries in this area.

(*a*) The United States Government shall acquire title in the United States to any invention made arising out of such engineering, design and development work, regardless of where the invention is made.

(*b*) The Saudi Arabian Government shall receive a royalty-free, nonexclusive, irrevocable license to practice such invention in the United States with the right to issue sublicenses.

(*c*) The United States Government shall have the right to file a patent application in any foreign country on such inventions and acquire title thereto.

(*d*) The Saudi Arabian Government shall receive a royalty-free, nonexclusive license with the right to issue sublicenses under any foreign patent that may issue as a result of foreign filing by the United States Government.

(*e*) Where the United States Government does not file for a patent in any foreign country the Contractor may receive authorization to do so from the United States Government and shall acquire title therein, subject to the reservation in the United States and Saudi Arabian Governments of a royalty-free, nonexclusive, irrevocable license with the right to issue sublicenses to any foreign government pursuant to a treaty or agreement said foreign government has with the United States or Saudi Arabian Government.

I have the honor to inform Your Excellency that if the foregoing conditions are acceptable to the Government of Saudi Arabia, the Government of the United States of America will consider this note, together with your note in reply concurring with the above, as constituting agreement between the two Governments with respect to this matter, such agreement to enter into force on the date of your note in reply.

Accept, Excellency, the renewed assurances of my highest consideration.

Talcott W. SEELYE
Chargé d'Affaires ad interim

Enclosures:

1. Report of June 1964
2. Form of letter of credit

His Excellency Sayyid Omar Sakkaf
Deputy Minister of Foreign Affairs
Ministry of Foreign Affairs
Jidda

No. 8419

APPENDIX I

PRELIMINARY APPRAISAL REPORT ON COMBINATION SEA WATER DESALTING AND ELECTRIC POWER PLANT FOR JIDDA, SAUDI ARABIA

PREPARED FOR THE GOVERNMENT OF SAUDI ARABIA BY UNITED STATES DEPARTMENT OF THE INTERIOR

Stewart L. Udall, Secretary
June 1964

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INTRODUCTION

This preliminary appraisal survey of a proposed combination sea water desalting and electric power plant for Jidda, Saudi Arabia, was undertaken by the United States Department of the Interior at the request of the Government of Saudi Arabia.

The study was made under provisions of the Anderson-Aspinall Act of 1961 (P. L. 87-295) which provided for cooperation with other nations to develop an economical means of producing fresh water from the sea.

The report was prepared by a Departmental team consisting of Robert E. Vaughan, Office of the Under Secretary ; M. G. Barclay and John W. Mueller, Bureau of Reclamation ; Melvin E. Mattson, Office of Saline Water ; and John Ricca, Office of Oil and Gas. The team made an on-site survey of the water situation in Jidda during March 1964.

To assist in the survey, a special committee was set up by the Government of Saudi Arabia. The committee, headed by Petroleum Minister Zaki Yamani, included Amir Muhamed Faisal ; Fadl Al-Qabbani, Deputy Minister of Petroleum for Minerals Affairs ; Muhammad Ba Dakud, Deputy Minister of Agriculture for Water Affairs ; and Mahmoud Taybah, Director General of Industry and Electricity Affairs of the Ministry of Commerce.

In addition, the survey team was aided by information furnished by a group from the Arabian American Oil Company (ARAMCO) working under the direction of John Lunde, Vice President, Engineering, and by Henry Backenstoss of Jackson and Moreland International, Inc., consultant on electric power to the Government of Saudi Arabia.

Richard Davis, Consultant on Water Affairs, in the Ministry of Agriculture of the Saudi Arabian Government, and Glen Brown, Head of the U. S. Geological Survey team on assignment to the Ministry of Petroleum, were of invaluable assistance in the evaluation of alternate sources of water supply for Jidda.

The team also wishes to express its appreciation to officials of the Saudi-National, Ltd., for Electric Power, Jidda, and of the Aziziah Water Supply Company, and to Dr. Omar Azzam of the United Nations Technical Mission working with the Ministry of Interior, for their help in making a considerable amount of information available to the survey team.

Finally, the team would like to extend its thanks for the support given to this undertaking by Ambassador Parker T. Hart and the staff of the U. S. Embassy in Jidda, especially Morris Draper, Second Secretary, who served as special liaison for the team during its stay in Jidda.

CONCLUSIONS

1. The entire fresh water supply for Jidda is obtained from the Wadi Fatimah. (See Figure 1.[1]) At present, this wadi supplies about 21 million gallons per day (mgd) distributed as follows :

Jidda	7 mgd
Mecca	2 mgd
Agricultural use . . .	12 mgd

[1] See insert in a pocket at the end of this volume.

It is estimated that the maximum sustained supply would be approximately 26 mgd with distribution as follows :

Jidda	10 mgd
Mecca	4 mgd
Agricultural use . . .	12 mgd

2. Based on estimates of population growth, better living standards, and an improved distribution system, water usage in Jidda will steadily increase outgrowing existing water supply sources by 1968.

3. Other possible sources of additional water for Jidda are the Wadis Usfan and Khulays. The potential yield from these sources is unknown, and several years will be required to obtain such information. In view of competing uses, however, it appears that their possible contribution to Jidda will be minor.

4. The most feasible method of meeting the growing water requirements of Jidda is the installation of a plant on the Red Sea to desalt sea water.

5. The demand for electric power in Jidda has been steadily increasing and will increase at a still greater rate if an ample supply of power is made available at more reasonable prices.

6. Based on the need for water and the demand for electric power, the most economical solution is to combine water production with electric power generation. Two combination desalting-power plants each with a capacity of 18,000 kw and 2.5 mgd of water would meet the requirements of Jidda until June 1971. These two combination plants could be in service by January 1968.

7. The capital cost of the total facility is estimated at $15,000,000 (power $9,300,000—water $5,700,000).

8. The cost of water from the plant would average 41 cents per 1,000 gallons. This is based on 90 percent operation, fuel cost of 17.5 cents per million Btu and a grant by the Saudi Arab Government to finance construction of the desalting plant.

9. The cost of electric power at the plant would be 6.5 mills per kilowatt hour. This is based on 50 percent annual operation and the financing of the plant by the Saudi Arab Government with a non-interest-bearing loan amortized over thirty years.

10. Existing water supply facilities, presently serving Jidda, can be integrated with the desalting plants at a reasonable cost. The lowest cost water would be obtained by operating the desalting plants at a uniform output and using the ground-water supply from Wadi Fatimah to meet daily and seasonal fluctuations in water demand up to the maximum safe yield obtainable.

Recommendations

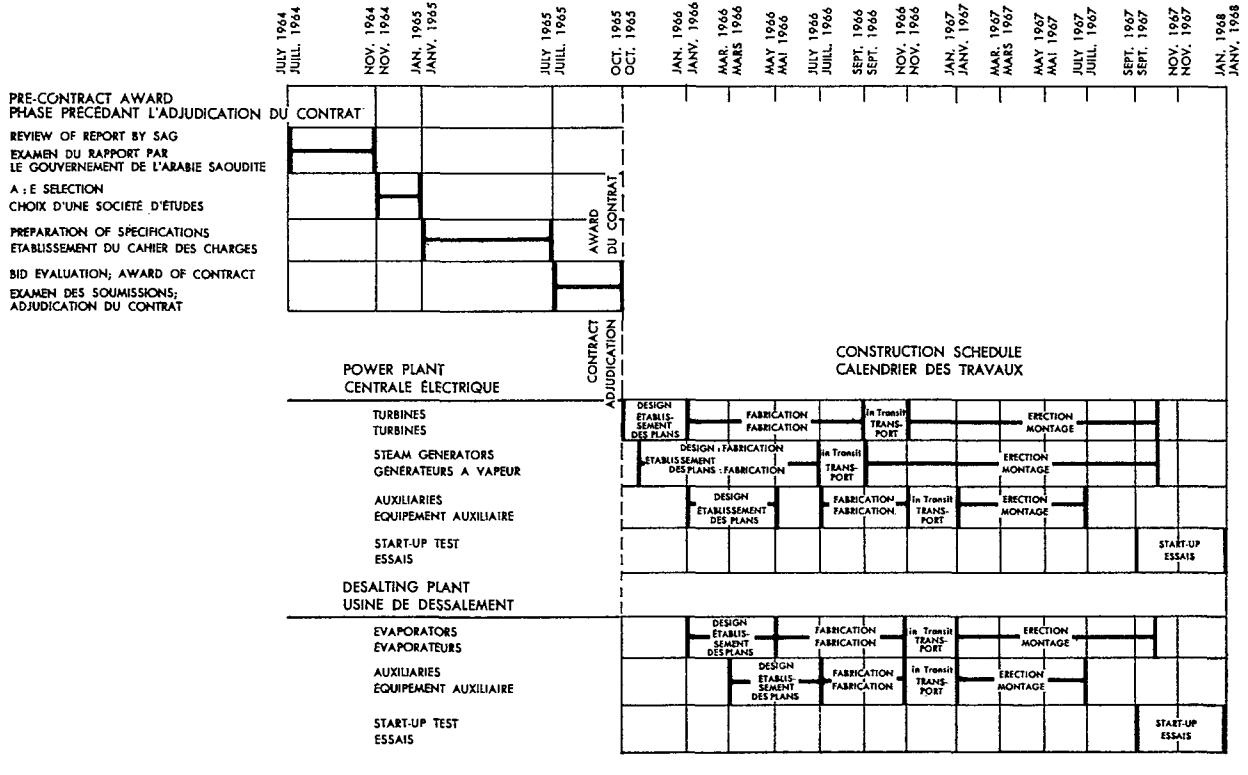
1. The Government of Saudi Arabia should proceed with the design and construction of two combination electric power and desalting plants for Jidda, each with minimum capacities of 18,000 kw of electric power and 2.5 million gallons per day of water. The first step would be the selection of an architect and engineering firm to prepare detailed specifications for the design and engineering of the plant. A proposed construction time schedule for the plant is set forth in Figure 2. [1]

