# Case Studies of RD&E Performance in Materials Technology

Final Report

# CASE STUDIES OF RD&E PERFORMANCE IN MATERIALS TECHNOLOGY

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By

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# EXECUTIVE SUMMARY

In May, 1992, the Science and Technology Development Program of the Thailand Development Research Institute Foundation (TDRI) was commissioned by the National Academy of Sciences (NAS) to conduct a study analyzing research projects which had been supported by the Science and Technology Development Board (STDB) and the National Metal and Materials Technology Center (MTEC), in the specific area of materials technology. The study focuses on two aspects: case studies of individual research projects in materials technology, and the future directions which can or ought to be taken by materials technology in Thailand. This report presents the results of the case studies analysis.

A total of nine cases were selected for analysis, five in metals technology, two in ceramics, one in plastics, and one in rubber. Six of these projects were funded by MTEC, two were funded by STDB, and one was jointly supported. The cases were selected on the basis of being completed or nearly completed, showing potential for commercialization and utilization, and representing as wide a mix as possible of disciplines, institutions, geographical locations, and researchers. The cases were analyzed by a variety of techniques, including interviews with the principal researchers and other members of the research team, observations of prototypes or processes, literature reviews, etc.

In conducting the case studies, the researchers for this report were asked to evaluate five propositions regarding the RD&E process, namely:

1. Researchers can produce concrete results.
2. A strong technological infrastructure is crucial.
3. There is a lack of linkage between the supply and demand for RD&E.
4. The commercialization of RD&E requires appropriate policy, planning, and management.
5. RD&E projects may not have short term gains.

Even though the projects cover a wide range of disciplines and subjects, they collectively demonstrate support or lack of support for these propositions.

The results of the various research projects leave little doubt that concrete results can be produced. In the analysis of the nine cases, a total of 20 local publications, 3 international publications, 1 licensing agreement, several training seminars, 28 prototypes or new materials, 3 patent applications, 3 processes transferred to industry, and more than 100 student projects were produced. While these will qualify as "concrete results", there is obviously also a need to assess the quality as well as the quantity of results produced. Another significant result was the cooperation and interaction exhibited between various groups of university, government, and industrial personnel.

There is overwhelming evidence to support the proposition that the success or failure of a project hinges on technological infrastructure, including sufficient manpower, access to information, adequate budgets and budget management, stores and spare parts, and standards and testing facilities. The lack of maintenance and repair personnel frequently required researchers to spend their time doing maintenance. Inadequate infrastructure also placed significant burdens on the projects' budgets, as for example requiring heavy expenditures in overseas travel or communications due to lack of sufficient information resources at home.

The cases pointed out that there is often but not always a reasonable linkage between the supply and demand for RD&E. However, this linkage is most likely the result of long years of personal relationship building between individual researchers and industrialists, rather than as the result of any external or systematic policy. Industrial involvement at an early stage of the research project, particularly at the planning stage significantly increased linkages between researchers and users.

The commercialization of RD&E results clearly needs a policy and management, and it is most likely that the individual researchers will have neither the time, expertise, or inclination to oversee the commercialization aspects themselves. There has not been much effort expended by either the government or the private sector in commercializing RD&E results, and understandably those projects most likely to be commercialized are those which are supported by industry and which include an industrial liaison member from their inception.

Finally, depending on the nature of the project, there is evidence to support the statement that in some cases short term gains are possible (within one to three years), while in other cases ten or more years may be necessary to build up the technical expertise necessary to produce definitive gains from the R&D process. This depends on the way gains are defined, but certainly the production of manpower, increase in experience on the part of the researchers, and enhancement of technical capabilities count as "short term gains". However, for an individual to reach the point where he or she can lead and direct a research team will require ten or more years of experience, and must be considered a long term process.

The framework and structure under which RD&E is carried out is the responsibility of the Government and the National Centers, even if this policy is ultimately to encourage private sector participation in RD&E. It is clear that a strong, consistent, and understandable policy must exist for RD&E to be effective and benefit the country. This policy must incorporate all the various agencies and personnel connected with RD&E in Thailand. The policy implications and recommendations drawn from the case studies are:

1. RD&E projects which increase the processing level of raw materials produced in Thailand, increase the quality of raw materials produced, or provide a higher technological content in a product or process already in existence should be encouraged.
2. Information about the needs of local and international markets should be provided to RD&E workers.
3. Guidelines that will help RD&E workers produce concrete results should be implemented.
4. Adequate and realistic funds for RD&E projects should be provided.
5. Remuneration to RD&E workers must be sufficient to provide realistic incentives and attract qualified people.
6. Availability and quality of technical and information services should be increased.

7. Strong linkages between government agencies, academic institutions, and commercial enterprises should be encouraged.

Finally, the single most important implication and recommendation to arise from the case study process is that

8. The level of technical manpower at all levels and the quality of training and educational services available to produce technical manpower should be increased.

CASE STUDIES OF RD&E PERFORMANCE IN MATERIALS TECHNOLOGY

## LIST OF CONTENTS

## LIST OF FIGURE AND TABLES

# ACRONYMS

| | |
|---|---|
| ABS | Acrylonitrile-butadiene styrene |
| AHP | Analytical hierarchy process |
| A.I.D. | Agency for International Development, U.S.A. |
| CAD | Computer-aided design |
| CAE | Computer-aided engineering |
| CAM | Computer-aided manufacturing |
| CIM | Computer-integrated manufacturing |
| CNC | Computer numerical control |
| COST | Commercialization of Science and Technology Program |
| CVD | Chemical vapour deposition |
| D/RDS | Diagnostic/Research Design Service |
| EC | Executive Committee |
| ESCA | Electroscopy for chemical analysis |
| GDP | Gross Domestic Products |
| GNP | Gross National Products |
| HAp | Hydroxyapatite |
| IDS | Industrial Development Support |
| IMPLANT | Incentives for Modernization of Production and Loans for Application of New Technology |
| INVEST | Investment in New Ventures for Enhancing Science and Technology |
| ITRI | Industrial Technology Research Institute, Taiwan |
| JIS | Japan Industrial Standards |
| KMIT | King Mongkut's Institute of Technology |
| MBE | Molecular beam epitaxy |
| MIDI | Metal-working and Machinery Industries Development Institute |
| MIS | Management information system |
| MOST | Ministry of Science and Technology, Korea |
| MOSTE | Ministry of Science, Technology and Environment |
| MRP | Management Review Panel |
| MTEC | National Metal and Materials Technology Center |
| NCGEB | National Center for Genetic Engineering and Biotechnology |
| NECTEC | National Electronics and Computer Technology Center |
| NIC | Newly industrialized country |
| NIEs | Newly industrialized economies |
| NMR | Nuclear magnetic resonance |
| NRCT | National Research Council of Thailand |
| NSF | National Science Foundation, U.S.A. |

## ACRONYMS

| | |
|---|---|
| NSTDA | National Science and Technology Development Agency |
| OR | Operations research |
| P.I. | Principal Investigator |
| PIF | Project Initiation Fund |
| PVD | Physical vapour deposition |
| R&D | Research and development |
| RD&E | Research, development and engineering |
| RD&S | Research, development and survey |
| S&T | Science and technology |
| STAMP | Support for Technology Assessment and Mastery Program |
| STDB | Science and Technology Development Board |
| STP | Science and Technology Policy |
| STQC | Standard, Testing and Quality Control |
| STRDP | Science and Technology Research and Development Park |
| TAC | Technical Advisory Committee |
| TDIF | Thai Die Industry Forum |
| TDRI | Thailand Development Research Institute |
| TIAC | Technical Information Access Center |
| TISTR | Thailand Institute of Scientific and Technological Research |
| TPA | Technological Promotion Association (Thai-Japan) |
| TRP | Technical Review Panel |
| USAID | United States Agency for International Development |
| UST/COST | United States-Thailand/Commercialization of Science and Technology Program |

# CHAPTER 1 OBJECTIVES, SCOPE AND METHODOLOGY

## 1.1 RATIONALE AND OBJECTIVES OF THE STUDY

### 1.1.1 Rationale

The Science and Technology Development Board (STDB) was established with assistance from the USAID Science and Technology Development Project as a project under the Thailand Institute of Scientific and Technological Research (TISTR) of the Ministry of Science, Technology and Environment (MOSTE)* in 1985.

In the initial conceptualization of STDB, the goal was to strive for self-reliance in science and technology for Thailand by way of enhancing the extent and effectiveness of S&T applications in support of Thailand's social and economic development. The STDB Project had as its mission to help strengthen university and government research institutes' capacities and competency in science and technology, to provide technical support to industry, and to develop strong linkages between industry and university/governments research laboratories.

In line with the government policy to develop, in particular, three priority technology areas, STDB was to focus its efforts to solving specific problems in biotechnology, materials technology, and electronics, consistent with the government's goal and objectives in Science and Technology as stated in the Sixth Five-year National Economic and Social Development Plan (1987-1991). The STDB Project was primarily designed with the following four main activity areas:

1. strengthening the existing institutional framework,
2. review of S&T policy,
3. research, development and engineering (RD&E), and
4. industrial development support.

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* Formerly known as the Ministry of Science, Technology and Energy

According to the original STDB conceptualization plan, the seven-year cooperative initiative between the Governments of Thailand and the United States of America was planned to terminate in the latter half of 1992. USAID, taking into account a recommendation by a mid-term evaluation team, has agreed to a further two-year extension of the Project Assistance Completion Date, to September, 1994.

In addition to STDB, there are three other national centers established under the Office of the Permanent Secretary, MOSTE to function as specialized R&D agencies for each of the three priority technology areas in biotechnology, materials technology, and electronics. They are the National Center for Genetic Engineering and Biotechnology (NCGEB), the National Metal and Materials Technology Center (MTEC),* and the National Electronics and Computer Technology Center (NECTEC). In brief each national center acts as a funding and coordinating agency to facilitate collaboration among the government sector, universities, and private firms in developing Thailand's industrial technology and capacity in each of the three priority technology areas.

The STDB program and the three national centers have since evolved into important S&T resource institutions for the country. Their various activities provide numerous support and services, from identifying user needs and relevant S&T resources or supplies, to organizing or providing funding to address those needs. In view of its vital role for S&T development in the country, legislation of a Science and Technology Development Bill to establish a permanent institution was passed by the Parliament on 30 December, 1991. With the formal enactment of this bill, the National Science and Technology Development Agency (NSTDA) was born, and now operates freely as an independent institution. Under the Act, NSTDA will bring together under its umbrella the above four former institutions of: STDB, NCGEB, MTEC, and NECTEC.

Although an end-of-project final review of the STDB Project is forthcoming in 1994, the transformation of STDB into NSTDA, which brings under it the existing three national centers for the development of the three priority technology areas, is bound to have significant implications for the future S&T

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* Formerly known as the National Center for Metal and Materials Technology (NCMMT)

development in the country, particularly in these three areas of technology. It is deemed necessary at this juncture to undertake a partial review of the operations so far, so as to provide policy inputs for the reorganization and the future plan of NSTDA (including of course the three national centers). This 8-week study is conceived as a component of the intended review.

### 1.1.2 Objectives of the Study

The RD&E activity area constitutes by far the largest share of the work and funding undertaken by the STDB project, and likewise for the three national centers under review. This study therefore aims to review specifically some past RD&E projects undertaken in the area of materials technology based on case studies, and to learn lessons from the successes or failures of the selected projects. The case study will identify factors influencing the RD&E project outcome such as: procedure in selecting projects, quality of researchers, level of funding, appropriateness of subject, impact on industry, timeliness with regard to market, and project support systems. An account of the achievements attained by each RD&E project under study will be made including things that should have been done but were not. Findings from the case studies will also serve as an indicator of the RD&E capability which will affect the future potential of the materials technology industry in the country.

## 1.2 SCOPE OF THE STUDY

The scope of this study is as follows:

1. To conduct a literature review of the Office of the Science and Technology Development Board (STDB) and the National Metal and Materials Technology Center (MTEC) and to examine their conceptions and implementations.

2. To gather information and opinions with regards to the RD&E program, as well as other aspects, of operations of STDB and MTEC based on interviews with a number of administrators, researchers and industrialists familiar with materials technology from the above two, as well as other relevant, institutes.

3. To hold a workshop with participation by a group of stakeholders: high-level management staff from NSTDA, industrialists, academicians, and the research team, for the purpose of reaching a consensus for the selection of:

- five or more RD&E projects as cases for the study,
- the case-study questions and propositions, and
- case evaluation criteria.

4. To undertake an investigation of the cases selected for study with the major goals to:

- assess the outcome of the RD&E projects and identify various factors influencing the outcome,
- identify any major problems encountered, and if and how they were solved,
- delineate common lessons of successes or failures and the reasons behind such successes or failures, and
- draw policy implications from the case-study findings.

## 1.3 METHODOLOGY

The study involves a number of stages with major tasks and activities as follows:

1. An investigation into the status of RD&E in Thailand in the area of materials technology.
2. A detailed design of the case study method including propositions for the study, data collection, data analysis linking data to propositions, criteria for case evaluation, and case-study report writing.
3. Selection of at least five RD&E projects supported by STDB and MTEC as cases for the study.
4. Conducting case studies according to the case-study design set out in (2).
5. A presentation of the case-study analysis, common lessons learned, and policy implications from the findings by means of a workshop and formal report.

An account of the RD&E status in material was made through various means, including a review of records of the Office of STDB and MTEC, other literature surveys and interviews with relevant administrators, industrialists, and academicians.

The process of picking appropriate propositions for the case study and the choice of case evaluation criteria were carried out through a workshop to seek consensus among stakeholders consisting of the research team, high-level management staff from NSTDA, and some external experts from academia and industry, while the selection of five or more RD&E projects as cases to be studied was done by consultation between the study team and NSTDA's officials. Where necessary, the Analytical Hierarchy Process (AHP) was employed as a tool to expedite and systematize the selection of propositions, case evaluation criteria and cases for the case study.

Based on the framework set out by the case-study design and the outcome of the workshop on the case-study propositions and evaluation criteria, the research team proceeded with the next stages of the case-study, namely, collecting the evidence, analyzing the evidence, and composing the case study report. Sources of evidence include RD&E project proposals and reports; physical evidence like a sample, device, or a prototype; field visits to the RD&E project site; interviews of RD&E project researchers/investigators; users of RD&E results; and any other relevant sources.

In analyzing the findings from the case studies, common lessons of successes and failures of RD&E performance were derived, and together with the current status of RD&E in Thailand, policy implications for RD&E in the area of materials technology were drawn up.

Results from the above study were presented at a workshop to a number of stakeholders. This workshop served as a forum to discuss the findings and obtain further inputs for improvement. It also served to provide background information to the group of participating stakeholders to assess the future potential of materials technology in Thailand and to derive appropriate strategies for realizing this potential.

# CHAPTER 2 CASE STUDY TECHNIQUES AND EVALUATION CRITERIA

## 2.1 CASE STUDY TECHNIQUES

Traditionally, there are prejudices against case study techniques concerning lack of rigor, difficulty of generalization and time consumption. Professor Robert K. Yin[*] has clearly demonstrated that all these prejudices can be overcome through careful research design and execution. Therefore, we decided to closely follow Dr. Yin's procedure to make sure that the case studies conducted by our investigators could be thorough and compatible so that common lessons could be drawn afterwards.

The first task was to define the research questions, which are "how" and "why" questions, to explain certain phenomenon that we are interested in answering. But these questions did not point to what we should study. The second task was to formulate propositions which would help focus the attention of the investigators to certain data, while ignoring others. The propositions reflect important theoretical issues that were to be proved or disproved by the case studies and, therefore, form the basis for generalization.

In this study, multiple case studies were used to investigate a number of RD&E projects at the project level. The number of cases need not be large for we were using replication logic instead of sampling logic for generalization. Replication logic is analogous to that used in repeating certain critical scientific experiments and is not the same as sampling logic where a number of samples are assumed to represent a larger pool of a population. However, each case was carefully selected to serve a specific purpose within the overall scope of inquiry.

In conducting the study, the investigators prepared a case study protocol consisting of an overview of the case study, field procedures, case study questions and a guide for the case study report before venturing out to

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[*] Robert K. Yin, "Case Study Research: Design and Methods", Applied Social Research Methods Series, Volume 5, SAGA Publications, U.S.A., 1989.

collect data. In collecting data, they looked for as many sources of evidence as possible. In our case, sources of evidence were mainly comprised of documentation, interviews, direct observation, and physical artifacts. The investigators collected documents such as project proposals, interim reports and working papers, final research reports, published papers and articles, correspondence between the research team and its sponsors, and minutes of relevant committee meetings. The interviews were conducted with the research project leader, collaborative researchers, and other stakeholders of the case projects studied. Identification of and interviews with users undoubtedly constitute a very important component. Various field visits to research project sites provided investigators with certain insights necessary to make judgements, especially on intangible aspects. In addition, observation of the research products such as a prototype in action were most valuable.

In data collection, care was exercised in checking the consistency of the data from multiple sources. A database was created for data storage and retrieval. Finally, investigators developed a logical chain of evidence of each case studied in order to support their findings and recommendations.

The analysis of the case study evidence focused on the theoretical propositions. The dominant mode of analysis was pattern matching. In addition to the analysis of individual cases, the report contains a section on cross-case analysis and policy implications derived from the analysis.

## 2.2 PROPOSITIONS AND CRITERIA FOR EVALUATION

In this study, our task was to evaluate nine research projects in materials technology which were supported by STDB and MTEC. Due to time constraints, a number of activities were conducted in parallel rather than in serially consecutive order. The case selection was done by consultation between the study team and NSTDA's officials. Two projects were selected from STDB, and six projects were selected from MTEC, and one project which was jointly funded were selected using the following criteria:

1. The project had been completed or was almost complete.
2. It had potential for commercialization and utilization.
3. The selected projects represented a mixture in terms of subject matter, experience of institutions, geographical locations, physical infrastructure, personnel, and research personnel.

On June 3, 1992, a workshop was organized between NSTDA's officials, researchers, and some industrialists to come up with the propositions for the case study. The researchers proposed five propositions and NSTDA an additional three. The 33 participants were also asked to suggest additional propositions, by writing one each on cards which were distributed with no limitation as to the number of propositions they could suggest. Each proposition was then read out and similar ones were grouped together. Further iterations were made to reduce the number of propositions to a minimum. Finally, it was agreed to focus on the five propositions described below:

1. Thai researchers are capable of being accountable in terms of concrete results. Obviously, not all Thai researchers can do so. There are complaints of a lack of professionalism and devotion on the part of some. The task of the investigators here was not only to verify the statement of the proposition in their case studies but also to look for the "how" and "why" as to why certain groups of researchers succeed while others do not. There were suggestions that the full impact of research depends on the results of several related projects, requires multi-disciplinary inputs, and invariably needs a large number of RD&E man-hours. Others think that RD&E has not been linked to the advanced education system, there is no career path for researchers in universities, and the lack of creativity can be traced down to their primary and secondary education whose ultimate goal is to pass a university's entrance examination rather than encouraging independent and analytical inquiry.

2. RD&E cannot be achieved without a strong technological infrastructure which comprises manpower, physical research facilities, suppliers, technical and information services, financing mechanisms, laws and regulations, and organizations to support RD&E. Here, the investigators assessed the impact of a lack of certain types of infrastructure on RD&E performance. In the workshop, the participants expressed concerns on financial support from

the government, fiscal incentives for RD&E, and monetary reward and social status for RD&E personnel.

3. RD&E can be better linked to the country's present social and industrial needs. This proposition deals with the demand and supply of RD&E as well as the linking mechanisms at various stages of development. From the supply side, researchers do not know the country's needs for technology. The demand side is more complex. There is no clear demand or commitment from the private sector on RD&E. Is it that the private sector is not aware of local S&T capabilities? Or is it due to the overconcern with secrecy by some Thai industrialists that prevents more direct communications with local S&T personnel?

4. Commercialization of RD&E needs policy, planning and management. Participants complained of there being little policy, unclear policy, and the inability to link policy with implementation. Some advocated for a policy directive in which research must lead industry while others thought that RD&E could be more effective if coupled with international technology transfer activities emphasizing absorption, adaptation and application of conventional technologies. In this case, the investigators will see how the policy and planning and management of an RD&E project from the conception of the research idea to the completion of the project and beyond, affect the successful rate of commercialization.

5. There are no short-term gains from RD&E projects though there are possible long-term gains. This proposition arises from the concern that the benefits from RD&E should not be limited to short-term, direct and tangible gains. RD&E capabilities will most likely be built up in stages. In the initial stage, the impact of RD&E may reside primarily in human resource development. Even a successful RD&E project will require a long gestation period before real economic and social impact can be felt. Here, the investigators will look for both short-term and long-term gains from the RD&E projects.

The participants decided to give each proposition equal weight. Therefore, they were not ranked by the Analytic Hierarchy Process (AHP) (see APPENDIX 2.1). In the second session, workshop participants were asked to propose criteria to evaluate the five propositions on cards. Similar ideas were combined. The lists of criteria were compiled and are shown in APPENDIX 2.2.

A closer look at the list may reveal that not all of them are actual criteria. Some sound more like recommended actions. They are, nevertheless, included for the sake of completeness.

The criteria to evaluate the first proposition which deals with the capability of Thai researchers can be divided into three categories. The first category concerns academic achievements like number of papers published, knowledge gained and skill enhanced. The second links the capability to the working environment of the researchers. Surprisingly, quite a number of criteria fell into the third group which tends to see utilization as the ultimate measure of successful research.

The criteria for the second proposition spells out what the participants regarded as technological infrastructure. The criteria can be grouped into eight categories, namely manpower, physical research facilities, suppliers, technical services, finance, law and regulations, institutions, and others. As for manpower, physical research facilities, suppliers, and technical services, the number and quality may be used as indications of their adequacy. Finance is not limited to the level of funding, but also how the money is used to fund various aspects of the research. Some funding laws and regulations can be real hindrances to R&D, but at the same time R&D organizations need good management as well as linkages to other institutions. The last group of criteria mostly deals with intangibles like research atmosphere, specialized experience accumulated through length of time and number of related projects, etc.

The third proposition is on the supply and demand of RD&E including their linkages. Here, the criteria to evaluate the supply of RD&E are much more practically oriented than the ones for the academic achievements of researchers in the first proposition and hence more difficult to quantify. Demand is even less clear. Perhaps one of the best indicators for supply, demand as well as linkage is the number and size of RD&E projects funded by the private sector.

The fourth proposition concerns policy and management for RD&E commercialization. It is divided into three categories, namely, policy, management, and institutions. We may look at the existence of policy for RD&E promotion as well as its effectiveness, the efficiency of project management, and the institutional framework to support RD&E.

The fifth proposition tries to measure gains from RD&E from a broader perspective. Criteria are divided into concrete results, indirect results and time considerations. The concrete results are tangible and visible including both academic, economic and industrial ones. The indirect results are by products of RD&E, and sometimes are quite tangible. Each item of concrete and indirect results may need a different time period (time constant) to filter through the complicated socioeconomic system to materialize.

This workshop received favorable feedback from the participants. They thought that the card technique allowed them to express their ideas in parallel and without hindrance. The intensity of communication was much higher than the traditional "one speaker at a time" approach. Thus, an atmosphere of participation was created.

## APPENDIX 2.1

## ANALYTICAL HIERARCHY PROCESS (AHP) METHOD

### 1. INTRODUCTION

In the ten years since its introduction, the AHP has been used by decision makers to gain insight into a wide variety of complex, costly, and important decision problems. Golden, Wasil, and Levy provide over 150 reference papers that apply the methodology in 29 different areas, ranging from health care to space exploration. While many of these papers apply the AHP to real-world problems, few provide detailed insights into the practical considerations that users (such as the conductors) must address in order to facilitate a successful decision-making process. Thus, this paper is to review the decision-modeling process when applying the AHP to successfully solve problems.

### 2. STEPS IN USING THE AHP

In using the AHP, a single decision maker or a group usually proceeds from problem identification, through an assessment of alternatives, to the final selection of a course of action. The overall process consists of the following ten steps.

Step 1: Define the Problem

It is important to establish whether the decision problem concerns allocating resources, choosing the best alternative, or planning a future course of action. Once this is clearly defined, the conducting team could provide advice about a workable structure for the problem. A workable structure must cover all factors and must properly relate alternatives to objectives, possibly through an intermediate level of criteria. Members of the conducting team with experience in applying the AHP and a Management Information System/Operation Research (MIS/OR) background usually possessed the skill required to determine the general outline of a hierarchy that was appropriate for a problem.

Step 2: Select the Decision Group

The conductors assist the client in selecting a decision-making group. This group could include senior decision makers, technical staff, and advisors (from outside the department or organization) with an external perspective about the problem. It is important to select a group which collectively has the necessary expertise and information to "attack" the decision problem. Sometimes external advisors would be clients of the organization which the decision is intended to benefit. Furthermore, if the decision must stand up to outside scrutiny, it may be essential to include potential adversaries in the group. Typically, groups consist of six to twelve members but larger groups were also used. We point out that the decision-making process is more "efficient" (mainly faster decisions) in the smaller groups (12 members or less). However, "effective" decision making (acceptance of the final decision and easy implementation) often requires a large group so that all stakeholders could be represented.

Step 3: Identify Issues and Objectives

The first task of the group is to identify the issues and objectives which need to be considered in the decision. This step is important since it solidifies the group with a specific decision-making, problem-solving focus. The conductors assist by facilitating the identification of important factors, by recording them, and by preparing draft definitions of them in written form. The conductors are continually funneling written materials to the group so that details are documented and potential problems over semantic issues are averted. This allows the group to focus on the task of generating pair-wise comparison matrices for the criteria and alternatives.

Step 4: Develop the Structure of the Hierarchy

The decision-making structure is an organized, hierarchical depiction of the decision problem in terms of the choices to be made, the objectives that are to be pursued, and the interests and criteria that must be taken into account. It is constructed by the group with the help of the conductors.

Step 5: Judge the Importance of the Decision Factors

Once a workable decision-making structure has been established (i.e., a structure that covers all factors and models the problem), the next step is to judge the importance of the decision factors. Factors are evaluated in a pair-wise manner. Decision makers are asked to verbally judge two elements in terms of their importance to the objective to which they contribute. The verbal judgments are then converted to a numerical scale and entered into a computer program that performs the mathematical calculations and produces a set of weights. Woods Gordon developed a mainframe computer package which is used on time sharing for very large hierarchies. This program contains several features designed to tally scores for projects with a large number of alternatives. The Expert Choice microcomputer package is used for problems that contain a smaller number of criteria and alternatives. We should point out that factors shown to have little importance can be dropped at this stage of the process.

Step 6: Evaluate Alternatives

The decision alternatives that appear at the bottom level of the hierarchy are compared by the decision-making group.

Step 7: Report on Results

The judgements of the group are synthesized and the overall priorities of the alternatives are calculated.

Step 8: Check Reasonableness

The group must allow time for consideration of the reasonableness and implications of the AHP results. It is possible that some of the results may not seem appropriate once the decision makers have "stepped back" from the element by element evaluation and have had time to consider the results of the process. It is important to provide an opportunity for the decision makers to think through and understand the implications of the decision and, if necessary, to revise the process. For example, a revision is necessary when a key decision factor has been omitted or the hierarchical structure fails to take into account an important consideration. The group would then "backtrack", that is return to earlier steps in the decision process and revise judgments, factors, or alternatives. This step also allows the group to recover from any "buyer's remorse" about the final decision. The consultants were always willing to address any criticisms about the analysis so that the group would realize that the final results were sound and not the result of some mysterious decision process.

Step 9: Finalize Choices

Once the reasonableness of the results has been carefully checked, the decision-making group convenes to resolve any outstanding issues and to finalize their decision.

Step 10: Documentation

The final step involves documenting the decision-making process. It helps to reinforce the soundness of the approach and also allows the group to easily review the process should the problem's characteristics change. A formal report would be drafted that states the definitions of decision factors, includes judgments about the factors and their importance, and documents the underlying rationale of the selection process. The report ranges in length from 20 pages to over 200 pages depending on the complexity of the project. Initial drafts of the report are circulated during the actual decision-making process and the report continues to evolve in the form of handouts for the workshop sessions. After the decision process is finished, the document usually requires only minor editing before it is completed.

A full project that followed these ten steps would last about eight weeks. This assumes three workshop sessions with the decision group. The first workshop is held in week 2 or 3 to identify broad issues and objectives. The second workshop, which occurs in week 4, is the main decision-making session in which the group would develop the hierarchical structure, judge the importance of the decision factors, and evaluated the alternatives. For a problem with a large number of criteria and alternatives, this session could span two days. The final workshop occurs in week 7 and is devoted to reviewing the results of the group's deliberations and to finalizing the group's decision.

## APPENDIX 2.2

## CRITERIA FOR EVALUATION OF THE FIVE PROPOSITIONS

Proposition 1 — Researchers can provide concrete results

a) Academic
- Number of papers published
- Number of seminars given
- Number of grants received
- Number of citations
- Number of M/Ph.D. graduates
- Prototypes (products and processes)
- Quality manuals
- Problems solved, knowledge learned, experience gained
- Knowledge learned applicable to university's teaching
- Adaptive and innovative steps
- RD&E results meet proposal objectives
- Expert judgement

b) Environment
- Background of researchers
- Commitment and devotion of researchers
- Physical research facilities
- Research atmosphere

c) Utilization
- Economic returns
- Number of patents
- Marketable products
- Potential for export
- Benefits to end users (agriculture and industry)
- Social impact
- Technological spill-over
- Strategic research needs

Proposition 2 — RD&E needs technological infrastructure

a) Manpower
- Research staff (Number and quality)
- Number of M/Ph.D. graduates
- Researcher's work load and types of duties
- Number of technicians/research assistants
- Training and coaching of researchers

b) Physical research facilities

c) Suppliers
- Suppliers of parts and components
- Supporting industries
- Time taken for equipment acquisition

d) <u>Technical services</u>
- Information on modern technology
  (literature, computer database access)
- Standards and testing capability
- Established S&T indicators (statistics)

e) <u>Finance</u>
- Level of funding
- Remuneration to researchers
- Rewards
- Bureaucracy in grant management

f) <u>Laws and regulations</u>
- Intellectual property protection
- Import tax on research equipment and supplies

h) <u>Institutions</u>
- Management of organizations
- Cooperation between laboratories and institutions
- Linkage between industry and know-how centers
- Strong graduate study program

i) <u>Others</u>
- Research atmosphere
- Related projects
- Length of time in research in an area of expertise
- Division of labor based on expertise
- Geographical location
- Government support for S&T

<u>Proposition 3</u> RD&E lacks supply, demand and linkage

a) <u>Supply</u>
- Solution to problems, application-oriented
- Technology transfer component
- Selection of research topics
- Benefits to end users
- Number of papers published
- Number of works with private sector
- Number of patents (sold)
- Prototypes
- Consultancy

b) <u>Demand</u>
- Size of market
- Private sector participation
- Competitive pressure to induce demand for technology
- Tax incentive for RD&E in industry
- Clear private sector demand
- Number and size of R&D projects funded by private organizations
- In-house capabilities of production enterprise

c) Linkage
- Researchers are bad salesmen
- Build up of linkage organization
- Economic incentives for linkage
- Coordination with other research groups
- Manufacturing associations to promote linkages
- Advertisements of real problems and skills available
- Understanding, collaboration and intensity of communication between researchers and private company

Proposition 4 Commercialization needs policy and management

a) Policy
- Clear policy
- Tax as an obstruction
- Integrating policy with implementation
- Existence and effectiveness of policy and management organizations
- Clear understanding of RD&E objectives
- Explicit RD&E policy of private sector
- Incentive to commercialize local RD&E work
- Government committing reliable financial support to project with well-defined goals and realistic time frames

b) Management
- Project management
- Marketing and business strategy
- Private sector participation
- Cost-benefit ratio
- Comparative earnings between professionals
- Bureaucracy in grant management
- Strong leadership
- Response to private sector demand
- Closely monitor targets of R&D project
- Understand industrial and social needs
- Understand R&D process and product innovation
- Inadequate use of liaison personnel
- Exposure of prototypes and researchers to public
- Procedure that research and industry must go through in order to commercialize
- Involvement of high-ranking government officers in promoting commercialization
- Convince industry to exploit RD&E for commercialization

c) Institution
- Pragmatic support program in commercialization
- Improve support industries
- Commercialization organization required

Proposition 5 No short-term gains from RD&E

a) Concrete results
- Patents, royalties, licensing agreements
- Marketable products
- Demand from users
- Economic value
- Number of papers published
- Improved products/processes

b) Indirect results
- Number of students in the research project
- Number of new researchers
- Knowledge learned and transferred
- Creditability
- Publicity
- Capability strengthening
- Researcher-user linkage

c) Time considerations
- Time span taken to commercialize RD&E results
- Depth of knowledge gained as a function of time
- Size of research team as a function of time
- Potential for future benefits
- Size or complexity of technology
- Nature of RD&E projects (e.g. adaptive VS innovative)
- Categorization of research types (eg. basic, applied, development)
- Short-term gain should not be emphasized but human resource development and research quality should be concentrated on.
- Short-term gain possible if research is problem-oriented
- Market size for expected RD&E output

# CHAPTER 3 RD&E IN THAILAND

## 3.1 AN OVERVIEW OF R&D IN THAILAND

Many countries, particularly the industrialized countries and the newly industrialized countries have invested up to 3% of their GNP annually for R&D. The reason is clear and simple: R&D is essential to create strong capabilities in high technology and manufacturing in order to generate wealth and a high standard of living for their citizens.

