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# INDUSTRIAL RESEARCH INSTITUTES:
## Their Role in the Application of Appropriate Technology and Development

# BRAZIL:
## Explosive Metalworking Program

James M Miller, Jim D Mote, and Henry E. Otto

A series prepared by the
University of Denver
Denver Research Institute
Office of International Programs
under the sponsorship of the
U.S. Agency for International Development
Office of Science and Technology

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# FOREWORD

This case history has been written to assist development planners, personnel of industrial research institutes, and USAID mission personnel in understanding the role that IRIs can and do play in the application of technology to development. This case history is one in a series of eight prepared by the Denver Research Institute under the sponsorship of USAID/Office of Science and Technology (contract AID/ta-C-1337).

The cases in this monograph series first appeared in another DRI publication, Appropriate Technology for Development: A Discussion and Case Histories, edited by Donald D. Evans and Laurie Nogg Adler (Boulder, Colorado: Westview Press, 1979). This book was sponsored by the USAID Office of Science and Technology in preparation for the United Nations Conference on Science and Technology for Development (UNCSTD).

# INTRODUCTION

## INDUSTRIAL RESEARCH INSTITUTES

In many countries the creation of a viable indigenous industrial sector has long been considered one of the key elements to economic development. Consequently, an industrial research capability is of significance in defining the industrial needs and priorities of a country or region and matching them with appropriate technologies. An industrial research institute (IRI) has been defined as a technical organization established to make direct contributions to industrial development in the private and public sectors[1]. In this context an IRI differs from private research entities which have no proclaimed mandate or responsibility in the practical application or adaptation of technology to their countries' development needs. Frequently industrial research institutes are in some manner government funded and are therefore closely allied to the economic, social and political climate of that government. Ideally, IRIs play a supporting role in the design and implementation of national policies that reflect economic development and growth, while functioning autonomously. In reality, however, government usually plays a substantive role in research institute operations. In any case, compatibility and cooperation among government agencies should be preserved, and selection of industrial research programs should reflect needs of both the public and the private sector.

In many instances, the IRI acts as liaison between government and industry. Ideally and particularly in less developed countries (LDCs), the IRI acts as an intermediary in determination of the need for and the subsequent creation, adaptation or transfer of technology. In fact, the study of technological opportunities or the choice of appropriate technology for development is one of the major functions of the industrial research institute.

In comparison to other technologies, appropriate technology represents the social and cultural dimensions of innovation[2]. As a mediator in an innovation process, a research institute's task is to identify the real needs of the local community, develop or introduce technologies and organizational means which can meet these needs and initiate a process of development based on the internal innovative forces of the local community[3]. In this manner, the IRI addresses the issue of appropriate technology and its role in the development process.

However, opportunities for innovation do exist in areas other than just industrialization--increasing agricultural productivity, developing

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[1] United Nations. Industrial Research Institutes, United Nations Publication No. E.70.II B.21. New York: UN, 1970, p. vii.

[2] Nicolas Jequier, Appropriate Technology: Problems and Promises. Part I, The Major Policy Issues, 1976, Development Center of the Organization for Economic Cooperation and Development (OECD). p. 9.

[3] Ibid., p. 36.

rural technologies, and offering incentives for small industrial projects are also duties that a research institute is likely to perform.

The methods by which IRIs assess technological choice and stimulate innovation are varied. Most often development strategies would include a combination of the following:

- Survey, study and develop uses for local raw materials.
- Develop new processes and improve existing ones.
- Develop new products and recognize new uses for existing ones.
- Improve industrial and agricultural productivity.
- Study the technological and socioeconomic feasibility of industrial and agricultural projects.
- Develop standards and specifications.
- Determine choice of technology and scale of operation.
- Determine industrial location and site.
- Conduct marketing research[4].
- Acquire and disseminate scientific and technological information.
- Systems design and management of development programs.
- Evaluate a chosen technology and its relationship to local economic and cultural traditions.

To establish solutions to identifiable problems, the research institute often adapts foreign technologies to suit local conditions and offers incentives to small industries to create new technologies. Technological innovation is accomplished in a variety of ways from actual adaptation of a chosen technology to training of researchers and engineers for institution building and infrastructural support, to establishment of extension services to help define and fulfill needs.

