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LEARNING AND TECHNICAL CHANGE IN THE STEEL PLANT OF ACINDAR S. A. IN ROSARIO, ARGENTINA

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This present study is the first in a series of case-studies on themes of Learning and Technical Change in Latin American Steel Enterprises.

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Preface

Since its start in April, 1975, the IDB-ECLA Program of Research in Science and Technology has been interested to begin research on technological change in the Latin American steel industry. This interest has now taken shape in two specific lines of research, (on which work has proceeded throughout 1976).

The first line of research is concerned with 'Learning and Technical Change in Latin American Steel Firms'. It is planned as a series of related micro-economic case-studies, each of which will be focused on one particular Latin American steel plant. The first of this series of studies was commenced at the end of 1975 and involved the plant of Acindar S.A. in Rosario, Argentina.

Similar studies are being organised in steelplants in Peru, Mexico, Colombia and also Brasil.

In broad terms the objectives in these micro-economic studies can be described as follows: a) to explore the annual rate and different kinds of technical changes that have been introduced in each plant over a substantial period of time; b) to examine the effect that these different varieties of technical change in the plant have had on manufacturing productivity; c) to explore the extent to which technical change has derived from technical efforts internal to the firm as against from licences, technical assistance contracts, etc.; and d) to explore the details of the technological learning process followed by each firm. In summary the principal goal of this first line of research is to generate both new detailed information and new descriptive hypotheses concerning the micro-economic technological behavior of the Latin American steel sector.

The second line of research is concerned with the relationship which exists between the technology in use in leading Latin American steel firms and the technology which represents the universally recognised best practice "frontier".

Research on this theme has begun with a study which the IDB-ECLA Program has commissioned from the Instituto Chileno de Acero (ICHA), directed at answering two basic questions: a) what changes have taken place in the last two decades in the 'state of the art' in steelmaking at the world level, and to what extent have these changes been adopted in Latin America; b) how has the process of technology absorption by the integrated steelworks of Argentina, Brasil, Mexico, Peru, Colombia and Venezuela been proceeding up until now, and how is it likely to proceed between now and 1985, a date for which many firms have already got fairly detailed investment and technology acquisition plans.

In other words the research commissioned from ICHA was aimed at providing a first broad view of the situation in Latin American steelmaking with respect to the universal technological frontier. It should serve as a useful basis both for future comparative studies and also for the development of Technology Policy proposals at the national and intra-regional level.

The present monograph presents the results of the initial study carried out in connection with the first of the two lines of research just mentioned - i.e. on Learning and Technical Change in Latin American Steel Firms.

The monograph deals with the technological experience of the steelplant of Acindar S.A. in Rosario, Argentina. It examines the record of the changes introduced in the plant from 1943, the start-up year of the plant, to 1976.

Chapter I explains the relationship between the Rosario plant and Acindar as a whole. Chapter II introduces the reader to the technology of the Rosario plant and then provides a detailed analysis concerning the nature and rate of the technical changes introduced in the plant, as well as seeking to explain how the observed pattern of technical change developed. Chapter III then takes up the theme of 'learning' and its connection with the generation of technical changes in the plant.

What emerges clearly from the monograph is the fundamental heterogeneity of technical change when it is viewed at the micro-economic level. Unit cost reduction turns out to be only one, and often not the most important, objective for the technical changes made in the Rosario plant. Other major objectives have included increasing production capacity, changing the product-mix, changing the product quality, reacting to changes in raw material inputs etc.

The monograph then seeks to show that this heterogeneous pattern of technical change, and the equally heterogeneous learning efforts that generate it, require the development of a new approach to the study of technical change.

Acknowledgements.

It is a pleasure to express my warm thanks to the Directors and Engineers of Acindar S.A. for their co-operation in making this study possible. In particular I would like to thank Ing. Ricardo Pujals and Ing. Juan Pedro Thibaud for encouraging the study, and Ing. Osvaldo Alsina, Director of Production in the Rosario plant for his support and hospitality during my three visits to the plant.

I also warmly thank Sr. Oscar Amorini and Ing. Luis Fernandez for the many hours they spent with me in explaining the workings of the Rosario plant, and I wish to express my appreciation to Sr. Masoni, Ing. Ramirez, and Ing. Moreira for their help in similar ways, as well as to many other members of the Rosario plant's staff who helped me.

The encouragement of Jorge Katz and Ricardo Cibotti of the IDB/ECLA Program, has been essential throughout the work, and I am greatly indebted to them for this and for many useful discussions.

I would also like to record my thanks to Charles Cooper, of the Science Policy Research Unit, University of Sussex, England, who is supervising me as a Doctoral candidate at the University of Sussex, for his support for my work in Acindar which is destined to form part of my Doctoral thesis submission.

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Buenos Aires, December 1976. Philip Maxwell

LEARNING AND TECHNICAL CHANGE IN THE STEELPLANT OF ACINDAR S. A. IN ROSARIO, ARGENTINA

Introduction

By modern technological standards the Rosario plant of the Argentine steelmaking enterprise Acindar is obsolete. The plant is 33 years old, it uses out-of-date Siemens Martin furnaces for steelmaking, a 26 year old primary mill for billet-rolling, and a semi-automated finishing mill of equally antique origins for the rolling of round bars and profiles. Added to this, the plant suffers an economic handicap owing to its small scale of operations, and has been starved of investment funds throughout most of its existence owing to the priority accorded by Acindar's directors to their two more modern steelmaking plants located 50 km away from Rosario in Villa Constitución.

At first sight the fact that the Rosario plant is obsolete, underscaled and investment-starved would not appear to recommend it as a candidate for an in-depth study concerned with technical change. Indeed one might well expect the study of such a plant to produce only a portrait of technical stagnation. But a closer look at the experience of Rosario plant reveals that a very great deal of technical change has in fact taken place there, and that several features of this rich experience of technical change offer worthwhile opportunities for investigation.

In the first place, the very success of this 'obsolete' plant in finding an economically viable path of technical adaptation over more than three decades raises questions as to the usefulness of the existing concepts of obsolete technology. It suggests that there might be many more possibilities for technically improving and adapting 'old-vintage' technologies than economists writing about technical change have tended to recognize. (1)

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(1) One economist who has recognized the possibilities is Samuel Hollander who states that "Consideration of investments at various plants suggests that relatively small investment expenditures incorporating modifications to existing plants are capable of generating large improvements in efficiency. Such improvements are sometimes sufficient to permit an older plant to produce at

In the second place, the fact that the technical changes introduced in the Rosario plant have been for the most part adaptations, adjustments and minor extensions of the existing installations offers the opportunity for a case-study of 'incremental technological change' in the plant which would aim to answer questions such as: 'What different kinds of incremental technical changes have been introduced?', 'What has been the effect of incremental technical changes on productivity?' 'Is there evidence of a saturation effect whereby the possibilities for incremental innovations run-out unless there are periodic major incorporations of new technology?' and other such questions which have been raised in the literature on incremental innovation. (1)

In the third place it is notable that the technical changes introduced in the Rosario plant have been to a great extent conceived and executed by the plant's own personnel. In other words, the plant has benefited from a considerable degree of endogenous technology creation, and it has not merely relied on exogenous sources of technological improvement such as machinery suppliers, outside engineering consultants, etc. So a study of the record of technical change in the Rosario plant offers the opportunity to explore how these endogenous technology creation activities arose in the first place (whether through learning-by-doing, for example, or through other means) and

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unit costs which are not substantially higher ... than those at a newly constructed plant embodying the latest technology." S. Hollander The Sources of Increased Efficiency. A study of the Du Pont Rayon Plants, M.I.T. University Press, Cambridge, 1966.

(1) Nathan Rosenberg has argued forcefully that "the prevalent conceptualization of technological change and innovation in economics has tended to confine analysis of innovation to characteristics likely to be true only of major innovations. Much of technological change, however, which produces important economic benefits, consists of the cumulation of minor improvements." N.Rosenberg An Assessment of Approaches to the Study of Factors affecting Economic Payoffs from Technological Innovation, Vol. I, Analytical Report and Summary, National Science Foundation, Washington D.C., March 1975.

also to explore how they have developed since. (1)

These three lines of investigation i.e. the questioning of the concept of obsoleteness, the possibility to contribute to the literature on incremental technical change, and the chance to explore the origins and growth of endogenous technical change in a steelplant in an industrially dependent country, were the reasons underlying our project to embark on an in-depth study of technical change in Acindar's Rosario plant, a project which was lucky enough to count on the generous co-operation of Acindar's directors.

The information on which this Monograph is based derives mainly from three visits by the author to Rosario in December 1975, April 1976 and September 1976, during which 10 complete days were spent in the plant. In these visits the activities undertaken were i) to become familiar with the main productive activities and technologies in use in the plant; ii) to interview several senior staff plant on the subject of the types of technical changes introduced and the circumstances surrounding these changes; and iii) to study the so-called 'Plant Reports' which had been prepared annually by the management in the Rosario plant. (These reports contain a good deal of interesting technological and economic information on the performance of the plant during the year in question).

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(1) Kenneth Arrow, in 1962, advanced the hypothesis that "technical change in general can be ascribed to experience, that it is the very activity of production which gives rise to problems for which favourable responses are selected over time". See K. Arrow The Economic Implications of Learning-by-doing, Review of Economic Studies, June 1962. However both Arrow's paper and the large literature which followed it then concentrated attention on proxy measures of learning related to such factors as cumulated output, cumulated elapsed time, etc. In this paper we are concerned to explore empirically what specific kinds of problems have arisen as a result of production activities in the Rosario plant, and what particular responses, involving technical change, have been developed by the plant's personnel to cope with these problems. It should therefore be possible to identify the mechanisms which generated the learning pattern in Rosario plant, and not just the results measured in terms of improved performance.

Besides, making use of information derived from these three plant visits it has also been possible to consult the complete set of Acindar's Annual Reports and Accounts from 1943 to 1974. In addition, the monograph draws on material gathered in taped interviews with two of Acindar's Directors in the company's headquarters in Buenos Aires, as well as on material contained in a recently published paper by the Deputy Director of the Rosario Plant.

CHAPTER I

THE ROSARIO PLANT WITHIN ACINDAR

The enterprise Acindar S.A. was founded on 24th. December 1942. Its first plant was constructed in the city of Rosario and began production in 1943. This plant still exists and continue production in the present day, and it is precisely the technological evolution of this plant which we are interested in exploring in the present study.

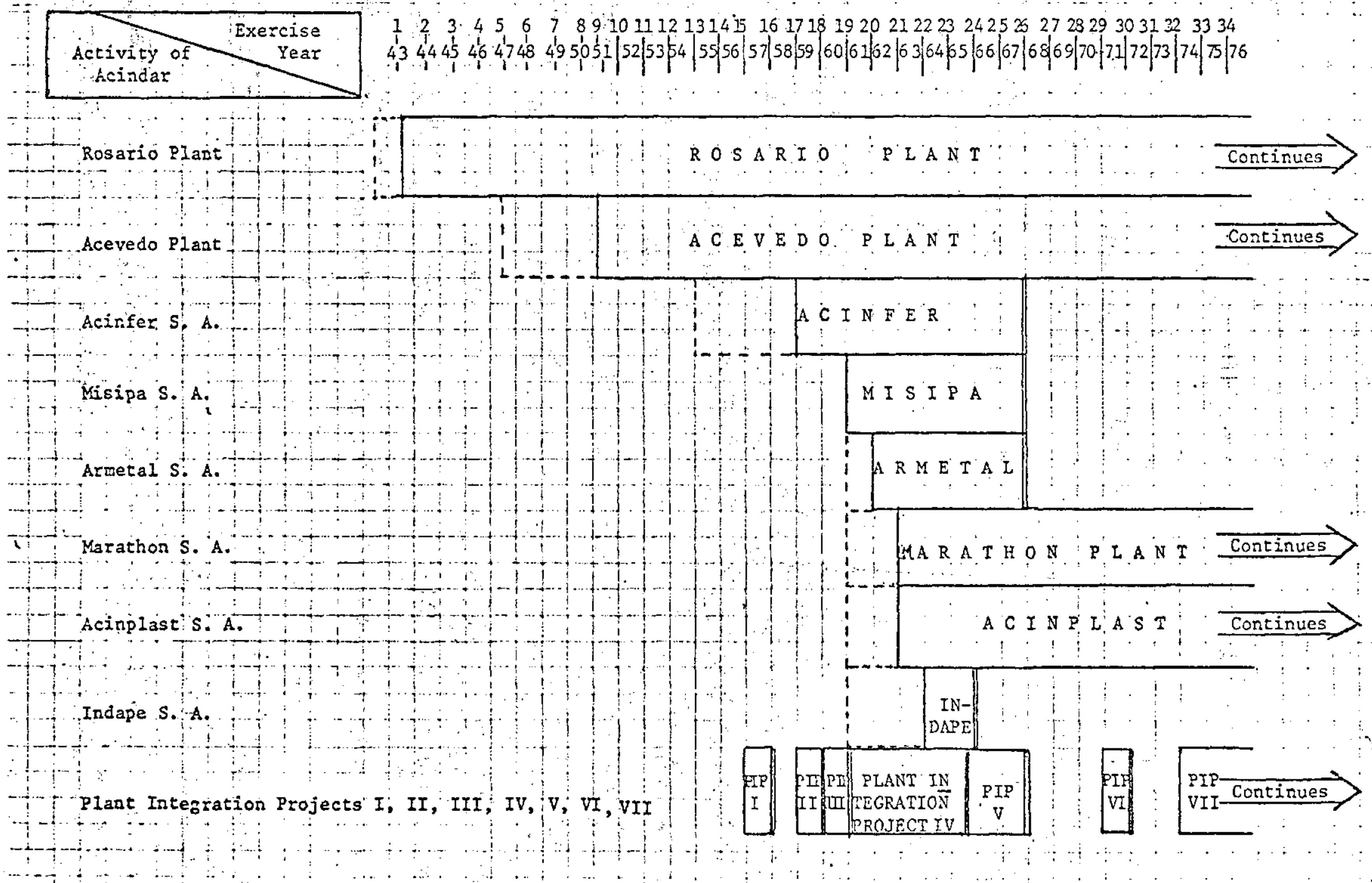
However, the fact that Acindar as an enterprise operates with other plants - and not only with the plant in Rosario - obliges us to consider the evolution of the Rosario plant within the framework of the evolution of the enterprise considered as a whole.

As a first step towards understanding the effect on the Rosario plant of Acindar's other industrial activities it is useful to examine the complete set of the Annual Reports and Accounts produced by Acindar since 1943. The information set out in these reports permits one to establish the chronology - not only of the initiation but also of some of the outstanding events in the succeeding evolution - of all the new plants, projects and affiliated enterprises which Acindar started up or participated in from 1943 onwards. A resume of this chronological information obtained from the Annual Reports is contained in the chart overleaf.

It shows that the Rosario plant evolved as <u>one</u> out of a set of altogether <u>nine</u> industrial ventures engaged in by Acindar.

Of these nine ventures, four can be considered to belong to the classic definition of steel industry activities (i.e. steel-making and steel rolling) and five can be considered as diversifications.

CHRONOLOGICAL TABLE SHOWING THE DATES OF FIRST INVESTMENT, START UP, AND DURATION OF ACINDAR'S INDUSTRIAL VENTURES 1943-1976



Key: Dotted vertical line indicates the approximate date of first investment; single vertical solid line indicates the date of start-up of the plant or activity; double vertical solid lines indicate the termination date of the venture.

The four steel-industry ventures are: i) the Rosario plant itself, which started production in 1943; ii) the Acevedo plant in Villa Constitución which started up in 1951; iii) the Marathon plant in Villa Constitución, which started up in 1962-63, and iv) the Plant Integration Project, which was first launched in the 1950s and is now finally going ahead with the construction of an Integrated Direct Reduction and Electric Steelmaking plant in Villa Constitución, to come on stream in 1976.

The five 'diversification' ventures are i) Acinfer (which made cast components for the auto-industry; ii) Misipa (which was set up to explore the iron-ore deposits of the Sierra Grande); iii) Armetal (which produced stamped pieces and parts for the automotive industry); iv) Acinplast (which produces PVC and Polyethylene Tubes and Pipes); and v) Indape (which made silicon-steel and special steel panels).

It is probably safe in a first approximation to neglect the effects of the 5 diversification ventures on the Rosario plant - except for their combined effect in altering the overall volume of investment funds available to the 4 steelmaking ventures (1).

However, it is certainly not possible to neglect the effects on the Rosario plant of Acindar's other steelmaking ventures.

The Acevedo plant, in particular, has had a dominating influence on practically the entire development of the Rosario plant. Indeed from as early as 1951 when the Acevedo plant first came on stream, the two plants (i.e. the Rosario and Acevedo plants) began to be run in tandem

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(1) This 'first approximation' is based on the short period of time during which three of the five diversification ventures lasted, and on the lack of 'fit' of their production with that of the Rosario plant. In the case of the two longer lasting ventures Acinfer and Acinplast, these have probably had some impact on decisions concerning the Rosario plant but their influence does not compare in importance to the influence of Acindar's steelmaking ventures.

and one can trace an ever earlier relationship in the sense that most of the profits made in the first five years of the Rosario plant's existence were ploughed into the building of the Acevedo plant.

The running of the Rosario and Acevedo plants 'in tandem' has meant that the decisions on the product mix and levels of output in the Rosario plant, and on the investments programmed for the plant have reflected Acindar's assessment of the 'comparative advantages' of production and investment in Rosario vs. in Villa Constitución; and this arrangement (as we shall see in Chapter II) has led to the Rosario plant evolving as a producer of billets for the Acevedo plant. It has also led to a sharing out of the production of commercial rolled products between the two plants - with the Rosario plant having to specialise in product types and dimensions involving small production runs.

The influence of the Marathon plant on the output levels and product-mix of the Rosario plant is of more recent origin (since the Marathon investment only began in 1960-61) and in general this influence seems to have been much less strong than the influence of the Acevedo plant - probably because there has been less opportunity or need for 'complementarity' in the type of products produced by Marathon and the Rosario plants (i.e. there has been less opportunity or need for one plant to produce inputs for the other plant or to reduce output in given lines in favour of the output of the other plant). However this situation may be changing. Exchanges of intermediate products between the plants appear to be increasing during the 1970s and the Marathon plant appears to have been a significant influence in stimulating the production of fine and special steels in the Rosario plant since about 1971. (For more details on this, see Chapter II).

As for the successive Plant Integration Projects, these appear to have influenced the Rosario plant mainly in terms of absorbing scarse investment funds of which fraction might have been used to modernize the Rosario plant. For instance in 1961 there was a project to install continuous-casting facilities in the Rosario plant which was considered very worthwhile, but it did not go ahead because the funds were being held in reserve pending the approval of Plant Integration Project No. III. (1)

The above examples of the effects of the Acevedo plant, the Marathon plant and the Plant Integration Projects on the evolution of production and investment in the Rosario plant suggest that these effects are sufficiently strong that they must inevitably form an integral part of the present study.

Furthermore, the influence of Acindar's other steelmaking ventures on the Rosario plant is not confined simply to effects on production and on investment in Rosario - thus in Chapter II we discuss some of the ways in which the existence of these other plants has affected the organization and the staffing of the Rosario plant. In addition, there have been many occasions when the Rosario plant has benefited from skills, information, ideas, machinery and services drawn free or at low cost from the other steelmaking ventures - i.e. when the Rosario plant has obtained external benefits from Acindar's other steelmaking ventures; and there have also been occasions when the Rosario plant provided external benefits to these other steelmaking ventures.

The combined influence of all these interactions has evidently greatly influenced the pattern, and the economics of technical change in the Rosario plant and means that we shall need to examine all these interactions explicitly if we are to fully explain the record of the Rosario plant in introducing technical change.

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(1) Incidentally, the effect of the new Direct Reduction and Electric Steelmaking Plant due to come on stream in Villa Constitución in 1978 may be dramatic for the Rosario plant because it will lead to a situation in which Acindar as an enterprise will for the first time be able to count on adequat supplies of its own crude steel to feed its rolling mills. This could well lead to the shut-down of the steelmaking section in Rosario.

At the same time, the existance of all these interactive effects raises a question concerning the applicability of the results of the present study. The question is: Does the fact that the Rosario plant has evolved in 'strong interaction' with the other steelmaking ventures of Acindar make the experience of the Rosario plant a 'special case'?

Obviously, if the experience of the Rosario plant really constitutes a 'special case' then the patterns of technical change discovered there might have only limited relevance to other plants based on old-vintage technology. But if, as we suspect, the endogenous generation of technical change in Rosario can not simply be explained on the basis of the peculiar status of the Rosario plant within Acindar, then the experience of the Rosario plant in technology generation may offer a paradigm of wide potential application.

CHAPTER II. THE NATURE AND RATE OF TECHNICAL CHANGE IN THE ROSARIO PLANT

An economist trying to understand the nature of technical change in the Rosario plant soon realises that there is a terrific gap between the way in which technical change is conceived and experienced by the plant's managers, engineers and personnel and the way in which technical change is presented in traditional economic textbooks.

This is inevitable - because the traditional economic analysis of technical change has tended to focus almost exclusively on the effects of changes of technique in reducing the unit costs of 'homogeneous' products produced by 'black-box' processes, and this kind of analysis tends to exclude such matters as product heterogeneity, changes in product mix and the investigation of just what goes on inside the 'black-boxes' (1). Yet in the Rosario plant we are faced by a multi-product plant which has diversified its product-mix several times, in which there have been significant changes in product quality, and in which technical change has been achieved very largely by making modifications to the existing installed 'black-boxes'. Thus, while not rejecting the importance and usefulness of analyzing the behaviour of unit costs in the Rosario plant, there is no doubt that our analysis must go considerably beyond that if we are to fulfill our objective of analysing the overall phenomenon of technical change in in the plant, rather than merely a fraction of it.

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1) The idea that the Economist's terrain does not extend to such matters has been expressed by no lesser an authority than Robert Solow, who once said that "The economist really need not know at all what it feels like to be inside a steel plant... he quantifies technological change by making measurements of output per man-hour, or output per unit of this or input per unit of that". See Solow, R.M. (1965) Education and Economic productivity. In Harris S., and Levensohn A. (Eds.) Education and Public Policy, McCutcheon, Berkeley, California.

To cross this gap which separates the traditional approach of economic analysis from the reality of technical change as it is experienced at the plant level, the logical starting point for our enquiry will be to understand in considerable detail the technology and activities of the Rosario plant itself. In other words to see just what the plant consists of, what products it makes, what processes it uses and how the plant is organised and operated. Hence the first section of this present Chapter is entirely devoted to explaining each of these facets of the Rosario plant which together make up what we might call the 'technological structure' of the plant.

It is then possible, in the second part of the chapter, to trace out some of the main ways in which the plant, its processes and its products have evolved over the whole period from 1943 to 1976. From this we are then able to draw some important conclusions not only about the different kinds of technical changes which were introduced in the plant, but also about the changing rate of introduction of technical changes at different periods in the life of the plant.

Finally, in the third part of the Chapter we try to explain why the pattern of technical change in the Rosario plant has followed the observed path. In particular we demonstrate how many of the technical changes appear to have been clearly provoked by specific exogenous events and demands which impinged on the Rosario plant, whilst other technical changes appear to have arisen essentially in response to persistent and identifiable endogenous pressures.

The unavoidable impression one gains from the evidence presented in this chapter is that the phenomenon of technical change in the plant is more interesting when it is not confined within the traditional economist's box and that the technologist can rightly say to the economist "there are more things, in heaven and earth than are dreamed of in your philosophy". Or, to put matters in a somewhat more cheerful way for the economist, our account suggests that there are several 'dimensions' of technical change in the Rosario plant - which, just like the unit cost-reducing dimension, seem to require economic analysis.[1]

SECTION I

The Rosario Plant, its Technology and Organization

The plant is located on one of the principal avenues leading into the city of Rosario in the Province of Santa Fe, Argentina. It is some miles inland from the river Paraná, yet the plant enjoys good communications both by paved roadway and by its own rail link into the Mitre railway and thus to the national railway grid.

In contrast to the giant integrated steelworks, Somisa, which is located further down the river Paraná in the port of San Nicolás and which makes its steel from the pig-iron resulting from the smelting of iron ore in blast furnaces, the Rosario plant is based on the use of scrap as its principal raw material.

The scrap that the Rosario plant requires is mostly bought by Acindar from outside suppliers and gets delivered to the plant by truck and by rail. However, these external supplies are supplemented by significant quantities of 'internal' scrap which is generated inside the Rosario plant itself as a result of its steelmaking and steel rolling operations.

The activity of the Rosario plant is i) to transform the scrap into steel ingots, ii) to then roll these ingots into intermediate products known as billets, and iii) to go on to roll a fraction of the billets into end products such as steel reinforcing bars, profiles, forging bars, etc. (1) The fact that the plant incorporates both steelmaking and steel-rolling facilities makes it what is called a 'semi-integrated' steel plant, in contrast to 'non-integrated' plants which typically have only rolling facilities installed, and in contrast to 'integrated' iron-ore based plants such

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(1) Ingots are products made by pouring liquid steel into moulds made of foundry-iron, and letting the steel cool down and solidify. Ingots usually are of square or rectangular cross-section and have a 'tapered' shape leading from a wider base-section to a narrowertop-section. Billets are uniform steel bars of square cross-section ranging from 50 x 50 mm to 125 x 125 mm. The other products are described later on.

as Somisa which must incorporate an ore-reduction stage, i.e. blast furnaces or direct reduction facilities (1), prior to their steelmaking units.

The productive sequence carried out in the plant

We shall now briefly describe the sequence of processing steps carried out in the Rosario plant:

To begin with the deliveries of iron and steel scrap get deposited in an immense scrap park, together with the stocks of internal scrap. Here, a series of operations such as cutting-to-size, densifying and classification of the scrap are performed so as to prepare boxes of graded scrap for use in the plant's steelmaking operations.

Next, the scrap is loaded into the plant's Open Hearth (Siemens Martin) furnaces where it is converted by melting and refining into batches of liquid steel. Then when each batch of liquid steel is ready, it is poured out into ingot moulds thus forming the intermediate products known as ingots. With its present technology the Rosario plant produces approximately 140,000 tons of these ingots per year.

In the next stage of transformation these ingots are shaped on the plant's No. I Rolling mill into long steel bars of square or rectangular cross-section known as billets. The plant currently rolls nearly 100% of the ingots it produces into billets, and it also rolls small quantities of other ingots acquired from Acindar's Marathon plant, plus a proportion of already formed blooms and billets which need rerolling.(2) Hence the annual tonnage of billets rolled is currently

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(1) Blast furnaces transform iron ore into liquid pig-iron which is then transferred to steelmaking units which usually consist either of oxygen converters or open-hearth furnaces. Direct reduction units reduce iron-ore to solid pellets of nearly pure iron which are then usually transferred for steelmaking to electric-arc furnaces.

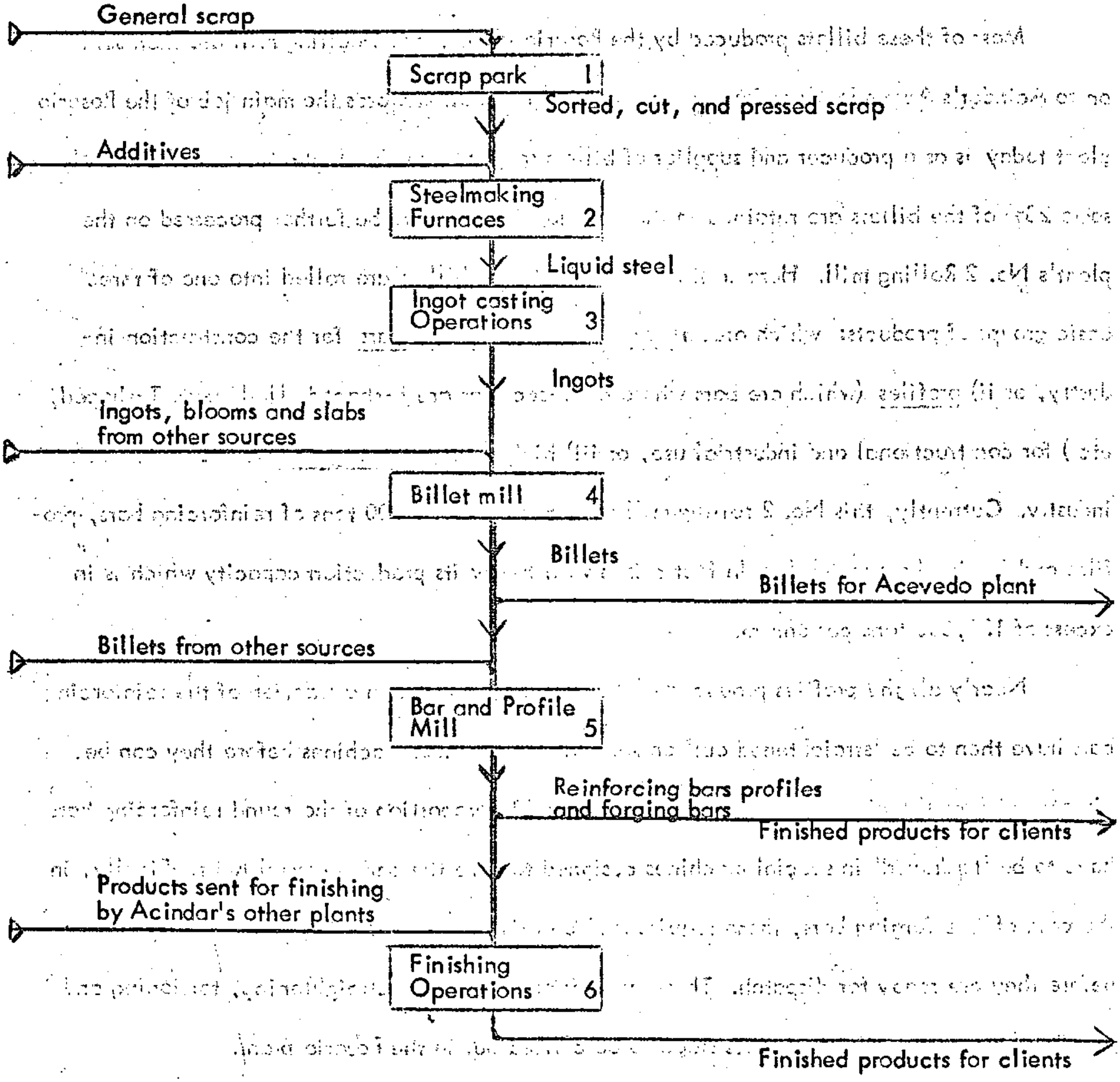
(2) Blooms are large billets, defined as being of square cross-section with sides larger than 125 x 125 mm.

somewhat larger than the tonnage of ingots produced the figure for billet production being around 160,000 tons per annum.

Most of these billets produced by the Rosario plant's No. I Rolling mill are then sent on to Acindar's Acevedo plant for further processing. In other words the main job of the Rosario plant today is as a producer and supplier of billets to the Acevedo plant. However, currently some 20% of the billets are retained in the Rosario plant so as to be further processed on the plant's No. 2 Rolling mill. Here in this second mill, the billets are rolled into one of three basic groups of products: which are, i) round steel reinforcing bars for the construction industry, or ii) profiles (which are bars whose cross-sections are L-shaped, U-shaped, T-shaped, etc.) for constructional and industrial use, or iii) high quality forging bars for the auto-parts industry. Currently, this No. 2 rolling mill produces about 30,000 tons of reinforcing bars, profiles and forging bars annually. In fact this is well below its production capacity which is in excess of 120,000 tons per annum.

Nearly all the profiles produced on the number 2 mill, and a fraction of the reinforcing bars have then to be 'straightened out' on special straightening machines before they can be dispatched from the plant. In addition, an appreciable proportion of the round reinforcing bars have to be 'torsioned' in special machines designed to give the bars an axial twist. Finally, in the case of the forging bars, these require surface grinding and intensive final quality control before they are ready for dispatch. These various operations i.e. straightening, torsioning and grinding, represent the last process stage to be carried out in the Rosario plant.

Schematic Flow Diagram Showing the Principal Inputs and Outputs of Each of the Main Sections of the Rosario Plant



NB. From now on we shall refer to the No. 1 Rolling mill as the 'Billet -mill', and to the No. 2 Rolling mill as the 'Bar and Profile mill'.

This description we have given of the successive main process stages in the Rosario plant is illustrated in the flow diagram. The purpose of the diagram is simply to communicate visually the basic sequence of process stages. (Of course, each of the process stages represented by a 'box' in the flow diagram is in itself a whole technology e.g. the technology of preparing scrap, the technology of producing liquid steel in the Siemens Martin furnaces, the technology of preparing the ingot moulds and casting the ingots, the technology of billet rolling, etc. all of whic we shall shortly describe).

Remarks on the production capacity of the Rosario plant

It will now be useful to say a few words about the production capacity of the Rosario plant. In the first place one can see from the flow diagram that there does not exist any single figure for the production capacity of the plant. What exists, instead, is a set of figures representing the capacity of each stage of production, expressed in terms of the particular output produced by that stage. The annual production capacity figures most frequently referred to are i) the figure for ingot output capacity, ii) the figure for Billet output capacity and iii) the figure for the output of Bars and Profiles which could be obtained given an adequate supply of Billets - and assuming in all three cases that the units are worked on a 3 day shift, 7 days a week. On this basis the present capacity of the Rosario plant can be roughly described as 160,000 tons per year of Ingots, 180,000 tons per year of Billets, and 120,000 tons per year of Bars and Profiles. (This places the Rosario plant clearly in the bracket of 'mini' steel plants i.e. those producing 80,000 to 400,000 tons of steel Ingots and/or rolled products per year. To see the plant in perspective, it is 'mini' compared to Acindar's Acevedo plant (700,000 t.p.y. capacity in rolled products) or to the Argentine State Steelplant, Somisa, (over 2 million t.p.y. capacity in ingots). However, 'mini' steelplants in the Latin American steel industry are extremely significant. Indeed, according to 1974 data, over 26% of Latin American steelmaking capacity is located in 29 integrated and semi-integrated 'mini' plants (1). Furthermore, recent years have witnessed a great upsurge of interest and investment in 'mini plants' all around the world (2). The Rosario plant is, therefore, not a rare curiosity so far as scale is concerned but is one of a large number of functioning small-scale steelplants in the region.

To sum up so far, we have seen that the Rosario plant is a multi-stage steelmaking and steel-rolling plant. It transforms scrap into steel ingots, ingots into billets, and a fraction of these billets into reinforcing bars, profiles and forging bars. The scale of its production identifies the plant as a so called 'mini' steelplant in contrast both to the high tonnage rolling mill plants such as Acindar's Acevedo plant and to the large scale integrated steelworks such as Somisa.

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(1) Out of the 90 integrated and semi-integrated plants functioning in Latin America in 1974, 41 plants had an installed steelmaking capacity above 80,000 t.p.a. and accounted for 93% of the region's steelmaking capacity, whilst the other 49 plants had installed capacities below 80,000 t.p.a. and accounted only for 7% of the region's steelmaking capacity. With regard to the leading 41 plants, 12 of these refer to integrated plants which had installed capacities ranging from 400,000 t.p.a. to 2,500,000 t.p.a. and accounted for 67% of the region's steelmaking capacity. The other 29 plants including 11 integrated and 18 semi-integrated plants - had capacities ranging from 80,000 to 400,000 t.p.a. - i.e. they come into the category of 'mini' plants - and accounted for 26% of the region's steelmaking capacity.
Source: Estructura Técnica y Productiva de la Industria Siderúrgica de América Latina, published by ILAFA as a supplement to the September 1976 issue of the journal 'Siderúrgia Latinoamericana'.

(2) Luigi Danieli, the Italian constructor of 'mini' plants and continuous-casting lines made the following point in a recent article about mini-plants. "In the world of steel an annual production of 250,000 tons, considered quite substantial 50 years ago, is dwarfed by today's concept of the 15 million t.p.a. unit... However, history and economic development does not always follow the script like a movie, but quite often just happens. In the world of steel one such unscripted happening is the emergence of small steel-works units not at all conforming to the prevailing concept of a minimum size of millions of tons - which not only seem to fulfill a very important function under specific circumstances, but also frequently appear to be far more economically successful than their big 'planned brother'. See L. Danieli, Observations on Mini-mills, UNIDO 3rd Interregional Symposium on the Iron and Steel Industry. Brasilia 1973, UNIDO Publication ID/WG 146/85, 25 June 1973.

Our next step will now be to look at the basic process technology employed in the Rosario plant to see how it compares with "best practice" technology and also how it compares with the process technology employed in other Latin American steelplants.

The technology employed in the Rosario plant

As could be expected for a plant installed in 1943, some of the basic technologies employed in the plant are today trailing a long way behind international best-practice technology for the particular scale of output at which the plant operates.

This applies in the first place to the steelmaking process employed in the Rosario plant, which is based on three Siemens Martin (Open-hearth) furnaces whose basic design dates back to 1943. Although these furnaces have been impressively 'upgraded' by means of design improvements and better operating practice, they still cannot produce steel so cheaply as modern electric-arc furnaces of the kind installed in Acindar's Marathon plant. In fact at 1977 prices, the cost-differential per ton of liquid steel was about 10 to 15% in favour of the Marathon electric arc furnaces, (assuming a similar scrap charge to both kinds of furnaces).

This long lag behind best-practice technology also applies in the next two stages of the Rosario plant's operations, which involve the transformation of the liquid steel into solid steel ingots (ingot casting) and then into billets (via the rolling of ingots in the billet mill). This classic two-stage process of producing billets from liquid steel has now been very largely overtaken by the so-called "continuous casting" process whereby billets (or blooms or slabs) are formed directly by pouring liquid steel into the top of a water cooled mould and by withdrawing the solified billet from the bottom of the mould. The advantages of continuous casting are a) that it greatly improves metallic yield and b) that lower capital and operating costs are involved, at least in the tonnage range produced by miniplants and possibly also at higher tonnages as well. Again a comparison with Acindar's Marathon plant, which operates with continuous-casting facilities, is revealing. The transformation costs for converting liquid steel into one ton of continuously cast billets in the Marathon plant are 20% lower than the transformation costs of rolling ingots into one ton of billets in the Rosario plant. There is, however, one important cost advantage scored by the Rosario plant over the Marathon plant. I can make use of a 'dirtier' and therefore cheaper supply of scrap the quantity of which would not permit the fabrication of billets by continuous casting. This factor brings down the cost of Rosario billets very appreciably, but, even so, the final cost of Rosario billets, in 1977 ends up some 13% above the costs of equivalent billets produced in the Marathon plant.

These figures clearly show that the Rosario plant is a high-cost plant in terms of billet production starting from a raw material base of scrap. Indeed, we can say more -for the processes which the plant employs for making billets from scrap are not just less efficient than electric arc-furnaces and continuous casting over the particular scale range at which the Rosario plant operates, and at the particular factor prices prevailing in Argentina - they are actually 'inferior' processes (in the economists sense of the word) over the whole range of factor prices obtaining in Latin America, and for virtually all scales of production (the possible exception being the use of ingot-casting followed by primary rolling (1) at large scales of production e.g. one million tons or more per year. In other words, we are saying that the basic processes employed in the Rosario plant for making steel billets from scrap would not now be selected by any rational Latin American entrepreneur putting up a new mini-plant (2). In this sense the processes are clearly outmoded.

