METALLURGY AT THE ARGENTINE ATOMIC ENERGY COMMISSION

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Introduction

Argentina is a country full of paradoxes. In saying that it is not suggested that Argentina is richer in paradoxes than other countries, but merely that it has its full quota! Relatively speaking, the country is practically empty, the population being 21,500,000 in an area of more than 4,000,000 square kilometres. In spite of this, land is more expensive in Buenos Aires than in London. The national economy is in very bad shape; unemployment is rising, the foreign debt is of the order of 3,000 million U.S. dollars, and civil servants have not received their salaries for the last two months. Nevertheless, the consumption of beef is the highest in the world, standing at a figure of 190 lb. per person per annum, and Buenos Aires possesses four separate television channels transmitting continuously from 9 a.m. to 1 a.m. every day. On the other hand the shortage of electricity is so great that street lighting is inadequate, shop windows may not be lit until 10 p.m. and breakdowns in the supply of electricity occur almost nightly.

Although it seems practically impossible for the Government to obtain the services of a qualified and independent economist to run the affairs of the Ministry of Economy, the most famous economist in South America is an Argentinian—Dr. R. Prebisch, Director of CEPAL (the United Nations Economic Commission for Latin America). Argentina is very often referred to as an underdeveloped country, but the rate of illiteracy there is lower than, for example, that in Italy. There are 55,000 students in the University of Buenos Aires alone, and there are more book shops in that city than there are in London. The welfare system is quite advanced; to take one example, most people retire at the age of 60 on a monthly allowance payable for the remainder of their lives, at a rate of 82% of their last salary continually adjusted to follow the cost of living index.

It can be realised from this brief discussion that many paradoxes indeed exist. Let us now consider the one which is most directly connected with the subject of this paper. In 1955, the Argentinian metal industry was the most important manufacturing industry in the country, since it had to support the home production of such items as washing machines, refrigerators, cars, motor-scooters, lathes, drilling machines, furnaces, hydraulic presses, tungsten carbide bits, elevators, etc. Academic activities, however, including both research and training, were substantially zero. In 1955, the National Atomic Energy Commission of the Republic of Argentina (CNEA), (i.e., Comision Nacional de Energia Atomica) decided to establish laboratories and pilot plants to carry out basic and applied technological research in metallurgy. As is well known, metallurgy plays a vital role in the production and utilisation of atomic energy—in the words of Sir John Cockcroft "In nuclear reactors, the problems of metallurgy are even more important than those of nuclear physics"—so it seems the decision of the CNEA was correct.

Bearing in mind the paradox which has just been described, that on the one hand there existed a strong metal industry whilst on the other neither did there exist metallurgical research laboratories nor was metallurgy taught systematically at the Universities, the CNEA had to organise its Department of Metallurgy to have the maximum breadth and flexibility. This was necessary in order that it should serve not only as an organisation capable of resolving specific research problems of nuclear metallurgy, but also as a true centre of metal research with the capability of contributing to the development of scientific and technological research in metallurgy, and promoting advanced training in this discipline to aid the furtherance of the Argentinian metal industry.

That was the situation in 1955. At the present time (1963) the academic activity in this field is flourishing. Metallurgy is taught at the Instituto de Fisica Jose A. Balseiro (sponsored by the CNEA) and located in Bariloche, a small town in the lake region about 2,000 km. from Buenos Aires, at the University of La Plata about 60 km. from Buenos Aires, at the University of Buenos Aires (a postgraduate school of metallurgy). New courses are planned at the Catholic University of Córdoba and at the Instituto Tecnologico de Buenos Aires; control laboratories and testing centres are organised in several metal industries and at the Instituto Nacional de Tecnologia Industrial (INTI);