The creation of linkages between research institutes has allowed increased communication and the transfer of information and technologies, not only between developed and developing countries, but among developing countries as well. In a few instances, regional research

[4] United Nations. Proceedings of the Interregional Seminar on Industrial Research and Development Institutes in Developing Countries, Beirut, Lebanon, 30 November-11 December, 1964. Vol. 1, New York: UN, 1966. p. 45.

institutes or networks of institutes have been established to facilitate development in common geographic and cultural areas. (ICAITI in Guatemala representing Central America is such an example.) Similarly, an international IRI organization called WAITRO (World Association of Industrial and Technological Research Organizations) has been created.

Industrial research institutes tend to become the foci for national S&T development and have offered essential infrastructural support. Research institutes, therefore, may play a very important role in mapping the future economic growth and development of a country. With this increasing responsibility, an IRI's task becomes more complex and difficult, particularly when original development goals are overwhelmed by other considerations. Factors such as politics, financial risk, societal or cultural considerations, legal restrictions, staffing problems, marketing problems, fear of change, and sheer inertia may impede or block the transfer process and thus weaken or negate its economic effect[5].

## CASE HISTORIES

Much can be learned about development from the investigation and analysis of industrial research institutes. The Office of International Programs (OIP) at the Denver Research Institute (DRI) has initiated linkage activities with a variety of research institutes worldwide over the last decade under the sponsorship of USAID's Office of Science and Technology. Through these linkage activites, choice and adaptation of technology, training of researchers and engineers, exchange of information and help in the management of research institute affairs have occurred. A dynamic process of communication has been established through DRI's relationship with each research institute, and much knowledge has been gained about the development process by all those involved.

Realizing the value of imparting research institute experiences to others in the development field, DRI has gathered several case histories of industrial research institutes' endeavors in the area of technology transfer. The cases were collected for the most part by OIP staff (often assisted by IRI colleagues) who acted as impartial reporters when collecting the information. The goal of the research was not to select cases that showed only successful adaptation of technology, but to show ways and means by which IRI's must operate to encourage and achieve progress in the development scheme. There are, in fact, examples where a transfer of technology is considered unsuccessful or unsatisfactory.

In the case, Brazil: Explosive Metalworking Program, written by James M. Miller, Jim D. Mote, and Henry E. Otto, the introduction of a metallurgical technology--explosive forming, cladding, and hardening--has opened up a small but profitable industry in the state of São Paulo.

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[5] James P. Blackledge, The Industrial Research Institute in a Developing Country: A Comparative Analysis. Washington, D.C.: USAID, 1975. p. 19.

Collaboration between the Instituto de Pesquisas Tecnológicas (IPT) and DRI made this transfer of technology possible. Under a linkage agreement, the two research institutes determined the technical feasibility and market acceptability of creating such an industry in São Paulo. This technical expertise has ten adpated to meet the needs and requirements of the area and advanced by close association of the two research institutes.

# BRAZIL:
# EXPLOSIVE METALWORKING PROGRAM

James M. Miller, Jim D. Mote, and Henry E. Otto

## ORIGINS OF THE PROBLEM

The Instituto de Pesquisas Tecnológica (IPT), originally a state-supported research institute, has been in operation for over fifty years. The director of IPT, Dr. Alberto Pereira DeCastro, began formulating plans in 1969 to develop methods by which IPT could better assist Brazilian industrial growth.

Since World War II, the economy of Brazil has been changing from an agricultural to an industrial base. The state of São Paulo has been the focal point of development. During the postwar era, Brazil's Gross National Product (GNP) increased as much as 16 percent in some years. Such dramatic industrialization gave rise to a multitude of problems. Many small- and intermediate-sized concerns lacked resources, human or technological, to adequately solve these difficulties. Brazil, therefore, was importing goods and services that required large capital expenditures and foreign currency.

Another Brazilian problem was the growth of multinational concerns that brought in their own technology to produce the goods they marketed. Most of this technology, captive to the particular multinational firm, is not disseminated to Brazilian-owned industries. Utilization of this technology to provide goods for the Brazilian market requires that royalties be paid, which, in turn, results in a capital outflow from Brazil. In addition, a large number of small concerns that are suppliers of parts and components to the multinationals have problems meeting the quality-control requirements of the large organizations. These small- to medium-sized firms need a better technological foundation to participate in economic growth.

