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THE KINGDOM OF SAUDI ARABIA

RESEARCH COOPERATION FOR

THE PROJECT OF THE SEA WATER DESALINATION TECHNOLOGY

BETWEEN

SAUDI SEA WATER CONVERSION CORPORATION (SWCC)

AND

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

FINAL REPORT

THE KINGDOM OF SAUDI ARABIA

RESEARCH COOPERATION FOR THE PROJECT OF THE SEA WATER DESALINATION TECHNOLOGY BETWEEN SALINE WATER CONVERSION CORPORATION (SWCC) AND JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

FINAL REPORT
SUPPLEMENT

JULY 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

Contents

INTRODUCTION

This is a supplementary volume for SWCC's convenience. It will be a great pleasure for JICA that SWCC uses the volume for reference to running a research laboratory. The supplement consists of two chapters; one is concerned with recommendation for management of a research laboratory and the other is transfer of technology from JICA's viewpoint, reviewed by SWCC.

Chapter 1. Recommendation for Management of Research Center

1.1 Present Situation of Seawater Desalination

Though the construction tempo of desalination plants in land installations is recently slowing down all over the world, they are still on the increase, and the capacity of the desalination plants in the world at the end of 1989 has reached 13,297,000 t/d. From a regional standpoint, though the increase in the North America and the Asia is somewhat remarkable, the Arabian Gulf area has an overwhelming market share. The increase of desalination plants is supposed to still continue because of demand for fresh water, due to industrialization and the improvement of living standards in the world.

The demand for fresh water and the desalination plants is increasing as mentioned above, the following points are pointed out as major features of recent desalination.

a) In various regions of the world where fresh water is required as the feed water used in newly installed desalination plants, the use of seawater is recently decreasing, and by contrast, the use of brackish water or others are increasing.

b) Reflecting the tendency as mentioned above, the adoption of the MSF process in newly installed desalination plants is decreasing significantly, while the RO process is used for seawater desalination. The capacity of RO process plants which have recently been installed therefore exceeds that of MSF process plants. Further, the increase of adoption of the ED method and the ME method, or the diversification of processes to be adopted, is observed.

   It is reported that solar energy with enhanced reliability is being used in the desalination process in arid areas where the energy cost is high.

c) The increase in RO process plants results from the increase of demand for their intended use in conventional brackish water desalting because membrane modules have been improved in performance, stabilized, and improved in economical efficiency and also from the increase of their intended use in seawater desalination. As is widely known, as the replacement of a plant using MSF process for seawater desalination, an RO plant with a capacity of 56,800 t/d was installed at Jeddah in Saudi Arabia in 1989, and is now in service.

An advantage of the RO process consists in remarkably low energy consumption needed for the desalination process as compared with that of the MSF process, and it is becoming probable that the advantage will further be strengthened due to the increase in crude oil price.

At present, the comparison of the cost of sea water desalination between the MSF process and other processes has been conducted in various ways, and has led to the conclusion that

without a power station installed nearby, the MSF process cannot compete with the RO process from the viewpoint of economical efficiency.

On the other hand, the advantages of possessing a few number of large scale MSF desalination plants over of possessing many number of small scale plants, are more economical efficiency, easier maintenance, and easier increase in desalination capacity. In any case, it is necessary to take concrete and steady measures for operating the existing MSF plants more efficiently and economically and measures against any emergency like spilt crude oil in feed water.

Since product water from the MSF process is distilled water, it has to be potabilized for drinking purpose. A method is being considered to mix with product water of the RO process at a certain ratio, and use the blended water for drinking.

This is the hybrid method of producing drinking water by combining the MSF process with the RO process. The feasibility of this method will be a subject for studying in the future.

1.2 The Present State of the SWCC Research Center

The Research Center is located on the premises of the Al Jubail seawater desalination station which has the world's largest capacity using MSF process.

This is an advantage for the Research Center. It has easy access to technological information on MSF plants such as technological problems encountered under normal operations, countermeasures to be taken and the consequent results of these countermeasures, which are normally known in plant operators only.

The Center is also conveniently located due to its proximity to the University of Petroleum and Minerals in Dhaharan a highly prestigious scientific engineering university. This proximity will allow ease of communication between the University and the Center.

Moreover, the Center contains advanced research facilities and employs a large number of researchers. Saudi Arabia and SWCC are proud of this because of fact that the Center is the largest desalination research institute in the world. Established in 1987, it has a relatively new facility, yet it has already made great progress in the field of corrosion, and chemical analysis.

1.3 Position of Research Center in SWCC

1.3.1 Fundamental Way of Thinking

In general, the aim of researches on technologies can be said to be to elucidate the relationship among scientific or engineering facts which exist in the background of given phenomena by means of theoretical and experimental studies and analyses and to make the results contribute to the development of science or engineering. For this reason, depending on which institution and for what aim a technology research center is established, there can be various research cen-

ters. In fact, research centers with a variety of aims and contents exist.

For desalination, public institutions and manufacturers in countries who use and manufacture desalination equipment, such as the United States and Japan, and in counties who use desalination equipment, such as Saudi Arabia, have been conducting various research and development activities for further rationalization of desalination, with their own aims. In the United States and Japan where research and development activities on desalination technology have been conducted most vigorously, public institutions and desalination equipment manufacturers are putting stress upon the following:

a) On what principle and under what reaction conditions can efficient desalination be realized?
b) How is the tendency of the technology for using solar energy with relation to desalination?
c) How do the advance of material technology and unused technologies affect the increase in efficiency of desalination technology?
d) How is the solution of technological subjects raised through the operation of delivered desalination plants accomplished?

Their major aims can be said to be research and development from the point of view of those who develop desalination processes and manufacture related equipment.

Under these circumstances of researches on desalination in the world, what research and development should the SWCC research center perform? To perform the research and development most efficiently both from the viewpoint of investment and of utilization of human resources, what method should be adopted? It is necessary to study on the above questions.

1.3.2 Roles Undertaken by SWCC Research Center

(1) Basic Roles Undertaken by SWCC Research Center

Since there are various research and development institutions for desalination all over the world, SWCC should aim at achieving results most efficiently, or with a minimum investment, while making the best use of the abilities of these existing research and development institutions.

From this point of view, the basic ideas concerning the research and development and the collection of information that the SWCC research center should conduct, can be sorted and arranged as follows.

