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9. ABSTRACT

The three papers presented in this report were prepared for a symposium on "Priorities on Innovating and Adapting Technologies for Asian Development". The scope of the papers was extended to include Africa and Latin America as well as Asia. The first paper, "The Role of the Research Institute in Industrial Growth", is based on observations during a one-year analysis of industrial research institutes in developing countries. The second paper describes "Research Interests of Foreign Assistance Agencies Concerning Appropriate Technology" by drawing on information acquired in a wide variety of forums. Although it is not intended to be complete in its coverage, most of the current activities of significant magnitude are discussed, with the exception of activities in the Peoples' Republic of China, the USSR, and Eastern Europe. The third paper addresses "Multi-national Corporations and Adaptive Research of Developing Countries". It examines selected types of activities of multi-national corporations as illustrative of their involvement and interest in the technological development of developing countries.

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APPROPRIATE TECHNOLOGIES
for
INTERNATIONAL DEVELOPMENT

Preliminary Survey of Research Activities

September 1972

Office of Science and Technology
Agency for International Development
Washington, D. C.

PREFACE

The three papers presented in this Report were prepared for a symposium on "Priorities on Innovating and Adapting Technologies for Asian Development" held at Princeton University, September 20-23, 1972. At the request of the conveners of the symposium, the scope of the papers was extended to include Africa and Latin America as well as Asia. The presentations contain considerable unpublished material collected during the past two years in the course of visits to developing countries, in discussions with individual experts in the field, and in consultations with representatives of organizations actively engaged in adapting technology to the conditions of developing countries.

The first paper on "The Role of the Research Institute in Industrial Growth" was prepared by James Blackledge, Associate Director, Denver Research Institute. It is based on his observations during a one-year analysis of industrial research institutes in developing countries carried out for the Office of Science and Technology. The material will also be included in a much broader report of his findings which is currently in preparation.

The second paper describing "Research Interests of Foreign Assistance Agencies Concerning Appropriate Technology" draws on information acquired by the Office staff at a wide variety of forums. While the discussion is not intended to be all inclusive in its coverage, most of the current activities of significant magnitude are described, with the possible exception of the activities of Mainland China, the USSR, and the countries of Eastern Europe.

The third paper addresses "Multinational Corporations and Adaptive Research for Developing Countries." This presentation is an attempt to describe selected types of activities of multinational corporations as illustrative of their involvement and interest in technological development of developing countries. The paper was prepared by Daniel Margolies, a Consultant to the Office. He drew heavily on current work of the National Academy of Sciences and National Academy of Engineering, as well as on discussions with a wide variety of specialists in the field. The assistance of the staffs and panels of the Academies, in particular, is gratefully acknowledged.

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THE ROLE OF THE RESEARCH INSTITUTE IN INDUSTRIAL GROWTH

Introduction

This paper is part of a more comprehensive document in preparation which will report on the first half of a two-year comparative analysis of selected industrial research centers in the developing countries. The objectives of the study are to:

- Analyze a variety of approaches to industrial research which have been tried;
- Identify those factors which have contributed to or inhibited effective coupling of industrial research institutes with industry and developmental interests;
- Differentiate between those types of constraints to development of viable institutes which are country specific and those common problems which have limited the value of these institutes regardless of their geographical location.

During the course of the study to date, some 50 research centers in 13 developing countries have been visited. Selection for on-site visitation was based on prior knowledge as well as available information regarding these centers and was particularly influenced by representative differences in modes of origin and financial support and in levels of country technological capability. Since it is impossible to evaluate an institute without examining its interrelated microcosm, representatives of development banks, government ministries, chambers of industries, universities, etc., were interviewed to the extent possible. During the second year of the study, additional research centers will be visited, and information regarding these will be added to the model matrix.

The Environment for Technological Research

The industrial research institutes and applied research centers in developing countries are expected to be aggressive interpreters and adaptors of technology needed for industrial development. These centers are expected to establish and maintain an institutional capacity to undertake a wide variety of technical

problem-solving which may or may not materialize and the costs for which may be, at best, only partially recovered. The staff of these institutes is expected to be adept at identifying and anticipating industrial technological needs, although they seldom have practical experience in such program development activities. Further, the institutes and research centers are usually unprepared to evaluate and assess those cultural, societal, economic, and political factors which are a necessary part of the technology transfer process.

In the face of the above, the research institutes must operate within a microcosmic array that is frequently reluctant to sustain R&D and generally indifferent to or unaware of the contributions that appropriate adaptive research and experimental technology could make to industrial growth. The government planning agencies and public enterprises, the development banks, and the industrial sector profess to recognize the importance of applied research and technological development, but unfortunately do not always include the research centers in their planning processes, nor do the governments always develop incentive programs for stimulation of industrial development which encourage partnership with the industrial research institute or research center.

Multi-national companies in a developing country seldom seek applied research or problem-solving assistance, preferring to send such problems to home base laboratories. These do, however, utilize a variety of local suppliers of materials, parts, etc., who may be potential buyers of technical assistance.

National large and medium industries represent a potential for exploitation; however, their attitude toward applied research and development assistance from indigenous industrial research institutes can be generalized as follows:

Industry lacks confidence in the ability of research institutes to provide meaningful solutions to their problems in a reasonable time and at a realistic cost;

Industry (and government enterprise) believes that it should not pay for the services provided by a research institute, since such institutes are largely subsidized by government funds derived from industrial taxes;

Industry usually is wary of the research institute-government relationship which could result in disclosure of potential patent possibilities, technical secrets, or management information to government agencies or competitors;

Industry does not often evidence a genuine interest in the research results of an institute until these have been carried through a pilot or demonstration plant phase, and production, economic and marketing feasibility have been resolved.

Small-scale industry usually does not have the management know-how to recognize technical problems nor how to seek assistance for the solutions to these. Who knows what to do about interaction with small-scale industry?

Research institutes in developing countries:

Suffer from a shortage of modern research institute management skills;

Seldom have programs of planning for the future;

Urgently need programs of promotion and program development;

Lack internal project evaluation and fiscal controls;

Have limited experience in acquisition and diffusion of available foreign technology; and

Need to develop appropriate mechanisms for technical assistance to medium and small industry.

A plethora of papers, documents, reports, etc., in the world body of literature gives advice to the research institute director and his staff on the "how to do it" of logical planning for successful interaction with the clients these people are supposed to serve. As mentioned above, the institutes are expected to provide broad gage services and expertise to be utilized on an "on call" basis. Somehow the thought persists that, if the service is available, clients will clamor for help and assistance <u>and</u> pay the bill! But in actual practice, the institute

director and his staff become soldiers of fortune who seek funding support from whatever source available, thus resulting in a mismatch between staff capability and contracted service needs. And, the evidence shows that these research institute people are not getting too much help from experts and institutes from the developed countries on "how to solve such problems."

There is little incentive for most research institutes to actively seek contract research support. Money and fees from contract research, royalty and other income-generating activities, in many instances, legally revert to the Government Treasury and are not under the control and management of the institute director for budget augmentation, institute building and growth. Such income often may cause a reduction of the government subsidy. The implications of such an operational constraint are obvious. The research institutes tend to engage in programs which have no real relevance to industry needs or problems or to the national plan. The research staff, with no real motivation and incentive, leans toward replication of the research of their graduate school days, or seeks the great breakthrough in single-cell protein, cancer chemotherapy, solar energy, or yet another use for bagasse. Interaction with industry and government enterprises is limited and infrequent. The research institute subverts what should be a prime role in the national development plan.

The developing countries suffer from an acute shortage of scientists and engineers suitably trained for problem-solving to meet the needs of the industrial sector. Experienced staff is difficult to recruit and hard to retain. University programs, locally as well as those in developed countries, are seldom directed toward preparation of graduates qualified for and interested in application of technology to industry's problems and to creation of new commercial processes. Close collaboration should take place between the universities and the research institutes--mutually attractive because of shared facilities and staff and production of graduates attuned to the national need and as potential employees for the institutes. Such interaction seldom exists except on an ad hoc and usually unproductive basis.

Most young research institute staff members are interested in trying to solve the problems confronting their nation but they don't know how to go about it.

This then is the environment in which technological institutes are expected to exert an influence on the industrialization process in the developing countries. It is no wonder that within this complex and non-communicatory environment, the results of research and development have been disappointing indeed.

The World Plan of Action projects the need for an average 15 percent per annum growth rate in developing country research and development expenditures during the decade of the seventies, with significant increases, as well, in expenditures by developed countries for developing country-related problems.1/ But, within the context of the above, it must be seen that increased expenditures alone are not going to solve the problem. Drastically new and innovative approaches must be devised--for training, for problem identification, for innovation and incentives for the use and application of R&D, for means of effective interaction between the government planning bodies, the industrial sector, the universities, the industrial research institutes and related segments of the developed countries. In the absence of new, bold and imaginative thinking about such problems, ten years from now the statement well may still be made: "It is estimated that less than one percent of Pakistan's industrial (development) program has been based on the technological research carried out under the auspices of the Council for Scientific and Industrial Research."2/

Approaches to Stimulation of Technological Research

As discussed above, the application of R&D to industrial growth requires inputs from the public and private sectors as well as from the applied research centers. A variety of approaches are being used in an attempt to overcome existing constraints and deterrents. A few examples are included here which perhaps may be useful as models.

The Minister of Science and Technology, formerly President, Korea Institute of Science and Technology (KIST), has created a Science Promotion Foundation of

1/ World Plan of Action for the Application of Science and Technology to Development, United Nations Document E.71.11.A.18, New York, 1971, pp. 56-57.

2/ Ibid, p. 177.

28 members, one-half from business and industry, one-half from the nation's scientists and engineers who meet each month to develop strategies for utilization of science and technology in industrial development. Under a new Ministry policy of providing matching funds for R&D, approximately 15 companies have approached KIST for technical assistance. To date, this fund-matching appears to be lopsided, with the Korean Government providing up to 90 percent of the total costs. Corporations or individuals who support contract research at KIST are given income tax exemptions up to the amount of the contract value.

The Ministry is currently contemplating establishment of an "imported technology" tax for support of development with, however, tax incentives to industry to compensate for the cost of importing technology, or alternatively, to stimulate development of indigenous technology. Other tax benefits will be provided for product improvement, etc., through the technology transfer process. KIST will be an active partner in such programs, either as an evaluator of the cost effectiveness, applicability to local conditions, or need for additional adaptive R&D, or as originator of new technology to meet the needs of industry.

The Government of Argentina has recently instituted a new development policy designed to reduce dependence of local industry on imported technology and to stimulate development of indigenous technology. Under the law, all present and future licensing arrangements which involve importation of technology must be registered with the government (this could lead to undesirable controls or constraints). Such licensing agreements will be required to meet certain criteria:

- The technology is appropriate and suitable for utilization in Argentina;
- The licensee is paying a fair price;
- There are acceptable or no restrictions on the licensees' market; and
- The licensing fee is based on profits instead of total sales.

The Instituto Nacional de Tecnologia Industrial (INTI) is responsible for administration of this program and thus will have opportunities for more frequent involvement with the industrial sector.

INTI financing includes, in addition to contracts and contributions, 0.25 percent of the value of all industrial loans granted to industry by the Bank of the Nation and the National Development Bank.