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(1) The term 'primary rolling' refers to the rolling of ingots into billets, blooms, or slabs. Blooms are simply large billets, defined as being of square cross section with sides larger than 125 x 125 mm. Slabs are bars of rectangular cross-section . At large scales of production it is usual for the primary mill to roll blooms or slabs or both. The blooms are then rolled on another mill to produce billets, or in the case of slabs these are then rolled into plates or other flat products. However, the Rosario plant, like many other small-scale plants rolls billets directly from ingots.

(2) The last newly built scrap-based open hearth furnace that we know of was a 45 ton unit installed by Tamet in Argentina in 1968 to replace three smaller Siemens Martin furnaces that the plant had been operating with.

A reflection of this is that out of the 29 'mini-plants' in Latin America in 1974 only 9 were employing open-hearth steel furnaces, compared to 22 with electric-arc furnaces. As for the employment of continuous casting, we do not have accurate figures on the extent to which existing mini-plants have adopted this relatively new technique - however the trend towards adopting continuous casting can be clearly detected from estimates which show that whilst the production capacity of continuous casting installations in all Latin America in 1974 was only 3 million tons, the capacity estimated for such installations by 1980 is 26 million tons (1). The conclusion is, therefore, that both the Siemens Martin furnaces of the Rosario plant and its Ingot-casting plus billet mill combination must be regarded as outmoded. The remaining proce[ss] in the Rosario plant which we must now consider is the Bar and Profile mill.

The Bar and Profile mill installed in the Rosario plant comes into the category of small-tonnage low velocity rolling mills for non-flat products with a basically 'open' layout of its various stands (i.e. rolling units). In these respects it contrasts with the high tonnage, high velocity rolling mills with a continuous layout of the kind installed in Acindar's Acevedo plant for producing wire-rod, bars and steelstrip. (In open layouts, the bar or the other product is only being rolled in one stand at a time, whilst in continuous layouts the stands are all set in lin[e] and the product is sent down the line and gets rolled by several stands simultaneously. The high speed continuous mills unquestionably produce the products at much lower cost if the production runs are long enough. However, for small markets, varied product mixes and consequent short production runs, the low velocity 'open playout' or semi-continuous mills are the economically viable choice. Furthermore, within this general category of low velocity open layout or semi-continuous mills for producing a range of non-flat products, the present Bar and Profile instal-

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(1) information derived from: La Siderurgia Latinoamericana en 1974-75 y Metas a 1980 Published by ILAFA, Santiago de Chile, January 1976, page 10.

lation of the Rosario plant is comparatively fast, automated and sophisticated (1) and cannot be regarded as outmoded (2) even though most of its production capacity is at present unutilized by Acindar due to the comparatively lower costs of producing most of the product range on the continuous rolling mills in the Acevedo plant.

In summary, then, the Rosario plant is operating with outmoded process technology in its steelmaking and billet producing operations but with substantially up-tp-date process technology (for the scale of production involved) in its Bar and Profile mill.

It is however, useful to recall that just because a process or technique is outmoded from the viewpoint of a new plant buyer this does not imply that the technique will be immediately replaced or scrapped by those plants in which the technique is already installed. On the contrary, such plants follow sound economic rationality by retaining the outmoded process for as long as its variable costs do not exceed the total costs (i.e. variable and capital costs) which would apply if the plant switched to some alternative newer technique (3).

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(1) This is partly due to a major modernization carried out recently. The mill's layout was revised in 1971 and at the same time its operations were extensively mechanized and automated thus greatly speeding the mill up. Also, in 1973, the mill was equipped with two new and sophisticated final rolling stands so as to be able to produce small production runs of precisely dimensioned forging bars for the automobile industry.

(2) Once again we are using the word outmoded to apply to processes that no Latin American entrepreneur would now adopt if starting from scratch. A recent article by Jorge Diaz Iramont entitled '<u>Presente y Futuro de la laminación Latinoamericana</u>' published in Siderúrgia Latinoamericana No. 192, April 1976, suggests strongly that rolling facilities similar to the Bar and Profile mill of the Rosario plant, are by no means outmoded yet. See especially page 32 of the article.

(3) As W.E.G. Salter has explained in the context of decision making within the framework of an individual plant -- the replacement of a machine (or a process-stage within a plant) will only appear an interesting investment possibility if the present value of the expected future operating costs of the whole plant with the machine retained is greater than the present value of the expected future operating costs of the whole plant if the machine were replaced plus the present value of the expected capital and installation costs of the new machine. W.E.G.Salter, <u>Productivity and Technical Change</u>, Cambridge University Press, 1960, Chapters IV to VI, especially p.86.

There are, however, two complications which enter into the application of this replacement

What is more, it is clear that a plant which is rationally retaining outmoded techniques in operation will also have a direct economic interest in improving these techniques (e.g. to bring about unit cost reductions, or increased throughput or improved product quality) even though the techniques are outmoded. In other words there is every reason to believe that plant managements will attempt to improve the performance of all the technology which they have installed and are utilizing and this of course includes the outmoded technology. In general one can say that so long as an outmoded technology is not "sufficiently outmoded to be profitably replaced"(I

criterion in the case of the Rosario plant. The first derives from the fact that the appropriate decision-making context for replacement decisions in the Rosario plant is the effect on both the Rosario and the Acevedo plants, since these two plants are closely interlinked. For instance a temporary suspension of steel production in Rosario in order to effect a switch to electric arc steelmaking would almost certainly result in a fall in production in the Acevedo plant thus raising the unit capital costs per ton of the products it produces). This complication can however easily be taken care of simply by considering the Rosario plant as a stage of the overall 'double-plant' formed together with the Acevedo plant, and by then applying the Salter replacement criterion to the 'double-plant'.
The second complication derives from the fact that replacement of one process by another - e.g. Siemens Martin steelmaking by Electric arc steelmaking - may involve not only reductions in operating costs, but also changes of product-quality as well. Indeed in the example cited, this effect is most important, since the more precise control over power input in Electric arc furnaces enables them to make higher quality steels than can Open Hearth furnaces. Hence the considerations which should rationally affect replacement decisions must often go beyond the obviously essential comparison of operating costs and capital costs, to also enter into the realm of product quality changes, their effects on production prices and demand, etc.

(I) This is from W.E.G. Salter op. cit. see footnore page 54: "The term obsolete will be reserved for plants which are sufficiently outmoded to be profitably replaced. Plants embodying techniques which are not up to current best practice but not yet obsolete, are termed "out-moded".

ıen it is not obsolete, and it is perfectly rational to attempt to improve such technology so as to ıcrease the economic contribution which it renders to the plant in which it is installed. Further- ıore, if a technique is just about to become obsolete, or has actually become so, then it is by o means inconceivable that a technical change may give the technology a renewed lease of conomic life, perhaps even a prolonged one.

All these considerations are specially relevant when considering the Rosario plant, be- ;ause the plant's technology as it is today is in large part the result of successive "upgradings" of he originally installed and now clearly outmoded technology of the period 1943 to 1950. Indeed ıne can describe the plant's technological history with some accuracy as a continuous (and so 'ar successful) effort to incorporate changes fast enough to prevent its outmoded technology from ›ecoming obsolete.

This point can be well illustrated with reference to the Steelmaking units of the plant and ılso to the Billet mill. In the case of the Siemens Martin furnaces, these have been modified on ;everal occasions so as to give them "the maximum efficiency possible within the limits of an ›bsolete and compliaated basic scheme". (1) As a result the annual production capacity per Siemens Martin furnace has been raised from approximately 20.000 tons per annum in the early 1940s to over 50,000 tons per annum today with the interesting consequence that the Rosario plant's Siemens Martin furnaces are today clearly superior in terms of annual output capacity to all the comparable furnaces in other Argentine steelplants (see Table overleaf).

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(1) Interview with Ing. Ricardo Pujals, the designer of the Rosario Siemens Martin furnaces, today Acindar's Director of Planning and Development.

Enterprise	Number of S-M furnaces and their capacity in tons per heat (batch) of steel	Total annual steelmaking capacity, tons	Total annual capacity per ton of static furnace capacity
Ohler S.A.	3 furnaces of 21 tons each	50,000	704 tons
Acindar Rosario	3 furnaces of 30 tons each	150,000	1. 667 tons
Santa Rosa	1 furnace of 30 tons 1 furnace of 40 tons	60,000	857 tons
La Cantábrica	4 furnaces of 25 tons	85,000	850 tons
Tamet	1 furnace of 20 t. 1 furnace of 35 t. 1 furnace of 45 t.	100,000	1. 000 tons

Source: Julio J. Montu Tendencias tecnológicas en los programas de expansión de las mini-plantas siderúrgicas en Argentina, ILAFA Congress, Buenos Aires, 1973.

A very similar story applies to the Rosario plant's billet mill. This was originally installed in 1950 with a production capacity of 50,000 tons per year, however this capacity has been raised by successive technical changes so that the Billet mill's capacity today is over 160,000 tons per year. This has been achieved "without any profound variations, simply by improving equipment, channel design, reheating furnaces, etc." and it is also claimed that the Rosario plant's billet mill is today "more productive than some of the more modern primary rolling mills in Argentina which have twice the horsepower of the Rosario Billet mill and involved five to ten times as much investment". (1)

(1) Interview with Sr. Oscar Amorini, Deputy Director of the Rosario plant.

These remarks on the performance of the Steelmaking units add Billet mill of the Rosario plant a) show that although the technologiesemployed in both cases are outmoded, they nevertheless have been greatly improved or 'upgraded' by comparison with their performance when first installed and b) suggest that the resulting performance of these technologies contrasts favourably with comparable technologies in other Argentine steelplants.

We can also recall our earlier observation that the Bar and Profile mill, too, has been extensively 'upgraded' and modernized in the period 1971 to 1973.

Hence it is clear that technical improvements to existing installations have been extremely important at all the central stages of the Rosario plant's technology.

We can now sum up the key points which have emerged from our discussion of the technology employed in the Rosario plant. They are as follows:

1) The Rosario is a semi-integrated 'mini' steelplant which uses outmoded process technologies for making scrap into liquid steel and liquid steel into billets. In contrast it uses reasonably up-to-date technology, in its Bar and Profile mill.

2) However, the use of outmoded technologies does not constitute an industrial 'oddity'. On the contrary, we saw that altogether 9 out of 29 Latin American mini-plants still use Open Hearth steelmaking (four in Argentina) and it can also be deduced from the figures we presented on the diffusion of continuous casting that many Latin American mini-plants must still be employing ingot casting and primary rolling.

3) Economic rationality suggests that plant managements will try to introduce technical changes to improve the performance of all their installed technology, including their outmoded technology unless this is irrecoverably obsolete (i.e. profitable to replace).

4) The brief evidence presented concerning technical changes in the Rosario plant suggests that the plant has indeed undertaken extensive technical changes designed to improve the

capability of its existing units. As a result its Siemens-Martin units are the most productive of their kind in Argentina, its Billet mill is considered to now be a highly productive unit in relation to the investment made in it, and its Bar and Profile mill has been extensively modernized in recent years and is today reasonably up-to-date and sophisticated within the concept of low-tonnage discontinuous rolling mills. Thus, technical change appears to have played an outstanding role in modernizing the basic technologies of the Rosario plant.

A more detailed analysis of the plant's product and process technology

So far, we have restricted our attention to describing the broad features of the Rosario plant's technology and to examining how the main process technologies currently in use in the plant compare both with "best practice" technology and with the process technologies used in other Latin American steelplants.

The step we now take is to examine and discuss the plant's product and process technology in more detail:

We begin by giving a more refined description of the products made in the Rosario plant, in which we draw attention to i) the marked heterogeneity of the intermediate and final products of the plant, and ii) the status of the plant's product mix as a key variable in the plans of the plant's management - and we then discuss some of the implications which this product heterogeneity and product mix variability have for the analysis of technical change in the plant.

Next, we turn to examine the plant's process technology. We first describe in detail the working of each successive process stage in the plant. Then we use this information to discuss some characteristics of the plant's technology which tend to both generate a 'field' of technological challenges for the plant's engineers, and also to limit the progress they can eventually achieve.

The key point is that analysing the plant's product and process technology in detail is essential for understanding the 'micro-environment' in which much of the technical change in the plant takes place.

We now begin with the analysis of the plant's product technology:

Description and analysis of the products produced by the Rosario plant

We have already noted that the Rosario plant produces a range of different products. Thus, we have mentioned ingots (which are intermediate products), billets (which are in their majority end-products from the viewpoint of the plant, and in their minority are intermediate products), and three different classes of end-rolled products (i.e. round reinforcing bars, profiles and forging bars). Our aim now is to explore each of these various classes of products in more detail. We shall begin with the products produced on the Bar and Profile Mill.

In the case of round reinforcing bars, it is important to note that the mill produces several kinds (1). Thus, one part of the production consists of plain round bars, which are then axially twisted, another part consists of round bars with two longitudinal ridges which take up a spiral pattern when the bars are axially twisted, and the remaining part of the production consists of ribbed round bars which, in addition to longitudinal ridges, also have a pattern of transversal or diagonal ribs designed to grip concrete, which emerge from the cylindrical surface of the bar. (NB. see figures below). Some of these ribbed round bars are later twisted, while others are designed for use without twisting. For ease of reference we can refer to these different kinds of bars as 'plain' bars (which are twisted), 'ridged' bars (which are twisted), and 'ribbed' bars

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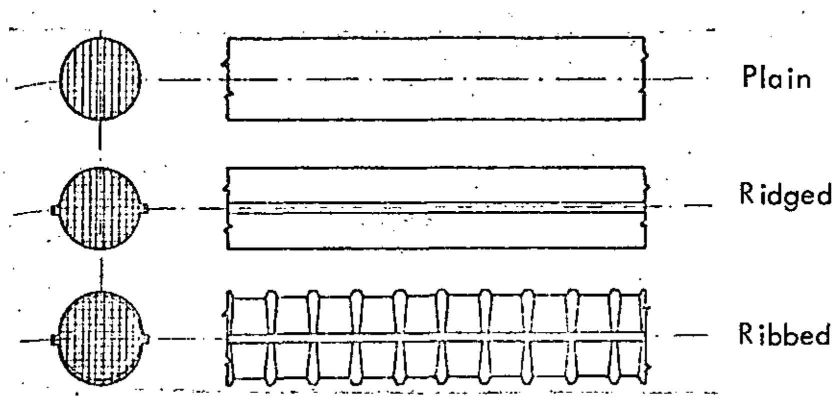
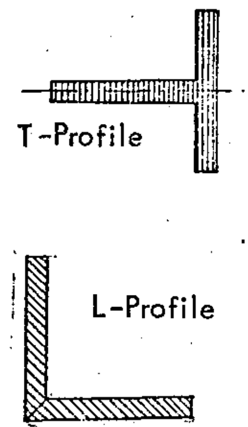
(1) A useful survey of the technology of reinforcing bars can be found in B.S.Krishnamachar Acero para Hormigón armado; Situación actual de su tecnología Revista Latinoamericana de Siderúrgia No. 174, Oct. 1974, (ILAFA, Santiago).

(which may or may not be twisted, depending on the particular rib design involved).

In the case of profiles, the two types most frequently produced on the Bar and Profile mill are 'Angles' and 'L-shapes'. However, the mill can also roll 'T-shapes', 'Double Ts' and 'U-shapes'.



Three types of round steel bars for reinforced concrete



Examples of Profile cross-sectio

With regard to forging bars, the Bar and Profile mill produces both plain round forging bars, and a small quantity of forging billets.

All these various products just mentioned are produced by the Bar and Profile mill in a range of different sizes in accordance with customers' needs. Thus, in the case of reinforcing bars, (of all three types) there are six standard diameter sizes produced on the mill. These are Ø 12 mm, Ø 14 mm, Ø 16 mm, Ø 20 mm, Ø 32 mm, and Ø 40 mm. For angles there are no less that 22 different standard sizes ranging from 15.9 mm x 15.9 mm x 3 mm to 76.2 mm x 76.2 mm x 9.5 mm. In the case of forging bars there are 11 different standard iameter sizes ranging from Ø 15.8 mm to Ø 47.6 mm. (Ø is the symbol for the diameter of cross ection of a round bar).

In addition to this variation in cross-section sizes, each of these products is also produced n a wide range of different standard lengths.

A further extremely important type of variation in all these end products produced by the lar and Profile mill is that they may be manufactured in steel of different grades (i.e. different hemical compositions). The grade of a steel product is determined at the steelmaking stage of perations by controlling the level of elements such as carbon, manganese, sulphur, phosphorus, etc. in the molten metal - and the resulting chemical composition of the steel, i.e. its grade, is then tabilized when the molten steel cools down into ingots, and this grade is maintained when the ingots are rolled into billets, and then when the billets are rolled into round bars, profiles, etc. The importance of the correct choice of steel grade for a product is that different grades of steel exhibit different mechanical and physical properties (1).

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(1) For example, in the case of round reinforcing bars, the tension that a bar can support (i.e. its 'limit of fluency') is positively related to the percentage carbon content in the steel. On the other hand the soldability of reinforcing bars is inversely related to their carbon content. A further most important consideration is the percentage by weight in the steel of impurities, such as sulphur or phosphorus. Too much sulphur, for instance, can result in the formation of non-metallic 'inclusions' which cause internal and superficial cracks to form in the product during rolling. Hence the grade of steel is of decisive importance in determining the performance level of products made of it.

At the present time, most of the profiles and many of the ridged reinforcing bars produced by the Bar and Profile mill are rolled in a grade of steel which involves a carbon content close to 0.17 %. Most of the plain reinforcing bars, however, are rolled in a grade which involves a carbon content of about 0.11 % and a less restrictive limit on the sulphur content and other impurities. The mill also occasionally rolls small quantities of reinforcing bars made of somewhat higher grades of carbon, and in the case of forging bars, the mill rolls these in three groups of different grades - i.e. up to 0.15 % Carbon, above 0.15 % Carbon and Alloy grades.

The Rosario plant today concentrates mainly in producing 'Mild Steel' grades which typically contain 0.10 - 0.24% Carbon. However, the plant has in the past produced significant quantities of higher-carbon grades of steel, e.g. 0.35 - 0.80% Carbon and there have also been short production runs of various different 'Alloy steels' (which are steels containing alloys such as Molybdenum, Tungsten, Vanadium, Chromium, Nickel and Manganese, etc. in proportions above some specified minimum). The point here is that the output of the Bar and Profile mill cannot simply be specified in terms of product type, product size (cross-section) and product length. The output must also be specified in terms of the grades of steel in which the products are produced.

A final set of characteristics which are needed to complete the specification of the output of the Bar and Profile mill may be called the product "quality parameters". The quality parameters refer to matters such as i) the dimensional tolerances of the product. ii) the surface quality of the product, iii) the degree of freedom from internal defects, iv) the straightness of the product, v) the degree of variation permitted in the grade of the product, etc.

For each product produced by the Bar and Profile mill there exists a set of 'Product Norms' which mark the upper and lower boundaries of variation that are permitted. All products which fall within these boundaries are regarded as 'first quality' and are classed and sold as the same product. Products whose specifications fall slightly outside the norms are 'detained' so that a decision can be made as to whether they are saleable as the same product or not, and products which depart substantially from the norms are 'rejected'. In some cases rejection involves the demotion of a product to an inferior specification, in other cases the rejected product gets recycled as scrap.

Thus, to sum up, we have seen that the output of the Bar and Profile mill is heterogeneous n four different ways. First of all the mill produces several different classes of product (defined by eir basic shape and function). These include plain, ridged and ribbed reinforcing bars, angles, .-shapes, T-shapes, double Ts and U-shapes, round forging bars and forging billets. Second, the nill produces each different class of product in a range of different dimensions (defined by cross-ectional sizes and product lengths). Third, the mill produces these products in a range of different teel grades (even though the majority of the present output is in two or three common steel grades). Fourth, the products produced by the mill vary in their quality parameters as between the ipper and lower limits set by the norms.

When we turn to examine the heterogeneity of the outputs produced in the plant's steel-naking operations and in the Billet mill we find a simpler situation because in both cases we are dealing with essentially a single class of output - i.e. ingots in the case of the steelmaking opera-ions and billets in the case of billet mill. Thus, we do not have to deal with multiple classes of output (i.e. different product types) as in the Bar and Profile mill (1). However, the other three

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(1) Actually this statement needs some qualification. In the first place the production of the Billet mill includes not only billets, but also, on occasions, blooms and slabs as well. But since these three types of product differ only in their cross-sectional dimensions, we shall in this paper refer to all three simply as 'billets' and treat them as a single class of output. Secondly, there have been years in which a minority of the output of the Billet mill has consisted of finished products - basically large diameter round bars and heavy profiles. However, this 'minority' output of finished products has never exceeded 20% of Billet mill production, and in recent years has been either zero or a very low percentage of output. Hence to a first approximation it is reasonable to consider the billet mill as producing a single class of output. This class is however heterogeneous with regard to its dimensions, grades and quality. Finally, with regard to the steelmaking section, the Rosario plant sometimes record a small level or production of "other castings" distinct from ingots. However, these do not appear to have ever accounted for more than 5% of the output of the steelmaking section, so we can reasonably consider the output of the section as consisting entirely of ingots.

kinds of product heterogeneity are present. Thus, a given production series of ingots may differ from the next series in terms of i) the grade of steel of which the ingots are to be made. ii) the physical dimensions of the ingots (e.g. cross-section of the base, angle of taper, and height of the ingots) and iii) the quality characteristics of the ingots (i.e. dimensional tolerances, surface qualit and degree of freedom from external scratches and folds, and from internal metallurgical defects)(1

Similar remarks apply to the plant's output of Billets. Thus, i) the grade of steel of the billets produced on the Billet mill depends on the grade of steel of the ingots being rolled (which are mainly ingots of mild-steel grades produced in the Rosario plant, plus a proportion of ingots of high carbon add alloy steel grades produced in Acindar's Marathon plant), ii) the cross-section of the billets depends on the settings of the rolling cylinders on the mill (the most commonly produced billets have cross-sections of 63 x 63 mm, 76 x 76 mm or 100 x 100 mm), iii) the length of the billets, can be varied by controlling the action of the cut-to-length shear (currently billets ar produced in lengths ranging from 2.29 to 3.40 metres), and iv) the quality paramaters of the billets vary according to the quality of the ingots fed into the rolling mill and according to the precision of the rolling process carried out there.

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(1) The characteristics of the ingots to be produced are programmed in relation to the further processing that these ingots will undergo later on so as to produce final products of the required specification. When the specification of the final product is going to be exacting, then this requires a correspondingly high quality of production in the preceeding process stages. One consequence of this is that a fraction of the ingots produced in the Rosario plant need to pass through an additional stage, known as 'conditioning' where defects are detected and where possible removed, whereas the majority of ingots - destined to be rolled into products with less exacting specifications - do not have to pass through the conditioning sector.

In summary the above description reveals the marked heterogeneity of the outputs produced n each of the three main processing stages of the Rosario plant. This heterogeneity has very important onsequences for our present study - because it means that measures of growth, efficiency, and echnical change in the plant cannot simply be referred to improvements in technique related to the roduction of a single homogeneous output. Instead we shall have to apply the analysis of efficiency, erformance, etc. to plant stages which each produce a 'mix' of diferentiated outputs.

A point of clarification is in order here - the Steelmaking furnaces can produce only ne particular grade of steel in each furnace batch, and each of the rolling mills only produces ne particular shape and cross-section of rolled product at any given moment - however if a period f production in the Rosario plant is analysed, such as a month or a whole year, then the output of ny of the three main plant stages will be found to consist of various different products classified y product class, dimensions, steel-grade and quality characteristics. The percentage distribution f the tonnages of the various product categories amongst the overall tonnage of product produced ives the 'product-mix' produced by the stage for the period under analysis.

A most vital feature of the product-mix produced by the Rosario plant is - obviously enough - that it can within limits be varied. Indeed the plant's management explicitly uses its capability o vary the product-mix to cope with such factors as i) changes in demand conditions, ii) changes n the behaviour of Acindar's competitors, iii) shifts in the comparative advantages of producing a articular product in the Rosario versus the Villa Constitución location, iv) technological improve-nents made in the Rosario plant, etc. Thus, the 1976 product mix of the Rosario plant is merely the urrent product-mix being produced by the plnat. This product-mix is in no sense immutable. In act, we shall see later on that the product-mix has changed very substantially over time in all the hree main stages of the plant.

This then poses the question of how to tackle the analytical problems raised by the fact that we are dealing with a plant which produces varying product mixes composed of heterogeneous outputs.

The approach which suggests itself is, first, that we will need to attempt to trace as precisely as possible the way that product mix has in fact varied over the lifetime of the plant; second that we shall need to enquire into the role played by technical changes in producing the observed changes in product mix; and third that we shall need to take account of the consequences which changes in product-mix may have in affecting the performance of the plant in such matters as unit costs, and production capacity (1).

So far as the first element of this approach is concerned, i.e. the tracing of the way product mix has varied, our findings about product heterogeneity suggest that it will be convenient to consider the product mix of each stage in the Rosario plant as being divided into a) the 'basic' product-mix, which refers to the percent distribution of the various classes of output defined in terms of their basic shape and function, b) the 'dimensional' product mix, which refers for each class of product to the percent distribution of the various different sizes in which this product is produced, and c) the steel-grade product mix which refers for each class of product to the percent

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(1) Differences in product mix can have very substantial effects on the tonnage of product that can be produced in any given production shift. For example, if we take the output of the Bar and Profile mill, it can produce 30 tons per hour of product when rolling round reinforcing bars of diameter 25 mm, but only 16 tons per hour when rolling round reinforcing bars of diameter 12 mm. Also to take another example, when this Rolling mill is producing Forging bars, it works slower so as to roll the product to more exacting tolerances. As a result, the tonnage per hour produced is much less than for reinforcing bars. In the case of a forging bar of 25.4 mm diameter the mill rolls only 8.9 tons per hour. Those examples show that the annual production capacity of the Bar and Profile mill, measured in tons of product can vary very substantially as the <u>product-mix</u> produced by the mill varies.

tribution of the various steel grades in which the product is produced. We could also define a uality' mix for each class of product, but for analytical reasons it is preferable to separate anges in product quality from changes in 'product mix'.

By dividing up the concept of product mix in this way, and separating out changes in pro- ict quality from changes in product mix, we now have some simple categories which we can make e of when we come, in the next section of the chapter, to analyse the changes in product mix that ve taken place in the Rosario plant and the extent to which technical changes have been res- nsible for them.

e process technology used in the Rosario plant - How the successive stages operate

The next step in our description of the Rosario plant's technology is to examine in more etail the process technology used in the plant, so as to see in what ways technical change in the ant may be said to be technically 'determined' or otherwise influenced by the nature of the process chinery installed there.

So we now explain the main operations involved in each successive process stage from raw terial to finished product. This inevitably involves a certain amount of technological detail - it we hope the reader will bear with this, since the explanation of the process technology will ot only help to clarify the sense in which the opportunities for technical change in the plant are etermined', but will also give the reader the essential technical information needed to understand e many different kinds of technical changes to which we shall refer in the second section of this apter.

We have endeavoured to keep the technical jargon down to the minimum. Our description llows the order of the principal plant stages noted earlier, i.e. scrap park, steelmaking, ingot-casting, billet mill, bar-and-profile mill and finishing operations and we include at the end a brief resumé of the quality controls which are utilized in each plant stage.

THE SCRAP PARK

To start with, consider the Scrap park. This is a paved area of approximately 240 x 26 metres where scrap is loaded and unloaded from wagons and trucks by cranes fitted with magnetic pick up devices. The park has two zones. The first one is where the stocks of classified scrap are kept and is also the reception area for deliveries of pre-classified scrap. In contrast, the second zone is for scrap that must first be processed or classified prior to being used. Deliveries of mixed or 'assorted' scrap are received in this second zone. The assorted bundles and varieties of scrap are the classified into various standard categories according to origin, density, size, chemical composition, cleanness, etc. (1) Scrap which is oversized is separated from the rest and then cut down to size either on a guillotine machine or by men operating oxy-acetylene cutters. Scrap which is to light for efficient changing to the furnaces is compressed into small dense packets by a specialized power-press. Then, once the scrap has been processed, classified and added to stock, the final job in the scrap-park is to prepare boxes of the different kinds of scrap (2) which will then be directly ready for use in the steelmaking operations.

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(1) The Pan American Standards Commission (COPANT) recognizes 38 distinct varieties of scrap, varying from heavy steel scrap to iron- foundry shavings.

(2) The proportions of the different kinds of scrap which are used as raw material for making each batch of steel depend partly on the cost and quality of the scrap available on the market and from the plant's own operations, and partly on the intended chemical composition of the batch of steel which it is desired to produce. Scrap which contains significant quantities of impurity elements such as Copper, Phosphorus or Tin will prejudice the quality of the steel produced - and so too will scrap which is 'dirty' in the sense of having accumulated various kinds of organic and inorganic residues. It is, therefore, necessary to control carefully the composition of scrap load. For one commonly produced grade of steel in the Rosario plant the load at present used in the furnaces is 32% steel scrap, 11% compressed light metal sheet, 8% briquetted steel shavings, 8% packets of tin-free cans, 6% packets of used cans, and 34% of 'hot metal' made by melting a mixture of steel scrap and compressed packets or cans in foundry furnaces.

STEELMAKING

The objective of the steelmaking stage in the Rosario plant is to convert the scrap into batches of homogeneous liquid steel of exactly the required chemical composition. The composition of melted scrap involves mainly the element Iron, but the scrap also contains a host of other chemical elements such as Carbon, Phosphorus, Silicon, Manganese, Copper, Tin, Chromium, etc. The steel making process must therefore change the chemical composition of the liquid metal, adjusting downwards the proportion of some elements, and upwards the proportion of others, so as to achieve the correct proportions of Carbon, Silicon, Manganese and other elements for the particular 'grade' of steel which it is desired to produce.

The steelmaking units of the Rosario plant consists of three Siemens Martin (Open-hearth) furnaces. The first of these furnaces dates right back to the beginning of the plant in 1943. The second and third of these furnaces were started up in 1949 and 1963. The scrap prepared in the scrap park is fed into these furnaces in two distinct steps. The first step is called 'charging'. Travelling cranes are used to pick up and load the boxes of prepared scrap through special vents directly onto the 'hearth' (i.e. floor) of the furnace. Some 60 separate boxes weighing a total of about 23 tons have to be charged, and this operation takes nearly two hours to complete. About two-thirds of the scrap is 'charged' in this way, together with boxes of limestone. When 'charging' is complete, combustion is started. The furnace flames then sweep over the solid scrap and begin to melt it.

An important aspect of the operations of the scrap-park which deserves comment at this point - is that a very significant proportion of the scrap coming into the park is internal scrap derived from the Rosario plant's own operations. Most of this internal scrap is dense steel scrap derived from rejected ingots, billets or bars, and from the 'ends' of ingots, billets and bars produced in the process of cropping or cutting-to-length. There is also a unit installed in the scrap park to recover steel from the slag produced in the plant's steelmaking operations. The 'recycling' theme is thus of great importance in the economics of the Rosario Plant.

At this point the second loading step is taken, which involves the pouring into the furnace of 12 to 13 tons of 'hot metal' on top of the solid scrap charge. This 'hot metal' constitutes the remaining one-third of the scrap charge to the furnaces. It is made in an auxiliary process by melting scrap together with coke in one of plant's three so-called 'shaft furnaces' (two of which were installed in 1948 and the third in 1960). Once prepared, the hot metal from the shaft-furnaces is then stored in a special ladle until the moment comes for it to be poured into the Siemens Martin furnace on top of the solid scrap thus completing the metallic charge which has to be made into steel.

The next step for the melting of the scrap charge to be completed as a result of the intense heat maintained inside the Siemens Martin furnace. That takes about an hour and a half and leads immediately on to the 'refining' stage whereby high temperature chemical reactions taking place in the metallic bath bring about the chemical transtition to steel of the required composition. (These refinement reactions can be crudely described as: 1) the 'burning out' of carbon by combination with the oxygen in the furnace atmosphere and with the oxygen gas which is blown into the furnace. 2) the reduction of the levels of phosphorus and sulphur via the absorption of these elements into the molten slag which floats on top of the metal, and 3) the adjustment of the final bath of steel to exactly the required composition by means of various additions which usually include anthracite (to adjust upwards the carbon level) and ferrosilicon and ferromanganese alloys to top up the silicon and manganese content to the required levels). The refinement reactions take typically 30-40 minutes to complete in the case of mild steel grades and once the composition of the samples proves satisfactory then the steelmaking process in the furnace is complete. Each Siemens Martin furnace makes approximately 32 tons of liquid steel per 'heat' (i.e. batch) and the whole cycle from the 'charging' of the scrap to the 'tapping' (i.e. pouring out) of the liquid steel takes about five hours to complete.

INGOT. CASTING

In ~~the first step of the ingot casting process three pre-assembled sets of ingot-moulds~~, (two of 12 moulds and one of 14 moulds) are brought on three separate rail wagons into the so-called 'casting bay' next to the Siemens Martin furnaces. Then, as soon as the liquid steel from the Siemens Martin furnace has been 'tapped' into a special ladle, known as the 'teeming ladle', the casting of the ingots begins. A complete 'heat' of steel takes about 35 minutes to pour out from the base of the teeming ladle into the three sets of ingot-moulds where it makes altogether 38 ingots (each weighing approximately 880 kg). These 'sets' of ingot moulds are so designed that the liquid steel only has to be poured down one central channel in each set, in order to fill all the moulds of the set. This is because the 'base' on which the ingot-moulds rest consists of a series of inter-connecting channels surrounded by refractory brick - and as soon as the central channel begins to be filled then each of the ingot moulds simultuneously starts to fill from the bottom with liquid steel.

Once the steel has been poured there then follows a waiting period which varies between 20 minutes for low carbon steels, to 4 hours for high carbon steels during which the ingots cool down. Then comes the 'de-moulding' process. The ingot-moulds are simply lifted up by a crane, leaving the free-standing ingots behind. (These ingots are still glowing red-hot and one can feel the heat from several metres away). The moulds are then dumped into a water tank for washing, cooling down, and painting with molasses (1). As for the free standing ingots - when they have cooled

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(1) The idea of this is to improve the surface quality of the ingots which will be formed in the next casting batch. What happens is that the new load of molten steel in the mould reacts with the dry molasses paint forming a layer of expelled gases between the ingot mould and the steel and driving any slag upwards and towards the centre of the mould. The result is to achieve a smoother and more uniform surface of the ingots produced than would be possible using unpainted ingot moulds.

down sufficiently they are removed either for stock or for quality inspection and 'conditioning'. This leaves behind the sets of mould-bases which are ~~then returned~~ to a special preparation area, where they are repaired and reassembled, prior to having a set prepared of newly ingot-moulds placed on them in readiness for the casting of a new ladle of steel.

THE BILLET MILL

The succeeding section of the plant is, of course, the Billet mill, where the ingots are rolled into billets (plus blooms and slabs). The basic equipment of this section of the plant is as follows: i) first comes a 'reheating furnace' fired by natural gas, through which the ingots travel on a conveyor belt and get heated up to a temperature of 1200° centigrade prior to being rolled. ii) then comes the rolling mill itself which is a 'three high' mill (see fig. 2 below) in which the heated ingots get passed back and forth several times between the rotating cylinders of the mill, thus progressively acquiring the desired cross-sectional shape and size of the billets. iii) then once the long billets emerge from the rolling mill they get cut by a 'motor-driven hot saw' into manageable lengths , and iv) finally comes a 'cooling bed' on which the billets cool down and which incorporates facilities for selecting, classifying and separating billets from each other as required.

The heart of the process is, of course, contained in the action of the rolling mill itself. The basic principle involved in rolling is that solid metal which is to some degree plastic will suffer a deformation when it is passed in between two cylinders or rollers rotating in contrary sense (see fig. 1). The friction which exists between the surface of the cylinder and the surface of the material being rolled causes the material to be gripped or 'bitten' by the cylinders and thus forced to pass in between them thereby being squeezed, widened, and above all lengthened in

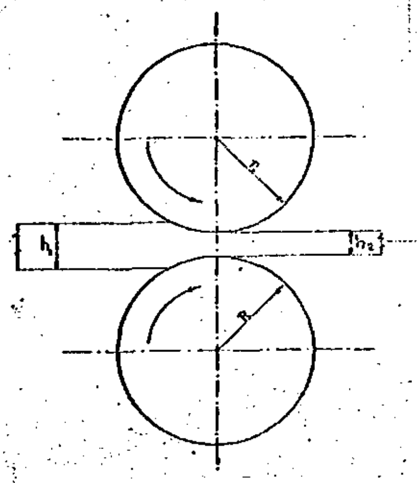

Fig. 1

The basic technique involved in rolling (1)

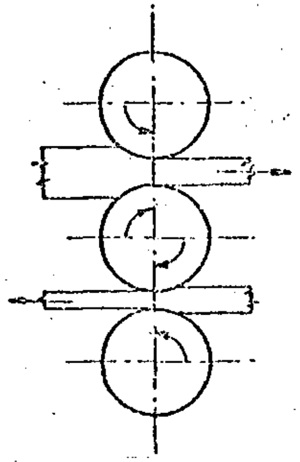

Fig. 2

Schematic diagram of the action of a '3 - High' mill (1)

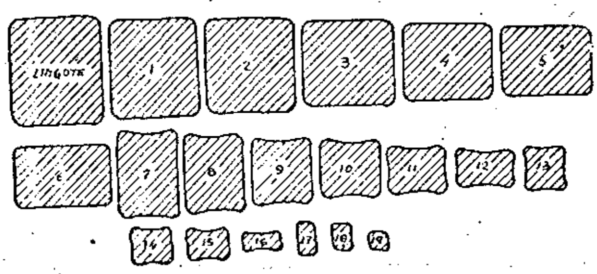

Fig. 3

Example of the progressive reduction in cross section achieved in rolling billets from ingots, in this case in 19 'passes' (2)

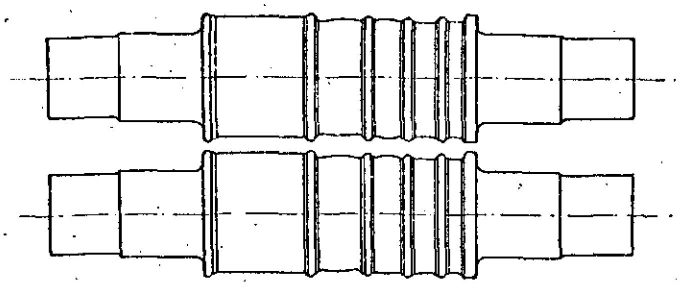

Fig. 4

Diagram of two rolling cylinders, showing the distinct channels for successive 'passes' (2)

(1) Source: Roberto A. Villanueva Las Tecnologías de Producción de Laminados, in report 'Posibilidades de instalación de plantas siderúrgicas en paises de menor grado de desarrollo relativo de América Latina' published by ILAFA, 1970.

(2) Source of description and diagrams Roberto A. Villanueva op.cit.

the process. The rolling mill which produces Billets in the Rosario plant is called a 'Three high mill because it has three rolling cylinders in line and thus permits successive 'passes' (of the produ being rolled) to take place alternatively between the top two cylinders add then the bottom two cylinders (see fig. 2). In practice the making of a billet may require from 9 to 15 passes through these rolling cylinders depending on the cross-sectional size of the billet being produced and this results in a progressive reduction in cross-sectional area of the sort shown in fig. 3, whi is accomplished by making the passes in the various successive 'channels' (1) of the rolling cylinders as the cross-sectional size gets progressively reduced (see fig. 4).

