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04880

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ID/WG.1[illegible]/[illegible]
1[illegible] July 197[illegible]

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Third Interregional Symposium
on the Iron and Steel Industry, 3d,
Brasilia, Brazil, 1[illegible] - 21 October 19[illegible]

Agenda item 3

THE INSTITUTE OF TECHNOLOGICAL RESEARCH, SÃO PAULO, (IPT): A CASE STUDY [1/]

by

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id.73-500[illegible]

04880

Distr. LIMITEE
ID/WG.146/94 RESUME
18 juillet 1973
FRANCAIS
Original : ANGLAIS

Organisation des Nations Unies pour le développement industriel

Troisième Colloque interrégional
sur la sidérurgie
Brasilia (Brésil), 14-21 octobre 1973
Point 8 de l'ordre du jour

RESUME

UNE ETUDE DE CAS : L'INSTITUT DE RECHERCHES TECHNIQUES DE SAO PAULO[1/]
(Instituto de Pesquisas Tecnologicas)

par
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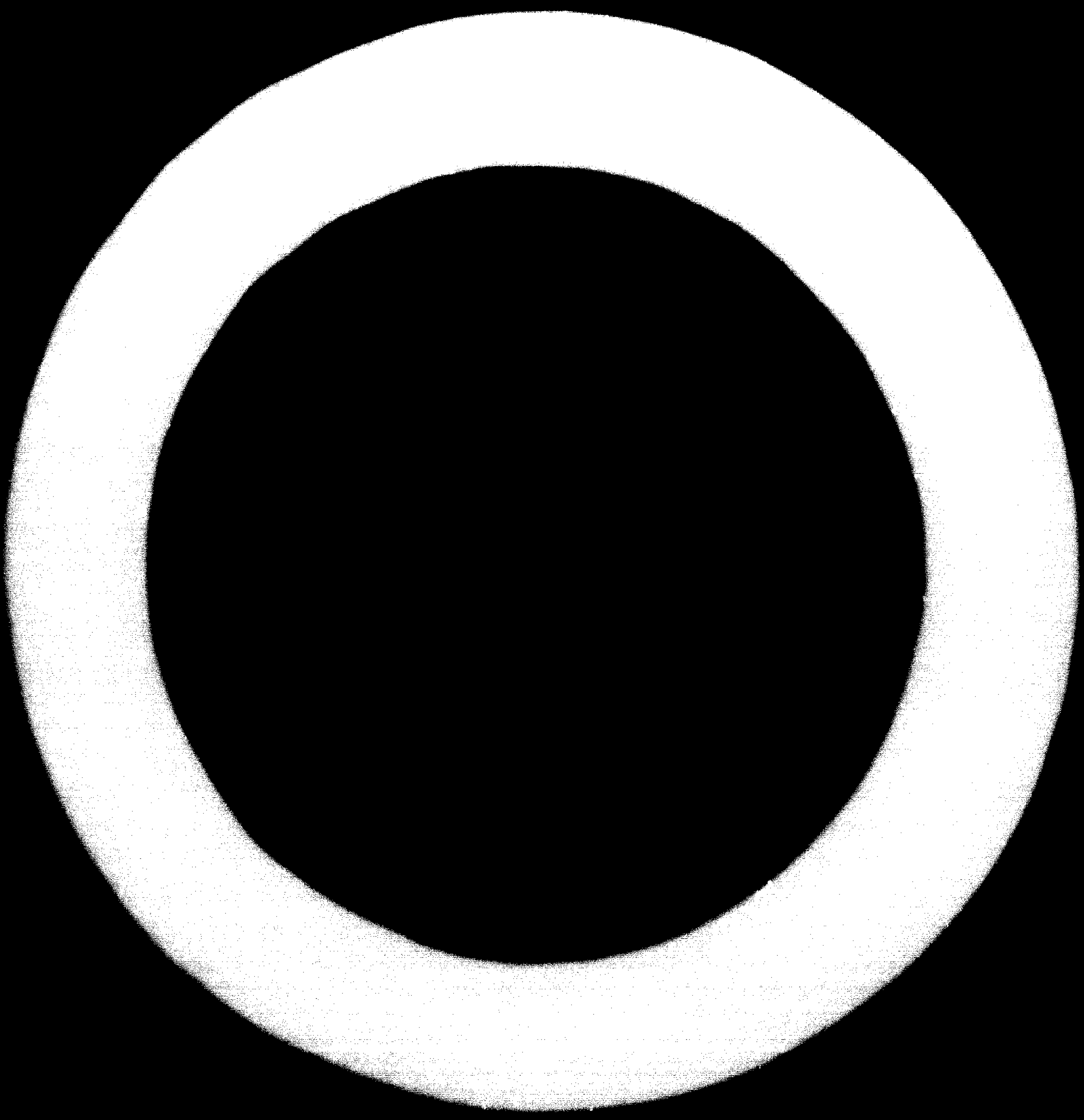
En prenant l'IPT pour exemple, les auteurs de cette communication examinent la contribution d'un institut de recherches techniques au progrès industriel d'un pays en voie de développement.