The National Council for Scientific and Technological Investigations (CONICYT) is responsible for the promotion of science and its relationship to technology, but unfortunately, less than three percent of CONICYT's funds support applied research and technology projects. Their hope is to move in the direction of increased technology support, but without reducing the existing science programs. CONICYT support is seldom obtained by staff of Argentina's industrial research centers and is generallly directed to individual university professors.

The Secretary of Planning for the State of Bahia, Brazil, has recently created a Council for Science and Technology which will coordinate three bodies having to do with science and technology in that state. These are: FUNTEC, a foundation for support of basic research in the state's universities and research centers; Centro de Pesquisas e Desenvolvimento (CEPED), responsible for all applied science and engineering research; and CIEB, a center for information, statistics, data analysis, etc.

The State of Bahia has imposed a "circulation of goods" tax, based on 15 percent of the wholesale value of materials produced or processed and used by another industry. Such taxes are collected by the state development bank, DESEMBANCO, which holds 60 percent of the taxes collected as a credit in the name of the taxed industry. But these credits are available for use only for development programs, such as research and development on new products, plant improvements and expansion, purchase of new equipment, etc. Irrespective of the nature of the proposed development program, DESEMBANCO has stipulated automatic, mandatory review by CEPED, thus in effect making CEPED the coordinator for technological development in Bahia. Review by CEPED may require technical evaluation, assessment of equipment or expansion desired, or may require research, economic analysis, etc., to verify the validity of the proposed development. Industry will contract directly with CEPED for such services, and on completion of the evaluation will be reimbursed by DESEMBANCO from that industry's credits. Certainly, it is clear that CEPED becomes an important partner in the development process, providing that the institute can produce. The program is too new for a meaningful analysis, but is interesting as a concept for forcing interaction between industry and the research center.

In São Paulo, the Fundação À Ampara E Pesquisas do Estado do São Paulo (FAPESP) has for several years supported research and development programs in Brazilian universities and research institutes which may be beneficial to São Paulo industry. FAPESP receives for such purposes an annual income consisting of one percent of the prior year state budget. Recently, however, FAPESP conducted an analysis of its supported research and learned that only one out of 1,000 projects funded during the past several years really had practical direction or application. Now, FAPESP is evaluating an increasing number of proposals on the basis of potential economic as well as technical considerations. While the management of FAPESP recognizes the need for continued basic research support, they are moving toward a more realistic ratio between basic and applied programs. FAPESP is fortunate in that its governing body consists of industrialists and business leaders in addition to researchers and university professors.

São Paulo state is heavily industrialized. Seventy percent of industry in Brazil is located in São Paulo; 50 percent of the GNP emanates from there. Sixty percent of the science and technology of Brazil is concentrated in São Paulo. Even so, there is a lack of articulation between the universities, the research institutes and the productive sectors which deters effective utilization of science and technology to the development effort.

The State Secretariat of Economy and Planning is responsible for the development and implementation of programs designed to assist industry in increasing its output. The Secretariat, therefore, has devised a project that seeks to link science and technology to the economic development of the state both as an important objective in its own right and as a model for the nation. Recently the Secretariat established a high level Council of Science and Technology (CET) and, amongst other purposes, charged it with responsibility for the following São Paulo Project in Science and Technology:

> "To promote the application of basic and applied scientific research and technology to the problems of Brazilian industry and agriculture;
>
> To develop the capabilities--in industry, government, universities and research institutes--for providing an increased proportion of this research and technology from Brazilian sources; and

To focus efforts for increasing capabilities in science and technology most closely on those industrial and agricultural sectors that hold promise for rapidly improving the capacities of commercial firms to compete successfully in world markets."3/

The CET and the Banco do Desenvolvimento do Estado do São Paulo (BADESP) will administer a financial incentives program of "soft" loans designed to:

Encourage industrial firms to undertake specific research and development projects, either internally or by contract to São Paulo research centers;

Aid and assist these research centers, both through the above industrial linkage and by direct financial assistance, in enhancing their capabilities to provide meaningful programs of technological research urgently needed for industrial development.

Approximately $50 (US) million in a revolving fund ($25 million as a technical assistance loan is being requested from USAID and an equivalent amount from the State of São Paulo and Government of Brazil) will undergird the project.

In concept, this is an exciting and innovative approach which clearly requires close and careful scrutiny as it proceeds, both as a model for development in Brazil and, equally important, as a model for other developing countries.

The Scientific and Technical Research Council of Turkey (TUBITAK) encourages and financially supports basic and applied research, usually undertaken by grants to individual professors in Turkish universities. Since 1964 TUBITAK has emphasized research programs related to industrial development.

TUBITAK has formed its own Marmara Research Institute in Istanbul, specifically designed to undertake applied research and development for Turkish industry in the areas of operations research and applied mathematics, process metallurgy and materials, industrial electronics and instrumentation and, at a later date, chemistry and life sciences. Marmara intends to provide a full spectrum of

3/ Private communication.

research services--analysis and testing, quality control, economic and market analysis, pilot plant operations, training, trouble-shooting, technical, extension research.

TUBITAK maintains an Industrial Relations group of several people who are in daily contact with industry throughout Turkey. This group uses a technical assistance approach; if possible, problems are solved on the spot in one or a few days' time. If it appears that the problem is more complex, the Industrial Relations group will propose the problem to one or more qualified university professors and contract with these to do the study. Industry may or may not join in financing of the project, although this is encouraged. The important point is that the TUBITAK group is seeking for problems that plague Turkish industry and then arranging for an appropriate solution to these problems. The response is rapid, since the researcher is not paid until the project is completed. Based on the experience of this Industrial Relations unit in Turkey, it is clear that an excellent model is being demonstrated--a broker to translate problems and answers to these between the industrial sector and the researchers in universities as well as research centers.

A similar industrial liaison group is the link between the Indian Council of Scientific and Industrial Research (CSIR) and Indian industry. But contacts are most often with government agencies such as the Directorate General of Technical Development, the National Research Development Corporations, the Indian Council of Science and Technology, the chambers of industry, industrial associations, etc. Direct contact is seldom made with individual companies; these are handled by CSIR laboratory staff or liaison units, the efficacy of which vary with the interest and management abilities of the laboratory director.

Institutional Innovations for Industrial Interaction

Several innovative mechanisms for increasing interaction with the industrial sector have been observed which, while dependent in part on the extent of research institute directorate autonomy, can nonetheless be utilized by other research institutes.

The Singapore Institute of Standards and Industrial Research operates in an environment where industrial unemployment is exceedingly low, and industrial development of the immediate future is expected to become increasingly skills intensive and highly sophisticated in nature.

Areas of concentration include: shipbuilding; electronics; petroleum, petro-chemicals and plastics; metal fabrication and precision engineering; food processing. Foreign industry is being sought which will provide good employment opportunities for skilled workers and a good potential for technological advancement. Philips of Holland, Plessey of the United Kingdom, and Rollei of West Germany are newcomers to Singapore.

From its inception in 1963, SISIR has had an active interaction with all segments of industrial development--the ministries, the universities, the vocational training programs, and most importantly, constant, continuous and frequent liaison with Singapore industry. The SISIR staff spends a considerable amount of effort in direct industry contacts. Routine services such as analysis and testing, quality control measurements, standards development and trouble-shooting are regarded as door-openers for a potential follow-on phase of applied research. SISIR staff who visit segments of industry is required to review contact reports from prior industry contacts and to feed potential research information to the directorate. This aggressive attitude on the part of SISIR staff and management is leading to more sophisticated testing and the initiation of considerably more applied research as Singapore industry gains confidence in SISIR and demands additional assistance for its own development; currently about 43 percent of SISIP's annual income derives from contract services to industry.

SISIR utilizes a three-year revolving fund approach as a stimulus for new areas of research involvement and thus industrial development. By agreement, up to $200,000 per year is available for such purposes from the Government. SISIR staff members, singly or in consortium with industrial representatives, make proposals to SISIR management for utilization of these funds--the amounts requested may vary from $1,000 to $200,000 over a three-year period--to support ideas which will pay off in new research programs of interest to industry. The requests for support may include prototype development, purchase of items of equipment, or employment of new staff with specialized qualifications. Irrespective of the nature of the request, the guidelines call for 25 percent return of the investment during the first year; perhaps 50 percent by the end of the second year; and full recovery by the end of the third year, except for extenuating circumstances. "Return on the investment" includes the face value of contracts or services emanating from this "seed money," use charges on equipment, royalties from patents or licenses, etc. It is expected that the

success of such a venture will lead to creation of a SISIR Development Corporation in the near future.

The important point, of course, in this tactic for promotion and program development is that all of the SISIR staff has an opportunity to express and receive financial support for their innovative ideas. They must stand the test of rigorous evaluation by their colleagues who also have new ideas and their innovations must stand the final professional test of resulting in returned income, in one form or another to the much sought after revolving fund for SISIR development.

Nearly all research in Pakistan is conducted under the umbrella of the Pakistan Council of Scientific and Industrial Research which was created in 1953 for the purpose of carrying out research in pure and applied fields relating to industrial utilization of the raw material resources of the country. The PCSIR is a heavily subsidized entity of the Pakistan Government and largely controlled by civil service regulations. Salary schedules are lower than industry and university salaries. There are few incentives which encourage ingenuity or creative thinking about the problems of the industrial sector. It is encouraging, therefore, to observe two approaches to increased interaction between industry and the research institute which are being attempted in the PCSIR research laboratories at Lahore.

The PCSIR-Lahore laboratory is located in the midst of a major concentration of industry, small and medium size, approximately 50 percent of which are multi-national firms. Production is geared to textiles, metal-mechanical, chemicals, sugar, petroleum products. Recently, as the result of aggressive promotion by the senior staff, a strong bilateral interaction has started to develop.

The industries approach the Lahore laboratory for help. The laboratory sends its staff as liaison representatives to industry. These may be engineers, scientists or economists--but they provide on the spot technical assistance and identify problems which require laboratory assistance. They have been particularly successful in technical extension efforts in glass and ceramics.

As an extension of this successful venture, an Industrial Advisory Service Group has been formed. Members pay annual subscription fees to the Lahore laboratory, according to size, nature of problems, frequency of contact, etc. In exchange, the members receive free advice and on the spot technical assistance, but agree to an additional charge if the laboratory does

any further work or details a staff member to that industry for in-plant service.

The laboratory and industry jointly establish committees to evaluate excess or wasted industrial production, identify the problems, and recommend solutions. The laboratory then conducts research to solve the problem and/or develop the process which is passed on to industry for utilization.

Industry is beginning to pay for part of such costs of development but at a slow rate. The mechanism in use at the present time specifies that interested industry pay a fixed amount for the research to be conducted and on a no-guarantee basis. If the research is unsuccessful, either for technical or economic reasons, the industry loses its investment; if successful, the laboratory and the industry negotiate a settlement for the total costs. This has been a successful approach to date, except for the low cost-share usually accepted by industry. In return, industry receives a three- to five-year protective license on the process.

The Pakistan Industrial Development Corporation (PIDC) will also take over processes developed by the laboratory and sell these to interested industry.

The Director of the Lahore laboratory, who has been largely responsible for this increased interaction with surrounding industry, has recently been transferred to the principal PCSIR laboratory in Karachi and intends to implement similar tactics there.