### 3.1.1 The Case of Super Economic Powers

Consider the country in the world with the highest standard of living and the highest total GNP, the U.S.A. The U.S. National Science Foundation (NSF) estimated that in fiscal year 1990, the U.S. would spend about US$ 150 billion for R&D in all fields, or about 2.8% of the country's GNP. That amount alone represents about two times Thailand's total GNP in the same year. In a recent NSF report, the U.S. had 77 full-time R&D professionals per 10,000 people in 1988, which translated into nearly 2 million personnel working on R&D in the U.S.[1]

Contrary to what is generally seen and believed among developing countries, Thailand included, private sector firms in most industrialized countries take a much bigger share in R&D expenditures than do governments. Most companies set aside a substantial portion of their sales revenue for R&D, either for in-house R&D laboratories or for contracting out to independent research organizations. The shares of revenue to be used for R&D expenditures are particularly high in rapidly advancing technologies and high-growth industries such as biotechnology, advanced materials, and electronics. Take the case of electronics, for example. Many top electronics companies are spending a high percentage of their revenues, far in excess of the overall average of 3% of their countries' GNP, on R&D, as Table 3.1 clearly shows.

Table 3.1 Top Electronics R&D Spenders in Relation to Sales

| Country | No. of Companies | R&D Expenditure (US$ millions) | Sales (US$ millions) | Percent of Sales |
|---|---|---|---|---|
| Canada | 3 | 727 | 5,448.0 | 13.3 |
| France | 5 | 3,755 | 40,499.0 | 9.3 |
| U.S. | 52 | 44,146 | 546,038.4 | 8.1 |
| Germany | 12 | 8,759 | 128,379.7 | 6.8 |
| U.K. | 7 | 2,346 | 36,111.1 | 6.5 |
| Japan | 22 | 16,854 | 280,305.8 | 6.0 |

Source: Compiled based on Elsevier Advanced Technology data cited in IEEE Spectrum, October 1990.[1]

IBM Corp. of the U.S. spent US$ 44 billion or 8.1% of sales on R&D in 1989, while Siemens AG of Germany spent US$ 8.7 billion or 6.8% of sales, and Philips of Netherlands US$ 2.3 billion or 8.2% of sales for R&D. Some of the R&D expenditures that companies spend are so huge that they amount to a considerable percentage of a nation's R&D budget. For example, Thomson-CSF's R&D budget in 1988 represented 43 percent of France's total R&D budget for electronics, and 5.5 percent of the country's total R&D budget.[1]

While it is hard to establish firmly a direct relationship between R&D and subsequent profit growth, one thing can be certain. That is that R&D is a vital source of innovation, and less innovative firms are likely to be less competitive, particularly in high-tech industries and services.

### 3.1.2 A Look at South Korea and Taiwan - the NIEs of Asia

Many newly industrialized and developing countries such as South Korea, Taiwan, Brazil, India and China are focussing considerable efforts on R&D in certain areas important to their industrial structure and social-economic development.

In South Korea, there are currently at least 12 national research institutes under its Ministry of Science and Technology (MOST). Many of them were formerly under various other ministries and had played an important role in the country's technological development and industrial growth. They were later regrouped in 1981 under MOST when the government saw that further development in a number of strategic industries increasingly demanded high technology and large-scale multidisciplinary R&D projects. Hence, a reorganization of the country's R&D resources was necessary. Throughout the 1980s, these national research institutes actively collaborated with the private sector to undertake national R&D projects aimed at resource saving and strengthening the country's international competitiveness. The South Korean government provided between 50 to 70 percent of these projects' funding while the private sector shared the rest. The number of these national R&D projects grew from just 25 in 1982 to 54 in 1985, and then to 151 in 1989 [Source: MOST, Korea].

In addition to these national R&D institutes, the government has encouraged the private sector to set up its own in-house research laboratories through tax incentives and financial assistance.

Several large and modern research laboratories that could rival those of national research institutes in scale and resource exist today among many of South Korea's Chaebols (conglomerates). As a whole, the total amount of annual R&D expenditures that the country has invested increased rapidly from just US$ 7.7 million in 1965 to US$ 480 million in 1980, and to US$ 3,870 million in 1988, an increase of over 500 times in just a little over two decades. In 1988, South Korea's R&D expenditures represented about 2.1% of its GNP of which the private sector shared up to 75% of the expenditures. In the same year, the country had some 56,500 researchers working in over 2,800 research institutes, representing a ratio of 13 researchers per 10,000 people (see Table 3.2).

Likewise, the Taiwanese government has actively promoted applied research and technology development through a number of state R&D institutes, which include among others 36 research institutes under the Ministry of Economics and 4 under the Ministry of Communications, in addition to basic research activities among the country's Academia Sinica and universities. As in Korea, Taiwan has also encouraged private firms and state enterprises to set up their own in-house research laboratories to develop their products and services.

Table 3.2 A Comparison of R&D Infrastructure among Korea, Taiwan and Thailand

| | Korea | Taiwan | Thailand |
|---|---|---|---|
| Population | ('90) 43.0 M | ('90) 20.2 M | ('90) 56.6 M |
| GNP per Capita (in US$) | ('90) 4,968 | ('90) 7,990 | ('90) 1,191 |
| GNP growth % | ('90) 6.8% | ('90) 5.2% | ('90) 10% |
| Inflation CPI | ('90) 9.4% | ('90) 4.1% | ('90) 6.8% |
| Student graduate (S&T) | | | |
| Ph.D | ('89) | ('87) 249 | ('90) 5 |
| M | 19,429* | 4,103 | 525 |
| B | NA | 38,829 | 5,076 |
| S&T Researchers | ('88) 56,500 | ('88) 35,437 | ('89) 4,084 |
| per 10,000 population | 13.0 | 17.8 | 0.74 |
| per 10,000 persons in labor force | 27.0 | 41.8 | 1.3 |
| R&D Investment (in US$) | ('88) 3,870 M | ('88) 1,559 M | ('89) 114 M |
| % of GNP | 2.10 | 1.22 | 0.17 |
| share of private R&D | 74.5% | 43.2% | 5.53% |

Note: * Figure represents combined Ph.D. and Master degree enrolment
Source: 1. MOST, Korea
2. Taiwan Statistical Data Book, 1989
3. National Research Council and NESDB, Thailand

Notable among the government's research institutes is the Industrial Technology Research Institute (ITRI), a good example of the government's initiative in assisting Taiwan's industrial sector. In particular, ITRI aims to help small and medium-size industrial firms become competitive through the provision of technical services, training, and contract research for the private sector. As an indication of the extent of R&D in Taiwan, Table 3.2 shows that in 1988, the country invested US$ 1,559 million or 1.2% of its GNP for R&D of which 43% came from the private sector. In the same year, there were over 35,400 researchers representing some 18 researchers per 10,000 of the population, a ratio higher than South Korea in the same year. According to ITRI, by 1995, the country's R&D investment should increase to 2% of GNP with the private sector share rising from 40% a decade ago to 60%, while the number of S&T researchers is expected to increase to 43,000 or some 20 researchers per 10,000 persons. Such is the extent and emphasis which both South Korea and Taiwan have placed on R&D investment, private sector participation, and infrastructure (such as government sponsored research institutes and an adequate research personnel), in support of their social and industrial development, targeting specially the strategic high technologies appropriate to them.

### 3.1.3 Thailand: Still to Get Its Act Together

In Thailand, the country has developed very little technology and technological capacity for its industries so far, except perhaps in its agro-industry sector. Most of the country's R&D activities have focussed mainly on agriculture, social development and medical and public health.

The extent of technological development, or more appropriately a lack of it, is best illustrated by taking by a look at some indicators of R&D expenditure and distribution, as well as the amount of payment for foreign technology acquisition.

As shown in Table 3.3, taken from a TDRI study,[2] the breakdown of research, development and survey (RD&S) budgets classified into areas of development confirms the expected emphasis of research toward agriculture, which clearly led other areas. With the exception of 1987 at only a 28% share, the research budgets allocated to agriculture ranged from one third to over half of the country's total budget in RD&S during the decade from 1978 to 1987. It is only in recent years that industry and energy, natural resources, public health and social development have assumed a somewhat more significant proportion of the RD&S budget. As a percentage of GNP, Thailand's total RD&S expenditure ranged from a meager 0.18 percent to 0.40 percent. If one should take away the survey component, which could vary widely from year to year from as little as 10% to over 30%, the R&D expenditure would represent an even smaller percentage of the country's GNP, and the share of R&D in agriculture would be more pronounced.

Table 3.3 R&D and Survey Budget of the Whole Country by Area of Development (million baht)

| Area of Development | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture | 797 | 559 | 661 | 1,024 | 1,097 | 920 | 1,783 | 1,464 | 1,188 | 734 |
| Industry & Energy | 109 | 131 | 141 | 248 | 147 | 128 | 717 | 783 | 573 | 223 |
| Natural Resource | 2 | 2 | 3 | 151 | 51 | 17 | 31 | 370 | 534 | N.A. |
| Environment & Conservation | 15 | 25 | 22 | 29 | 25 | 54 | 16 | 109 | 50 | N.A. |
| Commun & Transport | 48 | 64 | 107 | 170 | 172 | 68 | 51 | 46 | 27 | 2 |
| Science & Technology | 101 | 97 | 82 | 208 | 175 | N.A. | N.A. | N.A. | N.A. | 314 |
| Medicine & Public Health | 79 | 121 | 87 | 74 | 117 | 130 | 105 | 178 | 225 | 218 |
| National Defense | 137 | 164 | 200 | 222 | 824 | 0 | 42 | 16 | 14 | 59 |
| Social Development | 43 | 37 | 44 | 145 | 183 | 86 | 280 | 99 | 164 | 575 |
| Education, Religion & Culture | 21 | 23 | 9 | 52 | 175 | 35 | 87 | 128 | 210 | 181 |
| Other Areas | 116 | 108 | 151 | 226 | 305 | 217 | 183 | 280 | 160 | 360 |
| Total | 1,468 | 1,331 | 1,507 | 2,549 | 3,271 | 1,655 | 3,295 | 3,473 | 3,145 | 2,664 |
| (as % of GNP) | 0.32 | 0.24 | 0.22 | 0.33 | 0.40 | 0.18 | 0.34 | 0.35 | 0.30 | 0.22 |
| (as % of National Budget) | 1.81 | 1.45 | 1.38 | 1.82 | 2.03 | 0.94 | 1.72 | 1.66 | 1.44 | 1.17 |

Note: 1) 1978-1983 From National Budget Alone
2) 1984-1987 From National Budget and Outside Funding
3) The 1987 figure does not include the survey budget

Source: National Research Council
From MOSTE (1987)

The dependency on foreign technology is clearly reflected by the Ministry of Science, Technology and Environment's statistics on the remittance for the licensing of foreign technology of Table 3.4. During the period from 1982 to 1989, the country experienced a steady rise in technology acquisition at an average growth rate of 20.6 percent from 1,433 million baht in 1982 to 5,334 million baht in 1989. The rising trend is most rapid in 1988 and 1989 corresponding to the rapid expansion of the economy resulting partly from the rapidly expanding manufacturing sector. During the three consecutive years from 1988 to 1990, Thailand had the highest economic growth in the world with an unprecedented average rate of 11.0 percent in real terms. Given the country's weak state of technological development, which is unlikely to improve soon, Thailand can be expected to remain largely dependent on foreign technology, at least into the near future. This will thus remain a significant drain on the country's foreign exchange earnings.

Table 3.4  Remittance for Foreign Technology Licensing

(Unit : Million baht)

| Year | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|
| Amount | 1,433 | 1,611 | 1,954 | 2,022 | 2,036 | 2,383 | 3,440 | 5,334 |
| Growth | - | 12.4% | 21.3% | 3.5% | 0.7% | 17.0% | 44.4% | 55.1% |

Source: Ministry of Science, Technology and Environment

Regarding the state of R&D infrastructure in Thailand, it is not difficult for one to draw some quick conclusions by comparing a number of vital statistics with South Korea and Taiwan, as is shown in Table 3.2. Although both South Korea and Taiwan are already newly industrialized economies (NIEs) while Thailand is not, still such comparisons can most certainly be useful for Thailand to learn what it may take to gain and "assume" the status of the next NIE of Asia. One message from the exercise ought to be that Thailand must get its act together to shore up its R&D infrastructure and capability, and soon.

From Table 3.2, in terms of R&D investment, Thailand spent a meager US$ 114 million on R&D (1989) compared with US$ 1,559 million for Taiwan (1988) and US$ 3,870 million for South Korea (1988), or as percentage of GNP the ratios are 0.17% for Thailand, 1.22% for Taiwan and 2.10% for South Korea. Shares of private sector R&D funding were around a mere 5.5% for Thailand (1989), while it was 43% for Taiwan (1988) and 75% for South Korea (1988).

In terms of researchers, Thailand had some 4,084 or less than 1 researcher per 10,000 persons in 1987 as against over 35,400 or about 18 per 10,000 persons for Taiwan in 1988, and 56,500 or 13 per 10,000 persons for South Korea in 1988. The figure for Thailand was computed by the National Research Council (NRC) as full-time equivalent researchers, since many of them are not working full-time in doing research. Thus, Thailand's number of researchers needs to be qualified by additional factors such as the efficiency and devotion of researchers and the overall research environment.

Perhaps the most important factor of all which is likely to undermine its R&D capability could potentially come from the number of science and engineering graduates, particularly postgraduates, which Thailand is capable of turning out per year. In 1990, the country produced only 5 PhDs, 525 master-degree holders and 5,076 bachelor-degree graduates. This is in stark contrast with Taiwan, a country with less than 40% of Thailand's population but which turned out 249 Ph.D. holders, 4,103 master-degree and 38,829 bachelor-degree graduates in 1987. The conclusion here is clear: no matter how the country may increase its future investment in R&D, comparably good results will be difficult to achieve without adequate and well-trained R&D personnel. To this end, the efforts of STDB and the three national centers in providing scholarships to train postgraduate students in the three priority areas in biotechnology, materials technology and electronics is both timely and praiseworthy. However, it is doubtful whether their efforts alone are sufficient to overcome this potential bottleneck the country faces in its path to becoming the next NIE of Asia.

## 3.2 THE ROLES OF THE SCIENCE AND TECHNOLOGY DEVELOPMENT BOARD (STDB)

### 3.2.1 The Establishment of STDB

The Science and Technology Development Board (STDB) came into existence in July 1985 with the appointment of the STDB Board of Directors. The establishment of STDB was essentially the outcome of the initiatives in collaborative science and technology development efforts between the Governments of the U.S.A. and Thailand which began in 1983.

With the formal signing of an agreement in April, 1984, during the state visit of former Prime Minister Prem Tinsulanond to Washington, D.C., a team of experts from industries, universities and government agencies in the U.S. was provided by the U.S. National Academy of Science under the assistance of the USAID Science and Technology for Development Project. Led by Dr. Ernest Briskey, the team began to undertake the task of designing an S&T development project with their Thai counterpart - the Thailand Science and Technology Program Advisory Council.

The underlying concern was how to develop self reliance in S&T for industrial development while various constraints on science and technology development in Thailand existed at a time when the country was experiencing rapid industrialization. The country had registered strong growth in exports based on local raw materials and an abundant low-cost labor force, as well as an influx of foreign investment from countries whose strong currencies and high labor costs made labor-intensive manufacturing in the country highly competitive. The philosophy behind the project design was one of "problem oriented, opportunity focussed, and demand driven".[3] A number of special studies were commissioned to provide up to date background material to the project design team. They included such topics as "Status of Science and Technology in Thailand", "Constraints to Thai Development: Role of Science and Technology," and "Key Problems in Science and Technology in Thailand".

### 3.2.2 The Mission of STDB

STDB was established to be an organizational "driving force" responsible for developing a rational S&T support system for the enhancement of national productivity. STDB was conceived with the main goal of "providing an institutional framework to achieve self-reliance in science and technology in Thailand".[4]

The purpose of the STDB Project was to develop STDB into a S&T institution to support the acquisition of the following capabilities:

- to make deliberate, rational choices between importing specific technologies or developing them locally;
- to import suitable foreign technologies on favorable terms;
- to adapt imported technologies to suit local conditions;
- to generate new products and processes through domestic RD&E where appropriate and plausible;
- to achieve technological mastery in application of these technologies; and
- to sustain, advance and diffuse all these capabilities through education and training and through the continuing development of the S&T institutional infrastructure.

In short, STDB was designed to carry out the mission of enhancing the "effectiveness and extent of public and private sector applications of S&T to Thailand's development".[4]

### 3.2.3 Four Main Areas of Activity

With the goal and the mission above entrusted to the STDB, the activities of STDB were grouped into four main elements: strengthening the existing S&T institutional framework; research, development and engineering (RD&E); industrial development support; and science and technology policy.

#### a) Strengthening the Existing Science and Technology Institutional Framework

This element of STDB's activities aimed to create opportunities for interaction and cooperation between users and producers of RD&E; to establish effective linkages among the industrial or the agricultural sector, the RD&E community, and government policy makers and regulators to achieve an optimal S&T resources management and utilization targeted at solving priority problems which impede the country's industrial growth and productivity; and lastly, to lessen local dependence on foreign technology by enhancing Thai RD&E capability particularly in key priority areas.

In short, this program was designed to build a framework which would provide the venue and opportunities for linkages and cooperation among company chief executives and technical professionals, university and other public sector RD&E personnel, government policy makers and administrators through the brokerage role of the STDB.

#### b) Science and Technology Policy (STP)

The STP Program had as its main objectives "to influence policies and practices in the country in order to stimulate the development and utilization of S&T capabilities and to upgrade the S&T policy analysis capabilities in Thailand". Towards achieving the objectives, the program financed activities to:

- strengthen the capacity of public and private sector organizations to undertake their own necessary policy studies,
- analyze important policy issues through policies studies,
- support and promote professional exchanges and active interactions between policy analysts and relevant policy planners and decision makers beyond the usual dissemination methods of publications, seminars and conferences.

c) Research, Development and Engineering

RD&E activities fundamental to industrial development were focussed in the three priority areas of biotechnology and genetic engineering, materials and metals, and applied electronics and computers. Emphasis was placed on the development, transfer, and use of technology to enhance the industrial competitiveness of Thai industries. The RD&E activities were carried out by S&T personnel in universities, government research institutes and agencies, as well as private firm laboratories. Out of a total budget earmarked for the STDB Project of about US$ 49 million, an amount of US$ 30 million was allocated to support RD&E activities.

RD&E activities funded by STDB are grouped into three programs, namely, designated RD&E, competitive RD&E, and company-directed RD&E.

The Designated RD&E Program provided funding support to designated institutions to work on designated high priority problems. Supported RD&E projects were envisaged to simultaneously build the designated institutions' capacity to solve current as well as future problems faced by the industry in that area by providing the needed S&T infrastructural base to assist industry and maintain industrial growth in that area.

The program also aimed to assist designated RD&E institutions to be linked with relevant leading institutions in the U.S. The mechanism for the link was provided through budget allocations allowed within each designed RD&E project for the technical support required of the linked institution in the U.S.

The Competitive RD&E Program was directed principally at solving specific private sector problems. General expectations from these projects were improved or new processes or products, or improved state-of-the-art technology in industry relevant to the country's industrial growth.

Projects that came under competitive RD&E activities were mostly demand-driven geared to the needs of firms. Nonetheless, these RD&E activities can and will also help in building the technological capacity among RD&E institutions.

The Company-Directed RD&E Program aimed to stimulate the building of RD&E capabilities within small and medium-sized Thai firms. The objective was to promote and facilitate firms to undertake self-directed RD&E activities.

Originally, assistance provided to firms came in the form of low-interest loans from a pool of funds supplied by STDB, the government, and three financial institutions who administered the fund. Though loans were offered at attractive rates, firms seeking them were required to back them up with collateral. The requirement resulted in low participation and prompted a change to incorporate a grant component to the program whereby participating firms shared 50% of the project costs.

Under this program, firms could undertake in-house RD&E or could seek to take advantage of the S&T resources within universities and government laboratories.

Implementation Procedures:

For Designated RD&E projects funding, the process began with the identification of designated areas of RD&E by the STDB, after which project proposals were solicited from research institutions and universities. The ensuing proposal review process consisted of the following formal steps:

1. Preliminary proposal screening by STDB officers to assess suitability and ensure that they meet proposal preparation guidelines and project criteria.
2. Review of proposals by the Technical Review Panel (TRP) by Thai and U.S. technical experts in the field for comments on the technical aspects of the proposed project.

3. Review of proposals by the Technical Advisory Committee (TAC) to ensure that all or most of the project criteria are met, as well as to set a priority order for competing proposals.

4. Review of the proposals by the Executive Committee (EC) which gives the overall assessment and in-principle approval.

5. Review of the project's proposed budget by the Management Review Panel (MRP) to make revisions of the budget where necessary with the approved project's principal investigator before final formal agreement was signed.

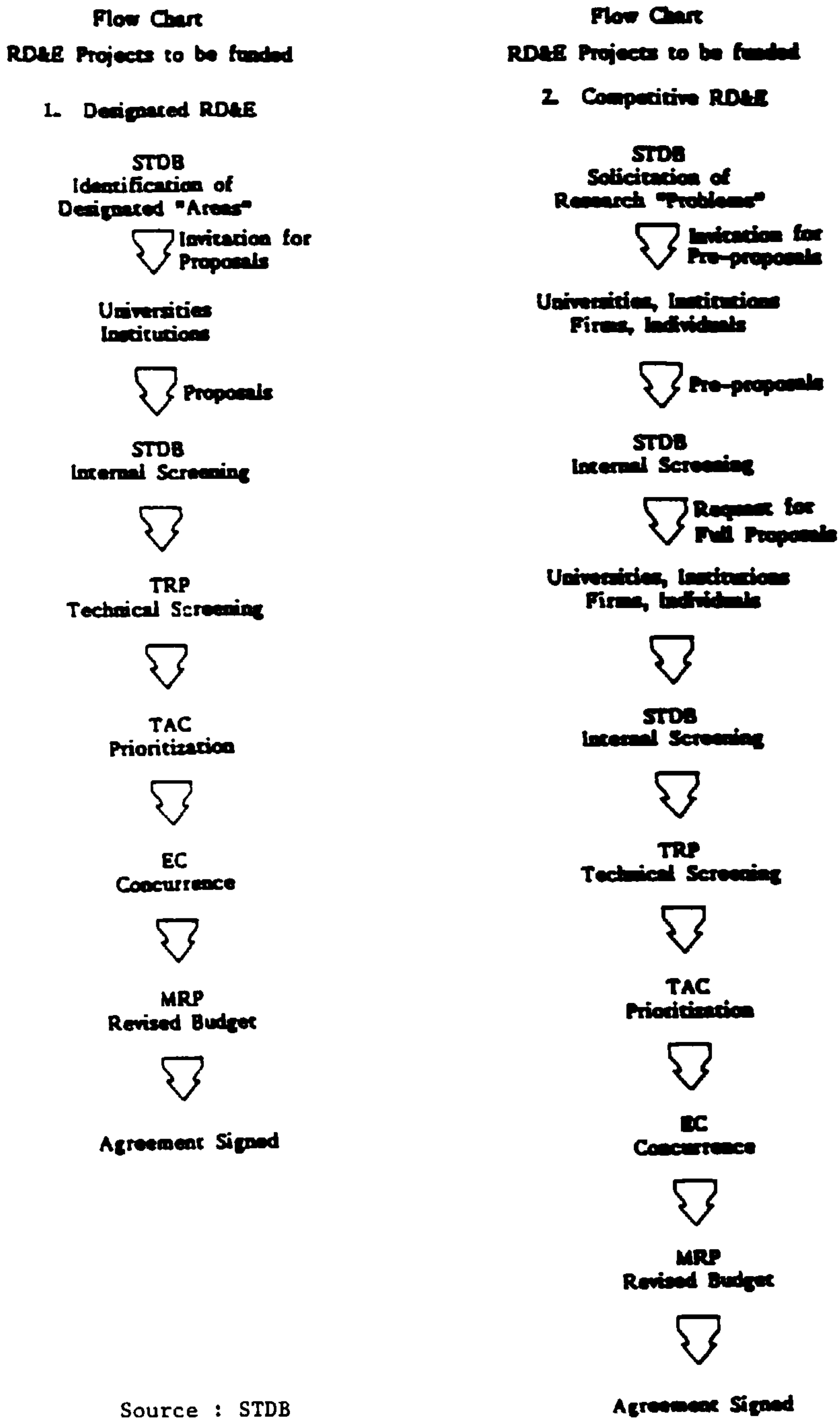
Membership on the three key committees (TAC, EC and MRP) consisted of STDB senior management staff and representation from a number of relevant ministries and government offices, including representation from the private sector in the case of TAC and EC committees, while NAS was represented on the TAC committee. USAID had one observer on all three committees.

The process for funding Competitive RD&E projects "to solve specific problems" was essentially the same as that of the Designated RD&E, with the exception that it required an additional step of submitting first a short Project Preproposal (of about 2 to 5 pages in length). Those eligible for funding included research institutions, universities, firms, or even individuals. Once the preproposal was judged by STDB officers to be appropriate and of good potential, a full proposal was requested and the same proposal review process as described followed.

The procedures for Designated and Competitive RD&E funding are shown in a flow-chart in Figure 3.1.

With regards to company-directed RD&E projects, the process was much less complicated. Firms applying for grants started by submitting a short and simple application form provided by STDB which was reviewed by a program officer. If the proposal was deemed worthy of support, the officer submitted his recommendation to the Program Committee consisting of senior STDB staff, the Team Leader of the NAS Technical Assistance team and a DTEC representative with a USAID observer. Projects approved by this committee were final and would be reported to the EC for acknowledgement purpose only.

Figure 3.1 Process in Funding RD&E Projects by the STDB




Source : STDB

The Graduate Fellowship Program was considered to be an RD&E support program with an aim to increase the number of M.S. and Ph.D. professionals in the three priority technical areas currently in acute short supply. The program also funded workshops, conferences and other professional exchanges in support of RD&E activities. The program made provisions to finance 210 Ph.D. and M.S. degree fellowships in leading Thai universities well staffed by overseas-educated faculty members.

Candidates seeking fellowships would need to be nominated by university faculties with on-going graduate programs in the three priority areas. Applications were judged and selected based on considerations of the applicant's academic record and work experience, if any; the expressed study and/or research interest, and faculties' opinions on the applicant's research potential.

d) Industrial Development Support (IDS)

This main element of STDB's activities included the following components:

- Standards, Testing and Quality Control Program (STQC)
- Technical Information Access Center Program (TIAC)
- Diagnostic/Research Design Service Program (D/RDS)

The STQC Program aimed to strengthen standards and metrological capability for calibration, and modern quality control system and practices to raise the quality standards of local products, in particular those for the export markets with stringent standards and safety requirements. STDB provided funding to finance short and longer term technical assistance to standards, testing and quality control organizations by way of upgrading their personnel (for workshops and training in the U.S.), and their equipment for improving quality of specific targeted products.

The TIAC Program was to create and operate initially a modern information service to provide reliable, up-to-date, low cost business, technical and scientific information to serve both the scientific and the industrial/business communities in Thailand. The program sought to subsequently develop Thai S&T databases and eventually evolve into an on-line S&T database vendor.

The D/RDS program had the objectives of stimulating the development of a Thai technical consulting services industry, and to promote more awareness and utilization by local firms of these services to diagnose technical problems encountered in their firms, and design RD&E activities to solve the problems.

The mechanism to achieve the program objectives was to contract an outside organization to act as a broker to bring together the users (industrial/business firms) and the providers (S&T experts in universities, public laboratories and private consulting firms) of technical consulting services. Major RD&E activities designed to tackle important problems faced by Thai industry so identified could then be given further RD&E financing support by the STDB.

e) New Programs Outside the STDB Project Paper

In addition to the above activities under the four main elements as contained in the original STDB Project Paper, three other new programs were subsequently initiated, two in 1990 and one in 1991.[3]

The first new initiative in 1990 was the Support for Technology Assessment and Mastery Program (STAMP) which aimed to assist firms intending to acquire foreign technology. Assistance provided came in two forms: provision of matching funds and expert assistance in selecting the most appropriate technology for their requirements. The second was the Project Initiation Fund (PIF) aimed at enhancing the chances of success of proposed or on-going RD&E projects which were considered to have significant benefits to the country's technological and/or economic development.

The latest initiative launched in 1991 was the United States - Thailand/Commercialization of Science and Technology Program (UST/COST). The program had as main objectives:

- facilitating commercialization of RD&E projects and available technologies, both Thai and foreign;
- identifying key U.S. experts to liaise U.S. and Thai technology suppliers and users;
- encouraging commercial cooperation among Thai and U.S. private sectors;
- stimulating the sharing of technology, financing and management expertise between firms by means of joint ventures, licensing agreements or technology transfer.

### 3.2.4 Work Accomplished

During the nearly seven years of STDB operation from July 1985 to April 1992, the STDB Project has proved to be an interesting and innovative cooperative initiative between the government of Thailand and the USAID/ Thailand to develop S&T capacity for industrial development in Thailand.

In a mid-term evaluation report[5] of the STDB Project by a 4-member team headed by a U.S. professional S&T consultant, although the team identified and suggested a number of opportunities for improvement, the STDB Project and its operations up to that point received high commendation by the evaluation team. It deemed the Project as "one of A.I.D.'s most creative projects for institutional development", and that "STDB is operating effectively as a resource institution, identifying needs of users as well as relevant science/technology resources, and organizing/funding programs to address these needs", while "staff members are competent, enthusiastic and hard-working to achieve STDB's goals". Finally the study team recommended that the Project be extended for three more years, from September 1992 to September 1995. However, with the political change in Thailand in February 1992, the USAID's assistance was curtailed. No new activities were allowed since then and the existing activities would only be funded by USAID up to September 1992. Hence, many targets cannot be met.