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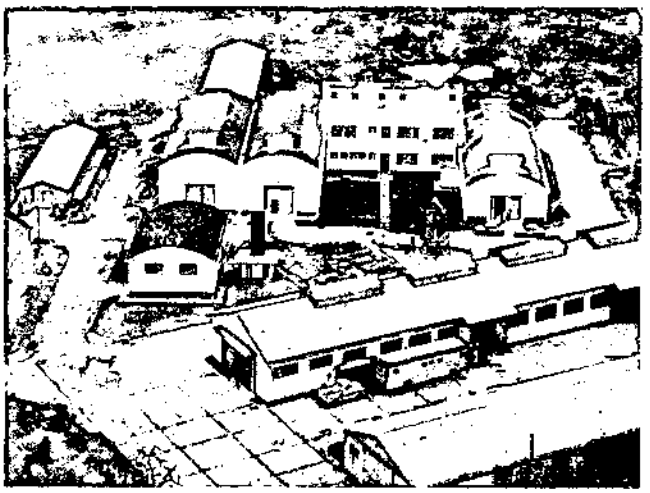
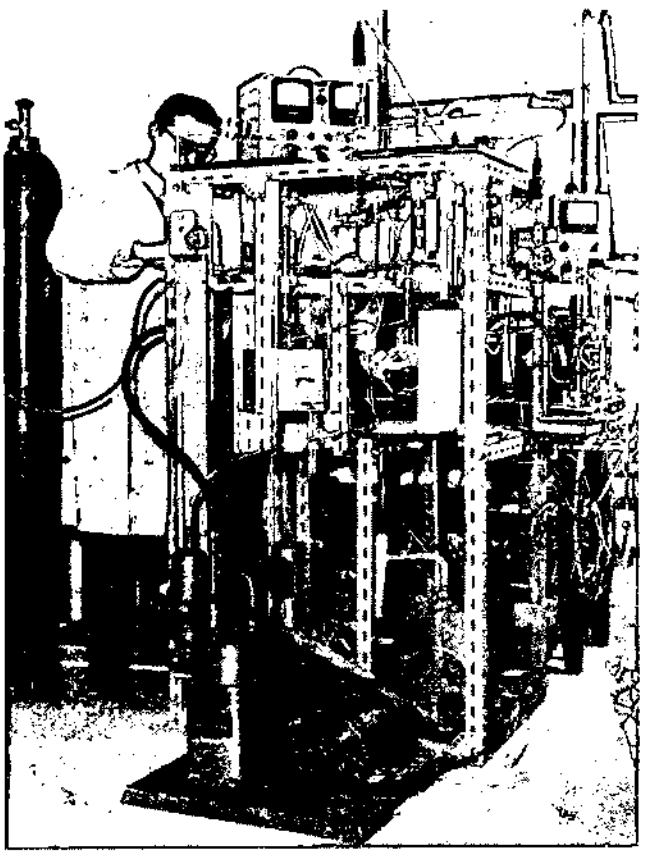


General view of the buildings—Department of Metallurgy, Argentine Atomic Energy Commission, Buenos Aires.

basic and applied research is being carried out at the Instituto de Fisico Balseiro and at the Department of Metallurgy (CNEA). However, a new anomaly is now developing because of the near-paralysis of the metal industry due to the severe political and economic crisis from which Argentina has been suffering recently. These are considerations beyond the scope of the present article, in which the work of the Department of Metallurgy at CNEA is described.



Research on the influence of gases on the mechanical properties of metals. Department of Metallurgy. Argentine Atomic Energy Commission, Buenos Aires.

Department of Metallurgy of CNEA

I. *Organisation*

To achieve its aim the Department of Metallurgy of the CNEA performs the following activities:

1. Studies and research in nuclear metallurgy.
2. Studies and research in general metallurgy.
3. Technical assistance to the Argentine metallurgical industry.
4. Training of staff in metallurgy and related disciplines.
5. Support of research and advanced graduate training in metallurgy in other centres.
6. Holding of courses, seminars and symposia.
7. Exchange of personnel with foreign scientific institutions.

Metallurgical research is accomplished in three principal areas—materials, processes and properties, and including studies of melting and casting, mechanical transformations, diffusion, metallurgical thermodynamics, metallography, welding of metals, alloy theory, design of fuel elements, powder metallurgy, applied physical metallurgy and radiation damage.

These studies are closely associated with one another and, although research is conducted at two levels—basic and applied, differences between them are not established. Actually, the organisation of the Department is very flexible and in practice it brings together all scientists at different levels into a team to work in the solution of a specific problem. This interaction permits the maximum utilisation of available talent at any given moment and the shortest time-lag for the technological application of new advances made in basic metallurgy. Finally, all these groups co-operate with the Servicio de Asistencia Tecnica a la Industria (SATI) which is the intermediary organisation through which the Department of Metallurgy offers direct assistance to the Argentine metallurgical industry.