Industrial Advisory Boards

Several of the research centers have established industrial advisory boards, consisting of local industrialists, government leaders, engineers, etc., which are intended to become an enhancing link with the public and private sectors. The PCSIR has recently created such a body consisting of 24 industrial representatives of the Federation of Pakistan Chambers of Commerce and Industry, who have an intense interest in the applications of research. Also, the various industry associations have liaison committees with PCSIR for consideration of specific problems. These committees make recommendations to PCSIR laboratories on the needs of industry and establish follow-on research programs and funding assistance (usually only part of the cost, however). It appears that industrial attitudes toward technical assistance are improving, but emphasis is directed toward reducing production costs, trouble-shooting, and problem-solving at the moment.

The Instituto Centroamericano de Investigacion Y Tecnologia Industrial (ICAITI), a regional organization of the Central American Common Market, has recently established an advisory council of six industrialists representing industry, the federation of chambers of commerce and industry, export promotion activities, and the Central American Bank for Economic Integration. It is too soon to determine the effectiveness of this advisory panel. It appears, however, that the Korean Institute of Science and Technology only occasionally seeks opinions or assistance from its advisory board and does not often request advice on areas of industrial research to be pursued.

The Marmara Research Institute in Turkey uses an industrial advisory board for each technical unit, such as materials, composed of two university professors, three to five people from specific interested industries and a representative of the state planning organization. These boards will meet frequently to scope the extent and nature of the problems of the particular industries concerned and recommend action to be taken by the Marmara Institute and industry. The composition of the board can be varied with the nature of problems to be resolved. In theory, at least, such advice and counsel will provide an invaluable assist to the Marmara unit director and his staff in undertaking research of practical relevance to Turkish industry.

On the other hand, the Lagos Chamber of Commerce and Industry has an industrial standing committee which is supposed to maintain close liaison with Nigeria's Federal Institute of Industrial Research (FIIR). The committee meets monthly to discuss current general problems of industrial growth as well as specific industrial areas such as construction, textiles, food production, pharmaceuticals, etc. FIIR experts in these areas are only occasionally invited to attend meetings. The FIIR director has attended committee meetings twice in 18 months.

In each of the 50 research centers visited to date the concern is commonly expressed that much greater interaction is urgently required with industry and government enterprise. In observing the research activities of these centers, it is apparent that such activities are often not relevant to the real world problems around them. As commented earlier, industry lacks confidence in the ability of the research centers to perform; the research centers lack knowledge of the needs of their potential clients. It seems obvious that

establishment and frequent interaction of industrial advisory boards would do much to solve these two oft-stated and as yet unresolved deterrents to application of technology to industrialization.

Salary Incentive Plans to Stimulate Applied Research

Many of the industrial research institutes and research centers, constrained by state or national civil service salary limitations, are devising schemes to create incentives for staff participation in contract research. These take the form of increased salaries for the most part and must usually derive from royalties, licensing fees, or income from contracts with sponsors. Institutes in Indonesia provide most of the incentive in the form of housing, cars, drivers and maintenance (approximately $400/month, estimated value). Most institute directors in developed countries would cringe at the thought of implementing such practices as these. Certainly, there is a clear imbalance in treatment of an institute staff member who is assigned in-house research, trouble-shooting or consulting to a government enterprise or industry which will not pay for services.

Even though such practices undoubtedly will return to haunt the institute directors in the future, there is clear evidence that these tactics are retaining staff and encouraging them to become more aggressive in their search for contracts with the public and private sectors. In most instances, such practices are clearly in violation of government policy, yet most government agencies are aware of these practices and have approved the establishment of revolving funds required to administer the incentive programs.

The general approach in use by various institutes is summarized below.

ARGENTINA.

Consejo Nacional de Investigaciones Científicas Y Tecnicas (CONICYT).

> Individuals from university and research centers are selected as "Science Career Researchers," and receive up to 2 x basic salary as incentive for conducting basic research.

Laboratorió de Ensayos de Materialés y de Investigaciónes Tecnologicas (LEMIT).

No incentive for applied research. Staff selected under CONICYT career program receive up to 2 x basic salary for full-time basic research; if one-half basic research, one-half applied research, factor reduces to 1 x basic salary.

Instituto Nacional De Tecnologia Agropecuria (INTA).

Same arrangement as LEMIT.

Instituto Nacional De Tecnologia Industrial (INTI).

Central laboratories, same arrangement as LEMIT and INTA. In research centers (joint ventures between INTI and various industrial associations) salaries of contract employees are competitive.

BRAZIL.

Instituto Nacional De Tecnologia (INT).

INT career staff receive no incentive for outside contract research. Contract employees are permitted to augment salary through support of research programs by the Brazilian National Bank of Development (BNDE) or the Brazilian National Research Council (CNPq) as long as the total salary so derived does not exceed 90 percent of the salary of the Minister of Industry and Trade.

Instituto De Pesquisas Tecnologia (IPT).

Staff receive up to 1.8 x base salary for obtaining and continuing contract research support. It is interesting to note that currently the range for São Paulo industry salaries is 1:3.9, while the salary range for IPT (based on base salary plus premium pay) is 1:3.8.

INDONESIA.

National Laboratories of the Indonesian Institute of Sciences (LIPI).

Staff can receive up to 2 x base salary plus car, driver, maintenance, and housing privileges; generally salary increments are derived from contract funds, car and housing may derive from institute's operational funds or from contracts. Exception:

LIPI's National Electronics Institute pays 3 x base salary from contracts for services, repairs, prototype production.

Ministry of Industry Laboratories.

Staff receive 1.5 x base salary for contract research. Team leaders may receive 2 x base salary if also investigator on another contract. In addition, some staff receive cars and housing allowance as fringe benefits.

Ministry of Mining.

Similar to LIPI.

Institute of Technology at Bandung (ITB).

Faculty members may receive 3 x to 4 x base salary from contract research.

TURKEY.

Scientific and Technical Research Council of Turkey (TUBITAK).

TUBITAK contracts directly with individual professors or researchers. Payment of an honorarium, agreed to in advance, is made on completion of research project. Such payments are overload and do not go through the university or institute financial system.

Middle East Technical University (METU).

Faculty members who undertake applied research for industry receive one-third increase in base salary with no reduction in teaching load; a higher increment corresponds to reduced teaching.

INDIA.

Council of Scientific and Industrial Research (CSIR).

Staff who develop exploitable processes or patents are paid 40 percent of the royalties, licensing fees, etc., received.

PAKISTAN.

Pakistan Council of Scientific and Industrial Research (PCSIR).

PCSIR staff receive similar incentives as CSIR staff. However, the Lahore laboratories (85 percent of

professional staff receive additional income) also make bonus or honorarium payments for developing good processes, even when no royalties are paid, e.g., programs for the Defense Ministry. The Karachi laboratories utilize the same royalty payment scheme but have no mechanism for bonus payments.

Other research institutes visited but not recorded here either have autonomous control over their salary policies and do not need such tactics, or they have been unable to initiate a suitable approach to the problem.

Research Institutes Directed to Specific Sponsor Needs

Scores of single-purpose research centers exist, almost always an entity of a particular government ministry or agency, totally subsidized and limited to research and technical assistance in specific subject areas such as rubber, forest products, fisheries, petroleum, etc. Virtually no contract services are undertaken so that incentive for aggressive attention to the problems of potential users of research results is usually left up to the individual. Each such institute is replete with its own professional,technical, administrative support staff, facilities, and projects.

There is no denying that most of these single-purpose institutes within a country greatly overlap and replicate each others' activities. It would seem apparent, therefore, that in most such instances the needs of developing countries would be more effectively met by integrating such single-purpose institutes into multi-purpose organizations so as to assemble critical masses of interdisciplinary professionals and, equally important, drastically reduce the costly burdens of duplication of equipment and facilities, and proliferation of large numbers of administrative and support personnel. Such integration is, of course, unlikely; most government agencies will not willingly agree to diminution of their empires, no matter how ineffective.

Two systems have been observed, however, which are interesting case studies. These are the CSIR (India) system and the INTI (Argentina) system.

Before describing the systems, the basic differences between CSIR and INTI should be outlined. Thirty-four separate research units--national laboratories, institutes, regional laboratories--along with 65 field stations, operate under the CSIR umbrella and are located at various sites throughout India. In addition, 14 research association laboratories have been established; these will be

discussed later. The national laboratories are engaged in research which is basic to industrial development. The regional laboratories are multi-purpose in character and are concerned with problems of industrial development in their respective geographic areas. Some of these laboratories are concerned with general needs of the nation, such as food, fuel, buildings, highways. Others devote their efforts to research in engineering, public health, geophysics, oceanography, experimental medicine, and toxicology. Laboratories have been established to deal with problems of interest to specific segments of industry--electronics, ceramics and glass, leather, minerals and metals, marine chemicals, drugs, scientific instruments. These research units are largely subsidized by the Indian Government. Approximately 6,000 scientists and engineers and an equivalent number of support personnel are involved in the CSIR system.

INTI, on the other hand, operates a group of central laboratories, located near Buenos Aires, and a network of 20 research centers throughout Argentina. The central laboratories include departments of chemistry, physics, metallurgy, non-destructive testing, building materials, structures, rubber, ore dressing, and metrology. These laboratories conduct research, testing and analysis, technical assistance, etc., for government enterprises and industry and also provide a back-stopping function for the research centers. Approximately 20 percent of the INTI operating budget derives from services and contract research. About 150 professional staff man the central laboratories along with an additional 500 support and administrative staff.

The key element to the CSIR-INTI system is the tactic which has been devised to create special-purpose research units outside of the normal organizational hierarchy of either CSIR or INTI and to dissolve these units when these have fulfilled their purpose or are no longer required. These research units are created on the basis of requests for assistance by particular segments of industry, by industrial associations, etc., and who, as a condition, pay 50 to 75 percent of the operating costs of the unit. Since the units are designed to meet specific needs, staff assignments can be made on a multi-disciplinary basis, and altered easily to meet changing needs. In each instance the CSIR or INTI permanent laboratories and staff provide backstopping, management advice and direction, use of specialized facilities, etc. In each case, executive committees review problem areas, recommend action to be taken and review the results.

The CSIR and INTI schemes are modelled on variations of similar schemes which have been successfully utilized in Europe.

The CSIR approach encourages the creation of "research associations" made up, in theory, of small, medium and large industries which have a need for technical assistance and which pool resources to share such assistance and pay 50 percent of the cost of operating the research association laboratory. The Government of India exempts funds spent for such research support from the computation of profits for income tax and excess profits tax. CSIR provides the balance of costs for capital and operational expenditures, and assumes the management of the laboratory. The stated objectives of the research association laboratory are to undertake, on behalf of the member companies, basic and applied research germane to the needs of those companies, and also carry out testing, quality control, operations research, market surveys and consumer trials. Currently, CSIR research association laboratories are concerned with the textile, cement, plywood, and tea industries, as well as paint, electronics, and automotive industries.

The INTI approach is somewhat different. If INTI attempts to contract directly with industry or industrial associations, the funds would revert to the government. However, INTI can establish, by law, research centers which can conduct research programs and services with the participation of industrial enterprises, universities, and government enterprises. Contract funds made available through such arrangements can be used to pay higher salaries to research center employees and for other developmental and institution building activities.

When an industrial group or association recognizes a need for technical assistance to a specific category of problems, arrangements can be made with INTI to establish a research center to investigate those problems. Generally, the industrial association agrees to provide 75 percent of the cost of such a center while INTI will provide up to 25 percent of the cost in terms of capital, use of facilities, equipment, or people. In several instances, the industry contribution approximates 90 percent of the total costs involved.