(a)Necessity of research and development as user of desalination plants
(b)Necessity of grasp and utilization of desalination related information
(c)Improvement of evaluation ability for manufacturer's proposal
(d)Execution of development research and applied research

(a) Necessity of research and development as user of desalination plants

As users have to make their plants exhibit maximum capabilities and perform desalination efficiently, they should perform operations according to site conditions, plant parameters, and environmental conditions.

Though the basic operating method of a plant is understood by the plant manufacturer, the following points become important to be considered by the user; (1) the pursuit of an optimal operation method suitable for the use of feed water and required water quality conditions, (2) problems which only the operators of the plant every day can know, (3) improvement of operating techniques to extend service life of the existing desalination plants, and so forth.

In process industries such as the iron and steel industry and petrochemical industry in Japan, significant efforts in increasing the life span of major plants have been realized; for example, the life span of blast furnaces in the iron and steel industry has increased from 4 to 5 years to nearly 10 years.

For other simple operational problems, users are required to improve their abilities to elucidate the causes and cope with them.

(b) Necessity of grasp and utilization of desalination related information

In order to perform the operation of existing desalination plants efficiently and improve the operation technology, it is essential to extensively grasp information on the operation of desalination plants in the world, the advancement of operation technology, and the improvement of the related unit operation technology in the world, and to utilize the information for the improvement of their own operation technology as occasion demands.

Besides, it is necessary to have information on the latest advancement of each desalination process all over the world and to select an appropriate process suitable for new installation of a desalination plant.

(c) Improvement of Evaluation Ability for Manufacturer's Proposal

To efficiently conduct research and development by users, it is necessary for the researchers to concentrate on the problems which only users can solve, making the public institutes or manufacturers in the world perform the themes from their standpoint. By doing this, it will be possible to accumulate enough information for the proper evaluation of various proposals by manufacturers on new installation or improvement of plants.

(d) Execution of development research and applied research

It is needless to say that the research and development on desalination technology that is essential from the standpoint of users of desalination plants should be restricted to the range of

applications.

(2) Subjects of Research and Development to be Tackled by SWCC Research Center

Based on the above the themes of research and development to be conducted by the SWCC research center are shown below.

1) Operation method of minimizing running costs by making existing plants exhibit their maximum abilities
2) Method of extending the life span of existing plants up to the maximum
3) Measures to cope with seawater contaminated with crude oil and sewage
4) Development of optimal systems of seawater desalination (e.g. RO – MSF hybrid method)
5) Preventive measures against corrosion and scaling in MSF desalination plants

1.4 Management of Research Center in SWCC

1.4.1 Concept of Management

This consists not only in performing research and development for improving desalination processes to be effectively tackled from the standpoint of the user of a desalination plant but also in arranging an information collection and management system and a patent information system which give an indirect aid to the research and development.

1.4.2 Management

(1) Organization

There may be various ways that the organization should be depending on its manager's philosophy on organization, experience of researchers, and so on. In order to perform the research and development effectively, however, it is general to establish laboratories by specialized domain, that is, desalination processes such as MSF and RO, materials such as metals and non-metals, and chemical analyses, and to assign a research leader to each laboratory so as to promote the research and development.

Usually, to perform research and development smoothly, besides the execution of research and development, the management department looks after budget, procurement of materials for research, time management for researchers, and maintenance and repair of research facilities.

(2) Preparation, Execution, and Evaluation of Research and Development Plans

In promoting research and development, it is necessary to take themes to be executed during about 5 years ahead from long-term and short-term needs, prepare execution plans by

year, and according to it, perform the execution of research and development activities, maintenance and procurement of equipment and materials, and adoption and upbringing of necessary personnel.

The preparation of research and development plans is needed to execute research and development effectively and systematically, and at the same time, is essential to maintain facilities related to research and development and arrange personnel systematically.

(a) Research and Development Plan

The research and development plan is the one which is essential to sort and arrange a number of needs of research and development in a given format, and evaluate by comparison the order of priority, method, and budget of research and development.

(b) Contents of Research and Development Plan

In preparing a research and development plan, it is necessary to clear up the following items.

* Needs and aim of research and development
* Contents of research and development
* Results of research and development and methods of utilizing them (as definitely and quantitatively as possible)
* Person responsible for execution
* Necessary materials, equipment, and procurement method
* Budget (by year, by major items of expense)

(c) Preparation and Execution of Research and Development Plan

Needs of research and development vary every moment, and so according to it, a new theme of research and development must be set one after another. Usually, a theme of research and development has been selected from both new and continuing items as a theme to be executed during about 5 years ahead at the end of the previous year, and has been executed during the year concerned.

If a theme of research and development to be executed urgently is given newly in the middle of the year concerned, the urgent theme will be incorporated while delaying the execution of part of existing research and development plans.

With regard to the research and development plan of each year, an original draft is proposed by the laboratory for each specialized research field, and finally the manager of the research center consults with the head of each laboratory to decide the plan of the whole research

center.

As the research and development plan, besides the yearly plan described above, there is the long-term research and development plan for studying nearly once in three years the basic skeletal structure of what research and development plans should be executed during about 5 years ahead. Unlike the yearly plan, this is the plan for defining the skeletal structure of long-term research and development while overlooking the long-term tendency of related technical fields, and is essential to prevent the research center from being badly affected due to short-term and daily business and to ensure the propriety of the direction of long-term research and development.

(d) Themes of Short-term Research and Development and Themes of Long-Term Research and Development

Ordinarily, research and development of which the period is 3 years or less is referred to as the short-term research and development; research and development that is longer in period than 3 years is as the long-term research and development. As a matter of course, the short-term research and development handles themes on technical improvement to be executed routinely; and the long-term research and development requires deeper investigation and often produces good results.

The allocation of research and development staffs should be adopted that gives bigger importance to short-term themes, which actually have such need, to cope with problems to be solved in a short period and gives smaller importance to long-term themes.

As long-term themes seem to contain many studies on fairly basic items such as desalination processes and corrosion resistant materials, discussion on whether they are the themes to be executed by users themselves of desalination plants should be done sufficiently.

(e) Interim Evaluation of Execution of Research and Development

Research and development plans are not always be advanced as planned at the beginning, and not a few plans can not achieve initial purposes. Nearly twice per year after starting a research and development plan, the manager must check the progress of the whole research and development periodically and evaluate about the following items.

* Whether or not it is progressing as the initial plan,
* Whether or not the initial plan should be corrected,
* Whether or not attainment of the initial aim has become difficult

To promote research and development efficiently, it is necessary to stop the research and

development immediately even in the middle of the plan if it is judged to be proper, and to assign researchers to other research and development tasks.