[1] See p. 44 of this volume.

Figure 2

PROPOSED CONSTRUCTION TIME SCHEDULE FOR THE POWER DESALTING PLANT AT JIDDA, SAUDI ARABIA

PROJET DE CALENDRIER POUR LA CONSTRUCTION DE L'INSTALLATION DE DESSALEMENT ET DE PRODUCTION D'ÉNERGIE ÉLECTRIQUE DE DJEDDAH (ARABIE SAOUDITE)



2. In order that sufficient information will be available to base a decision on the installation of another combination plant in the early 1970's, detailed ground-water studies should be made in the Wadi Fatimah to determine the maximum amount of water that can be withdrawn annually without depleting the water supply. Also, studies should be made of the ground-water supplies in Wadi Khulays and Wadi Usfan to determine whether water from either of these sources could be made available to Jidda.
3. A new water distribution system and sewage system should be installed in Jidda prior to the time when water will be available from the desalting plant.

Description of combination desalting and electric power plant *

The combination desalting and electric power plant would utilize the multi-stage flash distillation process to desalt sea water.

The heat necessary for the desalting process would be extracted from the turbines in the electric power plant after most of the energy had been expended in the production of electric power. The use of one heat source permits a very efficient combination of the two processes. Efficient generation of electric power requires high pressure, high temperature steam, while the desalting of sea water requires low temperature steam, which has little value for the production of power.

In the multi-stage flash distillation process, sea water is progressively heated and introduced into a large chamber where a pressure just below the boiling point of the hot brine is maintained. When the brine enters this chamber the reduced pressure causes part of the liquid to immediately boil (flash) into steam, which condenses as fresh water when it cools. This process takes place in a succession of chambers (multistages) at successively higher vacuum where the flashing and condensing of steam is repeated at progressively lower temperature.

Description of Jidda

Jidda is a city with a population of about 150,000, situated on the Red Sea about midway down the western coastal plain of the Arabian Peninsula.

It is the largest port and the most important commercial center in western Arabia, serving as the port of entry for the hundreds of thousands of pilgrims from abroad who annually visit Mecca, 45 miles to the east.

During the past two decades Jidda has experienced remarkable growth. No reliable population data were available until recently, but estimates for the early 1940's were in the range of only 25,000 to 40,000, whereas the census completed in early 1963 showed a population of 147,859.

The area growth of the city during this period is depicted on Figure 4.[1] This expansion was made possible by the availability of fresh water and electric power. In view of the large-scale development programs being undertaken by the Saudi Arab Government, this growth promises to continue into the foreseeable future, provided that adequate supplies of water and power can be obtained to support it.

* See artist's conception given on Figure 3, which is inserted in a pocket at the end of this volume.

[1] See insert in a pocket at the end of this volume.

JIDDA WATER SUPPLY

Because of the desert climate, Jidda has been plagued with water supply problems throughout its history.

At the present time Jidda is completely dependent for its water supply on the ground waters of the Wadi Fatimah which also provides a substantial part of the requirements of Mecca. In addition, the Wadi supports a sizeable area of irrigated agriculture.

The survey team examined all available reports on water supply and held conferences with company officials and operating personnel of the Aziziah Water Company, which operates the Jidda water supply system. Also, a field inspection was made to examine the water production facilities and observe water problems of the area.

The most comprehensive inventory of water supply developments in Wadi Fatimah was made in 1963 by Dr. Ahmed Hilmi Hilal for the Director General of Water Affairs of the Ministry of Agriculture. This study covered water production from both wells and dibbula * throughout the Wadi. He estimated that during winter Aziziah produced an average of 5 mgd, of which 3.5 mgd were produced by wells and 1.5 mgd by dibbula. Summer production was estimated by Dr. Hilal to average 7 to 8 mgd.

On the basis of its studies, the survey team estimates the average annual water production for Jidda at the present time to be 7 mgd.

The water is transported to the city from the Wadi by means of three pipelines, identified as follows :

Pipeline	*Year Constructed*	*Design Capacity*
"English"	1949	1.0 mgd
"Italian"	1956	3.5 mgd
"German".	1962	12.8 mgd
	TOTAL	17.3 mgd

These pipelines deliver water to Aziziah's 16.7 million gallon storage reservoirs, located at Kilo 14 (about 8.5 miles east of Jidda). However, only two lines with a total capacity of 8.9 mgd carry water from the storage reservoirs to Jidda.

It is estimated that Mecca is now obtaining approximately 60 percent of its water or about 2 mgd from three dibbula ** in the Wadi upstream from the area that supplies Jidda.

Irrigated agriculture has been practiced in Wadi Fatimah for centuries. Most of the irrigated areas are scattered throughout the broad sandy valley, starting as far downstream as Haddah and extending upstream about 25 miles to the vicinity of Abu Hasani. In addition, there are some irrigated tracts along the valley above Abu Hasani. Agriculture consists principally of numerous date gardens, although other crops such as alfalfa, bermuda grass, and some garden vegetables are also raised. There is no reliable information available as to the total area in Wadi Fatimah that is now under cultivation, but it is estimated that the irrigated area approaches 2,500 acres.

* Water tunnels constructed in the alluvium of the Wadi on a gradient which intercepts the water table thereby drawing water from the top of the water table.

** Ayn Mudig, Ayn Salah and Ayn Jadidah.

In the inventory made by Dr. Hilal in 1963, he found that there were some 104 wells in Wadi Fatimah above Haddah. Examination of statistical data in his report indicates that about 53 were being used at that time for irrigation and other wells were under construction. On the basis of hours operated daily and probable pumping rate, it is estimated that the combined production of the 53 irrigation pumps is some 10 to 12 mgd. Although irrigation is practiced throughout the year, the pumps are operated only about 80 percent of the time. Water pumped for irrigation, therefore, averages about 9 mgd annually. In addition to water obtained from wells for irrigation, it is estimated that about 3 mgd are being supplied to agriculture from dibbula.

In summary, the Wadi is now supplying an average of about 21 mgd. divided as follows :

Jidda water supply	7 mgd
Mecca water supply	2 mgd
Agriculture	12 mgd
TOTAL	21 mgd

There is no doubt that the ground-water table is being lowered throughout Wadi Fatimah in the areas of pumping, particularly during periods of extended drought. This is evidenced not only by drying up of dibbula, but also by the fact that many of the shallow irrigation wells are failing to produce enough water, and crops throughout the valley are showing signs of stress. Moreover, the Ministry of Agriculture has been receiving an increasing number of complaints from farmers in the area about their failing water supply.

Yet, new areas are being prepared for irrigation, and the use of water by agriculture will continue to increase unless it is restricted by shortage of supply, or by limitations imposed by government regulations, or both.

That the Wadi is producing in the range of its maximum sustained yield capacity is also indicated by an analysis of rainfall in the drainage area.

Rainfall in the lower reaches of the basin is very low, less than three inches. That which falls in the mountainous area of the eastern part of the basin, probably does not exceed five inches annually. Most of the flood flows having a bearing on the ground-water supply in the Wadi originate above Abu Hasani.

