

COMMISSION OF THE EUROPEAN COMMUNITIES

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MEMORANDUM

on the implementation of an iron and steel
research programme, with a view to obtaining
financial aid under Article 55 (2) (c) of the
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INTRODUCTION

This document contains a series of proposals on iron and steel research that have been submitted to the Commission requesting financial aid under Article 55 of the ECSC Treaty from funds derived from the levies provided for in Article 50. It should be pointed out that the preparation of this year's iron and steel research programme has been accelerated in order to advance the necessary administrative work and to reduce the time delay in the awarding of research contracts. This will allow research needs on the ECSC programme to be met more quickly and the results of the work to be more rapidly available to industry.

The proposed research deals with a wide range of activities which are directed at meeting current technological needs within the Community's steel industry. The areas covered by this programme include : further exploitation of indigenous raw materials, increasing options in the consumption of raw materials (replacement of steel scrap by sponge iron or pig iron) in steel-making, greater flexibility in the substitution of various forms of energy, lowering production and processing costs, improving control procedures and the quality of steel products together with further studies on the utilization of steel in building and engineering structures.

In the important field of raw materials, research is proposed on more advanced mining techniques to further exploit the available iron ore resources in the Community (P 194 and P 195) while another proposal deals with the processing of a complex pyrite ore (P 172/2). In direct reduction and blast furnace technology, a number of the projects are concerned with important aspects of energy consumption and productivity. In particular, a major effort is proposed on further research on the injection of reducing gases as a substitute for coke in the production of pig iron (P 039). Earlier results obtained in the ECSC research programme by AIRBO and Cockerill Ougrée clearly demonstrated the feasibility of this approach to energy substitution. To reach a definitive conclusion, however, on the extent to which coke consumption can be reduced, it is now necessary to conduct full-scale trials on a large production unit. This research is not only of major significance to the steel industry's energy needs but is also of considerable interest to future developments in coal gasification and the possible exploitation of nuclear energy in steelmaking. It is planned to carry out this project in Algeria in collaboration with the Société Nationale de Sidérurgie due to the availability of low-cost natural gas coupled with the appropriate production facilities required for this research.

A proposal to further develop the IRSID continuous steelmaking process (P 230) represents another large scale research effort in which the scope for using a granulated pig iron charge in place of liquid metal will be investigated; this approach is seen as a possible alternative production method to the steel scrap (or sponge iron) - electric-arc furnace route of steelmaking.

An additional requirement of research is to protect and extend the market for steel products so that the community does not become dependent on external sources of supply. In this regard, two projects are proposed on electrical steels (P 166 and P 215) with the aim of stimulating technological development so that improvements in present-day materials can be realised.

Other proposals in the field of used properties of steel as well as the related studies in physical metallurgy cover additional aspects of product oriented research. This effort ranges from investigations of corrosion (P 199), formability (P 208), fatigue (P 162, P 163) and brittle fracture (P 165) to more basic studies of the relationship between microstructure and mechanical properties (P 177, P 188) and of the surface protection of steel by galvanizing (P 216).

At both the production and product level, the steel industry requires reliable and practical methods of measurement, inspection and analysis. A number of projects in this field deal with non-destructive methods (P 168, P 182, P 207) of flaw detection in semi-finished steel products. Control is also a major theme in the research proposed on rolling; the main objective is to achieve better dimensional control and flatness of both hot and cold rolled material (P 147, P 158, P 186, P 210).

Research on steel utilization includes more effort both on the exploitation of steel in industrialised building (P 143) and on studies of the performance of structural elements made from cold rolled sections (P 192). Furthermore, due to the growing interest in the use of structural hollow sections, effort is proposed to generate mechanical property data that are specifically required to establish uniform design criteria and specifications (P 212).

All the selected projects have been approved by the Iron and Steel Technical Research Committee (CRT) as top priority and recommended for financial aid by the European Coal and Steel Community.