A summary of the STDB project's activity targets and accomplishment to date is given in Table 3.5 and a list of RD&E projects funded by STDB can be found in Appendix 3.1.

Table 3.5 Activity Target and Accomplishment of STDB

| Activities | Target | Status | (Unit) |
|---|---|---|---|
| 1. Expenditure Budget | 1,295 | n.a. | Million baht |
| 2. Designated and Competitive RD&E Projects | 108 | 94 | Projects |
| 3. Company-Directed RD&E Projects | 23 | 8 | Projects |
| 4. Fellowships | 210 | 221 | Persons |
| 5. P.I.F. | 11 | 9 | Projects |
| 6. STP studies | 10 | 4 | Projects |
| 7. STAMP | 17 | 4 | Projects |
| 8. TIAC Information Services | 8,000 | >1372 | Cases |
| 9. D/RDS projects | 100 | 3 | Firms |
| 10. STQC | | | |
| - Workshop/Seminar | 110 | 18 | Times |
| - Training | 22 | 15 | Persons |
| - Equipment Acquisition | 154 | 65 | Pieces |

Source: STDB

Out of the total 94 projects classified as designated and competitive RD&E, 58 projects are in the area of biotechnology, 24 are in materials technology and 12 in electronics. A similar disproportional distribution of RD&E activities among the three areas existed for the much smaller number of company-directed RD&E projects granted. Of the total eight projects, six are in biotechnology while one each is in materials technology and electronics.

## 3.3 ROLES OF MTEC

### 3.3.1 Background of the Establishment

Thailand,like other developing countries, believes that industrialization is the key to advance the economy toward modernization. It has officially attached importance to industrial development since the first National Economic and Social Development Plan some 30 years ago.

At present, the structure of the Thai economy has been transformed from an agricultural based economy to a more diversified one. The proportionate contribution of the manufacturing sector to GDP has overtaken that of agricultural since 1985. In the last three years, Thailand's economic growth rate has been very impressive, accelerating from a mere 3.5% in 1985 to 4.5% in 1986, and has varied between 8.4% to 10.5% during the period 1987 to 1991. The expansion of the economy was mainly due to the high growth of the manufacturing and servicing sectors, thanks to a significant influx of foreign investment in Thailand since 1987.

Despite the rapid growth of the economy, a sharp rise in the trade deficit has also taken place due to the large volume of imports, especially capital goods and intermediate raw materials, in response to the increase in domestic production needs. One of the main reasons for the large volume of imports, particularly for capital goods, intermediate raw materials, and parts and components is that it is due to the lack of technology for the materials industry.

The trade imbalance in this year amounted to around 70,000 million baht. It can be clearly seen that Thailand has to develop her ability in the metal and machinery industry, especially the ability to transform various minerals into value-added products for domestic use and for export in order to counter balance the deficit in this field.

The Ministry of Science, Technology and Environment has established a concrete policy to employ science and technology as an important tool for the development of the country. Through the development of the capability for RD&E in science and technology, Thailand can be self sustaining for steady economic growth. The Fifth National Economic and Social Development Plan emphasized technological research and development with the establishment of the so-called Institute of Metal and Materials Research. The Sixth National Economic and Social Development Plan stated the policy for the development of science and technology in the three most important fields, namely, Genetic Engineering and Biotechnology, Metal and Materials Technology, and Electronics and Computer Technology.

There was also the cooperative project between Thailand and the United State of America regarding Science and Technology for Country Development. The agreement was signed on August 15, 1985 for the loan of 26.5 million US dollars and grant aid of 8.5 million US dollars with the major activity being the promotion of Research, Development, and Engineering among the stated three most important fields corresponding to the priorities of the Sixth Plan.

In the case of the Genetic Engineering and Biotechnology, the cabinet approved the plan for MOSTE to establish the National Center for Genetic Engineering and Biotechnology on September 20, 1983. Despite the aim to establish the Institute of Metal and Materials Research in the Fifth Plan, the National Metal and Materials Technology Center (MTEC) was established as the National Center for Metal and Material Technology (NCMMT) on September 16, 1985, under the supervision of the Ministry of Science, Technology and Environment with the main objective to provide funding support for the research and development in five major material industries, namely, the metals, ceramics, plastics, rubber, and textile industries.

At the time of the establishment of MTEC, the R&D infrastructure in the field of metal and materials technology was concentrated in the government sectors due to the availability of funding and personnel. However, this infrastructure was rather low when compared to the level in other developed or newly industrialized countries. As for the private sector, the nature of the metal and material industry consists mainly of small and medium size industries. So, there are limitations in funding, personnel and equipment coupled with the lack of awareness or appreciation of the importance of R&D for the benefit of the firms. The R&D in the government sector was heavily geared towards improving production processes rather than increasing fundamental knowledge of the materials technology. The most important ingredient in R&D, namely research personnel and technicians, were and still are limited and scattered all over the country in various government institutions. There were no cooperative bodies such as professional societies or government institutions to link researchers and to provide the funding support which was badly needed in this field. This lack of cooperation among personnel and lack of funding led to the lack of equipment and lack of appropriate research work, and was the so-called vicious cycle of R&D in materials technology in Thailand.

So, the rationale for the establishment of MTEC is to supplement the existing R&D infrastructure of the country which is far from adequate; to enable the pooling of resources particularly expensive R&D facilities which, in many cases, are not even available in the country (e.g. electroscopy for chemical analysis (ESCA)/AUGER) equipment which costs around 0.5-0.6 million US dollars or molecular beam epitaxy (MBE) which costs around 1 million US dollars etc.). The other rationale is to encourage and coordinate R&D activities among various parties, namely academic institutions, private industry and the public sector, thus producing better planned, coordinated and strategic R&D programs and projects; and to develop specialized R&D groups which would eventually lead to excellence in specific areas, the lack of which is one of the major drawbacks for S&T development in Thailand at the present.

MTEC aims to be a one-stop information service center for industry, policymakers, researchers, academics etc., in either technical or nontechnical, aspects of materials and related fields. It will provide technical, consultancy, standardization and certification services in relevant areas. MTEC will have the ability to initiate, coordinate and lead joint R&D projects and programs among different parties and the ability to carry out quality research, development and engineering projects on advanced as well as traditional materials and processes in selected areas on a par with developed countries. Finally, through various coordinated activities, groups of "experts" with highly specialized knowledge and know-how will be created.

Strategies were drawn up in order to fulfill the aims and objectives of the MTEC. Some of the major strategies are:

- building up of the infrastructure and resources by acquisition of personnel, laboratory space, equipment and facilities.
- use of network institutions for personnel development, laboratory space and facilities, joint R&D projects, and visiting research fellows.
- develop contact with industry through industry surveys, joint or contract R&D projects, information and technical services.
- use of foreign experts and expatriates to assist in planning and operation matters.

The organization was designed with the use of a combination of both vertical (line) and horizontal (matrix) forms of organizations to allow for technical specialization as well as cooperation among different disciplines. Emphasis is placed upon flexibility and responsiveness of the organization.

So far the fields of endeavor were established by separation into 4 categories as:

1. Metals which are further subdivided into metal science and mechanics, solidification processing, deformation processing, machining and machine tools, surface technology, powder technology, specialty and advanced materials.

2. Polymers which are further subdivided into polymer chemistry, polymer physics, polymer processing, composite materials, rubber technology, fiber technology, specialty polymers.

3. Ceramics which are further subdivided into conventional ceramics, structural ceramics, functional ceramics, bioceramics.

4. Design and Supporting Activities which are further subdivided into design of devices and systems, materials characterization, materials testing and evaluation, computing for computer-aided design/computer-aided manufacturing/computer-aided engineering (CAD/CAM/CAE) and simulation.

In each group there are several R&D programs, the merits of which are rigorously assessed based on technical, economic and developmental bases as well as their strategic importance and practical constraints and possibilities. At the beginning of each fiscal year, the programs will be prioritized and implemented (or supported) according to their respective merits. Revisions of programs are carried out periodically or as new opportunities and threats arise.

The outputs expected by MTEC are as follows: services, both technical and nontechnical; new products including materials, devices and systems; new processes; reverse-engineered products; contract R&D projects; technology transfer projects; joint R&D projects; patents; publications; trained personnel; and new industries (firms) created.

### 3.3.2 Targets of the 7th Plan

MTEC has established the targets for achievement within the period of the 7th National Economic and Social Development Plan (1992-1996) as follows:

- 60% completion of the acquisition and setting up of R&D facilities, most of which to be operational.
- 30% of R&D personnel and supporting staff would be acquired and working.
- Able to provide most technical and nontechnical services to customers.
- Some patents would have been granted.
- Some new products should have been developed. A very probable list includes: injection blow molding machine to make plastic bottles and containers without wasting materials for local market and for export, small plastic extruder for use in vocational institutes or as a pilot plant in plastics industry, improved walking tractors including rotating tiller implements designed for local farmers, small engine for use with portable agricultural equipment, CNC milling machine designed and built in Thailand, amalgam for use as dental filler to replace imported amalgam, high performance magnetic materials, high-grade bone china with raw materials produced in Thailand, zircon pigment for ceramic industry, piezoelectric ceramics to be used as sensors and igniters, pure zircon to be made into engineering ceramics such as engine parts, bioceramics (Hydroxyapatite) to be used as artificial bone and bone cement, biomedical polymer for used as biodegradable surgical sutures, efficient recycling of plastics, etc.
- Certain new or improved advanced technologies will be transferred from abroad or developed e.g. powder injection molding, thermal spray coating, thin film technology including chemical vapour deposition (CVD), physical vapour deposition (PVD), ion implantation to increase surface hardness, reaction injection molding, isostatic pressing, polymer technology that will lead to the use of a higher proportion of natural rubber in polymer products, systematic design of machine with emphasis on ease and economy of production, formulation of Thai Code for manufacturing of machine parts, etc. More detailed assessments are also being carried out.

- University and industry personnel trained in advanced characterization of materials.

- Ten publications in international journals by MTEC personnel.

- Several joint and contract R&D projects with industry.

- A few new firms will be created as a result of MTEC sponsored RD&E works and from incubators of NSTDA Science and Technology Research and Development Park (STRDP)

### 3.3.3 Network Institutions

From the fiscal year 1992, MTEC has started the project called "Network Unit Operation for Metals and Materials Of MTEC" or "Network Institutions" to raise the capability level of the Network Institutions and MTEC in three aspects, namely:

- Personnel: to have more qualified and well-trained researchers and technicians in metals and materials fields by exchanging of knowledge and expertise between the personnel of MTEC and of the institutions.

- Equipment: to acquire sufficient equipment which is necessary for RD&E in the fields of metals and materials and to promote sharing of equipment between MTEC and the institutions.

- Academic Quality: to promote better academic knowledge and understanding of MTEC and of the institution's personnel in order to achieve better efficiency in research work through strong linkages between MTEC and the institutions.

The Unit Operations were designated in 9 Network Institutions as follows:

1. Solidification Processing and Surface Technology Operation Unit at Center of Operation of R&D, KMIT Thonburi.

2. Metal Working, Engineering Ceramics, and Polymers Operation Unit at Metallurgy and Materials Science Research Institute, Chulalongkorn University.

3. Surface Technology, Engineering Ceramics, Classical Ceramics, and Polymers Operation Unit at The Institute for Science & Technology Research and Development, Chiang Mai University.

4. Rubber and Plastic Unit Operation at the Department of Chemistry, Faculty of Science, Mahidol University.

5. Rubber and Machining Unit Operation at the Section of Polymer Technology, Department of Technology and Industry, Pattani Campus and the Department of Industrial Engineering, Hadyai Campus, Prince of Songkhla University.

6. Technology of Rubber Liquid and Technology for Production of Rubber Products Operation Unit at the Rubber Research Institute, the Ministry of Agriculture and Cooperation.

7. CAD/CAE/CAM Operation Unit and Agricultural Machine Center at the Science and Technology Research and Development Institute, Kasetsart University.

8. Machine Building and Solidification Processing and Polymer Operation Unit at the Institute of Technological Development for Industry, KMIT North Bangkok.

9. Engineering Ceramics Operation Unit at the Metal and Material Technology Department, Thailand Institute for Science and Technology Research.

These Operation Units in the Network Institutions will have responsibility as representative offices of MTEC and will be centers for research, development and services in each specified field. They will have roles in the training of MTEC personnel, transfer and exchanging of information and personnel among the institutions and MTEC, and will be the places for installation of the equipment funded through MTEC's budget, to satisfy the objectives stated above.

The total budget for the projects is 52 million baht with an operating fund of 500,000 baht per institution per year. The period of operation is 3 years.

### 3.3.4 Roles of MTEC

This section contains excerpts from the interview of Assoc. Prof. Dr. Harit Sutabutr, the Director of MTEC, about roles, operating policy, future targets, and the relationship between MTEC and other R&D institutions.

The roles of MTEC in the facilitation and promotion of RD&E in metal and materials technology are:

- Supplier of materials technology for the development of industrial and agricultural sectors which will lead to the development of Thailand as a whole. Thailand should be self sufficient in materials technology through the cooperation of MTEC and other local institutions or through the efforts of RD&E by MTEC.
- Strengthening the technical manpower base by providing scholarships for higher education both overseas and domestic, training and education of technicians, supporting of training and education by other local institutions.
- Establishment of the National Laboratory for Metal and Materials Technology and doing the RD&E towards pilot plant level. Analysis, testing and consultancy services for local customers would also be done by the laboratory.
- Promotion of cooperation and acting as a center for cooperation among various RD&E units in Thailand.
- Promotion of cooperation between the government and industrial sectors for the benefit of the country.
- To act as the information center for metal and materials technology for the government and private sectors.

In order to realize the established roles in a shorter period of time with effective and efficient operation, the operating policies for MTEC are:

- Reduction of operation steps and gearing toward flexibility in operation.
- Minimizing of manpower especially in the administrative jobs, which leads to cost reduction.
- Emphasis on the quantity of R&D projects funded by MTEC to achieve the utmost and fastest impact. The weakness in technical manpower could be corrected through the promotion of selected R&D teams with high potential and which are already assuming the roles of technology transfer and development.
- Emphasizing also the promotion pattern of Taiwan which is geared toward low cost and acceptable quality products instead of high quality and expensive ones.

The Future targets are:

- Metal Technology: emphasis on systematic design and production of machinery i.e. injection blow molding machine, walking tractors, etc. Promotion towards the learning of technology more than the production of prototype units. Foundry technology and die making technology are also emphasized.

- Ceramics Technology: emphasis on RD&E in advanced ceramics. In the case of traditional ceramics, development of raw materials would be encouraged.

- Polymers Technology: emphasis on the promotion of RD&E to achieve added value on domestic resources such as natural rubber and plastics. Searching for new products from natural rubbers and mixtures of rubber with plastics e.g. thermo plastic rubber technology.

In addition, MTEC will try to promote the cooperation among R&D units of the government sector such as the National Research Council (NRC) which is the forum for academicians to establish the national policy for R&D, or TISTR and the Rubber Research Institute, etc. which are the research units for specific fields. RD&E activities of all of the research units should be integrated through the cooperation activities of MTEC toward the development of materials technology based on benefitting the country.

### 3.3.5 <u>Summary</u>

From the beginning of the operation, MTEC has assumed the role of a funding organization to promote RD&E activities in metal and materials technology in the various government organizations in Thailand such as TISTR, the Rubber Research Institute, and numerous national universities. Cooperation among government organizations and between government and private sector operations concerning RD&E activities were emphasized as much as possible in the funded research projects in order to establish strong linkages between technology suppliers and users. The objectives during the initial phase of operation were steered towards technical human resources development, building research teams, and strengthening various research institutions through the acquisition of necessary equipment and the providing of sufficient operating funds. Metals, Ceramics, and Polymers are the three groups of materials emphasized in the RD&E projects funded. The systematic design and making of machinery and machine tools for industrial and agricultural use was also promoted. Recently, the so-called Network Institutions Project has started to strengthen the RD&E bases in various cooperating institutions. MTEC will further assume the role of research organization, information center, technical service center, and effective cooperating unit for the development of metal and materials technology in Thailand, once the recruitment of necessary technical personnel and acquisition of equipment have been completed.

### 3.4 ROLES OF NSTDA

A brief background of STDB and the emergence NSTDA were provided under section 1.1.1 of this Report. It was noted that NSTDA, as it is now set up, will bring together under one umbrella the four former S&T institutions, namely, STDB, NCGEB, MTEC, and NECTEC.

Unlike other government agencies or statutory boards, NSTDA operates under a special law which frees it from normal government bureaucracy while it still receives annual government budget allocation. In addition, it may receive endowment funding when necessary.

The many special privileges endowed upon NSTDA include a competitive salary scale on par with the private sector, the authority to manage freely its own income and expenditure, or to support technology investment of the private sector or even make its own investments as deemed fit.

According to the first Director of NSTDA, Dr. Yongyuth Yuthavong,[6] NSTDA has set three major goals. These are as follows:

1. To provide RD&E support systems.
2. To support and to undertake RD&E and technical services.
3. To venture into technology investment.

Under the first goal of RD&E support systems, NSTDA will devise a financial support system to manage grants and loans, a manpower support system, an information and other data support system by restructuring and enlarging the role of TIAC, and a priority setting and specific support measures system for determining priorities among areas for support.

Under the second goal of RD&E implementation and technical services, NSTDA aims to develop a strong human resource program to attract, retain and upgrade its manpower and build it into a high quality S&T manpower base. It also aims to establish a staff exchange program with network institutions around the country. A particularly significant and noteworthy difference in the missions of NSTDA from the former STDB is the dual missions to support RD&E and to undertake its own in-house RD&E. In addition, NSTDA plans to provide consultancy on contract, as well as technical and training services to the public.

Under the third goal of technology investment, NSTDA will continue with the Commercialization of Science and Technology (COST) Program (formerly UST/COST) and the Science and Technology Acquisition and Mastery Program (STAMP). In addition, NSTDA aims to launch two new programs. The first is the "Incentives for Modernization of Production and Loans for Application of New Technology" or IMPLANT, a program which, together with STAMP, promotes technology upgrading for industries. The second is the "Investment in New Ventures for Enhancing Science and Technology" or the INVEST Program, which aims to provide venture funds either to the private sector or to NSTDA itself, for the purpose of investing in technology enterprises abroad, especially in those countries possessing world technical leadership. The goal of this Program is to transfer technology to Thai industries.

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# APPENDIX 3.1

## LIST OF RD&E PROJECTS FUNDED BY STDB

| No. | Project Title | Pricipal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| | *BIOSCIENCE & BIOTECHNOLOGY* | | | |
| 1 | Employ Plant Regeneration and Other Tissue Culture Methods in Clonal Propagation and Improvement of Aracaceae | Dr. Kamnoon Kanchanapoon<br>Faculty of Science<br>Department of Biology (PSU) | 01-Sep-87 | 31-Aug-90 |
| 2 | Production of Modified Starch with Desired Rheological and Physical Properties from Cassava Starch | Dr. Chaisagna Taeratanachai<br>Fuculty of Graduate Studies<br>(MU) | 01-Sep-87 | 31-Aug-90 |
| 3 | Development of Specific DNA Probes for the Diagnosis of Babesiasis in Cattle | Dr. Chariya R. Brockelman<br>Faculty of Science<br>Department of Microbiology (MU) | 01-Sep-87 | 28-Feb-91 |
| 4 | Improved Broodstock Maturation Techniques for the Grant Tiger Praw (Penaeus monodon) in Thailand | Dr. Plamsak Menasveta<br>Sichang Marine Science<br>Faculty of Science (CU) | 01-Sep-87 | 28-Feb-91 |
| 5 | Develop and apply Plant Biotechnological Methods for the Production of Virus Resistant Plants | Dr. Supat Attathom<br>Plant Genetic Engineering Unit<br>(KU) | 01-Sep-87 | 31-Aug-91 |
| 6 | Development and Application of Tissue Culture Methods for Rapid Multiplication and Improvement of Coconut and Arecanut | Dr. Oradee Sahavacharin<br>Faculty of Agriculture (KU) | 01-Oct-87 | 30-Sep-90 |
| 7 | In Vitro Selection for Soybean Lines Toletant to Saline Soil and Acid Sulfate Soils | Dr. Peerasak Srinives<br>Faculty of Agriculture (KU) | 01-Dec-87 | 31-May-91 |
| 8 | Consturction of Hybrids from Aspergillus sp. for High Yield Citric Acid and Glucoamylase Activity | Dr. Supapong Bhuwapatnanapum<br>Faculty of Agro-Industry (KU) | 16-Oct-87 | 15-Oct-90 |
| 9 | Research and Development for a Complete Cycle of Seaweed Hydrocolloid Industry in Thailand | Mrs. Suwalee Chandrkrachang<br>Fuculty of Sciences (SWU) | 01-Feb-88 | 30-Jul-90 |
| 10 | Improvement of Aquaculture of Giant Fresh-water Prawn) Macro-brachium rosenbergii de man) Through Hormonal and Reproductive Mainpulations | Dr. Boonserm Poolsanguan<br>Faculty of Sciences (MU) | 01-May-88 | 30-Apr-92 |

| No. | Project Title | Pricipal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 11 | The Development of Biotechnology for an Improvement in the Production of Dairy Cattle | Dr. Kanok Pavasuthipaisit<br>Faculty of Science<br>Department of Biotechnology (MU) | 01-May-88 | 30-Apr-92 |
| 12 | Application of Tissue Culture Techniques for Improvement of Steriod and Alkaloid Yield from Solanum and Duboisia Spp. | Mrs. Phannipha Chumsri<br>Faculty of Pharmacy<br>Department of Pharmacognosy (MU) | 01-May-88 | 31-Dec-91 |
| 13 | Prevention and Control of Alfatoxin in Corn | Dr. Chamnan Chutkaew<br>Faculty of Agriculture (KU) | 01-Feb-88 | 31-Jan-91 |
| 14 | Dry Bean (Phaseous Vulgaris) Improvement Through Mutation Breeding and Tissue Culture Technique | Dr. Siranut Lamseejan<br>Department of Applied Radiation and Isotopes<br>Faculty of Science (KU) | 03-Oct-88 | 02-Oct-91 |
| 15 | Biological and Economical Studies on the Mekong Giant Catfish | Mr. Sanay Pholprasith<br>Department of Fisheries (MOAC) | 01-Oct-88 | 30-Oct-91 |
| 16 | The application of Biotechnology for Processing and Product Improvement of Fermented-Rice Noodle | Mrs. Lawan Kraidej<br>Faculty of Science (KU) | 01-Nov-88 | 31-Oct-90 |
| 17 | Comprehensive Study of the Control, Treatment and Prevention of the Diseases of Cultured Penseus Monodon Fabricius | Dr. Chalor Limsuwan<br>Faculty of Fisheries (KU) | 01-Nov-88 | 31-Oct-90 |
| 18 | Development of Innovative Technique for Local Production of Bacterial Agents for Biological Control of Agricultural Pests | Dr. Amaret Bhumiratana<br>Department of BIO Technology (MU) | 01-Nov-88 | 31-Oct-90 |
| 19 | Industrial Fish Sauce Fermentation by Recycling System | Mrs. Saipin Chaiyanan<br>(KMITT) | 01-Nov-88 | 31-Oct-90 |
| 20 | Potential Utilization of the Rock Salt-Affected Area in the Northeast of Thailand for Aquaculture and Fisheries Development | Mr. Anand Tunsutapanich<br>Department of Fisheries (MOAC) | 01-Apr-89 | 31-Mar-92 |
| 21 | Tissue Culture for the Propagation and Development of Papaya that are Tolerant to Papaya Ringspot Virus | Mr. Boonyuen Kijvicharn<br>Department of Science<br>Faculty of Agriculture (KKU) | 15-Jul-89 | 14-Jul-92 |
| 22 | Halophytes | Dr. Somsri Arunin<br>Department of Land Development (MOAC) | 15-Jul-89 | 14-Jul-92 |

| No. | Project Title | Pricipal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 23 | Development of Silkworm Seed Technology for Commercial Production | Dr. Somsri Kantaratanakul<br>Department of Entomology (KU) | 01-Jun-89 | 31-May-92 |
| 24 | Establishment of Vitality Lines of Thai Silkworms and Determination Their Modes of Inheritance | Dr. Panapa Saksoong<br>Department of Genetics<br>Faculty of Science (KU) | 15-Oct-89 | 14-Oct-92 |
| 25 | Application of Vegetative Propagation to Improve Timber Yield of Red Gum (EUCALYPTUS CAMALDULENSIS DEHAH) | Dr. Somkid Siripatanadilok<br>Department of Forest Biology<br>Faculty of Forestry (KU) | 01-Oct-89 | 30-Sep-92 |
| 26 | Genetic Improvement of Clarias Macrocephalus by Induction of Gynogenesis and Hybridization | Mrs. Uthairat Na Nakorn<br>Faculty of Fisheries (KU) | 01-Jan-90 | 31-Dec-92 |
| 27 | Maintenance of Soil Fertility and Improvement of Crop Yield in Highland by Biofertilizer, Mycorrhizal Fungi | Dr. Omsub Nopamornbodi<br>Dept. of Agriculture (MOAC) | 01-Mar-90 | 28-Feb-93 |
| 28 | Ruminant Nutrition Technology Research Project (RUNTERP) | Dr. Metha Wanapat<br>Faculty of Agriculture (KKU) | 08-Dec-90 | 07-Dec-92 |
| 29 | Development and Adapting Rhizobium Technology for Legume Cultivation in Northeast Thailand in Support of the ESARN KHEOW | Dr. Juckrit Homchan<br>Faculty of Agriculture (KKU) | 01-Mar-90 | 28-Feb-93 |
| 30 | Development of Postharvest Machinery for Durian Export Industry | Dr. Bundit Jarimopas<br>Faculty of Agriculture (KU) | 01-Mar-90 | 28-Feb-93 |
| 31 | Technical Development and Economic Assesment on Disease Control, Storage and Ripening of Durian Export | Dr. Jingtair Siriphanich<br>Faculty of Agriculture (KU) | 01-Mar-90 | 28-Feb-93 |
| 32 | Pineapple Improvement and Multiplication on by Aseptic Techniques for Canning Industry in Thailand | M.L. Charuphant Thongtham<br>Faculty of Agriculture (KU) | 01-Mar-90 | 28-Feb-93 |
| 33 | Utilization of Vesicular-Arbuscular Mycorrhizae (VAM) for Yield Improvement of Tomato in the Northeast of Thailand | Dr. Sawaeng Ruaysoongnern<br>Faculty of Agriculture (KKU) | 02-Apr-90 | 01-Apr-93 |
| 34 | Production of Potent, Polyvalent Purified Horse Antivenoms for Effective Therapy of Snake Venom Poisoning | Dr. Kavi Ratanabanangkoon<br>Department of Microbiology<br>Faculty of Science (MU) | 03-Jul-90 | 02-Jul-93 |
| 35 | Disposition of Antimicrobial Drugs in Tiger Giant Prawn (Penaeus Monodon) | Dr. Malinee Limpoka<br>Faculty of Veterinary Medicine (KU) | 25-Jul-90 | 24-Jul-92 |

| No. | Project Title | Pricipal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 36 | Technological Assessment of Intensive Shrimp Cultivation in the Songkhla Basin with Emphasis on Water Quality | Dr. Upathum Pavaputanont<br>Department of Fisheries<br>Songkhla (MOAC) | 23-Jul-90 | 22-Jul-93 |
| 37 | Improvement of Disease Resistance to Blast, Btawn spot and Bacterial Leaf Blight in Aromatic Tice Through Tissue Culture | Mr. Narong Singburaudom<br>Department of Plant Pathology<br>(KU) | 15-May-90 | 14-May-93 |
| 38 | Evaluation of Thai Herbs and Spices for Export | Dr. Wanchai De-Eknakul<br>Faculty of Pharmaceutical Sciences (CU) | 03-Sep-90 | 02-Sep-93 |
| 39 | Production of Monoclonal Antibodies Specific to Cymbidium Mosaic Virus and their use for Diagnosis | Mrs. Renu Vejaratpimol<br>Department of Biology (SU) | 02-Oct-90 | 01-Oct-93 |
| 40 | The Production and Testing of Lateinizing Hornorne Releassing Hornorne Analogues for Fish Propagation | Mr. Panu Tavaratmaneekul<br>National Imland Fisheries<br>(MOAC) | 01-Oct-90 | 30-Sep-93 |
| 41 | Application of Azolia for Rice Production in the North East of Thailand | Mr. Prayoon Swatdee<br>Department of Agriculture<br>(MOAC) | 01-Oct-90 | 30-Sep-93 |
| 42 | ECO-biotoxicological Studies of Organotin Pesticides and Proposed Control Measures for Freshwater Aquaculture | Dr. Pornsawan Visoottiviseth<br>Department of Biology<br>Faculty of Science (PSU) | 01-Oct-90 | 30-Sep-93 |
| 43 | Commercial Production of High Value Biochemical Compounds From Rubber Plantation Waste | Dr. Rapepun Wititsuwannakul<br>Faculty of Science (PSU) | 01-Feb-91 | 31-Jan-94 |
| 44 | Strain Selection Mass Production and Field Application of Hirsulella Thompsonii for the Microbial Control of Agricultural Mites in Thailand | Dr. Angsumarn Chandrapatya<br>Department of Entomology (KU) | 03-Dec-90 | 02-Dec-93 |
| 45 | Development of Rapid and Specific Immunodiagnostic Methods for Pseudomanas Pseudomallei Infection | Dr. Surasakdi Wongratanacheewan<br>Faculty of Medicine (KKU) | 02-Jan-91 | 01-Jan-94 |
| 46 | Development of Enzyme Technology for Production 6-Aminopenicillamic Acid | Dr. Vithaya Meevootisom<br>Faculty of Science (MU) | 02-Jan-91 | 01-Jan-94 |
| 47 | Indentification for Mulberry Root Rot Disease and its Control | Mr. Sompark Siddhipongse<br>Department of Agriculture (MOAC) | 02-Jan-91 | 01-Jan-94 |
| 48 | Development of Asiatic Canker Resistance in Pommelo Through Genetic Engineering | Dr. Surawit Wannakrairoj<br>(KU) | 01-Jun-92 | 31-May-95 |