Information taken from maps of the area indicates that the total drainage area above this point is about 1,100 square miles. Although estimates as to the amount of stream flow available for recharging ground-water must be speculative in nature, due to the desert climate, it is not likely that runoff will exceed 7 to 10 percent of the average annual precipitation. Therefore. total runoff probably would not exceed 26 mgd, compared with the present-day estimated production of 21 mgd.

In summary, it is concluded that the limiting factors of an adequate water supply for Jidda are (1) the amount of ground-water that the Wadi Fatimah can supply on a sustained basis ; (2) water production capability of the wells and pumps of the Wadi ; and (3) pipeline capacity between Jidda and the reservoirs at Kilo 14 (8.9 mgd).

The latter two can be easily corrected by installing additional pumps and a pipeline of sufficient capacity to meet the increasing demands. However, the amount of water

that can be safely taken from ground-water without depleting the ground-water supply of the area is a far more serious problem.

With adjustments in agriculture, and development of wells so as to fully utilize the storage and regulating potential of the ground-water reservoir, it is possible that a modest amount of additional water supply can be developed for municipal purposes. If water production is substantially increased, it is likely that agriculture would be sharply curtailed.

Consequently, further development and utilization of ground-water from the Wadi should proceed cautiously until a thorough investigation has been made covering a sufficient period of time—three to four years—to provide reliable information as to its safe and dependable yield.

JIDDA WATER REQUIREMENTS

In the previous section it was mentioned that the average water production by the Aziziah Water Company was estimated at 7 mgd.

The entire 7 million gallons, however, are not presently being used by the population of Jidda. The city receives its water supply through a 12-inch pipe serving the main section and a 6-inch line serving the area near the airport. In addition, Aziziah supplies the palace grounds through a 6-inch line. Another 6-inch line delivers water to a large privately owned garden and the agricultural experiment station at Kilo 8 is supplied by a pipe of unknown size. Aziziah also serves the villages and watering places along the pipelines in Wadi Fatimah.

It is estimated that an average of 4.5 mgd is consumed by the city proper and the remaining 2.5 mgd is consumed by the other outlets mentioned above. With a population of approximately 150,000, daily usage averages 30 gallons per capita.

Estimates of the population served with water connections vary from 20 to 50 percent. It is likely that at least two-thirds of the people of Jidda must rely on other, more expensive means to receive water. This includes many people who do not receive ample quantities of water through their water connections.

Many families are supplied by tank trucks which deliver water from the "German" pipeline at Kilo 28. It is estimated that there are possibly 180-200 trucks, some of which make up to five trips daily. The cost of water from the trucks, which average about 1,500 gallons in capacity, is about $2.50 per thousand gallons, over five times the cost (44 cents per thousand gallons) of water supplied through the Aziziah distribution system.

In order to get further distribution throughout the city, there are 40 water stations from which hundreds of water carriers with donkey carts operate. The cost of water delivered by these carriers ranges between $1.10 and $2.20 per thousand gallons. Some water is also delivered by hand carriers.

An additional water supply would therefore be of little value unless adequate means are provided for its distribution. The need for an improved distribution system in Jidda was recognized by all of the public officials the team contacted. Accordingly, it is anticipated that this project will be assigned a high priority by the Government and that a modern distribution system will be constructed by 1969. Plans are already under way for the construction of a sewage system for the city.

With the installation of water distribution and sewage systems it can be expected that the per capita use of water will rise from the present 30 gallons daily until it reaches a level which will be reasonably in line with the improving standard of living. This increase is expected to be gradual until mid-1968 when an additional water supply should be available and the new distribution system should be partially completed. Then it is estimated that per capita use of water will rise sharply to mid-1969, when the distribution system is expected to be complete. Thereafter, the anticipated rise will be gradual until 1975 when the per capita use will probably level off at about 60 gallons daily.

As mentioned previously, Jidda has experienced a remarkable growth during recent years since a water supply became available. Plans are being made by the government and others to bring industry into the area. Other government programs such as health and education are also being expanded. These programs have a marked effect on the growth of cities such as Jidda by drawing large numbers of Bedouins to the cities from the countryside. Consequently, it can be expected that Jidda will continue to grow at a rapid pace if the necessary water and power facilities are provided.

It is estimated that the city will experience an increase in population of 5 percent annually over the next several years and will reach a population of 300,000 by 1980. This projection is based on an increase of 5 percent annually for the period 1964 to 1975, inclusive, and 2.75 percent thereafter through 1980.

The projection of population and average daily water use for Jidda are given in the following table.[1] The population projection and per capita daily water requirement forecast are also shown graphically on Figure 5.[2]

[1] See p. 51 of this volume.
[2] See p. 50 of this volume.

Figure 5

JIDDA, SAUDI ARABIA—PROJECTED POPULATION AND PER CAPITA USE OF WATER, 1964-1980

PROJECTIONS DE LA POPULATION ET DE LA CONSOMMATION D'EAU PAR HABITANT DE DJEDDAH (ARABIE SAOUDITE) DE 1964 À 1980

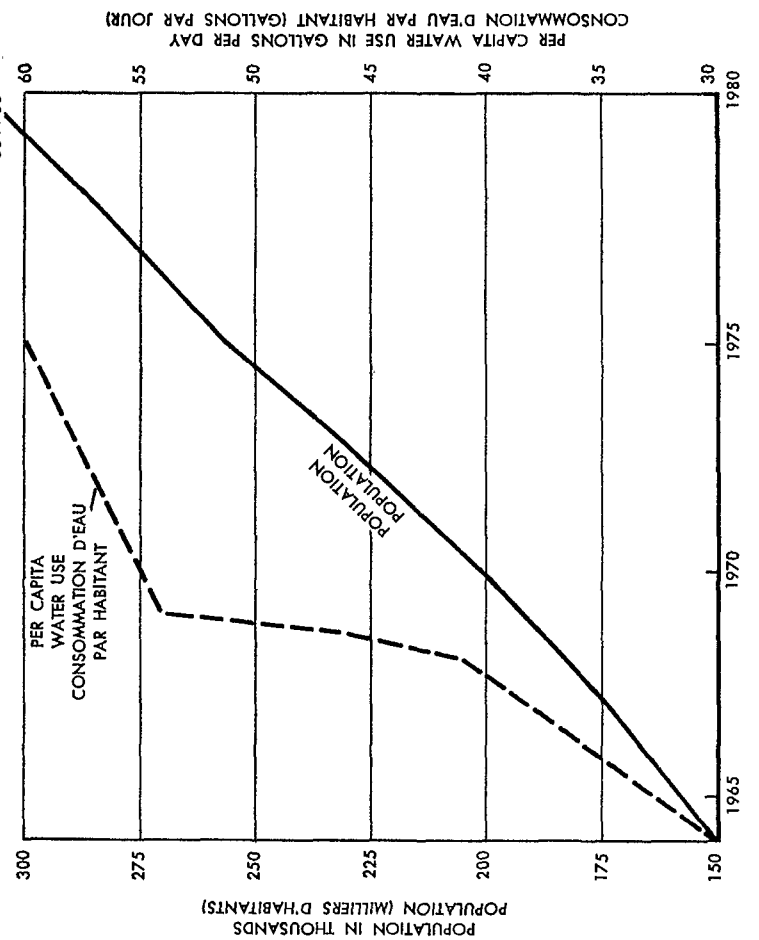


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Table 1

JIDDA PROJECTED POPULATION AND AVERAGE DAILY WATER USE, 1964-1980

Year	*Population (Thousands)*	*Average daily water use*	
		Per Capita (Gallons)	*Total (mgd)* [1]
1964	150.0	30.0	4.5
1965	157.5	32.8	5.2
1966	165.4	35.5	5.9
1967	173.6	38.2	6.6
1968	182.3	41.0	7.5
1969	191.4	54.0	10.3
1970	201.0	55.0	11.1
1971	211.1	56.0	11.8
1972	221.6	57.0	12.6
1973	232.7	58.0	13.5
1974	244.3	59.0	14.4
1975	256.6	60.0	15.4
1976	265.5	60.0	15.9
1977	274.8	60.0	16.5
1978	284.4	60.0	17.1
1979	294.4	60.0	17.7
1980	304.7	60.0	18.3

[1] Excludes 2.5 mgd requirements of palace, agricultural experiment station, and villages along pipeline.

MECCA WATER REQUIREMENTS

In analyzing the water requirements of Jidda, reference must be made to the requirements of Mecca which is also dependent on the Wadi Fatimah for the major part of its supply.

At the present time Mecca is using about 3 mgd, which represents a per capita use of 19 gallons daily for the normal population of 160,000 persons. * About 2 mgd of this supply are obtained from Wadi Fatimah and the balance is obtained from Wadi Na'Man and Wadi Asher. Plans for an improved and extended water distribution system to serve most of Mecca's population are now under way. It is assumed that modernization of the distribution system will be completed by 1968. With an adequate distribution system and an improving standard of living, per capita use of water should rise to 40 gallons daily by 1980.