THE BAR AND PROFILE MILL

The next stage in the Rosario plant is the Bar and Profile mill, where billets are transformed into reinforcing bars, profiles and forging bars. The first step involves the heating of the billets in a billet reheating furnace. From this furnace the hot billets are then fed to the first set of rolling units which consist of a "double three-high" rolling mill (see fig. 5) in which the first five 'passes' of the bar are made. From there, the bar is then sent on to the so-called 'intermediate' rolling units of which there are three. The bar either makes a single pass through each intermediate mill in turn (see fig. 6/I), or when heavy profiles, or forging bars are being produced, then the first mill is used as a trio, and the third mill is not used (see fig. 6/II).

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(1) The adequate design of the shape of the channels is skilled work. The cylinders themselves are made of found steel, and ordered from specialist producers, who make the cylinders in accordance to customer's design. To change from one billet size to another involves a change of cylinders on the rolling mill, and involves a certain amount of down-time during which no rolling can take place. The maintenance and regrinding of the rolling cylinders is carried out in a specialist unit inside the plant.

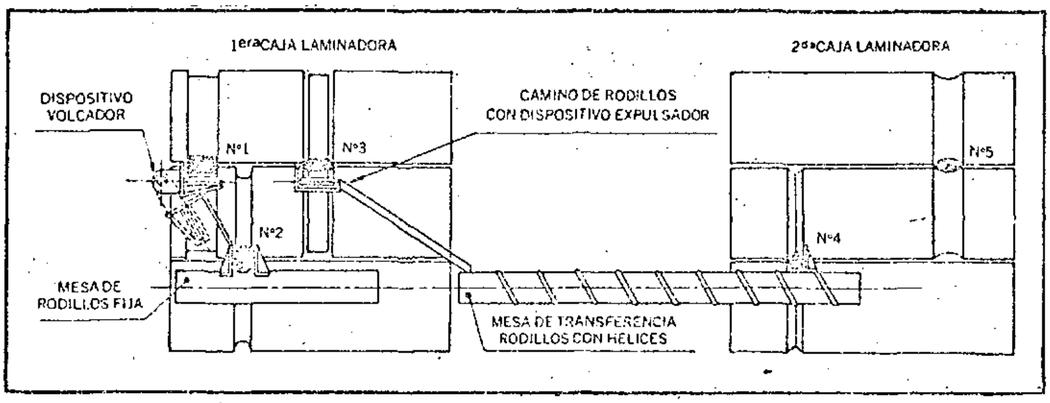
1era CAJA LAMINADORA
2da CAJA LAMINADORA
DISPOSITIVO VOLCADOR
CAMINO DE RODILLOS CON DISPOSITIVO EXPULSADOR
N°1
N°3
N°2
N°4
N°5
MESA DE RODILLOS FIJA
MESA DE TRANSFERENCIA RODILLOS CON HELICES

Fig. 5

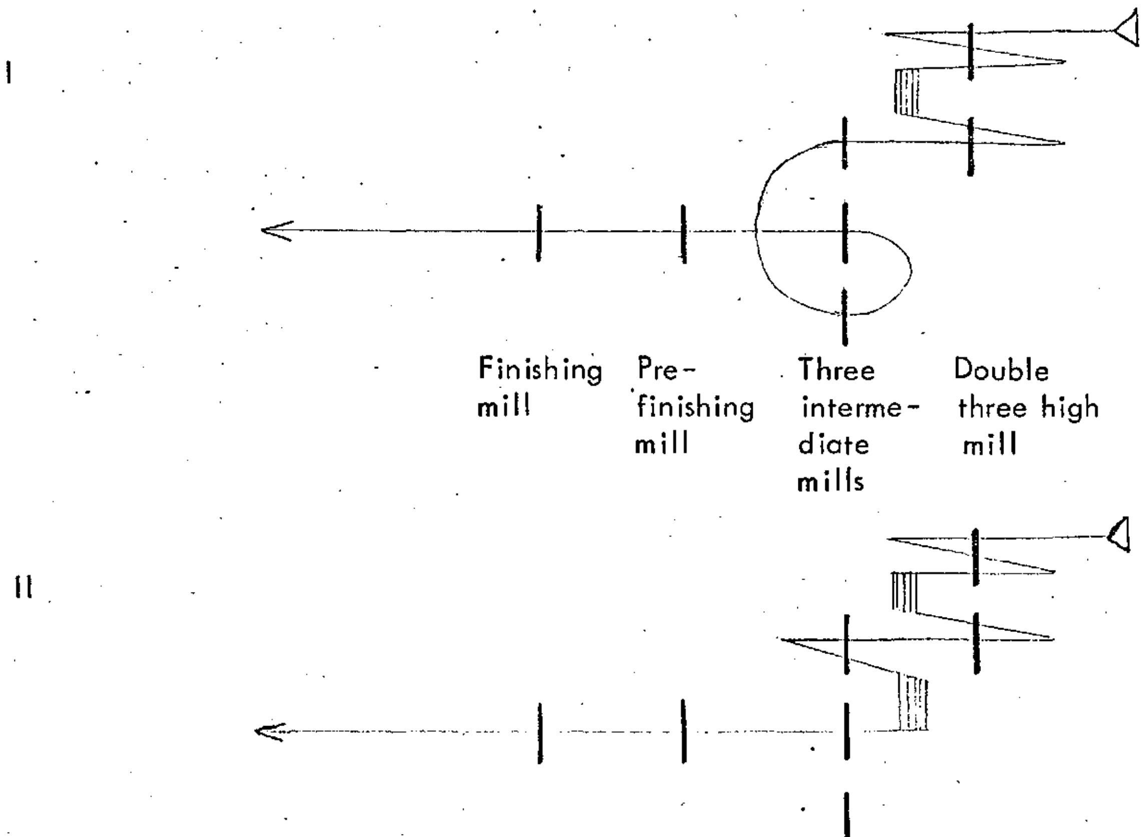
I
II
Finishing mill
Pre-finishing mill
Three interme-diate mills
Double three high mill

Fig. 6

Finally the bars may be sent (depending on the final product) to pass through one or both of the so-called finishing mill units. These are called the 'Prefinishing' and 'Finishing' mill units, and are also shown in Fig. 6.

It can be seen how - in contrast to the Billet mill in which the product passes back and forth several times in the same mill unit - the products produced by the Bar and Profile mill have been formed by up to seven separate mill units (or 'stands' as they are called in the jargon). Once the products, i.e. reinforcing bars, L-shapes, forging bars, etc. emerge from their final 'pass' (which is often but not in all cases through the final mill 'stand'), then they are cut to length by a hot-saw, and transported on rollers onto a special cooling bed where they can then be separated and classified as required.

FINISHING OPERATIONS

The final processing carried out in the Rosario plant is not a discrete processing stage so much as a set of distinct finishing operations. Some of the bars take up a curvature on cooling, and all the profiles do - therefore, these particular products must first be straightened out before th can be sold - an operation which is carried out on special 'straightening' machines. Next, a fraction of the reinforcing bars have to be 'torsioned', i.e. given an axial twist on a bar-twisting machine, before being sent for dispatch. Then, in the case of forging bars, when these have emerged from the Bar and Profile mill, they have to be sent to a special 'conditioning sector' where they are subjected to intensive quality control (see section below).

It is also worth mentioninq that all the various classes of products, once their processing is complete, get tied up into bundles, labelled, and then sent to be weighed in the balance prior t sending on to the section responsible for despatch.

Finally we will mention an aspect of the plant's operation which is common to all of the process stages discussed so far i.e. quality controls. These controls operate in each stage of the plant because defects in the intermediate product at any stage will automatically prejudice roduction in the next succeeding stage. Hence we find in the plant that there are inspectors who check the quality of the samples of the raw material delivered in the scrap-park; that the teelmaking section has its own laboratory for analysing the samples of steel in the Siemens Martin urnaces; that there is a Central Laboratory for assisting the Steelmaking section and for carrying out destructive and non-destructive tests on the plant's products; that there are Inspectors in the Billet mill, and in the Bar and Profile mill who check that the production is meeting the noms as regards dimensions and surface quality etc.; that there is a 'conditioning' sector in the plant where some of the ingots and billets are sent to have their defects detected and removed; and that there is a further 'conditioning' sector in the plant especially for forging bars where these bars come at each intermediate stage of their production (e.g. as blooms, as billets and as bars) for the detection and removal of defects by grinding and for the checking of their dimensional tolerances. All these various quality controls must be considered as an integral part of the process technology of the Rosario plant.

Technological challenges and limits set by the plant's process technology

This completes our initial outline of the process technology of the main stages of production in the Rosario plant. Inevitably the account has been schematic, and many important aspects of the plant's operations have, in the interests of brevity, been left out. However, enough has been said about the processing technology to now comment on several key characteristics of the production process in the Rosario plant which tend to generate and define a 'field' of technical challenges for the plant's engineers and work force.

In the first place we have seen that the process technology of the Rosario plant is multi-stage. This automatically generates the challenges of a) overcoming bottlenecks when the plant gr and b) striving to make use of the surplus capacity which will practically always exist in one or more of the plant stages. (1) We would, therefore, expect at least some of the technical changes in the Rosario plant to arise in response to the bottleneck - surplus capacity theme arising from the plant's multi-stage nature.

Secondly it can be seen from an account that each of the various stages of operation of the plant involves sequences of operations with specific cycle-times. In particular the long cycle time from the charging of the Siemens Martin furnaces to the 'tapping' of the liquid steel stands out as one of the determining cycles in the operation of the plant. It can therefore be predicted that the speeding up of the 'cycle time' for steelmaking will have been a major challenge in the co of the plant's development - and one would also expect attention to have been paid to speeding up of the cycle times needed for rolling both billets and the distinct end-products produced in the Bar and Profile mill.

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(1) A good example of this is afforded by the situation of the Rosario plant today (1976). Thus, at the present time, the plant is producing at approximately 90% of its ingot capacity, 90% of its billet capacity, but at only 25% of its Bar and Profile capacity. This is a clear example of one stage of production being 'out-of-balance' with the others - and the example is by no means a 'freak' situation since both surplus-capacity and bottleneck situations have arisen repeatedly throughout the life of the plant with varying degrees of severity in all the different stages of the plant.

The interest of this 'out-of-balance' theme for the present study is that when surplus capacity exists in a particular plant stage, or when production is being limited by a bottleneck, this can act as a powerful incentive for the execution of technical changes designed to exploit the surplus resources or to remove the bottleneck which is holding back production. The questio we shall need to explore, therefore, is the role played by this kind of incentive in causing technological change in the Rosario plant.

Thirdly it can be seen from our account that there is an intense movement of raw materials, mmediate products and end products involved in the production process in the Rosario plant. Trucks, cranes, and wagons transport the materials and products from stage to stage, while conveyor belts, cranes and rolling cylinders, move or propel the intermediate products within each stage. In fact ome 500.000 tons of materials and intermediates and end products have to be moved around in the plant each year. The efficient mechanization of all this movement and the careful layout of plant o as to minimize both the cost and time involved in it, are therefore permanent technological challenges in the Rosario plant.

Fourthly it is clear that the production process in the Rosario plant involves heating up the product as much as four times (i.e. in the shaft furnaces (scrap to hot metal), in the Siemens Martin furnaces (scrap plus hot metal to liquid steel), in the Ingot reheating furnace (ingot to billet stage), and in the Billet reheating furnace (billet to bar and profile stage). Hence improving the efficiency of energy use in the heating processes presents a third persistent area of technological challenge in the plant.

Fifthly the multi-stage nature of the process in the Rosario plant accentuates the problem of the metallic 'losses' which result in each process stage. These, of course, have the effect of reducing the tonnage of output obtainable per ton of metallic input and increasing the unit cost of the output. It is therefore a constant preoccupation in the plant to reduce these losses involved in each process stage, by i) minimising the 'irrecuperable' losses (e.g. those which result from surface oxidation of the metal at high temperatures), ii) reducing the percentage of reject products and waste material resulting fromcropping product-ends, cutting-to-length, grinding, etc., and iii) improving the efficiency of 'recuperation' (i.e. recycling) of those losses that can be recuperated. These objectives can be summarized as the attempt to increase the yields at each process stage.

Sixthly, it is clear that much of the processing machinery in the Rosario plant is subject to extensive thermal and mechanical stresses in the course of normal operations. For example the repeated cycles of high and low temperatures in the furnaces, the wear and tear caused by the loading of solid scrap, the heavy forces exerted on cylinders and bearings during rolling operations etc. all give rise to the need for regular maintenance and periodic extensive repairs to keep the plant's main units functioning. In addition regular maintenance and repairs service are required for all the plant's ancillary equipment such as cranes, motors, reduction gears, electromechanical devices, pumps, process instruments, etc. to prevent breakdowns in these from immobilizing the plant's principal productive units. It can be seen that the theme of maintenance and repair may generate a substantial set of technological challenges associated with such matters as i) reducing the incidence of breakdowns, ii) prolonging the useful life of the plant's principal units, iii) lowering maintenance and service costs (1). Indeed these challenges tend naturally to lead to all sorts of minor technical changes being made to process machinery, usually taking advantage of periods when the machinery is in any case down for regular repairs.

Seventhly, our account demonstrates the importance of product-quality throughout the whole sequence of process stages in the Rosario plant. One would, therefore, expect that the effort to achieve better product quality would be applied in all plant stages, e.g. by changing to more careful operating practice, by the devising of new quality controls etc. - and that this effort to improve product quality would represent yet a further area of regular technological challenge in the Rosario plant.

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(1) "During the life time of industrial equipment in industrialized countries, total cost of maintenance will account to 50-200 per cent of the initial cost of equipment. In developing countries the cost of equipment will probably be higher". Quoted from Guideliness for Contracting from Industrial Projects in Developing Countries, UNIDO Manual, p. 27.

To sum up we have now mentioned seven areas of technological challenge which arise practically automatically as a result of the process technology employed in the Rosario plant, i.e. i) the solution of bottlenecks and the bringing into use of spare capacity, ii) the speeding of process cycle times, iii) the introduction of improved mechanization and layout to speed the movement of materials and products within the plant; iv) the improving of the efficiency of energy use in the distinct furnaces of the plant; v) the obtaining of greater metallic yields at each process stage; vi) the introduction of improved maintenance procedures, and vii) the effort to improve product quality.

The point is that we would expect to discover that technical changes had been made in the Rosario plant in these seven areas simply by virtue of the kind of process technology installed there. In this respect, our expectations for Rosario steelplant are no different to what they would be for other steelplants. That is, we would expect these seven areas of technological challenge to also be relevant to other steelplants too. In this sense all that we have drawn attention to are seven particular areas of "general technological challenge" for steelplants and there is no difficulty in extending our list to many other areas besides the seven we have mentioned.

There is, however, another side to the technological 'challenge' coin which we shall now explain. The point is that whilst the Rosario plant's process technology may be said to 'generate' a series of challenges to the plant's engineers, this same process technology also contains, (like any other process technology) some inherent technological limitations and drawbacks which impose limits on the improvements in performance that the plant's engineers and workforce are likely to be able to squeeze out of the equipment, no matter how talented they may be.

For example, the use of the Siemens Martin steelmaking has several inherent limitations - in particular the slow cycle time for making a batch of steel (due to the length of time needed to charge the furnace) the relative lack of precise control over power input (compared to electric arc furnaces), and the high manning levels required compared to other steelmaking methods.

Secondly, the use of ingot casting is inherently more wasteful of steel than is continuous casting.

Thirdly, the billet mill also has some inherent limitations. It has a rather small entrance channel - which puts a maximum limit on the size of tha ingot-base sections which can enter it, of 280 mm. This in turn has the effect of limiting the types of steel that can be produced to the so called "killed" steels which produce relatively brittle products. In addition the small power available in the main mill motor - i.e. 1200 HP - limits the rolling speed attainable, etc.

Finally, so far as the Bar and Profile mill is concerned, its very conception (i.e. layout of the mill stands, power available, tec.) marks it out clearly as a slow-speed rolling unit in contrast to the high powered 'continuous' rolling mills of the sort installed in Acindar's Acevedo plant.

The conclusion is that <u>while there clearly exist many kinds of opportunities for upgrading the performance of the plant's units beyond their initial design performance, there also exists inherent features built into the processes employed which set limits to the degree of improvement in performance that can eventually be achieved without fundamentally transforming the technological basis of the units concerned</u>.

The fact that the record of the Rosario plant in upgrading the performance of existing units is rather impressive means that we will have a good opportunity, - in exploring the record of the technical changes made - to investigate the conditions in which technological opportunities were taken advantage of and the circumstances which permitted technical change in the plant to prosper in spite of the design-limits.

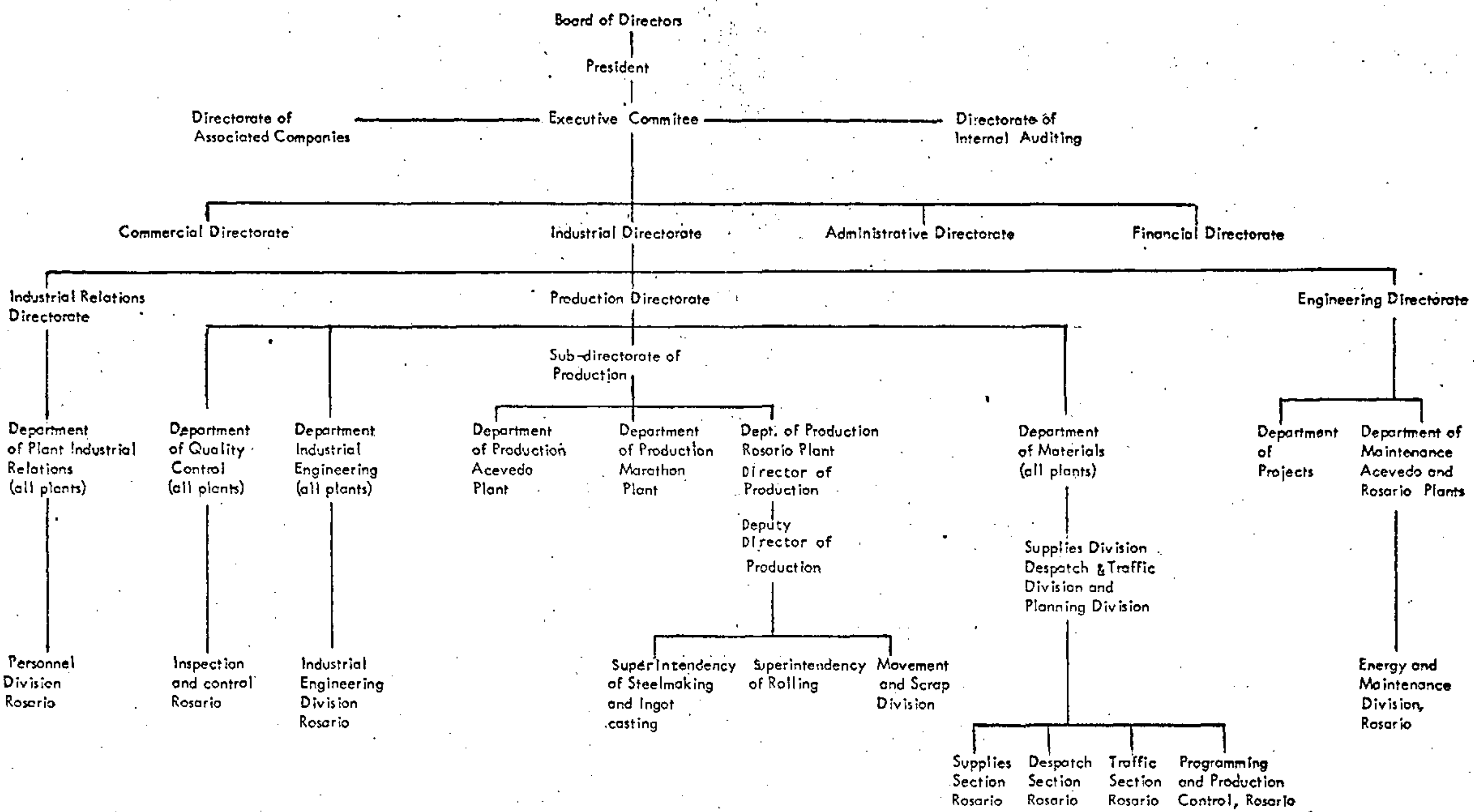
<u>The organization of the Rosario Plant</u>

We now switch from exploring the Rosario plant's product and process technology to providing a brief description of the plant's organization. This description throws light on i) the elationship between the Rosario plant and the overall organization of Acindar, and ii) on the parti-ular functions of the Rosario plant's various operating divisions. It enables us to reach some useful conclusions about the different sources of "technical change effort" which the Rosario plant can lraw on . So we now begin our review of how the plant is organized.

Almost one thousand people are involved in operating the Rosario plant, made up of ap-proximately seven hundred production workers, two hundred employees, plus their foremen, super-visors and managers, organized into 11 specialized divisions and sections.

These 11 divisions and sections are shown in the 'organigram' overleaf which also shows how the Rosario plant fits into the overall organizational structure of Acindar. As can be seen the fit is quite complex and we shall now explain it briefly. The first point is that Acindar's overall activities are largely controlled by four senior management groups formed into Directorates (see organigram). The Rosario plant, like Acindar's other two steel plants, falls under the responsibility of the Industrial Directorate, which controls all Acindar's 'production-linked' activities. This Industrial Directorate, which is based in Acindar's Head-Office in Buenos Aires, covers the areas of Production, Engineering and Industrial Relations, and it operates via the Chiefs of the three plants who are located in their respective plants, and via the Heads of the distinct Departments who are located in the Acevedo plant in Villa Constitución.

Acindar's other three Directorates - i.e. the Commercial Directorate, Financial Directo-rate and Administrative Directorate are responsible for all the vital 'non-production-linked' services such as sales, purchases, accounting, cash-flow control, legal services, data processing, etc. These services are centrally organized from Buenos Aires for the whole company. The key point is that these 'non-production' activities are not performed by personnel based at the plants and this explains why the Rosario plant organization, plus its links to Villa Constitución, Organigram showing the organization of the Rosario Plant, and its connection with the overall organization of Acindar



incorporates only those specialized activities needed for the plant to operate with success as a production unit.

Next we can turn out attention to the Rosario plant organization itself, and its links to Villa Constitución. As we can see on the organigram, three of the Rosario plant divisions (i.e. the Superintendency of Steelmaking and Ingot casting, the Superintendency of Rolling mills, and the Movement and Scrap Division) ruport unequivocally to the Chief of the Rosario plant. The other divisions or sections of the Rosario plant have a dual structure of responsibility. On a day to day basis they must cooperate with the Chief of the Plant, but their actual superiors are located in Villa Constitución in the respective 'Departments' which are responsible for two or more of Acindar plants. This dual structure of responsibility applies to the Industrial Engineering Division of the Rosario plant, the Control Division (i.e. Inspection and Quality Control) the Energy and Maintenance Division, the Personnel Division, the Production Control and Programming Section, and the Supplies, Traffic and Despatch sections.

The preceding outline of the Rosario plant's organization demonstrates clearly that the plant is organised as a component of the wider Acindar structure - a situation which clearly both stimulates certain kinds of technical changes in the Rosario plant (e.g. those that adapt to the needs of the organization viewed as a whole) and stunts other kinds of technical changes (e.g. those technical changes which might be adopted if the goal was to optimize the performance of the Rosario plant as a single unit).

However, the stimulating and stunting effects that can be expected are likely to be rather complicated since possibly harmful effects such as conflicts between plants over investment allocations, demoralization in one plant compared to another, or 'brain drain' from one plant to another may well form part of the picture alongside more harmonious effects such as lowered overhead costs, or improved central services to all plants achieved by combining resources, or useful complementarity of production programs, or healthy rivalry between plants in improving production performance (1).

These remarks suggest that it will be important to try to trace the historical effects - on technical change in the Rosario plant - of the evolving relationship between the Rosario plant and the rest of Acindar and that we can expect to find that quite a wide variety of stimulating and stunting effects have been at work.

Some further useful remarks can be made about technical change in the Rosario plant by analysing the functions of each of the Rosario plant's divisions and sections. Inspection of the Rosario plant reports enabled us to draw up the following summary:

Summary of the functions of the Rosario plant's various Divisions and Sections

Division/section	Function
1. Superintendency of Steelmaking and Ingot Casting	Operation of shaft furnaces, Siemens Martin furnaces, and ingot casting equipment
2. Superintendency of Rolling Mills	Operation of Ingot reheat furnace, billet mill and ancillary equipment, and operation of Billet reheat furnace, Bar and Profile mill, and straightening and torsioning machinery, plus responsibility for the ingot and billet conditioning sector.
3. Movement and Scrap Division	Reception, classification, processing and preparation of incoming scrap, and collection, classification and processing of internal plant scrap.

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(1) This topic raises many questions concerning the economics, management and technological development of 'multi-plant' operations. Obviously in this study we cannot pretend to do more than mention some features of Acindar's experience.

Division/section	Function
4. Energy and Maintenance Division	Maintenance and repair of all plant equipment, ex cution of modifications to equipment, operation and maintenance of the plant's power supply, engineering studies for proposed plant modification
5. Industrial Engineering Division	Determination of quantitative performance standar in all plant processing and operative stages. Re - paration of monthly standard costs per ton for each product produced. Revision of perfomance standar when process or operative technology is changed. Studies to determine in advance the performance standards that would apply to proposed changes in process or operative technology. Determination of real costs and their comparison with standard costs.
6. Inspection and Control Division	Quality checks on a) the raw materials coming int the plant, b) the intermediate products brought in by the plant, c) the intermediate products produced by the plant and d) the end-products produced by the plant. Inspection of on-going production to draw attentio to deviations from product norms. Periodic revision of norms. Investigations of defects in products to determine causes and recommend appropriate changes in operative technology. Development of new methods of analysis as required.
7. Personnel Division	Industrial Relations, plant security, social services, etc.
8. Programming and Production Control	Planning and recording of production.
9. Despatch and Traffic Sections	Stock control and product despatch.
10. Supplies section	Purchase of supplies.

The principal conclusion of which emerges from analysing this list is that the Rosario plant does not have any single 'technical division' which is the main source of the innovations introduced in the plant. On the contrary, the list shows that the technical change effort in the plant is

read out as between, at least, the Energy and Maintenance Division (e.g. execution of modifi-
ations to equipment and some engineering studies), the Industrial Engineering Division (e.g. vision of performance standards and studies to determine in advance the performance standards at would apply to proposed changes in process or operative technology), and the Inspection and ontrol Division (e.g. investigation of product defects, trials on proposed new raw materials and termediate products, etc.).

Furthermore we know both from the Rosario plant reports and from interviews with plant rsonnel that there is a substantial technical change effort located in the Steelmaking and Rolling visions as well (I) - i.e. which is generated by the divisions actually operating the plant's ain machinery - and that there is also an important input to technical change coming from the irector and Deputy Director of the plant.

Hence it is clear that in the Rosario plant itself, the technical change effort is sically in the hands of at least five of the divisions which have day to day operating duties as eir main responsibility, plus the two most senior plant personnel. In other words the technical ange effort exists alongside the plant's regular production activities and is carried out by the me personnel.

Of course, the links which exist between these personnel and the various departments Villa Constitución, and the links which exist between the Rosario plant and senior management oups in Buenos Aires such as the Engineering Directorate or the Systems Group of the Adminis- ative Directorate, mean that the Rosario plant can receive impetus and help in carrying out chnical changes from technical personnel outside the immediate orbit of the plant. Nevertheless,

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) The plant reports reveal many examples of technical changes being executed by these two operating divisions. Interview material also reveals that many projects have involved co-operation between these two operating divisions and the Energy and Maintenance Division, which used to be called the Plant Engineering Division - with the claim being made that the "initial push" for technical changes usually comes from the two operating divisions rather than vice versa.

so far as the purely internal technical change effort is concerned, this is clearly 'spread-out' amongst the various operating divisions of the plant, and is fundamentally an 'outgrowth' from regular manufacturing activities (1).

Summary of the findings concerning the technology and organization of the Rosario plant

We are now in a position to consider the results of this exploration into what we called the "technological structure" of the Rosario plant -to see what light it has thrown on the context in which the plant's managers, engineers and personnel operate, and in which technical changes are introduced.

The basic points which have emerged are as follows:

1. The Rosario plant is a multi-stage plant which comes into the category of 'mini'-plants in terms of its production capacity.
2. The process technologies which the plant operates to convert scrap into steel and then to billets are basically outmoded but they have been extensively upgraded compared their initial design performance, and are not obsolete. The plant's Bar and Profile mill, too, has been extensively modernized and is reasonably up-to-date.
3. The plant is a multi-product plant, which means that we will need to pay close attention to changes in product-mix both in the intermediate and the final product stages.
4. The nature of the process technology employed in the plant generates several obvious 'areas' of technological challenge for the plant's engineers and personnel - and at the same time imposes some inherent limits on the improvements in performance (compared to initial performance) that can be achieved.

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(1) We shall tackle the problem of describing this 'outgrowth' and its development in Chapter III, when we address the subject of 'Learning'.

. The organization of the Rosario plant does not incorporate any specialist technical unit, but technical change activities exist alongside the normal production activities in at least five of its divisions.

. It therefore seems clear that the context of the plant's engineers, management and personnel, which is also the world into which technical changes are introduced, in large part consists of 'micro-environments' formed by the particular process-machinery and divisional duties which fall under the responsibility of the particular plant managers concerned.

. This suggests that the phenomenon described in the economic literature by the crude term "learning-by-doing" is extremely important in the Rosario plant, and that a high proportion of the technical change carried out in the plant corresponds to what is known in the literature as "localized" (1) in the sense that it results from narrowly focused efforts to improve the performance of the particular process equipment and procedures already installed in the plant, and generates relatively little "spillover" of new knowledge which would be of general applicability to improving techniques in other steelplants.

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(1) The concept of "localized" technical change was given theoretical shape by A.B. Atkinson and J.E. Stiglitz in their article A new view of technological change, Economic Journal, Vol. LXXIX, September 1969.

SECTION II

Evidence Concerning the Nature and Rate of Technical Change In the Rosario Plant

Our concern in this second section of the chapter is to explore the evidence concerning the historical record of technical change in the Rosario plant in the period 1943 to 1976 - with the aim of identifying both the nature of the technical changes introduced, and wherever possible also their rate of introduction across time.

To begin with, we present a broad view of the evolution of the plant from 1943 to 1976 obtained by summarising all the distinct types of changes to establish the overall context of changes in the plant of which the technical changes form a part.

Then we turn briefly to the problem of definitions and methods of analysis, so as to define what we mean by technical change and to explain both the approach we have adopted in our attempt to investigate its nature and rate in the Rosario plant, and the different kinds of evidence we have collected, based on this approach.

Following this we then devote considerable space presenting and analysing all these different kinds of evidence which we have collected. This includes evidence concerning i) the growth in the volume of output produced by the plant; ii) the objectives of technical change in the plant; iii) changes in output-mix; iv) the growth of productive capacity; v) changes in product quality; vi) observations on changes in unit costs , vii) organizational changes, and viii) "incremental" technical changes.

It is then possible, in the final part of this section, to summarise the findings on the nature and rate of technical change in the Rosario plant, from 1943 to 1976 which have emerged from this evidence.

The evolution of the plant from 1943 to 1976

To get a picture of the overall extent and nature of the evolution of the Rosario plant, we shall begin by comparing the plant as it was in 1943 with the plant as it is today. As one might suppose, the differences which emerge from this comparison are quite striking.

First of all the plant today produces a very much greater volume of output than did the plant in its early years. This can easily be seen if we compare the average output of the plant in the years 1943-47 with the output in the years 1969-76. What we find is that Ingot output has risen from 17,000 tons per year to 130,000 tons per year, Billet output has risen from zero to 140,000 tons per year, and the output of end products (i.e. bars, profiles, etc.) has increased from 30,000 to 50,000 tons per year. Hence the first unmistakeable fact about the plant's evolution between 1943 and 1976 is that it has involved a process of very considerable quantitative growth in the volume of steel products produced.

Second, the plant today has more capital equipment installed. Instead of having only one Siemens Martin steelmaking furnace, as in 1943, today's plant has three Siemens Martin furnaces. While in 1943 there were no shaft furnaces for making hot metal, today three such shaft furnaces are installed. A further major addition to the capital equipment is the entire billet mill, which was installed in 1950. We can also mention the entire ingot casting system which involves new equipment which replaced the original installations, and further examples could be multiplied.

Third, virtually every important item of equipment which does remain from the early installations, or which dates back even a few years from today, has been modified so as to improve its performance. A good example is the first Siemens Martin furnace in the Rosario plant.

This originally had a capacity of 25 tons per heat (batch). Its interior was modified in 1949 increasing its capacity to 32 tons, it was also adapted for receiving part of its load as hot metal. Furthermore, its burners have been modified, the refining reactions to make steel are now speeded by the injection of oxygen into the furnace-bath, improved refractories are used, and innumerable other modifications have been made over the years in order to improve its capacity, cycle time and productive efficiency. When one examines the equipment used in the Scrap park, Ingot casting section, Billet mill, or Bar and Profile mill, the same pattern of modification add improvement of the equipment over the years is immediately apparent.

Fourth, the product-mix produced by the plant is today more sophisticated than the product-mix of the early years. The original product of the plant was plain mild steel reinforcing bars, plus a small quantity of square section mild steel bars. Today the plant produces three different basic varieties of reinforcing bars, plus a range of profiles and a range of forging bars. At the intermediate products stage, the plant now produces billets as well as ingots - and the ingots it produces weigh approximately 900 kg compared with 150 kg and are produced in a wider range of steel grades than before.

Fifth, product quality has improved dramatically since 1943 due to modifications in manufacturing methods and the intensification of quality inspection and control procedures.

Sixth, the operating technology has evolved - i.e. the actual jobs performed by workers and supervison have changedin many respects, both to match changes in equipment and changes in product-mix, and also to conform to superior practice developed through experience.

Seventh, the plant's organization has gone through several changes, becoming more sophisticated than before, giving rise for example to new divisions such as Industrial Engineering and Quality Control and incorporating a higher proportion of Engineers and Technical Staff in its ranks.

Eighth, the quality and mix of raw material inputs to the plant is in some respects different. The scrap available on the market today is of lower average density and quality than the heavy steel scrap that was available in the 40s; the plant no longer uses charcoal as it had to do when starting up for adjusting the carbon level in the steel; Pig iron is no longer economically available on the market for supplementing scrap load; gas is now used in preference to fuel-oil in the reheat furnaces.

Ninth, the unit costs of the plant's products measured in 'real' terms has fallen substantially between 1943 and 1976 - in other words the global productivity of the resources used in manufacturing steel products in the Rosario plant has increased.

This review shows that the evolution of the Rosario plant between 1943 and 1976 has had multiple aspects. These include quantitative growth in volume of output and in quantity of capital installed; growth in the complexity of the product-mix produced and in the sophistication of the organization which runs the plant; adaptation to changes in input-mix; improvements in product quality; and extensive modifications both to process equipment and to operating practice which have resulted - together with scale effects - in greatly improving the 'performance' of the capital, materials and labour resources employed in the plant. Between all these aspects of the plant's evolution there of course exist inter-relationships, causalities, spin-off effects, etc., many of which will become clearer when we turn to examine each aspect of the plant's evolution in more detail.

At this stage, however, our aim is only to have pointed out how the panorama of evolution in the Rosario plant embraces <u>multiple</u> different kinds of changes - it therefore offers a richer field for investigation than the single domain of unit-cost reducing changes, in which economists have tended to specialize their efforts.

Definitions and methods

We have just seen that the overall pattern of evolution in the Rosario plant has been complex and 'multi-dimensional'. The problem which is now relevant is - how can we begin to investigate the part played by technical change in generating this complex pattern? This problem involves both questions of definition (of what is meant by 'technical change') and questions of method (i.e. of the possible ways of exploring the phenomenon). Therefore, we now tackle both these questions.

The starting problem is to clarify how the phenomenon of 'Technical Change' inserts itself in, and relates to, the complex set of changes which we have seen constitute the 'evolution' of the plant. This clarification is absolutely necessary because not all of the changes in the Rosario plant which we mentioned above are either technical changes or also the result of technical changes. We therefore need a criterion for distinguishing technical changes from 'other' changes. We also need a method for distinguishing between improvements in performance caused by technical changes and improvements in performance due to 'other' causes.

The criterion we shall use for distinguishing technical changes from 'other' changes follows the one devised by Samuel Hollander for his celebrated study of technical change in the Du Pont Rayon plants. Hollander defines the realm of technical changes in-plant to include

> "methods used for the first time by the plant, or modifications of methods, regardless of the source of the underlying technology and regardless of whether from the point of view of the entire industry, the whole nation or the whole world the methods are imitative or not". (1)

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(1)Samuel Hollander, The Source of Increased Efficiency. A Study of Du Pont Rayon Plants, M.I.T. University Press, Cambridge 1965.

The great value of this definition of Hollander's is its inclusiveness. Thus, it includes changes in a plant's organization structure, and shifts to new procedures in labour operating practice as 'technical changes'. It also includes changes in the quality of the raw material inputs to the plant as 'technical changes'. Finally, of course, any changes in the process technology employed in the plant, changes in the design or specification of products, and any diversification into new product lines are also included as 'technical changes' in this definition.

On the other hand, any change which involves repeating methods, processes, designs, etc., which are already established in the plant is, of course, not regarded as a technical change. For instance, the installing of a duplicate facility to double production capacity is not a technical change. Nor is an increase from two shift to three shift production a technical change.(1) We can from now on refer to all changes of this second sort - which achieve expansions in output or in plant capacity via extending, duplicating or repeating procedures already in use - "scale multiplying" changes.

Hence we now have, following Hollander, a criterion for distinguishing "technical" changes from "scale-multiplying" changes, which we can use in our study of the evolution of the Rosario plant.

A further distinction which it will be vital to keep in mind is that which exists between the actual physical (or operational) changes introduced in the Rosario plant - and the effects of these changes, as measured by shifts in a whole series of "parameters" which describe plant output, and/or performance.

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(1) Strictly speaking expanding the scope of presently used procedures does usually involve someone *in the plant in doing something he has not done before - and therefore, cannot be regarded* as exact 'repetition' of what already exists. Furthermore an expansion of capacity via duplication of facilities may sometimes stimulate an organizational change designed to cope with the expansion - however, there is a fundamental distinction between "doing more of the same" (duplication) and doing something different (technical change) which the definition is designed to capture.