Dans la première partie de cette étude, les auteurs définissent le rôle d'un centre de recherches industrielles; dans la deuxième, ils font l'historique de l'Instituto de Pesquisas Tecnolcgicas de São Paulo (IPT).

Dans la troisième partie, ils décrivent de manière assez détaillée la collaboration que cet institut a apportée à trois branches de la métallurgie : l'industrie de la fonderie, la production des métaux non ferreux et l'industrie automobile.

Selon le secteur, l'IPT a adopté des méthodes différentes pour l'acquisition et le transfert des connaissances techniques nécessaires. S'agissant de la fonderie, les techniques ont été acquises essentiellement grâce à des voyages d'études aux

1/ Les opinions exprimées dans le présent document sont celles des auteurs et ne reflètent pas nécessairement les vues du Secrétariat de l'ONUDI.



Etats-Unis et leur transfert a été assuré au moyen d'une installation pilote conçue, construite et exploitée par l'Institut. Pour l'affinage des métaux non ferreux, il a fallu trouver des solutions originales en raison des conditions propres au Brésil et la diffusion des processus mis au point a été assurée grâce à des publications et à l'assistance technique de l'IPT. Enfin, l'IPT a fait bénéficier les nouvelles usines de construction d'automobiles de son assistance technique et de ses laboratoires. Cette collaboration a été rendue possible parce que l'Institut avait déjà de l'expérience en matière d'analyse des défaillances techniques.

Enfin, les auteurs décrivent brièvement la situation actuelle de l'institut et ils soulignent combien il importe que les instituts de recherches techniques puissent concurrencer sur le plan des traitements l'industrie dans le recrutement de personnel hautement qualifié.

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S U M M A R Y

The paper presents IPT as a case study of a technological research institute's contribution to industrial development in a developing country.

The first and second parts review, respectively, the roles of an industrial research institute and the historical development of IPT.

In the third part, three cases of IPT collaboration with the metallurgical industrial sector are described in some detail, i.e., collaboration with the foundry industry, non-ferrous extractive industry, and automobile industry.

The mechanisms used by IPT for acquiring competence and transferring know-how in these fields were different. In the foundry technology area know-how was absorbed mainly by study trips to the USA and transferred to the industry by planning, constructing, and operating a pilot plant. For the non-ferrous extractive metallurgy, innovative solutions had to be found due to the peculiarities of our conditions and transferred by the publication of papers and technical assistance. Collaboration with the automobile industry, in the form of technical assistance and laboratory support to the newly installed plants, was possible due to a previously developed competence in the analysis of service failures.

Final remarks are made to illustrate briefly the present situation of IPT and the importance that should be given to the possibility of an institute to compete, in terms of salary, for highly qualified personnel.

1. ROLES OF AN INDUSTRIAL RESEARCH INSTITUTE

The first industrial institute to be installed in an industrially developing area, as was the case of IPT, has to spread its activities on a wide variety of the most diverse cases and problems. For the sake of systematization its activities could be classed into three groups: technical activities, cultural activities, and internal activities.

. The technical activities comprise:

- Tests and analyses
- Supply of standard reference materials
- Supply of special technical instrumentation
- Research on specific problems
- Pilot plant experimentation and production
- Industrial metrology support
- Technical assistance and consulting

. The cultural activities comprehend:

- Training programs for students and young technicians
- Courses of extension and specialization for people in industry
- Cooperation with the technical associations
- Cooperation with the standardization agencies
- Technical publications
- Participation in government technical committees and councils.