* 1962-1963 census population was 158,908. During the peak week of the pilgrimage season there is a visiting population of close to 1,000,000.

Mecca is growing at a slower pace than Jidda. For purposes of this report its population growth is projected at 3.5 percent annually through 1975 and 2.75 percent thereafter until 1980.

On the basis of these projections, the population of Mecca will reach 267,500 persons by 1980 and the average daily water use will be 10.7 mgd.

If future demands for water grow as indicated by these projections, Mecca will have to develop an additional supply averaging 7.7 mgd by 1980. Any expansion of water production by Mecca in Wadi Fatimah which results in increased depletions will be in direct competition with Jidda and irrigated agriculture. Therefore, it has been recommended that detailed ground-water studies be made of Wadi Na'Man and the other wadis south of the city.

The future relationship of Mecca's water supply to the Wadi Fatimah, as mentioned above, will depend on the outcome of these ground-water investigations. In the event the city must turn to the Wadi for part of its additional supply, the method by which it obtains the water will have a bearing on the over-all water supply situation. In the past Mecca has acquired an interest in a portion of the flow of existing dibbula. If this means is used in the future, it would not lessen the amount of water available to Jidda.

For purposes of this report it is assumed that Mecca will obtain only an additional 2 mgd of its future requirements from new wells in the Wadi and that the remaining 5.7 mgd required by 1980 will be obtained from outside the basin or by purchase of existing rights within the Wadi.

Possible sources of future water supply

Estimates indicate that by 1980 the population of Jidda will double and that water requirements will be more than four times present use.

Potential sources of supply for meeting all or part of this increased demand are:

1. Further development of ground-water sources in the Wadi Fatimah.

2. Construction of surface storage reservoirs in Wadi Fatimah in order to capture flood waters.

3. Development of ground-water supplies at Wadis Usfan and Khulays some 30 and 45 miles, respectively, north of Jidda.

4. Construction of a sea water desalting plant at Jidda.

Each of these possibilities is discussed below.

Ground-water from Wadi Fatimah: Because of the delicate balance between water supply and use that now exists in Wadi Fatimah, expansion of water production should proceed cautiously until adequate ground-water investigations and related hydrologic studies have been made which would serve as a guide for further development, use, and management of the water resources of the basin.

Although it may be possible for Jidda to obtain a limited amount of additional water from Wadi Fatimah through construction of more wells and extension of the collection system, it is not conceivable that the city can obtain all or even a major part of its future water requirements from the Wadi without acquiring by purchase or pre-empting the rights of most all other water users of the basin. Agricultural uses would most certainly

be seriously affected and serious competition could develop between Jidda and Mecca over the limited supply available.

It is estimated that the expansion of Jidda's supply from the Wadi that is now under way will yield an additional 3 mgd supply by 1968. Any expansion beyond that amount would probably be at the expense of water presently being used for agriculture. Accordingly, unless a considerable portion of the irrigated agriculture of the basin is to be eliminated, and its water supply transferred to Jidda's use, it is apparent that new sources of supply will have to be developed in order to meet a substantial part of the city's future needs for additional water.

Surface Storage in Wadi Fatimah: There is a complete lack of hydrologic and engineering data on which to base an evaluation of the feasibility of developing storage in the Wadi Fatimah. However, informed observers in the area indicated that flood-flows frequently do not reach the sea, but are usually absorbed in the broad sandy channel and flood plain of the Wadi. The waters that are not lost by evaporation percolate downward and are eventually stored in the underground reservoir in the alluvium of the Wadi. This is the best storage possible, free from the high evaporation losses of surface storage in the desert and out of reach of the vegetation in the area.

Consequently, prospects for surface storage do not look very promising.

Wadis Usfan and Khulays: Ground-water has been developed at both Usfan and Khulays. In both Wadis considerable agriculture, consisting of date gardens and other tree fruits and garden vegetables, is irrigated from both dibbula and wells. In the Khulays area, development of ground water for irrigation has been accelerated in recent years, and date gardens, citrus groves, and other irrigated crops are being established.

The amount of water that might be available for Jidda would depend on the capability of the area to provide a sustained yield. This can be determined only on the basis of detailed ground-water investigation and other related hydrologic studies that will require several years' time. There is also the problem of the quantity of water to be reserved for agriculture. In the event that irrigated agriculture is expanded, which is the present trend, particularly at Khulays, little, if any water would be left for Jidda. This is a matter of government policy and is beyond the scope of this report.

Until these policy decisions and the required investigations are made there would be no basis for the expenditure of funds to develop these supplies and to build a pipeline to transport water from these wadis to Jidda.*

Sea Water Desalting: With recent developments in the technology of desalting sea water, the Red Sea is capable of furnishing an inexhaustible supply of fresh water to Jidda. Although significant progress has been made in reducing the cost of desalted water, it is still more expensive than the cost of pumping and transporting natural fresh water over reasonable distances.

However, in view of the probable limited supply of water available from the Wadi Fatimah, the length of time needed to evaluate other sources of supply which are not especially promising, and the critical need for water in the near future to meet Jidda's sharply increasing requirements, it is recommended that a sea water desalting plant be installed to supply fresh water to the city.

* It is estimated that the cost of a water supply system to deliver 7 mgd from Usfan and Khulays to Jidda would be about $8,600,000.

The most advanced sea water desalting process proven on a large scale is multi-stage flash distillation. This process has been successfully demonstrated by the U. S. Office of Saline Water and is clearly the most desirable type of plant to meet the needs of Jidda.

In considering the installation of a sea water distillation plant there are very sound technical and economic reasons for combining the water plant with a plant to produce electric power.

The desalting of sea water when done at relatively low temperatures (up to 250° F) will avoid the formation of scales which drastically reduce plant efficiency. However, at very little increase in capital cost, steam can be produced at higher temperatures and pressures. This high temperature steam can be effectively used in turbines to produce electricity. After the energy has been expended to the point where it has only slight usefulness for the generation of electricity, it can still be used very efficiently for the distillation of water.

In addition, the combination of the power and water processes permits economies in the construction of one large installation instead of two separate, smaller ones. The combination plant, moreover, permits a sharing of labor and avoids duplication of other facilities, such as the sea water intake.

Accordingly, an appraisal was also made of the need for electric power generating facilities in the Jidda area.

ELECTRIC POWER

Existing System: The first electric system for the Jidda area was initially installed in 1948 and 1949 as a source of power for construction activities on an airport project. It consisted of four 400 kilowatt (kw) diesel-electric units. Service was gradually expanded to serve a few nearby residences.

This system was acquired in the early 1950's by the Saudi-National, Ltd. for Electric Power, Jidda (SNJ), a privately owned public utility which holds a franchise for generating and marketing electric power in Jidda and vicinity.

SNJ has expanded the original facilities to a present day total installed capacity of 25,000 kw consisting of a 17,000 kw gas turbine plant and a 8,000 kw diesel plant.

Firm capacity of the system is 19,000 kw, this being the total installed capacity with the largest single unit (6,000 kw) out of service. Maximum generation to date has been about 16,700 kw with approximately 55,000,000 kilowatt-hours of annual energy. Based on peak demand, this represents a system load factor of about 38 percent.

The Jidda distribution system consists of a 13.8/4.16 kv network with loop service. There are five 13.8 kv feeders from the gas turbine plant and two from the diesel plant. Four 13.8 kv substations feed the 4.16 network. The system is mostly in underground cable with overhead lines in the outlying areas.

Mecca and Taif have been mentioned as possibilities for interconnection with the Jidda system. These communities are served by separate diesel-driven plants having installed capacities of 9,370 kw in 7 units, and 4,640 kw in 7 units, respectively. These systems are owned by the Saudi Electric Company, S. A. Mecca-Taif, which is a separate company having common principal shareholders with SNJ.

Projected Power Requirements: Load increases in Jidda have been sporadic and have varied from an annual increase of 65 percent to a decrease of 8 percent. The larger

increases were in the period of 1950 to 1957 when the system load grew to about 14,000 kw. After 1957, there was some variation in growth due to the moving of most government agencies from Jidda to Riyadh. However, the system continued to grow, and in 1963 the peakload was 15,600 kw. An unusually high peak of 16,700 kw was recorded in 1962 because of the extended stay of the Royal Family during the summer.