This point deserves further explanation. We noted in our review of the evolution of the Rosario plant that the plant's history includes various kinds of changes in 'output' (i.e. changes in product-mix, changes in product quality, and changes in the volume of output produced) and also various kinds of changes in the 'performance' of the capital, materials and labour resources employed in the plant, (whereby 'performance' we will understand both productivity measures of the output-per-unit-of-input variety and capacity measures of the throughput-per-hour variety). In other words we can say that we noted evidence of changes in the Rosario plant in five classes of 'parameters' constructed to reflect the shifts in plant output and performance. These are:

1) output volume parameters

2) output-mix parameters

3) output-quality parameters

4) unit cost parameters

5) throughput rate parameters

The distinction which we are concerned to make is simply that the changes which can be observed in these five types of parameters throughout the life of the Rosario plant are not <u>themselves</u> either 'technical changes' or 'scale multiplying' changes. Rather they are the <u>results</u>, or consequences of these latter types of changes. Furthermore many individual changes (whether technical changes or scale multiplying changes) affect two or more of the above classes of parameters simultaneously. Thus, even if one has identified a particular parameter movement as having been caused by a particular technical change - this does not mean that other parameters too may not have been affected by this same technical change. Hence, it is essential to maintain a clear distinction between a) the changes themselves; and b) their consequences in terms of their effects on one or more of the output or performance parameters.

This distinction between the changes themselves and their consequences suggests immediately that there are two basic 'lines of approach' available for exploring the nature and rate of technical changes in the Rosario plant, or for that matter in any other plant.

The first line of approach is to identify and construct a sample of actual individual technical changes introduced in the plant and then to analyse these so as to obtain data about such matters as the types of technical changes involved, their purposes, consequences, origins, the size of investment and the life span involved in introducing the changes, etc. Classification of the 'nature' of the technical changes in the sample can then be performed in accordance with whichever categories are used in the analysis. This approach, clearly is concerned with the direct analysis of the 'units' of technical change i.e. the actual technical changes themselves.

The second line of approach is to identify the movement over time of one or more of the output or performance parameters in which one is interested - and then to estimate the contributions made to this parameter movement by technical changes as against by scale-multiplying changes. This second line of attack can work either by a) subtracting from the over - all parameter movement the part of the movement which one has determined was contributed by scale-multiplication, leaving the rest as a 'residual' which one attributes to technical change, of by b) seeking to establish the complete sample of individual technical changes which contributed to the movement of the parameter during the period in question, and then estimating and adding up the separate contributions to parameter movement made by each individual change in the complete sample. (This latter method evidently requires an intimate knowledge of the technical changes carried out in the period in question and of their consequences on the parameter in question). Whichever method is used the virtue of this second line of attack is that it promises to provide date about the cumulative extent and rate of parameter movement caused by technical change in given time periods.

Summary of the evidence collected

In our exploration of the nature and rate of technical change in the Rosario plant we have tried to combine elements from both the above mentioned 'lines of approach'.

Along the first line of approach we have been able

i) to identify a sample of 30 important technical changes from the Acindar annual reports,

ii) to identify further important technical changes, in addition to the above 30, by means of the taped interviews carried out with plant personnel -and in many cases to explore the circumstances leading to the technical changes (both the original 30 plus the 'further' ones).

iii) to identify still other technical changes which are mentioned in the more recent Rosario plant reports (1968-69 and after), in particular many 'minor' technical changes.

iv) to identify some of the important 'organizational' changes introduced into the plant.

We then make use of this overall sample of technical changes plus accompanying data as the basis for various kinds of analysis which throw light on such matters as the objectives of technical changes, the incremental or non-incremental nature of the changes, the circumstances surrounding their introduction, the divisions within the company responsible for the changes, etc.

The greater part of our effort, however, has been concerned with the second 'line of approach', i.e. the exploration of the movement of various of the plant's output and performance parameters, followed by the investigation of the extent to which technical changes were the cause of these movements. Along this line, we have traced the movement of parameters relating to the output and performance of 1) the Steelmaking units of the plant (i.e. The Siemens Martin furnaces), 2) the Billet mill, and 3) the Bar and Profile millecause data on these was more abundant than was data about the output and performance f the plant's other units (i.e. the scrap park, or the various finishing operations).

The particular 'parameters' whose changes over time we have attempted to trace 1 the three plant units mentioned above are:

) growth in the volume of physical output

i) changes in the output-mix

ii) changes in productive capacity

/) changes in product quality

) changes in unit costs.

We then attempt in each case to identify the contribution made by technical hanges, as opposed to scale multiplying changes, in accounting for the observed parameter ovement. To help in this we make use both of the data on individual technical changes which e collected (see above), and also data which we collected about the scale multiplying changes ıtroduced into the three plant units in question.

The rest of this section is now devoted to presenting and analysing the evidence we ave collected using both the lines of approach mentioned above.

We first of all present data concerning the growth in physical output of the plant hich is useful because it demonstrates the "growth context" in which technical changes have ccurred.

Next we carry out an analysis of the objectives of technical change in the Rosario lant, based on the sample of 30 important technical changes mentioned in the Acindar annual ·ports. The main result is to demonstrate that technical change in the plant has had multiple ifferent objectives going far beyond simply unit cost reduction.

We then turn to analyse the changes over time in the output-mix produced by the steelmaking units, billet mill and bar and profile mill - and demonstrate the important role of technical changes in causing these changes in output-mix.

There then follows a detailed analysis of the growth in production capacity of the steelmaking units, billet mill and bar and profile mill, and a demonstration of the key role played by technical changes in producing this growth.

We next turn to analyse the changes introduced in product quality in the plant, and identify the technical changes which were responsible.

There then follows a set of observations on changes in unit costs of production and the relationship of unit costs to technical changes in the plant.

Following this we provide an analysis of the evidence concerning 'organisational' changes in the plant.

To conclude with we analyse a sizeable sample of the incremental technical changes introduced in the plant.

This completes the presentation and analysis of the evidence we collected. Then in the last part of this section of the chapter we summarize the major results which emerge from this evidence concerning the nature and rate of technical change in the Rosario plant.

he Growth of output in the Rosario plant 1943-1974

To see how the level of production has changed during the life of the plant, we con-ulted data available in the Rosario 'Plant Reports'.

As a result, we were able to compile three complete production series, covering every year from 1943 to 1973-74,* showing the total tonnage of output produced in 1) the Ingot casting ection, 2) the Billet mill, and 3) the Bar and Profile mill.

All three of these production series are displayed in the graph on the next page as well as being set out numerically in the adjoining table.

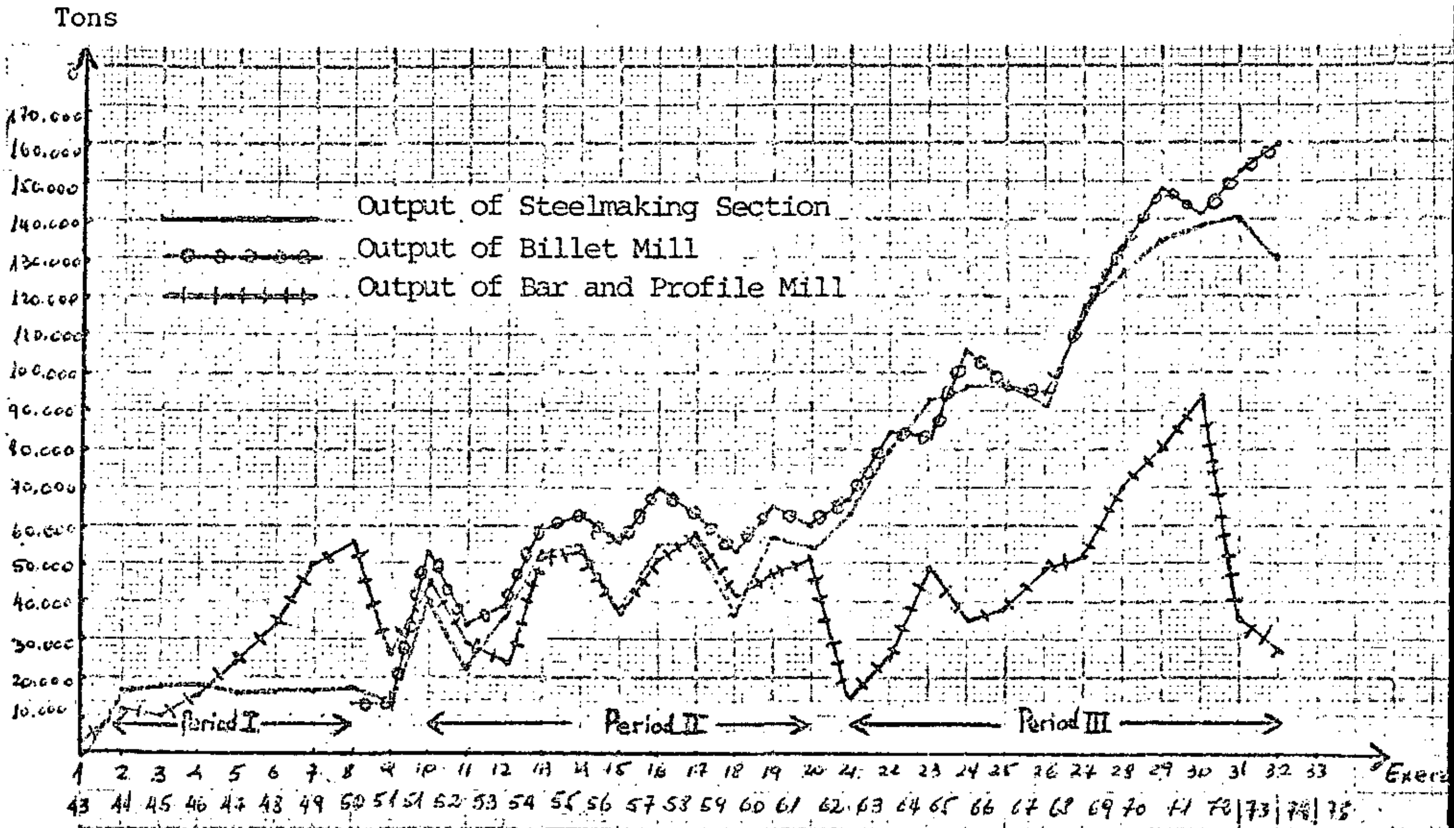
To help draw conclusions from these series we shall divide the overall period from 1943 to 1973-74 into three distinct long 'Periods' of growth plus some shorter 'start-up' phases. The long periods are: I 1944 to 19 50, II 1951-52 to 1961-62, and III 1962-63 to 1973-74. The start-up 'phases' are a) the year 1943, the start-up year of the Ingot casting section and the Bar Profile mill. b) the years 1950 and 1951 which correspond to the two start up years of the Billet mill, and c) the year 1951 for the Ingot casting section, since in this 'year' the second Siemens Martin steel-making furnace and the shaft furnaces were being started up, thus greatly increasing the output capacity of liquid steel to be made into ingots.

We will now comment on the growth in production with the aid of this scheme of 'periods' and start up phases.

We start off in 1943, the plant's start up year. The 'Bar and Profile' mill (then exclusive-ly a Bar mill) began production using very crude methods which involved rolling reheated rails or else rolling semi-melted packets of assorted scrap. It managed to produce 3,000 tons of reinforcing bars during the year. The steelmaking section started up its Siemens Martin furnace in December and managed to produce 111 tons of ingots in the few days that remained of the year.

* See note on next page concerning the annual accounting-periods used by Acindar.

Annual Growth in the Output of Each of the Three Main Sections of the Rosario Plant 1943 to 1973-74



* Acindar conducts its accounts in yearly periods, starting from 1st January 1943. However in 1951 the accounting exercise was closed on 30 June thus resulting in an anomalous 'year' of only six months. From then onwards all the accounts have been opened on 1st July and then closed on 30 June of the following year - and these years are therefore referred to as 1951-52, 1952-53, etc.

PRODUCTION SERIES FOR THE THREE MAIN PLANT SECTIONS

YEAR	EXERCISE	STEELMAKING SECTION Tons	BILLET MILL Tons	BAR AND PROFILE MILL Tons
1943	1°	111	-	3.106
1944	2°	17.185	-	11.080
1945	3°	18.358	-	10.051
1946	4°	18.139	-	15.443
1947	5°	16.866	-	24.009
1948	6°	16.549	-	34.998
1949	7°	16.594	-	50.302
1950	8°	17.822	13.691	56.473
1951 (1st. 6 months)	9°	14.494	13.932	26.059
1951/52	10°	40.334	53.156	44.207
1952/53	11°	22.716	34.631	29.088
1953/54	12°	36.441	39.367	23.439
1954/55	13°	53.075	59.094	51.520
1955/56	14°	55.050	63.272	53.347
1956/57	15°	38.115	56.467	38.982
1957/58	16°	55.009	70.542	51.167
1958/59	17°	55.111	63.917	58.482
1959/60	18°	37.103	53.977	42.790
1960/61	19°	57.798	65.989	47.888
1961/62	20°	54.651	60.557	51.331
1962/63	21°	63.660	67.427	15.104
1963/64	22°	80.057	84.629	25.915
1964/65	23°	93.235	83.381	49.694
1965/66	24°	97.401	106.770	36.636
1966/67	25°	97.510	96.127	39.228
1967/68	26°	91.116	95.559	49.181
1968/69	27°	118.394	116.253	52.666
1969/70	28°	127.510	134.303	70.503
1970/71	29°	134.510	148.701	80.960
1971/72	30°	140.692	141.699	94.271
1972/73	31°	140.135	153.432	36.193
1973/74	32°	130.196	160.676	27.936

Then we come to the first long period, i.e. Period I which includes the years 1944 to 1950. The production of steel ingots (based on the steel from the one Siemens Martin furnace) remai remarkably constant at around 17,000 tons per annum throughout the whole period whilst the production of the Bar and Profile mill in contrast rises rapidly, almost without a break, from 11,000 tons to almost 56,000 tons a year. This rapid increase seems to have been due to both "learning-by-doing" and to the replacement to the initial rudimentary rolling practice based on improvised raw material by more satisfactory operating practice based on rolling proper billets bought from outside suppliers. In fact one can consider the evolution of the Bar and Profile mill during this first long period as a prolonged start-up phase which led by the end of the period to the more or less complete use of the initial design capacity of the mill. In contrast, the start up of the Siemens Martin furnace appears to have taken not even one year to complete.

The year 1950 which is the end year of Period I also marks the first of two start up years of the newly installed Billet mill. The 'year' corresponding to 1951 is the second of these two start up years and is also a start up phase for the second Siemens Martin furnace, shaft furnaces, and other major technological changes in the steelmaking and ingot casting sections. Once this start up phase is complete one notes that in the first year of Period II, i.e. the year 1951-52 the Billet mill is already producing 53,156 tons per year (which corresponds to its estimated initial design capacity of 50,000 tons) while the production of Ingots has reached 40,334 tons representing an increase of some 120 % over the production obtained previously with only one Siemens Martin furnace operating.

We now come to analyse the growth of production during Period II, i.e. the 11 years from 1951-52 to 1961-62. The basic feature of the Period, as can be seen from the graph, is that the production levels of all three of the plant sections show a fairly similar pattern. First conider the output of ingots. The average level of ingots production for the period is 46,000 tons. One notes a large annual fluctuation in output and a slow rise throughout the period in the maximum evels of production achieved. Next, in the Billet mill, one notes that the level of production was consistently a few thousand tons higher than that of the Steelmaking section, averaging 56,000 ons per annum, and the level demonstrates almost identical annual fluctuations to those of the teelmaking section. As for the Bar and Profile mill, it too shows a very similar pattern, though t is notable that its average level of production during the period, which was 45,000 tons per annum, as considerably lower than the maximum output obtained during the first period.

We come, finally, to Period III. The growth pattern here appears, on the graph, to iverge dramatically from the growth pattern of Period II. Firstly, one observes that the roduction levels of both the Ingot casting section and the Billet mill rise rapidly and almost ontinuously and are practically in unison throughout the entire period (and have an average rowth rate that appears to be considerably higher than in Period I). Secondly, one can observe he very distinct behaviour of output of the Bar and Profile mill. Far from rising in conjunction ith the output of the other two sections, the output of this mill first falls drastically at the eginning of Period III, it then recovers slowly to its former maximum level, then recovers lowly to its former level for another three years only to then fall drastically again at he end of the Period.

At this point it is useful to ask – what conclusions can be drawn from this description of e growth in output in the three productive sections of the Rosario plant?

Several conclusions seem possible. In the first place is it useful to see what is common to d what is different in the three periods. The table on the next page collates - for all three proctive sections – the information concerning the initial, accumulated, average and peak outts in each period as well as the increases in peak outputs achieved during each period. It n be seen from the Table that the peak annual output levels and the average annual output

Output Comparisons for Three Periods in the Evolution of The Rosario Plant

Production figure	Period / Plant Section	PERIOD I* 1944 to 1950 (7 years)	PERIOD II 1951-52 to 1961-62 (11 years)	PERIOD III 1962-63 to 1973-74 (12 years)
Initial production (tons)	Steelmaking section	17,185	40,334	63,660
	Billet mill	-	53,156	67,427
	Bar and Profile mill	11,080	44,207	15,104
Accumulated production during period (tons)	Steelmaking section	121,513	505,403	1,312,292 (est)
	Billet mill	-	620,969	1,363,905 (est)
	Bar and Profile mill	202,356	492,241	578,287
Average production (tons)	Steelmaking section	17,359	45,946	109,415 (est)
	Billet mill	-	56,452	113,658 (est)
	Bar and Profile mill	28,908	44,749	48,190
Peak production (tons)	Steelmaking section	18,139	57,798	140,135
	Billet mill	-	70,542	160,676
	Bar and Profile mill	56,473	58,482	94,271
Increase in peak production achieved during period[1] (tons)	Steelmaking section	954	17,464	76,475
	Billet mill	-	17,386	90,134
	Bar and Profile mill	(45,393)[4]	2,009	35,789
Average anual % increase in peak production[2] during each period as a % of benchmark tonnage[3]	Steelmaking section	1%	4.3%	10.9%
	Billet mill	-	3.2%	12.2%
	Bar and Profile mill	(68%)[4]	0.3%	5.1%

Notes to the Table

* The first 6 months of 1951 have been excluded from the analysis.

1. This is given by taking the difference between peak production in the period and benchmark figure formed by either (i) the output in the first year of the period, or (ii) the peak production figure for the previous period, whichever of these latter two is the higher figure.
2. The % figures refer to simple interest increases, not compound interest.
3. The benchmark figure referred to here is the same as in note 1 above.
4. These figures will be disregarded since the benchmark figure certainly represents a point early in the start-up of the Bar and Profile Mill, and this is artificially low.

levels increase in each succeeding period in all three productive sections of the plant. In other words there is an overall tendency to growing output levels throughout the life of the plant in all three productive sections However, within this overall growth tendency one notices that the rates of output growth differ sharply as between the three productive sections. These differences in growth rates are best illustrated by the figures in the Table which refer to the average annual growth in the 'peak' production levels in each period. These figures indicate the growth achieved in the maximum output levels which each section become capable of producing. If we leave out of account the start-up phases (and we shall here count the whole of Period I for the Bar and Profile mill as a start-up phase), then the table shows that the output growth rates in the plant were:

Ingot-casting section	1 % per annum in Period I
	4.3 % per annum in Period II
	10.9 % per annum in Period III
Billet mill	3.2 % per annum in Period II
	10.2 % per annum in Period III
Bar and Profile mill	0.3 % per annum in Period II
	5.1 % per annum in Period III

The differences between each section emerge clearly in these figures. Furthermore, one notes how the whole of Period III represents a period of far more rapid growth in output that Period II.

What further conclusions can we draw from this foregoing examination of the growth in output levels? We have already seen that a) there has been an overall growth process throughout the life of the plant, and that b) this growth has been uneven as between periods of time and as between sections of the plant. An important further conclusion related to these first two is that there seem to be no indication in the growth pattern of output in the Rosario plant that any kind of "equilibrium point", "optimum output level" or "optimum degree of balance between the sections" having ever been reached. On the contrary, the growth process itself seems permanently to generate new imbalances as it proceeds, and no plant or output configuration is ever the 'final' one (1). The implication is that there are always opportunities for changes to be made in the configuration which will optimise inherent potentials in the plant which are at any given moment subutilized, (2) a point which is obviously relevant to our study of technical change in the Rosario plant, since it bears on such matters as the 'potential field' of technical changes that was available to the plant's engineers at distinct moments in the plant's evolution and on the question of the possible "saturation" of the opportunities for incremental technical change which has been raised as a hypothesis by Hollander and other authors (3).

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(1) This important point was suggested to us by the reading of Edith Penrose's outstanding book This Theory of the Growth of the Firm Basil Blackwell, Oxford, 1959. Penrose identifies "forces inherent in the nature of firms which at the same time create the possibilities for, provide the inducements to, and limit the amount of the expansion they can undertake or even plan to undertake in any given period of time." She then goes on to show that "this limit is by its nature temporary, that in the very process of expansion the limit recedes, and that after the completion of an optimum plan for expansion a new 'disequilibrium' has been created in which a firm has new inducements to expand further even if all external conditions (including the conditions of demand and supply) have remained unchanged." In our view many of Penrose's points apply to the growth of plants as well as to the growth of firms.

(2) According to Penrose, op.cit., there will always be "a pool of unused productive services, resources and special knowledge within a firm which will act as an incentive for the firm to expand in order to use the productive services available from its existing collection of resources more profitably than they are being used." The permanent existence of this "pool" of unused potential is guaranteed according to Penrose because of a) the indivisibilities of resources (i.e. the imbalance problem once again), b) "the fact that the same resources can be used differently under different circumstances", and c) "because in the ordinary processes of operation and expansion new productive services are continually being created".

(3) In Hollander's view "it should be recognized that there is probably a limit to the potential effectiveness of alterations to existing facilities. Ultimately the opportunities may be exhausted without some intervening major outlay". In support of this view he cites the results of his study which showed that "in the plants under investigation, the most striking stream of minor technical changes were introduced during the first 10 to 15 years after the construction of a new type plant". S. Hollander, op.cit. p.203.

It can be seen that all these conclusions we have drawn so far relate to the fact that the process of output evolution in the Rosario plant is a growth process - one which proceeds at different rates in different time periods and with a changing balance between plant sections, and which has no evident equilibrium or optimum point towards which it tends.

The importance of these conclusions, for this study, resides in the fact that any such growth process is bound to have had powerful effects in stimulating and requiring technical changes in the plant. Or, to put it another way, we would expect a plant (or section of a plant) which does not have, for whatever reason, a growth-of-output objective, to exhibit a very different pattern of technical change to a plant (or section) which does have such an objective. At first sight, this point seems so obvious as to seem scarcely worth mentioning - yet it does seem to have been systematically ignored by economic texts which have tended to regard technical change exclusively as progress in reducing unit costs at given levels of output, thus ignoring the important aspect of technical change whose objective is precisely to generate increasing outputs from basically given technology.

When one considers that the increases in output which have occurred in the three sections of the Rosario plant have amounted to between 140% and 600% over the lifetime of the plant, as compared to the original output capacity of these sections, then it becomes clear that the phenomenon of output growth is a central aspect in the overall evolution of the plant which requires to be taken into account. When it is further realised, as we shall demonstrate later in this chapter, that most of this growth of output cannot be explained by Scale Multiplying changes, but was a result of Technical changes, then it becomes clear that the generating of more output from existing machinery is an exceedingly important management objective which deserves detailed study along with the more familiar objective of reducing the unit costs of output.

This concludes, for the present, our exposition and analysis of the growth in output levels in the Rosario plant. Inevitably the analysis has left questions unanswered but it has been useful in illustrating the overall growth context in which the plant has evolved.

The objectives underlying the introduction of technical changes in the Rosario plant

In the text of the previous topic we drew attention to the fact that the evolution of the Rosario plant involved a marked process of growth, but we were not able to draw significant conclusions about the different kinds of technical changes involved in the plant's evolution (other than the obvious conclusion that technical changes which contribute to growth in output must have been very important). We know, however, that technical changes in the plant have pursued other objectives as well. Therefore, in this present section, we propose to explore what different kinds of objectives have inspired the introduction of technical changes in the Rosario plant.

To throw light on this question we have used some useful data contained in the set of Acindar Annual Reports. These reports, which are designed for distribution to shareholders and possible investors, are basically financial documents, but they contain a certain amount of technical information about the company's plants, and the new investments and changes made in them. In the case of the Rosario plant, the set of Annual Reports contain brief data on altogether 30 different technical changes which were introduced in the plant, plus the reasons for their introduction. The criteria for mentioning these 30 changes (plus various additions of duplicate capacity in the plant which we shall not analyse here) appear to have involved picking out those changes of greatest economic significance to the plant in each annual accounting period. The use we have made of this data is to analyse these 30 'important' technical changes according to the reasons given for their introduction. The results of this analysis are shown in the table overleaf.

Reasons given for introducing technical changes	Number of the technical changes carried out for these reasons out of 30 technical changes	
1. To increase production capacity	16	
2. To improve product quality	8	(analysis of single reasons)
3. To reduce unit-costs	7	
4. To introduce new products	5	
5. To react to falloff in input quality	2	
1. and 3.	3	(analysis of multiple reasons, when more than one was cited)
1. and 2. and 3.	2	
2. and 3.	1	

The value of this table is principally illustrative rather than quantitative - because the selection criteria which created this sample of 30 technical changes were not designed with quantitative analysis in mind. Nevertheless, the table is useful, and some comments are in order.

The most striking point to emerge is the high frequency of 'production capacity increase' amongst the objectives for introducing technical changes. In fact, as we shall see later, the effort to increase the capacity of the existing installations has been the dominating theme of technical change both in the steelmaking operations of the Rosario plant and in the Billet mill throughout much of the life of the plant. It has also been an important, though not so dominant theme in the evolution of the Bar and Profile mill. The frequency of technical change directed at raising production capacity is consistent with our observations in the previous section about the notable growth in output experienced by the plant.

The second most frequently cited purpose for technical change - as per the above table - was to improve product quality.

Third in the table comes the objective of reducing unit costs of production. However, this should not be taken to signify that the reduction of unit costs is of only minor importance in the osario plant. Far from it. In the first place virtually all the capacity increasing technical changes ıoted in the table will have been simultaneously intended to reduce unit-costs (via the reduced unit ıverhead costs obtainable by spreading fixed costs over a large volume of production). In the econd place this sample of important technical changes cited in the Acindar Annual Reports is ıot necessarily representative, so far as the analysis of their objectives are concerned, of the ersistent stream of 'minor' technical changes which are documented in considerable detail in ome of theRosario 'Plant Reports' and which appear to be connected with high frequency to the bjective of reducing unit costs. (These 'minor' technical changes are examined later on in this ection). Finally, it is worth mentioning that Senior Personnel in the Rosario plant explain that hey are under "constant, continuing pressure" from Acindar's top management to "drive costs down" Thus, our emphasis on the existence of other objectives for technical change in the Rosario plant is not intended to downplay the importance of the cost-reducing objective but rather to put it in perspective.

The fourth most frequently mentioned objective for the execution of the technical changes mentioned in the Annual Reports, was diversification into new product lines.

Finally, in the Table comes the objective of reacting to deteriorations in input quality (I).

(I) It is important here to emphasize the word "react". The point is that plant management will often deliberately seek to alter the quality or mix of some of the raw material inputs in order to reduce unit costs, improve product quality or increase production capacity. However, this situation did not apply in the cases referred to in the table. Here the Rosario plant was faced by a declining availability of scrap of the quality and mix required. In such cases, plant management does not have the choice between continuing to use the previous input mix and quality or changing to a new one. They only have a choice between accepting a declining mix and quality or doing something about it through technical change.

Obviously, therefore, one can see that important technical changes in the Rosario plant have been directed at several distinct objectives.

Furthermore, the second part of the table demonstrates the important point that some of the technical changes have been specifically aimed at more than one objective simultaneously. In fact this part of the table certainly understates the extent to which the 30 technical changes have actually affected various output and performance parameters simultaneously - for while there is often one main objective which constitutes the basic motivation for introducing a technical change, the actual carrying out of the change will very often cause other output or performance parameters to shift, besides the principal parameter which it was initially intended to change, (e.g. a capacity increasing change very often produces a unit-cost reduction, a product quality improving change may increase unit costs, changes in product mix may alter output capacity, etc.) To the extent that the various different impacts of the same technical change can be foreseen, they will of course affect the ex-ante judgement on the specification an potential profitability of the proposed technical change (1).

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(1) A good example of a recent multipurpose technical change carried out in the plant was the expansion and reform of the Bar and Profile mill carried out in two stages in 1971 and 1973. The objectives for the proposed change, as established at the planning stage were: a) to increase the production of the mill by 50,000 tons a year (Main objective, capacity increase); b) to effect the transformation of the mill with an interruption of production lasting no longer than 15 days (reduction of the cost of the technical change); c) To incorporate the rolling of semi-alloy forging steels for the automobile industry (production diversification); d) to design the new mill taking into account a future expansion consisting in the installation of a continuous finishing mill for the production of semi-alloy round bars of dimension Ø 6 mm to Ø 10 mm, (provision for future product diversification); e) to make use of equipment availabl in the company such as large electric motors, gear boxes, flywheels, mill stands, work-tables, etc. so as to make possible the implementation of the project in the shortest possible time (reduction of uncertainty stemming from time-lag in project implementation); f) to lower the consumption of combustibles per ton produced (unit cost reduction); g) to reduce the percenta of losses (unit cost reduction); h) to reduce the work force (unit cost reduction); i) to attemp to take into account the possible future rolling of rapid and special steels instead of the forged steels (provision for future product diversification); j) to diminish the downtime of the mill required by changes from one dimension to another in the production programme (capacity increase); h) to augment the cross-sectional dimensions of the inputs to the mill (capacity in-

In summary, we have seen to far how i) important technical changes in the Rosario plant have been directed at several different main objectives, ii) that some of these technical changes have been directed at more than one objective simultaneously, iii) that many of these changes will in fact have had a wider immediate impact than on merely the particular parameter which the change was most intended to affect (1).

Some important implications both for this present study and for other steelplant studies arise from these findings.

The key implication is that we shall have to modify the attractive (and often useful) idea that technical change in plants can be measured 'unidimensionally' by examining the progress of unit costs. As a corollary to this, we will have to be sceptical about the concept that the "technical efficiency" of a productive unit can be described by reference to its input requirements

crease); (Source: Oscar R. Amorini 'Remodelación del tren de laminación de perfiles pequeños y livianos' in Laminación, Tecnología, Equipos, Productos' published by ILAFA, Santiago de Chile 1976. The comments in brackets are ours).

(1) Furthermore of secondary, delayed, impacts of technical changes are taken into account then practically no technical change can be evaluated only in terms of its immediate effect on just one performance parameter. This position has been interestingly expressed by William S. Pierce, The Ripple Effects of Technological Innovation: The Case of Iron Ore Pelletizing, Omega, Vol. 2, No. 1, 1974, who points out that "When a single innovation is adopted within an existing system of production it sets up pressures and opens opportunities for successive "ripples" of change in other parts of the system. Such pressures may be manifest in successive bottlenecks at different stages of production as management strives to realize the full potential of an innovation. Alternatively, the adoption of an innovation at one stage of the process may impose more severe requirements for quality and uniformity on earlier stages. As a third, and more favourable possibility, the initial innovation may create or unblock a variety of possibilities for profitable change at other points in the production process or, equally important, obviate the necessity for costly or difficult adjustments that would otherwise be necessary".

per unit of output compared to some theoretically constructed "efficient production function" (1) The reason we cannot be satisfied with this unidimensional approach is that the empirical evidence about technical changes in the Rosario plant shows plainly how technical changes have been directed to many other objectives besides unit cost reduction - and this immediately suggests that, for the Rosario plant, it was more "efficient" to apply its "technical change effort" to changing several parameters of plant output and perfomance rather than just aiming to reduce the unit costs of its existing products.

This whole argument can be pushed further. Suppose that we profile the distribution of th technical change effort in a plant in terms of the percentage of the investment funds dedicated to each one of the various objectives of technical change which we have come across, e.g. X% dedicated to unit cost reduction, Y% to product quality improvement, Z% to changing the product mix, etc., then there is every reason to believe that different plants will have different XYZ profiles, depending on their particular circumstances, as well as on the influence on the choice of 'technical change strategy' exorted by the plant's management. Each plant's XYZ

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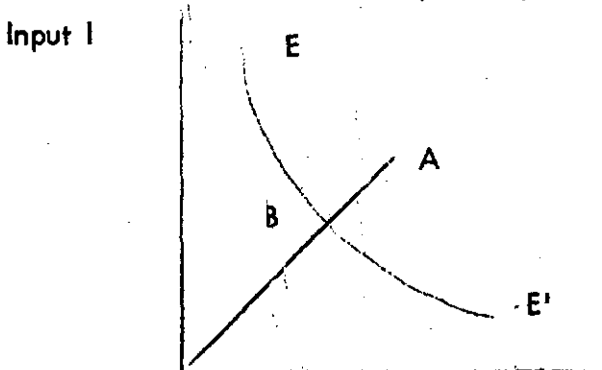
(1) The concept of the "technical efficiency" of a productive unit was put forward by Farrell in 1957, and is described in S. Eilon, B. Gold and J. Soesan, Applied Productivity Analysis for Industry, Pergamon Press, 1976, p.12, as follows: "Suppose a production system produces a single output from two inputs; the locus of all points of the most efficient way or producing a given output from combinations of the two inputs is called the "efficient production function" and is shown as line EBE' in Fig. I.3. All points on this curve are said to be equally efficient, while point A is said to be less efficient, since it requires more inputs than, say, point B for the production of the same output. The ratio OB/OA may then be regarded as a quantitative measure of the efficiency of a system operating at point A."



profile may also bd expected to evolve over time as previous technical changes are digested and as new pressures and opportunities for technical change arise. Hence it is easy to see that even two plants which start off identical are likely to grow apart -- as different external circumstances and different internal pressures and preferences will generate different "XYZ profiles" of technical change in each plant (1). Each 'round' of technical change is then likely to differentiate the plants still further from each other and it is perfectly possible to imagine that after several 'rounds' of technical change the first plant might be notably closer to the "efficient production function" than the second (where this production function refers to input requirements per unit of the original output), while the second plant has concentrated on diversifying its product line and may be a far greater economic success than the first plant.

This argument shows that we will need to consider carefully the question of how to measure the 'technical change effort' in steel plants, and how to devise valid methods of comparison between the 'technical change effort' in one steelplant and that in another given the reality that the objectives of technical change may be multiple and that each particular steel plant is likely to have been pursuing a distinct combination of these objectives.

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(1) In practice, as Katz has pointed out, it is most unlikely that two plants ever even start out identical. Different local conditions in terms of site, raw materials, markets, labour skills, product perfomance criteria, etc. always require some adaptations of construction, process and product design, even if the intention is to make one plant an exact copy of another. Thus 'identical' plants are already differentiated before their start-up. See J. Katz Creación de Tecnología en el Sector Manufacturero Argentino, Grupo BID/CEPAL, Monografía de Trabajo No. 1, CEPAL/BA/100, 10 de mayo de 1976, pages 6 to 8.

In this case study, the contribution we can make in this direction is basically to report as accurately as possible on the multi-dimensional nature of the technical change process in the Rosario plant. In the process, we hope to discover which measures of technical change appear to be useful in describing the process in Rosario, and these measures should, in turn, be suggestive of the measures that could be useful in other steelplants where similarly diverse objectives for technical change prevail.

Changes in the output-mix produced by the Rosario plant

The next topic to be explored is how the output-mix produced by the Rosario plant has evolved in the period 1943 to 1976. We touched on this topic earlier when we pointed out that one of the most significant aspects of the overall evolution of the plant has been the growth in the 'sophistication' of the product mix which it produces. For example whereas the plant started out in 1943 producing plain mild steel reinforcing bars, plus small quantities of square section bars - the end products produced by the plant today include three different basic varietes of reinforcing bars, plus a range of profiles and a range of forging bars. Also, whereas the plant in 1943 produced only common grades of steel, the steelmaking units of the plant today are capable of producing a wide range of steel grades including high carbon and even alloy steel grades. Finally, so far as billets are concerned, whereas the plant in 1943 did not produce these at all, today the plant's billet mill is equipped to roll billets (and blooms and slabs) in many different dimensional sizes and in a wide range of steel grades.

These examples are sufficient to give a broad idea of the importance of the changes in output-mix in the evolution of the Rosario plant. Our purpose now will be to explore this phenomenon of changes in the output-mix of the plant in more depth, to see what connections we can trace between these output- mix changes and technical changes.

The evidence which we are able to draw on about changes in output-mix relates, first, to the various end-products of the bar and profile mill; second, to the products of the billet mill (essentially billets); and third, to the end-products of the steelmaking operations of the plant (ingots). So far as the end-products of the bar and profile mill are concerned, we have got useful information about changes in the 'basic' product mix of the mill (i.e. about changes involving the production of new classes of products on the mill and about shifts in the proportions by weight of the various classes of products produced).

In the case of ingot output, we have information on changes in the proportion of common steel grades to special steel grades produced, and some information about changes in the dimensions of ingots produced.

In the case of billet output, we have some limited information mainly about dimensional changes.

Finally, to help in the interpretation of the relation between these output-mix changes and technical changes, we are able to draw on our information concerning technical changes introduced into the steelmaking operations, billet mill, and bar and profile mill.

We now present and discuss all this evidence:

i. Changes in the output-mix of the Bar and Profile mill:

To start with we shall examine the changes in the product-mix that have occured in the Bar and Profile mill. In particular we shall be concerned with the changes in the 'basic' product-mix - that is, with changes in the percentage by weight of each of the different classes of product defined only in terms of their basic shape and function. By contrast, we shall not here be exploring the changes in the steel- grade product-mix and in the dimensional product mix for each different class of product produced on the mill. Thus the remarks that follow relate only to changes in the mill's basic product mix. It turns out that the changes in the Bar and Profile mill's basic product mix constitute an extremely interesting story of product diversification.

The mill started off in 1943 producing practically 100% of plain reinforcing bars, plus small quantities of square bars. The first significant diversification came in 1948, when a further five 'stands' were added to the mill so that it could produce wire rod in addition to reinforcing bars. (This wire rod was then processed in the plant on newly installed wire-drawing machinery or nail-making machinery into either wire or nails). Also prior to 1950 small quantities of round foundry bars were added to the product mix. Then, in 1951, when production started up in Acindar's new plant in Villa Constitución, the production of many of the dimensions of reinforcing bars and wire rod was shifted from the Rosario plant to the new plant, leaving the Rosario plant producing only relatively low tonnages of the product that remained. This situation helped motivate the further diversifications made by the mill in the early 1950s into the production of industrial round bars (started prior to 1954-55) and into the production of profiles (as from 1955-56). Two years later, in 1957-58 a new type of reinforcing bars, "ridged" reinforcing bars were added to the product mix alongside the plain reinforcing bars, and in 1967-68, the production of the even more sophisticated "ribbed" reinforcing bars was begun (using an Acindar patented rib design). (The production of wire-rod, meanwhile, had been withdrawn from the product mix). By the late sixties, therefore, the product mix produced by the Bar and Profile mill involved plain, ridged and ribbed reinforcing bars, profiles (mainly angles and L-shapes, and foundry and industrial round bars). This product mix was maintained until approximately 1972-73. In that year - which for reasons we shall examine later, involved a drastic drop in the output level of the mill -, the product mix was substantially altered. A new diversification was carried out, into the production of special forging bars and billets for the automobile industry, and the production of foundry and industrial bars was dropped. Finally, it is worth mentioning that a further, future diversification is planned for the mill which would adapt the mill to incorporate the production of semi-alloy round bars of diameters Ø 6mm to Ø 10 mm into its product mix.