. Finally the main internal activities are:

- Training programs for the staff members
- In-house programs for the adaptation of foreign technology and research in selected fields.

The success of an institute will depend on a proper balance among the three groups of activities above which in turn is related with the resources available and the sources of income.

At least in the early years the demand will force the institute to develop an incredible variety of tests and analyses. The research and the technical assistance problems can be restricted to a narrower list of selected fields of competence. The in-house programs should be organized in a manner to broaden the fields of competence for research and technical assistance. The choice of these fields of competence in proper relation with the needs of the local industry is a second must to the success of an industrial research institute.

In IPT the choice of the fields of competence has been in general in accordance with the development of the industrial activities. Because of the importance of the building industry in a developing country, it started very soon with cement and concrete research. In the cement industry, for instance, there was the problem of high magnesia, the limestones in Brazil having a tendency for a higher magnesia content. The techniques for the rational proportioning of concretes and the methods for the choice of the proper aggregates were first developed in Brazil by IPT. From there IPT expanded its fields of research in building materials to heavy ceramics, tiles, cement-asbestos materials, light aggregates, etc. As an outcrop of its preoccupation with various building materials, IPT has developed a ceramic research group which undertook the systematic study of Brazilian clays, assisted in the development of the refractory materials industry and the development of white ceramic products. It has also developed many industrial uses of Brazilian clays as filtering agents in chemical processes or as components in pa per and rubber industry and a steadily expanding its research competence in the general field of nonmetallic minerals. As the buildings were becoming higher and there was a need for more elaborate and bigger public works like dams and roads, IPT has developed a field of competence in soil mechanics and foundations which later diversified in road building, applied geology, rock mechanics, etc.

In the metallurgical field, IPT developed first a capacity for the support of the metal-using industries, because the area of São Paulo had greater interest in the working of metals than it had in extractive metallurgy. A field of competence in metals structure and properties based on a strong metallographic foundation was first developed; later an important development was made to help the foundry industry and only afterwards, because of the demand from other areas of the country, did IPT develop studies on ore treatment and methods of metal extraction.

Examples of specific contributions made by IPT to the industrial development in these three areas of competence will be described later.

In this diversification of fields of competence, one must guard against the danger of spreading too thin the human resources available. There is a sort of a minimum size for the research groups below which it is almost impossible to achieve a steady progress. IPT has suffered in many instances the ill effects of not following this principle.

2. HISTORICAL DEVELOPMENT OF IPT

The historical development of IPT has been described before in publications such as the IPT Boletim nº 34, by Engs. João Luiz Muller and Francisco I. de Araujo Silva, issued in June, 1949 with the title : "Half a century of Technology (1899-1949). More recently Professor David Carneiro Jr. in a paper read at the Institute of Latin American Studies, University of London, on the 24th of February, 1970, under the title : "The development of Technological Progress in Brazil: a case study: IPT's role in adapting, transferring, and creating technology" summarised IPT's historical development.

As early as 1939, when no-one yet seemed to have been conscious of what was to happen to industry in Brazil, Ary Torres, a distinguished Professor and leading entrepreneur, was already saying:

"National industry needs to acquire in every one of its branches a position compatible with consumers' requirements and with the expectations of every Brazilian who wants to see the country ... capable of tackling with its own technicians the intricate problems generated by modern industry." "In our case" (he is referring to IPT) "it is necessary to cover in a few years all sectors of technology, and to supply our entrepreneurs, in a thorough and efficient way, with the technical assistance they may need." "No money is spent, though, which will bear better fruits for Brazil." This was stated in an introduction to an annual report.

One of Brazil's earlier and most important schools of engineering, the Escola Politécnica de São Paulo, was founded in 1894, sponsored by the State Government and financed by it. That is where IPT started.

From the outset the aims of its activities were clearly stated as being to provide younger generations with the scientific and technical skills necessary to guarantee domestic industries so that they would be able to produce what until then had been imported.

Over and above what had by that time already been achieved in local production of textiles, the concern was to establish a long-term policy of industrialisation, based initially on import-substitution and on an awareness of the needs to train people with the necessary skills.

In 1899, the same school, which was particularly concerned with the practical application of scientific knowledge, founded a testing laboratory for construction materials. This laboratory started to function in 1900. Its objectives were purely didactic. To give students the opportunity to carry out experiments on their own and therefore to measure by themselves the mechanical and physical properties of all sorts of engineering products. The school looked for assistance in Europe, mainly Zürich in Switzerland, in Vienna, and in France.