In the past the annual pilgrimage to Mecca has influenced the peak requirement in Jidda, as most of the pilgrims arrive at Jidda en route to and from Mecca. Since the pilgrimage is now during the spring and is moving into the winter season 11 days per year, it is not expected to influence the peak requirements in Jidda for many years to come. This peak will continue to be in the summer months as a result of the air conditioning load.

The average annual load growth from 1963 to 1968 is forecast to be about 7 percent per year. This will give a peakload in 1967 of about 20,400 kw, slightly in excess of the present firm capacity of 19,000 kw. However, this margin is so small and the risk involved is so slight that it does not warrant the installation of additional generation until 1968 when the recommended combination plants would be on-the-line.

An economical arrangement for meeting the anticipated electric load growth would be to install in 1968 two 18,000 kw steam electric generating units. The additional cost involved in the construction of two units instead of a single large one is more than justified by the greater reliability and flexibility in operation provided by two units.

These two 18,000 kw steam electric generating units can be operated to meet the total load in the Jidda area from January 1968 to June 1971. One thousand kw from each unit would be consumed by the associated water plant leaving 17,000 kw for commercial power loads. This proposal would enable the existing gas turbine plant of 17,000 kw capacity to be used on a standby and peaking basis, and provide 34,000 kw of dependable capacity with the largest unit out of service.

The diesel plant would not be used after January 1968. The 20 to 30 year old units would probably have only scrap value, but the units less than 15 years old could probably be moved to other cities.

The new power plant should provide an ample supply of power that could be sold at lower rates than are presently being charged, thereby stimulating load growth. It is reasonable, therefore, to assume that the load in the city of Jidda would increase by 10 percent annually from 1968 to 1972.

The major consumer of electric power in the Jidda area is the cement plant located about 10 miles north of Jidda along Medina Road. With its expanded load of approximately 6,000 kw this plant should become a customer of the system in 1968. Since it operates 24 hours a day 7 days a week the cement plant is a most important factor in enabling the combination plant to operate economically. There are also other new industrial plants planned for the area which would add a minimum of 1500 kw of demand by 1969.

The city load plus the industrial load would account for a total demand of 27,800 kw in 1968 and 33,900 kw in 1970. By the summer of 1971, the demand would be above the 34,000 kw of dependable capacity, and a third unit would be required before June 1971. (Figure 6.)[1] While this unit could be the same size as the first two units, a larger one

[1] See p. 56 of this volume.

should be given serious consideration. Since the unit would not have to be ordered until 1969, the exact size can be determined on the basis of conditions that prevail at that time.

Electricity Problems: The cost of power in Jidda will be reduced as a result of the inherent economy of larger generating units plus the improving load factors. * However, there are several obstacles which at present stand in the way of lower power rates ** and expansion of the Jidda electric system :

(1) The SNJ has for several years been forced to carry sizable amounts of unpaid bills equal to approximately one-third of its capitalization.

(2) The entire capital of SNJ is made up of equity securities that require a higher return than would be paid out on debentures, which make up a substantial part of the capital of utilities in most countries.

(3) Approximately five percent of the system's customers use no energy in a given year and a good many others use energy only for short periods. The small monthly metering charge of $.22 produces little revenue. Yet the system must have enough installed capacity to serve these potential loads.

(4) The present distribution system is in need of further strengthening to provide more reliable service.

(5) There are no programs to promote the use of electricity and new customers are required to pay a connection charge for extensions to their premises.

Both the Government and the SNJ have been studying these problems for some time and are working toward a solution. A constructive step was taken in 1963 when rates were reduced throughout the country.

If rates can be lowered significantly and service improved, the potential market for electric power is enormous. Present per capita consumption of electricity is quite low and could easily be doubled in a few years.

Proposed Interconnection of Jidda, Mecca and Taif: In addition, a decision is expected soon on establishing a uniform standard of either 50 or 60 cycle operation for all electric systems within the Kingdom. This is necessary before any steps can be taken toward the interconnection of the electric systems of Jidda, Mecca and Taif. Conversion of the systems to the same frequency would be the first step toward interconnecting the three cities as recommended by Jackson & Moreland, International, Inc.

The advantages of interconnecting these three cities come not only from the saving in the cost of generation at a central plant over the cost of local diesel generation in Mecca and Taif, but also from the diversity in the timing of peak loads between the three cities.

It is reasonable to assume that this conversion program would be decided upon by 1965 and work started in 1966. The transmission line to Mecca would probably be installed first and could be in service by 1968 or 1969, with the extension to Taif following

* It is estimated that the 1962 annual load factor of 38 percent will increase to 45 percent by 1968 and 48 percent by 1970.

** Present rates are 5.3 cents per kilowatt hour.

in about 1971. Thus an additional load for the Jidda central plant could be obtained by supplying a portion of the Mecca load in 1968-70. This increase in kilowatt-hours could be obtained for the Jidda area central plant in 1968 through 1970 without any increase in peak demand. By 1971, Mecca and Taif would need some additional capacity from the central plant at the time of the Jidda peakload, and the generating unit planned for installation at that time could be considerably larger than 18,000 kw.

DESALTING PLANT

A 2.5 mgd desalting plant can be efficiently coupled with an 18,000 kw power plant under the loading characteristics that prevail in Jidda.

Two such combination plants would meet the projected power and water requirements of the area thru 1971.

Assuming the requirements continue as projected in this report, additional units of 2.5 mgd would be required in 1971, 1974 and 1977. This would result in over half of the area's water being supplied by desalting in 1980. As is the case with electric power, however, the decision on the size of the next desalting units, or on alternate sources of water supply, should be made in early 1969 or thereabouts. It could then be based on more reliable information on ground water supplies and more timely data on water requirements.

Heat for the distillation process which would operate at a maximum temperature of 250° F, would be supplied by a condensing type, extraction steam turbine. While this type of turbine costs more than a back pressure turbine, it provides greater flexibility, permitting the turbo-generators to meet relatively wide variations in electric loads when extraction steam is being supplied to the desalting plant.

To account for those periods, particularly in early years of operation, during winter months when the power load will be insufficient to provide the required amount of turbine extraction steam, the plant would include a by-pass line leading from the boiler to the desalting plant. This by-pass line permits the water plant to be operated independently of the electric power plant.

A performance ratio (lbs. of fresh water produced to lbs. of steam) of 8.0 was selected for the desalting plant on the basis of the prevailing cost of fuel.

Calculations were also made on the basis of a higher performance ratio of 10.0, providing for a more efficient use of steam energy, but this would require an increase of about $1,000,000 in the capital cost for the initial 5.0 mgd plant, which more than offsets the savings in operating costs.

The initial price for fuel is based on the use of bunker fuel oil A-960 available at $1.07 per barrel from "Petromin" * at the bulk plant in Jidda. According to product specifications provided by ARAMCO, this has a Btu content of 6.1 million per barrel, giving a fuel cost of 17.5 cents per million Btu.

Capital Cost—Desalting Plant: The estimated capital cost of each 2.5 mgd unit is $2,850,000. This cost was based on data contained in the Office of Saline Water Research and Development Report No. 72, March 1963, entitled "A Study of Large-Size Saline Water Conversion Plants." Adjustments were made in the estimate to account for the

* Saudi Arab Government Petroleum and Minerals Organization.

smaller evaporators, and elimination of the sea water intake and steam generating facilities, which were included in the electric plant.

The total cost so arrived at represented cost of the erected plant in the United States. To this cost 25 percent was added to represent the additional cost of erecting the identical plant in Jidda. This factor was based on information obtained in Saudi Arabia and material supplied by United States firms who are familiar with construction costs in Saudi Arabia.

In addition, it will be necessary to install approximately 6 million gallons of storage capacity at the plant and also a 24-inch pipeline to tie the plant into the Aziziah distribution system. The storage will cost an estimated $510,000 and the pipeline about $360,000.

Desalting Plant—Steam Energy Cost: The cost of steam energy charged to the desalting plant is based on the difference in the cost of electrical power generation between an unassociated plant (i.e., one that would be built for power generation alone) and the recommended combination plant. This difference in generating costs results from a higher capital investment for the recommended combination plant due to increased boiler capacity and added cost of turbine extraction steam lines and valves. Also, the station heat rate, (Btu's per kilowatt hour (kwh)), is higher as a result of extracting steam before it has given up all its available work energy. This cost differential, in mills per kwh, is correlated with the amount of steam supplied to the desalting plant and the results are expressed in cents per 1,000 pounds of steam. Under the base conditions assumed in this study, the cost differential between the unassociated and associated plants amounted to 1.53 mills per kwh. The resulting cost of steam energy to the desalting plant is 17.1 cents per 1,000 pounds.