(f) Evaluation and Utilization Methods of Fruits of Research and Development

When a research and development task has been completed after the planned period, the results should be evaluated accurately and utilized concretely. The evaluation of results contains the following items:

* Whether or not the research and development has been executed leaving no room for review,
* To what degree the aim has been accomplished, and what the reason for it being incomplete.

The steps and budget necessary to put the results of the research and development into practical use, and the definite effects should be studied.

(g) Management of Research and Development Status

The decision about preparation and execution of research and development tasks, interim evaluation, evaluation and practical use of results, etc., is conducted by the manager of the research center when the scale of the research center is small; with enlargement of the research center, the decision about small research and development theme should be entrusted to heads of laboratories.

(3) Presentation of Research Results

For those who engage in research and development, they should present the results of their own research and development and to obtain evaluation about the results, especially to obtain high evaluation, means to be rewarded for their efforts and results in raising their morale higher. Usually, research results are presented in the following places: organizations to which researchers belong, academic societies, industrial organizations, and symposia in countries where they reside, and international academic societies and symposia.

Because the aim of researches on desalination technology in SWCC consists in making the operation more efficient for desalination facilities in Saudi Arabia and improving the operation technology, it goes without saying that contributing to it is to be evaluated most highly and researchers' pride is thereby satisfied.

Furthermore, becoming well known not only in his own country but also in the world and being highly evaluated by producing epoch-making results of research and development and further a possibility of the results being executed all over the world raise researchers' morale further.

The increase of contacts with a world-wide range of researchers through these opportunities may lead to further progress of research and development. The presentation of results of research and development which produces such effects should be encouraged positively after having taken legal protective means for results of research and development as described later.

(4) Contact with Outside

It is very profitable in the progress of research and development that researchers have contacts with internal and external researchers specialized in desalination and related fields, receive stimuli, and broaden their outlook. One method for such contacts is the presentation of research results mentioned above and attendant contacts with a wide range of researchers. It is also effective to have frequent contacts with personnel concerned every day.

It becomes an effective means to continue having contacts with the outside to publish in a periodical such as a technical report which describes what research and development is performed recently and what results are produced and to distribute it to colleges concerned with desalination, public institutions, corporations, etc., in the world for the purpose of advertisement.

Saudi Arabia is a country that possesses the largest desalination facilities, and the tendency of research and development there attracts the world's attention as representing the current situation and problems of desalination technology concentratedly. Also, it is thought to become a cue to obtain the cooperation of researchers related with desalination in the world.

1.4.3 Administration

(1) Maintenance of Research Environment

To perform research and development efficiently, in addition to researchers' efforts for research and development, the maintenance of the environment and system that enable it to be done efficiently is required. Experimental equipment and facilities, and materials such as chemicals and specimens for research and development should always be arranged so that research and development can be performed according to a research and development plan, and the safety should also be ensured at all times.

As mentioned above, to maintain equipment and facilities and arrange necessary materials so as to allow research and development to be done efficiently, preparation for the maintenance and inspection of equipment and the procurement of equipment and materials are needed. In order to perform such works efficiently, apart from the laboratories for research and development, an auxiliary department such as a management department is established to perform those works systematically based on the research and development plan by year.

(2) Management of Results of Research and Development

As the evaluation and the application of results of research and development are sometimes carried out by persons other than researchers participating in it, results are sorted and arranged definitely and in detail as internal documents. Usually, this is named the research results report.

By preparing this, a number of persons can understand the contents correctly, evaluate the results, and lead them to application. Also, a lot of results developed and discovered, factual relations, and casual relations are accumulated in the research center as documents, and utilized for later research and development activities over a long period of time. Research and development result reports are, in this sense, one of the most important documents to be accumulated and preserved by the research center.

1.5 Development of Researchers' Faculties

Research and development activities greatly depend on researchers' personal faculties and will, and it is necessary to conduct systematic development of researchers' faculties in accordance with the rapid development of new technologies and the principle of the growth of human faculties.

1.5.1 Basic Pattern of Research Activities

Usually, a young researcher who has just graduated from a college should start with a narrow and deep basic research in a specific field to acquire basic knowledge and research techniques required as a researcher. The researcher who possesses narrow but specially deep knowledge on specific research in a special field, as mentioned above, is referred to as the unimodal researcher.

However, as he grows to his thirties and his forties, he needs to become the T type researcher (type who, in addition to knowledge on a specialized technology, possesses knowledge on a wider range of technologies related with it) or the bimodal researcher (type who, in addition to knowledge on a specialized technology, possesses quite deep knowledge on specialized technologies in one or more different fields).

The reason is that he comes to require knowledge on related fields and different fields so as to find out themes of research and development and guide young researchers as a leader of researches. Also, as a general tendency, young researchers who have experience of a certain period come to feel the necessity of researches of the T type or bimodal type and wish for them. Some of investigations in the United States, Japan and other countries have given such analyses that there appears to be a tendency that T type and bimodal type researchers are likely to produce achievements rather than unimodal type researchers.

1.5.2 Life Cycle of Research Faculties

The progress and deepening of specific research and development in a special field also are often promoted by the progress of research and development in related fields. The recently observed progress of each advanced technology, in particular, is striking, and we must advance researches in specialized domains while taking such results up to the maximum.

To cope with such situations, the youthfulness and flexibility are necessary and so researchers' reshuffle according to the life cycle of researchers is one problem. In many instances, the absorption of microscopic knowledge on ever changing latest technologies and the absorption of new experimental techniques are entrusted to researchers below a certain age who have sufficient bodily strength and flexibility, and researchers who have many years' experience are transferred to fields where they can effectively exhibit experience and judgment accumulated over a long time.

Possible fields to which senior researchers are transferred in the future are the manager of the research center in the SWCC management department, the head of the management department in the research center, responsible persons in the technical investigation department and technical staffs of operation department.

1.5.3 Education and Training of Researchers

(1) Thorough specialized education

It is necessary to first give young researchers who have just graduated from a college sufficient basic education on basic knowledge and research techniques in the specialized domain of a laboratory to which each researcher belongs and to next let them share with a specific research theme to bring them up as researchers by means of the OJT.

After that, while confirming their growth and will, they are given education and works as the T type or bimodal type researcher.

(2) Bringing up Leaders

A leader such as laboratory head, who guides his researchers in promoting a concrete research and development, needs to be the T type or bimodal type researcher who has experience of researches on a field concerned, and further must be able to guide his researchers properly and to bear results of the research.