This evidently represents an extensive and continued history of product diversification throughout the life of the mill. Indeed it can be deduced from our above description that no less than 14 different classes of products have been produced on the Bar and Profile mill since 1943 (1) and that the average rate of launch of classes of new products by the mill has been approximately

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(1) We calculate this figure of 14 products on the basis that the mill has produced at least 4 kinds of profiles (angles, L-shapes, T-shapes, U-shapes) and at least 3 kinds of ribbed bars (A 60, Criss-cross, A 60 modified).

one class of new product every two years. (Furthermore, within each class of product, one must remember that the mill has produced various different dimensions and grades).

Thus, diversification is evidently a central feature in the evolution of the Bar and Profile mill and raises many issues of interest for our study. We shall now briefly deal with two. The first issue that particularly interests us here is -- what has been the role and extent of technical changes in bringing about these successive product diversifications?

The second issue is -what are the factors that have led to this pattern of product diversification? We shall now comment briefly on both issues.

So far as the first issue is concerned i.e. clarifying the contribution of technical change to the successive product diversifications, we can note that the launching of each new class of product produced by the mill has necessarily involved certain kinds of technical changes. These include, at a minimum, (i) the design and fabrication of new rolling cylinders with new channel-designs corresponding to the new class of product to be produced; and (ii) the development of a specific new 'standard operating technology' for producing the product, which involves such matters as determining the size and type of billet inputs, the temperature and timing of the passage through the reheat furnaces, and the particular rolling sequence involved. It also requires making whatever minor mechanical and equipment additions may be required for twisting, managing and guiding the new product in its passage through the mill stands.

Second, if we go beyond these technical changes, which must be carried out when any new product is produced by the mill, we can note that some of the new products have also require substantial prior additions or modifications to the mill's basic equipment, i.e. they have required substantial investment. This was particularly the case for wire-rod, which required an extra block of five mill-stands to be installed, and for the production of forging bars, which required the building of two variable speed pre-finishing and finishing stands with special bearings and other features designed to make for great precision in the rolling operation. Again, considerable additions to the mill's basic equipment will be required if the proposed future diversification into the production of small diameter semi-alloy round bars is carried out.

The conclusion is that whilst all the product diversifications have required investment in technical change, some of the diversifications have required only minor additions to the basic mill equipment, whereas others have needed substantial investment in additional or new equipment. It is therefore clear that the pattern of investment in product-diversifying technical change has been highly variable throughout the life of the Bar and Profile mill, even more variable than the rate of diversification itself.

The second issue we take up here concerns the reasons leading to the observed pattern of diversification. There seem to have been at least two major factors involved, the first being changes in the structure of demand, and the second being the inter-relationships between the Rosario plant and the Acevedo plant.

The influence of changes in the structure of demand can be most clearly seen with regard to reinforcing bars. Originally the mill only produced plain reinforcing bars, but once ridged reinforcing bars had been introduced into the Argentine market, the demand for plain reinforcing bars began to decline --since ridged reinforcing bars reduced the quantity of steel required to supply the required reinforcement properties, and therefore lowered the cost to the constructor. Later on, the same became true of certain kinds of ribbed reinforcing bars in particular applications. Hence, threatened with a decline in the demand for its 'classical' product - i.e. plain reinforcing bars, the Bar and Profile mill of the Rosario plant was able to maintain (and increase) its production levels by diversifying into the production of the substitute products, i.e. ridged and ribbed reinforcing bars. This process can be seen clearly in the chart opposite which shows the quantitative changes in the mill's product mix between the 13th Exercise (1954-55) and the 28th Exercise (1969-70).

In particular the chart clearly shows (a) the sharp fall over time in the percentage of plain reinforcing bars produced (88% to 20%); b) the notable rise in the percentage of ridged reinforcing bars produced (0% to 50%); c) the temporary substantial level of production which ribbed reinforcing bars achieved in the two years 1967-68 and 1968-69 (about 20%).

CHANGES IN THE PRODUCT-MIX OF THE BAR AND PROFILE MILL 1954-55 TO 1969-70

(The figures refer to the percentage by weight of each product-class produced in the year in question)

Exercise / Product		54-55 13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	69-70 28
Smooth round bars for reinforced concrete	%	88	76	66	79	73	65	67	68	35	38	40	43	36	28	19	20
Ridged bars for reinforced concrete	%	-	-	-	8	3	3	4	11	18	16	22	25	21	26	25	50
Ribbed bars for reinforced concrete	%	-	-	-	-	-	-	-	-	-	-	-	-	-	18	22	6
Industrial and foundry round bars	%	11	14	24	0	3	10	3	2	5	6	10	4	2	6	3	3
Profiles		-	10	10	13	21	21	26	19	42	41	28	27	41	19	31	21
Square and rectangolar bars	%	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Total of smooth, ridged and ribbed bars for reinforced concrete	%	88	76	66	87	76	68	71	79	53	54	66	68	57	72	66	76

These movements in the product mix for reinforcing bars basically reflect the growing sophistication of the demand for reinforcing bars - to which the mill's program had to respond. (The chart reveals other information too -particularly about the rise in the importance of profiles in the product-mix which we shall comment on below.)

The other major factor which has clearly had a very great influence on the pattern and timing of product diversification in the bar and profile mill is the coming on stream of rolling capacity in the Acevedo plant. The Acevedo plant's first Morgan mill started up with a capacity of over 200,000 tons per annum in 1951. A major extension of this capacity to 365,000 tons per annum was added in 1961-62. Then a second Morgan mill, specially for wire rod, was added in 1972-73. All three of these massive 'increments' in Acindar rolling capacity rebounded on the Rosario bar and profile mill, by making it profitable to transfer to the Acevedo plant the rolling of certain products that had previously been rolled in Rosario. The immediate result in each case was to leave the Bar and Profile mill with much of its capacity idle -as the reader can see by referring back to the graph showing the growth in the volume of output produced on the Bar and Profile mill.

On two of the three occasions when this happened, the Rosario plant responded by diversifying the production of the Bar and Profile mill. When the Acevedo plant started up in 1951 the response of the Rosario plant was to diversify the Bar and Profile mill into profile production; then, after the 1961-62 capacity increment in the Acevedo plant, there appears to have been no diversifying response made (mainly, we think, for the lack of billets with which to feed the Bar and Profile mill), and finally in 1972-73 the response was to diversify into the production of forging bars.

The key point which can be deduced from this experience is that the technical changes made to permit product diversification on the Bar and Profile mill have been important in permitting the mill to <u>maintain itself as a viable economic unit</u> in the face of changes in the structure of demand and of changes in technology. (This latter involving competition due to the coming on stream of the Acevedo plant's continuous rolling mills which were capable of producing many of the Bar and Profile mill's products at lower cost). In other words, in the case of the Bar and Profile mill we can interpret product-diversifying technical change as an important tactic for ensuring that the unit, when threatened by changing markets and rival technology, could broaden its product-mix to avoid becoming obsolete (1).

2. Changes in the output-mix of the Steelmaking section

To examine changes in the output min of the steelmaking section of the plant we will fix our attention on the output of ingots. The main changes involved over time are (a) changes in the dimensions of ingots produced, and (b) changes in the steel grades of ingots produced.

So far as changes in ingot dimensions are concerned, there was a major change from producing 150 kg. ingots (pre 1950) to producing 1 000 kg. ingots (post 1950). The practice today is to produce ingots of approximately 900 kg. A further change of some importance which took place in 1968-69 was to simplify the dimensional mix by removing 9 x 9 inch and 10 x 10 inch ingots from the production program, leaving only 11 x 11 inch ingots in the program

The question we can nowask is -to what extent were technical changes involved in

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(1) A hint of this kind of possibility was given by Salter when he noted that "The devices of imperfect competition -product differentiation, advertising and the emphasis on quality rather than price- may be regarded as attempts to make the fixed capital equipment of the firm mobile, an attempt to produce in a market where the competition is less intense" -see Salter, op. cit., p. 93. In the case of the Rosario plant it is not nthe "devices of imperfect competition" but technical changes to the "fixed" equipment which permitted the equipment to produce new products in more favourable competitive conditions.

ringing about these above mentioned changes in the simensional product mix?

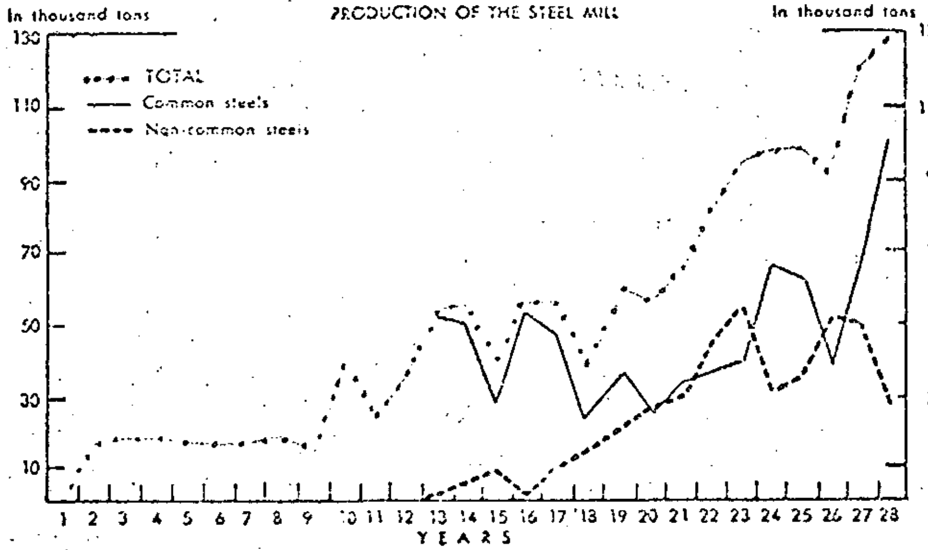
The answer is that technical changes were involved to a great extent. For example the hange over from 150 kg. to 1,000 kg ingots in 1950 involved shifting from an ingot casting ystem based on 'communicating channels' to a system of pouring the liquid steel directly into ne mouths of much larger ingot moulds, (i.e. a technical change). For the slightly less eavy ingots produced today, there has been a further change to a new system of communi-ating channels (1961-62).

On the other hand the dropping of the production of 9 x 9 inch and 10 x 10 inch ingots, annot be considered as a technical change.

The reason is that the criterion for seeing whether a change in output-mix involves echnical change or not is that the change must require the bringing into use of some new ethod, machine or technique not previously used in the plant. Once this new method, machine r technique is established and its operation has become routinized -then any changes in utput-mix which result from using this new mwthod, machine or technique either more often r less often are *not* considered as having been caused by technical change. Evidently, ien, the retiring-from-use of a method (such as in this case the use of 9 x 9 and 10 x 10 iches ingot moulds) does *not* constitute a technical change.

In terms of the reasons motivating the technical changes mentioned above it appears iat the change from 150 to 1,000 kg. ingots was carried out so as to increase the end-roduct rolling *capacity* of the plant (since the rolling of final products from billets made om 1,000 kg. ingots involves less down time and losses than rolling from 150 kg. ingots) whereas the second change, from 1,000 kg. to 900 kg. ingots, arose as a bye-product of multaneous changes designed to improve ingot *quality*. Hence in these two cases the changes i dimensional output mix appear to have been merely steps towards -or bye-products of-ie fulfillment of other objectives.

Next, so far as changes in the grades of steel produced are concerned, the following graph indicates how the production of 'special' steel grades has evolved over the years by com parison with common steel grades. (These 'special' steel grades refer mostly to carbon steels with grades from SAE 1017 to 1080 and also include a small fraction of alloy steels).



The graph shows that the production of special steels did not start until 1954-55, then remained on a small scale for five years or so, then rose rapidly to approximately half of total steel production in the years 1961-62 through to 1968-69, and finally fell back to a low propor tion of total steel output from 1969-70 onwards.

Once again, our question is, to what extent do these changes in output mix reflect the influence of technical changes? The broad answer seems fairly clear. The main technical changes which were required to permit the output mix to include a higher proportion of specia steels, took place early in the period of marked evolution of the output-mix, specifically between 1958 and 1962. The major changes were (i) the changeover from acid to basic refract lining in the Siemens Martin furnaces (1958-59); (ii) the introduction of automatic process controls for regulating the furnaces (1960-61); (iii) the bringing into use of improved laboratory techniques (1960-61); and (iv) major improvements in the ingot-casting section (1960-61) -particularly in the switch from top-poured to bottom-poured ingots which permitted the production of ingots of better surface and internal quality, which was required particularly for the special steel grades.

All of these changes required substantial investment, but once made, the output of special steels could be expanded without having to introduce further major technical changes. Indeed, after 1962, the only technical changes related to the steel grade output mix appear to have been minor changes in operative methods and techniques of chemical analysis, as required from time to time in the production of small runs of different alloy steels, e.g. Chromo-Nickel-Molybdenum steels after 1964, and Niobium steels in the period 1969-70.

If we enquire into the reasons motivating the changes in the steel grade output mix which we have been discussing, it appears that the 'proximate cause' of the increase in the output of special steels in the sixties was the need of the Acevedo plant to receive much large quantities of steel billets from the Rosario plant than before, with a high proportion of these having to be of special steel grades because they were destined for rolling into such products as high-resistance wire, (The 'shift' made by Acindar towards producing more products in special steel grades was in turn attributed by plant staff to the start-up of Somisa's steelmaking units in 1961, which it was believed would flood the market with mild steel products). In any event what matters for our purposes here is that the Rosario plant's steelmaking units were faced by a demand for special-steels --and were able to meet this demand by carrying out technical changes to permit the Siemens-Martin units, plus the ingot casting equipment to produce a more diversified steel grade product mix, including special steels as well as mild steels. Like in the Bar and Profile mill, it is clear that technical change permitted the steelmaking units to "break out" beyond pre-existing production lines, into new ones.

The changes we have noted in the billet product-mix consist of (i) changes in the steel grade product-mix (ii) changes in the dimensional product mix. We shall consider each in turn.

The mix of different steel grades of billets produced on the Billet Mill has largely followed the mix of steel grades of the ingots produced in the steel-making section, since these ingots have always been the principal input to the Billet Mill. Then, added to this mix of steel grades based on rolling the ingots from the Rosario Steelmaking section, the Billet Mill has often rolled small quantities of ingots or blooms of different steel grades from Acindar's Marathon plant, or from outside suppliers.

Hence, the principal 'technical change' involved for the Billet Mill in introducing new grades of steel into its output-mix has been simply the change of inputs. However, each change in the steel grade of the inputs being rolled also requires some hat different operating conditions in the Billet Mill. Furthermore, the shift in the early sixties to producing a higher proportion of special steel grades of billets, also led to technical changes in the Billet Mill's equipment aimed at improving product quality.

Thus shifts to producing new steel grades of billet in the Rosario plant required not only changes of inputs, but also some specific changes of operative technique in each case, -and in addition some more general improvements to the Billet Mill's basic equipment had to be made so as to ensure a sufficient quality of product. So, once again, we observe the crucial role of technical change in permitting product diversification.

We now turn to examine changes in the dimensional product-mix of the billets produced on the Billet Mill. Here, there have been important changes. The basic trend over time has been:

a) to increase the average cross-section of the billets produced.

b) to reduce the originally large number of different cross-sectional measures of billets produced, so as to concentrate most of billet production in a number of standard measures.

The advantage of this trend of change in dimensional product-mix is that wider cross-section billets require fewer passes through the mill and can therefore be rolled in less time, whilst fewer billet measures implies less downtime for changing the rolling cylinders. Hence, the changes in the dimensional output-mix over time in the Billet Mill have had the basic effect of increasing the capacity of the Billet Mill.

The connection between these changes in dimensional product-mix and technical changes is two fold: Firstly, there had to be concurrent technical changes in both the Morgan Mill of the Acevedo Plant and the Bar and Profile Mill of the Rosario plant, which permitted these rolling mills to accept a larger proportion of Billets of large cross-section. Secondly, modifications were needed in the Billet Mill itself so as to strengthen the equipment so as to withstand the rougher treatment involved in rolling greater numbers of ingots of larger cross-sections.

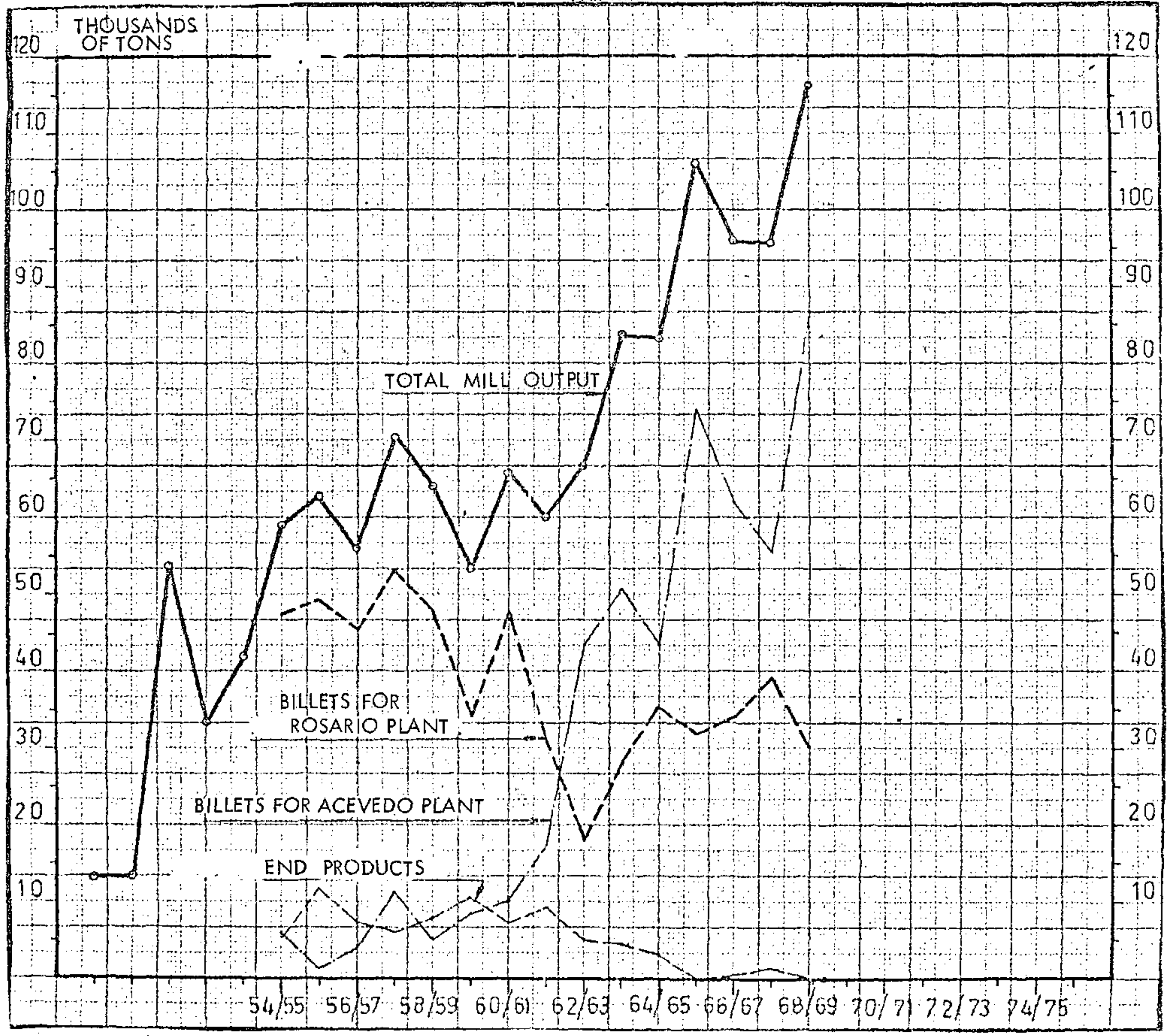
The point about these technical changes is that whilst their immediate purpose is to permit a change in the dimensional mix of billets produced, they also result in increasing the productive capacity of the billet mill - and there is yet a further effect in that the use of wider cross-section billets in the final rolling mills also increases the production capacity of these latter mills. Thus changes in the dimensional mix of billets produced can really be viewed as a technique for increasing billet production capacity and end-product production capacity.

We finally take a brief look at the reasons leading to these above-mentioned changes in the output mix of the billet mill. Without doubt the changing requirements of the Acevedo plant stand out as the single most important factor. The chart overleaf shows how in 1961-62 the Billet Mill abruptly had to shift the majority of its billet output to the Acevedo plant instead of sending it on the Bar and Profile mill of the Rosario plant, as it had done before. This is because the Acevedo plant, ever since 1961-62 was short of billets for its rolling operations. Therefore, the Rosario plant was required to do its best to make up the deficit. This naturally led to a great incentive to increase its output of billets. Hence it was the requirements of the Acevedo plant, both for more billets, and for billets of special steel grades, that mainly motivated the technical changes in the billet mill in the early sixties. Then, when the need of the Acevedo plant for special steel billets from the Rosario plant declined, the basic requirement for 'more billets' (of common steel grades) remained. Thus it can be said that the Billet mill has had an incentive to increase its output of billets each year since 1961-62.

The other source of technical change in the Billet mill has been the changing requirements of the Bar and Profile mill. In particular we can mention that the 1972-73 diversification of the latter into the production of forging-bars generated the need for a supply of forging-billets from the billet mill. This in turn led to the development of a special "double-rolling" practice to convert the ingots (from the Marathon plant) first to blooms and then to billets on the Billet mill. This can be considered as a product diversification made necessary at the intermediate products stage by a diversification at the final products stage.

The conclusions we can derive from the above evidence -which applies both to the Steel-making section and Billet mill, is that technical changes which alter the output-mix of intermediate products in the Rosario plant have been directed at two objectives. Firstly they have been directed towards final output diversification (e.g. via producing different steel grades at a suffici

ACEVEDO PLANT, BILLETS DESTINED FOR THE ROSARIO PLANT, AND END PRODUCTS PRODUCED DIRECTLY ON THE MILL



quality level which could serve as the inputs for the diversified final outputs. Second they have been directed to increasing productive capacity, both that of the units themselves (e.g. Siemens Martin furnaces, Billet mill), and that of the productive capacity of the end product rolling mills to which the billets go as inputs.

Summary

The evidence presented on the changes in the output mix of the Bar and Profile mill, Billet mill and Steelmaking section of the Rosario plant shows that

(1) Product diversification has been very frequent in the history of the Bar and Profile mill, as a method of responding to both demand changes and competitive technology. Some 14 classes of new products have been produced on this mill throughout the last thirty three years -- and the ability to diversify into these new product lines has depended in every case on technical change. While the majority of the new classes of products have not required major investments in new plant facilities, all the diversifications have required some investment plus the development of a new standard operating technology. In some cases, major investments in new equipment have been required.

(2) Changes in the output mix at the intermediate products stage have also been very significant. These changes consist in changes in the dimensional mix of the intermediate products produced, and changes in the steel grade mix. Associated with this latter set of changes are quality improvements. The changes in the dimensional mix, particularly of the billets produced, have had the effect (and were intended) to increase billet making capacity, which became urgent in the 1960s to make up for the shortage of inputs to the rolling mills of the Acevedo plant. The changes in steel grade product mix, both of ingots and billets, correspond to providing changed inputs suitable for the end-product diversification, being carried out either by the Acevedo

lant or by the Bar and Profile mill of the Rosario plant. Technical changes were required in ie Steelmaking section and Billet mill for making these dimensional and steel-grade changes ossible - and in the case of the changes needed for producing more special steels in the steel- aking units substantial investments were required.

3) We noted that both changes in market demand and the three major increments in production apacity in the Acevedo plant had been of decisive importance in leading the Rosario plant to lter its product-mix (both at the end product and intermediate product stages) in the way observed.

Data on the growth in production capacity of the Rosario Plant

So far, we have investigated the growth of the output level of the three principal plant sections and also the changes that have occurred in the output mix of these three sections.

Here, our intention is to explore the changes that have taken place in the production capacity of these sections.

To start with we make some brief remarks on the subject of production capacity and how it is defined.

Then we turn to an exploration of the growth in production capacity of the three plant sections based on evidence collected from the Rosario plant reports, other company documents and interviews. The growth in the production capacity of each of the three sections is dealt with in turn, and the attempt is made to distinguish the size of the contribution of technical change to this growth in capacity and to identify where possible the distinct kinds of technical changes tha have contributed.

Finally, once this evidence has been presented and discussed, we comment on the findi and relate them to some other contributions in the economic literature concerning capacity-incre ing technical changes.

Remarks on production capacity and its definition

The key concept involved in production capacity figures is that they refer to estimates of the quantity of specified output (measured in suitable units) which can be produced by a specified industrial unit (e.g. a machine, a section of a plant, a whole plant, etc.) in a specified time period, and under specified working conditions.

The particular assumptions made about working conditions are crucial to know if one wishes to make use of capacity estimates either for predictive purposes (to forecast what the uni ill actually produce under the expected working conditions), or for interpretive purposes (i.e. compare successive capacity figures across time or to compare actual production figures with e capacity estimates to see what the causes of the differences were.) Quite commonly, one omes across 'theoretical' capacity measures where some frankly unrealistic assumption has been ade about working conditions - such as for instance, that machines will be operating without ny stops for maintenance or repairs, or where actual bottlenecks in complementary installations e ignored. However, it is perfectly possible to develop, on the basis of past experience with the erformance of a production unit, and on the basis of the standard operating practice developed r running the unit, reasonably accurate estimates of what Gold has called the "practically stainable capacity at present " rather than "some theoretical maximum under temporary contions or in the future". (1) Indeed, as Gold also points out, most plant managements have had

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) It is useful to quote in full the passage of Gold's from which this extract was taken. "In theory, the precise measurement of productive capacity can be made extremely difficult if such efforts seek to encompass all kinds of imaginable but uncommon circumstances. The development of managerially useful estimates of practical capacity, however, involve less formidabld difficulties than is commonly supposed. This is specially true under the following conditions: l. if the measurement is focused on individual plants rather than on the economy at large or on major segment of it; 2. if the measurement is focused on practically sustainable capacity at present rather than on some theoretical maximum under temporary conditions or in the future; 3. if the estimate is made on the assumption that product design and quality, operating processes, and the general character of inputs remain unchanged; that the customary number of shifts and the normally acceptable length of work day and work week are retained; and that appropriate standard allowances are made for breakdowns, repairs and maintenance; 4. if it is assumed that sufficient labout, materials and other inputs are available to service the full utilization of present capital facilities; and 5. if it is assumed that product and factor price adjustments are such as to press for the efficient utilization of all serviceable resources. Such limitations are readily applicable to a wide range of productive activities. And if complied with, they permit the estimation of practically sustainable productive capacity with but moderate margins of uncertainty". ..."Of course, capacity estimates would have to be modified to allow for any deviations from the conditions listed above". See Bela Gold 'Productively Measurement Problems and Methods', Chapter 3 of S. Eilon, Bela Gold and J. Soesan, Applied Productivity Analysis for Industry, Pergamon Press, Oxford 1976, pp 48,49.

to develop such estimates because they are needed for such matters as production planning, and the estimation of production and cost standards. In this sense the Rosario plant is no exception, and its Industrial Engineering Department has an impressive amount of data on the current productive capacity of the plant's units.

We are, however, interested in the historical growth of capacity in the Rosario plant, and the data on this, particularly going back before 1970, is extremely partial and scattered abo We have however managed, with the aid of various of the Rosario plant reports, and various other documents and evidence from taped interviews to reconstruct some of the features of the growth of capacity which has taken place in the Siemens Martin furnaces, the Billet mill, and the Bar and Profile mill, and to extract from this reconstruction some interesting conclusions abo technical change. The way we have calculated 'production capacity' for each of the three sections ; - and the limitations of the data are explained in the course of the presentation which follows:

1 . Growth in the production capacity of the Siemens Martin furnaces

The Rosario plant today has three Siemens Martin furnaces. The first was installed and started up in 1943, the second was installed in 1949 and begun production in 1950, and the third was installed and started up in 1963.

These three furnaces are essentially identical. The first was originally designed to pro approximately 25 tons of ingots per heat (batch) but was enlarged in 1949 to equal the second furnace then being installed, with a capacity to produce approximately 35 tons of ingots per h The third furnace, when installed in 1963 was designed with the same load carrying capacity as the other two, i.e. again approximately 35 tons of ingots per heat. The dimensions and design o the furnaces, the refractories used in them, and practically all the essential details as well as t form of operating the furnaces can be considered as the same.

The fact that the three Siemens Martin units can be considered the same and that they ave had the same technical changes incorporated with the passage of time simplifies the problem e have to deal with, since we can work with the average capacity per furnace throughout the whole eriod from 1943 to the present day rather than having to track the capacity of each furnace eparately.

We now explain a) some of the features of the data, and b) the method we have used to race the growth in the capacity of these Siemens Martin units.

The first point is that the data available to us does not contain estimates for the changes n capacity of the Siemens Martin furnaces from year to year in which all the relevant factors which we would ideally like to be held constant, such as input quality and product mix, are actually held constant from year to year.

Instead what we have got is data about the actual realized production of the furnaces in ons from year to year together with the number of days for which the furnaces were actually operating, plus figures for the days not worked at all, and figures for the number of 'heats' of steel produced per year.

This data enables us to calculate for the Siemens Martin furnaces what we shall call their "actually realized capacity" under the particular working conditions which prevailed during the year in question. We shall now explain precisely what we mean by 'actually realized capacity', nd then we shall explain some of the problems involved in making use of the concept.

To begin with, it is important to distinguish between i) the total number of hours worked in ny particular plant or section called the sectional hours, and ii) the number of hours during which the section's equipment is actually operating, which we shall call operating hours. In any izeable period such as a year the sectional hours will always exceed the operating hours because of the time when the machines are 'down' either for planned maintenance and repairs or because of unforeseeable breakdowns which are not considered part and parcel of regular operating practice. Based on this distinction we can now define two actual realized 'capacity' figures: these are C_{op}, the actual realized production in tons of product per operating hour, and C_{sec} the actual realized production in tons of product per sectional hour.

The first obvious limitation of applying these definitions to historical production data so as to get estimates of historical capacity is that they will only be good indicators of the then-sustainable productive capacity of the units concerned (for the particular input mix used and product mix produced) if it is assumed a) that sufficient labor, materials and other inputs were available to service the full utilization of the units during all the operating days of the year in question, and if b) the number of days in the year during which the units were down was not exaggerated by any unusually prolonged breakdowns nor sharply diminished compared to standard practice, for some special reason. In other words the disadvantage of using this method for estimating capacity is that the estimate may be way off-beam if special circumstances caused the years production figures to be specially high or low compared to sustainable standard practice.

The second problem which arises is that if the input mix and product mix change appreciably from year to year then the time series of C_{op} and C_{sec} will not only reflect any changes made in the performance of the units themselves or in the standard operating practice for the units, but will also reflect changes due to the changed input mix or product mix, thus making any change in capacity more complex to interpret.

Fortunately, in the case of the steelmaking units of the Rosario plant there is good reason to believe that at least in the years following 1961-62 every effort was made by plant management to fully utilize the units and keep them serviced with all the inputs they required (1) so that the figures for C_{op} can be taken as accurate capacity estimates. As for the problem of 'unusual'

(1) The Annual Reports for the period make constant mention of the striving to increase the output of these furnaces.

ears so far as maintenance is concerned- what we can do is to report on the number of days ctually spent on this so as to see if any particular year emerges as an 'odd man out'. Hence the irst limitation mentioned above in connection with using 'average realized capacity' estimates o es not seem to peso big problems in our case.

The second limitation - i.e. the possibility that variations from year to year in the input ix and output mix of the units will make a time series of 'average realized capacities' difficult o interpret - does pose a problem in the case of the Siemens Martin furnaces. However, as we hall see, the availability of some data about the type of variations experienced in input mix and utput mix does enable the problem of interpretation to be mitigated.

Let us now turn to the data: the basic data from which the realized average capacity igures are derived is simply.

1. the weight in tons of total ingot production in the year in question. (we will represent this as 'Q'.)
2. the number of Siemens Martin furnaces operating during this year. (we will represent this as 'n' .)
3. the number of operating days in the year i.e. 365 days less the average number of days when each furnace was not operating through holidays or strikes ('H') less the time when each furnace is down for general repair ('R' days). We will therefore represent the average number of operating days per furnace as 365 - H - R.
4. the number of 'sectional' days per year (365 - H)

Given that data is available on Q, n, 365 - H - R, and H for several different years, is enables us immediately to calculate C_{op} , the average realized capacity per fornace operating our and C_{sec} , the average realized capacity per fornace sectional hour, by making use of the rmulae $C_{op} = \dfrac{Q}{n(365 - H - R) \times 24}$ and $C_{sec} = \dfrac{Q}{n\,(365 - H) \times 24}$

The plant reports also contain information on the total number of heats of steel made in each year. This means that $\overline{X}$, the average number of heats produced per furnace operating day can be calculated, and thus the average weight of ingots produced per day, $\overline{W}$, can also be deduced. Evidently $C_{op} = \frac{\overline{X} \cdot \overline{W}}{24}$, so the data on $\overline{X}$ and $\overline{W}$ will enable us to analyse the extent to which each has contributed to the observed increases in C_{op}.

The data we have compiled on all these variables is displayed in the table on the next page.

The Table shows that between 1944 and 1972-73, the realized output capacity per furnace per sectional hour, i.e. C_{sec}, rose by approximately 166% from 2.20 tons to 5,86 tons of ingots per sectional hour.

This was caused both by a 130% increase in the realized average output capacity per furnace operating hour (which rose from 2.75 to 6.32 tons per operating hour) coupled to a 14% increase in the 'availability' of the Siemens Martin furnaces,(which rose from 79% to 93% measured in terms of the ratio of operational to sectional hours).

The Table also shows that the greatly increased average capacity per furnace operating hour has been achieved mainly by speeding up the cycle of operation of the Siemens Martin furnaces in various ways, although there has also been a contribution (at least in the years from 1964-65 to 1972-73) achieved by increasing the average weight of ingots that can be produced per heat (i.e. by packing more tons of scrap into the furnaces).

As for the increased availability of the Siemens Martin furnaces this has been due mainly to the greater rapidity and with which repairs and maintenance of the furnaces have been undertaken compared to earlier years.

However, before concluding that all these important increases in capacity have been caused by improvements made to the process machinery or operating procedures (which is the natural conclusion), we must first be sure that the increases are not partly due to such matters as a hanged product mix or improved inputs. The problem of changing product mix we can dismiss airly quickly. The only change in product mix which can affect the capacity of the Siemens /artin furnaces is when special steels are produced instead of common steels. To make a heat f a special steel usually involves more care and slightly more time at the refining stage of the eactions. Thus the cycle time may be slightly longer - for instance by as much as half an hour. the case of producing 100% special steels instead of 100% common steels, the capacity per perating hour would, other things equal, fall by approximately 10 %. Given the pattern f evolution of the steel-grade output mix of ingots which we mentioned in the previous section, ny 'normalization' of our capacity figures to an all-common-steel base would mainly have the ffect of increasing the capacity figures we have quoted in the Table by between 5 and 10% in e case of the years 1960-61 to 1968-69. This normalization would not alter the basic pattern ve have observed in the table, although it might well help to clarify the real relation between rnace capacities in two successive years when the figures in the table show that they are close gether.

The problem of the changing quality of the raw material inputs is somewhat different. he chief point is that the average density of the scrap load to the steelmaking operations of the osario plant has shown a secular decrease between 1944 and 1972-73, and the quantity of various purities in the scrap has shown a secular increase. Both tendencies tend to reduce the quantity of ngots that can be made from 1 ton of scrap - and thus if we were to normalize our results as shown n the Table for the year to year variations (mostly declines) in scrap density and quality, this would ave the effect of increasing the capacity figures of the more recent years with respect to the arlier years. By leaving the figures un-normalized (for lack of the data with which to normalize hem) we are in fact understating the impact of the improvements that have been made in the

PRODUCTION CAPACITY DATA FOR THE ROSARIO PLANT'S SIEMENS-MARTIN STEELMAKING FURNACES 1944 TO 1972-73

Year/Period	No. of furnaces operating n	Quantity of ingots produced during the year Q tons	Total of heats per year	No. of days operated on average by each furnace $365-\overline{H}-\overline{R}$ days	No. of days of non-production due to holidays and strikes $\overline{H}$ days	Average No. of days of downtime per furnace for general repairs $\overline{R}$ days	Maintenance downtime per heat hours	Average No. of heats produced per furnace operating day $\overline{X}$	Average cycle time per heat $\overline{K}$ hours	Average weight of ingots produced per heat $\overline{W}$ tons	Realized average capacity per operating hour C_{op} tons/furnace hour	Realized average capacity per sectional hour C_{sec} tons/sectional hour
1944 to 1949	1	18,000	800 est	270 est	20 est	70 est (7)	2.0 est	3.0	8.0 (8) est	22 (8)	2.75	2.20
1960-61	2	56,000	-	317 (6)	-	-	-	-	-	-	3.68	-
1964-65	3	93.235	3,661	27.4	7	30.6	0.60	3.73	6.43	25.46	3.95	3.62
1965-66	3	97,385	3,516	325.7	13	26.3	0.54	3.60	6.67	27.69	4.15	3.84
1966-67	3	97,511	3,488	331.3	7	26.7	0.54	3.50	6.86	27.95	4.08	3.78
1967-68	3	91,116	3,119	315.9	27	22.1	0.51	3.29	7.29	28.84	4.00	3.74
1968-69	3	118.374	3.882	295.4	7	62.6	1.14	4.38	5.48	30.50	5.57	4.59
1969-70	3	127.510	2.940	314.2	9	41.8	0.75	4.18	5.74	32.36	5.64	4.97
1970-71	3	-	-	-	-	-	-	-	-	-	-	-
1971-72	3	140,692	4,199 (3) est	312 (4) est	31 (5) est	22 est	0.39	-	5.49 est	33.5 (2) est	6.26(1)	5.85
1972-73	3	140.135	-	308 (4) est	33 (5) est	24 est	-	-	-	-	6.32(1)	5.86

Notes: All figures are either taken from or deduced from data in the 1968-69 Plant Report unless otherwise indicated, as per the notes below.

(1) Source: 1972-73 Plant Report

(2) Source: Internal document provided to the author by the Chief of the Rosario Plant's Steelmaking Dept. Refers to estimate made in October 1971.

(3) Based on dividing the quality produced in 1971-72 by the estimated average weight of ingots produced per heat calculated from source (2).

(4) Based on dividing Q by 24 x the figure for C taken from source (1).

(5) Based on subtracting from the numbers of working days (taken from source (1) the number of operative days calculated as per note (4).

(6) The figure of 317 days is quoted in the 1960 -61 plant report.

(7) Based on figure of 25 days per repair quoted in interview with Ing. Pujalo the designer of the plant, and assuming 1 repair every 300 heats.

(8) Estimates deriving from interview with Ing. Pujalo.

(est. signifies estimated figure)

Siemens Martin furnaces and their operative technology. Also, as in the cases of changes in product-mix, our not being able to normalise our data for year to year fluctuations in input quality means that we cannot put much reliance on the exact relation between capacities in successive years when the figures are close together.

In spite of these limitations, the Table does nevertheless provide valuable data about the development of the production capacity of the furnaces, and permits us to draw some interesting conclusions about the contribution made by technical change to causing this growth in capacity.