Unlike CSIR, which has six research association laboratories devoted to textile research, INTI research centers have little overlapping of research interests. INTI classifies its research centers as follows:

-- Technology of construction and the human habitat. Research centers in building technology, building and housing (Bowcentrum Argentina), accoustical and illumination engineering, ambient engineering;

-- Productivity, work methodology and training, management, and industrial design.
Research centers for techniques and methods in small and medium-sized industry, industrial design, mathematical techniques applied to management;

-- Natural products and food.
Research centers in fats and oils, fruits and vegetables, leather technology, marine biology, cellulose and paper;

-- Mining industries and metallurgy.
Research centers in minerals, mineral industries, metallurgy;

-- Research center in combustion technology;

-- Research center in technology of elastomers and plastics;

-- Research center in textiles;

-- Research center in documentation.

How successful have these research centers and research association laboratories been? The evidence suggests that the benefits are, in many instances, marginal. Several persons of the CSIR directorate have commented that not much has been accomplished in the way of developing new processes and that virtually no increased industrial development has occurred as a result of programs of their research association laboratories. The principal activities of the laboratories have been to provide testing, quality control, and development of standards.

It turns out that, in India at least, the idea that industries have common interests has been misleading. Large industries solve their own problems or go outside of India for assistance--these infrequently become or remain part of a research association. Medium and small industries do participate (the small industries largely for prestige reasons) but their needs are largely limited to services.

It must be recognized, of course, that the role of these laboratories in providing testing and other services is of utmost importance; but they should be so structured and not include a policy and staffing for conduct of research.

The INTI research centers have faired somewhat better. These have been formed at the request of existing associations or government enterprises which are already working together and have identified common problems. It should be understood that a large amount of effort of these centers is directed towards analysis and tests, quality control, and other services. But, increasingly, the amount of adaptive research is increasing as industry gains confidence in the ability of these centers to solve their development problems.

Demonstration Plant Approach to Transferring Technology

Nearly every research center has a sizable collection of completed research projects waiting exploitation by an entrepreneur. These include processes for producing chip board (or some other product) from bagasse or bamboo or other fibers, anti-cancer or anti-fertility compounds from indigenous shrubs (usually with a history of folklore efficacy), or an enriched protein foodstuff, derivable from local raw materials, and which can substitute for that expensive imported variety. Programs of research emphasize production of single-cell protein from petroleum, solar energy processes for desalination of water, refrigeration, etc. But there are many other completed projects--in electronics, food products, pesticides, etc.--which should be important to industrial growth, but which are also sitting on the shelf. So far, contribution of much of this research has to be considered as a form of education for indigenous research staffs with very little input to industrial growth and development.

Thus, two major questions must be asked: Why such extensive replication? And, why haven't the entrepreneurs appeared on the scene? The first question relates to the lack of global information dissemination and communication of research results. The library holdings and annual acquisitions of many of the research centers are woefully inadequate. Generally, research institute staffs are concerned with difficulties in obtaining technical information quickly. If they are not acquainted with researchers in other laboratories, their problems are compounded. For example, the recently conducted survey

of 28 industrial research institutes conducted by WAITRO*/ showed that dissemination of technical know-how rated as priority seven out of 30; sources of technical information was priority nine; while needs for library service and operation of library ranked 14th.4/

The more serious problem relates to the difficulty in "selling" research results to a potential industrial user. The WAITRO study showed that industrial exploitation of R&D results and training in industrial applications of R&D shared the priority one and two spots along with industrial training of technical personnel as the most important and urgent need of the institutes surveyed.5/ Observations to date have revealed a surprising amount of uniformity in the similarity of the problem, influenced perhaps by the level of country technological sophistication, but nonetheless a recurring problem to nearly all research institutes.

The PCSIR laboratories in Karachi, for example, initiated a project in 1959 to develop a chlorinated petroleum-base insecticide. The process was patented in 1963 and 1964. Toxicity tests on the product, Petkolin, were completed between 1964 and 1967; a one-ton-per-day pilot plant was built in 1967. Total investment was approximately $300,000 (US) for research and $150,000 (US) for construction of the pilot plant, or $450,000 (US) total investment.

*/ WAITRO was organized in October 1970 and currently has 56 technical members and 18 sustaining members in 49 countries. One of WAITRO's prime objectives is to improve the dissemination of information about industrial research institutes throughout the world and to facilitate exchange of ideas and sharing of problems and experiences, and to coordinate programs of a regional or global character which may benefit its members. The referenced publication summarizes the initial phases of this important program.

4/ Priority of Needs of Industrial Research Institutes in Developing Countries, Publication No. 3, World Association of Industrial and Technological Research Organizations, Vancouver, Canada, pp. 2-3, June 1972.

5/ Ibid., p. 2.

Pakistan currently imports approximately $14 (US) million in pesticides per year. It is estimated that this new PCSIR process can replace 20 percent of the above imports.

The PCSIR is willing to lease its pilot plant to an industry on a rental basis and produce the product until a larger plant is completed. The PCSIR would expect a primary fee and royalty payments for use of the process, but apparently really expect to receive only a primary payment and feel that the royalty payments will be forgotten in a year or two.

On the surface, this appears to be a good investment and a process which should be put to work. One wonders why there have been no industrial takers to date.

The National Institute for Electrotechniques in Indonesia has developed some very interesting electronic communications devices--mobile dial telephones and multiplexing communication links--which they feel to be important to Indonesia's communications needs of the future. But the government agencies have not recognized such a need, and industrial manufacturing concerns which have reviewed the prototypes will become interested only after production, economic, and marketing considerations are resolved. There is no economic and marketing assistance available to the NIE laboratories. The Director recognizes the need for help in selling his developments, but is stymied in his efforts to go further.

The Federal Institute of Industrial Research in Nigeria has spent several years perfecting a commercial process for Gari, a low starch staple food from cassava roots and currently produced on a limited basis in almost all Nigerian villages. The local product lacks controls, and taste and starch content vary drastically. The FIIR process produces a good quality Gari but at higher unit cost than the village product. Two problems are unresolved. These are mechanical peeling of cassava roots and assured production of the root.

FIIR in cooperation with a foreign firm is attempting to sell the process and has tried to obtain financial assistance from the Nigerian Development Bank. NIDB, uncertain of economic feasibility of the process, is unwilling to finance the project.

In the meantime, in a separate deal with another agency of the government, a Brazilian company is entering into Nigeria to produce Gari, using its own equipment and process and ignoring the FIIR process.

The experience of KIST and the development of a capability to produce tantalum solid electrolytic capacitors should be mentioned. During the course of a program to identify, adapt and transfer hard aerospace technology to Korea,6/ KIST ascertained that three Korean electronics firms are interested in producing or using tantalum capacitors for use in electronic calculators and various military communications equipment. The present domestic market for these is estimated at $1 (US) million and can be expected to expand rapidly in the future. External markets are expected to be good.

On the basis of this expressed interest, KIST initiated a development project to establish procedures for fabricating, quality control, and reliability engineering. This capability has been achieved. KIST is in a position to assist in the establishment of production lines, training of industry personnel, and continued consulting to assure success of the project. A thorough study of economic feasibility of a tantalum capacitor industry has been proposed to be supported jointly by the interested industries. But these have indicated they are unwilling to proceed further until there are stronger assurances of an actual domestic market.

The potential producer of the capacitors, Sam-Wha Condenser Industry Company, currently produces aluminum capacitors and has received considerable assistance from KIST in product development and evaluation. The company is expected to contract with KIST in the near future for pilot plant operations for substitute raw materials for ceramic capacitors and sintering of ferrite cores.

6/ In cooperation with Illinois Institute of Technology Research Institute.

It appears that there is no lack of confidence in KIST; however, the incentives seem to be lacking for early production of tantalum capacitors which would enable Korea to become more aggressive in export sales of electronics components. Thus, KIST has undergone a process development program which may well be delayed in implementation for two to five years and may even be bypassed by other advances in electronics.

Interestingly, other KIST electronics projects in miniature transceivers and high sensitivity transceivers, initiated under the technology transfer program with IITRI, have resulted in prototype production and field tests are being conducted.

These examples point out the need for demonstration plant operations by the research institutes as a coherent and necessary segment of the institute's overall responsibility. It is clear that industry in the developing country is reluctant to invest in technological developments unless:

- The technical process is shown to be feasible;
- The process or production line can be observed;
- The economic feasibility can be demonstrated;
- Sufficient quantities of the product can be produced for marketing and consumer acceptance; and
- A mechanism exists to train industry employees in production or process operations.

There are distinct advantages to selling the pilot plant products in the commercial marketplace. The income from sales can be used in a private laboratory fund for incentives or to purchase new pilot plant equipment. A market demand is created where none may have existed. Actual sale of a laboratory-developed or improved product increases the confidence of the public and the industrial sector in the ability of the research institute. When industry is ready to undertake the process, operating data, cost and profit figures, and customers are available.

Many advisors abhor the suggestion that research institutes involve their staff in demonstration plant operations such as these and particularly when the sale of pilot plant produce is involved. Somehow this is conceived as being unprofessional.

But, the more successful research institutes do have such programs and, at least to some extent, have increased their liaison with the public and private sectors accordingly. The PCSIR laboratories in Lahore, for example, have been instrumental in establishment of new industries in their area which are producing glass bottles and insulators, clay products and ceramics, and essential fats and oils. The processes were developed or modified in the PCSIR laboratories, limited production undertaken, and after industry take-over, consultation has continued.

In a similar way, the CSIR Central Leather Research Institute in Madras is noted for its aggressive actions in identifying markets, both domestically and internationally, developing the process needed to produce items for those markets, training industry workers in the process, and providing assistance in marketing of the product.

The National Physical Laboratories of the CSIR system, through the Development-Cum-Production Unit for Electronic Components, has established know-how, conducted pilot production runs, and turned over to industry processes for ceramic and silver mica capacitors, soft and hard ferrites, and technical ceramics. During the period 1959 to 1971, sales from these products have amounted to $4 (US) million, with royalties to the NPL laboratory fund of approximately $90,000 (US).

A number of examples can be cited in the area of food technology. Instituto de Investigaciones Tecnologicas (IIT) in Bogota uses its well-equipped pilot plant to process batch lots of canned fruit juices, banana puree, sliced bananas, etc., which have been undergoing marketing trials in Europe. IIT will undertake small lot canning of mushrooms, for example, in order to help a small producer determine the market for the canned product. The producer provides the raw materials and pays a fee for service; IIT has an opportunity for input of new or improved technology to improve the process or develop a new process. In an

attempt to exploit an enriched wheat flour substitute IIT has set up a small bakery and is producing pasta to demonstrate to potential users the merits of the enriched product.

KIST is building a pilot plant to produce freon from calcium fluoride and will sell that product in competition with Japanese exports. The Cellulose Research Institute in Indonesia is utilizing an old rayon pilot plant and pulper to demonstrate the production of high quality paper from the non-productive trees of rubber plantations. As a by-product, and to defray expenses, carbon disulfide is produced and sold to Indonesian industry (although three-months operation of the pilot plant produces a 12-month supply of CS_2). The Ceramics Research Institute produces glass, vitreous enamel, refractories, structural clay products, lime, white ware, and electric insulators in sizable quantities to demonstrate these new products in Indonesia.