II. *Personnel*

As already stated, in 1955 there did not exist a single university in Argentina which offered a career in either metallurgical engineering or physical metallurgy. Nor were there specific courses in physical metallurgy or the physical chemistry of metals. Therefore, it was decided at that time, to offer a basic and modern training in physics and the physical chemistry of metals to a selected number of graduates in engineering, chemistry and physics by means of (a) courses given by distinguished foreign visitors, and (b) studies at scientific centres abroad (such as the University of Birmingham, the Max Planck Institute at Stuttgart, the School of Mines in Paris, the Argonne National Laboratory, and so on).

In this way, the core of our staff was trained. The permanent full-time staff of the Department now comprises sixteen professional staff, two advisors, thirty assistants and auxiliary technical personnel, three administrative personnel, and five service personnel.

The training of scientific personnel is continued in the Department of Metallurgy. For this purpose it awards Fellowships and accepts Fellows from other Institutions. University Fellows (postgraduates or research students) carry out work for theses, or undertake advanced training, attend seminars, courses and conferences.

Pre-university Fellows (i.e., secondary school leavers) carry out laboratory exercises, attend special courses, and study foreign languages from the technical point of view. This non-permanent staff comprises twenty-seven university Fellows and eight pre-university Fellows.

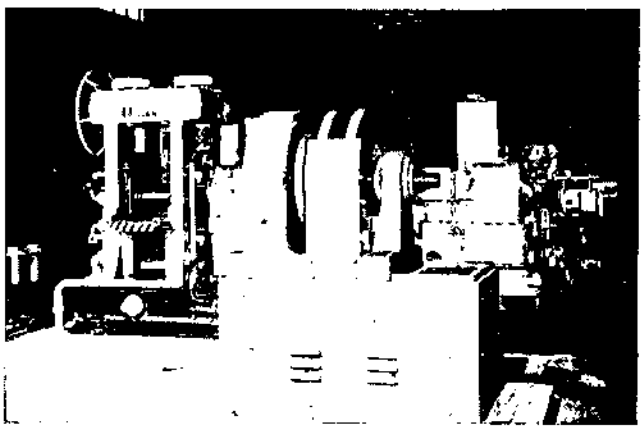
III. *Facilities*

The Headquarters of the Department of Metallurgy of CNEA are housed in a unit of specially constructed buildings which include:

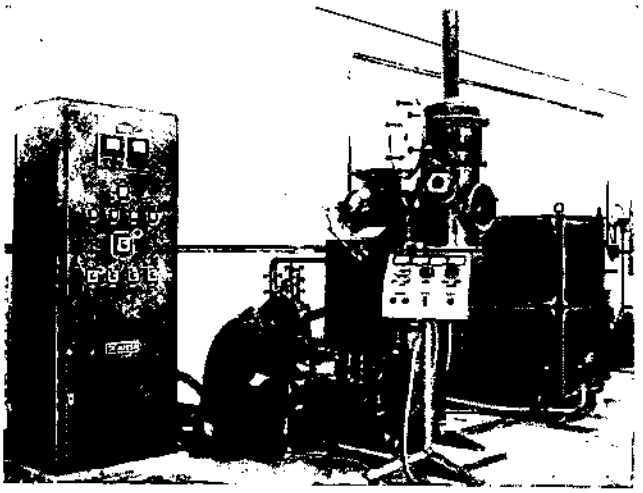
Pilot Plant No. 1. Casting and thermal heat treatment ($250m^2$).
Pilot Plant No. 2. Mechanical deformation ($352m^2$).
Pilot Plant No. 3. Powder Metallurgy ($180m^2$).
Central Building for research (basic) with a floor space of 750m2 (laboratories, classrooms and library).

The money invested in equipment—some of which is unique in Argentina—amounts to $625,000. Items which are of special interest include a high vacuum induction furnace (70 kW); a high vacuum consumable arc electrode furnace (150 kW); an arc furnace with inert atmosphere (15 kW); a high vacuum sintering furnace (2,200°C); a high vacuum thermal treatment furnace (500 litres capacity); a graphite resistance furnace (2,500°C); a double-action vertical press (100 tons); a horizontal press (80 tons); a double-action vertical press (60 tons); a high precision Stanat rolling mill; a Krupp hot rolling mill; and welding equipment, furnaces, milling machines, etc.