One method of developing this base was discussed by Dr. Castro with personnel at the United States Agency for International Development (USAID)/Brazil and with the state of São Paulo. The government recognized that science and

technology were fundamental in the overall development of Brazil. Under the program, the state of São Paulo proposed to give its research institutes the necessary financial support to improve their research and development (R&D) capabilities. They realized that the demand for new processes would increase, which would require an expanded capability for diversifying production and an efficient scientific and technological information service.

A loan agreement between the state of São Paulo and USAID was established on 30 May 1973 for $15 million to further the goals of the overall science and technology program. This loan agreement provided the mechanism to use personnel from the United States and to provide contract support for research institutes. One of the participating institutions was IPT, which was to initiate four demonstration projects, one of which was identified as "Explosive Forming, Cladding, Bonding, and Welding." The state placed these demonstration programs and others under the jurisdiction of a Program of Science and Technology for Development (PROCET) to support engineering development, product design, market analyses, and applied research.

Personnel from the Denver Research Institute (DRI) visited IPT in January 1974 to discuss a formal linkage with IPT and to prepare a proposal under the PROCET objectives. A direct link between the metallurgy divisions of the two research institutes was proposed. The demonstration projects selected were explosive metalworking, packaging, the surface quality of deep-drawing steels, and weathering steels. A proposal was submitted by DRI through IPT to the state of São Paulo to establish a contract with the Instituto de Pesquisas Tecnológica.

The program was approved, and work started on the Explosive Metalworking project in July 1974. The scope was: to develop processes to re-form metal plates or sheets into controlled shapes; to laminate dissimilar metals, such as titanium or stainless steel, onto steel, or to bond lead to steel; to weld oil and gas pipelines; and to produce dished heads of aluminum and steel for fuel tanks and chemical processing tanks.

This demonstration project indicated that the goals were viable and that IPT-industry interaction could be broadened. At the conclusion of the first two years, in 1976, the project was evaluated, and IPT, DRI, and PROCET decided to continue the effort, which was funded by a follow-on contract still operative under the USAID loan agreement.

## DESCRIPTION OF THE TECHNOLOGY

Explosive metalworking, in its broader sense, may be defined as the use of the energy released by a detonating

explosive to change the shape of a metal part (explosion forming); to join similar or dissimilar metals (explosion cladding or welding); to cause changes in the metallurgical and engineering properties of a material (explosion hardening); to separate metals (explosion cutting, shearing, and punching); and to compact metal or ceramic powders (explosion powder compaction). Explosives provide a relatively cheap and readily available source of power. Hence, for the types of metalworking mentioned above, the use of explosives as the source of power is attractive because of the versatility, low capital investment, and unlimited growth potential.

As applied to current commercial practice, the widest areas of use of explosive metalworking are explosion forming, explosion cladding, and explosion hardening.

## Explosion Forming

Explosion forming, as usually practiced, is a standoff procedure (see Figure 1). It is a dome-forming operation where the metal blank (workpiece) is positioned over a die cavity and clamped into place by a hold-down ring. The air is removed from the cavity behind the blank through the vacuum link via an auxiliary vacuum pump to allow the unimpeded flow of the metal blank into the die cavity after the explosive is detonated. The entire assembly rests on the bottom of a tank filled with water, which serves as an energy transfer medium.

An explosive charge is placed at a predetermined distance from the workpiece and detonated. The pressure produced is transmitted through the water and becomes a ram, forcing the workpiece into the die cavity. In addition to forming domes or leads for tanks, variations of the process can be used for tube bulging, leading or corrugating panels, forming or sizing of conical preforms, and other functions.

## Explosion Cladding

In explosion welding, or cladding, two metal surfaces, driven together by explosive forces, weld together as a result of their high-velocity collison. Neither of the metals melt during the collision. However, a jetting action occurs between the colliding plates that cleans the metal surfaces of contaminants just prior to their being forced together under great pressure.