In 1904, as a result of the research work conducted in this sector, the first handbook on physical and mechanical properties of products used in construction was published. It was prepared largely with the cooperation of students who performed most of the tests required.

By 1906 the laboratory had installed with only a few years' lag, perhaps only months, from its availability in Paris, a horizontal microscope specially designed for the analysis of metals. That was one of the earliest steps in steel and metal technology: metallography.

Until 1926 the laboratory had teaching as its main objective. But it also did work for the Government, for railroad companies and for local industries as a by product. Some of the leading industrial entrepreneurs in the country had been to College there and had had their initial training in this laboratory.

In 1925 a recently graduated engineer, Ary Torres, was sent to Zürich to look at what was being done there in the field, and on his return he was able to advise the State Government and the College (Escola Politécnica) on the best procedures to be adopted in the way of modernisation. This is an extremely interesting report because it led to the first important change in the policy until then followed.

It focussed on three points. First, on the need for more routine tests to be continued and expanded to provide local industries with the parameters that were characteristic of their raw materials, and associated with this on the urge for Brazilian Standards based on Brazilian conditions, i.e., natural resources endowments.

Second, it emphasized the need for research to be done for industry. It pointed out that because of the size of local firms they could not maintain their own laboratories so the State had to provide them with the facilities they might require.

Finally, it considered teaching. It is important to note the order in which these points were presented. The importance of research, which no-one would deny and which to this day is so much accentuated, was recognised then, and, even more important, became an adopted policy. Training would be a consequence of the work performed, thus introducing the idea of training in service which is the policy of the institute up to this day.

Among the suggestions presented for the new organisation, some are worth accentuating. Research should be carried on with its own financial resources and with the cooperation of local industries or other public or private institutions. This is very much what some European countries are successfully doing today - they are called cooperative research projects. Another very important suggestion was made: that the entire staff should have good salaries and work full-time. Its financial sources were the State Government, the Municipality of São Paulo, the railways and, for specific projects, local industries.

Until then'1925', the work had been biased in favour of, or exclusively devoted to, the construction industry, but it was obvious that this, as any other particular industry, can be studied in different degrees of detail as regards its inputs and its products. In the former case cement, steel, bricks, sand and gravel, timber, glass, and paints had to be known, as well as its manufacturing processes. In the latter the concern would be with ways of designing bridges, foundations and buildings, and paving roads. The research activities were oriented in these new fields and directions. It goes without saying that because of the nature of its work the Institute was simultaneously taking care of the preparation of specialised labour of the highest qualifications.

Thanks to the special attention devoted to the manufacture of cement, to the quality of cement plants, and to the uses of cement locally produced, the year 1926 represents an important benchmark in Brazil's industrialisation: domestic production was then started with 13,382 tons of output, growing steadily to 167,000 tons in 1931. Today it is about 50 times the output in the first year of production.

The pioneer research in cement technology was done in the U.S. in 1918 by Adams. It was soon adopted by IPT, and in 1927 one of its publications spread its technique and therefore its use throughout the country.

Work on these lines went on until 1934 when the Institute got its present name of IPT. It also turned into an autarchy maintaining close links with the School of Engineering. Research had been started on metals and on timber besides concrete and cement. Its fields of study and research were greatly enlarged. Research was started in several areas of Chemistry, in Metrology (Weights and Measures), Building Structures, Soil Mechanics and Foundations, Industrial Standards, and the production of high-quality plywood and propellers for light aeroplanes and even went into the design, prototype making, and testing of small gliders and planes. Starting in 1914, this challenging field of aeronautics was heavily sponsored by IPT from a technical angle and probably by the State of São Paulo for financial incentives. One company - Companhia Aeronautica Paulista (CAP) - was formed at this time which drew heavily from IPT's and Politécnica graduates for its staff. Several engineers went abroad for specialisation courses in the field. Until 1947 the firm produced about one thousand planes and then stopped production altogether.

Some years later the work in the field was resumed by a new and modern school of engineering in the State of São Paulo entirely controlled and financed by the Federal Government via the Ministry of Aeronautics. Output of aeroplanes is being resumed with their assistance.

Besides this very particular field of modern technology, IPT did pioneer work in several others.