First of all we can make use of the Table to estimate the relative contributions made to increasing steelmaking capacity by Technical Changes versus Scale-Multiplying changes. We can do this by making some simple assumptions. These are:

1) That the new Siemens Martin furnace installed in 1949 came into operation with $C_{op} = 3.68$ (the average figure for C_{op} in 1960-61). This assumption is certainly overgenerous to the efficiency of the newly installed furnace but ensures that we will not overestimate the contribution made by technical change in improving it.
2) That the further new Siemens Martin furnace installed in 1963 came into operation with $C_{op} = 3.8($ (interpolating between the values of C_{op} in 1960-61 and 1964-65).
3) That <u>after</u> its installation and start up, all the improvements in C_{op} in each furnace can be ascribed to Technical change, but that the <u>initial increment</u> to the whole section's capacity made by each new furnace is ascribed to Scale-multiplying change.

Using these assumptions, the calculation goes as follows: The overall improvement in the capacity per operating hour of the whole section between 1944 and 1972-73 was from 2.75 tons operating hour to 3 x 6.32 = 18.96 tons/operating hour, i.e. the improvements was 16.21 tons/operati hour. This improvement is composed of a) the following increments due to technical changes -

.57 tons/operating hour on Furnace one, 2.64 tons/operating hour on Furnace two, and 2.52 ons/operating hour on Furnace three - making 8.73 tons/operating hour improvement in total due to echnical change; and b) of the following increments due to the installation of new furnaces i.e. 1.68 tons/operating hour due to Furnace two, plus 3.80 tons/operating hour due to furnace three, naking 7.48 tons/operating hour in total due to scale-multiplying change.

We therefore conclude that out of the 16.21 tons/operating hour increase in the capacity of the whole steelmaking section which took place between 1944 and 1972-73, 8.73 tons/operating hour of the increase was due to Technical change and 7.48 tons/operating hour of the increase was due to Scale multiplying change.

This shows that Technical changes have played the outstanding part in expanding the output capacity per operating hour of the steelmaking section - accounting for 54% of the overall increase in capacity compared to 46% due to Scale-multiplying change. Furthermore if we were to consider capacity per sectional hour, the balance would swing even further in favour of Technical changes because of the effect of improved maintenance techniques in increasing furnace availability.

A second use can be made of the Table. This involves trying to correlate what the Table shows about the quantitative growth in the production capacity of the steelmaking section with what has been learned about the actual technical changes introduced, as revealed from data in the Annual Reports, Plant Reports and interviews.

Inspection of this latter data shows that the following types of technical changes have all contributed significantly to increasing the output capacity of the Siemens Martin furnaces:

1. Changes designed to increase the useable physical volume of the Siemens Martin furnaces (e.g. reform of the No. 1 furnace in 1949).
2. Changes designed to increase the rate of charging of the scrap onto the hearth of the furnaces

(e.g. building of shaft furnaces in 1949, so as to charge one-third of the load to the furnaces in the form of 'hot metal'; improvements in the mechanization of the solid scrap sharging process, various dates; installation of special scrap presses, in 1960-61 and 1970-71 to densify the light scrap so as to increase the loadable-tonnage and loading rate).

3. Changes designed to speed the melt-down of the scrap in the furnaces. (e.g. introduction of hot metal, 1949; relining of the furnaces with basic refractories, in 1959-60, permitting the installation of high power burners in 1961-62).
4. Changes designed to increase the rate of the refining reactions in the furnaces. (e.g. the introduction of oxygen injection into the bath in 1967-68).
5. Changes designed to increase the 'availability' of the furnaces by reducing the 'down time' caused by routine maintenance and repairs. (e.g. the use of improved refractory bricks (various dates); the introduction of preventive maintenance techniques in 1964-65 and their intensification in the early 1970's).

The first point to make is that technical changes in Classes 2, 3 and 4 above are all designed to reduce the cycle time per heat of the steel produced - and inspection of the table shows that the reductions achieved in this cycle time account for the bulk of the overall capacity improvement achieved.

The second point we can make concerns the very substantial impact on capacity of two individual technical changes: the first of these was the introduction of shaft furnaces in 1949. We already know (from the evidence of the growth in the level of output) that the changes made in 1949 fundamentally the introduction of the shaft furnaces - caused a very big increase in furnac capacity to take place in 1950 - probably as much as 1 ton per sectional hour. Also the table show that another very important increase took place in capacity in 1967-68, amounting to approximate

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).85 tons per sectional hour - which was apparently mainly the result of the introduction of oxygen injection. By calculating the impact of these technical changes on the whole section it can be ;hown that about 40% of the total increase in capacity due to technical change noted during he entire period can be ascribed to just these two important technical changes. The other 60% eems to have been due to the cumulative effect of all the other technical changes, such as ncreased furnace volume, higher power burners, scrap densifying, greater furnace availability, :tc. Even if we allow for the considerable limitations of our data, and in particular for the erturbing effects of not having been able to properly take into account the variations in scrap nput quality, the fact remains that a very significant proportion of the increased capacity due to echnical change was produced by only two important technical changes. Equally, however, the vidence supports the notion that the cumulative effect of all the other technical changes has been f greater impact than that of the two most influential changes.

This completes our analysis of changes in the productive capacity of the Rosario plant's iemens Martin units. Its main results have been to demonstrate the major role played by technical hange in bringing about the great increase in the plant's steelmaking capacity which occurred between etween 1944 and 1972-73. We estimated that 54% of the increase in capacity per operating hour as been produced by technical changes as opposed to scale multiplying changes. We also re- iewed the different kinds of technical changes which contributed to this increase, noting the articular importance of changes designed to reduce the cycle time per furnace heat. Finally e noted that only two technical changes seemed to account for about 40% of the total increase of apacity due to technical change.

2. Growth in the production capacity of the Billet mill

The Billet mill of the Rosario plant was installed and started up in 1949. Today the mill stil operates with same motor as originally, and the changes made to it are claimed to have consisted of a progression of small improvements rather than any very substantial modernization. Yet, as we shall now see, the increases achieved in its production capacity have been remarkable.

Once again, in the absence of historical capacity estimates, we shall make use of a time series of actual realized production figures as the basis for calculating capacity. The time series available to us is 'actual realized production per sectional hour' on an annual basis from 1959-60 to 1968-69, based on a table in the 1968-69 Rosario plant report. To this we have added figures for 1971-72, 1972-73 and 1973-74 based on the production figures for those years and assuming that the same number of sectional hours were worked in these years as in 1968-69. Finally, we were also able to add a figure based on data in the 1954-55 annual report. The resulting series is shown in the Table below.

Billet Mill

Actual realized production / sectional hour

Year	Tons/sectional hour	Year	Tons/sectional hour
1954-55	8.3	1964-65	11.1
1959-60	9.1	1965-66	12.7
1960-61	9.2	1966-67	12.6
1961-62	8.8	1967-68	13.8
1962-63	8.9	1968-69	15.9
1963-64	11.9	1969-70	-
		1970-71	-
		1971-72	16.5
		1972-73	18.0
		1973-74	19.0

This table clearly shows a) the substantial overall growth in capacity achieved, (130% growth in capacity between 1954-55 and 1973-74); b) the almost zero growth of capacity in the period 1954-55 to 1962-63, compared to the average of 70% annual compound growth in capacity achieved from 1962-63, onwards; and c) that particularly large increases in capacity were noted in the years 1963-64, and 1968-69.

We shall now make use of some information about the technical changes introduced in the Billet mill to help interpret this table.

Firstly, Rosario plant personnel explain that the increases in the capacity of the Billet mill have arisen essentially to match the progressive increases in capacity achieved in the steelmaking section.

In line with this, we can note that when the steelmaking section greatly expanded its capacity in 1963-64 by adding a new Siemens Martin furnace, and when in 1968-69 steelmaking capacity was again greatly expanded (through oxygen injection), the capacity of the Billet mill was simultaneously expanded to match - thus generating the two exceptional years of increase which we noted earlier.

Next we can provide some information concerning the <u>sources</u> of the increases of the increases of the Billet mill's capacity.

One major source of the increase in the mill's capacity has undoubtedly been the <u>changes in the mill's product-mix</u>. These changes have two aspects. The first is that the production of billets of greater cross-section increases the tonnage per hour of billets that can be rolled. This is because the larger cross-section billets need fewer 'passes' through the mill cylinders in order to be reduced to the correct size, hence the cycle time for rolling each billet is reduced. The second aspect relates to the reduction in the diversity of the product mix. The fewer the different measures of product that have to be produced on the mill, (and the longer the production runs are for each product), then the fewer times will the mill have to be stopped for changing the rolling cylinders and resetting the controls on the machinery. Hence a less diverse product mix (and longer production runs too) have the effect of increasing the ratio of "actual rolling" hours to sectional hours, which is a major factor making for an increase in the mill's production capacity. Since - as we noted earlier - there has been a trend in the billet mill towards rolling a greater proportion of billets of larger dimensions, and to rolling a less diverse product mix, these trends must certainly have substantially increased the mill's production capacity.

A second important source of the increase in the mill's capacity has been the modifications made in all the manipulating and handling devices of the mill. These modifications have been aimed at speeding up the handling of the product in between successive passes - thus reducing the duration of the intervals when the product is not actually being rolled. This of course reduces the cycle-time, and increases the quantity of billets that can be rolled per hour.

A third important source of capacity increases has been the boosting of the 'availability' of the mill by reducing the down-time necessary for maintenance and repairs. This has been achieve by several methods which include i) the redesign of the successive product passes so as to minimise the strain involved in the rolling operation; ii) increasing the robustness of certain of the mill elements and handling devices; and iii) by the introduction of preventive maintenance techniques.

A fourth significant source of capacity increase has been the reduction in the 'losses' cause by reducing the waste generated in the sawing and cropping of billets, and by reducing the proportion of billets rejected as being of inferior quality.

Finally, we can mention that much of the increase in the mill's capacity achieved by these above methods could not have resulted in greater production without there also having been increases made in the capacity of the mill's reheating furnace. i.e. as the capacity of the rolling mill itself was increased, it became necessary to increase the capacity of the reheat furnace to match so as to prevent it from becoming a bottleneck.

The most noteworthy feature of all these capacity-increasing changes is that they can all be considered as changes of the "incremental" type, not involving large investments in relation to the investment in the whole mill. Yet taken together they have resulted in a most impressive increase in the mill's capacity.

3. Growth in the production capacity of the Bar and Profile mill

We come, now to examine the growth in the production capacity of the Bar and Profile mill. Data on this is more limited than that which was available for the Steelmaking units and the Billet mill - and time series comparable to those exhibited for these other productive sections cannot be presented. Furthermore, it is not possible to take the realized annual production figures of the Bar and Profile mill and then simply divide these figures by a hypothetical number of operating hours, or sectional-hours, to obtain capacity estimates, because we know that there have been very wide fluctuations in the number of shifts worked in the Bar and Profile mill over the years. (This is in marked contrast to the situation of permanent 3-shift or 4-shift operation worked in the Steelmaking section and Billet mill).

However, all is by no means lost! We have been able to calculate figures for the capacity of the mill for four years. These are 1954-55, 1960-61, 1969-70 and 1970-71. These figures which are shown in the table below, refer to the capacity of the mill in tons per rolling-hour. That is, the calculation of capacity counts only the time when the mill is actually in operation. All the down-time due to repairs, changes of cylinders, and stops during production is excluded from the calculation.

Capacity of the Bar and Profile Mill

Year	Production Capacity tons/rolling hour	
1954-55	9.9	(1)
1960-61	10.9	(2)
1969-70	11.2	(3)
1970-71	17.2	(4)

The story told by these figures is basically a very simple one, and it is borne out by the information we have on the technical changes introduced. What the figures show is a near zero r of capacity increase in the fifteen years between 1954-55 and 1969-70, followed by a dramatic increase in capacity achieved in just one year, i.e. 1970-71.

This ties up with our information which shows that the main technical changes made to th mill's basic equipment between 1954-55 and 1969-70 were concerned with improving the quality of the mill's products, rather than their quantity.

Sources of the figures quoted in the table.

(1) This is an actual realized production figure, divided by the total number of rolling-hours, based on information in the 1954-55 Plant Report.

(2) Ditto, based on the 1960-61 Plant Report.

(3) This figure is based on information derived from source (4), see below. It is a real capacity estimate not a realized production per rolling hour estimate like the first two. In order not to underestimate the capacity per rolling hour, we have assumed a standard of 15% of down-time hours for mounting and 10% down time due to halts in the course of production, compared to 10% and 5% for these factors, respectively, which is the standard quoted in source (4) for 1970-71.

(4) Calculated from information on production standards quoted in Oscar R. Amorini, Remodelació del Tren de laminación de perfiles pequeños y livianos, published in 'Laminación, tecnología, equipos, productos.' The product mix to which the capacity figure quoted above applies, is th same as the product mix for the year 1969-70.

The technical changes carried out in 1970-71, however, were primarily aimed at increasing the mill's production capacity. This capacity was standing at 70,000 tons per annum for the product-mix produced in the year 1968-69. The main aim of the changes was to boost this capacity to 120,000 tons per annum, for an essentially identical product mix, i.e. the aim was to bring about a 70% increase in the mill's capacity in one go.

One of the remarkable features of this project - whose objectives were completely achieved - was that the entire project was engineered and executed by the Rosario plant's own staff. (It therefore constitutes a splendid example of 'endogenous' technical change which we shall be exploring in more detail later in the paper).

However, here we can simply note that this important increase in capacity was achieved, as a result of technical changes which included a) the use of billets of greater cross-section and length as inputs b) the speeding up of the cycle-time in the mill via improved mechanization, better layout, and the installation of some new mill stands and motors, and c) the installation of a new reheat furnace of larger capacity. The key point is that technical changes were responsible for the very big increase in capacity achieved.

Comments on the findings

The above findings concerning the role of technical changes in raising the production capacity of the Siemens Martin units, Billet mill and Bar and Profile mill, will now be commented on.

In the first place, the sheer magnitude of the capacity increases achieved via technical change deserve mention. These amount to 166% on the first Siemens Martin unit installed, over 130% on the Billet mill, and over 70% on the Bar and Profile mill. These figures show that very impressive advances over the initial design capacity have been achieved in the Rosario plant in all three of these productive sections.

A second interesting feature of these capacity increases is that in most cases they have been achieved by means of technical changes whose principal objective has been to increase outpu - and not merely as bye-products of changes intended to reduce costs, improve quality, or diversify production. Indeed, so far as the Steelmaking units and Billet mill are concerned, the objective of increasing their capacity has been a persistent and leading objective in the plant in the entire period from 1962-63 onwards.

A third most interesting feature of these capacity increases is that virtually all of the technical changes contributing to them have been of the 'incremental' type - involving such matters as faster product handling, lowered down-time due to better maintenance, lowered wastage and product rejection rates, higher power inputs, changes in product mix, etc., where the common denominator has been squeezing more performance out of the existing units without modifying their conception or basic operating technology in any fundamental way. Only a very few changes, such as the installation of shaft furnaces for making hot-metal for feeding to the Siemens Martin furnaces, or the piping of oxygen into the metallic bath or the installation of extra mill stands in the Bar and Profile mill, can be considered to have produced a modification in the basic operating technology of the units concerned, or in engineering terminology, to have resulted in a significant change in 'design-concept'. In other words, not only have the capacity increases achieved in the Rosario plant's units been very substantial, but they have been largely achieved by technical changes of the 'incremental' type rather than by changes involving the incorporation of new design-concepts into the plant's basic technology.

These three findings - that the capacity increases achieved in the Rosario plant have been large, that they have been achieved as a principal goal in themselves and not simply as a bye product of other objectives, and that they have resulted very largely from 'incremental' technical change made to the existing equipment and procedures open up some extremely interesting perspectives concerning the need for broadening the traditional economic approach to technical change - as we shall now explain.

To begin with, it is interesting to ask - how common is the kind of capacity-increasing technical change which we have noted in the Rosario plant? Is it a rare curiosity, or is this kind of technical change important in other steelplants as well? While we cannot obviously pretend to answer this question empirically here, we can nevertheless mention some findings in the literature, which strongly suggest that this type of incremental 'capacity-stretching' technical change is both widely-practiced, and of great economic importance.

For example Ramirez and Blanco (1) point out that in Latin America "the necessity of increasing the production capacity of (the existing) blast furnaces is continually being proposed", and they cite the shortage of investment capital as a strong economic incentive for doing so. Even more to the point, they quote figures for the initial and actual production capacities of four different Latin American blast furnaces, and these show increases of 73%, 68%, 51% and over 100% respectively, achieved by such techniques as modifying the blast-furnace shell so as to increase the useful volume, increasing the strength of the air-blast, injecting hydrocarbons into the furnaces, better preparation of raw material and of coke, augmenting refractory life, more sophisticated

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(1) Gonzalo Ramirez and Rafael Blanco Aumentos en la productividad del alto horno, Siderúrgia Latinoamericana, No. 174, Octubre 1974, ILAFA, Santiago de Chile.

process control etc. These authors also state that "there still exists a good margin for increasing the pig-iron production of the existing blast-furnaces, adopting techniques which have not yet been generalized in the subregion".

Further evidence on the importance of 'capacity-stretching' comes from Rosegger (1) who in reference to oxygen steelmaking plants has this to say: "An additional element of expansion was provided by frequently remarkable increases in the rated capacities of existing plants, through a cumulation of smaller technological improvements and through 'learning-by-doing'. Upratings of ten to fifteen per cent over a five year span are not unusual."

These passages and much other evidence in steelmaking literature, show that the phenomenon of incremental 'capacity-stretching' technical change, which has played such an important role in the Rosario plant, is by no means a rare one but - on the contrary - is extremely widespread. In fact we can expect examples of capacity-stretching technical change to occur in <u>all</u> steelplants serving growing markets.

The next point to be made concerns the finding that the capacity increases made in the Rosario plant largely result from changes whose <u>main objective</u> was to increase output, rather than from changes whose key objectives were, for instance, to reduce unit costs. This is an important finding, because it suggests a large gap in the existing economic literature. The point is that the <u>overwhelming</u> tendency in the economic literature on technical change is to conduct the entire analysis in terms of cost minimization strategy. Whether the subject is choice of techniques, economies of scale, learning-by-doing, or the economics of replacement and scrapping

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(1) Gerhard Rosegger: <u>On 'Optimal' Technology and scale in Industrialization: Steel-making,</u> Omega, Vol.3, No. 1, 1975, Pergamon Press, Oxford.

lecisions, article after article and book after book sets up a theoretical system whereby unit production costs are the key variable to be minimized subject to differing constraints. Now, of course, we are not claiming that cost-minimization is not extremely important but in the Rosario plant it is plain that output-maximization was, in many years of the plant's life, a more dominant objective guiding management's decisions on technical change - and it is a very strong conjecture that this situation has also applied at many periods and in many situations, in other steelplants too. If this is the case - and the conjecture is eminently testable - then what is needed is for the economic analysis of technical change to expand beyond its present lop-sided concern with unit cost reduction so as to also take into account the importance of output-maximisation from existing facilities.

One author who has developed a more realistic framework for analysing technical change is Bela Gold, and we shall now mention briefly a feature of Gold's approach which is particularly relevant to furthering our discussion of the findings about 'capacity stretching' in the Rosario plant.

According to Gold "Managerial decisions in private industry obviously cannot be based on the minimization of total unit cost in view of the over-riding importance of the rate of profit on investment. A simple model relating such profitability to physical as well as financial aspects of performance may be developed as follows:

$$\frac{\text{Profit}}{\text{Total Investment}} = \left(\frac{\text{Product value}}{\text{Output}} - \frac{\text{Total cost}}{\text{Output}}\right) \times \frac{\text{Output}}{\text{Capacity}} \times \frac{\text{Capacity}}{\text{Fixed Investment}} \times \frac{\text{Fixed Investment}}{\text{Total Investment}}$$

This suggests that variations in the rate of profit on total investment are traceable to changes in, and interactions among: average product prices; total unit costs; capacity utilization; the productivity of fixed investment; and the internal allocation of investment between fixed and working capital". (1)

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(1) Bela Gold, Technology, Productivity and Economic Analysis, Omega Vol. 1, No. 1, 1973

The term in this above equation which particularly concerns us here is the term $\frac{\text{Capacity}}{\text{Fixed investment}}$ which Gold calls the 'productivity of fixed investment'. It is evident from the equation that management has a permanent interest in increasing - or at any rate maintaining as high as it can - its installed capacity per unit of fixed investment - always assuming that the efforts directed to increasing or maintaining this ratio are not offset by the interactive effects on the other ratios in the equation.

In fact the ratio i.e. capacity over fixed investment, can be expected to rise automatically in the years following major investments in new capital facilities as depreciation charges bring down the book value of the fixed investment whilst leaving the capacity of the facilities unchanged - however what concerns us here is the situation that arises when increases of capacity are being planned.

Whatever value the ratio of capital to (depreciated) fixed investment has reached the firm will be interested, other things equal, in having a small ratio of $\frac{\Delta C}{\Delta I}$ when it <u>expands</u> capacity. The main hypothesis of interest that can now be put forward is that $\frac{\Delta C}{\Delta I}$ for <u>incremental</u> 'capacity-stretching' technical changes is usually notably <u>higher</u> than $\frac{\Delta C}{\Delta I}$ for capacity expansions involving investments in new facilities or in carrying out non-incremental modifications to the existing ones. In other words, in simple language, it usually costs far less to achieve a unit of increased capacity by <u>stretching</u> the capacity of an existing plant than by building brand new extra units or engaging in extensive technical revamps of the existing ones.

If this is so - and it certainly appears to have been the case for the Rosario plant where most of the capacity expansion was achieved on a very limited budget - then the whole subject of the 'learning' which permits incremental capacity-stretching to occur takes on a new light. For this 'learning' if it did not occur - would have a very high opportunity cost to the firm in question.

The suggestion is, therefore, that this kind of learning deserves close-up analysis to letermine not only its nature and the conditions promoting its development, but also - and crucially - to evaluate its economic contribution to the plants in which it occurs. The underlying hypothesis s that the learning which leads to incremental capacity-stretching technical changes may turn out to be a very profitable activity indeed.

We can now sum up this entire discussion in a simple way; 1) Our findings about the growth in capacity in the Rosario plant show that very substantial increases in capacity have been achieved by technical changes of a mostly incremental nature which were specifically aimed at stretching plant capacity. 2) These findings point to the need to extend economic theory to cover the apparently large domain of incremental capacity-stretching technical change and the learning that gives rise to it.

Changes in product quality

The next subject into which we enquire concerns changes introduced in product-quality in the Rosario plant.

A change in product quality involves basically a change in the specification which delimits the upper and lower boundaries that certain parameters of the product must conform to. These parameters, which we earlier called the 'quality parameters', refer to such matters as the chemical composition of the steel composing the product, the dimensions of the product, the surface quality of the product, the degree of freedom from internal defects of the product, etc. It is usual to speak of an 'improved' quality of a steel product when the admitted range of variation in the chemical composition and/or the dimensional tolerance of the product is reduced, or when the acceptable level of surface or internal defects is reduced.

There exist in the steelmaking field, as in most other industrial fields, standards-making bodies which publish standard industrial product specifications, however while these are very important as guidelines the usual practice is for steelmaking companies to develop their own internal product-specifications which are subject to variations over time, and which may sometimes differ in more than minor ways from the standard specifications. The internal product standards reflect both the particular process technology used by the company and the markets being served by it, and also reflect the company's product-quality strategy.

In principle, to improve product quality implies taking two steps. These are (i) to improve the actual process technology employed in making the product, so that an acceptably high proportion of the output will conform to the stricter quality standards that have been set; and (ii) to revise the quality-control procedures in line with these stricter standards, so as to detect and reject those products falling outside the specification.

Technical changes are inevitably involved in the first of these steps - i.e. improving the process techonology employed in making the product. Furthermore technical changes may also be involved in the second step - i.e. the revision of the quality control procedures. This will be the case whenever such revision implies bringing into use new methods of chemical or physical analysis, or new inspection procedures.

So much for these introductory remarks about the meaning of changes in product quality and the steps implied by efforts to improve product quality. We now turn to exdmine the experiense of the Rosario plant in the matter:

The record of the technical changes introduced in the Rosario plant contains - as we mentioned earlier - many technical changes which had as their main objective to improve product quality.

Interestingly, it turns out, that many of the most important technical changes with this objective took place in a single year, 1960-61. By examining the changes made in this one year in some detail, some very interesting conclusions emerge, which shed useful light on the other quality-changes introduced later on by the plant. Therefore we begin our analysis by considering the year 1960-61.

The background to the 'quality' changes made in this year was that (a) the Rosario plant was planning to diversify its production away from its near 100% concentration on 'common' steels towards producing a high proportion of 'special' steel products, and (b) a German consultant had been called-in by the Director of the Rosario plant to advise on the changes that needed to be made. A major factor then influencing the desirable goals of technical change in the plant was that the special steel products to be produced would have to be manufactured to more exacting quality specifications than the common steel products. In particular it was desirable that the special steel products should have a much lower degree of surface and internal defects than was acceptable in most of the common steel products.

The consultant's recommendations, which were adopted, led to important changes both in process technology and quality control procedures:

These changes were as follows:

(i) the replacement of top-poured ingot casting by bottom-filled ingot casting, (which led to a great improvement in both the surface quality and internal quality of the ingots produced).

(ii)the switch from fuel oil to natural gas in the re-heating furnaces (with led to more uniform heating of the intermediate products and so to less internal defects).

(iii)the setting up of a new plant section known as the 'conditioning' section, where the 'scarfing' (i.e. the removing of the surface scale from) ingots and billets could be carried out, and where defects in ingots and billets could be detected and restified.

(iv)the more intensive control of the chemical composition and quality of the incoming scrap.

(v) the introduction of inspectors on the shop-floor in the steelmaking, ingot casting, billet rolling and final product rolling stages of production, to check on fidelity of the output with respect to the internal norms applicable to each successive process stage.

(vi)the strengthening of the personnel in the plant's laboratory, and the improvement in the equipment and analytical techniques used.

These, and other more minor changes, constituted what Rosario plant personnel remember as a veritable "campaign" for improved product quality instituted in this one year.

An important feature of this set of changes is that whilst they were clearly instituted so as to meet the quality requirements involved in product diversification (to special steels), the resulting process changes and superior quality control procedures also resulted in some improvements in quality of the line of common steel products as well.

This is because whilst some of the quality changes were "product-specific" (such as the use of the conditioning sector for some grades of ingots and billets and not others), other changes, such as the modifications in process technology the inspection of productions on the shop-floor, and the strengthening of the plant's laboratories, contributed to improving the quality of all the product range produced by the plant.

Thus, the 1960-61 experience suggests that the major technical changes introduced so as to improve the quality of a new class of products also had important "spillover" effects leading to the improvement in quality of the existing classes of products too.

Next we turn to examine the record of product-quality changes introduced <u>since</u> 1960-61. Here, three particular features stand out.

First there begun in 1964 a program of cooperation with Acindar's Marathon plant. This led to the Rosario plant producing small production runs of various alloy steels and since these required great care in their elaboration, Rosario plant personnel needed to absorb considerable new knowledge so as to be able to produce these new steels to sufficient quality. Here again we see the effect to product diversification leading to the requirement for higher quality standards in the production operation, and in quality control. It is not clear, however, whether these changes had any significant spillover effects on the rest of the Rosario plant's production, although we would certainly expect that there have been some.

Second, there was a major investment in 1966 in a new 'cooling bed' for the Bar and Profile mill. This was designed to contribute to a more uniform cooling down of the rolled products and a more delicate handling of them - so as to minimize product bending and distortion and to maximise product uniformity. This change benefitted the quality of all the products by the Bar and Profile mill.

Third, there was an important incorporation of new inspectors, new quality control procedures, and new equipment, made in connection with the 1972-73 diversification of the Rosario plant into the production of forging bars. These bars, because of the use to which they will be put, have to be virtually 100% free of internal and surface defects, and also rolled to very accurate dimensional tolerances. In order to achieve this the Rosario plant had to introduce changes in process and operating technology and also a greatly boosted quality control effort by comparison with that required in the production of ordinary bars. So, here again, product diversification entrained the need for increased efforts aimed at improving product quality.

In addition to these three particular features of the experience of the plant since 1960-61, there are also some other items of evidence worth mentioning.

The first concerns the variations in end product quality attributable to changes in the raw material inputs available to the Rosario plant.

There are basically two sources of such variations, which are (i) the changing quality of the incoming scrap (ii) the changing quality of the consignments of billets which the Rosario plant was occasionally able to buy in from outside suppliers for rolling on the Bar and Profile mill. Changes in raw material inputs generate the need for quality-control

rocedures which identify the differences in input composition and test their effects through
variations in the final product.

The idea is to establish the suitability, or otherwise, of the raw materials for the roduction of particular end-products - and where necesary to guide the changes in perating process technology that may be needed so as to cope with the different inputs. his "input quality control" activity has ben important in the Rosario plant since the early 69 due to the continuously deteriorating quality of the scrap available on the market and ue to the variability in its extra sources of billet supply.

The other item worth mentioning is that the Rosario plant reports and the interviews ontain many references to minor improvements (such as the redesign of cylinder channels, djustments of cutting operations, refinements in operating technology etc.) aimed at proving the quality of specific products in small ways.

The conclusions which emerge from this brief review of quality changes in the Rosario lant are as follows:

Product diversification seems to have played the dominant role in catalysing most of the ajor improvements leading both to more precise process control and also to tightening quality control procedures which have been introduced in the Rosario plant.

) . Some of these improvements sparked by product diversification have undoubtedly been roduct-specific, but others have had what we called a " spillover" effect resulting in provements in the quality of all the plant's products.

) The occasion of product diversification is, however, not the only ,or the necessary, ondition for effecting improvements in the precision of process control and in quality procedures. Thus one major quality -improving investment (the cooling bed) and many minor product specific quality changes have been introduced, independently of product diversification plans.

4) Input quality control has also been an important theme in the plant, so as to minimise the output quality variations which tended to result from variations in the quality of scrap supplies and billet supplies from outside sources.

Observations on changes in unit-costs in the Rosario plant

Our aim here is to present some preliminary observations about the kinds of technical changes which have led to unit cost changes in the Rosario plant. The observations are preliminary because further research is intended to provide the detailed and quantitative account of unit cost changes in the plant which we would have liked to be able to make use of here. Nevertheless, these preliminary observations point to some useful findings.

Our starting point will be to review the various items which together make up the elements of 'unit-costs' in each particular productive section of the Rosario plant. These costs divide up into the following main categories:

Primary metallic material:

This refers to the basic metallic input to the particular productive section of the plant which is under consideration. For example, the input to scrap-park operations is unprocessed scrap; the input to the shaft furnaces is processed scrap; the input to the Siemens Martin furnaces is processed scrap plus hot-metal; the input to the ingot casting section is liquid steel, etc., etc.

Auxiliary raw materials:

These are the other raw materials which are directly involved in the production process -e.g. coke in the shaft furnaces, limestone in the Siemens Martin furnaces, and the various additives used.

Labour:

Including both the daily paid labour and the salaried labour and supervisory personnel employed in the particular productive sections being examined.

Indirect materials, and spares:

Indirect materials, include consumable items such as furnace refractories, ingot moulds, rolling cylinders, oil, grease, etc.

Electrical energy and combustion fuels.

Maintenance and repairs:

Depreciation charges:

8. General plant overhead:

This is the allocation to the productive section concerned of a fraction of the costs of the plant's top management, and of the costs of those divisions and auxiliary units of the plant which provide services to many different productive sections.

We shall now see what light can be thrown on these various cost items:

One aspect of the cost structure of production in the Rosario plant in recent years is contained in some figures published in various plant reports, referring to the standard production costs of the intermediate products produced by the plant. Overleaf we reproduce the information concerning the standard production costs of 76 x 76mm billets of grade 46B (a standard grade produced in the plant). The information consists of a breakdown of the production costs per/ton of billets into (a) the raw materials cost, and (b) the 'transformation' cost.

The 'raw materials cost' consists of the cost of the unprocessed scrap needed to make one ton of billets, plus the costs of all the auxiliary raw materials used up in each successive stage up-to and including the Billet mill in making one ton of billets.

The 'transformation' cost is the cost per ton of product generated by all the labour, indirect materials and spares, electrical energy, combustion fuels, maintenance and repairs, needed to transform the raw materials into billets, plus a part of the overhead costs involved (1).

The table shows the raw materials cost and transformation cost of billets in undefiated new Argentine pesos per ton in seven successive years.

The key point which emerges clearly from the table is the great importance of raw materials costs. These accounted by the end of the period being considered for virtually 50% of billet production cost. Other figures available to us, show that within the category raw materials,

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(1) As far as we can tell these include an appropriate fraction of the cost of services such as water, lighting, etc. provided by auxiliary units to all the plant's productive sections, but do not include any proportion of the overhead costs incurred by the plant's top management. We are not sure whether a fraction of the overhead costs of the divisions of Industrial Engineering and Quality Control are included or not.

the cost of scrap predominates --accounting for over three quarters of raw materials cost.

Another point emerging from the table is the rise in the proportion of raw materials costs within total costs. This reflects (a) the sharp rise in scrap prices relative to the general price level in the period covered by the table, and also (b) the effects of lowered real transformation costs per ton, expressed in terms of physical and labour inputs required per unit of output.

PRODUCTION COSTS PER TON OF 76 x 76 mm, BILLETS, GRADE 46B

	July 1966	July 1967	July 1968	August 1969	July 1970	July 1971	May 1972
Raw materials cost	104	119	133	157	195	248	409
Transformation cost	176	240	183	182	198	297	446
Total cost	280	359	316	339	393	545	855
% Raw materials cost	37	33	42	46	50	46	48
% Transformation cost	63	67	58	54	50	54	52

Units: Argentine pesos ley.

So far as transformation costs are concerned, we do not have a breakdown of these per ton of billet production, but we have a breakdown which applies to the output of the entire plant. This is shown in the Table below:

BREAKDOWN OF TOTAL 'TRANSFORMATION' COSTS INCURRED BY THE PLANT

COST ITEM	July 1966	July 1967	July 1968	August 1969	July 1970	July 1971	May 1972
	%	%	%	%	%	%	%
Labour	56.9	53.3	49.7	41.6	40.9	46.9	45.7
Indirect materials & spares	17.4	16.8	14.4	17.0	17.0	14.7	15.9
Energy & combustibles	16.0	17.1	15.9	17.5	14.6	14.0	13.3
Maintenance & repairs	8.5	10.4	13.4	16.2	20.2	18.8	17.6
"General" plant costs	1.2	2.3	6.5	7.9	7.2	5.7	6.1

Source: 1968-69 and 1971-72 Rosario Plant Reports.

Clearly, labour costs stand out as the main component in transformation costs. Interest-ingly, by the end of the period considered in the table, the second most important item in tra formation costs was maintenance and repairs. (One can see that particularly large increases in the percentage of transformation costs devoted to maintenance and repairs were recorded betw 1966 and 1970). Third comes indirect materials and spares. In this category the key items are furnace refractories, ingot moulds and rolling mill cylinders. Fourth comes energy and combus tibles, and then "general" plant costs.

In the light of the cost data so far presented one would expect that cost-reducing tech-nical changes would be the outcome of the following kinds of efforts:

1. Efforts to increase metallic yield at each process stage, i.e. by reducing losses to the minim and recuperating all recyclable losses. Such efforts aim to lower the net input requirements of primary metallic material per unit of output produced.

2. Efforts to increase the productivity of the auxiliary raw materials --i.e. to increase the out-put of product per unit of auxiliary material input.

3. Efforts to reduce the labour requirements per unit of output.

4. Efforts to reduce the consumption of indirect materials, per unit of output.

5. Efforts to reduce electricity consumption and fuel costs per unit of output.

6. Efforts to reduce maintenance and repairs costs per unit of output.

7. Efforts to reduce general plant costs per unit of output.

The evidence about technical changes in the Rosario plant confirms the expectation th all these 'lines' of cost-reducing technical changes have been pursued in the plant. What we now propose to do is to try to throw some light on the <u>nature</u> of technical changes introduced along these various lines and the circumstances leading to their introduction.

In connection with this effort to explore the nature of cost reducing technical change in the Rosario plant it will be useful to make use of the distinction made by Hollander, in his ıdy of Du Pont rayon plants, between "direct" and "indirect" technical changes.

"Direct" technical changes are ones which result in a decrease in unit operating costs ven at unchanged levels of output. "Indirect" technical changes are ones which, although they not result in a decrease in unit costs at unchanged levels of output, nevertheless permit the achinery to function at greater output levels than before -with the result that if this higher level output is indeed produced then the fixed operating costs can be spread over a larger volume of itput than before, thus resulting in a decline in unit operating costs. (1)

It will therefore be interesting, in the examination of the nature of cost-reducing tech-cal changes which now follows, to include in the discussion an effort to throw light on the re-tive importance of "direct" versus "indirect" technical changes in the Rosario plant. We now rn to the examination of the different kinds of cost-reducing changes:

The importance of the distinction is that it differentiates between those technical changes which do not depend on increases in output for their effect on unit costs, and those technical changes which have their effect precisely because of the increases in output which they permit.

Figures published by Hollander for five different rayon plants reveal the following division between "indirect" and "direct" technical changes in terms of the effect of each category of technical change on unit cost reduction.

Plant	% of unit cost reduction attributable to Indirect technical change	% of unit cost reduction attributable to Direct technical change
Old Hickory (1929-51)	28%	58%
Spruance I (1932-50)	48%	49%
Spruance II (1937-51)	-	38%
Spruance III (1938-52)	72%	23%
Spruanse IIA (1945-52)	68%	32%

So far as changes in metallic yield are concerned, these appear to have been mostly caused by technical changes of the "direct" type. In this connection the three themes of particular importance are (i) the quality of the raw materials used; (ii) the fraction of losses incurred in the processing operations; and (iii) the rejection rate of sub-standard products. With regard to the first of these themes i.e. raw material quality, the main technical changes introduced in the Rosario plant have been introduced as a reaction to deteriorations in the available scrap. These changes were therefore designed to stem the falling yield from the scrap inputs to the plant, and involved steps such as improved scrap quality control, improved scrap selection, and more intensive pre-processing of scrap. (All these are "direct" technical changes). Next, with regard to reducing processing losses, the plant reports reveal that many small technical changes have contributed to this objective, particularly those concerned with minimising the losses due to the "cropping" of ingots ends and rolled product ends, and minimising the irrecuperable losses due to surface- oxidation of ingots and billets in the reheat furnaces. Again these were virtually all "direct" changes. As for reducing the rejection rate of products, the technical changes in this direction have been part and parcel of the changes designed to improve product quality (which we described in the previous section). Again these are mostly direct changes.

In effect, we can say the technical change introduced in the Rosario plant to influence metallic yield (and hence unit costs) have been (a) mostly "direct" technical changes; (b) have been in part provoked by deteriorations in the scrap inputs to the plant; (c) have in part arisen as a result of changes simultaneously designed to improve product quality; and finally (d) have in their remaining part been "pure" cost reducing technical changes in the sense of not having been provoked by changes in the quality of input materials, and not having major effects on other performance or output parameters besides on unit costs.

Turning next to technical changes designed to increase the productivity of the auxiliary 'aw materials, the ones which have come to our attention are (a) improvements in the quality of he auxiliary raw materials resulting from stricter requirements being placed on the suppliers by he Rosario plant, and (b) technical changes incorporated in the shaft furnaces designed to increase he productivity of the coke used. The latter changes besides increasing coke productivity, also imultaneously increased the output capacity of the shaft furnaces. Both varieties of technical hanges mentioned above are "direct".