| No. | Project Title | Pricipal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 49 | In Vitro Breeding for Photoperiod-Insensitivity in Aromatic Rice | Dr. Prapa Sripichit (KU) | 01-Jun-92 | 31-May-95 |
| 50 | Biological Control of Root Knot Nematodes Meloidogyne Spp. With Paecilomyces Spp. and Verticilium Spp. In Highland Agriculture | Dr. Sueksak Sontirat (KU) | 01-Jun-92 | 31-May-95 |
| 51 | Control Management of Mosquito Bug, Helopeltis Sp. on Cashew | Ms. Parnpen Chayopas Dept. of Agriculture | 01-Jun-92 | 31-May-95 |
| 52 | Rapid Detection of Cholera | Ms. Wanpen Chaicumpa (MU) | 01-Jun-92 | 30-Nov-93 |
| 53 | Mass Production and Application of Trichoderma Species for Biocontrol of Sclerotum Rolfsii Sacc. | Dr. Chiradej Chamswarng (KU) | 01-Jun-92 | 31-May-95 |
| 54 | Selection of Strains and Improvement of Reproduction | Dr. Prapee Sretarugsa (MU) | 01-Jun-92 | 31-May-95 |
| 55 | Development of an Immunodiagnostic Assay for Circulation Fasciola Gigantica Antigens Using Monoclonal Antibodies | Dr. Prasert Sobhon (MU) | 01-Jun-92 | 31-May-95 |
| 56 | Population Genetics and Sexual Behavior in the Management of Dacus Species of Fruit Flies in Thailand | Dr. Visut Baimai (MU) | 01-Jun-92 | 31-May-95 |
| 57 | Development of Rapid Screening Method for Selecting Aspergillus-Resistant Corn Strains | Dr. Maitree Suttajit (CMU) | 01-Jun-92 | 31-May-95 |
| 58 | Improvement of Garlic Productivity Through The Establishment of Disease Free Stacks and Superior Clones Selection | Dr. Prasartporn Smitamana (CMU) | 01-Jun-92 | 31-May-95 |
| | ***MATERIALS TECHNOLOGY*** | | | |
| 59 | Ceramic Materials and Products for Electronic Industries (Part I: Material Development) | Dr. Tawee Tunkasiri Faculty of Science (CMU) | 01-Sep-87 | 31-Aug-90 |
| 60 | Development of High Power CO2 Laser for Materials Processing | Dr. Pichet Limsuwan Department of Physics Faculty of Engineering (KMITT) | 01-Dec-87 | 31-Aug-91 |
| 61 | Improvement of Rubber Product Manufacture Through Efficiency Processing | Dr. Krisda Suchiva Department of Chemistry Faculty of Science (MU) | 20-Nov-87 | 19-Aug-91 |

| No. | Project Title | Pricipal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 62 | Ceramic Materials and Products for Electronic Industries (Part II: Development of Ferrite Products for Radio and Television Appliances) | Dr. Charussri Lorprayoon<br>Dept. of Materials Science<br>Faculty of Science (CU) | 01-Oct-87 | 31-Mar-91 |
| 63 | Organotin Compounds Innovative Uses of Tin | Dr. Lek Uttamasil<br>Department of Chemistry<br>Faculty of Science (CU) | 01-Oct-87 | 30-Sep-90 |
| 64 | High Efficiency Low Cost Shuttle Kiln | Mr. Ampon Wattanarangsan<br>Dept. of Materials Science<br>Faculty of Science (CU) | 01-Jan-87 | 31-Dec-89 |
| 65 | Beneficiation Process of High Quality Kaolin | Dr. Ladawal Chotimongkol<br>Metal and Material<br>Technology Dept. (TISTR) | 04-May-88 | 04-Nov-90 |
| 66 | Scientific Technique for Improving Color of Gem Minerals | Dr. Ladawal Chotimongkol<br>Metal and Material<br>Technology Dept. (TISTR) | 04-May-88 | 04-Aug-90 |
| 67 | Appropriate Process Control of Kaolin | Dr. Quanchai Leepowpanth<br>Dept. of Mining Engineering and Mining Geology<br>Faculty of Engineering (CU) | 10-Mar-88 | 09-Sep-90 |
| 68 | Theoretical Investigations of High Temperature Superconductivity and Coordination of Superconductivity Projects in Thailand | Dr. Viruih Sa-yakanit<br>Faculty of Science (CU) | 09-Nov-88 | 08-Nov-91 |
| 69 | An Investigation of the Magnetic Properties of High Tc Superconductors and of Possible Structural Transitions Preceding the Transition into the Superconducting Phase | Dr. Rassmidara Hoonsawat<br>Dept. of Physics & Mathematics<br>Faculty of Science (MU) | 16-Nov-88 | 16-Nov-91 |
| 70 | Research on High Tc Superconductors: Operative Machanisms in High Tc Super-conductors | Dr. Suthat Yoksan<br>Department of Physics<br>Faculty of Science (SWU) | 01-Dec-88 | 30-Nov-91 |
| 71 | Research on High Temperature Superconductivity : Thermal Property | Dr. Pongsri Mangkorntong<br>Faculty of Science (CMU) | 01-Dec-88 | 30-Nov-91 |
| 72 | An Investigation of the Crystal Structures and Transport Properties of the High Tc Superconductors and of the Effects of the Fabrication Process in the Production of High Tc Superconductors | Dr. Narongsak Chaichit<br>Department of Physics<br>Faculty of Science (SU) | 01-Dec-88 | 30-Nov-91 |

| No. | Project Title | Pricipal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 73 | Fabrication, Characterization and Applications of High Tc Thin/Thick Film | Dr. Poonpong Boonbrahm Department of Physics (PSU) | 15-Nov-88 | 14-Nov-91 |
| 74 | Modification of the Annealing Processes in the Fabrication of "High Technology" Ferrites and YIG Garnets to Achieve Optimal Magnetic Properties for USE in Microwave Devices | Dr. Santi Vatanayon Dept. of Physics & Mathmatics Faculty of Science (MU) | 30-Jun-89 | 29-Jun-92 |
| 75 | Use of Natural Rubber in Rice Huskers | Dr. Boontham Nithi-Uthai Faculty of Science and Technology (PSU) | 21-Nov-89 | 20-Nov-92 |
| 76 | Developments of New Products and Services for the Ceramic Industry of the Northern Region | Dr. Kanchana Keowkamnerd Faculty of Science (CMU) | 02-Oct-89 | 01-Oct-92 |
| 77 | Development of Nickel-Zinc and Other "High technology" Ferrites for Use in UHF (400 & 800 MHZ) Telecommunication Equipment | Dr. Pongtip Winotai Faculty of Science (MU) | 01-Nov-89 | 31-Oct-92 |
| 78 | Prolonging the Lifetime and Improving the Quality of Asphalt in Flexible Pavement | Dr. Saiyavit Varavinit Faculty of Science (MU) | 01-Feb-90 | 31-Jan-93 |
| 79 | Heavy Ion Implantation in Metal and Alloys | Dr. Thiraphat Vilaithong Faculty of Science (CMU) | 01-Feb-90 | 31-Jan-93 |
| 80 | Development of Technically Specified Natural Rubber for Industrial and Engineering Application | Dr. Jariya Boonjawat Department of Biochemistry (CU) | 01-Feb-91 | 31-Jan-94 |
| 81 | Preparation of Thai Coals for Water and Waste Water Treatment | Dr. Benjavun Ratanaˆthien (CMU) | 01-Jun-92 | 31-May-95 |
| 82 | Development of Low Cost Toughened Plastics Utilising Ground Waste From the Rubber Industry | Mr. Pranee Phinyocheep (MU) | 01-Jun-92 | 31-May-95 |
| | ***APPLIED ELECTRONICS & COMPUTER TECHNOLOGY*** | | | |
| 83 | Research and Development on Engineering Production of Small and Medium Size EPABX | Mr. Narong Yamphayak (TISTR) | 26-Nov-87 | 14-Feb-90 |
| 84 | Development of a Computer Aided Engineering (C.A.E.) System for Electronic Design | Dr. Ekachai Leelarasmee Faculty of Engineering (CU) | 01-Feb-88 | 01-Aug-91 |
| 85 | Research and Development of Switched Mode-Power Supplies | Dr. Mongkol Dejnakarintra Faculty of Engineering (CU) | 15-Nov-87 | 14-May-90 |

| No. | Project Title | Pricipal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 86 | Research and Development on Engineering Production of Large Size PABX of SPC, PCM and TDM Type | Mr. Pramote Srisuksant<br>Faculty of Engineering (KU) | 01-Nov-87 | 30-Apr-91 |
| 87 | Electronic Equipment for Energy Management in Spining Industry | Mr. Banterg Suwantrakul<br>Faculty of Energy and Materials (KMITT) | 01-Jun-88 | 31-Oct-90 |
| 88 | Development of the Thai Microcomputer Package for General Application | Dr. Pichit Sukcharoenpong<br>Faculty of Engineering (KU) | 01-Mar-88 | 30-Jun-90 |
| 89 | Laser Diode Fabrication | Dr. Somsak Panyakeow<br>Faculty of Engineering (CU) | 11-Dec-89 | 10-Dec-91 |
| 90 | Data Acquisition System for High Performance Liquid Chromatograph | Mr. Wichit Sirichote<br>Faculty of Science (KMITL) | 01-May-90 | 30-Apr-91 |
| 91 | Development of Local Thai Capability for CAD-CAM/CIM Control and Technology Transfer | Dr. Somkiet Rujkietgumjorn<br>Department of Industrial Engineering (KKU) | 01-Aug-90 | 31-Jul-93 |
| 92 | Activated Carbon Electrode Biosensors for use in the Food Industry | Mr. Werasak Surareungchai<br>School of Energy & Materials (KMITT) | 01-Oct-90 | 30-Sep-93 |
| 93 | Pulsed Electromagnetic Fields (PEMFS) for Osteogenesis | Mr. Peerapong Prinyaroj, M.D. (PSU) | 01-Aug-92 | 31-Jul-95 |
| 94 | Development of Computer Software for Radiotherapy System | Mr. Vorachai Tangvoraphonkchai,M.D. (KKU) | 01-Oct-92 | 30-Sep-95 |
| | ***COMPANY-DIRECTED RD&E*** | | | |
| 95 | Quality Improvement and New Product Development of Diagnostic Reagents for Medical Laboratories | Mrs. Sunee Keeratipaisal<br>Seam Co., Ltd. | 04-Apr-89 | 03-Sep-92 |
| 96 | Scale-Up Tissue Culture Protocal of Plantation Crops and Adaptation for a Commercial | Mrs. Supranee Kavinlertwattana<br>Thai Orchids Lab Co.,Ltd. | 14-Aug-90 | 13-Aug-93 |
| 97 | Development and Improvement of Existing Fish Sauce Factory to Utilize the New Production Process | Mr. Piroon Rattanaprasit<br>Pichai Co.,Ltd. | 25-Sep-90 | 24-Sep-93 |
| 98 | Production of Agar from Seaweed | Mr. Swai Paiboonsirijit<br>Pure Agar Co.,Ltd. | 26-Nov-90 | 25-Nov-93 |

| No. | Project Title | Pricipal investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 99 | Production High Quality of Legume Inoculant | Mr. Montri Rongtrakoontien<br>Bangkok Seeds Industry Cpp.,Ltd | 29-Jan-91 | 28-Jan-94 |
| 100 | Development of Technology for the Processing of Potential Aquaculture Feed Organisms | Dr. William H. Klausmier<br>Aquastar Laboratories Co.,Ltd | 29-Jan-91 | 28-Jan-94 |
| 101 | Rubber Dams and Rubber Sheet Lining for Reservoirs | Mr. Kriang U-Udomying<br>Sang Thai Rubber Factory Co.,Ltd. | 31-Mar-89 | 30-Mar-91 |
| 102 | Development of Personal for Software Research and Development | Dr. Kanchit Malaivongs<br>Institute of Thai Information Technology Co.,Ltd. | 06-Dec-90 | 05-Dec-97 |

*Source : STDB*

# APPENDIX 3.2

## LIST OF RD&E PROJECTS FUNDED BY MTEC

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 1 | Establishing a Master Plan for Mineral Utilization. | Mr. Monthop Valayapetre<br>Dept. of Mineral Resources (MOI) | 29-Feb-88 | 28-Feb-89 |
| 2 | Experiment on Machinery Steel Making. | Mr. Somnuk Watanasriyakul<br>(KMITNB) | 26-Aug-88 | 25-Aug-89 |
| 3 | Improvements of Metal Properties with Rare Earth Elements from Tin Tailing. | Dr. Paritud Bhandhubanyong<br>Assoc. Prof. Manas Sathirachinda<br>Metallurgy and Materials Science Research Institute (CU) | 10-Aug-88 | 09-Aug-90 |
| 4 | The Development of Fine Casting by Using Lost Foam Method. | Assoc. Prof. Banleng Sornnil<br>(KMITNB) | 26-Aug-88 | 25-Aug-89 |
| 5 | Development of Chilled Cast Iron Roll Production. | Mr. Chao Niamsorn<br>(KMITT) | 26-Aug-88 | 25-Aug-89 |
| 6 | Research and Development on Pressworking Technology.<br>Phase II : Design and Construction of Low Cost Dies.<br>Phase III : Design and Making of High Grade Dies. | Assoc. Prof. Charn Thanadngarn<br>(KMITNB) | 26-Aug-88 | 25-Aug-90 |
| 7 | Research and Development on Welding Quality. | Mr. Yukol Julupal<br>Welding and Inspection Development Center (KMITNB) | 26-Aug-88 | 25-Aug-89 |
| 8 | Research Work on Manufacturing of Moulds and Dies. | Mr. Somsak Chantanaval<br>(KMITNB) | 26-Aug-88 | 25-Aug-89 |
| 9 | Technology Transfer in Injection Mould Design. | N.A.<br>Technology Transfer Center (MOSTE) | N.A. | N.A. |
| 10 | Research and Development Project for the Production of Machinery Parts and Machine Prototype. | Assoc. Prof. Banleng Sornnil<br>Dr. Somchob Chaiyawet<br>(KMITNB) | 26-Aug-88 | 01-Jul-91 |
| 11 | Research and Development of Rice Thresher. | Mr. Wuttichai Kabilgarn<br>National Agricultural Machinery Center (KU) | 02-Sep-88 | 01-Sep-89 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 12 | Shrimp Feed Grinding and Pelleting Machine. | Mr. Grot Kunchorn Na Ayuthaya<br>Dept. of Agricultural Engineering<br>Faculty of Engineering (KU) | 02-Sep-88 | 02-Sep-89 |
| 13 | Shrimp Grading Machine. | Mr. Vicha Muntumkarn<br>Dept. of Agricultural Engineering<br>Faculty of Engineering (KU) | 02-Sep-88 | 01-Sep-89 |
| 14 | Shrimp Separator. | Mr. Pongjet Bromvong<br>Faculty of Engineering (KMITL) | 02-Sep-88 | 01-Sep-89 |
| 15 | Programmable Automatic Lathe Project. | Mr. Tavan Sujaritkul<br>Dept. of Mechanical Engineering<br>Faculty of Engineering (CMU) | 02-Sep-88 | 01-Sep-89 |
| 16 | Design Construction and Testing of Continuous Sand Mixer. | Mr. Korbsin Taveesin<br>Faculty of Engineering (KMITT) | 26-Aug-88 | 25-Aug-89 |
| 17 | Design of Shrimp Grading Machine. | Mr. Sunchai Klinpikul<br>Faculty of Engineering (PSU) | 01-Sep-88 | 31-Aug-89 |
| 18 | Development and Design of the Spindle Sander. | Mr. Uthit Himakul<br>Faculty of Engineering (KKU) | 22-Sep-88 | 21-Sep-89 |
| 19 | Determination of Corrosion of Metals in Industrials Application under Various Environments and Simulated Conditions. | Dr. Ladawal Chotimongkul<br>TISTR (MOSTE) | 29-Feb-88 | 30-May-90 |
| 20 | Feasibility Study of High Tension Insulator Manufacturing. | Mr. Ampon Watanarungsun<br>Metallurgy and Material Science Research Institute (CU) | 10-Aug-88 | 09-Aug-89 |
| 21 | Development of Ferrites for Loud Speakers. | Dr. Rux Jira<br>Dr. Ladawal Chotimongkol<br>TISTR (MOSTE) | 29-Feb-88 | 09-Sep-92 |
| 22 | Production of Abrasive Material and Grinding Wheel. | Ms. Ananya Tribumrungsuk<br>TISTR (MOSTE) | 29-Feb-88 | 31-May-90 |
| 23 | Preparation of Bone China Body Compound. | Dr. Varunee Thiramongkol<br>Dept. of Science Service (MOSTE) | 22-Feb-88 | 25-May-91 |
| 24 | Development of Plastic Films for Outdoor Utilization in Thailand. | Dr. Krisda Suchiva<br>Faculty of Science (MU) | 26-Aug-88 | 25-Aug-89 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 25 | High Modulus Fibre Reinforced Composites. | Mr. Kemchai Hemachand<br>Ms. Paipan Suntisuk<br>Metallurgy and Material Science Research Institute (CU) | 10-Aug-88 | 10-Apr-92 |
| 26 | A Study of the Status of Technology in Plastics Industry. | Assoc. Prof. Banleng Sornnil (KMITNB) | 01-Sep-88 | 31-Aug-89 |
| 27 | Technology Development of Products from Gamma Radiated Vulcanized Natural Latex. | Mr. Chayakit Siriuppatam<br>Office of Atomic Energy for Peace (MOSTE) | 14-Sep-88 | 24-Jun-91 |
| 28 | Latex Tube for Medical Use. | Dr. Boontham Nithi-Uthai (PSU) | 02-Sep-88 | 02-Sep-89 |
| 29 | Development of Production Technology for Expanded EVA and Expanded Rubbers. | Dr. Krisda Suchiva<br>Faculty of Science (MU) | 26-Aug-88 | 25-Aug-89 |
| 30 | Directions for Producing Human Resources for the Textile Industry. | Mr. Pramote Vitthayasuk<br>Dept. of Industrial Promotion (MOI) | 22-Feb-88 | 21-Feb-89 |
| 31 | Study on the Preparation and Extraction of Ramie and Flax Fibres. | Mr. Satit Sirirungamanond<br>Textile Industries Industry<br>Dept. of Industrial Promotion (MOI) | 22-Feb-88 | 12-Jun-90 |
| 32 | Tax Structure and Import Tariff of Machine Tools and Equipment. | Assoc. Prof. Banleng Sornnil (KMITNB) | 23-Sep-88 | 22-Sep-89 |
| 33 | Research and Development of Specific Rare Earth for Production of Conductor. | Ms. Ratana Siangprasertgil<br>Dept. of Chemistry<br>Faculty of Science (CU) | 04-Jul-88 | 13-May-92 |
| 34 | Third Mining and Mineral Resources Conference. | Dr. Quanchai Leepowpanth<br>Faculty of Engineering (CU) | 29-May-89 | 28-May-90 |
| 35 | Reserve Exploration and the Management of Rare Earth Minerals for the - Development of Electronics Industry in Thailand. | Mr. Boonsom Siribumrungsuk<br>Faculty of Engineering (PSU) | 30-Jun-89 | 25-Mar-91 |
| 36 | Research and Development on Organ Reinforce Metal for Medical Use. | Mr. Pibul Ittiravivong<br>Metallurgy and Material Science Research Institute (CU) | 12-Jun-89 | 11-Jun-90 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 37 | Feasibility Studies of New Metal Production Industry. | Mr. Monthop Valayapetre<br>Metallurgy Division<br>Dept. of Mineral Resources (MOI) | 29-Mar-89 | 29-Jul-91 |
| 38 | Development of Production Technique and a Study of Structures and Properties of Metallic Glasses. | Dr. Panya Srichandr<br>School of Energy and Materials (KMITT) | 27-Jun-89 | 26-May-92 |
| 39 | Research and Development from Effect of Heat Treatment on Weld Cracking of High Strength. | N.A.<br>Welding and Inspection Development Center (KMITNB) | 30-Jun-89 | 29-Jun-90 |
| 40 | Improvement of Small Cast Iron Industry in Northeast Thailand. | Mr. Somkiat Rujikiatkumjorn<br>Faculty of Engineering (KKU) | 30-Jun-89 | 29-Jun-90 |
| 41 | Research and Development of Thin Film Process by Sputtering Method. | Mr. Pichet Limsuwan<br>Dept. of Physics (KMITT) | 27-Jun-89 | 12-May-92 |
| 42 | Surface Hardening by Ion Implantation. | Dr. Thiraphat Vilaithong<br>Institute for Science & Technology Research and Development (CMU) | 30-Jun-89 | 13-May-92 |
| 43 | Manpower Development Programmer in CAE/ CAD/CAM Based Injection Mould Design. | Assoc. Prof. Banleng Sornnil (KMITNB) | 30-Jun-89 | 29-Jun-90 |
| 44 | Computer-Aided Design of Metallic Parts. | Dr. Panya Srichandr<br>School of Energy and Materials (KMITT) | 27-Jun-89 | 26-Jun-90 |
| 45 | Research and Development of Universal Laboratory Plastic Extruder Set. | Assoc. Prof. Banleng Sornnil<br>Faculty of Technology Engineering<br>Rajamangala Institute of Technology | 30-Jun-89 | N.A. |
| 46 | The Development and Construction of 2 Stroke Engine. | Assoc. Prof. Banleng Sornnil (KMITNB) | 30-Jun-89 | 01-Jul-91 |
| 47 | Computerized Numerical Controlled High Precision Vertical Type Milling Machine. | Mr. Dilok Sriprapai<br>Dept. of Production Engineering (KMITT) | 27-Jun-89 | 04-Jul-91 |
| 48 | The Development of Sheller for High Moisture Content Corn. | Mr. Akkradej Attachinda<br>Dept. of Agricultural Engineering (KU) | 30-Jun-89 | 09-Sep-92 |
| 49 | Cleaning and Aerating Boat for Prawn Farm. | Mr. Julsiri Sringarmpong<br>Dept. of Production Engineering (KMITT) | 27-Jun-89 | 26-Jun-90 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 50 | CNC Laser Cutting Table. | Mr. Dilok Sriprapai<br>Dept. of Production Engineering (KMITT) | 27-Jun-89 | 21-Jun-91 |
| 51 | Pomelo and Lemon Sizing Machines. | Mr. Bandit Jarimopas<br>National Agricultural Machinery Center (KU) | 30-Jun-89 | 29-Mar-90 |
| 52 | Young Coconut Opening Machine. | Mr. Bandit Jarimopas<br>National Agricultural Machinery Center (KU) | 30-Jun-89 | 29-Dec-89 |
| 53 | Study of Labour-Saving Equipment and Machinery Demand for Shrimp Production for Export. | Mr. Bandit Jarimopas<br>National Agricultural Machinery Center (KU) | 30-Jun-89 | 29-Sep-89 |
| 54 | Planning of the Future Research Topics for Metal Industry. | Dr. Paritud Bhandhubanyong<br>Chula Unisearch (CU) | 15-Sep-89 | 14-Sep-90 |
| 55 | Biomaterial Ceramic. | Dr. Charussri Lorprayoon<br>Mr. Pibul Ittiravivong<br>Metallurgy and Material Science Research Institute (CU) | 12-Jun-89 | 12-May-92 |
| 56 | ZnO Surge Arrestor Feasibility Study of ZnO Surge Arrester Manufacturing in Thailand. | Dr. Lek Uttamasil<br>Metallurgy and Material Science Research Institute (CU) | 12-Jun-89 | 21-May-91 |
| 57 | Raw Material Substitution in Technology Glass Melting. | Assoc. Prof. Preeda Pimkaokum<br>Metallurgy and Material Science Research Institute (CU) | 12-Jun-89 | 11-Jun-90 |
| 58 | Zircon-Type Ceramic Pigments. | Dr. Suchinda Chotipanich<br>Dept. of Science Service (MOSTE) | 29-May-89 | 21-May-91 |
| 59 | Controlled Preparation of High Grade Silica from Thai Rice Husk by - Fluidization Method. | Assoc. Prof. Preeda Pimkaokum<br>Metallurgy and Material Science Research Center (CU) | 12-Jun-89 | 21-May-91 |
| 60 | Advanced Ceramic Industry. | Dr. Lek Uttamasil<br>Metallurgy and Material Science Research Center (CU) | 12-Jun-89 | 11-Jun-90 |
| 61 | Information Survey of Transducer Materials. | Ms. Jitiporn Phupaijitkul<br>TISTR (MOSTE) | 01-Jun-89 | 31-May-90 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 62 | Tile Testing Center for Export. | N.A.<br>(CU) | N.A. | N.A. |
| 63 | Development of the Instrument for Magnetic Property Measurement. | Ms. Jitiporn Phupaijitkul<br>TISTR (MOSTE) | 12-Sep-89 | 11-Sep-90 |
| 64 | Formulation and Processing Technique of Cling Film for Food Packaging. | Mr. Chatchaval Surussavadee<br>Faculty of Technology Engineering<br>Rajamangala Institute of Technology | 30-Jun-89 | 04-Jun-91 |
| 65 | Study and Development of Microencap-sulated Pesticides. | Mr. Supon Chotiwan<br>(KMITNB) | 30-Jun-89 | 24-Jun-91 |
| 66 | Biodegradable Polyesters for Users in Surgical Applications. | Dr. Nipapan Molloy<br>(CMU) | 30-Jun-89 | 13-May-92 |
| 67 | Photo Degradability of Plastics. | Mr. Patrapan Prasasarakij<br>Dept. of Chemical Technology<br>Faculty of Science (CU) | 01-Aug-89 | 24-Jun-91 |
| 68 | The Academic Meeting for the Cooperation in Polymer. | Ms. Supawan Tantayanond<br>Petroleum and Petrochemical College<br>(CU) | 29-May-89 | 28-May-90 |
| 69 | Development of Photoresists Used in Electronics Industry. | Ms. Supawan Tantayanond<br>Petroleum and Petrochemical College<br>(CU) | 05-Sep-89 | 04-Jun-91 |
| 70 | Research and Development of Thermo - plastic Elastomers from Natural Rubber. | Dr. Krisda Suchiva<br>Dept. of Chemistry<br>Faculty of Science (MU) | 15-Jun-89 | 24-Jun-91 |
| 71 | Survey of Rubber Manufacturing Industry to Specify Directions of Research and Development. | Dr. Krisda Suchiva<br>Dept. of Chemistry<br>Faculty of Science (MU) | 30-Jun-89 | 29-Jun-90 |
| 72 | The Establishment of Weft Silk Yarn Standard. | Ms. Preeda Thammakasem<br>Thai Silk Development Group<br>Dept. of Industrial Promotion (MOI) | 13-Jun-89 | 04-Jul-91 |
| 73 | Study on Properties and Utilization of Thai Cotton. | Ms. Lalita Kijkrailas<br>Textile Industries Division<br>Dept. of Industrial Promotion (MOI) | 03-Jun-89 | 12-Jun-90 |
| 74 | A Study of the Status of Technology in Textile Industry. | Dr. Werasak Udomkichdecha<br>Chula Unisearch (CU) | 14-Aug-89 | 13-Aug-90 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 75 | Feasibility of Using Fibers form Water Hyacinth in Textile Industry. | Dr. Werasak Udomkichdecha<br>Metallurgy and Material Science Research Institute (CU) | 12-Sep-89 | 11-Sep-90 |
| 76 | Production of Antimony Trioxide Directly from Antimony Ore by Hydrometallurgical Process. | Dr. Lek Uttamasil<br>Metallurgy and Materials Science Center (CU) | 26-Sep-89 | 25-Sep-90 |
| 77 | The Development of Tin, Tin Alloys, Zinc and Zinc Alloys Electroplating Processes. | Ms. Paipan Santisuk<br>Metallurgy and Materials Science Research Institute (CU) | 26-Sep-89 | 25-Sep-90 |
| 78 | Development of Tin Compounds as Fire Retardants and Smoke Suppressants. | Dr. Paritud Bhandhubanyong<br>Metallurgy and Materials Science Research Institute (CU) | 26-Sep-89 | 25-Sep-90 |
| 79 | Development of Powdermet Technology. | Dr. Panya Srichandr<br>School of Energy and Materials (KMITT) | 26-Sep-89 | 25-Sep-90 |
| 80 | Development of Cemented Carbide Tools Using Powder Metallurgy Processing. | Mr. Somkiat Rujikiatkumjorn<br>Dept. of Production Engineering<br>Faculty of Engineering (KKU) | 09-Aug-89 | 08-Aug-90 |
| 81 | Precision Electromagnets for Science and Hightech-Industry. | Mr. Veerapong Paesuwan<br>Institute for Science & Technology Research and Development (CMU) | 22-Jun-90 | 12-May-92 |
| 82 | Superplastic Forming of Metals and Alloys. | Dr. Panya Srichandr<br>(KMITT) | 03-Jul-90 | 02-Jul-91 |
| 83 | Computerized Numerical Control Machining Center. | Mr. Dilok Sriprapai<br>Dept. of Production Engineering<br>(KMITT) | 30-Jul-90 | 15-Sep-92 |
| 84 | Manpower Development of Using the CAD/ CAE/CAM Systems of Plastic Injection Mould Making with CNC-Machine. | Mr. Chupong Virunha<br>(KMITNB) | 05-Jun-90 | 04-Jun-91 |
| 85 | Development of Packing House's Equipment of Horticultural Product for Export. | Mr. Bandit Jarimopas<br>National Agricultural Machinery Center (KU) | 22-Jun-90 | 12-May-92 |
| 86 | An Application of CAD/CAM in an Integrated Mould Design and - Manufacturing System. | Mr. Manop Riewdecha<br>Faculty of Engineering (CU) | 03-Jul-90 | 02-Jul-92 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 87 | A Study and Improvement of Non Ferrous Alloys. | Mr. Taweesak Akkrangool<br>Dept. of Production Engineering<br>Faculty of Engineering (KKU) | 05-Jun-90 | 09-Sep-92 |
| 88 | The Development of Measures Against Corrosion of Metal Cans. | Dr. Paritud Bhandhubanyong<br>Mr. Paipan Santisuk<br>Metallurgy and Materials Science Research Institute (CU) | 26-Jun-90 | 10-Apr-92 |
| 89 | Research and Development for Hard Facing Manual Arc Welding. | Mr. Yukol Julupai<br>Welding and Inspection Development Center (KMITNB) | 22-Jun-90 | 21-Jun-91 |
| 90 | Development of Piezoelectric Ceramics for High Voltage Source. | Mr. Narin Sirikulrat<br>Dr. Tawee Tunkasiri<br>Dept. of Physics, Faculty of Science (CMU) | 22-Jun-90 | 13-May-92 |
| 91 | Research on Oxide of Transition Metals for NTC Thermistor Sensor. | Mr. Somchai Tongtem<br>Dept. of Physics, Faculty of Science (CMU) | 22-Jun-90 | 21-Jun-91 |
| 92 | Uses of Tin Compounds and/or Plastic to Develop Glass Coating Industries. | Dr. Lek Uttamasil<br>Matallurgy and Materials Science Research Institute (CU) | 22-Jun-90 | 12-May-92 |
| 93 | Development of Sand Blast Tube by Isostatic Pressing Technique. | Dr. Lek Uttamasil<br>Metallurgy and Materials Science Research Institute (CU) | 22-Jun-90 | 21-Jun-90 |
| 94 | Development of Raw Materials and Refractories for Industrial Uses. | Mr. Sompong Chanpee<br>Dept. of Geology, Faculty of Science (CMU) | 25-May-90 | 13-May-92 |
| 95 | Investigation and Production of Some Pure Chemical Materials for Industry. | Mr. Man Amornsit<br>Dept. of Chemistry<br>Faculty of Science (CU) | 22-May-90 | 21-May-91 |
| 96 | Purification of Iron Oxide from Mill Scale of Industrial Steel. | Ms. Thitipan Kuangsuksatit<br>Dept. of Chemistry<br>Faculty of Science (CMU) | 22-May-90 | 21-May-91 |
| 97 | Construction of High Temperature Electrical Furnace and Computerized Control System. | Mr. Aree Vichainchai<br>Dept. of Applied Physics<br>Faculty of Science (KMITL) | 22-May-90 | 21-May-92 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 98 | Development of Technology and Product in Alumina. | Dr. Lek Uttamasil<br>Metallurgy and Materials Science Research Institute (CU) | 22-May-90 | 12-May-92 |
| 99 | Development of Capability in Engineering Ceramics. | Dr. Nongluck Pankirddee<br>TISTR (MOSTE) | 25-May-90 | 29-Jul-92 |
| 100 | Development of Polymer Supported Catalyst. | Ms. Supawan Tantrayanond<br>Petroleum and Petrochemical College (CU) | 17-Sep-90 | 19-Sep-92 |
| 101 | Research and Development of Plastic-Plastic Blends. | Mr. Supon Chotiwan<br>(KMITNB) | 25-Jun-90 | 15-Sep-92 |
| 102 | Research of Foam Used for Cushionings Materials. | Mr. Chanchai Ruengdejvorachai<br>TISTR (MOSTE) | 25-Jun-90 | 24-Jun-91 |
| 103 | Development of Plastic Films for Agricultural Uses : UV-stabilized and Wavelength Selective Polythylene Films. | Ms. Saovarop Bualek<br>Faculty of Science (MU) | 05-Jun-90 | 13-May-92 |
| 104 | Radiation Graft Copolymerization of Cassava Starch for Agricultural Applications. | Dr. Suda Kiatkumjornwong<br>Petroleum and Petrochemical College (CU) | 05-Jun-90 | 21-May-92 |
| 105 | Development of Concentrated Latex for High Quality. | Dr. Boontham Nithi-Uthai<br>(PSU) | 25-Jun-90 | 24-Jun-91 |
| 106 | Research and Development of Prevul-canized Latex. | Dr. Krisda Suchiva<br>Faculty of Science (MU) | 25-Jun-90 | 06-Aug-92 |
| 107 | Research and Development of Medical Gloves Production. | Ms. Varaporn Kajornchaikul<br>Songkhla Rubber Research Center<br>Dept. of Agriculture (MOAC) | 25-Jun-90 | 10-Apr-92 |
| 108 | Prototype Latex Thread Process. | Mr. Preeda Pongpal<br>(PSU) | 25-Jun-90 | 24-Jun-91 |
| 109 | Development and Promotion the Use of Skim Rubber from Concentrated Latex Factories. | Ms. Pornpan Nithi-Uthai<br>Faculty of Science and Technology (PSU) | 25-Jun-90 | 24-Jun-91 |
| 110 | A Study on Technology Capability of Open End Spinning. | Dr. Werasak Udomkichdecha<br>Metallurgy and Materials Science Research Institute (CU) | 22-May-90 | 21-May-91 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 111 | A Study on the Appropriate Utilization of Shuttleless Weaving Technology for Thai Textile Industry. | Dr. Werasak Udomkichdecha<br>Textile Industries Division<br>Department of Industrial Promotion (MOI) | 22-May-90 | 21-May-91 |
| 112 | Thai Silk Knitted Fabric. | Mr. Pichai Pongvirat<br>Textile Industries Division<br>Department of Industrial Promotion (MOI) | 22-May-90 | 21-May-91 |
| 113 | The Quality Improving of Thai Silk. | Ms. Pisamai Likitbunnakorn<br>Textile Industries Division<br>Department of Industrial Promotion (MOI) | 22-May-90 | 21-May-91 |
| 114 | Synthesis of Gamma-$Fe_2O_3$ for the Tape Recording Industry. | Dr. Lek Uttamasil<br>Metallurgy and Materials Science Research Institute (CU) | 11-Apr-91 | 10-Apr-92 |
| 115 | Utilization of Mineral Raw Materials in Industry (Development of Alumina Raw Material Preparation from Indigineous Resources). | Dr. Quanchai Leepowpanth<br>Faculty of Engineering (CU) | 17-May-91 | 12-May-92 |
| 116 | Composite Lead for Radiation Shielding. | Mr. Nara Jirapatrapimol<br>Faculty of Science (CMU) | 14-May-91 | 13-May-92 |
| 117 | The Production of Amalgam as Tooth Filler. | Ms. Vacharee Suchartlumpong<br>Faculty of Dentistry (MU) | 26-Apr-91 | 25-Apr-92 |
| 118 | Research and Development on Jigs and Fixtures Technology: Phase I. | Assoc. Prof. Charn Thanadngarn<br>(KMITNB) | 07-Jun-91 | 06-Jun-92 |
| 119 | Information Service Center and Technology Transfer in Metal Casting Technology. | Dr. Panya Srichandr<br>School of Energy and Materials (KMITT) | 27-May-91 | 26-May-92 |
| 120 | The Development of Automatic Monitoring System of Cathodically Protected Pipe-lines. | Asst. Prof. Wikrom Vajaragupta<br>Metallurgy and Materials Science Research Institute (CU) | 11-Apr-91 | 26-May-92 |
| 121 | Surface Treatment of Die by TD Process. | Dr. Paritud Bhandhubanyong<br>Metallurgy and Materials Science Research Institute (CU) | 11-Apr-91 | 16-Apr-92 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 122 | CAD/CAM Center Project. | Mr. Saree Savetseranee<br>Faculty of Engineering (KU) | 24-Jun-91 | 25-Apr-92 |
| 123 | Design and Production of CNC Vertical Milling and Boring Machine. | Dr. Somchob Chaiyawet<br>(KMITNB) | 26-Apr-91 | 25-Apr-92 |
| 124 | A Research and Development of the Hydraulically Operated Coconut Milking. | Mr. Mongkol Kuangvaropas<br>Faculty of Engineering (KU) | 11-Apr-91 | 10-Apr-92 |
| 125 | High-Intensity Magnetic Separator for Mineral Separation. | Mr. Aree Vichianchai<br>Faculty of Science (KMITL) | 22-May-91 | 21-May-92 |
| 126 | The Development of Prototype of an Electrically Operated Net to Harvest Shrimps in Farms. | Mr. Prakarn Kuruhongsa<br>Research and Development Office (PSU) | 11-Apr-91 | 10-Jan-92 |
| 127 | Mangosteen Cutting Machine. | Mr. Bandit Jarimopas<br>National Agricultural Machinery Center (KU) | 11-Apr-91 | 10-Apr-92 |
| 128 | Research and Development of Rice Combined Harvester. | Mr. Vicha Muntamkarn<br>National Agricultural Machinery Center (KU) | 11-Apr-91 | 10-Apr-92 |
| 129 | Research and Development of Shrimp & Mackerel Fish Sizing Machine for Commercialization. | Mr. Vicha Muntamkarn<br>National Agricultural Machinery Center (KU) | 13-May-91 | 12-May-92 |
| 130 | Development of Walking Tractors Tillage Implements. | Dr. Surin Phongsupasamitr<br>Faculty of Engineering (CU) | 14-May-91 | 13-May-92 |
| 131 | Rotary Tiller for Walking Tractor. | Mr. Thanya Niyamapa<br>Faculty of Engineering (KU) | 11-Apr-91 | 13-May-92 |
| 132 | Vibrating Subsoiler. | Mr. Thanya Niyamapa<br>Faculty of Engineering (KU) | 11-Apr-91 | 10-Apr-92 |
| 133 | High Viltage Capacitors in the Range of 1-5 Kilovolts. | Dr. Tawee Tunkasiri<br>Faculty of Science (CMU) | 14-May-91 | 13-May-92 |
| 134 | Resin Bonded Grinding Wheels Production Research. | Ms. Orachun Kaewkungwal<br>TISTR (MOSTE) | 03-Jul-91 | 02-Jul-92 |
| 135 | Research and Development of Guides for Threads. | Dr. Suchinda Chotipanich<br>Department of Science Service (MOSTE) | 13-May-91 | 12-May-92 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 136 | Production of Ceramic Novelty Items with Esan's Identity as a Local Industry. | Mr. Sumruag Inban (KKU) | 26-Apr-91 | 25-Apr-92 |
| 137 | Mica Beneficiation. | Mr. Vichit Vichitamornpan Department of Mineral Resources (MOI) | 22-May-91 | 21-May-92 |
| 138 | Research and Development for Diatomite. | Mr. Pitak Harnjavanich Department of Mineral Resources (MOI) | 13-May-91 | 12-May-92 |
| 139 | Development and Application of China Stone. | Ms. Nipa Julajarit Department of Mineral Resources (MOI) & Department of Science Service (MOSTE) | 13-May-91 | 12-May-92 |
| 140 | Quality Control of Kaolin from Northern Esan for Ceramic Industry. | Mr. Sumruag Inban (KKU) | 26-Apr-91 | 25-Apr-92 |
| 141 | Heat Treatment of Gems by Locally Developed Furnace. | Mr. Pinyo Meechamna Metallurgy and Materials Science Research Institute (CU) | 13-May-91 | 12-May-92 |
| 142 | Survey of R&D Projects in Ceramics in Thailand (1980-1989). | Dr. Ladawal Chotimongkol TISTR (MOSTE) | 13-May-91 | 12-May-92 |
| 143 | The Improvement of Natural Fiber's Strength as Plastic Reinforcer. | Ms. Jintana Leekijwatana Department of Science Service (MOSTE) | 14-May-91 | 13-May-92 |
| 144 | Development of Natural Rubber-toughened Polyamide (Nylon6). | Dr. Krisda Suchiva Faculty of Science (MU) | 14-May-91 | 13-May-92 |
| 145 | Research and Development on the Use of Polymerized Cyclodextrin in Decaffeination Process. | Mr. Amnag Sititrakool Faculty of Science (SU) | 14-May-91 | 13-May-92 |
| 146 | Development of Ziegler-Natta Catalyst. | Mr. Piyasai Praserttham Metallurgy and Materials Science Research Institute (CU) | 13-May-91 | 12-May-92 |
| 147 | Water Hyacinth Fiber Reinforced Natural Rubber Composites. | Ms. Saovaroj Chuayjuljit Metallurgy and Materials Science Research Institute (CU) | 13-May-91 | 12-May-92 |
| 148 | Experiment on Producing Cosmetic Rubber Hand. | Ms. Patra Karntasil Songkhla Rubber Research Center Dept. of Agriculture (MOAC) | 11-Apr-91 | 10-Apr-92 |