Therefore, he must possess the leadership which can guide his researchers in research, the wide outlook and cognitive faculty for current situations which can properly judge what research and development should be done, the negotiation faculty which can negotiate with concerned personnel inside and outside the research center such as desalination plant manufacturers, material manufacturers, and public institutions.

Though the manager of the research center is also a research leader, higher-level judgment, flexibility, leadership, and negotiation faculty than the laboratory head are demanded from him. Such a leader of research and development must ascertain his own aptitude through daily research activities and bring up his faculty as leader through expansion of the range of research activities and the range of guidance for his researchers.

1.6 Information Management

Though the collection and analysis of patent information and information on the tendency of research and development concerning the desalination technology inside and outside the research center are essential from the viewpoint of the setting of themes of research and development, the status of research and development, and the evaluation of results, the utilization of the patent system is essential even for the legal protection of their own research results. In such a sense, the recognition that information management is inseparable from the execution of research and development is required.

1.6.1 Science and Technology Information Service and its Utilization

Recently, the publication and exchange of science and technology information and the construction of databases of such information has been advancing remarkably in every field all over the world. Therefore, so as to promote research and development effectively in colleges, public institutions, and corporations, it has become an essential prior-condition to grasp information on such research and development sufficiently.

The construction of databases was begun on a full scale when the United States made great efforts at establishment of the system for collection and publication of science and technology information in the world by the reason that it was preceded by USSR at launching an artificial satellite. Every country in Europe and Japan, following the United States, has been accomplishing the construction and replenishment of databases.

At present, the amount of information published all over the world a year is enormous: about 5 million pieces of science and technology documental information, and about 2 million pieces of patent information. It is therefore impossible to read through them all and collect and select related documental information.

The means which enables that work is only an online information retrieval system for databases, which uses a computer. In such a sense, in promoting research and development, the utilization of an online information retrieval system is essential. The research and development which does not use the system is preferably said to be impossible. The development of such databases was realized only when there were strong needs for it and computers making it technically possible were developed. It is said that there are approximately 3,000 databases according

to applications in the world at present.

In setting a new theme of research and development, it is necessary to check on the following items:

a) Whether or not such research and development was and is performed in the country or in foreign countries,
b) If performed, what the status of progress, contents, method, and results are.

The check is done for the reason that even if a research and development is performed from the same standpoint as that already conducted by other corporation, it is apprehended that results of the research and development can not be put into practical use due to protective measures by industrial properties of an advance corporation, etc. To conduct research and development efficiently, it is necessary to use as many results, if practical, of the research and development performed by other corporation as possible.

In such a sense, not to mention the case that research and development is commenced newly, even for the case that it is studied in the halfway evaluation for a research and development how it should be advanced thereafter, we must select an efficient way of advancing it while comparing with internal and external trends of the research and development concerned.

This is a basic principle in advancing research and development, and holds true even for advancing the research and development in the desalination field. Thus, in SWCC also, it will be necessary to equip facilities to have access to online databases in major countries and to acquire techniques to utilize those facilities rapidly. Since it is the best way of having access to related information most accurately that researchers themselves perform retrieval, all researchers need to acquire the ability to use databases.

1.6.2 Databases in the World and Their Uses

When utilizing databases, it is proper to have access to databases in the United States, which hold a larger amount of information. Among them, the world's largest database, DIALOG (holding over 100 million pieces of information), is a proper one, because it covers almost all fields and data from major advanced countries, and retains patent information as well as science and technology documents.

In Japan, on the other hand, for the database for science and technology information, it is proper to utilize JOIS; for patent information, PATOLIS is helpful.

These databases have problems: it is only a short time since they began to accumulate data in 1975; and they handle data in narrower fields than DIALOG does. However, in the fields which these databases deal with, they have accumulated the world's largest amount of data for

information of Japanese origin, of course; even for information of European origin, they are on a comparable level with DIALOG.

At present, however, they are inconvenient in that those who can not understand Japanese can not have access to them. Judging from the above, it is necessary in SWCC to accomplish the arrangement of facilities required for having access to DIALOG and the acquisition by researchers of the use of DIALOG.

1.6.3 Utilization of Industrial Property System

(1) Significance of System

The industrial properties are subdivided into the patent right, the right of utility model, the design right, and the right of trade mark. These rights have the common spirit of respecting the precedence of those who suggested and invented new ideas and technologies and of protecting them as a specified right. These are collectively referred to as the industrial property.

Here, the patent system intended for the protection of the right on invention of new technologies is described.

Inventors of new technologies are awarded the patent right in compensation for the publication of invention by application, and the invention is exclusively protected for a specified period (approx. 15 years after application and announcement, usually). The aim of the patent system is that the invention becomes widely known, serves to improve the people's living, promotes the development of new technologies, and contributes to the development of industries.

This system has been established based on nearly the same basic spirit in major countries of the world, and application for patents and publication of inventions of new technologies have been made in every country, asking for justified exclusive right protection.

For the invention of a new technology to be protected as the patent right, its application for a patent must be made and it must be examined in countries from which we desire protection. Therefore, the application of inventions by SWCC for patents have to be made in countries from which we desire protection as the patent right, not to mention in Saudi Arabia, according to their application procedures.

For desalination facilities, to prevent new technological inventions from being used without permission, we must make application to countries in which desalination facilities are manufactured or there is a high possibility of installing facilities. The aim of the patent system is to justly evaluate such efforts for inventions of new technologies and to protect as the right which allows to use the results preferentially.

The patents applied for in countries of the world at present are the ones asking for this justified right protection.

(2) Utilization as Information Source of Research and Development

With increasing invention and development on industrial technologies, and intensified technological development competition, enormous applications for patents are made in countries of the world asking for justified right protection.

Databases for such patent information are DIALOG of the United States and PATOLIS of Japan, as described above. By analyzing the fields and contents of patents applied for with these databases, we can know the fields and contents of new technologies on which invention or research and development is conducted in the world.

In advancing research and development, it is necessary to avoid the research and development of new technologies by means of methods overlapping with preceding technologies or to advance research and development by means of methods superior to those, by analyzing the tendency of such patent application all over the world using patent information databases in the world.

Because the patent information databases contain quite microscopic information from a technical viewpoint in their nature, the direction and theme of research and development can be selected more accurately both from a microscopic and macroscopic viewpoint, by using databases for science and technology documental information having the nature as macroscopic information together. Such a way is another important use of the patent related system.