There are many similar examples. Few of the institutes have industrial feasibility and economic units, or existing units lack an effective voice in program development.

The evidence is clear that the demonstration plant approach is the major potentially successful link that joins the industrial research institute to the industrial development process. Developing countries have an urgent need for institutes which are prepared, both physically and philosophically, to provide trouble-shooting and technical assistance, analysis and testing services, including quality control, and technical extension services, principally to the small and medium-sized industries which do not have access to outside assistance. These activities, coupled with a demonstration plant and adaptive research approach, lend credence to the oft-repeated suggestion by Dr. Laurence Bass that such institutes are not research institutes at all but should more properly be called technological institutes.

RESEARCH INTERESTS OF FOREIGN ASSISTANCE AGENCIES CONCERNING APPROPRIATE TECHNOLOGY

Origins of Current Interest in Relating Technology to Factor Endowments

During the past several years there has been a sharp increase in interest of the development community in the relationship between the types of technology that are introduced in developing countries and priority development objectives, such as increased employment opportunities, improved income distribution, and more efficient use of locally available materials. For some development practitioners the notion that borrowed technologies are often inconsistent with the factor endowments of developing countries comes as a new revelation; others welcome this revival of long-held views that instant industries, western style, can result in harmful secondary effects.

For the technologists, the World Plan of Action for the Application of Science and Technology to Development, together with the supporting documents prepared by UNIDO, represented a major breakthrough in the level of sophistication of thinking about technology transfer and the relationship between technical change and social and economic factors.[1/] This step was reinforced by inclusion for the first time of a solid discussion of science and technology in the 1971 annual report on development assistance prepared by the Organization for Economic Cooperation and Development (OECD).[2/]

The development economists have discovered in the phrase "science and technology" a new peg for their employment concerns and a ready source of funds within

1/ See particularly Chapters VI and X of the World Plan of Action for the Application of Science and Technology to Development, United Nations, New York, 1971, and the related document Appropriate Technology and Research for Industrial Development, Report of the Advisory Committee on the Application of Science and Technology to Development, New York, 1972.

2/ Chapter VII of Development Assistance, Organization for Economic Cooperation and Development, Paris, December 1971.

foundations and development agencies to pursue studies concerning technology transfer and technological innovation.

For many years agriculturalists have been pleading for machinery better suited to the manpower situation in rural areas. The new debate has spotlighted a number of their experimental programs in this direction.

Recently, under the stimulation of the UNCTAD conferences and concurrent pressures from Latin American countries at a number of other international forums, multinational corporations have been reassessing their approach to technology adaptation. Developments such as the Ford Fiera have begun to merge with broader conceptual approaches in the development community.

Finally, advocates of village technology are now being heard. They have long argued that the usefulness of equipment is directly related to simplicity of design and operation.

Differing Perspectives on Technology Adaptation

The economists have mobilized behind the expression "labor intensive technology" as a principal concern within development circles. They have even begun to count the number of employees in different types of plants producing the same types of goods in building their case.

The technologists are less enamored with this phrase, and many argue that "capital saving technology" represents a far better conceptual and practical approach to industrialization in developing countries.

Meanwhile, the village oriented specialist discusses "intermediate technology" which usually refers to simple and primitive techniques that may have been passed over by developed countries many years ago.

Rather than stumbling on words, the phrase "appropriate technology" seems best suited to the problem. It can be defined simply as technology which is as responsive as possible to the capital, manpower, natural resource, institutional, and social realities of a particular developing country environment.

Overview of Recent Activities

The activities of foreign assistance agencies are many and varied in this field. Most of these efforts are not deliberately designed to capitalize on factor endowments. However, in project implementation they interact very directly with the concept of appropriate technology.

This presentation is limited to highlighting some of the most interesting current approaches, of development agencies, emphasizing "what's new" in the field. The discussion will be limited to engineering technologies, and more specifically, manufacturing technologies and technologies related to construction and operation of economic infrastructure activities, such as transportation, communication, water resource development, power, roads, buildings, and housing. Analytical efforts as well as laboratory research efforts supported by assistance agencies are described, recognizing that laboratory research often includes a substantial analytical component.

A wide variety of traditional development activities, closely related to research, are not considered, even though these activities may often be the decisive determinants of the success of foreign assistance in influencing the direction of industrial growth. These omissions include such activities as training of developing country engineers and technicians,[1/], minor adaptation of standard engineering techniques for large construction projects, and industrial supporting services, such as industrial standards and quality control, testing and measurement laboratories, and technical information.

Last year OECD began to survey the activities of the bilateral donors in selected areas of science and technology, including adaptation of industrial technologies. These efforts are currently in mid-stream and will probably continue for several years. In addition to surveying the general field of industrial research, specialized studies have been initiated in utilization

1/ The importance of training should not be underestimated. For example, there are more than 12,000 developing country engineers enrolled in U.S. graduate schools.

of tropical forests, building and engineering construction, and non-food uses of agricultural products including fibers, and are being considered in processing and preservation of food products and industrial uses of non-agricultural natural resources. The principal objective of this activity is to identify high priority research gaps in the kaleidoscope of foreign assistance efforts and then to stimulate action to fill these gaps.

With regard to analytical efforts of other organizations, UNIDO has clearly led the way for several years. The principal techniques have been seminars in Vienna and elsewhere on many aspects of industrial technology, and survey missions to assess specific technologies in particular country settings. Indeed it is difficult to identify a single aspect of the industrialization process that is not covered in a series of UNIDO reports. As two specific examples, a recent UNIDO seminar report "Production of Panels from Agricultural Residues" and a consultant report "The Use of Bamboo and Reeds in Building Construction" lay out a series of steps, including research priorities, which interested organizations might follow in these field. With regard to broader economic questions, the five-year old report "General Issues of Industrial Policy" was an early effort followed by a series of reports directed to far ranging policy consideration.

A.I.D. has launched its share of analytical efforts in recent years. The employment oriented program at Yale is well known. This program involves both country studies and sectoral studies on employment problems related to transfer of technology, choice of technology, capital markets, and other areas.1/ A new program with a somewhat broader technological base is now underway at the National Academy of Sciences, involving bilateral workshops on industrial research (India, Indonesia, Brazil), conceptual studies of the suitability of technology, and specialized technical studies (ferro-cement, solar energy, power sources). Denver Research Institute has recently completed the first phase of a wide-ranging

1/ Two recent studies concerning appropriate technology prepared under the Yale program are included in Technology and Economics in International Development, Report of a Seminar, Agency for International Development, Washington, D.C., May 1972.

analysis of the strengths and weaknesses of industrial research institutes in developing countries. Finally, Arthur D. Little is analyzing opportunities for reducing costs and increasing use of local materials in the public works sector in Colombia and the Philippines.

Recently the World Bank entered the research arena in a serious manner with its well publicized studies of road building techniques. The Highway Design study investigates the economic costs of East and West African highways built to a variety of design standards. The Labor-Capital Substitution study analyzes the Indian construction industry to uncover uses of labor-intensive technologies in constructing highways of a particular design standard. Other Bank research involves forecasts of markets for electronic components assembled in developing countries, markets for synthetic competitors of natural products, and alternatives to the automobile.

The International Labor Organization is of course continuing its case studies of capital/labor tradeoffs in selected countries, and is considering studies of employment effects of technological change in specific sectors. The Organization of American States is launching a major experimental effort to identify technologies particularly well suited to Latin American industrial needs. UNITAR has completed its series of technology transfer studies (UNITAR Research Reports 7, 8, 10, 11, 12, 14), while the UN Economic Commissions and associated research institutes have begun modest efforts, principally seminars. The British have also recently initiated several analytical efforts. The University of Strathclyde is examining technological choices in the shoemaking, textile, and sugar industries of Ghana and Ethiopia. At Oxford studies are underway analyzing the economic rationale for appropriate technology, and particularly the necessity to conserve management and technical skills in addition to capital.

Support of Developing Country Research Institutes

UNIDO and A.I.D., and to a far lesser extent several other donors, have for some years provided assistance to many of the several hundred industrial research institutes in developing countries, in addition to training opportunities provided by almost all donors.

At present UNIDO has 29 projects which have been approved or are under action consideration targeted on

these institutes, with 13 of the projects exceeding $100,000 and involving equipment, advisers, and training (e.g. Colombia, Israel, Libya, Malaysia, Paraguay, the Sudan, Thailand, Trinidad and Tobago). UNIDO's stated objectives are directed to (1) reviewing national plans and organizations for streamlining existing structures for industrial research, and (2) strengthening national organizations that can assist in introducing appropriate technology, design processes that utilize local raw materials, and supply services to local industry.[1/]

A.I.D.'s efforts initially were directed to broad financial support of selected institutes with the largest undertaking being the Korea Institute of Science and Technology, a $25 million A.I.D. investment.[2/] More recently A.I.D. support has been for specific projects sited at these institutes, e.g., agriculture vehicles at IRRI, milling machines at the East African Industrial Research Organization, and road construction techniques in laterite soils at the Ghana Building and Road Research Institute. Now the A.I.D. emphasis is on projects designed specifically to couple the institutes more closely with industry, e.g., strengthening the local food industry through collaborative efforts with the Central American Technological Research Institute.

Judging from the information available through the OECD survey and from recent personal visits, the British, Swiss, and Dutch also support research activities at industrial research institutes in developing countries. The British have traditionally provided advisors and training opportunities to building, road, forestry, and other types of research institutions in Ghana, Nigeria, and Kenya. The Dutch efforts are largely on a small-scale, ad hoc basis, but there are major efforts involving two food laboratories in Saudi Arabia and the fish processing station in Nyegazi, Tanzania. The Swiss support the nutrition institute in Recife, Brazil.

1/ Program of Work for 1973, Part Two, Addendum 1, Industrial Development Board, May 23 - Jan 2, 1972, UNIDO.

2/ Report on Battelle's Assistance to the Korea Institute of Science and Technology, 1966-1971. Battelle Memorial Institute, Columbus, Ohio, June 30, 1971.

The most recent entrant into the field is the Inter-American Development Bank which is in the process of providing major financial assistance to technological research institutions in Brazil, with possible follow-on efforts in other parts of Latin America.

Support of Technological Research at Developing Country Universities

Foreign assistance agencies have supported many research activities at developing country universities, but unfortunately far too little of this effort has been reflected in the economic activity of the country. At long last, OECD, the Banks, and some of the donors -- with generally enthusiastic support from the developing countries themselves -- are beginning to stress the relevance of university research.

One of the best known examples of a university seeking to contribute directly to development activities is the Asian Institute of Technology (AIT). Originally an A.I.D. undertaking justified on educational grounds in the field of civil engineering, AIT now has broad multi-donor support with a sharp emphasis on partial self-sufficiency through contract research. While AIT has yet to earn its spurs in producing truly meaningful research products on a significant scale, a modest start has been made in carrying out water resource and port and harbor research efforts.

Another recent example, supported by A.I.D., is the establishment of an applied research institute at the Middle East Technical University. The concept is to provide within the University an administrative focal point to facilitate the matching of the University's professional talent with local industrial research needs, leading to contract research in various University departments. Other examples of recent donor support of potentially important research activities at universities include Swiss support for the Faculty of Mines in Medellin, Colombia (metallurgical machinery), Dutch support of the Hydraulics Institute at the University of the South in Puerto Alegre, Brazil (modelling of reservoirs) and of the Bandung Institute of Technology in Indonesia (radio transmission devices), Swedish support of the Building Technology College in Addis Ababa (schoool construction techniques), and British support of the Engineering Faculty of the University of Nairobi (mechanical devices for village use).