| No. | Project Title | Principal Investigator | Starting Date | Ending Date |
|---|---|---|---|---|
| 149 | Study of the Production of Natural Rubber Cutless Bearing for Fishing Boat to be Used in Place of Wooden Bearing. | Mr. Preecha Pongpai (PSU) | 13-May-91 | 12-May-92 |
| 150 | Developing Method of Producing Catheter. | Ms. Pronpan Nithi-Uthai Faculty of Science and Technology (PSU) | 13-May-91 | 12-May-92 |
| 151 | Adhesive for Bonding Textiles to Rubber. | Mr. Sopon Ruengsamran Faculty of Science (CU) | 14-May-91 | 13-May-92 |
| 152 | Research and Development of Rubber-to-Metal Bonding Technology (Bonding of Natural Rubber to Metals). | Dr. Krisda Suchiva Faculty of Science (MU) | 14-May-92 | 13-May-92 |
| 153 | Strengthening of Rubber Technology Network Project. | Ms. Varaporn Kajornchaikul Faculty of Sciences (MU) | 22-May-91 | 21-May-92 |
| 154 | The Development of Technical Personnel in Textile Industry Using Video Tape. | Dr. Rojana Kosaiyanond Metallurgy and Materials Science Research Institute (CU) | 13-May-91 | 12-May-92 |
| 155 | The Survey and Collection of Data on Personnel and Works on Textile Technology. | Dr. Werasak Udomkichdecha Metallurgy and Materials Science Research Institute (CU) | 13-May-91 | 12-May-92 |
| 156 | The Research on Construction of Data Base in Textile Industry. | Dr. Rojana Kosaiyanond Metallurgy and Materials Science Research Institute (CU) | 13-May-91 | 22-Feb-92 |
| 157 | Utilization of Banana Fiber. | Dr. Werasak Udomkichdecha Metallurgy and Materials Science Research Institute (CU) | 26-Apr-91 | 25-Apr-92 |

CMU = Chiang Mai University
CU = Chulalongkorn University
KKU = Khon Kaen University
KMITL = King Mongkut's Institute of Technology Lat Krabang
KMITNB = King Mongkut's Institute of Technology North Bangkok
KMITT = King Mongkut's Institute of Technology Thonburi
KU = Kasetsart University
MOAC = Ministry of Agriculture and Cooperatives
MOI = Ministry of Industry
MOSTE = Ministry of Science, Technology and Environment
MU = Mahidol University
PSU = Prince of Songkla University

Source : MTEC

# CHAPTER 4 CASE STUDIES ANALYSIS

## 4.1 CASES SELECTED FOR STUDY

A total of 9 projects, 6 funded by MTEC, 2 by STDB, and 1 jointly by STDB and MTEC, have been selected for study. Five of the projects are in the area of metals, and these can be further subdivided with 3 projects regarded as hardware development and 2 projects as materials development. Two of the projects are in the area of ceramics. The last two projects are in the area of polymers; one is in rubber and the other in plastics. The number of projects selected for study is weighted in favor of metals and also in favor of projects funded by MTEC. The reasons for this are that there are more projects funded in the metals area than in the other two areas, and also that MTEC started funding for metals RD&E before STDB. The projects are numbered 1 through 9, and these numbers will be used in section 4.11, Cross Case Analysis, to refer back to a specific case.

The following is a brief description of the 9 projects selected.

1. The project "Research and Development on Pressworking Technology" was a 3 years project granted by MTEC for the fiscal years 1989 to 1991 to study the status of pressworking technology in three areas : machine tools, the designing and making of sheet metal press die, and the particular difficulties of the pressworking industry in Thailand. After a survey of industry problems, the procedures for making simple sheet metal press die, low cost die, and high quality die were investigated. Next, standard operating procedures for materials selection, standard parts selection, die design and production, and die testing and inspection were made. Production testing of presswork products was done in order to test the useful life of die materials and to assure the quality of dies. Academic papers including manuals for sheet metal press die design, production, and testing, papers on design and production of low cost die, die parts standards, and standards for inspection of die making procedures, etc., were published and distributed for use in various local die making companies. Seminars and workshops were also held to disseminate die designing and die making technology to public and private

organizations. A full report on "High Quality Die Design and Making" is expected to be submitted to MTEC in 1992.

2. "Research and Development of Technology for the Production of Machine Parts and Machine Prototypes - The Development and Construction of an Injection Blow Moulding Machine" was an 18 month project funded by MTEC during the fiscal years 1988 to 1989 with the aim to develop indigenous engineering capabilities in a systematic manner. The project proceeded from conceptual product development to production planning, production of parts, and final construction of industrial machinery, namely, the injection blow moulding machine. The project was divided into two phases. The first phase focused on the development and construction of the injection unit, and the second phase the development and construction of the blowing unit. After combining these two units together on the same machine frame and equipping with automatic alternate function capability, the machine was completed as an injection blow moulding machine.

Normally, the production of liquid holding plastic vessels, such as bottles, has been carried out extensively in Thailand by the so-called extruding blowing machine which necessitates a certain loss of plastic scrap that must be reprocessed. Such loss could be eliminated using injection blow moulding machines, which are normally imported. The development of this machine locally could help to mitigate the trade imbalance and develop the capabilities of local engineers to design and develop other necessary machinery in the future. The developed machine was specified to have a shot weight capacity of 2.98 ounces, with an injection screw diameter of 30 mm and an injection pressure of 1,500 bars. The machine development included hydraulic, pneumatic, and electronic automatic controls, and emphasized precision, rigidity, proportionality, and ease of operation.

3. "The Development of Walking Tractors and Tillage Implements" was a one year project funded by MTEC during the fiscal year 1991. The walking tractor is an important agricultural machine for soil preparation and other agricultural functions for Thai farmers. At present, all of the walking tractors used in Thailand are locally made and only minor improvements have been developed. In fact, the model and the production process has not changed for 15 years due to the lack of R&D capability on the part of the domestic

producers. The use of this walking tractor is limited in capacity and ease of handling. This project had as its objective to test the capability and to analyze the power transmission system with the aim of developing a prototype model with emphasis on capacity, productivity, ease of use, safety, and economy. The model developed would then be distributed to local producers to improve the domestic production of the walking tractors. The developed model was driven by a 5-10 hp diesel engine with 3 forward and 1 reverse gear drives. In addition, tillage implements for farming were also developed. This project achieved strong cooperation between Japanese engineers and local producers resulting in the successful development of an improved model for Thai walking tractors. The results were also presented in various technical conferences both domestic and international.

4. "Surface Hardening by Ion Implantation" was funded jointly by STDB and MTEC. Ion implantation is a method whereby atoms of nitrogen, boron, and aluminum in a vacuum chamber are excited through a magnetic field and implanted as ions into metallic substrates. The implanted surface will have marked improvements in its properties such as wear resistance, fatigue strength, and corrosion resistance. Examples of ion implanted metals include implanted nitrogen into steel to improve wear resistance and implanted aluminum into copper for improved corrosion resistance. Ion implantation's advantages over other processes are the versatility of materials couples and the finer dimensional tolerances.

The primary objective of the project was to construct the ion implantation machine which is composed of an ion source, a particle accelerator, and a target chamber. The machine was constructed with a zero degree beam line, and has been tested for its functionality. Even though no substantial materials improvements have been obtained, the achievements in hardware development and design have been considerable. In addition, the program has produced a number of graduates and has helped improve the capability of the support staff tremendously, partly as a result of good team work and excellent research environment.

5. "Innovative Uses of Tin" was funded by STDB for a duration of 3 years to investigate and research innovative or new uses of tin. Until recently, tin was a major export of Thailand. The worldwide slump in the

price of tin about ten years ago brought about a sharp downturn in mining and smelting activities. New and innovative uses of tin will invariably create new demands and would be welcomed by the industry. The project was carried out by a strong group of researchers and two expatriate experts. Organo and organotin compounds were produced with the aim to create pesticides, insecticides, and a fire retardant. An important advantage of organo-tin compounds is that they are degradable and less toxic to humans than some other chemicals but still very effective for their purposes. Field tests of the synthesized chemicals were carried out at Mae Cho Agricultural College with positive results. The project yielded a substantial amount of useful information and extended the research capability of the group and produced many graduates as well.

6. "Bone China Production" was a project supported by MTEC and conducted by a group of researchers from the Department of Science Service, MOSTE. The project studied and developed technologies for the production of bone ash, bone china clay mixtures, and bone china products almost entirely from local raw materials. Bone ash produced from cow leg bones has whiteness exceeding 80% Elrepho which is suitable for bone china production. The clay mixture produced from local clay minerals and bone ash from local manufacturers has a quality comparable to that of imported materials, but at a much lower cost. The bone china products developed, particularly the novelty items, are of good quality, though table ware production still needs further improvement. The technologies developed have been transferred to about 24 factories in the Northern and Central regions.

7. "Biomaterials: Hydroxyapatite" is a project conducted at Chulalongkorn University and funded by MTEC. This project aimed at developing reliable techniques for fabrication of implant specimens such as blocks, bars, granules, etc., from hydroxyapatite (HAP) produced from cattle bone. In this project 3 types of hydroxyapatite were tested: HAP from natural cattle bone ash, HAP from chemically treated cattle bone, and chemically precipitated HAP. It was found that specimens produced from chemically treated HAP and the chemically precipitated HAP have better properties than those of natural cattle bone. The results have also shown that HAP originating from chemically treated cattle bone can be used to produce implant specimens in place of the more expensive chemically precipitated HAP, normally used elsewhere. Speci-

mens produced by the method developed in the project are now being tested in animal and human beings with positive results.

8. "Use of Natural Rubber in Rice Huskers" is an STDB funded project given to investigators from the Faculty of Science and Technology, Prince of Songkhla University, Pattani, for a period of three years, from 1989 to 1992. This project proposes to develop a technology for replacing synthetic rubber (nitrile rubber), with natural rubber for the production of rubber rollers used in rice huskers. If achieved, the importation of synthetic rubber would be reduced by an estimated 43 million baht and the use of natural rubber in value added applications would be increased by about 950 tones per month. Factors affecting the wear of the rubber rollers and the efficiency of rice huskers, such as roll hardness, clearance between rollers, and the pressure applied to the rolls have been investigated, and the rubber formulations based on natural rubber were adjusted so that the required results would be obtained. The project is due for completion by the end of 1992.

9. "Biodegradable Polyesters for Use in Surgical Applications" was a project granted by MTEC to the Faculty of Science and the Faculty of Medicine, Chiang Mai University. The project was for three years, during the fiscal years 1989-1991. The objective of the project was to produce sutures, preferably the monofilament type, from polyesters or blends of polyesters with other polymers, that possess the same physical, thermal, and biodegradable properties as those of the commercial sutures. The polyesters of interest are those based on glycolide monomer and poly (diethylene glycol oxalate). The hope is that the sutures developed will replace the 100 million baht of sutures imported annually.

## 4.2 CASE 1: RESEARCH AND DEVELOPMENT ON PRESSWORKING TECHNOLOGY

Reporter: Dr. Paritud Bhandhubanyong

### 4.2.1 Background Information

a) Introduction

Dies are indispensable tools in pressworking to produce numerous kinds of metallic products and/or parts. Without dies, mass production would be impossible. The quality of products also depends partly on the quality of dies used. In Thailand, die shops began about thirty years ago in the Satupradit and Rajaburana areas where machining shops were operating. In those days, die shops were evolving from the machining shops. They started by repairing dies and when the necessary skills were developed, began to manufacture simple cutting, stamping, and plastic dies. There were then a number of plastic injection and metal parts factories. The birth of these factories was to respond to domestic demand and allow for the substitution of imported products and parts. The increase in demand gave rise to the importation of dies as well as inducing the birth of die shops. Many of them later diversified into manufacturing of products and parts. In fact, none of the die shops today exist without diversification into other operations besides die making. Still about 85% of die shops are small and medium sized factories, and only about 15% can produce high quality die within the accuracy of 0.01 mm. or less, the level required by almost all of the die users who produce high value added products such as automobiles, electrical appliances, etc. About 45% of these factories obtained technology from years of experience, 24% from foreign know-how, 15% from universities or technical institutes, and 11% from seminars conducted by various domestic organizations. Die designing was the most needed technology followed by production planning and control, material selection, selection of standard parts, try-out procedures, die maintenance, finishing, die fitting, casting and machining. With only 5% of the die shops employing engineers or university graduates, the development of in-house technological capability is difficult if not impossible. With the increasing trend of demand in high quality dies and the high cost and the long time required for the imported ones, there exists an urgent need to raise the technology level of domestic die makers. Therefore an attempt has been done by researchers in Thailand to study in as much detail as possible the appropriate procedures or steps in the design, making of dies, and the production of press parts which are vital to various key industries in Thailand such as automobiles, electrical and electronic appliances, machinery, machine tools, furniture, etc.

The research team was composed of 9 researchers, 4 from various universities and five from local die makers and was headed by Assoc. Prof. Charn Thanadngarn of KMIT (North Bangkok).

b) Objectives of the research

The research aimed at surveying the status of pressworking technology in Thailand to determine the kinds and level of technology needed in the local industry, as Phase 1 of the research. At the end of Phase 1 and through out Phase 2 and 3 the design, making, selection of materials and standard parts, standard operation procedures for try-out and inspection and presswork were studied and developed from various technical sources such as textbooks, sheets, overseas experts, teaching materials and the experiences of the researchers and local die makers. Die type ranging from the simple and low cost to high quality die were studied and analyzed. The dissemination of technology through seminars, manuals and textbooks, and consultancy were also included in the objectives.

c) Results of the research

The present level of pressworking technology in Thailand in the area of machine tool is low, namely, most of the pressworking factories employ second-hand machine tools or second grade tools imported from Taiwan and mainland China due to the low cost of investment but which results in a low level of accuracy. In the case of the design and making of sheet metal press die, technology is low to medium, namely, design and making are still done by using in-house draftsmen, customer's drawing, sample parts, process sheet, operation sheets and inspection sheets. These die makers can produce only simple die with a satisfactory level of quality. Less than 10 of the 450 local die makers employed CAD/CAM, process planning, and can make progressive dies.

The main difficulties for the development of pressworking technology in Thailand are lack of experienced personnel, high turnover rate, low accuracy of machine tools, high price of imported machine tools with high quality while having low price and low quality for domestic ones, lack of knowledge regarding the selection method of materials and the high price of standard material, lack of working standards and manuals, lack of production and market planning or public relations.

The quality of products from low cost die is rather low compared to normal dies and could not be used for outer parts of products. For the given quality criteria cast iron die can produce around 10,000 pieces of press parts while mild steel and epoxy dies can produce around 5,000 and 800 pieces of press products, respectively.

High quality dies such as the ones used in automobile parts manufacturing can be designed and made by local die makers with a satisfactory quality level through the cooperation and advice from researchers.

d) Other users of results

The users of the research outcome are various automobile parts makers and assembly companies such SNN TOOL AND DIE Co., Ltd., SRI THAI GARNPRADIT Co., Ltd., HINO MOTOR Co., Ltd., SUMMIT MOTOR Co., Ltd., CH. AUTO PARTS, and ISUZU Co., Ltd. These companies are using the standard operation procedures, text books, manuals and inspection sheets developed by the research team for their normal operations. The productivity of these companies in terms of lead time for die design and making improved remarkably.

e) Other fields that can use the results

The research and development on die design and making could lead to a study on the selection of die materials to suit the production objectives. Metal removing technology, finishing technology such as plating and surface treatment, and heat treatment technology are other related fields that could use the results. This research project could also be used as a basis for further study such as process analysis, and CAD/CAM/CAE and CIM in the die manufacturing and pressworking industries.

#### 4.2.2 Problems Encountered

The main problems encountered in this research were the inadequacy of financial support, and the time constraint of the researchers who have to devote their time for teaching or for their regular work rather than doing full time research. The other problem cited was that the research head had to spend quite a lot of time to search for local die makers who would cooperate in making high quality die.

#### 4.2.3 Analysis and Lessons Learned

a) PROPOSITION 1: RESEARCHERS CAN PROVIDE CONCRETE RESULTS

The concrete results which were produced by the researchers in this project are:

Academic publications

- Manual for Sheet Metal Press Die Design, Making and Testing, Published by MIDI, Bangkok, 1989.
- Report on "Research and Development on Pressworking Technology, submitted to MTEC, Bangkok, 1989 and published in concise version in the Engineering Journal of the Faculty of Engineering, Chulalongkorn University, 1990.
- Report on "Design and Making of Low Cost Die", submitted to MTEC, Bangkok, 1991 and submitted in concise version to the Asia Pacific Conference on Material Processing to be held in Singapore on February 23-25, 1993.
- Work Standard on Die Design and Making, Standard of Die Parts, and Inspection Standard for Die Making; as seminars' teaching materials, 1991-1992
- Report on "High Quality Die Design and Making" to be submitted to MTEC in 1992.

Prototypes of products and processes

- A set of sheet metal press die
- A set of low cost die
- A set of high quality die

- One unit of a specially designed device for testing the useful life of various die materials

Problems solved, knowledge and experience gained

Knowledge and experience were gained in die design and making, and selection of materials and standard parts for manufacturing a wide range of dies from simple die, and low cost die to high quality die.

Adaptive and innovative steps

Adaptive and innovative steps were taken in the process of low cost die design and making. The researchers used the specially designed device to test the useful life of various die materials which shortened the time consuming process of actual production testing.

Knowledge learned applicable to university's teaching

The knowledge learned during the research work was applied in teaching the students in the Department of Mechanical Engineering, KMIT and the Department of Metallurgical Engineering, Chulalongkorn University, at both the undergraduate and graduate level.

RD&E results meets proposal objectives

The RD&E results could be considered to meet the proposal objectives in analyzing the status of pressworking technology in Thailand. Standard operation procedures in die design and the making of dies with various quality levels were achieved and transferred to local die makers through seminars, workshops and various publications.

Commitment and devotion of researchers

The researchers met once a week to determine the progress of the research work. The participation rate was high through out the project period even though many researchers especially from the private sector were very tied up with their routine work. All of the researchers contributed their knowledge, experience and other physical objects as much as their resources allowed.

b) PROPOSITION 2: RD&E NEEDS TECHNOLOGICAL INFRASTRUCTURE

Manpower

Due to the fact that most of the researchers were from the private sector in the position of middle management on the technical side, their work load and types of duties did not permit them to spend their efforts as full time researchers. As for the researchers from the academic institutions, they also had to devote most of their time for teaching. Sometimes, the meetings had to be held in the evening and the research work was done during the weekend.

Suppliers and Technical Services

The head of the research team achieved strong cooperation with local die makers through the relationships with the researchers from private sectors and through the position as the advisor of the Thai Die Industry Forum of the head of the research. These were necessary factors that facilitated the supply of parts and technical information concerning the die design and making. However, the research head had to spend a lot of time in securing the cooperation of high quality die makers in the third phase of the project, and this resulted in some delay in the completion of this phase.

Financial

The budget received from MTEC totally amounted to around 2.3 million baht, which was quite low considering the output of 3 sets of die and numerous publications. The costs of high quality die in the third phase were quite high, e.g. the draw die cost around 700,000 baht, with 500,000 baht, 700,000 baht, and 1,000,000 baht for trim, flange and cam flange die, respectively. The total cost of the high quality die set came to around 2.9 million baht which was considerably above the total budget. Other costs such as recruitment of part-time student for drafting, a computer for data processing and typing, and a video for documentation and recording of the processes were also very costly and caused serious strain on the budget of the research project. As for the bureaucracy in grant management, the researchers praised MTEC for good cooperation and coordination in the budget distribution and flexibility in budget spending.

### c) PROPOSITION 3: RD&E LACKS SUPPLY, DEMAND AND LINKAGE

There were minor problems concerning supply, demand and linkage of this research project due to the strong linkage between researchers from academic institutions and researchers from private sectors. Collaboration and cooperation between these two parties were effectively established. Knowledge in theories from academicians and knowledge gained from work experience were actively exchanged both among the researchers and between researchers and cooperating local industries. As stated in Proposition 2 about the low budget for research work, the outcomes in term of hardware were possible because of the strong cooperation among researchers and local die makers such as SNN Tool and Die Co., Ltd., Sri Thai Garnpradit Co., Ltd., and Summit Motor Co., Ltd., and local material suppliers such as CIBA-GEIGY Co., Ltd. As for the demand side, the number of participants in seminars and training workshops which were held 9 times at the Thai-Japan Technological Promotion Association (TPA), MIDI, KMIT (North Bangkok), Chulalongkorn University and Central Plaza Hotel in the past three years amounted to 500 persons from local industries and academic institution, indicating the strong demand in die design and making technology which was the main subject of the research work.

### d) PROPOSITION 4: COMMERCIALIZATION NEEDS POLICY & MANAGEMENT

Due to the increasing trend in demand for good quality dies in numerous key industries in Thailand such as automobiles, electrical and electronic appliances, machinery and machine tool, furniture, etc., and the linkage of the researcher with the local industries, commercialization of the outcome of this research project progressed rather smoothly. The cooperation and activities of MIDI which is responsible for the development of metal and machinery industries in Thailand also helped to facilitate the commercialization especially in terms of arranging the seminars and workshops and the publication work.

### e) PROPOSITION 5: NO SHORT-TERM GAINS FROM RD&E

The present tangible and intangible results from this research project can be concluded as follows:

1. The textbook, manuals and standards are now being used as teaching materials in various technical colleges such as Minburi, Samutrsongkram and Satahip Technical College, etc. SNN, HINO, SMM, CH.Auto Parts and Isuzu Co., Ltd., are also using the manuals for training of their technicians. Additionally, the die check list, inspection check list, and work standard developed by the research team are also being used by the stated companies for in-house die design, making and inspection.

2. Seminars and training workshops were done as stated in Proposition 4. They had a number of participants ranging from 60 to 140 each time. These seminars and training led to an increase in membership for the Thai Die Industry Forum (TDIF) from less than 100 to around 300 in only 3 years. The TDIF can now do a better job in exchanging information and technology transfer for the benefit of local die makers.