As early as 1939 it was doing research in the techniques of producing soluble coffee. In the early years of the war a patent was registered for rights on the techniques of mixing castor oil with mineral oils for use as lubricant. This was a result of research work conducted in IPT. The technique was adopted and for the duration of the war at least one area in the State of São Paulo made exclusive use of castor oil as a lubricant for its motor vehicles. IPT also did pioneer work in different specialised areas of metallurgy, ferrous and non-ferrous alike. Research and also semi-industrial production in stainless steels, foundry techniques, powder metallurgy, heat treatment, were conducted there. National demand being too small to justify an industrial plant of normal size, the state sponsored industrial production and appropriated corresponding technologies. It also permitted savings in stocks within those firms which needed those inputs.

Its permanent assistance was vital for the motor industry and all sectors of different engineering industries when they went into production in the country. By its initiative the Brazilian Standard Association (ABNT) was formed and several individual industrial standards were first drafted in IPT. It played also a leading role in the creation of the Brazilian Metals Association, the Brazilian Steel Institute, the Brazilian Chemical Association, the Brazilian Portland Cement Association, and others

To sum up, IPT's main activities have been:

First, research in industrial problems at large.

Second, training of technicians in ordinary engineering undergraduate courses, in specially provided courses of intermediate level, and at graduate level.

Third, the provision of technical assistance to local industries and to technological institutions which were started in other states with the same purpose as IPT's. Technicians from several Brazilian states and firms and other countries in Latin America worked there for varying periods, being trained in different industrial techniques.

Finally, it also turned into an important source of entrepreneurial talent, many of São Paulo's leading industrial leaders having done several months or years of training in its laboratories, after graduation or even before.

3. THREE CASES OF IPT CONTRIBUTION IN THE METALLURGICAL FIELD

3.1 Foundry industry

Pig iron production in Brazil in 1930 is estimated as 35.000 t; there were 56 iron foundries in the states of Minas Gerais, Rio de Janeiro, and São Paulo, nine of which used manual molding machines and one produced European malleable iron; the production of steel casts and non-ferrous casts were respectively 1500t and 2100 t.

In the Materials Testing Section of IPT, several samples of cast iron and steel casts were examined and the comparison of the results with foreign specifications showed clearly the deficiency of these products and the urgent need to improve the technical know-how of these foundries. In the cast iron foundries the ignorance of the metallurgy of the processes led to the production of material with poor mechanical properties and with several foundry defects; the only criterium was to obtain a "clean iron" in the general belief that the more pig iron in the charge, the "cleaner" the product. For the steel casts the major problems were connected to the molding materials and heat treatment technologies.

The first efforts to improve the quality of the products were made through the publication of papers based on foreign literature surveys. These efforts, however, were largely inefficient; it was difficult to convince foundry men to follow the advices of the "theoreticians in white overalls of the LEM (Laboratory of Materials Testing)". It was concluded that a direct approach was needed: IPT should produce, in pilot scale, cast iron, steel and non-ferrous casts to show the advantages of a sound knowledge of the metallurgical aspects involved and of modern methods of production and control.

In November 1937, an engineer from IPT was sent for an eleven months trip to the United States to visit the most advanced foundries and metallurgical laboratories in this country. On his return, a project was submited to the Estate Authorities to build in IPT an "Experimental Foundry", a pilot plant equiped with a steel electric furnace, 1 t capacity, a Detroit-type furnace, a cupola furnace, 2 t/h production, complete equipment for the preparation, testing, and recovery of molding sand, molding machines, ovens for cores and cleaning devices.

An implementation plan was prepared in three stages: cast iron, cast steel, and non-ferrous metals. Due to a delay in receiving the necessary funds, the plant was not installed during 1939 as programmed. During this year technical assistance was given to industry with the active participation of IPT engineers in the production of high-resistance cast iron and introduction of quality control methods. In 1940, the budget allowed the construction of the molding materials section, including a laboratory. A systematic program was developed to study the preparation, characterization, production, and recovery of synthetic sand, preparation of core sand, and identification and development of local suppliers of raw materials.

In 1942, the Experimental Foundry was in full production. Brazil's involvement in the Second World War altered the program of work which had to be adapted to an almost industrial scope: imports were restricted, industry could not cope with an increasing demand, and several casts with special production problems were left to IPT.