The equipment of the laboratories includes a Vickers hardness tester, optical microscopes (Leitz and Reichert), a Chevenard micromachine, a high vacuum dilatometer



Rolling Mill facilities, Department of Metallurgy, Argentine Atomic Energy Commission, Buenos Aires.



Electro consumible arc furnace, Department of Metalllurgy. Argentine Atomic Energy Commission, Buenos Aires.

(Bollenrath), a Cooke microhardness tester, X-ray equipment, radiofrequency furnace and so forth.

Other facilities of the CNEA are available, such as the main workshops (well equipped and manned by well qualified personnel) for manufacturing instruments and machines, the electronic laboratories, and the glass-blowing shop.

Thus the manufacture of special equipment and its modification or adaptation of new experiments is possible. Also, other laboratories of the CNEA co-operate with the Department of Metallurgy in such branches as diffraction and electron microscopy, analytical chemistry, organic chemistry, and optical spectroscopy.

IV. *Training Courses*

Courses given have included metallurgy courses two to three months for university graduates, a shorter course for industrial personnel, and a Pan-American Nuclear Metallurgy Course (March—December, 1962).

In addition shorter internal courses have been held for the training of temporary staff: courses at the Institute of Physics of San Carlos de Bariloche and courses for the School of Metallurgy of the Faculty of Engineering of the University of Buenos Aires.

V. *Foreign Scientists*

Distinguished metallurgists from abroad who have visited the Metallurgy Department of the CNEA to give lectures, conduct research in co-operation with senior members of staff of the laboratories or to supervise research, include: Dr. Robert W. Cahn, University of Birmingham, Dr. Paul Lacombe, Ecole des Mines de Paris, Dr. Erich Gebhardt, Max Planck Institut, Stuttgart, Dr. Frank Foote, Argonne National Laboratory, Dr. Ralph Feder, Frankford Arsenal, Philadelphia, Dr. Clarence Zener, Westinghouse Research Laboratories (U.S.A.), Dr. Robert A. Noland, Argonne National Laboratory, Dr. Gunther Schoeck, Max Planck Institut

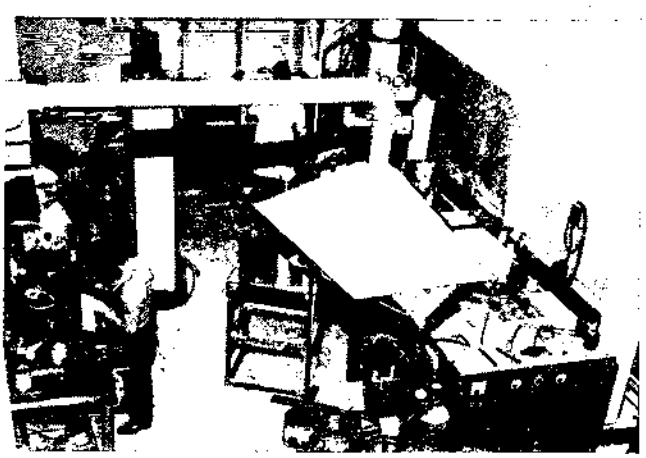
and Westinghouse Research Laboratories (U.S.A.), Dr. Nahum Joel, Centro de Investigaciones y Cristalografia, Universidad de Chile, Dr. J. Wittke, Centro de Investigaciones y Cristalografia, Universidad de Chile, Dr. H. Olliern, Commissariat Français de l'Energie Atomique, Dr. Fred Bolling, Westinghouse Research Laboratories (U.S.A.), Dr. Yves Adda, Centre d'Etudes Nucleaires de Saclay (France), Dr. Cecil Stone, Argonne National Laboratory (U.S.A.), Dr. Oleg Sherby, Stanford University (U.S.A.), Dr. T. Massalski, Mellon Institute (U.S.A.), Dr. A. Goldberg, U.S. Naval Postgraduate School, Dr. J. M. Alexander, Imperial College, London, Dr. Alberto Arantes, Instituto de Pesquisas Tecnológicas (Brazil), Dr. T. Blewitt, Argonne National Laboratory, Dr. L. Correa da Silva, Instituto de Pesquisas Tecnológicas (Brazil), Dr. Victor Kondic, University of Birmingham, Dr. F. Lenel, Rensselaer Polytechnic Institute, Dr. H. Chiswick, Argonne National Laboratory, Dr. J. Salkovitz, Army Research Office (U.S.A.), Dr. D. Milner, University of Birmingham, Dr. R. Oriani, U.S. Steel Research Laboratories, Dr. H. Polakowski, Illinois Institute of Technology, and Dr. J. Wistreich, British Iron and Steel Research Association.