In the third place we come to technical changes which made it possible to reduce labour equirements per unit of output. Although there are important exceptions, the basic situation eems to be that these changes have been "indirect", i.e., the reduction in labour requirements er unit of output has usually been achieved by having basically the same workforce produce ore tons per hour with their existing or improved equipment, rather than by laying off men and roducing the same or a higher output than before. This conclusion follows from the fact that nployment in the plant has declined much more slowly in the past ten years than the output has icreased. This basic observation does not of course rule out many direct technical changes of a inor kind having been made to reduce labour teams slightly, and, as we mentioned there have een some important direct technical changes such as switching maintenance and repair work in 69 away from plant labour to a system of contracting out. (This resulted in a reduction of the bour force by about 100 men who were previously employed in the plant carrying out maintenance ork). However, the basic observation, that the reduction in labour requirements per unit of output has been accomplished by indirect technical change, remains.

Next, coming to technical changes designed to reduce the consumption of indirect materials per unit of output --the main type of changes involved have been changes tending to prolong e useful life of refractories, ingot moulds, rolling cylinders, etc. The plant reports contain many references to minor technical changes designed to increase the service life of these items, these are direct technical changes except for the prolonging of refractory life, which also has importa effects in increasing production capacity.

Then, with regard to technical changes designed to reduce unit electrical energy and combustion fuels costs -our evidence reveals (a) direct technical changes to adapt the furnaces to working with gas instead of fuel-oil (1961), and then a further adaptation back to being able to use fuel-oil in at least one furnace (1969); and (b) many minor direct modifications to increas the efficiency of fuel usage in the furnaces; and (c) some important enlargements in the capacity of the furnaces which also increased the efficiency of fuel usage (indirect technical changes).

Coming finally to technical changes designed to reduce maintenance and repairs costs, a very notable series of changes took place in the period 1969-70. In the first place, as we have mentioned, much of the maintenance and repair work was switched from being done by plant staff, to being done by outside contractors, in order to save money. In the second place a newly organized Division of Maintenance was created with the mission of establishing a ration system of preventive maintenance throughout the entire plant which would be able to reduce maintenance costs. In practice it required a substantial investment of time and resources to set up this new system, because extensive study of the equipment, spares, operating practice,etc. was required, plus the preparation of many new engineering drawings, maintenance manuals, et thus unit maintenance costs actually increased sharply in 1969 and 1970 before falling somewhat in the succeeding two years. The organizational and procedural changes involved are clearly direct cost reducing technical changes, however, they also had the effect of increasing the 'availability' of the plant equipment and thus increasing plant capacity.

This above account has left out technical changes concerned with reducing unit depreciation and unit plant overhead costs, because we do not have information on these. Howeve we can note 'en passant' that all the indirect technical changes help to reduce unit overhead costs through spreading these costs over a larger volume of output.

So much for our examination of the evidence concerning cost reducing technical changes. We can now ask , what conclusions about cost-reducing technical change emerge from this examination?

It seems possible to draw the following conclusions:

1) There are many different kinds of technical changes which have contributed to unit cost reduction in the Rosario plant. These include technical changes which (i) increase metallic yield, (ii) increase the productivity of the auxiliary raw materials, (iii) reduce unit labour requirements, (iv) reduce unit consumption of indirect materials, (v) reduce unit electricity and fuel consumption, (vi) reduce unit maintenance and repairs costs, (vii) reduce unit depreciation costs, (viii) reduce unit plant overhead costs.

2) It appears that "direct" technical changes have been involved to a great extent in accounting for the cost reductions achieved via increasing metallic yield, increasing the productivity of the auxiliary raw materials, reducing unit consumption of indirect materials, and reducing unit maintenance and repairs costs, whereas "indirect" technical changes have been most responsible for the reduction in unit labour costs. Both "direct" and "indirect" technical changes have contributed significantly to reducing unit electricity and fuel consumption costs.

3) Quite apart from the "indirect" technical changes which by definition involve capacity increases in order to achieve unit cost reductions, it is also clear that many of the "direct" technical changes which reduce unit costs were not simply cost reducing technical changes. Thus many direct technical changes were simultaneously capacity-increasing and/or quality-improving changes as well, and in many such cases the unit-cost reduction effect may well have been only a 'secondary' objective of the technical changes involved.

4) In parallel with this point concerning the multiple objectives of many of the technical changes which reduced unit costs, it is worth recalling that the technical changes incorporated in the preventive maintenance campaign caused unit maintenance costs to increase sharply (at least in the first two years) obtaining increased plant availability in return. Thus unit cost reduction is not in any sense a 'sacred' objective of technical change, but rather an item that is sometimes "traded-off" against improvement in other plant parameters.

5) A significant type of cost-reducing technical change in the plant is connected to the supply of primary and auxiliary raw materials to the plant from outside suppliers. In particular the deterioration in the quality of such raw materials is a factor tending to provoke compensating technical changes in the plant to offset the negative effect on unit costs caused by the reduced productivity of the raw materials concerned.

6) There is also some evidence that changes in materials input prices have provoked technical changes in the Rosario plant. For instance the technical changes adapting the furnaces first from fuel-oil to gas and then back again seem to have been responses, in good measure to price changes. Also there is some evidence that the very sharp increases in scrap prices which occurred from 1969 onwards had the effect of intensifying the efforts of plant management to obtain offsetting unit cost reductions both by direct and indirect technical changes made in the plant.

hanges in the human organization of the Rosario plant

The next variety of changes we shall be examining in this section of the report concerns hanges in the human organization of the Rosario plant.

For the purpose of discussion it will be useful to distinguish two types of organizational echnical change. The first type consists of routine organizational changes. These are very often ound up with technical changes involving changes to equipment. For example if a change is made hich involves automating some of the functions on a rolling mill then this may well require changes f working methods on the part of the mill's remaining operators and it may possibly also require ome reorganization in the functions of the mill's supervisory personnel. This type of change -from ne work-routine to another- is obviously frequent. Indeed such changes do not necessarily require prior change in equipment, although most often this provides the stimulus.

The second type of organizational changes concerns those changes in organization whose urpose includes contributing to more 'open-ended' tasks and goals than those involved in the first ype. For instance, the strengthening of the plant's Quality Control Division in 1960-61 was an rganizational change which we would class as of the 'open-ended' rather than of the 'routine' ariety.

The important difference between these two varieties of organizational change is that the ew organization created by an 'open-ended' organizational change is usually designed not only o accomplish specific inmediate objectives, but is also expected to generate new ideas, new asks and procedures for improving performance in its broad area of competence in the future.

The most important examples of 'open - ended' organizational changes we have come across in the Rosario plant concern those changes which, from an organizational viewpoint, generated new specialist divisions within the plant, or else greatly strengthened existing ones.

The three examples we have particularly in mind are (1) the strengthening of the plant's Quality Control Division in 1960-61; (2) the setting up of the Industrial Engineering Division, we believe in 1964, and (3) the setting up of the Maintenance Division, in 1969.

As we saw in Section I of this Chapter, these three divisiones not only contribute to the regular production activities of the plant by inspecting and controlling the quality of production, setting up production and cost standards, and maintaining and repairing plant equipment -- they also contribute to technical changes by such activities as investigations of product defects, trials of product variations, studies to determine cost-reduction possibilities, and machinery modifications made in the course of repair work. Hence the changes involved in setting up, or strengthening, each of these divisiones, not only represented technical changes in themselves, but also gave rise to many new technical changes in their respective areas of competence.

In other words, some organizational changes, which we have called 'open-ended', have tended to generate a future 'stream' of technical changes arising out ot their normal activities.

The next point of interest we want to investigate is - what led to these 'open-ended' organizational changes?. We have already noted, when discussing product quality changes earlier in the chapter, that the 'catalyst' leading to the setting up of a strengthened Quality Control division in the 1960-61 period was the fact that the Rosario plant was planning to diversify its production into the special steels field and that special steels required more delicate process control and more stringent product standards. Also we noted that this planned diversification was itself ascribed to the impending start up of bulk steel production by a competitor firm, Somisa. In other words the re-organization of the quality control department of the Rosario plant can be seen as a direct response to very specific and pressing circumstances.

A similar situation of urgency seems to have applied in the case of the setting up of the Maintenance Division in 1969. Here the problem was that in the years 1967-69 the Rosario plant had been even more than usually starved of investment funds due to Acindars commitments and problems with its vast integrated plant project. As a result much of the worn out equipment and parts in the Rosario plant could not be replaced or renovated, and the plant's production started to be seriously interrupted by more and more frequent machinery breakdowns. The response was to greatly increase maintenance expenditures to keep the machines running - and this led to the setting up of the Maintenance Division to put into motion a really comprehensive programme of preventive maintenance designed to keep the plant's units functioning and to systematise and rationalise maintenance procedures so as to stop maintenance costs from escalating.

Thus, in this case too, an important organizational change was clearly a response to immediately pressing circumstances whose origin lay in changes outside the Rosario plant. Since it was the overall financial situation of Acindar which had cause the deterioration of the machinery in the Rosario plant to reach the crisis point).

Obviously it would be misleading on the basis of just these two examples, to reach the conclusion that all important organizational changes in the Rosario plant have been produced as responses to pressing external circumstances - indeed we know of several examples of significant organizational changes which have arisen for other reasons, e.g. as part of company - wide reorganization programs put into march by Acindar as a whole - but the example of the Rosario plant does suggest that the emergence of at least some specialities within industrial plants is likely to be in circumstances of 'forced response' rather than 'forward planning'.

Incremental Technical Changes

Our concern here is to explore-in somewhat more detail the nature of the incremental technical changes that have been introduced in the Rosario plant.

We propose to do this by analysing a sample of the individual technical projects performed by various of the plant's divisions, and reported on in the annually compiled Rosario 'Plant Reports'. Not all of these individual technical projects constitute technical changes. However this is an advantage for our purposes, because it will permit us to see how technical change activities spring up alongside the ordinary activities of the divisions concerned.

I. Maintenance Activities

We shall first analyse the projects which were reported on by the Energy and Maintenance section of the Plant Engineering Division in the 1968-69 Plant Report and also the projects reported on by the Maintenance Division in the 1969-70 Plant Report (1). We use the term 'project' to denote each repair task, maintenance task or other task which was individualized in these plant reports as having been performed. For example the "initiation of a program of inspection of equipment, starting with the steelmaking units, to examine their state and determine when to program repairs" counts as one project. So too does the "continuing of trials of refractory materials to determine the productivity of imported versus national refractories". Further instances of activities counted as single projects are "the construction of a new mixing ladle" and "a complete repair carried out on the G22 Morgan crane" (2).

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(1) The 'Energy and Maintenance' section of the Plant Engineering Division was made into an independent Maintenance Division in 1969.

(2) Evidently this method of analysing the data suffers from the problem that big projects

The two Plant reports which we referred to above make brief mention of altogether 110 different 'projects' carried out by the Maintenance section/Division in the years 1968-69 and 1969-70.

For the purpose of analysis we have divided these 'projects' into the following categorie

1) Projects which consist of changes made in the methods of carrying out or organizing maintenance work (e.g. the change to the contracting out of much maintenance work in 1968-69, or the appointment of an additional engineer to the special charge of preventive maintenance activities). These projects we call "Changes in work organization".

2) Projects which consist of (a) the reviewing and creating of basic engineering information about the existing equipment and spares, or (b) inventory development and inventory control for spares, or (c) standardization activities applied to equipment, spares, lubricants, electrical devices, etc. - including the development of standard plant manuals covering purchases, repairs, maintenance and lubrication schedules. This group of projects will be termed "Review, Inventory and Standardization Activities".

3) Projects which consist of inspections performed on machinery or refractories in order to determine their state and to assess the need for repairs and/or modifications. These projects are termed "Inspection of Machinery or Refractories".

4) Projects which consist of using non destructive tests carried out on equipment or of trials performed to test the suitability of alternative refractory materials. These projects will be called "Tests on Machinery or Refractories".

5) Projects which involve straight forward repairs being carried out to equipment, when no mention is

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and small ones get the same status within the sample but this does not prevent the analysis from revealing a good deal about the nature of maintenance activities in the plant and the way that technical changes arise from them).

made of any modifications having been carried out. These we will call "Repairs to Machinery".

6) Projects in which modifications were made to existing machinery or in which new machinery was installed. These will be called "Modifications made to Machinery".

The breakdown of our sample of 11 projects divided into these six categories is shown in the following Table.

ANALYSIS OF PROJECTS REPORTED ON BY THE PLANT'S MAINTENANCE DIVISION, 1968-69 AND 1969-70

TYPE OF PROJECT CARRIED OUT		NUMBER OF PROJECTS
Changes in work organization		5
Review, inventory and standardization activities		18
Inspection of machinery or refractories		5
Tests on machinery or refractories		6
Repairs to machinery		44
Modifications made to machinery		
Modifications made as part of repair projects	11	
Modifications apparently made as separate projects	18	32
'Modifications' involving installation or construction of new machinery	3	
		110

This table is interesting for a number of reasons. First of all it shows that a significant fraction of the activity of the plant's maintenance division in 1968-69 and 1969-70, was concerned with modifying machinery rather than merely maintaining and repairing it.

Secondly, it is clear from the nature of the changes made in work organisation and from the projects in the sample, that at least some of the modifications made to machinery did not follow from a "learning by doing" strategy, but, rather, from a systematic "preventive maintenance" strategy which had already begun to be implemented in 1968-69 and which was then greatly emphasized throughout 1969-70.

The essence of this preventive maintenance strategy is that it involved a systematic strategy designed to lead to greater machinery availability and lower maintenance costs. This strategy consisted, first, of information-gathering activities designed to put at the disposal of the maintenance division the basic engineering data needed for carrying out maintenance work efficiently. This data included engineering drawings of all the plant's machinery, machinery components and spares, plus information about permitted tolerances, about materials properties and lubricating reeds, etc., much of which information was missing or simply not available in systematic form. Hence the presence of all the "Review, Inventory and Standardization" activities in the Table.

The second element in the strategy consisted of a programme of preventive inspections of machinery (and refractories) designed to lead to suggestions for planned repairs and/or modifications that needed to be made.

The third element consisted, of course, in the carrying out of the repairs and modifications which were decided on. Indeed the table shows how, in 11 out of 32 projects, repairs and modifications were carried out simultaneously.

The central point which emerges from this account is that "preventive maintenance" is not so much a learning-by-doing strategy as a research-type strategy which consists of the sequence: Basic information gathering ⟶ Inspection ⟶ Diagnosis ⟶ Planned Repairs and Modifications.

This whole strategy has as one of its key elements the aim of being able to predict the performance and deterioration of machinery in working conditions - and successful prediction tends to require a research effort to determine what the relevant working conditions are. Inevitably a research effort of this kind will systematically uncover possibilities for improving performance-in-use by means of modifications -especially when this improvement objective is formally part of the Division's duties. Hence there seems to be a good case for regarding the stream of small machinery modifications which flow from the work of the Maintenance division in the Rosario plant, as a stream generated via a modest form of in-plant R&D, which is carried out by maintenance personnel and in which the object of research attention is the gaining of knowledge about the performance characteristics of the particular assembly of capital equipment which they have to maintain. The value of adopting this view is that it suggests the possibility of arriving at an 'optimal' assignment of resources to this "maintenance R&D" activity given that a valuable output can be expected to result from it in the form of incremental performance-increasing modifications.

2. Activities of the plant's Engineering Division

The second sample of projects which we shall analyse are those which were reported on by the 'Technical Office' of the Plant Engineering Division in 1968-69, plus those reported by the Engineering Division in 1969-70 and 1971-72 (1).

In 1969-70 a large part of the work of the Engineering Division was absorbed in generating both basic engineering data and standardization data about equipment and spares, because this data was needed by the Maintenance Division in the setting up of its Preventive Maintenance Strategy. However, quite apart from these "technical assistance to maintenance" activities, the plant reports reveal a sample of 55 other projects carried out under the responsibility of the plant's Engineering Division in the three years 1968-69, 1969-70 and 1971-72. These projects are analysed in the Table opposite.

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(1) In 1969 the former "Plant Engineering Division" was split into two separate Divisions, the "Maintenance Division" and the "Engineering Division." For simplicity we shall

ANALYSIS OF 54 PROJECTS CARRIED OUT BY THE ENGINEERING DIVISION OF THE ROSARIO PLANT IN THE YEARS 1968-69, 1969-70 and 1971-72

TYPE OF PROJECT	NUMBER OF PROJECTS
Major engineering projects involving extensive modifications to the plant's main processing units *	2
Projects involving the installation of additional equipment in plant	13
Projects involving modifications to equipment	16
Projects involving amplifications of buildings	3
Projects involving relocation of equipment	3
'Pre-project' studies	17
TOTAL	54

*These two projects were carried out in conjunction with the Plant's Rolling Division, and consisted of (i) a general reform carried out on the Billet mill in 1969 - which involved no less than 19 different modifications to various parts of the mill's equipment; and (ii) the major modernization carried out to the Bar and Profile mill in 1971.

We can now make a number of observations about this table. First, the table suggests the existence in the plant of considerable internal engineering capability. In fact, in all the projects noted, with the exception of the 17 pre-projects, the responsibility of the Engineering Division included (i) the Pre-project, (ii) Cost-estimation, and (iii) the carrying through of the project itself, including inspection of equipment, components and supplies, and the installation work. The use of outside suppliers to supervise installation was mentioned in only one of the 37 completed projects.

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from now on refer, for all three years, to the "Engineering Division", and we shall exclude from the following analysis all the Maintenance projects for the year 1968-69 which we analysed earlier.

The sophistication of this internal engineering capability is most clearly evident with regard to the carrying through of the two 'major' engineering projects which are shown in the table.

The second point worth noting is the approximately equal frequency of projects involving modifications to equipment, and projects involving the purchase and installation of new equipment.

The third point of interest concerns the activity registered as 'pre-projects' in the Table. Whilst 9 of these 17 pre-projects were later implemented, it appears that the other 8 were not. Amongst the 8 rejected were ambitious projects for electric-arc steelmaking units to be installed in the plant, a project for converter steelmaking units, a project concerned with the handling of 40 ton 'heats' of steel, a project for new stands for the billet mill, and a project to install machinery for making steel posts. These projects evidently represented efforts to trace out some fairly radical future options for the plant.

The conclusions we can draw from this brief survey, based on the Table, are that a substantial amount of 'endogenous' engineering is involved in the implementation of incremental technical changes in the Rosario plant - and that the engineering 'capability' within the plant has been strong enough to also permit the Division to contribute to two major technical changes in the plant, as well as to engage in speculative engineering studies concerning the plant's future.

3. The activities of the Industrial Engineering Division

The third sample of projects we shall analyse are those which were reported in the 1968-69 Plant Report by the Industrial Engineering Division.

The table overleaf shows the results of this analysis.

The most interesting thing that can be observed is how the Industrial Engineering Division functions *ex ante* in considering the economic effects of *proposed* technical changes, as well as *ex post* in adjusting production and cost standards to those changes that have been introduced.

Another interesting point is that out of the 43 technical changes introduced or proposed (all incremental) only 8 involved new machinery or modifications to machinery, compared to 12 involving output mix changes, 6 involving input mix changes, 13 involving operative changes of various kinds, and 4 involving output quality changes. This is interesting because it suggests that much "incremental" change resides in these variations to output and input mix, output quality and operating techniques as well as occurring in the more well-known form of machinery modifications and additions.

ANALYSIS OF 72 SEPARATE PROJECTS CARRIED OUT BY THE INDUSTRIAL ENGINEERING DIVISION 1968-69

Type of project			Number of projects of this type
* Studies of remunerations and incentives.			8
* Budget presentations and cost accounting projects.			11
* Studies of methods, input quantities etc. in particular plant sections - for which no special mention was made of any immediately prior or planned technical change which provoked the studies.			6
* Projects to classify or standarize particular product ranges.			4
* Projects aimed at determining ex-post the change in production standards effected by the introduction of specific technical changes.			
Type of technical change involved	Number of projects		
Shifts in the basic or dimensional product mix.	7		
Changes in the grade, quality or dimensions of intermediate products used as inputs.	3		
Changes in product quality specifications.	4		
Modifications to machinery.	2	24	24
Operational changes affecting process yield.	3		
Changes in the number of shifts operated or hours worked.	2		
Other changes in operating methods.	3		
* Projects aimed at determining ex-ante what the economic effects (including the effects on production standards) would be if specific proposed technical changes were adopted.			
Type of technical change involved	Number of projects		
Product diversifications.	2		
Shift in the basic or dimensional product-mix.	3		
Changes in the grade, quality or dimensions of intermediate product inputs.	3		
Introduction of new machinery.	3	19	19
Modifications to machinery.	3		
Changes in the number of shifts operated.	1		
Other changes in operative methods.	4		
TOTAL			72

Notes to the Table:

1. 14 of thetotal of 86 projects mentioned in the 1968-69 Plant Report have been regarded as "miscellaneous" and left out of the classification.
2. Most of the projects shown in the Table refer to analyses carried out on the activities of particular productive sections within the Rosario plant, rather than to the plant as a whole.

4. The activities of the Quality Control Division

We come, now, to look briefly at the activities of the Quality Control Division. The projects recorded in the 1968-69 Plant Report are analysed in the Table below.

ANALYSIS OF 27 PROJECTS CARRIED OUT BY THE QUALITY CONTROL DIVISION 1968-69

Type of Project	Number of Projects
Instrument repair, calibration and construction.	4
Routine controls on the mechanical parameters of products.	3
Intensification of control procedures for certain products.	1
Development of new or modified methods of analysis.	4
Quality control efforts applied to raw material inputs.	3
Destructive and non destructive tests to determine quality of various different products.	5
Participation in plant experiments designed to improve process conditions thus raising product quality.	2
Learning in cooperation with outside organisation about how to process a new kind of steel grade in the Rosario plant.	2
Investigation of the origin of product defects.	1
Investigation aimed at increasing process yields.	2
TOTAL	27

The key point which emerges concerns the last four items in the table, representing 7 out of 27 projects in all. These projects display a clear "research type" activity taking place within the Quality Control division.

Conclusion

The basic conclusion which emerges from this very brief survey of individual technical projects performed by various of the Rosario plant's divisions is that the generation of incrementa echnical changes within a plant is very far from being a completely assured thing which just "happens" as output volume increases. On the contrary, the experience of the Rosario plant suggests that incremental change needs to be explicitly organized for. Indeed it appears that a considerable fraction of the incremental changes introduced in the Rosario plant were generated by "research-type" strategies rather than by pure trial and error methods.

Summary of the findings on the nature and rate of technical change in the Rosario plant

Our aim here is simply to review very briefly the main findings about the nature and rate of technical change which have emerged from all the evidence and analysis presented previously in this section. We present these findings in the order in which the analysis was carried out.

1. To begin with we noted that the panorama of evolution of the Rosario plant embraced multiple different kinds of changes.
2. We then explored the distinction between technical changes and 'scale multiplying' changes, and pointed to the need to distinguish between the actual technical (or scale-multiplying) changes made, and their effects in influencing the various different 'parameters' relating to output and performance.
3. Next we looked at the pattern of growth in the volume of output from the three principle productive sections of the Rosario plant, and observed (a) the overall growth-context in which technical change in the plant had taken place, (b) the uneven growth rates experienced by the different sections of the plant both with respect to eachother, and across time, and (c) the lack of any obvious optimum or equilibrium points on the growth path.
4. After this, we then turned to examine the objectives of technical change in the Rosario plant. What we discovered was (a) that capacity-increasing technical changes had occurred with great frequency in our sample of 30 important technical changes carried out in the plant, and (b) that product quality changes, product diversifications, unit cost reducing technical changes and technical changes to offset input deteriorations had also figured in the sample. This clearly showed that the objectives of technical changes in the plant had been multiple, not just unit cost reduction. Furthermore we saw that the

picture was still further complicated by the fact that many of the individual technical changes in the plant had had multiple objectives and consequences -i.e. they were designed to affect more than just one of the 'parameters' of plant output and performance at a time.

5. Turning next to analyse the changes in the output mix of the Rosario plant, we noted (a) an impressive history of product diversifications which were carried out on the Bar and Profile mill (involving the launching of no less than fourteen new classes of products during the mill's life), and (b) that there had also been very significant changes introduced in the output mix of the intermediate products produced by the plant. We saw that technical change was responsible for <u>all</u> the product diversifications of the Bar and Profile mill and also for permitting <u>most</u> of the changes in the steel grade product mix and dimensional product mix of the intermediate products to take place. We also saw that the new product launches on the Bar and Profile mill had on several occasions played a vital role in keeping the mill occupied in the face of fall offs in its effective demand due to competition from the Acevedo plant; and we saw that the changes in the dimensional output mix of billets and ingots had largely been carried out for the sake of increasing the plant's productive capacity.

6. There then followed a detailed analysis of the growth of production capacity in the plant's three main production sections. The main findings which emerged were that (a) technical change had been responsible for rather more than half of the productive capacity increases achieved in the steelmaking section and for all of the productive capacity increases achieved in the billet mill and the bar and profile mill, (b) that incremental change had played the leading role in accounting for the capacity increases due to technical change in the steelmaking section and billet mill (although not in the

bar and profile mill), and (c) that most of the technical changes which produced the observed capacity increments had had as their main objective to produce increases in capacity.

7. After this come an analysis of the changes in product quality introduced in the plant. It was shown that a very important set of technical changes affecting product quality were introduced in 1960-61 as a consequence of the planned diversification of the Rosario plant into producing special steels. Further analysis then confirmed that intended product diversification was often, though not always, the catalyst of product quality changes.

8. Next to be analysed were changes in unit costs in the plant. It was shown that both 'direct' and 'indirect' technical changes had contributed to unit cost reductions --the former having been more important with regard to increasing metallic yields, increasing the productivity of auxiliary raw materials, reducing unit consumption of indirect materials and reducing unit maintenance and repairs costs, and the latter having been more important with regard to reducing unit labour costs.

9. Then we turned to changes in the human organization of the Rosario plant, and pointed to the great importance of the emergence (and strengthening) of new specialist divisions within the plant -since these new or strengthened divisions then became the sources of future "streams" of minor technological changes. We also showed that in two cases these major organizational changes had arisen in circumstances of "forced response" rather than "forward planning".

10. Finally we briefly analysed the complete 'set' of technical activities reported in a number of the Rosario 'Plant Reports' as having been performed by (i) the Maintenance Division of the Plant, (ii) the Engineering Division, (iii) the Industrial Engineering

Division, and (iv) the Quality Control Division --in order to see what light such an analysis would throw on the subject of incremental technical changes in the plant. This analysis showed clearly the important role played by these Divisions in generating incremental technical changes in the plant, and also produced the interesting finding that much of the learning leading to the generation of technical changes by these divisions is rather clearly the product of 'research-type' strategies.

SECTION III

Observations on the Causes of Technical Changes in the Rosario Plant

The account we gave in the previous section of the technical changes introduced in the Rosario plant suggests that many of them emerged as responses to sharply changed external circumstances which came to affect the plant.

Most notably, the "effective demand" faced by the Rosario plant was abruptly changed on several occasions by the impact of changes which took place in the production capacity of the Acevedo plant. The most important of these changes occurred in the years 1951, 1962 and 1972. All three of these changes had the effect of drastically reducing the utilization of capacity of the Bar and Profile mill of the Rosario plant -- and resulted, in two out of the three cases, in technical changes being made in the Bar and Profile mill to diversify its production into new classes of products.

The other major effect in the case of the 1962 and 1972 changes, was to generate a sharply increased demand for billets from the Rosario plant to service the raw material requirements of the then underutilized new rolling capacity in the Acevedo plant. To meet this sharply increased demand, the Rosario plant had to respond by doing its best to increase ingot and billet production as fast as possible.

Furthermore the major technical changes carried out in the 1960-61 period to diversify production into special steel grades, and to produce to more stringent quality standards, were also a response to sharply changed external circumstances, in this case the coming on-stream of the large-scale steel producing units of a competitor firm, Somisa, which threatened Acindar's hold on the demand for common steel products then being serviced by the Rosario plant. This can be nsidered as an example of technical change being caused by an imminent change in the composi-on of the effective demand facing the plant.

Another important example of technical change being carried out in response to sharply hanged external circumstances was the intensification of preventive maintenance procedures arried out in 1969 in response to the deteriorating situation of the plant's machinery which was self provoked by Acindar's marked cash shortage for investment in the preceding two years (i.e. n event external to the Rosario plant).

The common element in all these examples is that an abrupt change in circumstances ex-ernal to the Rosario plant generated an urgent need for technical changes to be performed in the lant. The urgency derived from the fact that, in every case, the result of not doing anything ould have been to permit or perpetuate a damaging underutilization of productive capacity, ither in the Acevedo plant's rolling mills or in the Rosario plant's Bar and Profile mill. In these ases, then, technical changes can be seen as a response virtually forced on the Rosario plant in rder to avert the serious penalties implied for Acindar in having large amounts of underutilized xed capital. We shall call these kinds of technical changes 'exogenously demanded' so as to ndicate the presence of strong external factors generating urgent demands for technical change on e Rosario plant.

In fact the historical situation of lack of sufficient billet inputs for the Acevedo plant's ills, which first became important in 1962, has persisted ever since then (1), and this has led to practically permanent exogenous demand on the Rosario plant, since 1962, to increase its billet utput destined for the Acevedo plant.

) The main reason for the persisting shortage of billets was that Acindar's successive integration projects, aimed at installing blast furnaces and primary rolling facilities in the Acevedo plant, were continuosly postponed by the Argentine government, and it was only in 1974 that Acindar received a definite go-ahead to integrate the Acevedo plant, this time with Direct Reduction Units that are expected to come on-stream in 1978.

The next category of technical changes which we can distinguish in our effort to analyse the different causes of technical changes in the Rosario plant, is what we call 'exogenously stimulated' technical changes. These are technical changes made in the plant in response to anticipated or actual changes in the volume and composition of effective demand, or in the quality, composition or price of the plant's raw materials inputs. However, unlike in the 'exogenously demanded' changes the external factors which stimulate the changes in this second category are not of the kind that pose immediate threats to the company's profitability if they are not responded to. For instance, in the case of the Rosario plant, the cumulative deterioration in scrap quality over the years became a stimulus to technical changes which were made to improve scrap quality control, scrap selection procedures, and scrap densification, but these technical changes could not be regarded as falling into the same category of urgency as the ones described earlier. Further examples of 'exogenously stimulated' technical change were stimulated by demand side factors. For example, the important product diversifications in reinforcing bars carried out in the Bar and Profile mill were stimulated by the growing sophistication of market demand, and the expansion of the output of the Bar and Profile mill carried out between 1969 and 1971, which involved major technical changes, was also stimulated by expanded demand and further examples could be given.

The third category of technical changes which we can distinguish may be termed 'endogenously generated' technical changes. The important feature of these changes is that they do not arise as responses to deal with changed external factors -rather they arise from the regular activities of plant personnel (and plant divisions) who are concerned with increasing plant efficiency, and who are on the lookout for opportunities to do so.

Many kinds of technical changes we noted in the Rosario plant fall into this third category. For instance the machinery modifications regularly made when equipment is down for repair, the cost reduction studies of the Industrial Engineering Department, the improvements in operating procedure made as a result of greater familiarity with equipment, etc. etc. may all be regarded as 'endogenously generated'. The common denominator is that the technical changes we have called 'endogenously generated' do not depend or respond to particular changes in the external environment of the plant but arise from the application to equipment and procedures of improvement criteria which may be thought of as "internalised" in the heads of plant personnel and also "formalised" in some of the regular tasks of the plant's operating divisions. The stimulus for 'endogenously-generated' technical change may come from an equipment breakdown, or in the course of an internal plant study or from an idea of the plant's manager or an engineer, foreman or worker. The key point however, is that the source of the stimulus is internal rather than external to the plant.

Now that we have defined and given examples of these three categories of technical change we shall make use of them in discussing the particular path of technical change taken in the Rosario plant.

The central point to be made is that a high proportion of the most significant technical changes made in the Rosario plant appear to have been 'exogenously demanded' i.e. carried out under pressure to meet urgent external requirements and it is also evident from the record that the plant has been able to react successfully when faced with these requirements. In particular we can note that the urgent requirements from 1962 onwards for higher billet output from the Rosario plant were met by a highly successful record of capacity-stretching technical change in the steelmaking units and billet mill, and that the successive crises imposed on the Bar and Profile mill by the changes in the Acevedo plant have been met by a successful program of product diversification.

In addition to responding directly to the particular immediate requirements that gave rise to them, many of the 'exogenously demanded' technical changes have also stimulated a greater intensity of 'endogenously-generated' technical changes in the plant. Such an effect is clear to trace in the cases of the exogenously-demanded technical changes which caused the strengthening of the Quality Control division and reorganisation of the Maintenance division, since these two strengthened divisions quickly began to generate 'streams' of minor improvement-type technical changes in their areas of competence.

It is also likely that the virtually permanent urgent need of the Acevedo plant for more billets from Rosario must have caused Rosario plant personnel to 'internalise' more intensively than normal the value of being on the lookout for capacity-stretching technical changes in the plant.

The interesting conjecture one can raise in connection with the importance of exogenously-demanded technical changes is that perhaps the overall success of the Rosario plant in adapting itself so successfully on a low investment budget has been partly due to the very urgency of the external pressures which affected the plant? The suggestion is, in other words, that being forced to adapt by strong external pressure led the personnel of the Rosario plant on many occassions to learn quickly how to strech, adapt and adjust their plant to changing circumstances, and that this "learning under pressure" was in some sense extremely "efficient" in producing successful technical changes in the plant, both directly in the sense of giving rise to specific responses to the original external stimuli involved, and also indirectly in terms of intensifying the overall endogenously generated technical change effort within the plant.

This conjecture -concerning the efficiency of 'learning under pressure' - has a plausible ring to it. However the form in which the conjecture usually gets attention in the literature is in connection with the rather narrowly circumscribed set of pressures connected with bottlenecks. For instance Paul David, in reference to Nathan Rosenberg's idea of "compulsive sequences" of technical change states that:"Internal technical relations among the elements of a production process rather than external market conditions generate a succession of more or less obvious 'engineering challenges', practical difficulties that serve to focus inventive effort in one direction or another at different moments of time. The need for resolution of each of the compelling problems typically is signalled by breakdowns, equipment malfunctions, or more generally, by the materialization of physical bottlenecks of highly specific kinds" (1)

We do not quarrel with this view so far as it goes, but evidently the experience of the Rosario plant with technical change shows that external market conditions can have a powerful effect in 'orienting' the profitable direction of engineering challenge. For instance it is obvious that the undertaking of a sequence of technical changes which involves removing a succession of bottlenecks will seem a more worthwhile activity in a plant where there is a need to expand beyond its existing output than in one facing a static or declining demand. Conversely, in a case when demand does decline (as happened for the "effective demand" of the Bar and Profile mill of the Rosario plant on many occasions) then management is likely to be compelled to think about the possibilities of adapting the capital equipment concerned so as to diversify its production. As Edith Penrose put it "the significance of existing resources may not be noticed by particular firms when their management is preoccupied with satisfying the demand for existing products, but it becomes very much in evidence when demand falls off". (2)

To sum up - the basic point which we have made concerns the great importance of

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(1) P. A. David Technical Change, Innovation and Economic Growth, Cambridge University Press, 1975, p. 33.

(2) E. T. Penrose, The Theory of the Growth of the Firm, Basil Blackwell, 1966, p. 87.

'exogenously-demanded' technical changes in the evolution of the Rosario plant. We also conjectured on the possible "efficiency" of urgent external requirements in calling forth adequate technological responses from the plant.

Indeed it is our impression that the particular external circumstances of the Rosario plant's evolution created a situation in which the technically determined 'domain' of the possible improvements and adaptations of the plant's technology has been very much more fully explored and utilized than the equivalent 'domains' of similar old-vintage steel-plants. The remarkable degree of up-grading achieved in the Rosario plant may thus be in good measure due to the unusual historical circumstances which have affected the plant.

But if the upgrading possibilities which were stumbled across in the Rosario plant out of historical necessity were, as seems to be the case, achieved at very low investment costs, then this raises the question as to whether other steelplants are taking full advantage of the upgrading possibilities which their history has not forced them to explore.

CHAPTER III. LEARNING AND THE GENERATION OF TECHNICAL CHANGE IN THE ROSARIO PLANT

In this Chapter our aim is twofold. Firstly to review very briefly a number of approaches to the subject of 'learning' that appear in the economic literature, and secondly, to present and discuss evidence concerning the types of learning that have taken place in the Rosario plant.

Some approaches to learning in the literature

The first approach we can mention has received a good deal of attention in the economic literature and may be called the learning-by-doing view of technical change. The basic empirical observation underlying this literature is that the unit costs of many products have been observed to decline as production experience grows. Originally the empirical observations referred only to unit labour costs. For example in the case of data on World War II airframes it was found that "doubling cumulative airframe output was accompanied by an average reduction in direct labour requirements of about 20% (1). However, more recent empirical studies have suggested that the basic relationship between accumulated production and cost declines "appears to apply" to the full range of costs including development, capital distribution and overhead as well as labour costs" (2). The basic relationship is simply that "costs appear to go down on value added at about 20 to 30% every time total product experience doubles for (an) industry as well as for individual producers" (3).

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(1) Quoted from W.Z. Hirsch, Firm Progress Ratios, Econometrica, April 1956, page 136.

(2) The Boston Consulting Group, Perspectives on Experience, published by the Boston Consulting Group, Inc., 1970, see Introductión.

(3) See The Boston Consulting Group, op. cit., page 12.

The explanation given for these cost declines -which are usually represented as 'learning curves', 'progress functions' or 'experience curves'- is that "experience" of production is bound to lead to greater efficiency. Hence the more a firm or plant can accumulate experience of production, the greater the efficiency improvements that it can be expected to introduce. Firms and plants, in other words, learn from experience, or in the usual terminology they 'learn-by-doing'.

To formulate and represent this 'learning-by-doing' phenomenon economically the approach most often taken in economic literature has been to multiply the statically defined production function of the firm by an "experience term" where this experience term is represented by some function of the quantity of the firm's past output of the good in question (1). In these models the firm produces "experience" automatically as a bye-product of its production of goods, and what determines the degree of cost-reduction obtained is only the firm's cumulated past output of the good in question and the particular functional form selected for the experience term.

As an alternative to this formulation, some authors have used elapsed time since beginning production as the variable which enters into the "experience-term" (2) and various alternative functional forms of the experience term have been suggested.

However an important difficulty with models in the learning-by doing tradition is that whilst undoubtedly some fraction of the knowledge relevant

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(1) Learning-by-doing is assumed in these models to operate on the production function in a Hicks neutral function.

(2) See for instance the suggestions put forward by Robert B. Zevin and William Fellner for using cumulated time as the index of experience -as quoted in P. A. David 'Learning by doing and tariff protection', Ch. 2, of P.A. David Technical Change, Innovation and Economic Growth, Cambridge University Press, 1976, pp. 116, 117.

to improving productive efficiency does get generated as a _bye-product_ of production activities, it is also clear that much of the relevant knowledge for improving productive efficiency gets generated as a result of _specific knowledge-gaining programs_ to which resources are assigned by management. These latter type of programs, which may be termed "education and research" programs, cannot be successfully handled within the learning-by-doing framework. They represent 'learning-by- spemding' rather than 'learning-by-doing' activities and they require a framework in which one can represent the output of specific kinds of learning as being related to these specific actions and expenditures taken to produce it.