1.7 Maintenance and Control of Research Facilities and Equipment

The maintenance and control of plants, research facilities and equipment are classified under the following three categories.

(1) Check and inspection at startup and shutdown
(2) Maintenance, inspection and tests during operation and cessation of operation.
(3) Abnormality (Trouble)

1.7.1 Check and Inspection at Startup and Shutdown

Normally, check and inspection items are predicted expressly in the operation manual prepared by the engineering company that designed and/or constructed the plants or facilities or by the manufacturer of the equipment.

Procedures for operation such as warming-up and adjustment during switching-on of the equipment, and during running of the equipment, must be carried out in accordance with the instruction manual presented by the manufacturer of the equipment. On the other hand, general maintenance, adjustment, test and inspection, etc. of apparatus are standardized by ASTM or JIS. The user of the equipment must comply responsibly with the manufacturer's manual or standards.

1.7.2 Check and Test

Check and test are carried out in order to maintain the facilities and equipment in a condition conducive to operation whether they are running or not, and to prevent troubles and faults arising.

There are items which must be checked daily and tested or inspected periodically; e.g. weekly, monthly, or yearly, etc. Inspection is carried out to check if there are any abnormalities, and tested to check performance.

Visual observation is a method to detect any looseness, damage, crack, deformation, discoloring, fouling, corrosion, unusual vibration, or overheating. It is known from experience that following daily sensuous checking:

* Visual observation
* Listening to the mechanical sound carefully
* Checking the temperature by touch (or reading the thermometer)
* Checking mechanical vibration by placing a driver on the equipment
* Detection of an unusual odor

They are very effective for the detection of abnormal conditions. In many cases the fatigue of bearings or the dislocation of shafts were detected at an early stage by the above visual observation, and serious difficulties were prevented by fastening or replacing glands and packings, or by replacing machines.

Machine items are periodically inspected to ensure that performance is maintained; e.g. by testing of insulation resistance, pressure and oxidized degree of the insulating oil, rate voltage, etc. for the transformers and the checking performance voltage and current/calibration for other instruments.

If there is any reference to maintenance and inspection in the instruction manual produced by the manufacturer of equipment, conform to the instructions given.

Generally, when equipment and apparatus are not used for a long time, performance is reduced and they are more susceptible to faults. It is therefore recommended that equipments or apparatuses are made to run every 6 months to test the standard substance or to carry on the blank test. The manual related to such measurement and record keeping will ensure as part of normal maintenance and control procedures.

It is thus desirable to establish a consistent maintenance and control system; to list up maintenance and inspection items, to produce a manual on maintenance and inspection of each facility and equipment depending on the circumstances of each research center, to organize an administration system to identify and clarify areas of responsibility, and to keep detailed records.

1.7.3 Reparation

When the detection of abnormalities is not immediate, or when problems arise even after the necessary measures have been taken, normal operation must be restored swiftly. Some repairs can be easily completed by the user but other repairs must be referred to the manufacturer of the equipment or apparatus or to a repair specialist.

With the advancement of technologies and improvement of quality control in the manufacturing process, the equipment and apparatuses manufactured recently in Japan have exhibited high accuracy, high performance and durability. To maintain accuracy and performance, equipment utilizing monoblock in which mechanical parts and electric systems cannot be overhauled, prevails. Users cannot inspect or repair the internal part of the monoblock, and this structure is consequently called "a black box". Generally, a block must be replaced when problems arise because if the user overhauls the "black box", the manufacturer does not guarantee the performance of the equipment.

The capacity of the microcomputer is being increased for further convenience; adjustment, compensation and calibration of equipment so far carried out manually are now automatized, and data processing functions such as complicated calculation, diagraming, and substance fitting are being incorporated. Most equipment requires only the insertion of the sample and a certain operation to print out the data needed.

To advance performance and functions further, models are being changed frequently, and, as a result, the number of parts which must be stored is vast. That and the fact that the performance of some of the parts deteriorates when stored for a long time, make it difficult to obtain parts for old models of equipment and apparatus although it is obligatory by law to store major parts for a certain period of time.

Users used to store spare parts susceptible to breakage and study the hardware structure so that they were able to repair or mend equipment, and now however it has become difficult to do so. One of the reasons is that the parts susceptible to breakage have been improved by the manufacturer successively, and it has become difficult to predict the parts which could cause difficulties.

Electrodes, light sources, and x-ray tubes and bulbs are consumables and they have to be replaced periodically.

Occasionally equipment faults are connected to the installation environment. Affects of severe conditions are often referred to during installation of sophisticated equipment and apparatus, but when they are used under environmental conditions which manufacturers cannot foresee or when they are used for 3 or 4 years, problems have a tendency to occur.

When a problem arises, the person in charge of the maintenance and control of equipment and apparatuses must check with the "fault detection flow chart" in the instruction manual pro-

vided by the manufacturer. If it is impossible to restore to normal operation, the manufacturer or the agency are contacted by phone or facsimile, and the user follow their instruction. If necessary, the user purchases and replaces the part. When the replacement has proved to be ineffective, the user must ask the manufacturer to repair the equipment. These are the measures usually taken for reparation in Japan.

In such cases, the superintendent of maintenance and administration judges whether the request for the repair is appropriate or not, and makes a recommendation.

1.7.4 PM (Preliminary Maintenance)

In order to avoid the inconvenience caused by the shutdown of equipment and apparatuses up to the completion of the repair by the manufacturer, most of the national research institutes in Japan have an annual contract with manufacturers and maintenance experts and expects them to carry out periodical inspections and repairs to ensure that the equipment always runs normally. This type of contract is usually used for equipment of more than 5 million yen, and the annual cost is estimated to be about 10 % of the purchase price.

If the facilities and equipment are not made in Japan, and the delivery agent is not in Japan either, it is difficult to contact the manufacturer or the agent by phone when difficulties occur and consequently repairs take a long time and the equipment is left unused. It is therefore advisable to have an annual maintenance contract with the delivery agent or the manufacturer at the time of purchase in such a case.

It is necessary to appropriate about 2 – 3% of the overall budget for the operation of research centers for the maintenance and control of facilities and equipment, including the cost for replenishing the parts in normal service such as pipes, bulbs, and packings; electric cables, cords, plug sockets, switches and fuses, etc.