Desalting Plant—Operation and Maintenance: A table of positions of personnel needed for operating the desalting plant was developed. Rates of pay were assigned to each position based on information supplied in the "Lahmeyer Report" * and also by ARAMCO. Supervisory, operation and maintenance labor costs for the initial 5.0 mgd installation, including 20 percent fringe benefits, amount to $135,000 (26 positions) per year.

Associated general and administrative expenses were assumed to be 14 percent of the total payroll and amount to $18,000 a year. In the development of these labor costs it was assumed that certain maintenance and labor personnel would be shared between the desalting plant and associated power plant.

Maintenance materials were estimated to cost 0.5 percent of the capital investment. For the initial plant, this amounted to $28,000 per year.

Desalting Plant—Chemical Costs: The pH method for scale control, requiring the addition of acid to the sea water feed, would be used in the desalting plant to permit plant operation with a brine heater outlet temperature of 250° F. A chemical treatment cost was estimated at 3.0 cents per 1,000 gallons. This was based on a probable source of chemical supply located in Europe or the Near East.

Desalting Plant—Fixed Charges: Amortization and financing charges were not included in this study, but an annual fixed charge of .85 percent of the capital investment

* "General Survey Report on the Development of Industries in Saudi Arabia" 1961, prepared for the Government of Saudi Arabia by W. Lahmeyer and Co., Frankfurt, Germany.

was applied to include cost of insurance (.35%) and interim replacements (.50%). For the initial desalting plant, this amounts to $48,000 a year.

Desalting Plant—Electrical Energy Costs: Each 2.5 mgd desalting plant will require 1,000 kw when operating at design capacity. The cost of this energy is chargeable to the desalting plant at a rate of 6.45 mills per kwh, the net cost of electricity from the power plant.

COST OF DESALTED WATER

The cost of desalted water will vary depending on the manner in which the desalting plant is integrated into the water supply system. For purposes of this report costs were calculated for the two most probable methods of operation.

The first method assumes that the desalting plants will operate continuously for 90 percent of the time. The other 10 percent of the time would be required for periodic shutdowns for maintenance. The cost of operating the first two desalting units according to this method would be 41 cents per thousand gallons of water (Table 2).[1]

The second method assumes that the desalting plant would operate only to meet the city's water requirements in excess of the estimated supply of 10 mgd from the Wadi. These costs are based on the water requirements curve (Figure 7)[2] and are projected through 1977 (Table 3).[3]

The cost of operating the desalting plants under this method would average 42 cents per thousand gallons ranging from $1.40 per thousand gallons for the limited output in 1968, down to 38 cents per thousand gallons in 1977 when four units would be in operation.

Table 2

ESTIMATED COST OF DESALTED WATER

Method No. 1
17.5 cent fuel
90% Operation—330 Days Per Year

Year	*1968*	*1971*	*1974*
Plant Capacity	5 mgd	7.5 mgd	10 mgd
Total Investment	$5,700,000	$8,500,000	$11,400,000
Direct Operating Costs:	*Thousands*	*Thousands*	*Thousands*
Steam Energy	$291	$437	$582
Electricity	102	153	204
Chemicals	50	74	99
O & M Labor	112	135	162
Stores & Maint. Mat'l.	28	42	56
Indirect Operating Costs			
Payroll Fringe Benefits	23	27	33
G & A Payroll Overhead	18	23	27
Interim Replacement Insurance	48	72	96
TOTAL ANNUAL COST	672	963	1,259
COST PER 1,000 GALLONS	41¢	39¢	38¢

[1] See below.
[2] See p. 61 of this volume.
[3] See p. 62 of this volume.

Figure 7

PROPOSED SOURCE OF WATER SUPPLY—JIDDA, SAUDI ARABIA

SOURCES D'APPROVISIONNEMENT EN EAU PROPOSÉES POUR DJEDDAH (ARABIE SAOUDITE)

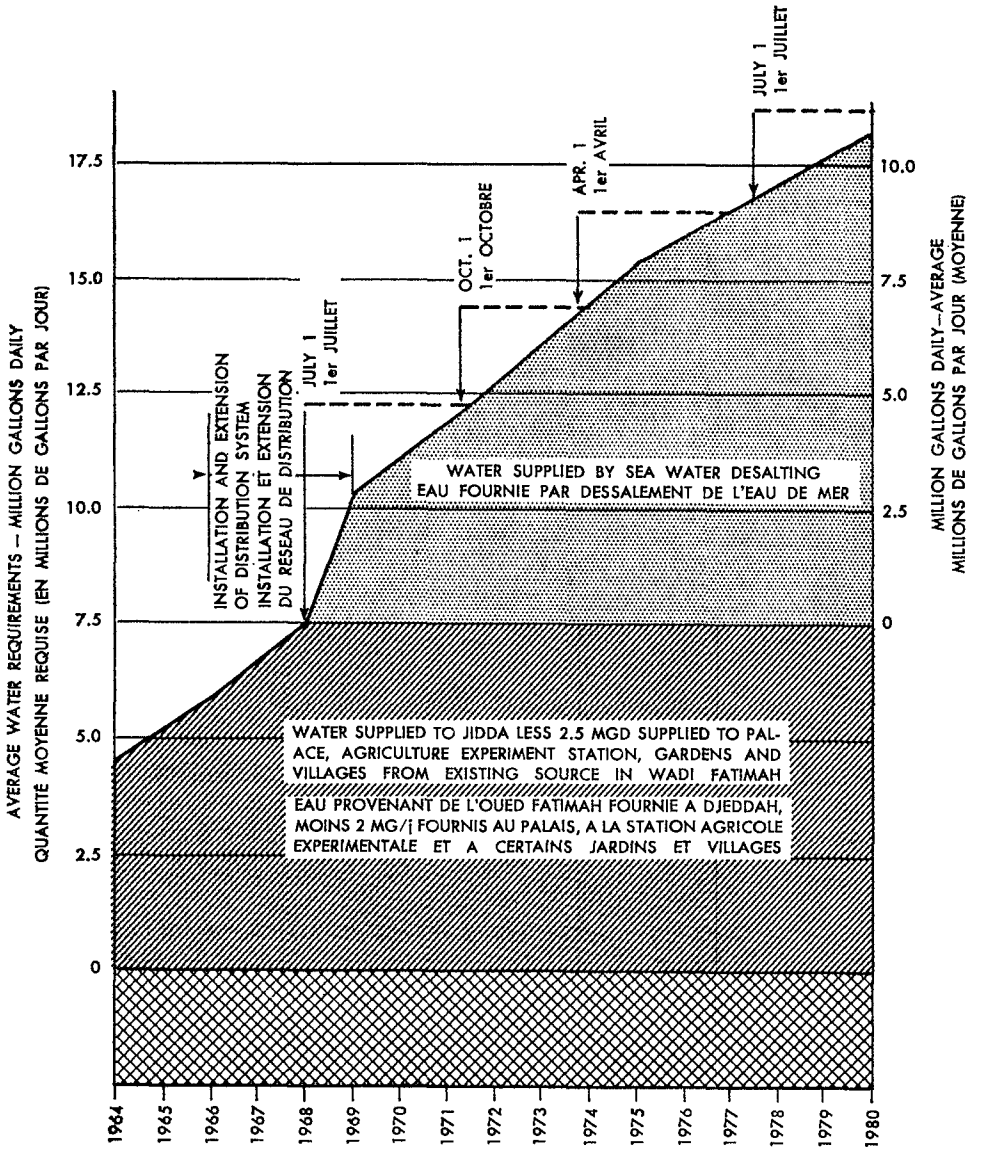

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Table 3

ESTIMATED COST OF DESALTED WATER

Method No. 2

Operated to meet requirements in excess of 10 mgd

17.5 cent fuel

Year	*Effective desalting Plant capacity* [1] *mgd*	*Estimated production*	*Total annual cost Thousands*	*Cost per 1000 gallons*
1968	4.5	.3	$127	$1.40
1969	4.5	2.4	465	.53
1970	4.5	3.6	582	.44
1971	6.75	4.3	666	.43
1972	6.75	5.1	796	.43
1973	6.75	6.0	885	.41
1974	9.0	6.9	1,028	.41
1975	9.0	7.8	1,130	.40
1976	9.0	8.4	1,193	.39
1977	9.0	9.0	1,259	.38
1968-1977 Average Cost				.42

[1] Maximum Operation—90 percent of total capacity.

ELECTRIC POWER PLANT

Electric Power Plant—Capital Cost: The estimated capital cost of the proposed electric power plant, consisting of two 18,000 kw units is $9,300,000. This estimate includes the 25 percent cost increase factor utilized in estimating the cost of the desalting plant.