In parallel plate cladding, the metals are arranged so that the cladder metal is positioned exactly over the backer metal at a predetermined standoff distance (see Figure 2). An explosive of the required detonation velocity is placed on top of the cladder metal. The quality of explosive, explosive detonation velocity, and standoff distance are selected

FIGURE 1
ESSENTIAL ELEMENTS OF AN EXPLOSION FORMING OPERATION

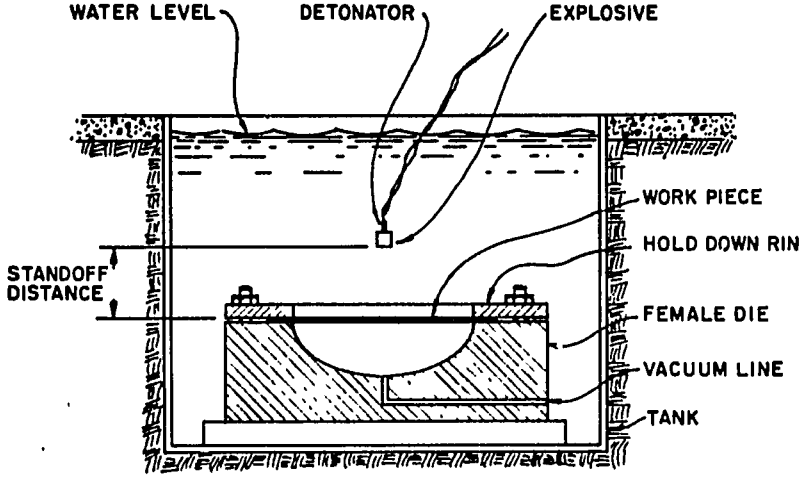
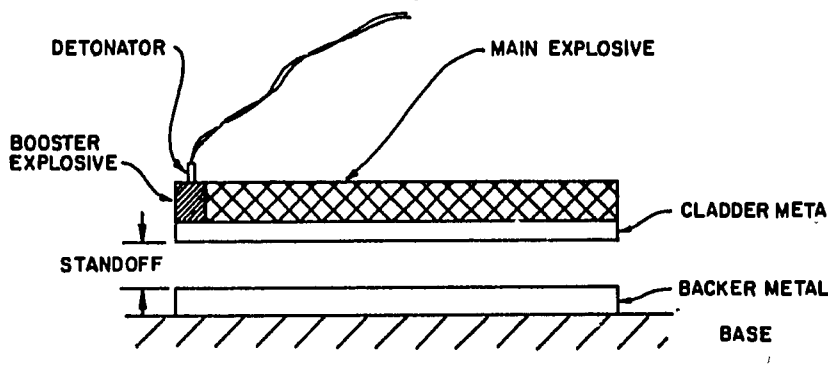



FIGURE 2
SCHEMATIC FOR PARALLEL PLATE CLADDING



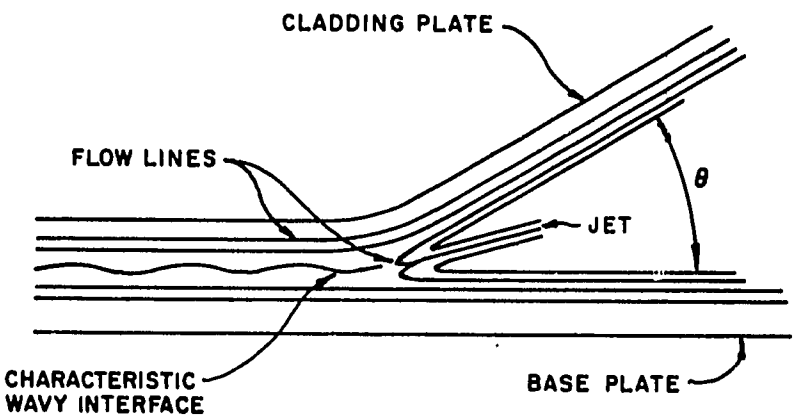
so that the two plates will collide at a characteristic velocity and angle. The main explosive charge is detonated by a booster charge, and the two plates collide (see Figure 3). A very high pressure is generated near the collision point, and the metal surfaces can flow as a spray of metal from the apex of the angled collision. The surfaces are stripped of contaminants, which are expelled in the jet, thus removing bond-inhibiting surface films. The resulting contaminant-free surfaces are pressed together by the high pressure so that atomic attractive forces are established and a metallurgical bond is formed.

The greatest tonnage of explosion-clad products is in the form of flat plates that are used for corrosion protection of chemical processing equipment, electrical transition joints, and structural transition joints.

Explosive Hardening

Explosive hardening is accomplished by placing an explosive with a fast detonation velocity in contact with a metal. The hardening is effected by high shock pressures that are generated in the metal, which causes internal microstructure change resulting in much stronger metal with little alteration in material dimensions.