3. There are strong indicators that local die makers increased the application of standard parts in die design and making which led to the improvement of quality and technology level. Some of the indicators are the increasing number of local standard parts suppliers participating in the Intermold Exhibition in May 1992 and numerous requests for information about the standard parts received during the seminars.

4. Low cost dies are now being used instead of hand-work for blanking and cutting of leather and plastic in local leather and plastic product making factories in Thailand. These led to the improvement of the quality and productivity in these industries. One bus assembly company in Barnpong district also employs the low cost die in the production of parts.

5. The potential benefits of the research work are: increase of die export by local manufacturers due to the increase in quality level, increase of qualified and well-trained personnel in die technology, increase of local content of press parts in various domestic and export products, and ease of technology transfer both from domestic sources and overseas sources due to the increased level of technology of textbooks and manuals.

6. The short-term gains from this research work were possible due to the problem-oriented nature of the project.

7. This project is regarded to be successful technically and commercially since the objectives of the research study were all achieved. There are numerous indications of users of the research results both in public and private organizations. The strong linkage between the research team and the local industries stimulated various favorable results both in the supply and the demand side despite the limitations in financial support from the granting organization.

### 4.2.4 Conclusion and Policy Recommendations

It is concluded that Thai researchers are capable of doing R&D activities and can produce numerous concrete results. Infrastructure in terms of manpower and financial support has to be provided adequately to facilitate the smooth progression of the research work and to help the researcher to devote more time for the project.

Success and failure of the R&D also depend on the strong linkage between research team and end-users which in this case are the local die makers. Strong coordination with the government organization responsible for the dissemination of research results was also a basic factor for the success of commercialization of this project. However, the government agencies should pay more attention concerning the policy implications of the research results. Researcher meetings and conferences should be organized frequently in order to stimulate the exchange of information and ideas among research teams. Finally, strong linkages and coordination between researchers and end-users should be emphasized in this kind of action-oriented research in order to assure the success of the project.

## 4.3 CASE 2: THE DEVELOPMENT AND CONSTRUCTION OF INJECTION BLOW MOLDING MACHINE

Reporter: Dr. Paritud Bhandhubanyong

### 4.3.1 Background Information

a) Introduction

The production of liquid holding plastic vessels, such as bottles, has been carried out extensively in Thailand by the extruding blowing machine. The working process of this type of machine results in a certain loss of plastic scrap which has to be brought back for reprocessing. Consequently, cost is incurred and reduction of quality may result due to the impurities in the scrap. Such loss could be eliminated by using an injection blowing machine. A number of local machine makers in Thailand are actively producing extruding blowing machines for the domestic market, and importation of their products,in the amount of several hundred units each year, is being done by other countries in Asia. The capacity of these machines ranges from 0.5 to 200 liters per vessel. Therefore, an attempt has been made by researchers in Thailand to develop an injection blowing machine with superior performance over the extruding blowing one. The price of this machine ,if imported, costs around 0.5 million US dollars. The domestic production of this machine could be used for import substitution, with 200% increase in productivity over the conventional extruding blowing machine used at present.

b) Objectives of the research

The research aimed at the design and development of the total system of the injection blowing machine. The hardware system of the injection unit and the blowing unit would be made locally to assemble with the control system which was designed by researchers and imported from overseas. The machine developed was aimed to have a shot weight capacity of 2.98 ounces, with the injection screw diameter and injection pressure of 30 mm. and 1500 bars, respectively. The machine developed emphasized precision, rigidity, proportionality and ease-of-handling with hydraulic, pneumatic and electronic automatic control.

c) Results of the research

Design, fabrication of parts, and one complete unit of an injection blow moulding machine was achieved as a prototype model. The testing of the model revealed one minor problem in the indexing control which can be corrected to operate satisfactory in the near future. Liquid containing bottles could be produced with satisfactory quality by this machine.

d) Other users of results

So far, the only user of the research outcome is the S.M.C. Machinery Co., Ltd. which plans to produce the machine for local users and export in the future. Due to the licensing agreement between the researchers and this manufacturer, no other local producers can build this kind of machine with the same design.

e) Other fields that can use results

This injection blow molding machine has an ejection mechanism developed which can be applied to produce injection machines. The researchers plan to further develop a computer controlled injection machine in the near future. Additionally, the results can also be applied to develop an even superior machine, namely, the stretch blow molding machine. By adding the stretch mechanism even stronger vessel products will result. The extrusion machine can also be developed using the results of this research.

4.3.2. Problems Encountered

The main problems encountered in this research were:

1. Lack of immediate demand for the model developed due to capacity higher than the traditional model. Major users of this machine will still import it from overseas due to the lack of reliability in the locally made model.

2. Lack of local supplier for materials and control systems. Local casting and heat treatment were still unreliable at the level of quality desired by the researchers.

3. Some researchers did not fully devote their time and efforts for the research work due to the inadequate financial gain. This hindered the progress of the research work.

#### 4.3.3. Analysis and Lessons Learned

##### a) PROPOSITION 1: RESEARCHERS CAN PRODUCE CONCRETE RESULTS

The concrete results which were produced by the researchers in this project are:

Prototypes of products and processes

- one complete unit of the injection blow molding machine hydraulic, pneumatic and electronic automatic control systems.
- the processes for design and fabrication of the hardware mechanical parts, and assembly and testing were established as standard production procedures and transferred to a local maker through a licensing agreement.

Problems solved, knowledge learned, experience gained

Knowledge and experience were gained in the designing, fabrication of parts, assembly and inspection of the unit developed. The optimum plastic temperature which must be controlled in various parts of the injection and blowing system in order to produce high quality products was also learned.

Adaptive and innovative steps

Due to the lack of a complete unit for analysis, the researcher team had to travel overseas to observe the injection and blow moulding machine performance during a trade exhibition. Several days were spent in observation and the knowledge gained were adapted in the designing and production of the prototype. Several parts also had to be developed and adapted due to the unavailability of data and local suppliers.

RD&E results meets proposal objectives

Despite the minor problem in the speed of the indexing unit acquired through a local supplier, the results could be considered to have met the proposal objectives of the development and construction of an injection blow moulding machine. The products obtained from the developed unit satisfied the requirement of end users as liquid containing vessels.

Environment

The technical background of the researchers in designing, fabricating of machine parts and assembly were the major factors which facilitated the progression of the research work. Availability of machining and inspection facilities were also good assets for smooth operation during construction.

Utilization

A marketable product and the potential for export were the factors assisting the researchers in acquiring the linkage with the local maker. Benefits to end users are still not evidenced since the cooperative maker has not yet started the real production of the unit developed.

### b) PROPOSITION 2: RD&E NEEDS TECHNOLOGICAL INFRASTRUCTURE

Although the research project could achieve the proposal objectives, the researchers faced obstacles in conducting the research work. The lack of adequate financial gain to some of the researchers led to inadequate devotion to research work. Progression of research was sometimes delayed or hindered due to the lack of manpower. Variation in the quality of parts supplied by local makers also resulted in loss of time for construction and testing of the developed unit. Lack of technical information in Thailand forced the researchers to acquire information elsewhere by travelling to Italy. The unavailability of a complete unit and standard testing specifications were also obstacles for smoothly designing and testing the developed unit. Red tape and bureaucracy in grant management from the university's side also lengthened the time for acquiring necessary parts and supplies.

### c) PROPOSITION 3: RD&E LACKS SUPPLY, DEMAND AND LINKAGE

The research team achieved strong cooperation from local makers in developing the injection blow moulding machine. A licensing agreement was signed with one local maker after completion of the development. Still, the actual production of the developed unit has not commenced due to the lack of production capacity. Demand for the developed unit is still not high enough to justify the investment of an additional production facility. So, the economic impact is still not evidenced. However, the research team achieved good public relations through various media such as television broadcasting and interviews with local newspapers.

### d) PROPOSITION 4: COMMERCIALIZATION NEEDS POLICY AND MANAGEMENT

Despite the small size of the local market as stated in the previous proposition, the researchers foresee the increasing trend in demand in the local market due to the popularity of liquid holding plastic vessels in the consumer market. The developed unit is very advantageous over the traditional ones due to more than a 200% increase in productivity. Zero loss of scrap is also a favorable factor especially in the production of small bottles which results in enormous loss if the traditional machine is employed.

### e) PROPOSITION 5: NO SHORT-TERM GAINS FROM RD&E

The demand for the developed unit has yet to be developed in the local market but there exists strong demand in foreign countries in the neighboring region. The researchers obtained a licensing agreement with the local maker. The results gained from this research work were applied to teaching both undergraduate and graduate students at KMIT, Chulalongkorn University and other institutions. Creditability of the researchers is enhanced through good publicity in various media. The results obtained could also be applied for training industry personnel in machine production and production of plastic products.

Aspects of successes and failures and their reasons, this project is regarded to be successful technically since the objectives of the research were mostly achieved. However, the commercialization and economic impact have yet to be felt due to the small size of the local market. The strong linkage with the local maker stimulated several favorable results while inadequate financial gain for some researchers somewhat hindered the smooth progress of the research work. Lack of local suppliers and supporting industry for good quality parts were also the main obstacles for acquiring the necessary parts for construction. Lack of linkage with end-users and unavailability of market information of domestic users led to the slow development for commercialization.

#### 4.3.4. Conclusion and Policy Recommendations

It is concluded that Thai researchers are capable of doing R&D activities and can produce various concrete results. However, various kinds of technological infrastructure are needed for the smooth operation of research work, particularly R&D manpower, adequate financial gain for researchers, availability of technical information and suppliers of necessary materials and parts. Strong linkage with end users is also needed to facilitate the speedy development for commercialization. Success and failure of R&D also depend on the linkage between researchers and end-users. Without immediate demand, even though the development of the unit is completed the actual production and the economic impact are still not realized in a short time span.

The government agencies especially the funding organizations should set a master plan and strategies for research grants. Emphasis should be made concerning priority in research subjects with respect to the needs of the country and the domestic market. Strong linkage with end-users should also be stressed in the granting policy in order to achieve quick commercialization and economic impact. The government agencies should also establish various supporting units such as technical data services, machining and fabri-cation services and other necessary inspection and testing services to insure the quality and specifications of the developed machine unit.

## 4.4 CASE 3: DEVELOPMENT OF WALKING TRACTORS AND TILLAGE IMPLEMENTS

Reporter: Dr. Paritud Bhandhubanyong

### 4.4.1. Background Information

a) Introduction

In Thailand, riding tractors as well as farm implements have been imported from advanced countries as sample machines since 1910. Two-wheel tillers or walking tractors and their attachments for low-land paddy fields have been developed since 1960.* At the beginning of the tractorization period, walking tractors and plows were mostly developed by small machine repair shops scattered all over the country.** These walking tractors are called "iron buffaloes" and have a very simple structure, especially in their power transmission systems. The transmission case was made by steel plates which are formed into elliptic boxes. Sprockets and chains were used for speed reduction. There were no steering clutch and heavy diesel engines of 8 to 12 horsepower were commonly used. Furthermore, with a long handle structure, it was very tiresome for plowman to support and handle such a heavy walking tractor. Moreover, it could be easily turned while plowing resulting in injuries to the handlers. So, the researcher teams set out to develop better walking tractors than the former ones, especially in the power transmission system. They use gears as power trains and have steering clutch. Moreover, with the development of a shorter handle and lighter weight, the whole structure is smaller than the old one. Generally, in the current locally made walking tractors, there are two forward gears and one reverse gear and also steering clutches, but it is necessary to develop their transmission systems for multi-purpose uses. Therefore, in this R&D project a new model walking tractor has been developed with a better structure, improved power transmission, greater ease-of-use, and increased ease of production by

* Chakkapak, C., Farm Machinery Industries in Thailand, National Seminar on Strategies, Methods and Plan of Agriculture Machinery, Thailand, 1986, p.1

** Agricultural Engineering Division, Ministry of Agriculture and Co-operatives, Thailand, 1985, p.28-29.

domestic makers in order to be used domestically and to export to neighboring countries.

The research team was composed of two researchers from the Department of Mechanical Engineering, Chulalongkorn University; one from the Department of Agricultural Technology, Ministry of Agriculture; one from the Department of Agricultural Engineering, the University of Agriculture, Khampangsaen Campus; one from the Metal-working and Machinery Industries Development Institute (MIDI); and three advisors from Japan which include one Professor from the Department of Agricultural Engineering, Kyushu University and two engineers from Iseki Co., Ltd. This research team was headed by Assoc. Prof. Dr. Surin Phongsupasamitr who is also a former student of the Professor of Kyushu University.

b) Objectives of the research

The research aimed at testing and analyzing the performance of the walking tractors produced domestically and comparing them with the ones that are produced in Japan. Problems and disadvantages of the domestic ones especially in the power transmission system and related structures such as clutches, wheels and accessories were analyzed. New models of walking tractors which solved all of the problems were then developed, with the aim to develop tillage implements such as a turn-wrest plow and a disk plow in the second and third phase of the project, respectively. The design and production technology of the developed model were then transferred to a local manufacturer in order to up-grade the local capability in design, analysis, inspection and production standards.

c) Results of the research

The analysis and inspection of the old or traditional walking tractor model used in Thailand revealed that:

- The engine performance tests conducted by the JIS standard, especially the power curves, are higher than the tests in tropical countries where temperature and relative humidity are high. It is found that the maximum engine horsepower is about 0.3-0.5 hp less than the JIS specification. This engine is used both with the old model and the developed one.

- The gear ratio of walking tractors in Thailand is higher than the one from other countries because of having two forward gears. The second gear is designed for transportation with the speed of 30 km/hr.

- The maximum axle power for the forward gear in the old model is 6.5 hp and 6 hp for gear 1 and gear 2, respectively, while the input power from the engine is 8.0 hp at 2,070 rpm. Therefore, the maximum mechanical transmission efficiency for forward gear 1 and 2 is 81% and 75%, respectively.

- The slip of the V-belt is more than 10% at the maximum axle horsepower while the recommended value of the slip for the V-belt is about 2-3%. That is because the size of the pulley grooves is larger than standard and the two V-belts are not enough. Moreover, the ratio of pulley diameter is higher than the minimum value of the standard, that is about 3.3. Considering the V-belt section, the minimum ratio of pulley diameter should be 2.5, and the minimum diameter of the pulley should be 115 mm.

- From the traction test, the maximum drawbar horsepower was 4.7, when the walking tractor speed was 4.2 km/hr., and wheel slip was 12%. The maximum drawbar pull was 312 kgf while the gross weight of the walking tractor and the supporting frame was 414 kg. Therefore, the maximum gross traction ratio is 0.75, (312 kgf/414 kgf). The dynamic traction ratio should be higher than this value because of the weight transfer.

- The turning mechanism of the old model was not suitable for turning control because of the slipping and the shape of the gear set.

- The old model's brake mechanism was in the pulley of the gear box which resulted in brake failure when water or humidity leaked into the gear box.

From these short comings, coupled with the comment and/or request from the farmers and planters in the rural areas of Thailand that a more compact model which can be used both in rice paddy and other farmland, i.e. tapioca fields, is more favorable, and that the forward gears should be 3 instead of 2, the new model was designed and manufactured with the cooperation from the Japanese advisors and one local manufacturer. Five of the new models were built, with three of them in Thailand and two of them in Japan. They were tested and analyzed in comparison with JIS and the ones being used in Japan. The results are:

- A prototype of the developed new model with improved transmission mechanism, turning mechanism, and brake mechanism. This new model is shorter with a length around 2.00-2.20 meters compared with over 2.5 meters for the old one. The total weight is 170 kg., which is less than the old one resulting in a lower horsepower engine required. A 6 horsepower engine is employed instead of the 9.5 horsepower one which was traditionally used. As for the gear drive mechanism, there are 3 forward gears and one backward gear with driving speeds of 2.7, 4.2, 18, and 2.3 km/hr, respectively. The first gear is suitable for grass cutting, chemical spraying and tilling while the second and third gears are suitable for tilling and driving of farm transportation on the road, respectively.

- The technology level for design and production of the local manufacturer is increased about 20%, especially in the transmission mechanism.

- A shape of the wheel was developed which resulted in more stable performance in all soil conditions. Additionally, the width of the wheel span could be adjusted which to correspond to the overseas model specifications, resulting in more potential for export to neighboring countries.

- A split power shaft was developed in order to be able to attach tilling and other accessories, instead of the single power shaft of the traditional model.

- All of the weak points of the old model were eliminated resulting in ease-of-production, ease of handling, and safety in operation in various agricultural applications.

- Design, fabrication, production and inspection technology are transferred to a local cooperative maker resulting in productivity and capability improvement.

d) Other users of results

Besides the cooperative local maker which is Vichien Chakkol Kaset Co., Ltd., the researchers received about 40-50 letters from farmers all over the country who would like to buy the developed model directly from Chulalongkorn University. Other potential users are farmers and field owners in other countries especially in the South-East Asian region. The old model tractors were exported to Vietnam and Cambodia but all were rejected because of the weak points of large size, high weight, inappropriate transmission mechanism and brake system.

e) Other fields that can use the results

Another possible field that can make use of the results of this research is urban construction. The developed model can be used as a lorry for pavement work. The transmission mechanism can be employed with other agricultural machinery such as the combine machine for rice harvesting and the picker car for field products such as beans, sugar cane, etc. It also could be used for spraying of chemical insecticide in fields and farmlands.

The know-how of gear fabrication and heat treatment can also be applied in other machinery and metallurgical industries. The design process can be applied in various engineering fields.

4.4.2. <u>Problems Encountered</u>

A major problem encountered in this research work was the lack of the domestic supplies of raw materials for machine parts, especially special steel such as JIS SCM21, S45C etc. The other problem was lack of manpower, despite the large number of researchers, the head of the team is the only one who could do the design work with advice from the Japanese advisors. Lack of practical knowledge i.e. how to translate from design to production, inspection techniques, and materials selection, were also difficulties. Inadequate financial support was also stated as a problem because the budget had been calculated for only one unit ,but for testing and comparison purposes 5 units had to be built.

#### 4.4.3 Analysis and Lessons Learned

a) PROPOSITION 1: RESEARCHERS CAN PROVIDE CONCRETE RESULTS

The concrete results which were produced by the researchers in this project are:

Academic publications

Report on "A Power Transmission Model and External Forces Acting on Walking Tractors" Presented in the Fifth Mechanical Engineering Conference organized by the Mechanical Engineering Network of Thailand during October 17-18, 1991 and published in the conference proceedings (24 pages).

Report on "Studies on Power Transmission System of Thai Walking Tractors" submitted to the International Conference on Agricultural Engineering organized by The Beijing Agricultural Engineering University to be held during October 12-14, 1992 in Beijing, China and to be published in the conference proceedings (6 pages).

Report on "Development of Walking Tractors and Tillage Implements" to be submitted to MTEC in 1992.

Prototypes of products and process

- Prototypes of transmission system, wheel, brake system and complete units of Walking Tractors.
- Prototype of production process for domestic production.

Problems solved, knowledge learned, experience gained

Solved the problems of the traditional model concerning size, weight, stability and performance.

Knowledge learned and experience gained in design, material selection, fabrication, testing, inspection and assembly of complete workable unit of walking tractors.

Knowledge learned applicable to university's teaching

The research finding in design, material selection, fabrication, testing, inspection and assembly from this project have been applicable for teaching purpose in the Department of Mechanical Engineering and Metallurgical Engineering, Chulalongkorn University and Kasetsart University for both undergraduate and graduate levels.

Adaptive and Innovative steps

Adaptive and innovative steps are evidenced in the design of various parts especially the transmission system, and the wheel and brake system which are all prototypes. The head of the research team applied his knowledge and experience gained while studying in Japan and while working in collaboration with the Japanese advisors.

R&D results meets proposal objective

The prototype model characteristics and performance met the proposal objectives including raising the technological level of the domestic manufacturer.

Commitment and devotion of researchers

Researchers worked enthusiastically with the local maker and the advisors even during holidays and after office hours. Multiple units of the machine were built despite the inadequacy of funding support.

Utilization

One patent of transmission system and design is under registration processing.

The prototype model is marketable both domestically as well as overseas due to the superiority of performance.

Benefits to end users especially farmers in the Northeastern region are more safety in handling, less fatigue, more productivity and multiplicity of uses.

#### b) PROPOSITION 2: RD&E NEEDS TECHNOLOGICAL INFRASTRUCTURE

Manpower

The researchers faced the problems of shortages in various types of manpower e.g. research staff, graduate students, technicians and draftsmen. The high work load in teaching also hindered the progress of the project considerably. Researchers also needed training and coaching from overseas experts, resulting in high facsimile costs due to the need for continuous contact.

Suppliers

Lack of domestic supplies in raw materials and special parts such as pulley clutches and oil seals resulted in delay times while waiting for imported parts. Lack of high quality casting, heat treatment and precision measurement were also obstacles for the progress of the project.

Finance

Bureaucracy in grant management on the university's side caused frustration for the researchers and resulted in delays for acquiring necessary parts and supplies.

#### c) PROPOSITION 3: RD&E LACK SUPPLY, DEMAND, AND LINKAGE

Researchers in this project achieved strong cooperation from the local maker and good coordination with the other government institution with direct linkage to end users. Still more participation from other local makers is needed instead of only one. One major reason that the other local makers did not join was due to the wait-and-see policy on their side. If the project is a success copied models will be developed soon in the local market. Tax incentive for RD&E in private sectors and tax exemption for special parts could also help to stimulate the R&D in private and public sectors. This research project achieved good advertising with a special documentary broadcast by NHK Japanese Broadcasting Company in the Kyushu area this year.

d) PROPOSITION 4: COMMERCIALIZATION NEEDS POLICY AND MANAGEMENT

The policy of MTEC which emphasized the cooperation between the researchers and local makers or industry is very effective in the commercialization of this project. Input of requirements from end-users couple with strong linkage with local maker facilitate the suitable development of marketable model both for domestic user and for export to neighbor countries in the near future.

e) PROPOSITION 5: NO SHORT-TERM GAINS FROM RD&E

With the strong support from the local maker, there were short term gains in marketable products. High demand from users was also evidenced. One patent is under processing through the university. The researcher submitted two papers for presentation the conferences both domestic and overseas. The product and the process were improved through the success of this research. The indirect results are the knowledge learned and transferred to the local maker and improved strong researcher-user linkage. Publicity was also gained from the broadcasting of the research in Japan. As for time considerations, the short-term gain is possible due to the problem-oriented nature of the project.

Aspects of successes and failures and their reasons, this project is regarded to be successful technically and commercially due to the strong linkage and cooperation of the research team with local maker, Japanese advisors and end-users. The capability and devotion of the head of the research team was also the major reason for the success of this project.

### 4.4.4 Conclusion and Policy Recommendations

It is concluded that Thai researcher are capable of doing R&D activities and can produce numerous concrete results. Infrastructure in the form of manpower and suppliers are needed to facilitate the research work. Success and failure of the research work depend on the linkage between researchers and various parties, especially overseas experts and local makers. Linkages in this case were the major reasons for the excellent results achieved in the research work. Short term gains in commercialization of the research products were possible due to the problem-oriented nature of this research.

## 4.5 CASE 4: HEAVY ION IMPLANTATION IN METALS AND ALLOYS

Reporters: Dr. Chatchai Somsiri
Asst. Prof. Wikrom Vajragupta

### 4.5.1 Background

a) Introduction

The project was funded by STDB and MTEC. Ion implantation is a process whereby a selected type of atom is excited in a vacuum chamber, accelerated through a magnetic field and implanted as an ion on a metallic substrate. The implanted surface will have a marked improvement in its surface properties. This research program was established to construct an ion implanter and to study the implantation process and the physics of atomic interaction. The project was headed by Dr. Theerapat Vilaithong. There are 11 co-investigators in the team from various departments such as electrical engineering, nuclear physics, and solid state physics.

b) Objectives of the research

The primary objective of the project was to construct an ion implantation machine which is composed of an ion source, a particle accelerator and a target chamber. The project's aim was also to investigate surface atomic interactions and the implantation process in general.

Statements are made that the "know how" from CASE 4 can be applied commercially in industry and agriculture. How? For this same research project, the statements under propositions 4 and 5, are vague, non-specific and contradictory.

c) Results of the research

One ion implanter was completed. Some work on implantation were carried out, but none was reported. It is believed to be an insignificant quantity up till now. Nonetheless, the hardware construction is proof of achievement. The program also produced a number of graduate students and solid infrastructure for further work.

d) Other users of results

Up till now, the knowledge gained from this research has been shared and used among the researchers of the group. Other potential users are researchers at the Department of Nuclear Engineering, Chulalongkorn University and researchers at the Office of Atomic Energy for Peace, Bangkhen.

However, at the commercial level, the know-how can be applied to improve properties of metals used in agricultural and industrial machinery.

e) Other fields that results can be used

Other possible areas that the results can be used in are nuclear physics, food science (preservation) and quantitative analytical chemistry.

4.5.2 Problems Encountered

For the STDB funded project, the most prominent problem was that the regulations were too rigid. Purchasing and dispensing of funds were severely regulated. This occurred repeatedly throughout the course of the research. The stipulated rules required that all purchases and carriers used must be of U.S. origin. This was a policy which undermined the research program. The research suffered from long delay for the procurement of equipment and general supplies. On two occasions, the U.S. suppliers shipped out defective or inferior quality equipment to the research group. These instruments were later re-exported to the U.S. and new units were sent as replacements. By doing so, the researchers lost many valuable months.

The procurement of general supplies was also a major problem as almost everything had to be sent from Bangkok.

Lack of data and information was also mentioned as a problem which needs to be improved.

The Department of Physics, at the beginning of the work, had an inadequate machine shop. It also was short of qualified and skilled machinists. This is one thing which has been improved markedly since then.

4.5.3 Analysis and Lessons learned

a) PROPOSITION 1: RESEARCHERS CAN PROVIDE CONCRETE RESULTS

The work shows much evidence of the level of technology and success, Even though there is not yet a technical paper published. Reports submitted to STDB and MTEC were of good quality. It may be assumed that after the equipment has been completed, the group can generate concrete and useful results.

Many problems were overcome during the construction of the apparatus viz materials and equipment procurement, workmanship of local workers (welding), poor quality of equipment bought, etc.

The researchers admitted that the above problems slowed down the work and were very discouraged.

Publication

A paper has yet to be published in a journal, 5 progress reports were submitted, four to STDB and one to MTEC. Their contents deal with hardware construction.

Prototype of Products

One ion implanter was fully constructed and tested. The first prototype has a zero degree beam. The future plan is to construct the second prototype with $45^0$ angle beam.

### Knowledge Applicable

The applicability of the knowledge gained from this research may by used for teaching and research in the areas of materials science, metallurgy, and physics. As the level of know-how reaches the objectives, it will prove to be much more beneficial to the industry. However, its final goals seem to require much more persistence and efforts by the researchers.

### Adaptive and Innovative Steps

The project is a good example for adaptations and innovations. Various parts of the hardware were locally manufactured. The magnetic lens was designed by the researchers and manufactured by students at King Mongkut's Institute of Technology. Many adaptive and innovative steps were taken to utilize the more readily available supplies.

## b) PROPOSITION 2: RD&E NEEDS TECHNOLOGICAL INFRASTRUCTURE

The researcher faced many difficulties particularly with the infrastructure. The lack of supporting staff, technicians and quality research assistants were grave concerns. The technical and information services were almost non-existent.

The researchers need a general store where most supplies can be obtained without delay. There should be a central body to promote linkages and conferences where researchers can meet and exchange their thoughts.

Complaints were made regarding the structure of the salary which is far lower than the industrial sector.

The government must provide conveniences and support to the researchers from the time of grant application until the conclusion of work. Commercialization must be facilitated by a central organizing agency.

## c) PROPOSITION 3: RD&E LACKS SUPPLY, DEMAND AND LINKAGE

A direct linkage between the researchers and the users was established after the seminar organized by the researchers. The users were identified and expressed their keen interest in commercializing the process. However, no indication of funding was shown. This is understandable as the commercialization requires more time and money and there is no guarantee that the investment will be sound. The users stated that when the machine was ready they would come to use it.

#### d) PROPOSITION 4: COMMERCIALIZATION NEEDS POLICY AND MANAGEMENT

The researchers agreed that commercialization of their project needed help and management from the funding agencies or other governmental organizations. They felt that they were not well fitted to do such task.

However, it was commented that the virtue of scientific research cannot be judged by its commercialization alone. Its value in terms of basic understanding of the problem must also be credited.

#### e) PROPOSITION 5: NO SHORT-TERM GAINS FROM RD&E

Short-term gains from this project are the improved quality level of human and technical supporting staff.

Since the inception of the project, its technicians and supporting staff have been increased in number and as well as their capabilities. Moreover, the project has stimulated the staff awareness in research and it has produced a number of graduates.

If the technique was perfected, it would have immediate gains as it would help improve service life of tools and machinery which would be very much welcomed by the industry.

### 4.5.4. Conclusion and Policy Recommendations

The project was well thought out and executed. There is no doubt of its success and concrete results. Given them more time and better infrastructure, the researchers' work would have been better in terms of quality and amount.

Two areas which need to be improved immediately are the infrastructure and the ease with which supplies can be obtained.

For Chiang Mai University, being in a province, travelling to and from work can be done in a short time and its general working environment are excellent. These two factors enable the research to be done in an excellent environment.

Regarding commercialization, although it is important, it should not be over-emphasized. A balance between the basic and applied research must be struck so that, later, they will support one another.

Annex 4.5.1

| | | |
|---|---|---|
| Project Title | : | Heavy Ion Implantation in Metals and Alloys |
| Funder | : | STDB |
| Project Code | : | DSN 88B-2-02-142<br>Total Project Budget 7,200,000 Baht |
| Institution | : | Chiang Mai University |
| Time Period | : | August 1991-February 1992 |
| Project Team: | : | T. Vilaithong<br>N. Chirapatpimol<br>S. Wiboolsake<br>V. Teeyasoontranont<br>S. Singkarat (Co-Principal Investigator)<br>W. Pairsuwan<br>D. Suwannakachorn<br>D. Boonyawan<br>B. Yodsombati<br>N. Boonthanom<br>S. Dumronggittigula<br>V. Tayati<br>S. Limpiti |

## 4.6 CASE 5: INNOVATIVE USES OF TIN

Reporters: Dr. Chatchai Somsiri
Asst. Prof. Wikrom Vajragupta

### 4.6.1 Background

a) Introduction

The project was funded by STDB for a duration of 3 years to investigate innovative uses of tin, to spark a new interest and revitalize the tin industry in the country. The grant of 3.5 million baht was given to the research team led by Dr. Lek Uttamasil and Dr. Padet Sidhisunthorn. The co-investigators were from the Departments of Materials Science and Chemistry.

Tin can readily combine with other anion and organic groups, after which its properties can changed drastically. The potential uses of tin compounds are so numerous that academic investigations are therefore warranted.

b) Objectives of the research

The researchers set out to investigate:

i) The synthesis process of organotin compounds
ii) The effects of organotin compounds on rubber wood infected with fungi.
iii) Effectiveness of certain chemicals against soybean rust.
iv) Effectiveness of certain chemicals against soybean downy mildew.

Field tests of the synthesized chemicals were carried out at Mae Cho Agricultural College.

c) Results of the research

The team successfully synthesized organotin compounds, namely, Tetrabutyltin, Tetraphenyltin, Tetraallyltin, Tributyltin Chloride etc. in the laboratory. The compounds were then tested for their potency. They were found to be effective agents for the said uses.

Their final report showed that the experiment was well carried out and the investigation was thorough and meticulous. Good and strong coordination between members of the team was evident. However, complaints were made that some certain members of the team did not get involved enough and lacked devotion.

The joint work between the two institutions (Chulalongkorn and Mae Cho) was well noted.