Chapter 2. Transfer of Technology

2.1 Introductory Remark

2.1.1 Background

Research activities of SWCC research center are supervised by Mr. Al-Azzaz, General Director of Research and Technical Affairs of SWCC Headquarters and carried out by foreign researches with doctorate and Saudi researchers(experience: 3 to 5 years). In this chapter, the training program and results for technology transfer to the Saudi researchers were summarized.

2.1.2 Present Status of Saudi Researchers

Research activities are mainly carried out by foreign researchers whose nationalities are Indian, American, and Canadian. These activities are in the fields of heat transfer, chemical analysis and corrosion control. The results of the research have been somewhat publicized in the related academic societies, and most Saudi researchers are assisting the foreign researchers and gaining experience.

It was observed that the following skills of the Saudi researchers needed to be developed.

(1) Literature investigation, especially, literature retrieval ability by means of data base.
(2) Ability to draw up a research planning
(3) Ability to draw up an experimental planning
(4) Experimental technique and ability to develop them
(5) Analytical ability of experimental data
(6) Ability of report writing

2.1.3 Method of Transfer of Technology

From the present status of research abilities as above-mentioned, the JICA team adopted the following methods.

(1) Lectures for the retrieval technique and OJT to improve literature retrieval ability.
(2) Related literature investigation, lectures of basic concepts of related specialized fields and cooperative studies of execution planning to improve ability to make a research planning.
(3) Cooperative studies of experimental programs and introduction of related experimental technique to improve ability to make experimental planning.
(4) Cooperative work to improve experimental technique
(5) Cooperative work to improve analytical ability of experimental data.
(6) Correction of reports to improve report writing technique.

2.1.4 Result of Training

(1) A short literature retrieval course was held to promote an understanding for the effectiveness and importance of literature retrieval with data base. The report completed in the course may be used as valuable guidance for the execution of research to Saudi researchers. For foreign researchers it may also be used as a valuable reference for planning research and finding themes of research because there has been no overall technical information regarding sea-water desalination technology at SWCC until now.

(2) For preparation of research planning, they have gained ability of planning with advice to some extent. A researcher proposed a new theme of research by himself, which showed a result of the training.

(3) For preparation of the experimental program, principal techniques have been obtained through research meetings.

(4) For experimental technique, reliable data has been obtained through cooperative working by advice.

(5) For abilities to analyze experimental data, analysis in line with the object has been understood through cooperative work by advice.

(6) Part of a report was prepared by the researchers and corrected as necessary to improve their report writing ability.

The Saudi researchers had already mastered fundamental technique before the training program started. Therefore, their ability of research developed fairly through the joint research activity. However, the items described in from (1) to (6) are ability to be obtained through long year's experience. Accordingly sufficient results may not be obtained by such short training courses. Therefore, it is highly recommendable that SWCC prepare and promote intensive and continuous curriculum for the Saudi researchers on the basis of content of technology transfer.

2.2 Targets, Procedures and Results for Each Themes

The targets, procedures and results in transfer of technology to the young Saudi scientists and engineers are reviewed by both JICA and SWCC and summarized below.

2.2.1 M-1 Laboratory Experiment on Scale Prevention

(1) Targets

1) Basic concept on the effect of preventing scaling by the C.D. Method when seawater contam-

inated with crude oil is used as raw seawater.

2) Experimental method to expose and solve problems in order to improve the operating efficiency of the plants which use the chemical dosing method.
3) The planning method of experiments and improvement of technology related to experimental techniques.
4) Ability for analysis of obtained experimental data.

(2) Procedures

1) Analysis of the data obtained from the main experiment was carried out by JICA researchers together with Saudi Arabia's project team and opportunity for through discussion were constantly arranged (refer to APPENDIX M1-3-2 to -3-7).
2) Survey research was also carried out by the Saudi Arabian team who took responsibility in dealing with the essential points. From these results, it became possible to find the advantages and disadvantages of the C.D. Method based on objectives and counter measures. (refer to APPENDIX M1-3-7)
3) Experimental techniques were mutually agreed upon with SWCC team before conducting the main experiments. (APPENDIX M1-3-1 and -3-2)
4) Similar to the techniques in (1).

(3) Results

1) Experimental data on distillation where oil is present in seawater could be of use to improve operational practices in the MSF plants at Al-Jubail and other locations in Saudi Arabia. The experiment itself seemed to be of great interest to our counterparts. Technological evaluation of experimental apparatuses have been planned jointly by SWCC and JICA. Also recommendations for future research have been pointed out and discussed by the JICA team and SWCC.

2) Continuous discussions between SWCC staff and JICA team throughout the courses of planning and actual implementation of the experiment and also during drafting of the report have been very constructive and mutually beneficial. It is believed that the main targets of this experiment have been achieved.

2.2.2 M-2 Corrosion Tendencies for Some Kind of Materials

(1) Targets

1) Information of the general trends for anti-corrosive materials used in MSF plants and related anti-corrosion technology.
2) Research and development topics for related anti-corrosive materials used in MSF plants and related anti-corrosion technology that should be used by SWCC from now on.
3) Techniques to search references in DIALOG.

(2) Procedures

1) SWCC took responsibility for the search of references in DIALOG and for the determination of main points. The general trends of anti-corrosion technology were summarized by combining this result with those in DIALOG and JOIS surveyed in Japan.
2) Similar techniques to those used in (1) in the Targets.
3) Similar techniques to those used in (1) in the Targets.

(3) Results

1) An evaluation of corrosion resistance of the following materials for MSF, and, a recommendation for future research, have been presented to SWCC.

    * Copper alloys
    * Titanium and titanium alloys
    * Aluminum alloys
    * Stainless steels
    * Non-metallic materials

2) The literature survey carried out on the above mentioned materials through DIALOG and JOIS is an excellent collection of references. It is commendable job and SWCC will be most benefited due to its use in future research on corrosion.

2.2.3 M-3 Study on Some Materials by Corrosion Measurement Apparatus

(1) Targets

1) Information of the general trends for experimental equipment to evaluate anti-corrosive properties of materials used in the MSF seawater desalination plant.

2) Research and development topics for the experimental equipment to evaluate anti-corrosive properties of materials that should be considered by SWCC from now on.
3) Techniques to search references in DIALOG.

(2) Procedures

1) SWCC took some responsibility for the research of references in DIALOG and for the determination of main points. The general trends of anticorrosion technology were summarized by combining this result with those in DIALOG and JOIS surveyed in Japan.
2) Similar techniques to those used in 1) in the Targets.
3) Similar techniques to those used in 1) in the Targets.