FIGURE 3
SCHEMATIC OF COLLIDING PLATES SHOWING JETTING ACTION DURING EXPLOSION WELDING PROCESS



The process has been employed successfully in hardening railroad frogs made from Hadfield steel. It has also found use in hardening hammers for rock-crushing equipment. Explosive hardening has the advantage of being easily used in remote locations on massive machinery.

## TECHNICAL SOLUTIONS

In the beginning, IPT had no capability in the field of explosive metalworking but had an on-going metallurgy division with forty years of experience. The implementation of the program was divided into: (1) original market survey; (2) training of IPT personnel; (3) facility development; (4) production of clads; and (5) related production.

### Market Survey

The initial market survey was conducted during July and August 1974 in the United States to determine products and users of the technology. This preliminary survey provided an understanding of the basic marketing and economic factors involved in the explosive-metalworking technologies and offered a model for a similar survey in Brazil.

A survey followed in Brazil from August to October 1974. In-depth interviews were held with thirty-four industrial organizations, the majority of which were considered potential users or specifiers of the technology. Width of application was stressed rather than depth, to give a broad view of the market situation, which, in turn, made it easier for IPT to contact the firms after the IPT staff had acquired the necessary training.

The initial survey indicated that the easiest market to penetrate was for clad products. This market was highly variable, but general trends and forecasts were made in market size projected on the annual increase in Brazil's GNP in 1974. Another factor was the large expansion underway in the Brazilian steel industry, which was projected to reach 30 million tons per year by 1980. The closely allied heavy-mechanical industry, a user of clads, had been growing at a rate of about 16 percent a year between 1969 and 1972. It was concluded that the demand for clad products would follow the trend for primary metal users and heavy equipment manufacturers.

Other factors were considered. Brazil was planning to start the production of stainless steel sheet and plate in 1976, which would assist in developing the clad market. However, the projected stainless steel mill did not start operations until September 1977. Also, expansion of the Brazilian petrochemical industry would increase the demand for clads.

In Brazil the most logical explosive-forming area was for storage and pressure-vessel heads. At the time of the initial survey, many firms were using gore segments, in which the gores were welded together to form large heads. Of the 1,000 heads per year being made, it was thought that 750 could be produced by explosive forming. Other heads that were manufactured by spinning and thin-stainless heads could be explosively formed, too. The initial survey, however, indicated that the market would be hard to penetrate due to the existing technology.

Subsequent surveys were conducted by IPT personnel. On one survey, the market was found to be unfavorable. The manufacture of heads in Brazil was based upon a wide number of international specifications that varied enough to give a large product mix. The product mix in turn meant that a large number of dies would be required rather than just a few of standard size. The result was that it was not economically feasible to explosively form heads in the one to two meter diameter sizes. Subsequently, a 6,000 ton press, capable of making most heads, was installed in Brazil. This press precluded the development of explosive-forming facilities by IPT.

A market survey was also conducted for explosive hardening of railroad cross-overs (jacares). The jacares for heavy-duty use are made of manganese (12 percent) steel and are explosively hardened by many railroads and suppliers throughout the world. This survey indicated that about five hundred jacares a year would constitute the Brazilian market when it is developed. One drawback in introducing the technology, though, is the lack of data comparing explosive hardening with other hardening methods, such as hammer or roll hardening. The potential market value was estimated at $50,000 to $100,000 per year (1974) based on a cost of $100 per jacare. However, costs for hardening per jacare have risen since the survey to better than double the original figures (1979).

## Training

Seven IPT personnel were trained in explosive metalworking at DRI in two different groups. The first group of four Brazilians was trained in all aspects of explosive metalworking during August to December 1974. Three IPT engineers were assigned to the Explosive Metalworking Project. They received on-the-job training at Campo Experimental do Lorena in explosive welding. These Brazilian engineers subsequently were sent to DRI for training in explosive forming and theoretical aspects of explosive welding. However, a turnover in trained personnel occurred, indicating one of the problems in insuring continuity of the

project. Progress was consequently delayed. Moreover, none of the engineers who left IPT were able to use their training in their new jobs.

Another phase of the technology transfer was the presentation of course work in explosive metalworking at the University of São Paulo (USP). Seven graduate students completed a course in explosive metalworking, but alternate schools for the presentation of course work in explosive metalworking were not instituted.

## Facility Development

A facility for explosive metalworking was developed by IPT near Lorena, São Paulo, in the Vale de Paraiba. The site, called Campo Experimental do Lorena, is midway between the industrial centers of São Paulo and Rio de Janeiro and is accessible to the state of Minas Gerais.