Until 1949 several problems were tackled and the know-how developed was made available to industry. To give an idea of the contribution made by the Experimental Foundry we can mention the following problems studied:

a. Molding materials - preparation and use of synthetic moulding sand; moisture, granulometry and additives control; characterization of clays; use of corn oil as a substitute for linseed oil in core sand; use of locally produced dextrine.

b. Production of cast pieces, steel and non-ferrous materials:

(i) cast iron - corrosion-resistant type Ni-Resistant; wear-resistant type Ni - hard; with Cr for rolling-mill rolls; wear resistant with high Cr content; with Cr for electrical and high-temperature applications; chilled for high surface hardness; with P for thin walls; high-alloy cast iron such as Ni-Cr and Ni-Cr-Mo for rolling-mill rolls.

(ii) steel - low-carbon carburizing steel; low-alloy steels; die tool steels 10% W, 3% Cr, 0,5% V; free-cutting tool steels type 18-4-1; stainless steel type 18-8.

(iii) non-ferrous metals - Alnico for permanent magnets; Al alloys; bronze; Zn alloys.

(iv) special studies for the production of components difficult to mold or cast, such as: piston rings for internal combustion and diesel engines; heating elements for large furnaces; molds and dies for glass; containers for hydrochloric acid; small components for welding torches, sand pumps, centrifugal pumps, compressors; railway connections; large molds for airplane tyres.

At the same time these studies were developed a large effort was dedicated to training programs for technicians at all levels. For the development of its own staff the Experimental Foundry adopted two criteria: (i) technicians recruited should have no previous experience to avoid the influence of bad practices which prevailed in industry at that time; (ii) learning should be accomplished "in service"; people were taught by doing and not just by learning how it should be done. As mentioned before, this second criterion has been the major guide-line for staff development in IPT ever since.

The results obtained by the Experimental Foundry, demonstrating the advantages of modern methods and equipments, were key factors in promoting the progress of our foundry industry. Several engineers and technicians, trained in IPT, played a major role in modernization plans undertaken by industry or in the elaboration of projects and implementation plans for new foundries. Among these it is worth mentioning the new maintenance foundry of Companhia Siderúrgica Nacional (CSN) and that of the steel foundry of Companhia Brasileira de Material Ferroviário (COBRASMA); the projects for both these new foundries were developed by American consulting firms with technicians from IPT as advisers. The pre-project for COBRASMA was developed by a group with IPT technicians as majority.

3.2 Non-ferrous extractive industry

In many instances non-ferrous extractive metallurgy plants have difficulties in [illegible] extraction processes due to peculiarities of the ores, the limited size of deposits, or to local conditions such as availability of electrical power, fluxes, fuel, etc. It is than necessary to adapt classical processes to the peculiarities of the local conditions or to develop new solutions. IPT had to develop both adaptations and innovations to contribute to the extractive metallurgy, in particular of lead, copper, and nickel.

An initial problem found when considering lead and copper plants of limited capacity, necessary due to the small size of the deposits, is the sintering process. It is necessary to adopt a solution based on intermittent furnaces, requiring lower initial investment and having greater flexibility to receive charges of varying composition in replacement of continous Dwight-Lloyd machines. IPT planned, installed, and operated from 1939 to 1942 a pilot plant for lead and silver in Apiaí in the State of São Paulo, which produced approximately 300 t/month of refined lead. The experience acquired allowed IPT engineers to design, instal, and operate the largest plant with intermitent Mace furnaces in Itapeva, with 20 units and total capacity of 250 t/day. The problems of the quality of the sinter produced and its relation to the operation of the furnaces and simple reductibility tests were solved.

Another basic problem in the operation of shaft furnaces for the production of lead, tin, and copper is the knowledge of the fluidity of slags. This is particularly important in the production of copper from Cu_2O

sinter, in order to maintain the temperature at a minimum to avoid the simultaneous reduction of FeO. The studies made at IPT resulted in the reduction of Cu_2O to produce copper with less than 0,5% Fe and 0,8% Cu in the slag, an excellent result when considering the usual content of iron in the copper obtained by this process, 1 to 3%, and the losses in copper, 3 to 6% in the slag.