Although the tests were positive, the lack of publications and linkage with the industry have resulted in the situation where the commercial potential have not been utilized. And because of their commercial potential, the researchers feel that they will publish their findings after patents have been awarded.

#### 4.6.2. Problems Encountered

As with other STDB funded projects, the researcher expressed his grievance over the set rules regarding the way the money could be spent and how the money could be managed. The same policy of "made in U.S.A. "also met with similar reactions (see Heavy Ion Implantation). In his opinion a more relaxed and flexible policy would help their work tremendously.

It was suggested that a central store where the researchers could obtain their supplies quickly and easily was badly needed.

#### 4.6.3. Analysis and Lessons learned

a) PROPOSITION 1: RESEARCHERS CAN PROVIDE CONCRETE RESULTS

Their concrete results were shown by the quality of their final report. Academically, its standard is high, however its results are not known to the public. The STDB and MTEC after having funded the project should make good use of the results or at least make an attempt to disseminate them. It can also assist or encourage the researchers to do similarly.

Therefore, in terms of utilization and commercialization, its value is yet to be realized.

Other evidences which support their concrete results are:

1. Two reports were examined, one on uses of organotins submitted to STDB and another on uses of tin compounds as fire retardants submitted to MTEC.

2. The researchers showed their adaptive and innovative abilities in their research work. They found new methods of synthesis of some compounds which proved to be better methods.

### b) PROPOSITION 2: RD&E NEEDS TECHNOLOGICAL INFRASTRUCTURE

Major complaints are difficulties in getting supplies, customs and tax regulations. The researcher expressed a need to have a large area designated for construction of a "pilot plant". Shortages of skilled workers and technicians were a concern and the government should rectify this problem.

The research was successful up to the laboratory scale. It is believed that with a bigger injection of money and involvement of engineers a pilot scale plant would be possible. Efforts to establish links between the two interdisciplinary groups need management and assistance from the funders. Otherwise all would be wasted.

Salaries and fringe benefits of the researchers need to be improved. Such improvement, it is believed, will result in more people interested in RD&E and in greaser commitment on their part.

### c) PROPOSITION 3: RD&E LACKS SUPPLY, DEMAND AND LINKAGE

The demand of the synthesized chemicals exists. However, links between local producers or entrepreneurs and the researchers do not exist. The researchers agreed that commercialization should not be over-emphasized. There is a need to establish the link by funders.

d) PROPOSITION 4: COMMERCIALIZATION NEEDS POLICY AND MANAGEMENT

Already stated above.

e) PROPOSITION 5: NO SHORT-TERM GAINS FROM RD&E

Immediate use of the results is also possible if the technology is taken up by industrialists who are actively involved in the production and processing of chemicals.

Technology and engineering are not just outputs of the researcher; they could as well be inputs to other fields which could prove to be highly beneficial.

At present, hardly any possibility of commercialization exists as no attempts have been made to publicize and disseminate the technology.

### 4.6.4 Conclusion and Policy Recommendations

The project can be judged to be a successful one in terms of academic and technical merits. However in terms of value for money, its evaluation needs a closer scrutiny. Its potential are significant but as yet no attempts have been made to utilize them.

Dr. Sophon suggested that universities have better potential to conduct research work than other government research centers, as it has teaching and learning programs and research students where other research institutions do not. Dr. Sophon attributed the program success to his master degree students. Therefore, research funding should be given preferentially to universities.

Annex 4.6.1

| | | |
|---|---|---|
| Project Title | : | Organotin Compounds Innovative Uses of Tin |
| Funder | : | STDB |
| Project Code | : | Total Project Budget DSN 87B-2-06-110<br>3,511,000 baht |
| Institution/Place of work | : | Metallurgy and Materials Science Research Institute |
| Starting Date | : | October 1, 1987 |
| Project Duration | : | 3 Years |
| Project Team | : | Asst. Prof. Dr. Lek Uttamasil<br>Prof. Dr. Padet Sidhisunthorn<br>Prof. Dr. Dep Shiengthong<br>Assoc. Prof. Dr. Pensri Tangkanasing<br>Assoc. Prof. Dr. Sophon Roengsumran<br>Assoc. Prof. Dr. Prakitsin Siganonth<br>Asst. Prof. Onusa Saravari<br>Asst. Prof. Worawan Sukwong |

Annex 4.6.2

| | | |
|---|---|---|
| Project Title | : | Use of Tin Compounds and/or Plastics to Develop Glass Coating Industries |
| Funder | : | MTEC<br>Total Project Budget 1,329,000 baht |
| Institution | : | Chulalongkorn University |
| Time Period | : | October 1990-September 1992 |
| Project Team | : | Dr. Lek Uttamasil<br>Dr. Daval Wiwatanadej |

Annex 4.6.3

| | | |
|---|---|---|
| Project Title | : | Development of Tin compounds as Fire Retardants and smoke Suppressants |
| Funder | : | MTEC<br>Total Project Budget 1,554,145 baht |
| Institution | : | Chulalongkorn University |
| Time Period | : | October 1990-September 1992 |
| Project Team | : | Dr. Lek Uttamasil<br>Dr. Rattana Saengprasertkit<br>Dr. Sophon Proengsumran |

## 4.7 CASE 6: BONE CHINA PRODUCTION

Reporter: Asst. Prof. Wikrom Vajragupta

### 4.7.1. Background Information

#### a) Introduction

Bone china is a kind of pottery product. The particular characteristics that are appealing are whiteness, the translucency, the high glaze and decoration quality, and the high strength, and much of this derives from the use of bone as a constituent. As much as 40 or 50 percent calcined bone may be used.

The source of supply of bone is mainly cattle bone which is normally collected from abattoirs. Organic constituents of the bone are separately removed and used as raw materials for glue and other chemicals. The residual bone is normally used in fertilizers or animal feeds. For use in the ceramic industry, the bone has to be calcined to around $1000^0$ C. The degree of calcination has a considerable influence on the crystal size, which in turn influences the size distribution on grinding. The calcined bone consists mainly of hydroxyapatite, small quantities of $Na_2O$, MgO and carbonates. The minor constituents are important in that they affect the fluid properties of slips (clay mixtures) containing bone.

The function of bone in the ceramic body is to react with other constituents, clay and feldspar, to produce a new assemblage of crystals in a glassy matrix. The firing composition is roughly 25 percent anorthite, 45 percent tricalcium phosphate, and 30 percent glass. The properties of these components give rise to a high degree of translucency of the body. The mechanical properties are also good, since there are no weakening crystalline inversions. Thermal expansion is in the range of 0.40 to 0.45 percent, thus making it easy to find a suitable glaze.

Such excellent properties of the bone china have made it become very popular in many countries. The only limitation is the cost as it is very difficult to find good sources of bones and in enough supply. In Thailand, the bone china clay mixture has to be imported at a rather high price, therefore limiting their production to only large companies. Realizing the problems the research team led by Dr. Varunee Thiramongkol has conducted research to study and develop technology for bone china production using local raw materials. The project, supported by MTEC, also studied the process for production of calcined bone and the possibility of obtaining a reliable source of bones.

b) Objectives of the research

The research aimed at studying the production process of bone china from local raw materials and transferring the technology obtained to industries, particularly small and medium scale industries in the north and central part of Thailand. It also aimed at studying the calcination process of bones so that the major constituents could be produced locally.

c) Results of the research

Bone ash produced from cow leg bone calcined at 1000°C and ground for 15 hours can be used to produced the clay mixture for bone china bodies

Different sources of clay can be used and the best mixture found was calcined bone 47 percent, china clay 25 percent, feldspar 28 percent, and silica 5 percent.

Addition of bentonite improved green strength of the mixture together with an increase in shrinkage and reduction in whiteness and translucency.

Substitution of calcined bone by bone ash from local manufacturers resulted in narrower firing range which led to warpage of products.

The mixture can be used to produce novelty items such as artificial flowers which are of good quality. However, applications in the tableware industry are still doubtful due to the narrow firing range of the mixture.

The cost of the mixture had been calculated and found to be much lower than the imported one.

d) Other users of results

So far the technologies obtained have been transferred to 26 factories or companies in the northern and central regions. These companies include raw materials suppliers and pottery manufacturers. The technology for the production of novelty items such as lockets, display plates and artificial flowers is regarded to be successful although production of tableware need further development, particularly increasing the firing temperature range.

e) Other fields that can use results

Another possible field that could make some use of the results of this project is biomaterials, which is interested in using calcined bone for hydroxyapatite production.

### 4.7.2 Problems Encountered

The major problem encountered is to get good quality calcined bone; even though the one produced by the researchers is of good quality it was only a small sample. In terms of commercial production a reliable supplier of good quality calcined bone is surely needed. Due to the low quality calcined bone obtained from local suppliers, the firing temperature range of the product is very narrow which results in poor quality products, particularly tableware. The other important problem is red tape in the bureaucratic system (grant management procedure, report system etc.) which very often discourages the researchers from applying for further research grants.

### 4.7.3 Analysis and Lessons Learned

a) PROPOSITION 1: RESEARCHERS CAN PROVIDE CONCRETE RESULTS

The results which were produced by the researchers are:

Prototypes of products

Various designs of novelty items particularly artificial flowers were produced. These items are very unique in design and craftsmanship.

Knowledge applicable for production of novelty items

The technology developed by the researchers is now being used by some companies in the northern part of Thailand. The researchers are now continuing transferring the technology to other users.

Adaptive and innovative steps

The success of this research was due to good relationships between the research unit and private industry. Practical problems were always taken into account while tackling problems in the experiments. This has led to practical know-how for industries. One important thing should also be mentioned at this point. Despite the fact that the research results are not technically so successful due to the very narrow firing range of the composition developed, the researchers had adopted the technology to the production of novelty items, particularly artificial flowers. Combining the delicacy of Thai craftsmanship and the good nature of bone china, successful results were obtained. The reason why the composition developed is not so satisfactory is the attempt to use as much local raw material as possible. The calcined bone, in particular, produced locally is of very poor quality and is not actually meant for bone china production. The researchers' attempt to use such materials and successfully find a suitable application is considered to be the research highlight.

### b) PROPOSITION 2: RD&E NEEDS TECHNOLOGICAL INFRASTRUCTURE

This research project did not face much difficulty in terms of manpower and research facilities. However, the major obstacle is the red tape in the bureaucratic system, particularly the grant management system in the researcher's own department. Up to the writing of this report there are 500,000 baht left unused and will be returned to the MTEC later while better results could be obtained by this amount of money. The researchers who never get any honorarium were often discouraged by the system. Apart from the above mentioned items, the supply of good quality raw materials is also a problem which limited the quality of the results.

### c) PROPOSITION 3: RD&E LACKS SUPPLY, DEMAND AND LINKAGE

In this project the linkage among suppliers, researchers and users seems to be quite good; however, many problems still exist. The major problem is to get a sufficient supply of good quality calcined bone, which is the most important constituent in bone china. Though the demand of good quality bone china is high and production technology is now available the supply of good quality raw materials is still lacking. Further efforts should be done to find ways of improving the quality of the materials and/or find new sources of supply.

Furthermore, cooperation from big companies who have already obtained know-how from abroad is still not very good as they think that the technology is a trade secret and do not want technologist to support them. This problem can be overcome through better coordination between government agencies and the private sector and better training and eduction systems. One multinational subsidiary plans to produce bone china raw materials in October 1992.

### d) PROPOSITION 4: COMMERCIALIZATION NEEDS POLICY & MANAGEMENT

Commercialization of the outcome of this research project has been done to some extent. Cooperation from the private sector in general is also good. This is because of long term relationships between the research division and those private companies. However, some improvement can still be made if upgrading of the raw materials is possible. Better coordination among suppliers, users, and government officials cannot be overlooked.

### e) PROPOSITION 5: NO SHORT-TERM GAINS FROM RD&E

The outcome of this research project has already been applied, but maximum usefulness of the research work is not yet reached. A lot of work is still to be done, particularly increasing the firing temperature range, improving calcined bone quality, and studying of other forming processes (ie. roller forming), so as to increase the applications of the technology into the production of tableware which is of more value and has a greater market volume. Developing technology for calcined bone production will also benefit other fields as well (e.g. biomaterials, animal feeds, fertilizers etc.).

Aspects of successes and failures: This project is considered to be successful technically since the objectives of the research study were almost all achieved, although some improvements can still be done. Furthermore, adaptation of the technology to suit some local industries can be regarded as fairly successful in terms of commercialization. However, if the research is continued on a deeper level regarding technical aspects, better results will be obtained. This is somewhat limited by the policy of the research organization which is aimed at applying the results as soon as possible and fundamental research is not fully supported.

### 4.7.4 Conclusion and Policy Recommendations

It is concluded that Thai researchers are capable of applying research results in practice. Linkages between research institutes and industry can be made if results are useful and applicable. Clear demand from users is a significant input for the research, and close coordination between researchers and users in various stages of the work should always be considered. More favorable regulations for a better R&D atmosphere, particularly the removal of red tape in bureaucratic systems, and improvement of the working status of the researchers, are all needed to encourage more effective research work.

Commercialization of the research outcome, although it is very important, should not lead to overlooking fundamental aspects of technology. Success of research work also depends on a thorough understanding of the subject which sometimes takes time and the courage of the researchers. In this aspect, government agencies should lay out clear policies for R&D objectives so that technologies can be fully developed.

Annex 4.7.1

| | | |
|---|---|---|
| Project title | : | Bone China |
| Institution | : | Department of Science Service<br>Ministry of Science Technology and Environment |
| Place of work | : | Research Division, Department of Science Service |
| Principal Investigator | : | Dr. Varunee Thiramongkol<br>Director, Research Division |
| Reported Co-investigators | : | Mr. Suthichai Theepprasarn<br>Mr. Surapant Borisuth<br>Ms. Pornthip Viengampol<br>Ms. Sumalee Temchai<br>Ms. Sumalee Likitvanitchkul<br>Ms. Thepevan Jitvacharakomol |
| Total Funding | : | 890,000 baht |
| Project Duration | : | 2 years (1988 - 1990) |

## 4.8 CASE 7: BIOMATERIALS : HYDROXYAPATITE

Reporter: Asst. Prof. Wikrom Vajragupta

### 4.8.1 Background Information

a) Introduction

Calcium hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$), a mineral normally found in natural teeth and bones, has been widely used for bone replacement in dental and orthopaedic fields due to its excellent biocompatibility. Commercial hydroxyapatite (HAp) is usually synthesized by precipitation from an aqueous solution of calcium and phosphate compounds under controlled pH and temperature. Other methods such as solid state reactions at high temperature under controlled atmosphere or hydrothermal methods can also be used. Such processes rely on high purity starting materials and, therefore, result in very expensive products.

However HAp can also be produced from natural cattle bone by calcination under controlled atmosphere and chemical treating processes to produce high purity HAp equivalent to that of the synthetic ones. HAp produced by this method is much cheaper than the synthetic ones as the starting material is cattle bone which is locally abundant. The researcher, Assoc. Prof. Dr. Charussri Lorprayoon, has been working in this field for over 14 years and has successfully developed a reliable technique for producing high purity HAp from cattle bone. She has published 2 papers on high temperature phases of cattle bone and modifications of cattle bone to tricalcium phosphate and HAp by chemical treatment. These research topics were funded by the Rachadapiseksompoj Foundation, Chulalongkron University.

Applications of HAp, however, are still limited by some properties, such as modulus of elasticity, strength, and fatigue. The research project, funded by MTEC, was, therefore, aimed at studying and developing fabrication processes for HAp specimens to be used in dental and medical applications. The research is the first part of a 3 year project aimed at applying HAp in orthopaedic fields.

b) Objectives of the research

The research aimed at studying forming processes of HAp to produce specimens for orthopaedic implant. The study is concerned with a comparative study of HAp obtained from calcined cattle bone, chemically treated bone and chemically precipitated HAp in terms of their characteristics, sintering behavior, and mechanical strength of the sintered products.

c) Results of the research

It was found that the characteristics and thermal behavior of the 3 materials i.e. HAp from calcined cattle bone, chemically treated bone and chemically precipitated HAp were similar in terms of Ca : P ratio, morphology and phases present. However, organic substances and other impurities are higher in HAp from calcined cattle bone.

The fabrication process of HAp from calcined cattle bone required the removal of organic substances and impurities as they caused crystal growth due to the recrystallization of the ill-crystallized apatite. After grinding this yielded a coarse particle size distribution and leads to poor properties in the specimen. This coarse particle size distribution also leads to higher sintering temperatures required to obtain high density specimens. Such high temperatures would give rise to the dissociation of HAp which cannot be allowed.

Specimens produced from chemically treated and chemically precipitated HAp gave similar results. It can, therefore, be concluded that HAp from cattle bone by a chemical treatment process can be used to substitute for expensive chemically precipitated HAp.

In the research report, it also suggested that further investigation on fabrication techniques using isostatic pressing or hot isostatic pressing should be done with calcined cattle bone to obtain better properties for lower cost HAp.

d) Other users of results

So far, the only user of the research outcome is Assoc. Prof. Dr. Pibul Itiravivong, an orthopaedic surgeon at Chulalongkorn Hospital and his colleagues. They have been doing the experimental application of the HAp specimens produced by Dr. Charussri for orthopaedic purposes by involve testing on numbers of animals, i.e. mice, rabbits, and dogs. Dr. Pibul informed us that specimens tested in mice had been sent to Japan to check the biocompatibility properties and very positive results were obtained. In the case of rabbits the test animals were infected during the operation and no results were obtained. At present, the specimens have been implanted in dogs and are now waiting to be evaluated. It is expected that successful involve testing of HAp specimens will soon enlarge its application for other purposes and fields, particularly for bone replacement.

e) Other field that can use results

HAp can also be used in dental applications as well as other medical field, such as plastic surgery. This can be done through coordination of personnel among these fields. Improvements in fabrication processes are also needed such as HAp-polymer composites, or metal coated with HAp, to obtain more suitable materials for certain applications.

4.8.2 Problems Encountered

The main problems encountered in this research were the shortages of qualified and well-trained research assistants and scientific equipment in the laboratory. This is because the field of biomaterials is new, specialized and multidisciplinary. Research assistants have to be trained by Dr. Charussri herself which consumes a lot of her time. In the case of equipment, although common facilities can be used special techniques are still needed and in some cases special environment (clean room) are also required. These problems together with the time constraints on the researcher herself who must devote a lot of her time for teaching and administration duties resulted in some delay of the project.

#### 4.8.3 Analysis and Lessons Learned

##### a) PROPOSITION 1: RESEARCHERS CAN PROVIDE CONCRETE RESULTS

The concrete results which were produced by the researchers in this project are:

Academic publications

- Report on "A Comparative Study of Hydroxyapatite from Different Origins", submitted to MTEC, Bangkok, 1989.

- Report on "Synthesis of Calcium Hydroxyapatite and Tricalcium Phosphate from Bone Ash", pp.329-336, published in MRS International Meeting on Advanced Materials, Vol.I by Material Research Society, 1989.

- Report on "Phases of Cattle Bones at Elevated Temperature", J: Sci Soc. Thailand 12, 159-170 (1986).

Prototypes of products

Various pieces of hydroxyapatite specimens with different size and density were produced for medical experiment purpose conducted by Dr. Pibul and his colleagues.

Knowledge applicable

- The research's findings on the characteristics of HAp from different origins as well as the complicated production process learned from this project have been applicable for teaching purpose at the Department of Material Science, Chulalongkorn University (both at Bachelor and Master degree levels).

- The knowledge has also been transferred to users, i.e. Dr. Pibul and his colleagues, to better the understanding of HAp and make a better use of the materials.

Adaptive and innovative steps

The success of this research was mainly due to the unique R&D capabilities of the project leader who is a specialist in this technology field. Know-how and know-why related to this R&D process have been accumulated by the project leader over a decade. The results of several related studies prior to this project have been adapted in this study (see Appendix 4.8). However, the outcome of this study clarified the detailed characteristics and properties of HAp from different origins, which later brought about the innovative R&D process for HAp production.

### b) PROPOSITION 2: RD&E NEEDS TECHNOLOGICAL INFRASTRUCTURE

Although this research project could achieve its objectives, the researchers faced difficulties in conducting R&D mainly due to the shortage of research assistants and physical research facilities. Technical and information services were not provided to the researchers from elsewhere. Therefore, the researchers acquired specific information needed for the research from international sources by themselves.

These unfavorable technological infrastructure constraints plus some red tape in the bureaucracy system (grant management procedure, report systems) very often discourage the researchers from applying for R&D grants from government R&D agencies.

### c) PROPOSITION 3: RD&E LACKS SUPPLY, DEMAND AND LINKAGE

The researchers in this project were quite individual in the sense that they did not have much coordination with other parties (industry, end-users, academicians in other fields, etc.). After solving the problems as stated in the project's terms of reference, the researchers did not pay much attention to its application and commercialization. Although, the results of the research were published in some academic papers, as well as presented in some seminars, little advertisement of the R&D outcome has been done. Despite being certain that the market demand is quite high, the researchers did not have any free time to build up linkages with others (researchers in the same field, end users of product prototype, industrialists from related industry). Even with Dr. Pibul, who has been using the product obtained from this R&D project, understanding and linkage were not as great as would be desired. As a result, misunderstanding of the product specifications and properties sometimes caused a failure in the medical experiment performed by Dr. Pibul.

d) PROPOSITION 4: COMMERCIALIZATION NEEDS POLICY & MANAGEMENT

Commercialization of the outcome of this research project needs the exposure of prototypes and researchers to the public. No participation by the private sector and no involvement on the part of other government officials are significant factors which have limited commercialization so far.

e) PROPOSITION 5: NO SHORT-TERM GAINS FROM RD&E

Indirect results gained from this project are the increasing number of more knowledgeable researchers participating in R&D, more skillful students as research assistants, sophisticated knowledge and innovation partly transferred to the students. Last but not least, market potential is high once the research outcome is exposed to the public and private sector. Diversified products including import-substitution synthetic HAp are expected to be significant in both types of products and value.

Aspects of successes and failures and their reasons, this project is regarded to be successful technically since the objectives of the research study were all achieved. Furthermore, innovation in the production process which is new internationally was also gained. However, in terms of commercialization, the results of this project have not been publicized to the private sector. Application of the results was quite limited and slow (used only for medical experiments by Dr. Pibul). Marketable products have not yet been produced for economic returns. Therefore, this project may be judged as a failure in terms of commercialization. This failure is mainly due to the time constraint on the researchers themselves, the lack of private sector participation and understanding, and the poor linkages among the researchers, grant coordinators, and industrialists.

### 4.8.4 Conclusion and Policy Recommendations

It is concluded that Thai researchers are capable of doing R&D activities and can produce numerous concrete results. However, many components of the technological infrastructure are needed to facilitate R&D, particularly qualified manpower (research team & assistants), R&D equipment, more favorable regulations for a better R&D atmosphere and improved status in society for researchers.

Success and failure of R&D also depend on the linkage between researchers and end-users. Clear demand from users is a significant input for the researchers and is needed from the start-up. Close coordination between researchers and users in various stages of research and development should always be maintained. Commercialization of R&D results must not be ignored by the researchers. In this aspect, government agencies should lay out clear policies for R&D implementation, particularly commercialization, as well as be catalysts for both the researchers and the private sector to fully utilize the result of R&D.

Though sometimes the R&D outcome can not be reflected academically and commercially in the short-term period, the possibilities of its utilization in the long-term period should be thoroughly explored.

<u>APPENDIX 4.8</u>

Prior studies related to this project are:

1. C. Somberthawee, "Calcium-Strontium Phosphate Bioceramics", Ph.D. Thesis, New York State College of Ceramics at Alfred University, New York, 1981.

2. C. Lorprayoon, "Phases of Cattle Bones at Elevated Temperatures", J. Sci. Society Thailand 12, 159-170, 1986.

3. C. Lorprayoon, "Syntheses of Calcium Hydroxyapatite and Tricalcium phosphate from Bone Ash" MRS International Meeting on Advanced Materials Vol.I by Material Research Society, 329-336, 1989.

Annex 4.8.1

| | | |
|---|---|---|
| Project Title | : | Biomaterials: Hydroxyapatite |
| Institution | : | Metallurgy and Materials Science Research |
| Institute | : | Chulalongkorn University |
| Place of work | : | Department of Materials Science<br>Faculty of Science,<br>Department of Orthopaedics<br>Faculty of Medicine<br>Chulalongkorn University |
| Principal Investigator | : | Asst. Prof. Dr. Charussri Lorprayoon<br>Department of Materials Science<br>Faculty of Science |
| Reported Co-investigators | : | Assoc. Prof. Dr. Pibul Itiravivong<br>Assoc. Prof. Dr. Adisak Surgret<br>Department of Orthopaedics<br>Faculty of Medicine |
| Total Funding | : | 1,000,000 baht |
| Project Duration | : | 1 year (12 July 1989 - 12 July 1990) |

## 4.9 CASE 8: USE OF NATURAL RUBBER IN RICE HUSKERS

Reporter: Dr. Krisda Suchiva

### 4.9.1 Background

a) Objective of the Project

The objective of this project was to develop a technology for replacing synthetic rubber (Nitrile rubber), partially or wholly, with natural rubber for the production of rubber rollers used in rice huskers. If achieved, the import of Nitrile rubber is expected to be lowered by an estimated 43 million baht and the use of natural rubber in value-added applications would be increased by about 950 tones per month.

b) Outcomes/Results Achieved

This project has not been completed. The project is due to end in October 1992 but a 6-month delay is expected.

So far, 7 new rubber formulations based on blends of natural rubber and butadiene rubber had been successfully developed. They had been made into rubber rollers and tested on commercial rice huskers. The data are being collected and compared with commercial rubber rollers made from Nitrile rubber. The investigators have learned a great deal about the mechanism and factors affecting wear of rubber rollers used in rice huskers and are confident that the objective of developing natural rubber-based formulations to replace the presently-used Nitrile rubber will be achieved.

As a spin-off from the study, the investigators also learned that design of the rice-husking machine might also have considerable influence on the life (wear) of the rubber rollers and reckon that, perhaps, another 2-3 years might be required in order to develop a high performance rice husker, with performance much improved over those of existing machines.

c) Other Users of Results

The products developed from this project are specifically aimed for the benefit of the local rice mills. Therefore, there are no other users of results other than the local rubber roller manufacturers.

4.9.2. Problems Encountered

The investigating team from the Faculty of Science and Technology, Prince of Songkhla University (Pattani) have considerable experience in rubber technology. The principal investigator has more than 20 years experience in rubber technology and the rest of the investigators share an average of at least 10 years experience among themselves. Furthermore, the Department of Polymer Technology where the present project is being carried out has been running a B.Sc. course in rubber technology for 12 years. Therefore, they are well-equipped with respect to processing and testing machines. The staff members of this Department are well-acquainted with local rubber product manufacturers, raw materials, and equipment suppliers. They also made prior contact with rice mill owners in the southern part of the country before the conception of this project or at the very beginning of the project. Therefore, the investigating team has had no problems relating to technical knowledge, infrastructure, material supplies or working with users of technology.

Other problems, however, existed:

Recruitment of research assistants and technicians

Uncompetitive salary was cited as the cause of the problem this project had with the recruitment of research assistants and technicians. Although STDB set up a salary scale 30% higher than that of the civil servants, it still was uncompetitive compared with the salary scale in operation in the private sector. This problem could have had serious effects on the progress of the project if the R&D site was not a university. The investigators could rely for a substantial part of their work on students of the rubber technology course who have to work for 1 year on their senior projects. Four students so far had been involved in this project in addition to a hired technician.

Use of Grant Money

All the expenses to be drawn from STDB grant had to be requested 3 months in advance. This proved to be an inconvenience on some occasions when unanticipated expenses arose. Procurement of some items, therefore, had to be delayed. Particular problems occurred with the purchase of "materials" items. STDB expected the principal investigator to advance the payment, or find some means to do so, and then obtain reimbursement from STDB.

This situation was a major problem which the project encountered and could have seriously affected the progress of the project had it not been that the research group happened to have access to other sources of finance (other research grants) from which they could borrow.

It is incorrect to state that 2-3 months were "typically" required for processing payments from STDB (CASE 8). This is a frequent complaint voiced by P.I.'s, however it is rarely substantiated. The actual record of payment processing time is on file at NSTDA.

### 4.9.3 Analysis and Lessons Learned

#### a) PROPOSITION 1: RESEARCHER CAN PROVIDE CONCRETE RESULTS

As stated earlier, the investigators of this project each had between 10 and 20 years experience in rubber technology. The principal investigator (Dr. Boontham Nithi-Uthai) has a Ph.D. Degree in rubber technology and the rest of the researchers in the team possess M.Sc. qualifications in polymer technology or related fields. They also lecture and provide other training to B.Sc. students in rubber technology (about 15 students each year). Over the years the staff of this research team have become well-acquainted with the local rubber product manufacturers and materials/equipment suppliers, so that any technical assistance or cooperation they require could be sought from industry.

It is apparent from the background given that the researchers of the rubber technology group, Prince of Songkhla University (Pattani) are highly qualified to carry out R&D on rubber technology. This is substantiated by the results they have achieved with the present project and also by a number of grants they have received from other funding agencies such as the National Metal and Materials Technology Center (MTEC) over the past 3-4 years (see Annex 4.9.2). The MTEC-supported rubber products that have been successfully developed by this research group and are ready for technology transfer to the industry are:

- Development of High Quality Concentrated Natural Rubber Latex
- Development of Prototype Latex Thread Process
- Development of Rubber Tubing for Medical Applications

The Group recently also started contract development work with a few local rubber manufacturers.

The performance of this research group lends support to the proposition that Thai researchers are capable of producing concrete results although the leader of the group admits that their achievements today are the fruits of a long collective experience of well over 10 years plus sustained effort and devotion to the work throughout the period.

b) PROPOSITION 2: RD&E NEEDS TECHNOLOGICAL INFRASTRUCTURE

The present research group has strong infrastructure backup in manpower, research facilities, financing methods, technical services and information support, which contributed greatly towards the success of the team.

Manpower

A systematic build-up plan for manpower over a period of over 10 years had seen the Department of Polymer Technology of Prince of Songkhla University (Pattani) steadily increase their manpower. Present staff had been trained in France, England or the USA with Ph.D. or M.Sc. qualifications or for short-term specialized training. The hiring of technicians in electronics and mechanics, through research grant funding, is believed to be an important factor contributing to the smooth running of the R&D work.

Equipment

The Department of Polymer Technology is well-equipped with both rubber processing and testing equipment. Again the present collection of machines and equipment is the result of an over 10 years procurement scheme. Grants available from STDB and MTEC enabled the Department to procure large, expensive equipment (1-2 million baht range) that would be difficult to obtain through government budgets. The ready availability of equipment will ensure that the RD&E group at Prince of Songkhla University can become engaged in increasingly more sophisticated project work which will have greater impact on the needs of the country in rubber-related areas in the future.

Information Access

The research group has an adequate budget to buy technical books but not for scientific or technical journals. The group adopted an interesting means to overcome the problem by becoming a member of the National Lending Library in Britain. They now have access to published research papers at a small cost. Although access to information of this research group could be improved, the existing situation proves that this inadequacy is not a major obstacle preventing this research team from achieving success in RD&E.

Finance

The size of the grant from STDB is substantial and permits the research team to carry out RD&E without financial problems. The group also receives RD&E grants from MTEC every year of the order of 200,000 - 600,000 baht per project. This aspect of infrastructure is therefore, not a problem for this research group.