The four most important explosive manufacturers in Brazil are in the vicinity of Lorena. The largest steel mill in Brazil, CSN, is located at Volta Redonda, less than one hundred kilometers from Lorena. The second largest steel mill, Usiminas, is located near Belo Horizonte, as is Acesita, the mill that produces stainless steel plate. Lorena is also midway between the ports of Santos and Rio de Janeiro, which would be the ports for exporting explosive clads if the requirement arises.

Plans have been formulated for the construction of a new port eighty-five kilometers from Lorena, which will serve the southern part of the state of Minas Gerais as well as the Vale do Paraiba. A railroad spur is located three kilometers from the site. Thus, Campo Experimental do Lorena meets all of the requirements of being remote but has good access to supplies and market.

The site at Lorena, consisting of 360,000 square meters of land, was donated to IPT by the municipal government of Lorena. A local engineering firm was employed to develop the site. The roads, drainage, and welding site were developed first, followed by the buildings for setups and explosive storage. The planned explosive-forming facility was not built due to market conditions. However, a large materials-handling building was erected. The facilities at Campo Experimental do Lorena include laboratories for complete metallographic examination and nondestructive testing of clads.

## Production of Clads

The main product produced by IPT at Campo Experimental do Lorena has been tube sheets for use in heat exchangers. IPT takes the manufacturers' materials and

performs the explosion bonding. The clad composite is then returned to the manufacturer for fabrication (see Figure 4 and accompanying photographs). Materials clad on the carbon-steel substrate have included naval brass, stainless steel, and cupronickle.

The process has allowed for a reduction in the importation of clad tube sheets into Brazil. Also, some manufacturers using weld overlay and brazing, which are not too satisfactory, have supplemented these processes with explosion bonding and obtained a cost reduction.

The first tube sheets were explosion bonded by IPT in June 1975. Since then, the number of tube sheets produced and the quality of bonding has steadily increased as has the number of customers. Early tube sheets were not tested nondestructively, and the only quality control was whether or not tapping on the surface gave evidence of voids. Ultrasonic inspection equipment is now used to determine if the tube sheet is totally bonded. Reject rates are on the order of less than 3 percent of the total tube sheets welded.

## Other Production

Explosion-clad sheets of 304 stainless steel to carbon steel were made for evaluation by one fabricator. These clads were formed with no problem into the desired configuration.

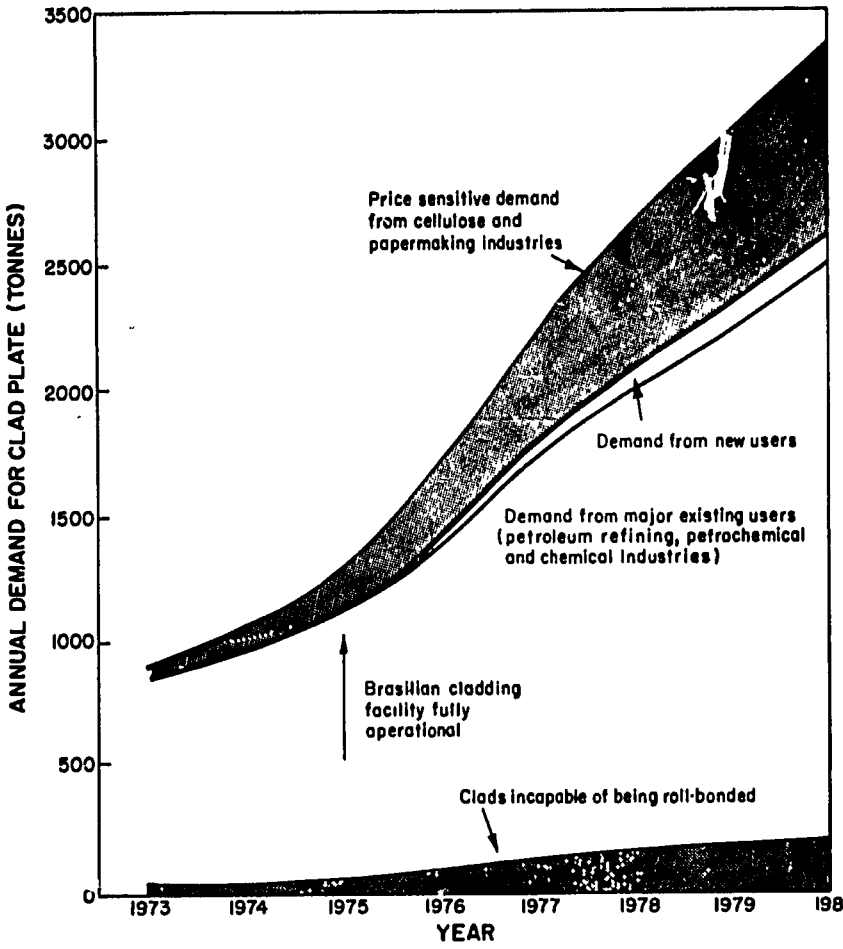
This type of clad was evaluated for applications by Petrobras. Conventional tests as specified in the American Society of Testing Materials (ASTM) 262 were conducted on the clads. These tests indicated that clads of nineteen millimeters and greater met all specifications.