VI. *Contracts and Grants*

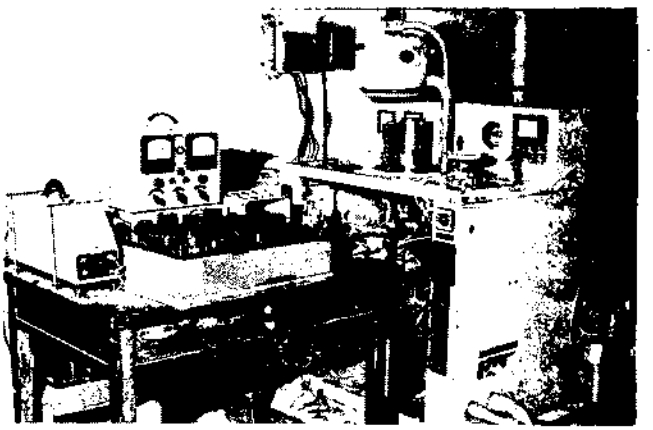
Various research projects have been or are at present being carried out, with the help of grants, or under contracts with the following Institutions, either Argentine or foreign: Consejo Nacional de Investigaciones Cientificas y Técnicas (Argentina); Instituto de Investigaciones de las Fuerzas Armadas (Argentina); Comisión Argentina de Fomento y Ayuda del Desarrollo Economico; Organisation of American States; National Science Foundation (U.S.A.); Army Research Office (U.S.A.); Office of Naval Research (U.S.A.); U.S. Atomic Energy Commission, and the U.S. Agency for International Development.

VII. *Scientific Meetings*

The Department of Metallurgy initiated and undertook a very active part in the organisation of two international scientific meetings.



Some of the facilities for powder metallurgy work at the Department of Metallurgy, Argentine Atomic Enery Commission, Buenos Aires.



Research on point defects in body centre cubic metals at the Department of Metallurgy, Argentine Atomic Energy Commission, Buenos Aires.

(a) *International Colloquium at Bariloche*

As metallurgy is, in the widest sense of the word today, in an 'explosive' state of development, it is very important to assess correctly the exact nature of the relationship between technological practice and its scientific basis.

The purpose of this colloquium was to state a strategy for the conduct of research concerning the relationships between composition, structure, properties and the behaviour of metals, and at the same time to try to evaluate the technological impact on the production and utilisation of metals.

Those taking part in the colloquium included: Dr. William Baldwin, Case Institute of Technology, U.S.A.: Dr. W. Boas, University of Melbourne; Dr. Trevor Broom, Central Electricity Research Laboratory, U.K.; Dr. Joe Burke, General Electric Research Laboratory, U.S.A.; Dr. Robert W. Cahn, University of Birmingham; Dr. L. Correa da Silva, Instituto de Pesquisas Tecnologicas (Brazil); Dr. Bruce Chalmers, Harvard University; Dr. H. M. Finniston, C. A. Parsons & Co. Ltd.; Dr. J. Harwood, Ford Motor Co., U.S.A.; Dr. J. P. Howe, Cornell University; Dr. S. T. Konobeesvski, Academy of Sciences, U.S.S.R.; Dr. I. I. Kornilov, Academy of Sciences, U.S.S.R.; Dr. Werner Köster, Max Planck Institut, Germany; Dr. Robert Maddin, University of Pennsylvania; Dr. A. G. Quarrell, University of Sheffield; Dr. Jorge A. Sabato, CNEA, Argentina; Dr. Cyril S. Smith, Massachusetts Institute of Technology; Dr. A. H. Sully, The British Steel Casting Research Association; and Dr. Morris Tanenbaum, Bell Laboratories, U.S.A.

(b) *Colloquium on Powder Metallurgy*

This was the first colloquium held in Latin America on this topic: it was also the first time that industry had given financial assistance to a colloquium.