(3) Results

1) An evaluation of the effectiveness of corrosion measurement equipment (some of which are shown below) for MSF maintenance, has been presented to SWCC.

    * Laboratory scale equipment
    * Corrosion monitoring equipment
    * Pilot plant scale equipment

2) The planning of such corrosion /scaling testing facilities needed (in the near future) if SWCC undertakes experimental research in the field of corrosion protection, has also been carried out .

3) It is one of the best evaluation and presentation of the techniques in seawater corrosion research. This information will be applied in experiments carried out under laboratory and MSF plant simulated conditions.

2.2.4 M-4 Analysis of Oil Dispersed in Raw Seawater at the Heat Rejection Section of MSF Plant

(1) Targets

1) Basic ideas which take account of the mixing of the crude oil with seawater for the design of plans for plants.

2) The technology of experimental techniques and the design of the experiments.
3) The ability to analyze the experiments.

(2) Procedures

1) The results obtained from the main experiment together with the Saudi Arabian team were analyzed and a report was prepared. Opportunities for thorough discussion were constantly arranged.
2) Similar to techniques used in (1) in the target.
3) Experimental techniques were transferred most effectively and expediently by conducting the main experiment jointly with the Saudi Arabian team.

(3) Results

1) This collaborative study is considered to have contributed in the development of SWCC's research in physico chemical and chemical engineering.
2) A laboratory experimental set up was assembled to simulate the MSF process. This equipment was very helpful in studying the carryover of oil from seawater to distillates. The results obtained were in good agreement with the theoretical calculations carried out by JICA team.

2.2.5 R-1 Sterilization

(1) Targets

1) Prospect of technological advance on optimum sterilization.
2) Technique of cost evaluation for sterilization.
3) Proposal of development subjects related to sterilization.

(2) Procedures

1) Literature retrieval and evaluation of the materials were conducted in collaboration with S.A. researchers.
2) Cost evaluation and development subjects of (1) in the previous section.
3) Using JOIS, STN, DIALOG (Japanese team) and NRS (Saudi team)

(3) Results

1) Together with evaluations on the efficiency of the following sterilization methods for RO desalination plants' feed seawater, technological research about conventional methods and their future development, has been presented to SWCC.

* Sterilization by chlorine gas
* Sterilization by ultraviolet ray application
* Sterilization by copper sulfate
* Sterilization by SBS (sodium sulfate)

2) Information was collected (retrieved) on the above sterilization techniques employed in the sterilization of feed to the seawater RO plant and documented from page 4.3.1 of the Final Report, Vol. 1. The information should serve as a good reference on the sterilization of feed to the seawater RO plant.

* A training of young Saudi (of an average of 3 years experience) on retrieval of information was accomplished.
* The work led to the possibility of utilizing new, more safe sterilization technique, e.g. ClO_2 and chloramine.

2.2.6 R-2 Pretreatment of Seawater

(1) Targets

1) Retrieval technology using several data-bases.
2) The measuring technology of oil in seawater by the fluoro-chloro-carbon solvent extraction method (FCC-IR).
3) The measuring technology of oil particle diameter by the flash freeze fixing method.
4) Determination and sensitivity of IR spectroscopy in determining low oil concentration in seawater
5) Evaluation of effect of coagulation, using various coagulant on oil removal from oil contaminated seawater

(2) Procedures

1) Information Retrieval

* Information retrieval on pretreatment of oil contaminated seawater was carried out in cooperation with JICA and SWCC researchers.
* A lecture was given to SWCC researchers on fundamental techniques such as selection of databases, selection of database keywords and formation of information retrieval formulas.

2) Analytical techniques of oil concentration in oil contaminated seawater such as oil meter calibration and determination of the lowest detectable level of oil concentration on the oil meter, were established.
3) Oil particle diameter measuring techniques using microscopic photographs were taught by OJT.
4) Oil determination in oil contaminated seawater

(3) Results

1) Information retrieval has not yet been used in SWCC, however , after introducing databases such as DIALOG, STN, NRS, and how to use them to retrieve information on the pretreatment of oil contaminated seawater, SWCC is now able to use the information retrieval system by the above retrieval methods.
2) Necessary basic technology on the determination of oil concentration and particle diameter were transferred to the Saudi side.
3) This technology will contribute to the improvement of research on the pretreatment of oil contaminated seawater and on the removal of oil from oil contaminated seawater. Moreover, it was found that ferric chloride added at low concentration (3 mg/l) was an effective coagulant in the removal of oil from the seawater feed after filtration. This new information can be utilized by both sides in the pretreatment of seawater contaminated with oil.
4) The jar test technique which was used during this experiment is known to the young Saudi scientist. The jar test is a preliminary and a quick method for the evaluation of the pretreatment of oil contaminated seawater.

2.2.7 R-3 Pollution Effect of Membrane Cleaning Discharge

(1) Targets

1) Waste water disposal system for membrane cleaning and membrane preservation solution.
2) Information for construction and operation costs for waste water treatment system.
3) Information for operation and maintenance.
4) Waste water treatment system in Japan.
5) Optimization of the waste water treatment system to Saudi Arabian environment.

(2) Procedures

1) Information retrieval work for literature
2) Evaluation of the collected materials

(3) Results

1) With regard to waste water treatment for RO desalination, investigation on the present state of membrane and plant manufacturing technology and how to coexist with national operating regulations in Japan, has been carried out. From this study, recommendations for future research in cases where desalination plants may be installed along the coast of partly enclosed water bodies such as the Red Sea, the Arabian Gulf etc., have been presented to SWCC.
2) Document covering the subject was produced from the retrieved literature (see Draft Report pages 4-1 to 4-232).
3) Information was also collected by SWCC on the frequency of cleaning of the six SWCC SWRO plants. Because of the low frequency of membrane cleaning average once per year, the effect of dumping the cleaning reagent has a minimum damaging effect on the environment.

2.2.8 R-4 Selection of Membranes

(1) Targets

1) State of the art RO membranes for seawater desalination technology.
2) Information on RO membranes, suitable for the local conditions of Saudi Arabia.

(2) Procedures

1) Information retrieval work for literature and patents was carried out jointly by Saudi Arabian and Japanese researchers.
2) Collected information was jointly classified and investigated by Saudi Arabian and Japanese researcher.