Tube to tube sheet expansion was carried out on two heat exchangers. Over four thousand tubes were expanded successfully. Hydraulic tests were conducted after expansion to insure the quality of the expansion process. Eight leaks were repaired mechanically. Wax was used as the transmission media, which is less costly than the molded polyethylene plugs used in other countries.

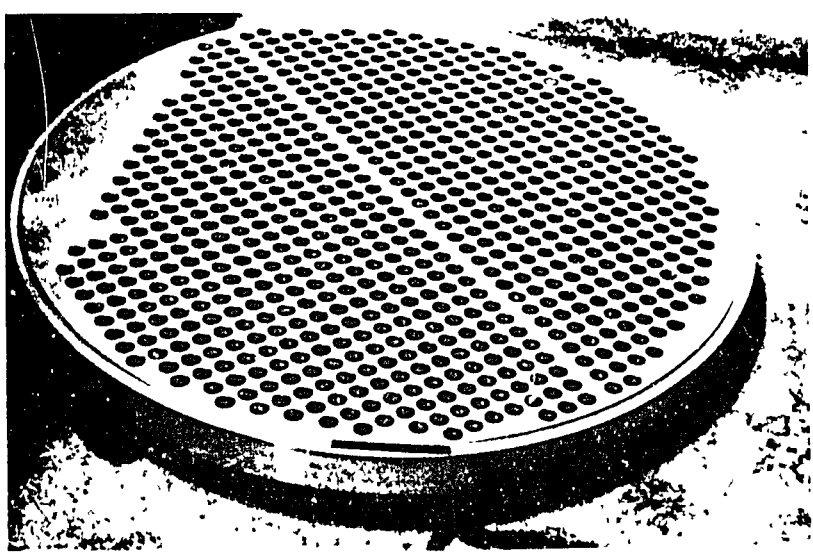
Bimetallic thermostat materials were explosion bonded. Billets were first melted and rolled at IPT, then explosion bonded. After welding, the composite was rolled to size. These materials provided another market for IPT that formerly required the material to be imported by Brazilian industry.

The hardening of jacares for a manufacturer of railroad hardware has been done successfully. Several jacares have been hardened and are currently being evaluated on Brazilian railroads. It is anticipated that this market will expand after further evaluation.