Additional Power Investments: For purposes of this report, the cost of electric power was calculated only at the plant. However, additional expenses will have to be incurred to integrate the two units into an efficient distribution system. The following is a rough estimate of the cost involved :

69 kv plant transformers, breakers and lines around city and to cement plant	$1,600,000
13 kv and lower voltage distribution system	$4,000,000

In addition, it is estimated that the Jidda-Mecca and Mecca-Taif interconnections would each cost $1,000,000.

Electric Power Plant—Operation and Maintenance Cost: A table of positions and personnel was prepared for the initial 36,000 kw installation. Rates of pay were assigned to each position based on data supplied in the "Lahmeyer Report" and by ARAMCO.

Supervisory, operation, and maintenance labor costs arrived at in this manner, including fringe benefits of 20 percent, amount to $178,000 (38 positions) a year. Associated general and administrative expenses were assumed to be 14 percent of the total payroll cost, amounting to $25,000 a year.

To provide for maintenance materials and supplies, a cost of 0.4 mill per kwh generated, or $57,000 per year, is added.

Electric Power Plant—Fixed Charges: It was assumed that the power plant would be financed through a non-interest-bearing 30-year loan. On this basis, total annual fixed charges amount to 4.03 percent of the capital investment broken down as follows:

Repayment of loan (30 years at no interest)	3.33 percent
Insurance	.35 percent
Interim replacements	.35 percent
	4.03 percent

COST OF ELECTRIC POWER

Cost estimates were developed for both an unassociated plant and the recommended associated plant. The estimates as given below are based on a fuel cost of 17.5 cents per million BTU and the assumption that the plants would operate for 7,000 hours each year supplying power for an average system load of 20,400 kw. Deducting the 2,000 kw load attributable to the desalting plant, this amounts to a yearly plant factor of about 50 percent. With these base conditions, the cost of producing electric power is estimated to be as follows:

	Unassociated Mills/kw-hr.	*Associated Mills/kw-hr.*
Fixed Charges	2.28	2.62
Operation & Maintenance	1.82	1.82
Fuel Cost	2.35	3.54
TOTAL COST	6.45	7.98

The net production cost of electricity from the associated plant is assumed to be the same as that from the unassociated plant or 6.45 mills per kw-hr. The difference of 1.53 mills per kw-hr. is charged to the desalting plant in the form of a steam energy cost.

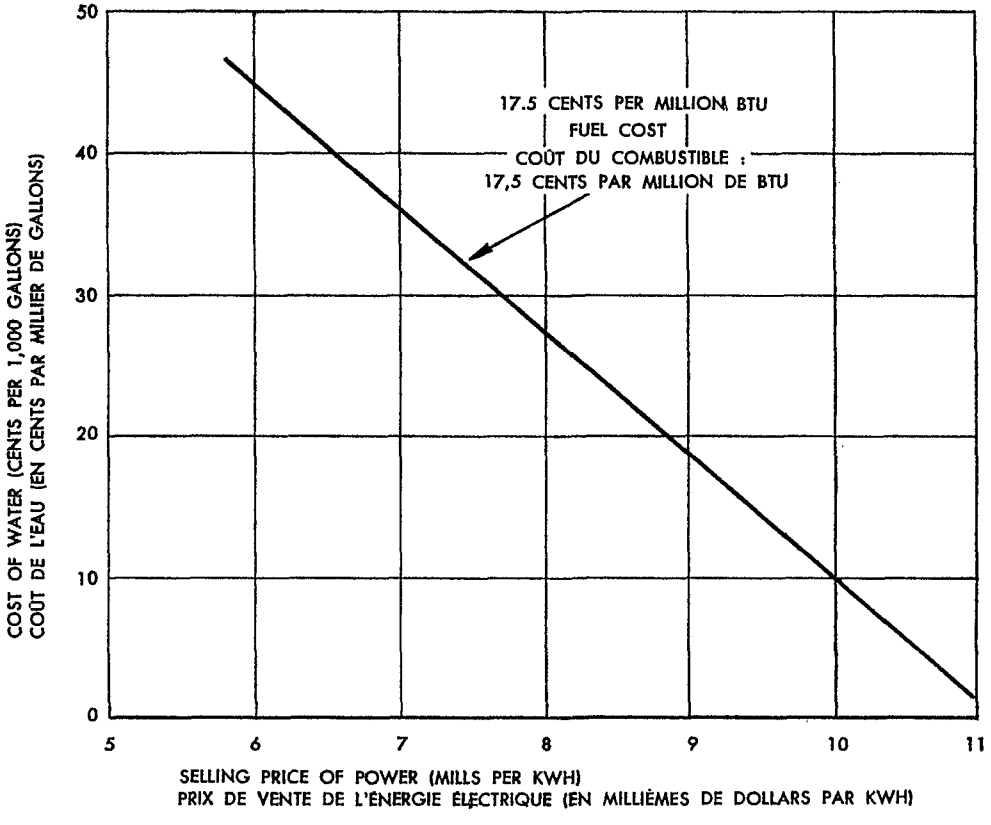
The effect of selling price of power on the cost of water production is shown graphically on Figure 8.[1] For example, by increasing the selling price of power from 6.45 mills per kwh to 10 mills per kwh, the cost of water is reduced from 41 cents per 1,000 gallons to 11 cents per 1,000 gallons.

[1] See p. 64 of this volume.

Figure 8

SELLING PRICE OF ELECTRIC POWER VS. COST OF WATER BASED ON PRODUCTION COSTS AT THE PLANT SITE—JIDDA, SAUDI ARABIA

PRIX DE VENTE DE L'ÉNERGIE ÉLECTRIQUE ET COÛT DE L'EAU DESSALÉE CALCULÉS SUR LA BASE DES COÛTS DE PRODUCTION PRÉVALANT À DJEDDAH (ARABIE SAOUDITE)



COST OF ELECTRIC POWER AND WATER WITH CHEAPER FUEL

Due to the possibility that cheaper fuel may eventually be available in Jidda, estimates were also prepared on the cost of water and power using fuel costs of 10 cents per million Btu. (See Appendix.) [1] A reduction in fuel costs from 17.5 cents to 10 cents per million Btu would lower the cost of electric power by 15 percent and reduce the cost of water by 25 percent.

WATER SUPPLY MANAGEMENT

The success of this project will be determined in large part by the manner in which the proposed desalting plant is operated in conjunction with the natural water supply from the Wadi Fatimah. Both sources should be utilized in such a way as to obtain the greatest possible benefits from each at the least cost to the government and the consumer. For this report it is assumed that the safe yield production from the Wadi will approximate 10 mgd and that this average rate will be continued indefinitely thereafter. By July 1, 1968, the initial desalting plant would become operative, and it would produce all water requirements above those that can be safely supplied from the Wadi Fatimah.

Based on a cross section of the alluvium at Al Jumum, it is believed that there is adequate ground-water storage capacity in the Wadi (possibly 13-16 billion gallons in the reach between Al Jumum and Abu Hasani). Therefore, it should be possible to draw heavily from underground storage to meet peak requirements of Jidda during the summer months. In the winter months, pumping would be greatly reduced, thereby permitting replenishment of the ground-water reservoir by runoff which usually occurs during November and December.

Such an operation would result in substantial fluctuations in the water surface elevation of the ground-water reservoir, but would provide the most economical method of operation in line with sound conservation principles.

By such a scheme, the ground-water supply would be operated in a manner as to meet fluctuations in daily and seasonal demands, but the annual withdrawal from ground-water would not exceed its maximum safe yield, now estimated to average 10 mgd. If this is done, the required desalting plant capacity and operating cost would be kept at a minimum.

To be successful, this plan will require major adjustments in irrigation water supply systems as well as the water production facilities that serve Jidda. Jidda is particularly fortunate in that the present water production facilities in Wadi Fatimah, including the pipelines and storage reservoirs can be expanded and modified at reasonable cost to integrate the system with the desalting plant as proposed.

Since the Wadi Fatimah system must be able to meet high daily and seasonal peaks, the following extensions and modifications should be considered :

(1) Construction of an additional 30-inch pipeline with a capacity of 19 mgd between the storage reservoirs at Kilo 14 and the distribution point at Jidda at an approximate cost of $1,100,000. When integrated with the two existing pipelines and the desalting plants, this line would enable the city to meet peak delivery requirements of about 40 million gallons daily.

[1] See pp. 67 and 68 of this volume.

(2) Expansion of the collection system in the Wadi so that additional wells can be constructed at the most favorable locations. This collection system should be integrated with the existing pipelines between Abu Sha'ib and Kilo 14.