More than twelve papers were presented, four of them being by Argentine metallurgists on the staff of the CNEA, the others by specialists from Poland, France,

the U.S.A., Austria, Germany, Sweden, Brazil, Czechoslovakia. This colloquium was attended by experts from Argentina, Chile, Brazil and the following representatives from foreign countries: Dr. Richard Kieffer, University of Vienna, Austria; Dr. Henry H. Hausner, Brooklyn Polytechnic Institute, U.S.A.; Dr. Hans Wolff, Soderfors Bruk and Stora Kopparbergs, Bergslag AB, Sweden: and Eng. Vicente Chiaverini, Instituto de Perquisas Tecnologicas, Brazil.

VIII. *Co-ordination of Research*

The Department of Metallurgy and the Department of Materials Science of Stanford University have agreed to work in co-operation on a research programme in physical metallurgy. The topic of this proposed research programme would be the role of the defect state in crystalline solids on atomic mobility and on other properties controlled by atomic diffusion processes.

There is no doubt that the interchange of ideas by means of the close association of senior scientists and Faculties is of mutual benefit. The duration of the agreement is three years, starting in 1962, and provides for the exchange of personnel.

IX: *Pan-American Nuclear Metallurgy Course*

Fourteen University graduates from different Latin-American countries took part in the Pan-American Nuclear Metallurgy Course, from March to December, 1962. This was a full-time course—the students had to attend all the theoretical and practical classes held in the Laboratories of the Department of Metallurgy from Monday to Friday, for eight hours a day.

The teaching staff consisted of Argentine University professors, foreign professors under special contract and research scientists from the CNEA.

The course was organised by the Department of Metallurgy (CNEA), in collaboration with the Inter-American Nuclear Energy Committee of the O.A.S., the International Atomic Agency (Vienna), the Agency for International Development (U.S.A.), the Instituto Torcuato Di Tella (Argentina), and C.A.F.A.D.E. (Argentina).

X. *Technical Assistance Service to Industry (SATI)*

This is the means by which the Department of Metallurgy, by direct assistance, consultation and research, makes its contribution to the improvement of the Argentine metallurgical industry. SATI was formed in January 1961, with the co-operation of the Asociación de Industria les Metalúrgicos. The Servicio de Asistencia Tecnica is thus able to carry out development of new quality control methods, dissemination of new methods of production and the use of new metals, machines and raw materials, methods for better and more comprehensive access to scientific and technical information, and development of investigations necessitated by the special characteristics of the Argentine market, the nature of the raw materials at the disposal of the Argentine, and the availability of machines, equipment, etc.

The service is thus engaged in the preparation of the radical technological transformation that will occur in the course of the next few years, owing to the important developments that are taking place in the fields of plastic deformation, alloy theory, ceramics, etc.

During its first working year, fifty-four problems were presented to SATI for consideration and study. This figure is interesting—it is an average of one major consultation each week. But it must be pointed out that much is achieved which cannot be expressed by figures—for example, the resultant links which have grown up between SATI and Argentine industries, the professional and personal relationships which have come into being between those engaged in production on the one hand and those engaged in research on the other, the mutual respect and understanding regarding each other's limitations or potential, the appreciation of semantic difficulties in planning the solution of problems, and finally, the realisation that mutual advantage is to be derived from working together.

In order to give an idea of the diversity of the problems presented to SATI some examples are given below:

Setting up an installation for the bright annealing of copper;
Possibility of producing by centrifuge techniques bushings of high lead content;
Electromechanical polishing techniques for stainless steel tableware;
Analysis of steel balls used in cement grinding;
Cracks in steel sections during rolling;
Causes of fermentation tank rupture through the welds;
Testing by gamma-radiography of tank welds;
Tempering of dies;
Production of an "Everdur" type copper alloy.

XI. *Published Papers—Patents*

An (incomplete) list of the papers published by the staff of the Department of Metallurgy is given below:

Journal of the Institute of Metals, *86* (1957-58), pp. 17-23.
Proc. and UN International Conference (Ginebra 1958), 15P/584.
Métaux, Corrosion, Industries, *40*, 1959, p. 137.
American Journal of Physics, Vol. 28, No. 3, 1960, p. 228.
Canadian Journal of Physics, *39*, 1961, pp. 1501-1507.
Proc. 3rd Inter-American Symposum on the Peaceful Application of Nuclear Energy, Rio de Janeiro, 1960, p. 131.
Comptes Rendus, *248*, 1959, pp. 2578-2580.
Memoires Scientifiques, Revue de Metallurgie, LIX, No. 3, 1962.
Ciencia Interamericana, Vol. 3, No. 1, enero-febrero 1962.
Journal of Nuclear Materials, *3*, No. 1 (1961), pp. 115-119.
Comptes Rendus, *240* (1959), pp. 2769-2771.
Acta Metallurgica, 9. Feb. 1961, pp. 138-149.