One interesting model of the 'learning-by-spending' variety has been developed by Katz, in which firms devote a proportion of their revenue specifically to inventive activity designed to produce a stream of _minor_ adaptations, improvements and innovations in plant processes and in the products produced (1). A key point on which this model depends is that the improvements are all assumed to take place within the framework of an essentially 'given' technology -i.e. the improvements are 'minor', which has the important consequence that the 'output' of spending on the inventive activities can be assumed to follow on closely in time and also with minimal uncertainty once the expenditure has been made- behaviour which does not apply in the case of expenditures on 'major' innovations when the risks of failure are considerable and the gestation time likely to be long. The inventive activity in Katz' model may be engaged in at any time from the beginning of 'normal plant operations' onwards, and entrepreneurs treat

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(1) Jorge Katz, _Importación de tecnología, aprendizaje e industrialización dependiente_, Fondo de Cultura Económica, México, 1976.

their 'learning expenditures' as variable costs. Katz is then able to demostrate under certain simplifying assumptions what an 'optimal' rate of learning expenditure for a firm would be, and he is able to extend his model to consider optimal learning strategy given the possibility that learning expenditures may produce external benefits for competitive firms as well as internal benefits to the firm which generates the learning. He also demostrates empirically -for sample of firms in three Argentine industries in the period 1960-68, a high oorrelation between the increases in global productivity achieved by these firms and the accumulated firm expenditure on 'adaptive R and D' undertaken in the period per person employed. The expenditure on adaptive R and D was calculated as the sum of all the expenditures undertaken by the R and D departments of the firm concerned (if it had one), plus the expenditure on related technical departments such as the Eng neering Department Quality Control Dept, Technical assistance to production Department, etc.

It is clear that Katz's model of 'adaptive R and D' aimed at producing minor technical changes in plants after the start of their normal operations does address itself to a highly important aspect of industrial reality, however it is also pertinent to note that the model excludes, by virtue of its assumptions, the consideration of (a) the learning that firms may angage in before the start of normal plant operations (i.e. the learning done in the pre-investment phase, the construction phase, and the start-up phase of new plant investments; and (b) the learning associated with major modifications to plant technology.

In general we can remark that the well known phenomenon of productivity increases which arise from investment in new plant and improved capital goods is not usually regarded in economic literature as a field involving any "learning" contribution by the firm (1) but is usually analysed as a static "choice of techiques" problem whereby the entrepreneur chooses the least-cost technique available on the (known) isoquant of best-practice technologies for the desired output, taking into account his factor prices. The objection to this traditional view is that it sweeps under the carpet the real-world problems of (i) learning about the existence of the different best-practice techniques, (ii) learning about what their capital and operating costs can be expected to be when set up in the specific location planned by the firm and within the specific technological and economic context of the firm's existing operations, (iii) the learning involved in plant construction, (iv) the whole learning process involved in training staff to operate the new facilities, (v) the learning process involved in starting up the new facilities, and then (vi) the learning involved raising output up to the intended design level.

Even if it can be argued, quite correctly, that many firms hire specialist consultants to supervise most of these steps, it is plain that the firm concerned must nevertheless still be engaged in an extensive learning process, at the very least one which involves learning how to successfully operate and maintain its new investment.

Thus, learning processes of great economic importance go on inside firms both in connection with the making of substantial new investments, and with the generation of all manner of adaptations and improvements in

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(1) Although Kennet Arrow in his seminal learning-by-doing paper, proposed that cumulative gross investment should be made the measure of experience, he assumed that technical progress was due only to improvements made by capital goods suppliers, i. e., that it was due to experience gained in machine building. The idea that a learning process by the firm was needed to accompany acts of investment in improved capital goods was not taken into account: see K. J. Arrow, The Economic Implications of Learning-by-doing, Review of Economic Studies, XXIX (June 1962) pp. 155-173.

the efficiency of their existing investments. All of this learning, evidently, involves the use of the time of the firm's personnel and of the firm's resources and has an opportunity cost. The question is raised, therefore, as to what kinds of learning is it most worthwhile for a firm to engage in? The existing learning-by-doing theories cannot, in principle, answer this question, except by saying "to learn, you most produce more" and the 'learning-by-spending' model of Katz which is concerned with spending on adaptive R and D does not attempt any comparison between this particular kind of spending, and spending on the learning involved in making major new investments and/or major alterations to existing facilities. Yet, it is clear that if empirical and theoretical economic analysis could throw lightt on the comparative costs and benefits of these different kinds of learning (and also throw light on the complementarities which exist between them) then it would be rendering a most valuable service to industrial project analysis and industrial planning.

Two further, quite different, approaches to the learning problem will now be mentioned, in closing this brief literature review.

The first approach stems from the conception, due to Hirschman, that all projects are subject to "a set of possible and unsuspected threats to (their) profitability and existence" (1). Given that one or more of these threats -which may consist of matters such as supply-side difficulties, severe problems of inadequate or excess demand, financial uncertainty, faulty administrative arrangements or political interference- are highly likely to materialize during the lifetime of the project, then what

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(1) Albert O. Hirschman, Development Projects Observed, Brookings Institution, 1967.

distinguishes one project from another is principally its ability to overcome the severe problems which it will sooner or later face.

However just as Hirschman holds that all projects have a high propensity to "run into trouble", he also holds that projects are sometimes unexpectedly resourceful in getting out of trouble. In other words whilst promoters tend to underestimate the magnitude of the potential threats to the success of their projects, they also tend to underestimate the possibilities of taking remedial actions should a threat become real.

The relevance of this conception of Hirschman's to the question of 'learning' is that an industrial plant may be expected to have passed through a number of "crisis-periods" in its existence during which a greatly accelerated learning process will have taken place designed to search out, select and then implement a remedial path of action leading away from the situation of crisis into which the plant got itself. The Hirschman conception therefore leads one to expect that an important component of the "learning" going on in plants will consist of "crisis-induced" learning. It suggests that in interpreting the overall evolution of industrial plants, one will need to pay specific attention to the "crisis-induced" learning as well as to the less frenetic types of learning associated with the more normal periods in the plant's life.

The second approach which we will briefly mention here is that of Edith Penrose. In her classic book, The Theory of the Growth of the Firm (1) Penrose demostrates that "both an automatic increase in knowledge and an incentive to search for new knowledge are, as it were 'built into' the very nature of firms possessing entrepreneurial resources of even average

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(1) E.T. Penrose, The Theory of the Growth of the Firm, Blackwell, Oxford, 1959.

initiative".

The learning process which Penrose refers to is not simply one of learning to reduce costs on already installed processes, but a much more wide-ranging process of learning progressively more and more about the "productive possibilities inherent in the resources of the firm". In Penrose's model this learning process going on inside the firm acts as a powerful internal inducement for the firm to expand in directions which permit its existing collection of physical managerial and entrepreneurial resources to be more profitably used. As a result, "learning", in Penrose's view is the crucial factor in determining the character of the expansions that a firm undertakes, and the way that a firm's product-mix alters, as well as being important in leading to efficiency improvements in existing processes. Evidently this is a much broader conception of "learning" than the one explored in the "mainstream" learning literature to which we referred earlier on.

Evidence about learning in the Rosario plant.

This completes our brief literature review. Now our aim is to present and discuss evidence which throws light on the way "learning" has developed within the Rosario plant.

What we do is to first analyse a selected number of the most important technical changes which have been carried out in the plant so as to see what kind of "learning" was involved in these changes. This evidence, together with evidence presented earlier in the report, then enables us to build up a picture of the development of learning in the Rosario plant which we then contrast with the literature approaches to learning reviewed briefly above.

1. The construction and start-up of the plant

It can truly be said that "learning" got off to a rapid start in the Rosario plant from the very beginning, in 1943. This was due to the virtual impossibility of obtaining capital goods from the USA or Europe during wartime -which meant that Acindar had no choice but to engage in a "do-it-yourself" operation to translate its financial investment. into a working steelplant.

The success of the operation was no mean achievement for an enterprise fresh to the steelmaking field. The founder of Acindar, Arturo Acevedo, persuaded General Savio, the "father of the Argentine steel industry" to part with a set of the plans of some small Siemens-Martin furnaces installed in a plant belonging to the Argentine Armed Forces - and Acevedo then gave these plans to a young engineer, Ricardo Pujals, who he had recruited from another small Argentine plant, La Cantábrica. It was Pujals' job to design a 'scaled-up' Siemens-Martin furnace for the Rosario plant, based on these plans, and to supervise the construction of the furnace. Making use of his previous experience of having helped in the construction and operation of two Siemens-Martins furnaces in La Cantábrica, Pujals was able to design a furnace for the Rosario plant which was not only scaled-up (from 15 tons to 25 tons nominal capacity per heat), but which also incorporated significant design improvements compared to the Siemens Martins furnaces in La Cantábrica and in other Argentine plants. Then when it came to the construction of the furnace, Acindar had to display great ingenuity in obtaining the needed structural materials, and finally ended up having to dismantle railway wagons and bogies to obtain the needed metal parts.

Still further ingenious improvisation was required in fitting out the furnace with satisfactory refractory bricks -for the supply of these from the USA was becoming less and less reliable. In the case of silica bricks, Acindar was helped by the start up of national manufacture of these, but in the case of Magnesite bricks, Acindar had to engage in the manufacture of its own by means of a process involving the compression of mixtures of fried imported magnesite and glue.

Finally, when it came to the operation of the furnace then installed in the Rosario plant, Acindar again had to improvise. Since coke was not available, charcoal had to be used in the furnace for bringing up the carbon level in the metallic bath to the required levels - and it was necessary to develop a "home-grown" method for keeping the charcoal from floating to the top of the metallic bath and burning off. The method developed was the crude one of packing the charcoal in together with limestone on the hearth of the furnace and then tamping it down by loading all the solid scrap on top.

A similarly high degree of improvisation was involved in the installation and initial operation of the Rosario plant's bar rolling mill -which is now something of a legend amongst the senior staff at the Rosario plant today. However we shall not go into details here.

There are a number of observations worth making about the "learning" involved in Acindar's successful effort to bring the Rosario steelplant into existence and to get it functioning successfully under difficult wartime conditions.

The first observation concerns the remarkable success of the entire operation considering the virtual elimination of the usual channels of 'technology-transfer' from abroad that would have been available to Acindar in normal times. This suggests that the economic potential of 'local' learning efforts may well be a largely neglected or else a totally unknown and dormant potential in times of comparatively easy access to imports.

The second observation is that Acindar was able to benefit from the 'embodied' learning contained in the furnace plans which General Savio gave to Arturo Acevedo, and, even more important, from the learning about furnace design, construction and operation which Ricardo Pujals brought with him by virtue of his four years of prior experience with La Cantábrica. In other words a significant element in Acindar's success in putting up the Rosario plant was that the company organised itself to take advantage of external learning benefits generated in other Argentine steelplants.

A third observation concerning this early "learning" in the Rosario plant is that it spelled out what was to remain as a hallmark of Acindar's technological approach ever since - namely a definite "technological optimism" both as regards the development of "home-grown" adaptations and improvements when required and also as regards advancing into technological fields completely new to company (1)

2. The enlargement and modification of the first Siemens-Martin furnace and the building of a second one (1947-49)

The design of the second furnace and the modification of the first one benefited from several minor improvements suggested by the practical experience gained in the construction and operation of the first furnace. (A clear example of learning-by-doing).

3. The installation of shaft furnaces for producing hot-metal from scrap and coke, for serving as part of the charge to the Siemens Martin furnaces. (1948-49)

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(1) Acindar has pioneered, within Argentina, in continuous rolling mills for bars and wire rod, in forged products for the automobile industry, in iron-ore exploration, in special steels, in plastic tubes, and in certain kinds of electrodes.

This important technical change was sparked off by the fact that senior Acindar personnel had noticed the successful use being made of shaft-furnaces by a small-scale steelworks in Illinois, U.S.A. (i.e. learning about the availability of a previously unknown technique).

4. The installation and start-up of the Billet mill (1949-50)

This major technical change involved investment in new capital equipment of entirely foreign design which was mostly imported. Furthermore, both the installation and start-up of the mill was supervised by a north-american expert seconded from the Republic Steel Company, who worked full-time with Acindar throughout the period 1947-51. In practice this expert worked closely together with Acindar's own engineers and a sizeable contribution was made by many of Acindar's personnel to the detailed engineering design required by the billet mill, particularly in so far as civil and mechanical engineering was concerned. There was also extensive participation and training of Rosario plant personnel throughout the start-up period which appears to have lasted over a year. It is therefore clear that Acindar was actively involved in "learning" throughout the investment and start-up phases of the Rosario plant's billet mill, and that the company was able to 'internalise' virtually all the relevant specialist knowledge brought over by the foreign expert.

5. The changeover of the Siemens-Martin furnaces to basic refractory lining. (1958-59)

As far as we can tell this change was undertaken entirely by plant personnel. It corresponded to a well-known and widely tested improvement already made in countless other Siemens Martin furnaces all over the world. It cannot therefore be usefully regarded as a result of 'learning-by-doing'.

6. The changes made from top-poured to bottom-poured ingot casting, the improvement of the plant's laboratories and the setting up of inspection procedures at each process stage from raw materials acceptance to finished product. (1960-61)

These changes were made as a result of the recommendations made by German consultant who was invited to Rosario by the plant's Director, following one of the periodic visits made by this Director to Europe. Experiments were conducted in the plant to demonstrate the superiority of bottom-poured to top-poured ingot casting before the changeover was made. All above changes involved the learning of new operating practices in the plant. However the improvements themselves cannot be considered to have arisen in evolutionary form from the plant's previous knowledge stock as a result of learning-by doing. Instead they resulted clearly from the specific incorporation into the plant of both new capital equipment and new procedures recommended by the foreign consultant.

7. Successive modifications made to shaft-furnaces

The performance of the plant's shaft furnaces has been improved on several occasions. For example, in 1958-59 the furnaces were fitted out with a much more durable refractory lining which greatly increased their availability. Shortly after, the furnaces melting rate and their coke productivity was increased by injecting hot-air, and in 1972-73 a further advance was made by injecting gas into the furnaces. All these advances required considerable experimentation and input of engineering by Rosario plant personnel.

8. Oxygen injection into the metallic bath of the Siemens-Martin furnaces.

Like the changeover to basic refractory lining this change had been frequently proved successful in other Open-Hearth furnaces. The impulse for this change apparently came from Acindar's central engineering group rather than from within the plant - and the implementation of the change was apparently also done with their help. This is therefore a case of learning and experimentation with a new technique when the Rosario plant was able to benefit from the skills and experience of Acindar's central organization.

9. The Reform of the Billet mill, 1969-70

This project is an extremely interesting example of internally generated and executed technical change resulting basically from the experience of the staff most closely involved in operating the mill. The project consisted of some 19 separate modifications to the Billet mill, affecting virtually all its component units. For instance the reheat furnace was redesigned and enlarged, and the ingot charging and discharging zones were upgraded and modified. Additions and layout changes were made to many of the transporting units between the mill's successive stages. The mill's lifting table was completely redesigned and its hydraulic system replaced, some changes were made in the foundations to the mill itself, and many improvements were introduced in the cooling bed, and the mill was fitted out with improved electrical and control systems. All these changes were designed by the senior staff of the plant's Rolling Division in cooperation with the plant's Engineering Division which was responsible for executing the changes.

This project - which had amongst its major objectives to increase the capacity of the billet mill - is a virtual archetype of an important engineering advance achieved by means of a large number of incremental improvements. One normally thinks of incremental advances as being carried out peacemeal, first on one component of a productive unit, then on another, and so on - but there is no special reason why incremental changes should have to be carried out in this way. Indeed in terms of reducing the down-time involved in making modifications it makes far more sense to make several changes in different components of the mill all at the same time, rather than having to stop the mill several times in order to make one change at a time. In fact this particular project to reform the Billet mill was also timed to coincide with the scheduled general repair of the mill - so that the down-time due to technical change should be reduced to the absolute minimum. The key point about this whole project is that both the prior learning that made it possible and the engineering of the project itself were entirely internally generated in the Rosario plant.

10. The reform of the Bar and Profile mill, 1970-71

Like the previous example, only more so, this project is a 'case-book' example of what can be achieved by internally generated learning and engineering. As explained previously, the project was designed with three purposes (stages) in mind, viz. (i) to increase the capacity of the Bar and Profile mill with its existing product mix by a factor of 70%, from 70,000 to 120,000 tons per annum, (ii) to permit the mill to diversify into the production of forging bars for the automobile industry, and (iii) to take into account in the design a possible future diversification into the production of small diameter semi-alloy round bars. The design was developed under the leadership of the Director of the Plant's Rolling Division, with assistance from his Deputy and from the plant's Engineering Division. All the new installations, modifications and layout changes involved in stage (i) of the redesigned mill were effected by the Rosario plant staff in record time, causing only a 15 day halt in production. It took a further 30 days to completely iron-out the training, maintenance and machine-adjustment problems associated with the start-up of the new mill, and this stage of the project (i.e. the capacity expansion) is claimed by Acindar to have entirely paid for itself in its first 3 months of operation.

Stage (ii) of the project - i.e. the modifications necessary to permit the mill to diversify into the production of forging bars - was carried out in 1972-73, and Stage (iii) is being held in reserve pending the evolution of market demand.

We can now ask what light this most interesting project throws on the phenomenon of "learning" in the Rosario plant? In the first place it is clear that the experience of the project's designers in having operated the Bar and Profile mill over many years was a key factor in making the project possible.

The then Director of the Plant's Rolling Division had been working in the Division since 1943 and his deputy since 1950. Both had therefore accumulated immense practical experience of the mill's equipment as well as experience in designing and helping to implement previous changes to the mill. Hence there was a highly important fund of previous "learning-by-doing" on which to draw, which must certainly have included an intimate knowledge of all the mill's current operative problems and design limitations as well a clear conception of many engineering and practical details relevant to possible modifications. On the other hand the project cannot itself be regarded as a pure outcome of learning-by-doing, since it required an autonomous effort of project design and engineering in which the previously accumulated "learning-by-doing" had to be coupled to the project's specific objectives, and in which resulting gaps in knowledge and design had to be filled-in by a deliberate knowledge search and creation effort.

Furthermore the determination of a project's objectives is itself an activity which goes beyond the limited terrain of learning-by-doing. In the case of this project, one notes an impressive degree of anticipatory technological strategy was built-in to its objectives. (The project foresaw three successive stages of development, the first of expansion in the output of the existing product-mix, the second of product diversification, and the third of a still further, future, possible product diversification). Thus, we can say that (i) the objectives of the project were clearly exogenously stimulated, however (ii) the feasibility of the project depended to an important extent on the accumulation of "learning-by-doing" type knowledge about the mill, and (iii) the coupling of the exogenously-stimulated objectives with the endogenous accumulation of knowledge about the mill required an autonomous engineering project to be developed.

. An indicator of the great success and originality of the reforms carried out on the Bar and Profile mill is that a report on the project was accepted for presentation at the ILAFA Conference on Rolling Technology, Machinery and Products held in Buenos Aires in May 1976 (1).

Observations and Analysis

The above account of ten important technical changes provides a good deal of direct evidence about learning in the plant. We now propose to use this evidence, together with some inferences about learning which can be drawn from the earlier analysis of technical changes presented in the report, in order to explore and discuss some aspects of the "learning" phenomena in the Rosario plant.

To begin with we can note that many qualitatively distinct varieties of "learning" have contributed to, and influenced, the path of technical change in the Rosario plant. For instance one can identify from our analysis of the ten important technical changes listed above and from our previous discussions about incremental technical changes in the plant at least the following different kinds of learning.

(i). Learning from the outside world about the availability of new types of capital goods and operative techniques

(e.g. via visits abroad, or from consultants advice)

(ii) Learning about how to construct; to adapt; to instal; to start-up; to operate; and to maintain new capital goods

(e.g. by do-it-yourself methods, or in cooperation with outside experts, or with help from Acindar's Central staff)

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(1) Oscar R. Amorini, Remodelación del tren de laminación de perfiles pequeños y livianos, published in "Laminación: tecnología equipo productos", ILAFA, Santiago de Chile, May 1976.

(iii) Learning about how to marginally improve the performance of existing capital goods installed in the plant

(e.g. through on-the-job learning, through maintenance activities, through the efforts of the industrial engineering division, through feedback from the quality control division)

(iv) Learning through engineering projects and studies

(e.g. generating alternative amplification and modification possibilities, gaining familiarity with alternative layouts, and with the features of additional capital goods that may be needed, exploring the economics of proposed changes, drawing together and synthesizing previous ideas and suggestions derived from learning-by-doing, etc.)

The above classification of distinct learning activities could clearly be extended and also made more detailed. However it is sufficient to indicate that there exist many forms of learning activities associated with different phases in the ongoing process of finding out about, projecting for, constructing, installing, starting up, operating, maintaining and then modifying the capital goods used in production.

Hence, prima facie, it seems improbable that any single learning 'function' will successfully approximate the economic effects of such an inherently heterogeneous set of activities as the ones described above - and it seems more promising to adopt a more disaggregated, empirical, approach to the phenomenon attempting to delineate the economics of the different types of learning and also to build up a picture of the important kinds of interactions, mutual reinforcements and trade-offs which exist between them.

Next, we turn to analyse some features of the historical development of learning efforts in the Rosario plant.

The record of the technical changes introduced makes it clear that the locus of attention for learning efforts within the plant, and the time variation of learning activities has displayed in many respects a shifting pattern, as attention and "learning efforts" got focused with varying intensity first on one part of the plant, then on another, and so on. In other words, instead of learning being "smoothed out" over the whole plant and over time, the characteristic pattern seems to be one of successive "spurts" of learning directed at highly specific machinery and/or problems.

Furthermore, as we saw repeatedly in the previous chapter, the "learning efforts" which lead to technical changes are not only concerned with attempts to reduce unit costs of production, but are very often aimed primarily at other objectives, such as capacity-stretching, product-mix changing, product quality altering, etc.

The main light we were able to throw on this complex historical learning pattern --consisting of "spurts" of different kinds of learning, directed at different plant sections, with varying intensity and with varying objectives across time-- was that the pattern could be considered as derived from (i) urgent exogenous demands (ii) exogenous stimuli and (iii) the endogenous pressure for changes. In other words the particular learning-path taken by the Rosario plant, and the objectives of learning efforts at different times, betray the very marked influence of specific external pressures and opportunities, as well as the influence of an endogenous pressure for improvement based on the application of what we called an engineering 'improvement ethic' within the plant.

We can now try to clarify this picture further: the way forward is through recognising that those sets of factors which we have postulated as "causing" technical change in the Rosario plant (and also causing the learning giving rise to technical changes) clearly did not operate in a vacuum, but only became operative via the actual learning efforts made by the plant's managers, engineers and personnel.

Hence it seems clear that an adequate explanation of the path of learning and technical change taken by the Rosario plant will need to consider such questions as the "learning capacity of the plant's personnel", and the theme of the accumulation of relevant experience by these personnel. So we shall now briefly consider these two questions.

We first take up the question of the capacity of plant personnel. The fact that the Rosario plant was able to successfully stretch its productive capacity, diversify its product mix, etc. when faced by urgent exogenous demands shows that its personnel (in particular the technical personnel) must have had the capacity to react successfully when required to meet urgent exogenous demands. Furthermore, in those technical changes which were exogenously-stimulated, rather than urgently demanded, it is clear that Rosario plant staff in many cases exhibited a capacity to anticipate the emergence of pressures or opportunities, and to develop engineering proposals and projects in advance of the immediate need for them. And we can also note that so far as the technical changes which we ascribed to "endogenous pressure" are concerned, the ability of plant staff to generate a stream of such "improvement type" changes also assumes the existence of some significant inbuilt capacity and concern for plant improvement on the part of Rosario plant personnel which was present even in the absence of urgent external demands or external stimuli.

We are saying, in effect, that the technical changes observed in the Rosario plant show that plant personnel displayed (a) the capacity to react, (b) the capacity to anticipate, and (c) an inbuilt capacity to effect improvements independently of particular outside stimuli or urgent demands.

Clearly enough, the development of these three capacities must be inter-related and we can now suggest some of the particular ways in which the inter-relationship has worked. For instance:

A) Exogenously-demanded changes can give rise to organizational changes which in turn strengthen the resulting "stream" of endogenously generated improvements. (This applied to the strengthening of the Quality Control Division in 1960-61, and of the Maintenance Division in 1969).

B) The accumulation of "endogenously-generated" learning over time is likely to reinforce the "capacity-to-react" if technical changes are suddenly required. This is because many ideas will already exist as to improvements which may be made to the equipment, ways of stretching its capacity etc., so that response-time is likely to be fast, and the costs involved in project generation relatively low compared to what they would have been if no "stock" of more-or-less worked out improvement ideas existed. (e.g. The Billet Mill reform 1969).

C) The repeated exposure to the crises produced by exogenously demanded changes can be expected to lead to a greater 'anticipatory' capability involving the preparation of projects for reform in advance of the immediate need for them (1) (e.g. the reform-project for the Bar and Profile mill in 1971).

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(1) This is analogous to the competitive situation described by Schumpeter "But in capitalist reality, as distinguished from its textbook picture, (the)... kind of competition which counts (is) the competition from the new commodity, the new technology, the new source of supply, the new type of organization... it is hardly necessary to point out that competition of the kind we now have in mind acts not only when it is in being but also when it is merely an ever-present threat. It disciplines before it attacks". Joseph Schumpeter, Capitalism, Socialism and Democracy New York: Harper, 2nd Ed. 1947, pp. 84-85.

These are evidently only three of the many possible interactions. In general the experience of the Rosario plant suggests that an advance in any one of the three learning capacities - i.e. reactive, anticipatory and inbuilt - is likely to lead to positive feedback on the other two.

We now turn briefly the subject of the accumulation of experience within the plant:

There clearly is an important relationship which exists between what we called the capacity of the staff to carry out technical changes and the state of their accumulated experience. As examples of this, we noted the importance in the design and construction of the Rosario plant of the previously acquired experience in La Cantábrica of Ing. Ricardo Pujals when it came to the design and construction of the Rosario plant's first Siemens-Martin furnace in 1943 and we also noted the crucial role played both in the Billet mill reform of 1969 and in the Bar and Profile mill reform of 1970-71 by the long accumulated in-plant experience of the Director of the Rolling Division and his Deputy.

Besides showing the importance of accumulated experience in permitting certain technical changes, these two examples also illustrate how the benefits of acts of learning (experience) may often be delayed benefits. This point is of course well-known. However what is perhaps less well appreciated is that even the type of learning activity associated with marginal improvements to existing facilities may sometimes prove to generate some or all of its benefits only with a considerable time-lag. (E.g. much of the value of the 'marginal' learning activities in the Rosario plant's rolling division over the years had to 'wait' until the 1969 Billet mill reform and the

1970-71 Bar and Profile reform before getting translated into actual technical changes of economic value to the plant). This suggests that a learning-by-spending model, such as that of Katz, which assumes only a short-time lag between expenditure on 'adaptive (minor) Rand D' and the economic results may be leaving out of account significent future benefits which can occur, with a substantial time-lag, to the plant.

In parallel with this point about the potentially delayed effects of learning is the obvious but important point that an appreciable amount of learning which went on in the Rosario plant, was wasted. This can be illustrated with a number of examples.

In the first place an appreciable number of engineering studies and projects put forward from time to time by the plant's Senior Management or by its various Divisions were not taken up. (1).

Secondly, some of the specific educational experiences acquired by various of the Rosario plant's engineers and technical staff in the period 1958-1968 - for instance involving courses on blast Furnaces and on oxygen steelmaking, did not ever prove to be useable either in the Rosario plant or within Acindar as a whole. (Because the Acindar blast-furnace and oxygen steelmaking project was finally balked by the Argentine government in 1968).

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(1) For instance, ambitious projects to instal continuous casting, electric arc furnace steelmaking and even steelmaking by converter were not taken up. On a more modest scale, proposals for adding extra stands to the billet mill were not acted on, and many projects involving the acquisition of additional capital goods did not receive the go-ahead.

Thirdly, the fact that, inevitably, in the course of the years, some of the Rosario plant's engineers and technical staff have left the plant -either to continue their careers in Acindar's other plants, or to work for competitive enterprises or to go abroad- means that a significant fraction of the learning they accumulated in the plant became no longer available for the plant to use. (1)

Hence it is clear that there is no simple one to one relationships between the accumulation of experience in the Rosario plant and the technical charges introduced there. The fact is that much of the experience accumulated in the Rosario plant was not all usable immediately but constituted what might be called "potentially usable learning" and some of this was then applied with a considerable delay, or was never applied.

These simple observations are useful in that they demonstrate some of the pitfalls involved in trying to develop any all-encompassing model of how "learning" activities and expenditures rebound on the economic performance of plants.

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(1) Another sort of 'waste' of accumulated experience is described by Penrose, who notes that.... "Many of the productive services created through an increase in knowledge that occurs as a result of experience gained in the operation of the firm as time passes will remain unused if the firm fails to expand.... The unused services created in old as well as in newly acquired personnel through increases in both 'objective' knowledge and experience do not often exist in the open form of idle man-hours but rather in the concealed form of unused abilities". E.T.Penrose, op.cit, p.54.

It will now be useful, before proceeding, to summarise what has been said so far about learning in the Rosario plant. The first observation was that many kinds of "learning" activities had taken place in the Rosario plant associated with different phases in the ongoing process of finding out about, projecting for constructing, starting up, operating, maintaining and then modifying the plant's capital goods.

Secondly we pointed to the shifting pattern of learning efforts over time in terms of their intensity, locus within the plant, and objectives.

Third we recalled that this shifting pattern of learning efforts could be usefully explained in terms of (i) reactions to urgent exogenous demands, (ii) responses to external stimuli, and (iii) the 'endogenous pressure' for plant improvements which was 'built-in' to the plant's organization and in its technical personnel.

Fourth we noted that the Rosario plant's personnel (particularly its technical personnel) had exhibited a definite capacity to react to urgent exogenous demands, to anticipate and respond accordingly to exogenous stimuli, and to generate a significant stream of "endogenous" improvements, and we were able to point to instances in the experience of the plant which suggested that these three kinds of "capacities" were inter-related in a mutually reinforcing manner.

Fifth we pointed out that there was unlikely to be any simple relationship between the accumulation of experience in the plant (via learning) and the resultant flow of technical changes which brought economic benefits to the plant - because of the problems of the considerable delays withwhich some of the benefits of learning in the Rosario plant got realised and because of the incidence of wasted learning.

Conclusions

The foregoing observations concerning the Rosario plant suggest three useful ways to carry forward the analysis of the "learning" phenomenon.

To begin with, it would be valuable to initiate a series of empirical studies concerning the "rates of return" obtained by plants from the qualitatively different kinds of leraning activities in which they engage. For instance it would be valuable to know what rates of return are obtained by plants from their expenditures (i) on learning during start-up, (ii) on learning associated with maintenance expenditures, (iii) on the learning carried out by industrial engineering departments, etc. Even though such studies are bound to be beset by many kinds of measurement difficulties, they would have the great virtue of clarifying the distinct kinds of costs and benefits associated with the many distinct kind of learning activities, and in many cases it may well be possible to give a reasonably clear idea of the average rates of return involved in such projects as well as the range of variance involved. Such studies would be a useful empirical contribution to the working out of better theoretical models of learning by the firm than those that are currently most widely put foreword in the economic literature.

In the second place, it would be valuable to try to distinguish between firms (plants) on the basis of the different kind of "learning paths" that they have pursued. We saw that in the Rosario plant the learning path has involved a high incidence of (a) incremental capacity-stretching technical change, and (b) product diversification. However, as we pointed out in Chapter II different plants often have very different sets of objectives for technical change. In some plants, cost-reducing technical change may be the most important, or else quality changes may have the first place and of course these priorities are subject to change over time. The result of the existence of different objectives and priorities for technical change is that firms will tend to travel along different learning paths. There is also another factor at work -which is the availability of investment capital. Some plants are clearly more capital-starved than others, or else cannot undertake major investments because government restrictions block the way. In such cases, the learning associated with incremental improvements to the existing facilities will be all important, because major new incorporations of outside technology are completely ruled out.

Hence it seems highly appropriate to seek to develop an empirical classification of the alternative "learning paths" which firms (plants) pursue, in order that optimization theory can then be guided by the requirements of these different paths rather than being guided by the unrealistic assumption that all firms are pursuing the same unique objective of unit-cost reduction.

Thirdly and finally, the importance of the way in which firms (plants) organize themselves for learning activities has emerged clearly in this case study of the Rosario plant. Even if -as Hirschman points out, and as the experience of the Rosario plant confirms- much crucial learning takes place as a response to crisis, it is still pertinent to enquire how firms are able to organize themselves to get out of crises, and whether by better organization such crises could not be either softened in their economic effects or else turned to even better advantage.

As for the 'non-crisis' learning activities, there is every reason to believe that the intensity and effectiveness of these is greatly influenced by the way in which the firm organizes itself. Thus comparative empirical studies of the way firms "organize for learning" should be useful in helping to account for variations in firm's performance. If such studies could be linked to the earlier ones we have suggested, i.e. concerning the "rates of return" to learning expenditures and concerning the study of alternative "learning paths", then some valuable findings should result, which would be of interest both to practical project-analysis and policy-making, as well as to the improvement of the economic theory of "learning" which is still in a rather primitive state.

CHAPTER IV

THE RESULTS OF THE CASE-STUDY

In this final chapter our aim is simply to review the main results which emerge from the case-study. In brief form, these can be expressed as follows:

1) The objectives sought and obtained by technical change in the Rosario plant have gone far beyond merely reducing the unit costs of production. Whilst unit cost reduction has certainly been one of the persistently important objectives, other objectives, in particular increasing production capacity, diversifying the product mix, and improving product quality, have been of major importance too. (1)

2) Very many technical changes in the Rosario plant have had multiple objectives. Thus, we encountered many instances of capacity increasing changes which were also designed to reduce unit cost; of 'direct' unit cost reducing technical changes which also increased-capacity; of product quality changes which also led to reductions in unit costs; of changes in product mix which led to increased capacity, etc., etc.

3) The history of the Rosario plant displays a very impressive degree of adaptation in a basically 'old vintage' plant to prevent it from becoming obsolete --achieved through capacity-stretching, product-diversifying and quality improving technical changes, as well as by

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(1) Indeed one or more of these have often taken precedence -as objectives sought by technical change- over the objective of reducing unit costs.

direct cost-reducing technical changes.

4) Both the distribution of effort as between the different objectives of technical change, and the 'rate' of technical change measured by its impact over time on the principal plant output and performance parameters, have varied greatly throughout the life of the plant. Indeed the record shows that the locus, intensity and objectives of technical changes within the plant have been continously changing over time in response to changing pressures and opportunities.

5) The nature of these changing pressures and opportunities was explored, and the following conclusions were reached:

(a) Many of the most important technical changes introduced were responses adopted in the light of pressing external circumstances such as radical increases or reductions in the volume of effective demand faced by the plant, changes in the composition of effective demand, problems with raw materials supply, problems associated with unexpected lack of investment funds etc., etc., all of which made technical changes in the plant extremely pressing so as to avoid the imminent and sizeable economic penalties that would have ensued for Acindar if the technical changes had not been made. (We saw that these penalties would have arisen in the form of a low degree of utilization of Acindar's installed capital, either in the Rosario plant itself, or in the Acevedo plant.) We called these types of changes "exogenously demanded".

(b) We also saw how many technical changes (including some of the major ones) could not be regarded as urgently required responses to radically changed external circumstances, but were nevertheless stimulated by changed exogenous circumstances such as -typically- those occurring in the pattern of demand. These we called "exogenously stimulated" changes.

(c) Finally we saw how a large number of the minor technical changes could not be regarded as having been demanded or even stimulated in any direct way by specific exogenous factors, but resulted instead from what we called the "endogenous pressure" for plant improvements arising from the regular activities of plant personnel and divisions concerned with, or specifically charged with, the mission of increasing plant efficiency. These changes we called endogenously generated.

6) Whatever the origin of the initial impulse towards technical change (i.e. whether exogenously-demanded, exogenously-stimulated or endogenously-generated) we noted that virtually all the incremental technical changes, and most of the major technical changes too were both engineered and implemented largely by Rosario plant personnel. Only two of the dozen or so most important technical changes in the plant have been carried out under the leadership of outside consultants.

7) This in-plant capability to engineer and execute technical changes appears to have arisen and developed in several different ways: -through the previously acquired experience of the plant's engineers, through the on-the-job experience acquired in the plant itself, through having to respond to urgent exogenous demands, through responding to exogenous stimuli, and through the deliberate reorganizations carried out which improved the plant's built-in capability for generating endogenous, improvement-type changes.

8) In terms of the peculiar historical factors which might suggest that the experience of the Rosario plant is an unrepresentative special case --it is worth noting that the Rosario plant was both favoured and blocked by its relationship with the rest of Acindar. It was favoured to the extent that the plant could rely on a never satisfied demand for its billets after 1961-62-and was also favoured by Acindar's technological 'ethos' of willingness to experiment and by being able to consult with Acindar's central engineering group. But the Rosario plant was nevertheless very much the 'junior partner' to the Acevedo plant, which led to its being relatively cut-off from investment funds, and forced to make do with largely outmoded technology. Whilst this historical situation <u>has</u> led to the undertaking in the Rosario plant of an unusually high degree of "incremental capacity-stretching" technical change- we noted that there is nothing inherently rare about this <u>kind</u> of technical change, in fact just the opposite, it is common in other steelplants too. As for the many other objectives of technical change which we noted in the Rosario plant, e.g. unit cost reduction, product mix diversification, product quality changing, etc., these are also common objectives in other steelplants- so at most we can say that the 'balance of objectives' of technical change in the Rosario plant has perhaps been unusually biased towards capacity-stretching technical change.

9) The study has demonstrated in many different ways the importance of <u>incremental</u> technical changes in the evolution of the Rosario plant. Incremental technical changes accounted for over half the increase

in steelmaking capacity due to technical change, and virtually all the increase in billet mill capacity. They have also been extremely important in reducing unit costs, changing product mix, and improving product quality. A particularly interesting point noted was that many incremental changes did not simply derive from on-the-job learning, but were produced as a result of deliberate 'research-type' strategies in the areas of preventive maintenance, industrial engineering and quality control, as well as through engineering projects.

10) The study throws light on the existence of (a) many distinct varieties of technical changes and (b) many different forms of learning which have occurred in the Rosario plant. It therefore casts serious doubt on the adequacy of the economic analysis of learning and technical change in terms of unit cost-reduction alone, and it also suggests the inherent difficulties which are likely to beset all learning models which attempt to approximate the <u>overall</u> learning behaviour of a plant or firm in a single formula.

11) In view of these difficulties we suggested that a promising way to advance the economic analysis of the "learning phenomenon" would be to develop a more solid <u>empirical</u> basis for theory. The particular research lines put forward were (i) rate-of-return studies on qualitatively distinct kinds of learning, (ii) studies concerning the 'learning-paths' taken by firm's and plants (taking due account of considerations such as investment constraints), and (iii) studies of how firms and plants organize their learning activities.