(3) Development of new wells throughout the ground-water reservoir so as to bring the combined water production capacity of all wells, and dibbula, if possible, up to at least 17 mgd, the estimated combined capacity of the pipelines between Abu Sha'ib and Kilo 14. A few additional wells should be provided so that wells can be rotated or shut down for servicing and repair without reducing the production capacity of the system below the capacity of the pipelines. The wells should be adequately spaced so as to distribute the effects of pumping over the ground-water reservoir. This avoids great lowering of water table such as occurs in concentrated areas of heavy pumping. A projected plan of water system operation for sample years, 1970, 1975 and 1980, is set forth in Table 4.[1]

Table 4 was based on a typical monthly water use distribution for a desert area in the United States. If the optimum distribution in Jidda differs, this distribution can be modified accordingly, provided that the average amount taken from the Wadi for two or three years does not exceed the safe sustained yield of the ground-water supply. Also, in the event that the safe ground-water yield is ultimately determined to be different from that used in this plan, appropriate revisions can be made as required. If less water can be obtained from ground-water on a sustained basis, correspondingly larger amounts of water would be supplied from the desalting plant. However, whatever ground-water supply is available would be utilized in the manner given in the tables to meet fluctuations in daily and seasonal requirements.

Table 4

PROJECTED JIDDA WATER SUPPLY

Monthly Distribution
Selected years 1970-1975-1980
Million Gallons Per Day

Month	*1970*			*1975*			*1980*		
	Desalting Plant	*Wadi Fatimah*	*Total*	*Desalting Plant*	*Wadi Fatimah*	*Total*	*Desalting Plant*	*Wadi Fatimah*	*Total*
January	3.6	4.6	8.2	7.9	2.8	10.7	10.8	2.7	12.5
February	3.6	5.6	9.2	7.9	4.2	12.1	10.8	3.3	14.1
March	3.6	7.7	11.3	7.9	7.1	15.0	10.8	6.6	17.4
April	3.6	11.0	14.6	7.9	11.2	19.1	10.8	11.5	22.3
May	3.6	12.7	16.3	7.9	13.6	21.5	10.8	14.2	25.0
June	3.6	14.0	17.6	7.9	15.3	23.2	10.8	16.2	27.0
July	3.6	14.1	17.7	7.9	15.4	23.3	10.8	16.2	27.0
August	3.6	14.1	17.7	7.9	15.4	23.3	10.8	16.2	27.0
September	3.6	14.0	17.6	7.9	15.3	23.2	10.8	16.2	27.0
October	3.6	10.2	13.8	7.9	13.1	21.0	10.8	10.3	21.1
November	3.6	6.3	9.9	7.9	5.2	13.1	10.8	4.4	15.2
December	3.6	5.7	9.3	7.9	3.9	11.8	10.8	2.9	13.7
Average Daily for Year	3.6	10.0	13.6	7.9	10.0	17.9	10.8	10.0	20.8

[1] See below.

WATER CONSERVATION AND SALVAGE

Due to the serious deficiency in water supply in the Jidda area, it is essential that water be conserved by all reasonable methods. Immediate consideration should be given to obtaining increased efficiency in use of water for irrigated agriculture and reclaiming sewage effluent for certain acceptable uses.

More efficient use of water for irrigated agriculture would not only conserve water, but would also substantially benefit the farmers. Information should be developed and farmers educated as to amounts of water required for irrigation of different kinds of crops. Improvement in irrigation facilities, including distribution works, would no doubt also help to conserve water in many areas.

Water reclaimed from sewage can be used safely for irrigating tree crops and other crops not directly used for human consumption. As the city grows, water that can be developed from sewage is relatively inexpensive in relation to the volume of water handled ; this potential source of water should not be overlooked for certain permissible uses which are now widely accepted.

APPENDIX

Table 5

COST OF ELECTRIC POWER

10 cent fuel

	Unassociated Plant 2-17,000 kw Units Mills/kw-hr.	*Associated Plant 2-18,000 kw Units Mills/kw-hr.*
Fixed Charges	2.28	2.62
Operation—Maintenance	1.82	1.82
Fuel Cost	1.35	2.02
TOTAL COST	5.45	6.46

Table 6

ESTIMATED COST OF DESALTED WATER

Method No. 1
90% Operation—330 Days Per Year
10 cent fuel

Year	*1968*	*1971*	*1974*
Plant Capacity	5 mgd	7.5 mgd	10 mgd
Total Investment	$5,700,000	$8,500,000	$11,400,000
Direct Operating Costs:	*Thousands*	*Thousands*	*Thousands*
Steam Energy	$159	$239	$318
Electricity	86	129	172
Chemicals	50	74	99
O & M Labor	112	135	162
Stores & Maint. Mat'l.	28	42	56
Indirect Operating Costs:			
Payroll Fringe Benefits	23	27	33
G & A Payroll Overhead	18	23	27
Interim Replacement Insurance	48	72	96
TOTAL ANNUAL COST	524	741	963
COST PER 1,000 GALLONS	32¢	30¢	29¢

Table 7

ESTIMATED COST OF DESALTED WATER

Method No. 2
10 cent fuel
Operated to meet requirements in excess of 10 mgd

Year	*Effective desalting plant capacity* [1] *mgd*	*Estimated production*	*Total annual cost Thousands*	*Cost per 1000 gallons*
1968	4.5	.3	$123	$1.34
1969	4.5	2.4	385	.44
1970	4.5	3.6	464	.35
1971	6.75	4.3	520	.34
1972	6.75	5.1	631	.34
1973	6.75	6.0	688	.31
1974	9.0	6.9	804	.32
1975	9.0	7.8	876	.31
1976	9.0	8.4	920	.30
1977	9.0	9.0	963	.29
1968-1977 Average Cost				.33

[1] Maximum Operation—90 percent of total capacity.

APPENDIX II

IRREVOCABLE LETTER OF CREDIT

(Name of Bank Issuing Letter of Credit)

(Address of Bank)

(No. of letter)

(Date)

Treasurer of the United States
Washington, D.C. 20220

Dear Sir :

We hereby establish our irrevocable credit No. ———— in your favor by order and for account of United States Department of the Interior up to an aggregate amount of $14,000,000.00 available by demand drafts drawn on us by a representative of the United States Department of the Interior or his designee. Such draft shall be payable at our New York or Washington correspondent banks, in New York the ———— Bank, in Washington, D.C. the ———— Bank. Drafts must be accompanied by a written statement that the amount drawn under this credit represents costs incurred pursuant to the notes between the United States Government and the Government of Saudi Arabia, dated ————.

Very truly yours,

Authorized signature of bank official

جـــــدول المصطلحـــــــات

Conversion Table

Acre	فـدان
BTU (British Thermal Unit	وحـدة حرارية برايطانيـــــة
Dollar 4.5 SR 20 Piastres	دولار ـ ٤٫٥ ريال سـعودى (ر س) ٩٠ قرشـا سـعوديا
Dibbula	سـراديب المـياه ـ سـراديب
Galon	جالـون
Kilowatt (kw)	كيلوات (ك و)
Kilowatt per hour (kwh)	كيلوات سـاعة (ك و سـاعة)
Mile	ميـل = $\frac{٣}{٥}$ ١ كيلومـتر
Million Gallons Daily (mgd)	مليون جالون يوميـا (م ج ى)
Per Capita	حصـة الفـرد
Desalting	ازالة الملح من المـاء ـ التقطـير
Desalting plant	مقطـرة

[TRANSLATION [1] — TRADUCTION [2]]

KINGDOM OF SAUDI ARABIA
MINISTRY OF FOREIGN AFFAIRS

7/25/85 Hijra
corresponding to : [11/19/65.]

No. 90/15/1/9356/2

Mr. Chargé d'Affaires of the United States :

I have the pleasure to inform you that I have received your note No. 362, dated 11/11/65, concerning the desire of His Majesty's Government to construct a water desalting and electric power plant in the Jeddah area and your reference to the assumption by your Honorable Government of responsibility for negotiating contracts on behalf of His Majesty's Government with qualified American firms for the architectural and engineering study and design and for the supply of construction and installation equipment, required by the project, in accordance with the obligations set forth in your aforementioned note.

I have the pleasure to inform you of the approval of the Kingdom's competent authorities to carry out the project in accordance with the terms and provisions set forth in your aforementioned note.

Therefore, His Majesty's Government agrees to consider your aforementioned note and our present reply thereto as an agreement between our two Governments.

Please accept the assurances of our highest consideration.

Omar SAKKAF

[1] Translation by the Government of the United States of America.
[2] Traduction du Gouvernement des États-Unis d'Amérique.