(3) Results

1) By comparing the characteristics and performances of several kinds of RO membranes in use at present, the most suitable RO membrane for desalination in the Saudi Arabian situation has been identified by SWCC-JICA joint team and reported to SWCC.
2) At the present, the thin film, composite membrane may be considered as the best performing membrane in seawater RO desalination.

3) Document covering this subject from the retrieved literature was produced. (see Final Report pages 4.5.1 to 4.5.69)
4) As in other previous cases R-1, R-2 and R-3, the document should serve as a good reference on the above topic.

2.2.9 R-5 Chemical Cleaning of the Fouled Module

(1) Targets

1) The method for investigation of the cause of membrane degradation.
2) The removal methods of fouling matter on membrane.
3) The evaluation methods for effect of the removal process of fouling matter on membrane.

(2) Procedures

1) Survey of literature and patent information through joint research.
2) Investigation and classification of the collected information through joint research.

(3) Results

1) One reason for the decline of RO membrane performance in the desalination plants may be the influence of foulants. Therefore, research on membrane cleaning techniques has been carried out. A basic flow diagram of such a pilot plant which investigates the cause of fouling has been presented to SWCC.
2) Only limited information was available on membrane cleaning, mostly supplied by membrane manufacturers including the Japanese companies.
3) Document covering the subject was produced(see Final Report, Vol.1, pages 4.6.1 to 4.6.23).
4) Membrane cleaning technology is not highly developed and greater efforts are required to establish the best and most suitable cleaning method for the cleaning of fouled membrane.
5) For proper cleaning of fouled membrane, analyses must be made of the foulants collected from the membrane and the membrane itself using the best available analytical techniques.

2.2.10 R-6 Selection of Membrane for Hybrid RO Process

(1) Targets

1) Evaluation methods of the RO performance by flat membranes.

2) Methods for analyzing fouling membranes.
3) Optimal RO membrane specifications for the hybrid RO method and acquisition of information on other required items.

(2) Procedures

1) Organization of literature was conducted jointly by researchers from Japan and Saudi Arabia.
2) Collected information was organized and studied. (refer to Final Report Vol. 2, Appendix R6-1 to R6-4)

(3) Results

1) Evaluation of six different types of membranes of Japanese make for use in hybrid plants was made using a flat sheet membrane test unit. The two membranes UTC80HF and NRT759HR are found to be the best candidate for the purpose i.e. use in hybrid plant.
2) Document was produced which include experimental work and literature search. (see Final Report Vol. 1, pages 3.4.1 to 3.4.18)
3) Training of Saudi scientists on membrane evaluation and methodology was also accomplished.
4) More effective and suitable research information material for process development in future test plants was found to be necessary.

2.2.11 R-7 Standardization of the Main Analytical Methods

(1) Targets

1) Literature search for standard method of analysis
    * Seawater (feed, product and reject)
    * Waste water treatment processes
    * Membranes
    * Foulants
    * Bacterial count

2) Method for analyzing fouling of membranes
3) Methods of data analysis

(2) Procedures

1) Literature retrieval for standard methods of analysis
2) Literature retrieval related to waste water treatment
3) Techniques for data analysis and equipment analysis
4) Evaluation of the related information

(3) Results

1) By examining literature on the standard analysis method, information was selected regarding the method of chemical analysis for water and other substances in each process of the RO desalination system. (refer to p.4.7.5–20 in the Final Report Vol.1)
2) Sophisticated apparatuses for analysis in relation to membrane fouling have been used. There was no patent information, but some literature. (refer to p.4.7.21–34 in the Final Report Vol.1)
3) From a literature survey, routine practices concerning analytical measurement and data analysis in research institutes were recommended.
4) The literature survey was carried out in order to find analysis elements necessary for operation practices in waste water treatment units. The survey gave an instance of activated sludge treatment for organic waste water.
5) Document was produced on the above topic. (see pages 4.7.47 – 56 in the Final Report Vol. 1)
6) Analysis of seawater, permeate and reject and also in particular, the analysis of fouled membranes e.g. use of EPMA in the analysis of fouled membrane.

2.2.12 Information Retrieval

(1) Targets

1) To collect, analyze and edit the document information on desalination by the MSF and processes for the projects described later under M–1, M–2, M–3, M–4, R–1, R–2, R–3, R–4, R–5, R–6 and R–7.

(2) Procedures

1) Four sources of data information were researched.
    * JOIS
    * DIALOG
    * STN
    * NRS

2) In addition, information available from JICA, SWCC and some Japanese desalination companies were also collected and included in the documents.

(3) Results

1) Based on experimental research work and literature survey work, three documents were prepared.

a) Summary of Final Report
b) Final Report Vol. 1 (Main Report)
c) Final Report Vol. 2 (Appendix)

2.3 SWCC's General Comments on Transfer of Technology

The following are the SWCC's general comments on the transfer of technology.

(1) The training of young Saudi scientists and engineers, each with an average experience of 3 years, on the methodology of conducting R&D work in the field of seawater desalination by the MSF and SWRO processes was conducted.

(2) The extensive survey of literature on desalination for the last two decades was conducted utilizing various data bases: JOIS(Japan), DIALOG(U.S.A), STN(German) and NRS(Saudi) in retrieving the information. Information also was collected from both makers and users of RO membranes in Japan and Saudi Arabia. Information retrieval was done for both the four experimental research projects(M1, M2, R2 &R6) and the seven literature survey projects (M2, M3, R1, R3, R4, R5, and R6).

(3) The retrieved information was documented in a detailed and a summary texts which also included the detail and the finding of the experimental part of this joint program. The contents of both the draft detailed and summary texts are up-to-date and reflect the amount of work put by the two parties into this joint program. These documents should serve as an excellent reference in the desalination field for both Saudi and Japanese researchers. Moreover, once the documents are cleared for public use, it shall also serve as an excellent reference worldwide for other researchers engaged in the desalination field.

(4) As a result of the experimental part of this joint program new technical information was

generated which was not known earlier. The results are valuable and could contribute to an improvement in the operation and performance of desalination plants.

(5) Technology can be transferred from a technologically more advanced society, organization, such as Saudi scientists and engineers by the more experienced Japanese counterparts falls in this category. On the other hand, technology transfer can also be done by the exchange of technology and know-how between two equally technologically advanced parties. This is being witnessed on almost daily basis among giant, technically advanced Japanese and Western firms with sophisticated, state-of the-art high technology. The cooperative work and the exchange of know-how is mutually beneficial to both parties, JICA and SWCC. Additionally, this cooperation is also beneficial to the entire desalination community.