Transactions AIME, Vol. 218 (1960), pp. 166-176.
J. Nuclear Energy, 7, 1958, pp. 189-198.
Journal of Applied Physics, Vol. 33, No. 1, pp. 242.
Comptes Rendus, *255* (1962) p. 2435-2437.

The following patents are now in hand:
'New method for the production of uranium aluminium alloys from uranium Hexafluoride'.
'Welding of aluminium and alloys with an arc of 10,000 cycles'.
'Continuous sinterization of UO_2'.

The Department of Metallurgy manufactured the fuel elements of the RA-1 reactor, the first to be constructed in Latin-America. The 'know-how' for the construction of these elements was licensed to a German firm.

XII. *Work in Progress*

Below is a list of the research programmes at the Department of Metallurgy, CNEA.

1. *Corrosion of Aluminium and Alloys in High Temperature Water*

Aim: Development of an aluminium alloy with low content of solute resistant to corrosion by water in the range 100° to 350°C.

Projects: (a) Corrosion in water of alloys Al-0,2-0, 5% Ni.
(b) Survey of the segregation of Ni and Al using radioactive tracers.
(c) Substructures produced in Al during solidification.

2. *Metallic Uranium*

Aim: Properties of uranium and methods of fabrication.

Projects: (a) Production of single crystals of uranium by phase transformation and by critical deformation.
(b) Plastic deformation of Sigma phase and beta uranium single crystals.
(c) Sub-structures of metallic uranium and its influence on creep.
(d) Secondary recrystallisation of uranium.
(e) Multiple casting of vacuum melted uranium rods.
(f) Direct transformation of gaseous uranium hexafluoride to metallic uranium.

3. *Fuel Elements*

Aim: Development and/or manufacture of different prototypes.

Projects: (a) Direct production of U-Al alloys from uranium hexafluoride.
(b) Fuel elements for reactor RAEP, MTR type, uranium 90% enriched, Al cladding.
(c) Fuel elements for a sub-critical reactor: natural metallic uranium, aluminium clad.
(d) Fuel elements for a sub-critical reactor: UO_2 pellets, Al clad.
(e) Fuel elements for the RA-1 reactor: enriched uranium, aluminium clad, produced by "swageing".

4. *Uranium Oxide*

Aim: Properties of UO_2 and methods of fabrication.

Projects: (a) UO_2/U cermets.
(b) Production of UO_2 by "swageing".
(c) Sintering characteristics of UO_2.

5. *Graphite*

Aim: Properties of graphite and methods of fabrication.

Projects: (a) Production of high density graphite using Argentine raw materials.

6. *Plastic Deformation*

Aim: Investigation of various processes.

Projects: (a) Deformation by rolling of anisotropic metals.
(b) Co-rolling of Al-Al: Al-Cu: SS-Cu.
(c) Dimensional analysis of extrusion process.
(d) Deformation of Al by explosives.
(e) Relation between the rolling variables, deformation mechanisms and interaction defects.

7. *Dispersion Systems*

Aim: Properties and methods of fabrication.

Projects: (a) Production of SAP plates.
(b) Welding of SAP.

8. *Recrystallisation*

Aim: Study of the recrystallisation mechanisms in relation to deformation produced at different speeds.

Projects: (a) Recrystallisation after impact deformation and explosive deformation.
(b) Cold working sub structures.

9. *Defects*

Aim: Production and annihilation of defects: interaction.

Projects: (a) Point defects in Nb.
(b) Gases in Ta.
(c) Self-diffusion in Ti.
(d) Defects produced by bombardment with neutrons and deuterons.
(e) Internal friction in Hf.

10. *Solidification*

Aim: Mechanisms of solidification.

Projects: (a) Segregation in single crystals of Al-Cu in relation to crystal orientation function.
(b) Linear diffusion and solidification substructures in Al.

11. *Welding*

Aim: Development of new processes.

Projects: (a) Electrolytic welding of fine wires.
(b) Slag welding of Al.
(c) Welding of Al at 10,000 Hz.

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