Support of Research Centers in Developed Countries

Linkages between developed country and developing country research institutions are now being stressed both in UN circles and among bilateral donors. However, such linkages have difficulty surviving in the absence of subsidies to the developed country participants.

The British have for some years led the pack in this area, largely as the result of ties established during the days of its colonial empire. Among the better known British research organizations which receive subsidies from foreign assistance agencies to maintain linkages in the industrial sector are the Tropical Products Institute (e.g., cashew nut processing machine), Road Research Laboratory (e.g., highway design studies), Building Research Establishment (e.g., on-site concrete panel casting), and National Institute of Agricultural Engineering (e.g., thresher, cotton picker, rope way for banana extraction). Many French institutions have been involved in West Africa for some years, but with minimal orientation to industrial research, largely due to the state of development of the area.

Other developed countries are now also beginning to subsidize selected institutions. The Dutch support the Central Organization for Applied Scientific Research (TNO) which is concerned with such problems as an instant coffee plant in Uganda and the anti-rodent agents in Surinam. The Japanese Consulting Institute in Tokyo carries out research in manufacturing rayon pulp from bamboo, obtaining newspaper material from bagasse, and spinning using tropical plants. The Institute of Agricultural Technology of the Norwegian Agricultural University is developing a combined spreading machine for seed grains and fertilizers in developing countries.

In the field of techno-economic analyses, the Norwegians support activities at the Christian Michelsen Institute at Bergen, the Germans at the University of Aachen, and the British at the University of Sussex.

A.I.D. recently gave a five-year grant to MIT for strengthening its capabilities in "Adaptation of Industrial and Public Works Technology to the Conditions of the Developing Countries." It's initial spread of research activities includes;

Application of Highway Cost Models to Venezuela Road Transportation

- -- Application of Modern Water Resources Planning Techniques to a River in a Developing Country
- -- Adaptation of Urban Transportation Systems Analysis Techniques to Developing Country Problems
- -- Analysis of Patterns of Air Transportation Systems Development in Developing Countries
- -- Systems Analysis in the Nutrition Field as an Aid to Latin American Development
- -- Substitution of Indigenous Materials for Mechanical Engineering Functions
- -- Adaptation of Housing Technologies in Kenya
- -- Development of Basic Performance Standards for Urbanization and Housing Technologies through Testing of Models in Kenya
- -- Studies of the Role of Indigenous Organizations in Brazilian Development
- -- The Nature of R and D by Industrial Firms in India

Other Types of Technology Efforts

Several other types of activities should be mentioned in rounding out the picture of activities and interests of foreign assistance agencies.

On a few occasions research has been conducted in developed countries on specific devices which seem particularly important to developing countries. For example, in the United States an inexpensive, durable hand pump and a plastic roof were developed under A.I.D. financing. Unfortunately, neither has yet found its way into use in developing countries although efforts to introduce the pump are still underway. While the technical aspects of these projects were sound, the economic realities of developing country manufacturing interests were less well understood.

Clearly, the development of small industry in developing countries is very significant in the diffusion

of appropriate technology. A variety of institutions in developing countries that are concerned with small industry (e.g., intermediate credit institutions, productivity centers, small industry extension services) have and will continue to receive assistance from multilateral and bilateral assistance agencies.

A final aspect relates to the activities of the Intermediate Technology Development Group (ITDG) in London and the Volunteers for International Technical Assistance (VITA) in Schenectady. ITDG is interested in a number of village level developmental activities ranging from a hand operated medical centrifuge in Nigeria to catchment basins in Botswana. VITA provides technical information hand-tailored to specific developing country inquiries in many fields. This information, which includes original design of machinery, is provided by interested experts throughout the United States. Some of the innovative ideas are summarized in VITA's Village Technology Handbook.

An Experimental Approach to Clarifying Technology Transfer

In early 1970, an experimental project was undertaken by A.I.D. in collaboration with NASA to determine to what extent selected types of technology developed under NASA auspices during the past 15 years are relevant to specific industrial problems of a developing country and whether a structured program could facilitate the transfer to developing country industry of the technologies of most relevance. The Korea Institute of Science and Technology (KIST) and the Illinois Institute of Technology were selected as the transfer agents. The U.S. specialists assisted the Koreans in searching the NASA technology data banks and in developing a methodology for relating the data to specific industrial problems. The Korean specialists were responsible for adapting the most promising technologies to specific Korean needs, with particular emphasis on industrial opportunities for generating employment, developing export opportunities, and utilizing indigenous raw materials and local skills. Several significant lessons were learned from the experiment which is considered to have been successful, both in clarifying many aspects of the technology transfer process and in upgrading Korean technological capabilities.

The lessons learned include:

(1) An A.I.D. input -- in terms of program design and modest financial support -- can serve as an important catalyst in facilitating the transfer of technology by stimulating an improved coupling between potential U.S. and developing country transfer agents and between the developing country agents and manufacturers.

(2) A developing country transfer agent can serve a crucial role in the selection and adaptation of U.S. technology which individual developing country firms usually cannot duplicate in dealing directly with U.S. industry or U.S. transfer agents.

(3) The developing country transfer agent must supplement its scientific and technological capabilities with an extension capability that will assist manufacturers incorporate the technologies into their production processes.

(4) While the NASA technology data bank contains information of interest to developing countries, the U.S. transfer agent should have access to a far broader data base which would be more responsive to many of the highest priority problems of urban-industrial growth.

Some specific results of the experimental project are:

(1) Several "hard transfers" to Korean commercial manufacturers are in various stages of completion. The innovations directed to reducing costs, improving performance, and enhancing acceptability of radios, TVs, calculators, and related electronic products include: miniature transceivers, high sensitivity communications circuits, tantalum capacitors, and improved electronic circuitry.

(2) Steps have been initiated toward other possible "hard transfers" in the fields of food technology (e.g., all-purpose survival rations, retortable food packaging); instrumentation and testing (monitoring battery charges, microwave non-destructive testing, measurement of flow variables); metallurgy and materials (explosive metal working, thermal insulators); and chemicals (carbon monoxide reduction, high alkali detergents, magnetic ink).

(3) The overall competence of the KIST laboratories involved in the project has been upgraded significantly.

(4) The project has heightened awareness of Korean industry of the value and limitations of technological innovation and adaptation and the importance of KIST as a transfer agent.

(5) KIST has begun to establish the capability to advise the Government and industry on a more discriminating selection of imported technologies and alternative development of indigenous technologies.

(6) The project has sharply oriented KIST towards U.S. technology sources and has significantly increased the probability that KIST will recommend to Korean industry U.S. sources for products, processes, and technologies rather than comparable Japanese suppliers.

(7) The capability of KIST to tap U.S. technical information sources has been greatly improved.

(8) A long-term linkage between KIST and the Illinois Institute of Technology has been stimulated by the project.

(9) The project has already generated $100,000 worth of KIST contract work for the Korean Government and industry.

What Difference Does It Make?

The success of foreign assistance agencies in stimulating the introduction of appropriate technology is difficult to assess. To date the short-term results have not been particularly impressive. However, a wealth of experience has been accumulated by both the developing countries and the donors, and there now seems to be a determined effort to increase the effectiveness of industrial research activities.

In the years ahead the concept of appropriate technology will increase in importance. The prospects seem promising that intervention by assistance agencies can reinforce the efforts of developing country to influence the orientation of the technology that flows within both

the public and private sectors toward a greater responsiveness to developing country development needs and priorities.

MULTINATIONAL CORPORATIONS AND ADAPTIVE RESEARCH FOR DEVELOPING COUNTRIES

Technological Transfer and Industrial Research

Until recently, attention of the development community has been focused on the commercial and financial aspects of technological transfer from the advanced countries to the developing countries. Considerable ingenuity has been devoted to the development of fiscal and monetary policies that create a climate which attracts foreign private investment and stimulates industrial growth. The choice of industrial technologies has been left to the private sector. It was assumed that the normal operation of market forces would determine the selection of technologies that can operate efficiently in the developing country environment.

For a variety of reasons, these policies and assumptions have now been challenged. Experience has shown that policies that are tilted in favor of capital investment in industry to the disadvantage of agriculture have frequently had unfavorable economic and social consequences. Thus, the emphasis on import-substitution industries in some countries has fostered, through overprotection, an unhealthy growth of high-cost inefficient industrial plants. Nor does industrial expansion per se create a corresponding increase in employment. An industry exempt from competition can rely on high-cost capital-intensive labor-saving equipment, with the result that its contribution to increased job opportunities is disappointingly modest. Moreover, to the extent that such industries displace local labor-intensive enterprises they further aggravate the unemployment problem.

As a consequence, attention is now turning toward the problem of a better selection of industrial technologies appropriate to the human and natural resources, as well as the capital investment capabilities, of the developing countries. There is also concern over the need for adaptive research to orient industrial technologies developed in the advanced countries to meet their requirements toward the particular requirements of the developing countries. The use of the term, adaptive research, in this connection has led to

some misunderstanding. To many adaptive research means simple adaptive engineering as applied to the different stages of the production process or to product design. Others are referring to the ability on the part of the developing countries to select among alternative technologies that which is best suited to a particular environment, or to blend technologies from different sources for that purpose, or to apply adaptive engineering to modify a given package of technology better to meet a given requirement. These activities may well require high professional training and sophisticated skills, but they do not necessarily correspond to the term industrial research as customarily used. For purposes of this presentation, however, the term adaptive research will be used to include adaptive engineering and discriminating selection of technology as well as innovative research for new industrial processes or new industrial products.

With the new recognition of the importance of adaptive research, broadly defined, there is increasing interest in the role of the multinational corporations. They have broad experience and unique talents in the industrial research area. This presentation is addressed to their interests in application of research to problems relevant to the developing countries and in increasing the capabilities of the developing countries to carry on such research on their own behalf.

Current Studies of Multinational Corporations

A number of studies of multinational corporations have been made and many others are in progress. Most of these are devoted to the role of multinational corporations in shaping international finance and international trade.1/ But some of the recent efforts are pointed more sharply towards development. One of the resolutions adopted by the recent United Nations Conference on Trade and Development (UNCTAD) held at Santiago last spring called for a study, which is now in progress under the direction of the U.N. Secretary-General, of the role of multinational corporations

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1/ See, for example, S. S. Katz, "The Multinational Corporation". Studies in U.S. Foreign Investment. Department of Commerce March 1972/3, Vols. 1-3.

with reference to their impact on the process of development, especially of the developing countries, and their implications for international relations. The Council of Americas recently completed a survey on the "Impact of Private Foreign Investment on Latin America's Scientific and Technological Progress". Under grants from several foundations and industrial organizations, the Graduate School of Business of New York University is conducting a broad study of multinational corporations, including aspects of their relations with the developing countries.

The National Academy of Sciences and the National Academy of Engineering have undertaken a study, financed by the Agency for International Development, on the role of multinational corporations in supporting research for developing countries. This study, carried out by a group of panels concerned with the industrial sectors of electronics, pharmaceuticals, food technology, chemicals and automotive and earth-moving equipment, has not been completed; but when available, it will present the expert views of leading industrialists, economists, scientists, and engineers on the interaction of the activities of multinational corporations and the technological infrastructures of developing countries.