The problems related to lead extraction metallurgy, including the recovery of silver, tackled by IPT were particularly complex due to the high impurity content and variable composition of the ores to be processed, which came from mines in the Ribeira de Iguape Valley in the State of São Paulo; some of these ores had high As, Sb, and Ag contents and others had medium Ag and high Cu contents. The several stages of the extraction and refining process were studies and many original solutions found, such as:

a. removal of copper from lead: the process developed reduced S onsumption from 2 to 0,2 kg/t and produced a non-oxidized drosse, which could be treated to produce a matte of high Cu content, a speiss of high Fe and low Pb contents, and Pb of low As and Cu contents.

b. removal of As, Sb, and Sn from lead: by the process developed, lead with 4,3% As could be economically treated.

c. recover of Ag and Zn: the process developed to concentrate the Parker crusts resulted in the absence of oxides which would interfere with subsequent processing, allowing several innovations in the treatment of these crusts to be successfully employed.

The problems of nickel extraction metallurgy are mainly related to the nature of the Brazilian ores; these are silicates of low Ni content and impossible to concentrate. The hydrometallurgical processes depend upon low-cost ammonia, which is incompatible with the location of the mines; pyro-metallurgical processes based on reduction at high temperatures in electric furnaces result in appreciable reduction of iron, dissolution of carbon, and reduction of silicon; the normal product is a nickel pig iron with a maximum of 30% Ni, 2 to 3% C and Si which require a complex refining process. The studies developed in IPT gave interesting results, such as:

a. refining of nickel pig iron in electric furnace containing 2% Si and 3% C to produce iron-nickel of low C and Si contents.

b. direct production of iron-nickel with up to 74,6% Ni and less than 0,1% C and 0,04% Si in electric furnace by appropriate control of the reduction reactions.

c. production of mattes from ores with 4% Co and 2% Ni, using the residue high in FeSi of the processing of coal from Santa Catarina.

3.3 Automobile industry

Before the installation of the automobile industry in Brazil IPT had developed the capability of service failures analysis based on a sound metallographic foundation. Experience was built up through the examination of components brought by Ford, General Motors, and the Technical Police, interested in investigating road ac cidents; information about the behavior in service of components such as axles, transmission systems, gears, springs, etc. under our conditions was thus being accumulated in IPT.

In 1948, for the first time, an attempt was made to produce locally automobile components with a certain degree of concern for quality. Ford tried to produce external shaft with SAE 1045 steel shallow quenched; experiments were being conducted simulteneously in the USA in an effort to substitute alloy steels by carbon steels properly treated to give the right distribution of residual stresses in components submited to bending or torsion. IPT participated in this effort in Brazil, helping to plan the experiments, supervising the execution, and giving laboratory support for the examination of the treated samples. After the initial disappointing results, a solution was found using SAE 1046 steels and adjusting properly the heat-treatment conditions. This procedure is used to this day by Braseixos in São Paulo for the production of external shafts for trucks.

The first two automobile industries to be installed in Brazil were Willys Overland of Brazil to produce the Aero Willys and the Jeep, and Vemag-Auto Union to produce the DKW.

Willys Overland requested IPT collaboration as a laboratory and training center. Willys in the USA had many suppliers with whom Willys do Brasil had no agreements for know-how transfer and thus many problems were found due to a lack of drawings and detailed specifications. IPT studied the fabrication procedures of many components, mainly for the steering and transmission systems. The Metallography Section received samples from different American suppliers and developed an "intelligence" service to establish their mechanical and performance characteristics through a series of tests such as impact, bending, tension, etc.; the samples were then submitted to a metallographical examination to determine the fabrication process. Through this method it was possible to select the best fabrication procedures in terms of quality, reliability, and price, and local production was initiated following these procedures.

By the time Willys was being installed in Brazil it was very difficult to find people trained in laboratory techniques. Practically every engineer and technician hired by Willys for its laboratory, technical assistance to suppliers, or product engineering department was trained in IPT, in programs directed to Willys' needs. Very few general courses were given; training was very specific, accomplished mainly in service, under IPT's supervision and using its laboratories whenever necessary.

IPT also collaborated in the development of local suppliers, since, by that time, there were very few industries capable of producing automobile components with acceptable quality from drawings and specifications. Foreign technical assistance could be used with limited success due to the totally different conditions prevailing in Brazil. One interesting case to illustrate this point was the design of foundry patterns for the Willys foundry. These were made in aluminum with a hard deposition of chromium and worked quite well in the USA. In Brazil these patterns wore out very quickly. A study developed by IPT showed that this was caused by a difference in the morphology of the sand particles which were angular, instead of rounded as in the USA.