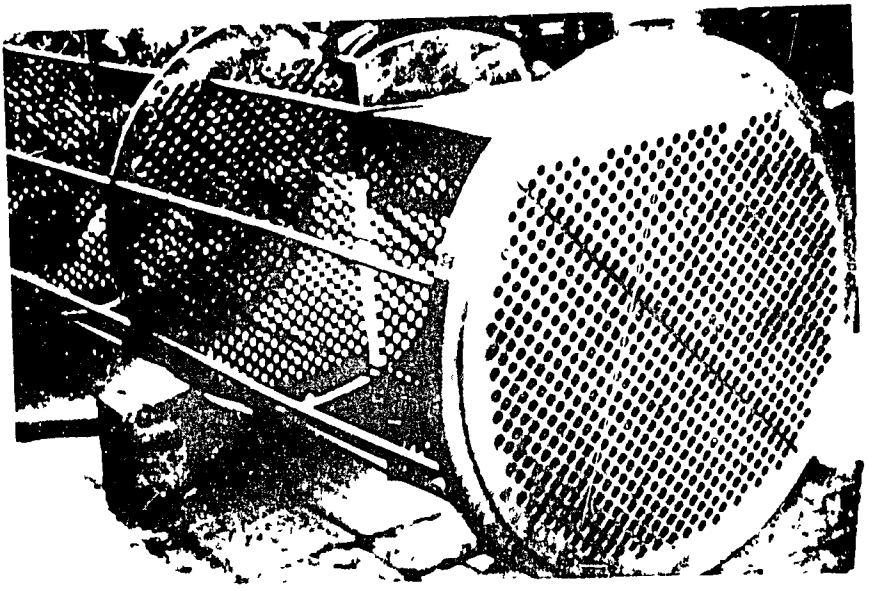
FIGURE 4
PROJECTED INDUSTRIAL DEMAND FOR CLAD PLATE
IN BRAZIL



As clad tube sheet composite



Tube sheet composite after machining



Tube sheet during fabrication into tube bundles

Stainless clad plate after explosion bonding

## TECHNICAL COMPETENCE OF THE STAFF IN TERMS OF OBJECTIVES

IPT products currently rely on explosive metalworking, cast-products technology, and foundry techniques. An increase in the volume of these products has required IPT to demonstrate their capabilities to industry.

In the Explosive Metalworking Project, which introduced an entirely new product to Brazil, time and perserverance were required to show that good-quality "clads" could be made. The project staff needed to gain necessary experience, but present evaluations indicate that the IPT personnel recognize the problems of their industry. A sampling of industrial sponsors indicates a high level of confidence in this IPT group. The staff is now stable and has a capable marketing ability.

The Explosive Metalworking Project was one example of introducing totally new products and services into Brazil. IPT and DRI agree that the success in this area was due in part to the training program.

## INTERNAL/EXTERNAL COMMUNICATIONS

Because of the distance between the Lorena field station and IPT (approximately two hundred kilometers), problems existed at the former of which headquarters was unaware. Strengthened communications and closer personal relationships have resolved many of these difficulties.

Communications with other divisions have not been so successful and need improvement. The Package Engineering Laboratory, which requires assistance from the wood, plastics, and ceramics division, has experienced difficulties on interdivisional projects.

Sponsor relationships have been good, as reported by the contacts made with industrial sponsors. The individual project managers are responsible for these relationships. Difficulties do occur on most research and development projects, but the sponsors have been kept aware of problems as they arise.

Promotional efforts concerning IPT's capabilities have been made through the presentation of papers, seminars, and classes in some disciplines. Coordinated promotional efforts have helped toward this effort, but if a particularly industrious project manager leaves, it may jeopardize the program. Industry awareness of IPT's capabilities could insure success of the new technologies.

## ECONOMIC ASPECTS

Starting with 1976, the project income has been:

| | |
|---|---|
| 1976 | 234,243 Cruzeiros ($ 22,098)* |
| 1977 | 1,518,781 Cruzeiros ($106,357)** |
| 1978 | 971,027 Cruzeiros ($ 57,644) (to 31 August 1978) |

A reported backlog of orders for September 1974 totals 600,000 Cruzeiros.

In terms of customers in this project, there were:

| | |
|---|---|
| 1975 | 7 |
| 1976 | 9 |
| 1977 | 10 |
| 1978 | 13 |

* approximate conversion 1976 and 1977, June rate.
**approximate conversion 1978, April rate.

## IMPACTS OF THE TECHNOLOGY

Explosive metalworking is an example of the transfer of a new technology to Brazil. The goods produced have been accepted by Brazilian industry. However, industry must continually be convinced that a quality product is being produced, which means that manufacturing techniques and continued experience must continue to be developed by IPT.

Objectives of this project (and others) were:

(1) Increase the interaction between IPT and industry to assist in the industrial growth that is required to increase Brazilian industries' export capacity;

(2) Develop a greater competence on the part of IPT to undertake programs to solve industrial problems;

(3) Develop a managerial capability in IPT to assume leadership in the above considerations;

(4) Use specific metallurgy and materials projects to stimulate, increase, and train IPT staff in mechanisms for institute-industry interaction.

Originally, four demonstration projects were undertaken by IPT and DRI. Two survived the entire period of the five-year loan agreement.

The IPT-DRI program has demonstrated that technology can be transferred by the interaction of two research institutes, and that the technology can create new services and products for recipient industries. If the transferring process is to be successful, however, a high degree of interest is required of the recipients. They must actively promote the technology with the industries concerned in addition to acquiring a working knowledge of the new technology.

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