This presentation describes activities of United States multinational corporations, using information in the published literature supplemented by discussions with a wide variety of knowledgeable individuals. Multinational corporations headquartered in countries outside the United States, such as the Philips Corporation of The Netherlands, are known to have developed imaginative programs in this area. However, detailed information on their activities is not readily available,and therefore the discussion does not include such activities.

Preinvestment for Research

The role of the multinational corporations in raising the general level of technical competence and of managerial skills in the countries where they operate is indeed impressive. This has been accomplished by extensive in-house training programs for employees and their families, by cooperative programs with Governmental and private educational institutions,

and by philanthropic contributions to local foundations devoted to advancing skills in science, technology and management. The report of the Council of Americas referred to above cites a long list of specific examples of training programs, educational programs, and philanthropic projects by a representative sample of leading multinational corporations operating in Latin America. The report shows that as of the end of 1966, 37,000 Latin Americans held management positions in U.S.-owned companies in Latin America, and 90,000 were in professional or technical employment categories. Since that time, the process of training employees to replace expatriate professional and supervisory personnel has been stepped up, and the figures today would undoubtedly be far larger.

The role of the corporations in providing a wide range of courses in management and in scientific areas is particularly noteworthy. Some of the training is accomplished in the United States. Many of the courses are offered in-house within the plant. In addition, arrangements are made with local universities for curriculum and institutional development, for lecturers for special courses, and for practical training experience for students and teachers within the plant on a part-time basis.

Many of those trained by American corporations have moved away to take employment with other industries and have carried their training and experience with them. The report observes that one-third of the Brazilians who received advanced training by the General Motors Corporation have taken positions in Brazil with other automobile companies or other industries.

A number of corporations have set up foundations to support education and research. The Creole Foundation, established by a subsidiary of Standard Oil of New Jersey in Venezuela, has a long and impressive record in supporting economic development in that country. The Gillette Foundation in Argentina has been concerned with "the brain drain" in that country and has contributed in a tangible way to bringing back talented Argentine scientists and engineers working abroad to assignments in Argentina. The Fund for Overseas Grants and Research in Education, known by its acronym FORGE, has received support from a number of corporations as well as the Ford Foundation and others

in the United States, and has conducted a valuable program in support of scientific research in Latin America. In short, there is no question that the multinational corporations have exerted a powerful influence within the countries where they operate for upgrading the quality of managerial and technical performance.

In some cases, the Governments of the developing countries have worked out cooperative arrangements to avail themselves of the talents offered by the presence of the corporation. This has undoubtedly accelerated the process of technological diffusion which otherwise might take place more slowly. For example, when the Singer Company approached the Government in Taiwan in the 1960's about locating a plant to manufacture a low-cost sewing machine for the East Asian market, the Government negotiated an arrangement calling for the Singer Company to upgrade the quality of the small family-run establishments in Taiwan which manufactured replacement parts and accessories for sewing machines. The arrangement worked out well to the mutual advantage of the company and of the local enterprises. As a result the location of the plant did not displace the local shops but raised the general level of competence.

Adaptive Engineering in the Processing Stage

The establishment of a manufacturing plant in a developing country involves a large number of engineering problems resulting from the new environment. A routine application of a well-established process in a technologically advanced country becomes an exercise in experimental development in a developing country. Apart from differences in the climate which may affect the manufacturing process and the lubricants and fuels which are employed, there is the lack of normal supporting services which are part of the infrastructure of the developed countries. In addition, the scale of the operation is likely to be smaller than typical plants in the developed countries involving a redesign of the entire plant.

In countries with a highly undeveloped technological infrastructure, the manufacturing process may be limited to a simple assembly of parts brought in from abroad. If a more complex manufacturing plant is established, there is greater scope for adaptive

research. Ideally, the plant should be designed to optimize the relationship between technology and local factor endowments, including the abundant supply of unskilled labor which is typically available in a developing country. In particular, there are obvious opportunities to substitute labor for capital investment in the pre-processing stage involving the inward movement and handling of material inputs and in the post-processing stage involving the packaging and outward movement of the final product. There is very little evidence available on the extent to which multinational corporations have been innovative in this area.

An interesting study by Howard Pack of a group of industries in Kenya suggests that technical know-how may play an important role independently of overall economic policy. He found that plants operated by multinational corporations in Kenya do adopt ingenious capital-saving practices, with some exceptions, whereas plants operated by local entrepreneurs whose background is commercial rather than technical often overlook these opportunities. The explanation appears to be that the owner of the locally owned plant has through lack of technical expertise allowed himself to be sold unnecessarily expensive capital-intensive equipment by engineering firms with a vested interest in selling as much equipment as possible. The multinational corporation with its greater experience with production in developing countries is on the lookout for inexpensive equipment. With its familiarity with sources of supply, it is in a position to locate and to purchase such equipment. Furthermore, the manager of the plant owned by the multinational corporation has the technical training and experience, plus the experience shared within the organization, so that he is able to organize production in such a way as to optimize the use of low-cost labor. On the other hand, Mr. Pack also found an efficient locally owned plant where the local manager had received his engineering training abroad.

Mr. Pack's conclusions are two-fold. In the first place he found no evidence in those industries he studied to support an oft-repeated assumption that multinational corporations have a propensity to purchase the same high-cost capital-intensive equipment for use in their plants in developing countries as they use in

their plants at home. In the second place, there is scope for adaptive engineering in certain stages which would optimize the use of the manufacturing process favorable to local endowments. 1/

Governmental policy obviously plays an important role. If the plant is to produce for a sheltered domestic market, and if the product can be sold at whatever price is needed to bring in a profit, there is little incentive on the part of the producer to design the plant to operate efficiently and economically. On the other hand, if the product is to be exported and is to meet the competition of world trade, there is a great incentive to cut costs and to operate the plant at maximum efficiency. It is for this reason that an export-oriented industrialization policy is likely to develop a healthier industrial base than policies aimed at import substitution.

Governmental policy also contributes to multinational corporations moving into materials research and into quality control. Many countries which pursue an import substitution policy set requirements for a progressively larger amount of the components of the product to be derived from local sources over fixed periods of time. The multinational corporation is thus required to embark on a program of materials research which is often conducted at least in part at the local plant. This can involve a significant research effort. It also stimulates a program of technological diffusion which can have a multiplier effect. The corporation has a direct incentive to develop a network of local suppliers and to assist them in their managerial and technical skills to assure a reliable supply of materials meeting quality standards.

Governmental regulations controlling the quality of products also stimulate the establishment of research facilities. In the pharmaceutical industry, quality control involves the application of professional skills in clinical testing. In the automotive industry, quality control can involve huge investments in testing grounds and testing equipment

1/ Howard Pack, "The Use of Labor Intensive Techniques in Kenyan Industry", Technology and Economics in International Development, Agency for International Development, May 1972.

and highly professional skills. The multimillion dollar testing facility of the General Motors Corporation at Sao Paolo, Brazil, compares favorably with similar facilities in the developed countries.

In short, there is wide scope for adaptive engineering in the production stage. The degree of sophistication brought to this by the multinational corporation is greatly influenced by local governmental policy, by the size of the market, and by the general level of technical competence within the country.

Adaptive Engineering in Product Design and Development

There are a number of examples of modifications of products to meet local requirements and market opportunities. This usually involves the application of familiar techniques, but may well encompass highly professional training and sophisticated skills. It normally takes place in countries that have made substantial technological progress. The National Cash Register Company, for example, has in production in Argentina a cash register which was designed and engineered in its plant in Argentina. The plant initially produced a cash register intended for a relatively restricted market of large-scale commercial enterprises, such as department stores. About 80 percent of the commercial establishments in Argentina are small family-operated enterprizes that require a much simpler machine to store money and to perform simple arithmetic functions, such as addition of sales items and registering the amount of change due. The machine designed in Argentina is intended for this market. A similar machine is being designed in their Brazil plant, appropriate for a comparable market in that country.

In the pharmaceutical industry, adjustments to local conditions can take the form of product development, involving highly sophisticated work in chemical and pharmaceutical development, although not qualifying as industrial research as that term is used in the pharmaceutical industry. G.D. Searle Company, a company that produces ethical drugs, specialized medical instruments and other medical supplies, carries out product development in the laboratories of its plants in Mexico, Argentina, Brazil, Colombia, and Chile. In this case, the local plants have built on the technical capabilities which started with a

clinical testing program. As the laboratories gained in experience and in technical competence, they moved ahead into more sophisticated areas of experimental development.

Among the more imaginative programs in the area of product design are the basic multipurpose transportation vehicles recently displayed by the Ford Motor Company and the General Motors Corporation at the Transpo 72 Exposition at Dulles International Airport. These are simplified low-cost vehicles specially designed to meet the requirements of developing countries. Conventional cars produced for the developed countries are usually luxury items for a limited group in developing countries and are frequently ill-suited to local road conditions. The multipurpose transport vehicle, as developed by Ford and GMC, can be used as a pick-up truck for farm and light commercial use, can be converted into a minibus, or can be placed on jacks and used as a power source to operate a water pump, a saw, or a rice-husking machine.

The Ford vehicle was designed for the market in Southeast Asia. At a modest investment of $700,000 a research and development program conducted in Australia designed a vehicle that can be made almost entirely from materials and with manufacturing facilities available in the region, apart from the motor which will come from the Ford plant in the United Kingdom.1/ The market in Southeast Asia for this type of vehicle has become more attractive because of rising incomes in rural areas resulting from higher agricultural productivity arising from the Green Revolution. The imaginative approach of the Ford Motor Company in consolidating and developing this market is as innovative and significant as the changes in product design to reduce costs of manufacture. Specifically, the normal requirement by developing countries that within a limited period of time a fixed percentage of the components will be produced locally

1/ William Bourke, "Basic Vehicle for Southeast Asia", Technology and Economics in International Development, Agency for International Development May 1972.

has been ingeniously finessed by Ford's devising an agreement with the participating countries that a component produced in one country, such as in Singapore, will count toward meeting the fixed percentage requirement of all of the other countries. This will serve to optimize efficient use of local materials and to bring down the cost of the vehicle.

The innovative feature of dividing production of components on a regional basis as a means of broadening the market and reducing costs is an example of the way in which the multilateral corporation can bring its special competence in the marketing area to bear on technological adaptation. However, the success of the program will depend on the cooperation of the Governments within the area in implementing the regional concept.

Another example of equipment designed to meet the specific requirements of the developing countries is the so-called DNT tractor of the Ford Motor Company. The DNT or Developing Nations Tractor is a low-cost, one-man tractor that is intended to replace the ox or the water buffalo as a source of power in rural areas of the developing countries where higher cost farm equipment is uneconomical. The DNT tractor has been tested in Jamaica and elsewhere and apparently has been well received from the technical point of view. However, the product is still in the stage of experimental development, with possibilities being explored in different countries for arranging for credit facilities and for dealer organizations to assure after-sale service and maintenance.