Institution

Situated in the small campus of Prince of Songkhla University (Pattani), the research group enjoys the privilege of working in a close knit and friendly atmosphere. The group could obtain a fair share of support from the university and could also work independently without interference from the university. However, this case may be considered as unique since the head of the research team was a co-founder of Faculty of Science and Technology and is quite a senior member of staff of the Pattani campus. Therefore, it was not surprising that he could gain support and cooperation from other staff members of the Faculty.

c) PROPOSITION 3: RD&E LACKS DEMAND, SUPPLY AND LINKAGE

The position of the present research group is quite unique with respect to links to the industry for the following reasons:

- The head of the research team and a few other members of the team were among the very few early qualified rubber technologists of the country some 20 years ago.

- The Thai rubber manufacturers in general are very weak in technological know how. For a long time the rubber group at Pattani was the only source of technical assistance for them. Many close contacts had, therefore, been developed between the rubber group (suppliers of technology) and the rubber industry (users of technology)

- The research group, through the Department of Polymer Technology, has now trained nearly 200 rubber technologists (B.Sc. degree) over the past 12 years or so. These rubber technologists are now working in various sectors of the rubber industry and have become an automatic link between the university and the rubber industry.

- The Department of Polymer Technology organizes short courses on rubber technology regularly for the rubber industry. This forms another mechanism of establishing links between the suppliers and users of technology.

The interest of this research group is well defined and clear - the technology of rubbers. Through close links with the industry, the research group has always been conscious of the needs of the industry and of new opportunities that exist. Being situated in the developing part of the country, the group is also conscious of the needs of the region. It is not surprising, therefore, that RD&E of this research group has always been goal-oriented, towards development of new products or processes (see Annex 4.9.2 for research projects of this team).

### d) PROPOSITION 4: COMMERCIALIZATION NEEDS POLICY AND MANAGEMENT

No lesson can be learned from this project since none of the products have reached commercialization. However, the investigator expressed the following opinions:

- Short-term RD&E work (1-2 years) could not be expected to yield commercializable results or products. Sustained work input of some 10 years or more in a single subject or in only a few closely related ones is believed to be a prerequisite for commercialization success.

- The manager of a research project (who needs not be a technical person) should play a part in helping to increase the efficiency of running the project. He can also help shorten the period to commercialization of the products.

#### e) PROPOSITION 5: NO SHORT-TERM GAINS FROM RD&E

Although the researchers of this project have basic knowledge and experience in rubber technology, their study on rubber-rollers for rice huskers was started just over 2 years ago. Although the group made steady progress in developing the technology for making rubber-rollers for rice huskers, their lack of experience in this field did not allow them to reach their target in the time frame intended (3 years). After 2 years of research work, the researchers realized that they are still some may away from attaining their goal. There occurred many unforeseen technical problems during their study such as the method of assessing abrasion resistance of the rubber rollers.

However, the researchers are learning all the time and they expected to achieve a certain level of success in replacing nitrile rubber with natural rubber in the manufacturing of rubber-rollers for rice huskers. For satisfactory or a more complete results, another 3 years or so would be required, making a total of approximately 6 years before this group of researchers can produce a full gain from RD&E.

#### f) ASPECTS OF SUCCESSES AND FAILURES AND THEIR REASONS

The research group in the present case study may be described as a successful research group. The following reasons for success have been agreed upon by the experienced leader of this research team:

- Long research experience on the part of the researchers is a prerequisite. In particular, for the leader of the research team, experience of at least 10 years is required.

- Leadership is very important. It is difficult for a research team to be successful without good leadership. Good leaders are not only people who can lead the team academically or technically but must also possess managerial skill. Leaders of research groups have to manage the finances of the project, coordinate the work of researchers in the team, monitor the work progress and exert a certain amount of control and create the right atmosphere for research.

- Members of the research team must be able to work together. Conflicts between members of the staff can affect the performance of the team.

- Institutional support or support from the researchers' superior can also be a deciding factor. Troubles created by the superior or the institution could discourage the researchers which would certainly affect their research performance.

#### 4.9.4 Conclusion and Policy Recommendations

The following conclusions can be learned from the present case study:

1. In the relatively unfavorable environment for research which exists in the country, the quality of the leader of the research team appears to be, perhaps, the most important factor deciding the success or failure of the research work. The leader of the research group has to perform all kinds of functions from selecting research topics, finding research grants, leading and coordinating researchers and managing the project. A capable leader can solve and overcome problems related to inadequacy in infrastructure as the leader of this project has demonstrated.

2. Infrastructure is an important factor contributing to the success or failure of the project but is of secondary importance to the quality of the leadership.

3. Short term research (1-3 years) cannot be expected to produce concrete results. Only sustained research efforts of at least 10 years stand any chance of yielding commercializable results or products.

4. Thai researchers can be accountable in terms of concrete results but certain requirements for success in research must be met.

5. Links between RD&E results and the needs of the industry or the country are natural consequences of close contacts (usually personal) between the researchers and the end-user of the technology. Opportunities for forming contacts between research groups and end users of the research results should be encouraged. Organized seminars or workshops on common subjects of interest

may be a good method for bringing together the researchers and end users of technology.

Annex 4.9.1

Project Title: USE OF NATURAL RUBBER IN RICE HUSKERS

| | | |
|---|---|---|
| Investigators: | * Dr. Boontham Nithi-uthai | Principal Investigator |
| | * Dr. Preecha Pongbhai | Co-Investigator |
| | * Mrs. Pornpun Nithi-uthai | Co-Investigator |
| | * Dr. Priboon Inajit | Co-Investigator |
| | * Miss Orasa Patanapaiboolchai | Co-Investigator |
| | ** Mrs. Varaporn Kajornchaiyakul | Co-Investigator |

* Faculty of Science and Technology
Prince of Songkhla University, Pattani

** Rubber Research Institute
Ministry of Agriculture and Cooperatives

Duration of the Project: 3 years (November 1989 - November 1992)
Funding Agency: Science and Technology Development Board
Project Budget: 4,644,000 baht

Annex 4.9.2 LIST OF RD&E PROJECT GRANTED TO PRINCE OF SONGKHLA UNIVERSITY (PATTANI) BY MTEC

1988 Development of Rubber Tubing for Medical Use.

1990
1. Development of High Quality Concentrated Natural Rubber Latex
2. Development of a Prototype for the Latex Thread Process
3. Development and Promotion of the Use of Skim Rubber From Concentrated Latex Factories

1991
1. Production of Natural Rubber Cutlass Bearing for Fishing Boat To Replace Wooden Bearing
2. Development of Method of Producing Catheter

## 4.10 Case 9: BIODEGRADABLE POLYESTERS FOR USE IN SURGICAL APPLICATIONS

Reporter: Dr. Krisda Suchiva

### 4.10.1 Background

a) Objective of the Project

The objective of the project was to develop absorbable sutures of the monofilament type from biodegradable polyesters which can replace commercial sutures, which presently have to be imported. It was hoped that the developed sutures could replace 100 million baht's worth of imported sutures per annum.

b) Outcome/Results Achieved

This project has not been completed. The project is presently progressing into the third year and is faced with some technical difficulties. A 6-months delay is anticipated before the work is fulfilled.

The project proposed to prepare 4 types of biodegradable polyesters which exhibit physical and biodegradable properties comparable to those of the commercial sutures of the monofilament type.

So far 2 types of polyesters have been successfully synthesized and partially characterized. At the end of the project in 1993, the investigators are confident that the proposed 4 types of polyesters will have been prepared. These polyesters will possess the desired properties and can be potential candidates for further development into absorbable sutures.

In the next phase of R&D scheduled to begin by the end of 1993, the pilot scale production of monofilament polyester fibers, based on the materials developed, will be implemented. A grant from MTEC has already been committed for the next phase of work.

### 4.10.2 Problems Encountered

#### a) Equipment and Techniques

The present project involved synthesis of specialized materials for medical use. The work is confined only to laboratory work. By the nature of the project and with good management of research by the leader of the project, no serious problems were encountered with regards to material supplies and access to basic equipment. The problem, however, arose with sophisticated and expensive equipment such as high resolution NMR which is not available in Chiangmai.

The leader of this research team believes that it may not be necessary for every research laboratory to have duplicates of large and expensive equipment of their own since it involves a huge budget and could easily be wasted if each institute does not make full use of the equipment. Instead, he suggested the formation of specialized network centers where equipment, and, perhaps more importantly, specialized knowledge could be made available outside the center. Possession of equipment alone is not very useful in itself, and experience, training, and specialized knowledge regarding the use of that equipment are also necessary. Thus, the network system of specialized centers could play an important role in giving technical support to member institutions. It was suggested that MTEC is an appropriate body to set up the proposed network.

#### b) Technical Problems

Lack of experience in the fields of polymer synthesis and biomedical polymers was the main cause of technical problems the team encountered. The initial research plan was overly ambitious and many unforeseen problems occurred, such as the lack of facilities for characterization of the microstructure of the polymer molecules synthesized. The *in vitro* tests of the developed polyesters as absorbable sutures could not be carried out due to the very high costs involved. This was a factor which had not been anticipated. As a consequence, the work progress lagged behind the schedule by some 6 months, so that the scope of work may have to be adjusted to a more realistic level.

### 4.10.3 Analysis and Lessons Learned

a) PROPOSITION 1: RESEARCHERS CAN PROVIDE CONCRETE RESULTS

The key to success of this research project was the ability of the team leader. The scope of work in the first phase of development confined the other team members to minor roles. The leader of the group is an accomplished researcher who has more than 10 years experience in research. The project under study had been well thought out and planned. It has also been well managed and received full commitment from the researchers.

The achievements of the project so far are promising, although the lack of experience of the researchers in this field of specialization prevents them from achieving the level they expected. However, the researchers are all the time learning about the new subject and given more time, (3-5 years), they should finally succeed. Thus, absorbable sutures for surgical use are expected to be a developed product from this research group in 3-5 years time.

b) PROPOSITION 2: RD&E NEEDS TECHNOLOGICAL INFRASTRUCTURE

Manpower

The leader of the project made a systematic plan to build up the personnel in the field of polymer science and technology for the Faculty of Science, Chiangmai University about 6 years ago. In a few years time, the Faculty of Science will have 10-12 polymer scientists or technologists working together. The Graduate Program in chemistry of this university also contributes to the manpower strength of the Polymer Research Group. The present project on absorbable sutures also relies heavily on M.Sc. students for experimental work.

The manpower problem of this research group is the lack of technicians to handle and maintain the equipment. The present situation compels the researchers to spend part of their time on the service of equipment. The researchers would prefer to devote more of their time to research work. Efforts to recruit technicians have been made without success, and an unattractive salary was proposed as the cause.

Equipment

The Department of Chemistry of Chiangmai University is fairly well-equipped with basic scientific equipment. The present research group could benefit a great deal from the ready availability of equipment. The research group also was able to acquire additional equipment they needed for carrying out this research project from MTEC. The research group, therefore, has no problem with access to equipment and can carry out their R&D work without difficulty. The facility for in vitro tests of the biodegradability of polyester fibers is also available in the Department of Surgery of the Faculty of Medicine where a member of this research team works.

Supplies

The Department of Chemistry, Chiangmai University operates a good system of technical services with respect to materials supplies and access to equipment. This lends significant support to the work of the present research group, saving having to be faced with various kinds of delays and inconveniences.

Finance

This project obtained a substantial grant from MTEC (3.7 million baht). Therefore, financing the research work is not a problem here. About one third of the budget went into the purchase of equipment.

Institution

It is the policy of the Department of Chemistry of Chiangmai University to encourage research studies among its staff members. Thus, this research group enjoys the support of the Department and University through various infrastructural factors. There are problems, however, relating to the teaching work load. At this Department of Chemistry, the research supervision duty does not receive the same weight in the work load as teaching does. Eventually, every staff member still must commit themselves to heavy teaching loads, naturally at the expense of research activities.

### c) PROPOSITION 3: RD&E LACKS DEMAND, SUPPLY AND LINKAGE

The leader of this research project stated his criteria for selecting research topics as follows:

1. The research team's background and experience.

2. The work can be carried out by using the Department's equipment and facilities as far as possible. No expensive equipment are required.

3. The work should be compatible with the Departments's background. Therefore, the project will not be too applied.

4. There must be end-users of the research results.

Therefore, the leader of this research team is aware that results of the research work should be linked to the demand in the country. The researchers are also aware of their disadvantage in location of the project site, which is away from industry. They therefore adopted a link with the local need, viz sutures for surgical applications.

Before the researchers committed themselves to this project, they sent out questionnaires to surgeons working in the Northern region of the country, in order to find out their real needs.

The present research group did not work on industrial problems. The research result proposed was the development of an innovative product (i.e. absorbable sutures). Therefore, they have no need to form linkages with the private sector at this stage.

### d) PROPOSITION 4: COMMERCIALIZATION NEEDS POLICY AND MANAGEMENT

Research carried out by the present group of researchers is very much a scientific endeavor. The results are still far away from commercialization. The investigators have not thought of commercialization of their products. Therefore, there is nothing to be learned from this project in this respect.

### e) PROPOSITION 5: NO SHORT-TERM GAINS FROM RD&E

The present research project is a 3-year project. At the end of the project, the project leader reckons that 50-60% of the objective set out initially will be achieved. They intend to carry out further development on polyester sutures, including working on the production technology at the laboratory scale. They believe that they can succeed in 2-3 years' time.

Therefore, the total number of years from their initial study to successful production of laboratory-scale sutures will be 5-6 years. Judging from their present rate of progress, this period should be the minimum possible.

It is obvious that short-term RD&E cannot be expected to produce substantial results. The experience of this group of researchers shows that many unforeseen problems could arise, particularly during the early stage of the research work.

The researchers also regard their research activities as part of the training process for students. So far about 100 students (B.S. and M.S.) have received research training from the staff of this research group. This is an important indirect gain since qualified manpower is widely believed to be an important, if not the most important, factor contributing to success of RD&E work.

The leader of the project also believes that engagement in research will increase the experience and specialized knowledge of the researchers. This is one method of generating centers of excellence in the country. Various research groups can then gain benefits from interactions with these centers of excellence.

### f) ASPECTS OF SUCCESS AND FAILURES AND THEIR REASONS

The leader of the research team has been active in research for more than 12 years. 2-3 projects have been done as contract research for industry such as the development of ABS plastics. Results of the research projects were regularly presented at the annual Congress on Science and Technology of Thailand. Publication in international journals has not been done due to the lack of time to prepare such articles. The leader of the group is heavily committed to teaching, research and administrative work. Apart from giving research training to almost 100 students, the leader of the research group also succeeded in building up the number of staff in the Polymer Research Group. The number of polymer staff members has now reached 10.

The group leader attributes his success to:

- Good management of projects, Close attention is paid to the personnel of the group, equipment, orderliness in the laboratory and atmosphere in the workplace.

- The systematic design and approach to the project.

- Close interactions and good relationships between the researchers in the team. Team spirit is emphasized.

- Maintenance of good infrastructure.

- Devotion of the leader to group work. He also believes that human capacity is the most important single factor determining the success or failure of RD&E work.

### 4.10.4 Conclusion and Policy Recommendations

#### a) Conclusion

The following lessons can be learned from the present case study:

- Success of research project depends primarily on good leadership. The tasks of the leader are: selecting good research topics, managing research activities, and taking care of the research team.

- Good infrastructure provides strong support for productive RD&E.

- RD&E results can serve the needs of the country if the researchers take an interest in the problems and needs of the country and approach the project professionally.

- Considerable accumulated research experience is required for researchers to produce concrete results. Some 6-10 years are usually the norm. The indirect gain of short-term research is usually connected with the training of manpower.

#### b) Policy Recommendations

A network of specialized centers should be established in order to share research facilities and expertise. This network can be realized through MTEC.

Annex 4.10.1

Project Title: BIODEGRADABLE POLYESTERS FOR USE IN SURGICAL APPLICATIONS

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Duration of the Project: 3 years (March 1990 - February 1993)
Funding Agency: National Metal and Materials Technology Center
Project Budget: 3,700,000 baht

## 4.11 CROSS CASE ANALYSIS

The purpose of analyzing the cases has not been to critique a particular project for its strengths and weaknesses. Rather, the attempt here is to generalize from specific cases to broader statements about the research process, how it is handled, what results can be achieved, what problems are encountered, and what common themes emerge from across a wide range of individual projects. The cases have discussed three broad classes of materials, and have been concerned with both the materials properties aspects and the processing and equipment aspects of materials technology. This section now synthesizes the results of the nine case studies into an analysis and summary of the findings, following in broad outline the format used in the individual cases. In this section the numbers in parentheses indicate what specific case or cases are most applicable to supporting a particular statement, observation, or conclusion.

### 4.11.1 Background

There are several broad generalizations which are suitable to make as background comments. The first is that materials technology in Thailand covers a wide variety of topics and concerns. Thailand is blessed with an abundance of natural resources (exemplified here by such materials as rubber, tin, clays, and petroleum products), and it is entirely appropriate that these be used as the basis for technological development and investigations.

The second observation that is important is that Thailand has always been an agricultural society, and though this is changing rapidly it must be recognized that agriculture is still vital to the livelihood of the country and to individual citizens. We can thus see improvements in farm implements, rice processing, use of calcined cattle bone, etc., as efforts that will have strong roots in the society.

A third background statement is that Thailand currently imports a wide range of equipment, materials, and raw supplies. Such importation increases the balance of payments deficit, and uses currency which is then not available for other activities. In the country as a whole, then, attempts to produce or upgrade local manufacturing and technology efforts to lessen the dependence on imports will have a beneficial financial impact.

### 4.11.2 Objectives

It is clear that the objectives of a project can be of a wide variety. Very specific objectives, such as the design of a machine with given characteristics, or more general objectives, such as studying the current status of a technology, are all equally valid. Regardless of the nature of the objectives, however, it is important that they be clearly defined at the beginning of the project, and that project members keep these objectives in mind as the project progresses. Objectives may also have to be redefined as the work advances, owing to changes in circumstances, and this possibility must be allowed for.

### 4.11.3 Results

The results obtained by the selected sample of case studies represents a considerable set of achievements. This is especially true in light of the fact that the budgets for the projects are typically in the range of 1 to 1.5 million baht per year. This budget is quite low considering the cost of technical equipment, materials, supplies, etc. The 9 projects produced 20 local publications (including progress reports and agency reports), 3 international publications, 3 patent applications, 1 licensing agreement, several training seminars, 28 prototypes built or materials synthesized, more than 100 senior projects or graduate students, 3 processes transferred to industry, and significant amounts of skill and knowledge developed among the personnel involved. Another important result is the significant cooperation and interaction between different universities, government agencies, and private companies.

#### 4.11.4 Other Users

There appears to be considerable benefit for other users in addition to the original focus of the project. Other users include other research groups, other governmental organizations, and private sector users. Several automotive parts manufacturers will benefit from the die making project. More than 40 farmers from around the country have approached Chulalongkorn regarding the walking tractor. It thus appears there will be additional benefit that is hard to quantify or monitor for each project, but which extends beyond the primary research group.

#### 4.11.5 Other Fields Using Results

Often the results obtained in the major field of the project can be extrapolated or modified slightly to provide useful results for other fields. The die making technology can be extended to other metal working and metal finishing industries. Once the mechanics of a particular project are understood, they may be computerized and computer controlled, leading to wide ranges of applicability. The walking tractor may be modified to provide construction lorries or implements for other types of agriculture. Ion implantation may be useful in a wide variety of situations, including food preservation, nuclear physics, and analytical chemistry. Biomaterials projects may provide results that are useful not only for bone but for dentistry. The adaptation of results from one field to another can thus extend the efforts of the initial research group and multiply the benefits even further.

#### 4.11.6 Problems Encountered

Despite the wide range of endeavors involved in the 9 projects, the case studies show remarkable consistency in the nature and types of problems encountered. The most mentioned problem is insufficient manpower. This problem is exacerbated by the low levels of compensation able to be offered, and as a result the researchers often had to do maintenance and repair, administrative work, technician training, etc., themselves, reducing their efficiency for research. A lack of sufficient financial rewards and incentives to the researchers is a problem in itself, and a contributor to sometimes low morale and low dedication.

Lack of information and reference sources is a also cited as a persistent problem. Many times the researchers had to find their own solutions to the problems of locating information (Cases 7,8), and the effort involved here again will reduce the time available for research efforts.

Another problem arose due to the low experience levels of many of the researchers, and often the group's success depended almost totally on the knowledge and capability of the project leader (Cases 3,7,8,9). Should the project leader have become incapacitated it is likely no results would have been obtained.

The cumbersomeness of the bureaucratic processes necessary to obtain support were also cited in every instance. Restrictions placed on the use of funds, mechanisms for payment and reimbursement, and allowable expenses were also sources of irritation and frustration.

A final major problem is the insufficiency or unavailability of necessary raw materials (Cases 2,6) or spare parts (Cases 1,2,3). Often materials had to come from abroad, and the time delays in receiving parts and the expenses involved were considerable.

#### 4.11.7 Analysis and Lessons Learned

The first proposition addressed in this investigation is that "Research can produce concrete results". There is no question that researchers can produce concrete results which can be measured and quantified, as the summary in section 4.11.3 shows. However, the criteria used to measure results should be quantifiable in both quantity and quality. Thus, international papers which are peer reviewed on an international level will indicate a higher level of results than an interim progress report which must be submitted to the funding agency regardless of whether or not results have been achieved. Likewise, patents granted will indicate a certain amount of success, while patent pending may or may not indicate the same level of achievement.

The second proposition is that "RD&E needs a technological infrastructure". The analysis of each case brings home forcefully the need for adequate technological infrastructure. It is in fact apparent that to a large extent, a project's success is dependent upon the components of infrastructure. Problems have been encountered at all levels of with insufficient manpower. This includes not only not having enough research assistants, mechanical and electrical technicians to keep equipment operating, and machine operators for parts fabrication, but also insufficient administrative and other support personnel. It has also led to sometimes unreasonable demands on the researchers themselves, such as having to personally train new assistants (Case 7), and divide their time to teaching or administrative duties at the expense of research (Cases 3,7,9).

The insufficiency of information available to the researchers was cited as a major concern and often a serious impediment to research. Unavailability of information necessitated extensive foreign communications (Case 3), foreign travel (Case 2), and other personal initiatives by individuals to secure information from abroad (Cases 7,8).

A simplified system of handling the applications for support and disbursement of funds is crucial. Indeed, the frustrations involved with bureaucratic "red tape" have led some researchers to decide not to apply for further aid (Cases 6,7), and even to return some money which had already been allo-cated but which was not used (Case 6). Many restrictions are simply inappropriate for RD&E, such as requiring researchers to pay for expenditures and then be reimbursed later (Case 8), needing to apply for materials several months in advance (Case 8), or specifying country of origin for purchased equipment (Cases 4,5).

A readily accessible store of basic supplies is vitally important (Csses 4,5). It is frustrating and time consuming to have to spend effort on locating simple objects, such as consumables, electrical components, glassware, etc., which should be obtainable almost on as needed basis. Without a good, reliable, and efficient source of supplies, much effort and time are wasted.

A final component of technological infrastructure which must be met is the availability of standards and testing facilities (Case 2). Particularly if the results of RD&E are to result in export items or items that could be used in critical applications (such as medical implants), the ability to test these items adequately to international standards must be available.

The third proposition is that "RD&E lacks supply, demand, and linkage". The cases presented here show that there is in fact frequently fair to good supply and demand for an RD&E result, and a fairly good linkage between the two. It is important to note that those projects which have the most likelihood of success are in fact those with strong demand from local users and local manufacturers (Cases 1,2,3,6,8). The close contacts between industry and researchers, often personal contacts developed over many years, are important for securing aid for supplies, manpower, and testing facilities (Cases 1,8). For those cases where there is not yet such a strong demand for the outcome of the research (Cases 4,7), it is perhaps more difficult to quantify the results obtained, and this may lead to increased frustration on the part of the researchers. It should be mentioned that demands from industry are often more concrete (such as "must be able to use a 6 horsepower engine in place of the 9.5 horsepower engine currently employed") than academic demands ("study the surface properties of ion implanted copper"). Of course, basic research is vital and is not to be seen as less necessary than applied development and engineering. Rather, the issue is that demands are presented differently, and the linkages between supply and demand for applied research are often easier to define than for basic research. Industrial involvement at an earlier stage in the research process, including input in the initial process of determining what research to pursue, would lead to increased linkages between supply and demand at every stage of the RD&E process.

The fourth proposition is that "Commercialization needs policy and management". It is clear that commercialization, if it is to be achieved most successfully, needs a well established policy and sound management. Too often, commercial success depends rather haphazardly on whether or not there are already personal contacts established between the researcher and industry (Cases 6,7,8), or if the researchers have time and inclination to pursue commercialization. Given the heavy work loads required of most researchers, and the fact that many perceive the universities' role as primarily one of research and teaching, it is not surprising that individual researchers do not have the time or desire to seek commercialization of their results. Lack of commercialization is unfortunate, because the fruits of research leading to patents, royalties, further industrial grants, etc., could become a source of revenue for the institutions conducting the research. However, commercialization will often require different skills than those required for basic research and prototype development, and a central office responsible for patent applications, issues of trade secrets, continuing service and maintenance, etc., would clearly be a useful tool in realizing more of the potential of RD&E projects.

The final proposition is that "there are no short term gains from RD&E projects although there are possible long term gains". There is evidence to both support and disprove this proposition. On one hand,it appears that RD&E does require a long time to produce results. The principle researchers in the cases analyzed often had 10 to 20 years of experience (Cases 7,8,9) in the technology of their project before they received the particular grant analyzed here. This is a strong indication that significant amounts of time are required to train and give experience to RD&E personnel before they will make substantial contributions to RD&E and be able to pass on their experiences to others. It is also clear that the time required for "gains" will vary from project to project. In the case of materials for medical implants (Case 7), for example, extensive testing with laboratory animals will be required before trials can progress to human subjects, and the even longer times will be required before products become widely used. Other researchers express the opinion that a period of 5 to 10 years is necessary before major results can be expected (Cases 8,9).

However, there have also been extensive examples of relatively short term gains which have been made in the cases studied. It depends in part, of course, on how we define "gains", but surely the papers produced, patents applied for, prototypes built or materials synthesized, processes transferred to industry, and personnel trained all indicate that gains are possible within a few years of a project's inception.

# CHAPTER 5 LESSONS LEARNED AND POLICY IMPLICATIONS

## 5.1 LESSONS LEARNED

The cases highlighted the fact that Thailand contains a wide variety of natural resources, and that many of these natural resources, such as rubber, metal ores, minerals, petroleum, etc., are being used by Thai industry. However, all too often these materials are used only as raw materials and commodity items, or at most they are used in low technology, often low quality and low value added, industry. Thus, for example, ceramic novelty items can be produced with satisfying results, but higher quality and technical ceramics still need more research and development. Consumer plastics can be produced locally, but higher level engineering and technical plastics are still some time away in the future. Likewise, high grade steel is not locally produced, and as a consequence many special types of steel must be imported.

All these factors indicate that Thailand is a long way from reaching the fullest value of its resources, and that further benefit will only occur as the technological content and quality of materials and products rises, and the losses from scrap, waste, and defective items decrease.

The cases have shown that there is frequently an insufficient or undeveloped market for the results of Thai RD&E efforts. In some cases the researchers do not have the time or desire to establish a commercial market for their results, preferring instead to work more specifically for the advancement of knowledge or to aid the efforts of another research project. And, the people who are capable of doing a good job at RD&E may not have the best skills necessary to communicate with the business and commercial community.

For the situation where there is a clear and strong linkage between the development of a prototype or new process and a commercial user, the results of the work can be quite satisfactory. It is important to note that such linkages require market information concerning the size, needs, and restrictions of markets, both international and domestic. This information must be available to RD&E planners and workers, and suitable schemes must be undertaken to reach these markets.

From the cases studied we have seen that RD&E can produce concrete results, and that researchers can be held accountable for the results of their efforts. The results may take many forms, including publications, patents, licenses, processes transferred to or adapted by industry, textbooks or manuals prepared, standards written, seminars and training programs presented, etc. In some cases economic gains may be obtained in a relatively short time, within two to three years, while in other cases ten years may be required before there are any appreciable gains. And, in some cases there will never be any real commercial gains for a project, but the results in terms of people trained and experience gained will still be considerable.

The calibre of RD&E often depends on the calibre of the project leader, and such a project leader may need ten to twenty years of experience before he or she will be in the position to lead an RD&E team to produce creditable results.

The technological infrastructure is a crucial component in the success of an RD&E project. Without sufficient support no project can be expected to achieve its goals.

The most pressing need at the current time in Thailand is the lack of sufficient manpower at all levels. This includes the technical manpower of researchers, instructors, technicians, and skilled workers, as well as the administrative manpower for project management, executive planning, and administrative support. The support systems necessary to maintain the manpower that does exist is insufficient. Researchers frequently feel they are isolated, and have no way of feeling fully integrated into the technical community on the local or international level. Continuing education or specialized training to upgrade people's skills in new areas is also not given a very high priority.

Another pressing concern of the technological infrastructure is insufficient funding or unnecessary difficulties in obtaining available funds. Researchers are discouraged by the low rates of remuneration and the additional burdens for administrative and teaching requirements placed on them. Laboratory assistants, equipment maintenance technicians, machine shop operators, etc., cannot be hired because the private sector pay scales are much more attractive. The budgets allocated for research do not accurately reflect the high costs of equipment, standards, spare parts, high quality materials, information, communications, etc.

Information is often not available, or there is no easy access to it. Researchers spend a lot of time trying to find information, and such efforts are not very productive or efficient.

Technical services are required for calibration, standards testing, and analysis of properties. If projects are to be commercial successful and meet product export expectations, they must be capable of being tested to international standards, such as ISO 9000 or JIS or DIN or whatever. Often an individual researcher or project cannot justify the cost of a major instrument, but the equipment needs to be available within the country so that occasional users can benefit from it. Technical testing services of a high calibre are a prerequisite for having the results of Thailand's RD&E efforts be accepted commercially both here and abroad.

Linkages between the providers of RD&E and the users of RD&E are vital. This means that for commercially viable projects, the end users such as factories or commercial manufacturers must be connected with the RD&E workers, they must have some input as consultants or supporters or providers of direction to the RD&E workers, and they must be agreeable to helping to bring a product to the marketplace. One of their most important functions is to provide feedback as to how well a particular process or product satisfies their needs, and what improvements or changes would they like to see.

## 5.2 POLICY IMPLICATIONS

The overall framework within which RD&E projects are carried out must be set by the policies of the National Centers and ultimately the National Government. Without the security of long-term planning and long-term commitment, it is difficult to pursue RD&E efforts effectively. From the results of the case analyses, there are several overall directions and concerns which should be given priority.

Policy implications are:

1. Encourage RD&E projects which increase the processing level of raw materials produced in Thailand, increase the quality of raw materials produced, or provide a product or process already in existence in the country with better quality and high yield.

2. Provide information to RD&E workers about the needs of local and international markets, actively encouraging and supporting projects which indicate a likelihood of success in a given market.

3. Implement guidelines that will help assure RD&E workers of producing concrete results, and make sure expectations are understood at the beginning of a project.

4. Increase the level of technical manpower at all levels, and increase the quality of the training and educational services available to produce technical manpower.

5. Provide adequate and realistic funds for RD&E projects, and simplify the entire financial system, for applying for support, receiving funds, importing equipment, and paying taxes and duties.

6. Remuneration to RD&E workers must be sufficient to provide realistic incentives and attract qualified people.

7. Increase the availability and quality of technical and information services, and disseminate information about what resources are already available.

8. Encourage strong linkages between government agencies, academic institutions, and commercial enterprises. This may be done by financial incentives or other means.