The collaboration with Vemag was also in three main areas: the laboratory, the product engineering department, and technical assistance to suppliers.

In many cases the collaboration had to be even more extensive than in the case of Willys. A general lack of detailed specifications was also felt but even in the cases where these were available they refered to DIN standards and hardly any material produced to these standards could be found in Brazil by that time. It was then necessary to develop a systematic study, component by component, starting from the vital ones. Since guaranteeing supply in small quantities was also a problem, it was necessary to develop 5 or 6 possible deviations for each steel composition specified and to study the correct heat treatment and the mechanical properties required to obtain an equivalent or better performance for the locally produced component.

Another problem that had to be faced was that of re-designing the suspension system of the DKW to obtain acceptable performance under the poor conditions of our roads and the common practice of over-loading the vehicle. This problem was not solved by foreign technical assistance and it was necessary for IPT to re-design the suspension system based on its previous experience of failure analysis.

When the others automobile manufacturers came to São Paulo, like Ford, General Motors, Volkswagen, the general situation had changed; qualified suppliers could be found and technical people with experience hired. These manufacturers, however, used IPT for laboratory support and training.

Suppliers could be found which could guarantee a certain level of quality and uniformity in their products, but the new manufacturers had little knowledge of the conditions in Brazil and were reluctant to adopt deviations. IPT had to collaborate with the suppliers to help them meet the more stringent specifications and to develop proper production and control procedures.

The technical assistance given to Vibar for the production of piston rings, cylinder bore liners, and other cast-iron components is an example. The problem of producing high-quality cast-iron pieces in Brazil was aggravated by a lack of homogeneity in the pig iron and, in consequence, a sound knowledge of the metallurgy of cast iron was needed. The liners were made of pearlitic centrifugal-cast iron which demanded a close control to avoid the production of soft pieces or chilled ones which, in turn, would become soft during heat treatment. In the case of piston rings, the main problem was the low elasticity modulus obtained when a large volume of graphitization was permited through the use of a carbon equivalent too high.

The collaboration with the automobile industry produced many indirect benefits. Studies were undertaken which were helpful to the large steel producers, such as the influence of directionality in hot-rolled sheet steel for truck-frame side rails and bumpers, development of a test method to evaluate the fatigue resistance of stub axles based on impact resistance, proper control procedures for cold-rolled deep-drawing sheets.

Of large value to the Brazilian industry in general was also the possibility to transfer the experience gained by IPT in the form of a close collaboration to the Associação Brasileira de Normas Técnicas in the development of standards for alloy steels, malleable cast iron, test methods, etc.

4. FINAL REMARKS

IPT's evolution in more recent years has been marked by an increasing participation of industrial contracts in its earned income. At the present time IPT has 91 of these contracts with industries from several sectors: Wood and Wood Products Industry, Metallurgical Industry, Mechanical Industry, Naval Construction Industry, Ceramics Industry, Rubber Industry, Civil Construction Industry, etc. The evolution of IPT's earned income in recent years reflects this fact:

Year	Earned Income US$	Tests and Analysis % of earned income	Industrial contracts and technical assistance % of earned income
1969	333.200,00	60%	40%
1970	705.000,00	50%	50%
1971	..130.000,00	45%	55%
1972	2.233.000,00	40%	60%
1973 (estim.)	3.340.000,00	30%	70%

Since IPT does not act officially on behalf of the Government, and is not in charge of any official inspection activity, it has no coercive power. Therefore this increasing interaction with industry reflects the acceptability of its work and its value for the industrial community.

The absolute increase in its earned income is also important. From the examples cited in Section 3 one can see that a constant in IPT's contribution has been the supply of trained personnel to industry. In many periods this represented a problem to the Institute due to the large turn-over and the continuing necessity to train new staff, but, in general, it had positive consequences to the industrial development. However, a serious problem may appear when this is a one-way flow process, i.e., when the institute is not able to attract trained people from industry to bring new ideas and experiences, thus suffering the ill effects of "in-breeding".

The partial utilization of its earned income to compete, in terms of salary, for highly qualified professionals is one way to increase the institute's capacity to maintain its vitality and active presence in the industrial environment.

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