The remarkable advances in electronics and in chemistry have had widespread repercussions within the developing countries. However, it is difficult to identify particular developments which resulted from research directed toward unique requirements within developing countries. One such example is a versatile, low-cost, rugged communications system, capable of being operated on ordinary flash-light batteries, designed by an employee in the Public Safety Division of the Agency for International Development. The equipment was developed and is being produced by the Hallicrafter Company, a subsidiary of the Northrop Corporation, with a commercial sale in developing countries ranging between $1 million and $2 million a year, primarily for the use of police services. The

equipment is now also beginning to find a market with U.S. Government agencies operating in remote areas such as the U.S. Forestry Service and the Indian Health Service in Alaska.1/

Innovative and Adaptive Industrial Research

As far as can be determined, there are only a few examples of innovative or adaptive industrial research, as that term is customarily used, performed by U.S. multinational corporations solely or primarily with reference to requirements in the developing countries. Industrial research is directed toward the conversion of human talent and available resources into products for which there is a commercial market. A limiting factor on research on problems peculiar to the developing areas is the lack of a sizeable market for a product that might be produced as a result of the research. At the same time, the multinational corporations are naturally interested in extending the market for products that result from their research as widely as possible. Therefore, the developing countries are often the beneficiaries of new industrial processes or new products which have world-wide application, even though these processes or products were not developed exclusively within the context of the developing countries.

Corporations concerned with the production and marketing of agricultural products intended for industrial or commercial purposes occasionally locate their research facilities within the area where the products grown. The United Fruit Company, for example, has its principal laboratory in Honduras with a staff of some twenty-five scientists drawn from Latin America, the United States and Europe. The laboratory is concerned with plant genetics and plant pathology in

1/ See "Multipurpose VHF-FM Tactical Transceivers OPS/FM-1B and OPS/FM-5B", Standard Specifications for Public Safety. Agency for International Development, February 1, 1968. See also Paul Katz, "New Multipurpose VHF/FM Equipment to Meet Internal Security Needs for Developing Countries", Law Enforcement Science and Technology, S.A. Yefsky, Editor, Vol. I Thompson Book Company, Academic Press 1967.

programs aimed at improving the production of bananas and palm oil. The Firestone Rubber Company which operates the largest rubber plantation in the world (80,000 acres) in Liberia maintains a laboratory in that country to work on problems relevant to rubber production. The laboratory has a staff of twenty-five scientists. Under a policy of training Liberians in the research area, almost thirty Liberians hold professional and technical positions in the management and research operations of the laboratory. Since the company is a leader in the field of rubber latex, its research programs are in the area of biology and plant genetics aimed at developing better producing and disease resistant rubber trees, and in the fields of chemistry and biochemistry aimed at developing better methods for preserving latex for shipment to industrial consumers around the world.

As a general rule, basic and applied research on problems of principal concern to the developing countries, to the extent that the multinational corporations perform such research, are performed by company laboratories located in the technologically advanced countries, where the long established research organization and facilities exist. Rubber companies, for example, with subsidiaries or affiliates in the developing countries, produce tires better suited to local climatic and road conditions than tires produced for home markets. The product design in such cases rests on research done in the United States, but the local factory depending on its capabilities may contribute its knowledge and skills to producing a product best suited to the particular country. Tires produced in Chile may therefore differ from those produced in Brazil or Argentina. In some cases, the local work on tire engineering and product development may extend to other forms of industrial research. The General Tire and Rubber Company, for example, has joint ventures with rubber companies in a number of countries in Latin America, including arrangements for technical assistance. In Argentina, its local affiliate FATE S.A.I.C.I. of Buenos Aires has built up an impressive research staff, and has recently entered into an arrangement with General Tire for a long-term cooperative program looking toward advanced research in chemistry, physics, and other scientific fields requiring the skilled services of chemists, mathematicians, engineers, aerodynamicists and astrophysicists.

It remains to be seen whether the General Tire and Rubber Company will find it practicable to have a portion of its industrial research program carried out in the laboratories in Argentina under this arrangement. However, the experiment points to the advanced scientific and technical capabilities of research institutions in Argentina.1/

The food processing industry has become increasingly involved in research aimed at developing low-cost high protein foods which would be of particular benefit to countries in the developing world whose populations suffer from malnutrition. At the same time, the products should be beneficial to low-income families in the developed countries. The programs have been stimulated by the attention focused on the nutritional problem in the developing countries by the Agency for International Development, and its modest program of grants initiated in the mid-1960's for market surveys in this area. However, the leading firms at present in this area have also devoted their own funds to research and development of such products. One of the better known high protein foodstuffs is the so-called Golden Macaroni, developed by the General Foods Corporation at its laboratories in Tarrytown and Battle Creek. The macaroni, made from wheat mixed with soy and corn, is about 20 percent less expensive than conventional macaroni and contains about seven times more protein. The product has been field tested and has had a successful market in institutions in the United States and in the developing countries, principally for school lunch programs. A subsidiary is producing the macaroni in Brazil for school programs and a Brazilian manufacturer has obtained a license to make the product for sale to other institutions in that country, such as the army and hospitals.

CPC International of New Jersey, generally referred to as Corn Products, has developed a product known as Duryea, designed for babies after weaning and before they start on a conventional diet. The product is based on the new breed of high lysine corn, developed at Purdue University, which has essential protein for babies

1/ Enno Hobbing, "Impact of Private Foreign Investment on Latin America's Scientific and Technological Progress", Council of Americas, 1971.

at that critical period of their development. The product costs the equivalent of 13.8 cents for ten feedings, and is in production in Colombia where it has already extended to an estimated 40 percent of the potential market. Colombia was selected in part because of its success in introducing high lysine corn into production and because of the active interest of the Government in the nutritional requirements of its population. Plans are now being worked out to set up production in Brazil.

Another area that is being actively explored is a soft drink with a protein content. Quaker Oats has set up an international soft drink department and has taken over the experimental distribution of a product which had been initiated by Monsanto Chemical Company in Guyana. The drink called PUMA is similar to the VITASOY beverage which was an early form of soft drink with a protein content developed in Hong Kong. The drink appears to have reached almost 30 percent of the population of Guyana with sales running into the millions of bottles. The Coca Cola Corporation is working out the first soft drink of this type that fizzes. It is called TAI, and has an orange flavor. The technology in carbonating a soft drink with a protein content was difficult. The product is now being market tested in Africa. It costs a little less than a bottle of coca cola.

Other food programs are under active consideration, involving the marketing of a protein additive for manioc, the development of low-cost foods from the soy bean, the development of edible protein from cottonseed meal, and the like. The oil companies have worked out methods for developing edible protein from petroleum, but as yet they have not found a technology for producing this at low-cost .

The oil companies have been interested in supporting research involving pesticides and fertilizers. Standard Oil of New Jersey developed a spray at its Linden, New Jersey, laboratory to combat the banana fly. The Standard Oil Company of California's local chemical group worked with a Colombian rice research group to develop applications of one of their pesticides to save the Colombian rice crop from devastation by the white leaf disease. In this connection, the multinational corporations have played a significant role in helping to

bring the results of research, not necessarily conducted in their own laboratories, to practical application in the developing countries. Fertilizer corporations fulfilled a key function in connection with the Green Revolution in bringing to the farmers the new high yield seeds, plus the fertilizers and expert guidance in the appropriate inputs and other techniques required to bring the seeds to successful fruition.

Another example of research relevant to the needs of developing countries are the techniques developed by petrochemical companies for controlling desert encroachment, of particular interest to countries bordering the Sahara desert. The Standard Oil Company of New Jersey conducted experiments in its laboratories in the United Kingdom on sand dune behavior as simulated in a wind tunnel, and developed a system for spraying oil as a sealant with favorable results in Libya in preserving young trees against sand storms. Other similar programs have been developed by other companies, but high costs still constitute a deterrent to widespread applications of technologies produced thus far.1/

Although examples such as the foregoing could be multiplied, the fact remains that there appear to be only isolated examples of industrial research, properly so-called, being conducted by multinational corporations in the developing countries, and comparatively few examples of research conducted in their own laboratories which are specifically directed toward problems of primary concern to the developing areas of the world.

New Environment for International Development

Over the past decade there has been a significant change in the environment for international development. Developed countries, formerly preoccupied with their own problems of recovery from World War II, are embarked on major assistance programs for the benefit of developing countries, so that the U.S. program, although still the largest, is no longer dominant in this area. The U.N. organizations have gained in experience and expertise in their work with the developing countries. The work

1/ Desert Encroachment on Arable Lands: Significance, Causes and Control, Office of Science and Technology, Agency for International Development, August, 1972.

of the donor countries, the multilateral financial institutions, the UN and other multilateral institutions, and the foundations have all contributed to substantial gains by the developing countries. As a result, the developing countries now have their own cadres of highly trained professional and technical personnel, and are showing a greater determination and ability to take charge of their own development programs. In consequence, the modes of operation of foreign assistance agencies give greater recognition to the developmental goals and priorities which the Governments of the developing countries are setting themselves.1/

The multinational corporations have played a significant role in helping to upgrade the managerial and technical skills which have contributed to the new international environment. The corporations are aware of the changes that have taken place, and many are seeking ways to respond to the concerns of the developing countries. Within some of the corporations this is being reflected in organizational changes. For example, the Dupont Company had been using the same staffs to handle all overseas operations. Now a reorganization is underway that will place under a separate staff the planning and development responsibilities for its products for the developing countries. This opens up greater possibilities for imaginative programs aimed at the markets in those countries and for greater sensitivity to the interest of those countries in strengthening their competence in the industrial research area.

If the multinational corporations are to play a greater role in supporting industrial research relevant to the requirements of the developing countries, other changes will probably be necessary. In the first place, market opportunities will need to be expanded for the products of such research. This will come about in due course as the developing countries achieve economic and social progress, and as incomes rise on a broader scale. There is scope, however, for developing countries to take measures at this time which will assure an adequate market for a given product or to work out cooperative regional arrangements to broaden and deepen such market opportunities. Secondly, reasonable inducements

1/ President Nixon, For a Generation of Peaceful Development, Message to the Congress, April 21, 1971.

will be required to encourage corporations to undertake the relatively high-risk and relatively long-term investment involved in industrial research. Finally, the multinational corporations will need a different type of managerial talent involved in their operations in the developing countries. It is only rarely that the current executives of their plants in the developing countries have the capability for organizing and directing first-class research operations.

It is clear, therefore, that if the burden of developing research capabilities within the developing countries is left entirely to the private sector, progress will be made very slowly. If more rapid progress is to be made, the developing countries will have to take measures themselves to create market opportunities for the products of research and to develop more rapidly their own capabilities in science and technology. To this end they should devote more resources to research and development themselves, and they need to concentrate their resources within the framework of a coherent and appropriate science policy that is reflected in education and training as well as in research.1/

Significant progress can be made in the area of adaptive engineering by Governments through skillful economic policies buttressed by the creation of appropriate governmental institutions with technical competence in applied science and industrial technology.

The area of industrial research is more difficult since this depends not only upon the availability of talented people, who already exist within the developing countries, but upon the healthy growth of institutions which is complex and can take place even under a favorable climate only over a relatively long time span.

This is an area where the United States and other donor countries have much to offer. If the developing countries, with increased institutional strength and a coherent strategy for building up their own scientific and technological capabilities, offer the multinational

1/ Report of the Commission on International Development to the President of the World Bank, Partners in Development, Praeger Publishers, 1969.

corporations adequate market opportunities and appropriate incentives for cooperative research programs, there is a good possibility that the unique strengths in the industrial research field of the multinational corporations could be brought to bear more widely and effectively on some of the critical and urgent problems facing the developing world.