THE RESEARCH PROGRAMME

I. "IRON ORE MINES" Programme

In the light of the changing circumstances which have affected world raw material markets, continued working of the Community's iron ore mines is an important factor in maintaining the independence of the iron and steel industry. The ore extracted has the particular advantage that it can be used either as the basic element of the melt or as an additive to regulate the basicity.

To be able to keep the iron ore mines in operation, the present rate of technical progress must be maintained and stepped up if, despite wage increases, costs are to remain competitive with those of imported ores.

The aim of current research is to replace the present method of extraction (winning by blasting) by one based on mechanized winning of ore. This new approach is the outcome of encouraging trials carried out in connection with earlier research and is in response to the rising cost of explosives; it should also enable hitherto unworkable average seams to be mined.

II. "DIRECT REDUCTION" Programme

The three research projects have one thing in common: they all provide for the use of cheap charging materials.

The Rotored process has been newly developed by CSM in Rome. Its further development is of particular interest because ore fines (saving in pelletizing costs) and cheap fossil fuels can be used, capital costs are very low and a molten reduction product is obtained.

The Novalfer process is one of the direct reduction methods operating on the fluidized bed principle. Here too ore fines can be used. However, hydrogen is used as the reducing agent with an eye to the future cheap production of this reducing gas by nuclear energy.

The third project is aimed at the processing of calcined pyrites containing Zn and Pb into pellets suitable for use in a direct reduction process. Prospects for the sale of pellets containing Zn and Pb to blast

furnace operators are steadily deteriorating both because of their lower strength and because of the environmental problems caused by lead and zinc. Some direct reduction processes offer - at least in theory - a solution to the problem. The main purpose of this project is therefore to allow better use to be made of a local raw material, the 30 million tonne pyrite deposit of Campiano in Tuscany.

III. "BLAST FURNACE" Programme

Three projects come under the heading of burden preparation:

- P 126: Solid fuels for the production of iron pellets
- P 151: Relations between the morphology and quality of sinter
- P 156: Investigation of important metallurgical relationships in the sintering of iron ores.

The energy required for the firing of pellets is generally supplied in the form of natural gas or oil. In project P 126, part of this energy is to be replaced by adding solid fuel to the pellets. Preliminary experiments have shown that energy savings of around 40,000 kcal/tonne pellets can be expected from this. A 15-25 % increase in output is also possible because of the shorter firing period. Better plant utilization and energy conservation are therefore the main aims of this research. Research projects P 151 and P 156 are to be carried out in very close cooperation. Both are concerned with sinter quality.

P 151 is designed to investigate more closely the relationship between structure and quality - such as cold strength, hot strength and reducibility.

Project P 156 will investigate the relationships between factors such as specific sintering efficiency, fuel requirements, particle size, strength, reducibility and decomposition on reduction. Previous results in this field cannot be transferred to large modern plant. Consequently there is a serious lack of information to be rectified.

The other three blast furnace research projects come under the heading of blast furnace technology proper:

- P 039: Blowing of hot reformed gas into the blast furnace
- P 130: Investigation of burden movement
- P 155: Optimization of the pig-casting machine process.

The Commission has already helped to finance earlier research on the blowing of hot reformed gas into the blast furnace. However, the

experiments then carried out at AIRBO and later at Cockerill Ougrée left three important questions unanswered:

1. What is the maximum quantity of coke that can be replaced by reducing gas?
2. How does a large blast furnace behave in continuous operation when this technology is used?
3. What improvements in efficiency are possible in a specific blast furnace?

To answer these questions, experiments in a large blast furnace (P 039) with a capacity of at least 1500 tonnes per day are required. The results of such research are of great general interest to the European steel industry, mainly in connection with the current efforts to gasify fossil fuels by nuclear energy. As the right economic and supply conditions for this research cannot be found in the Community at the present time, it is planned to carry out the project in an Algerian steelworks (2000 tonne blast furnace of the Société Nationale de Sidérurgie in Annaba). This will reduce the cost of the research to about one-third.

Research project P 130 concerns simulation experiments on the descent of the stock in the blast furnace. The purpose is to investigate the relationships between hanging, tuyere spacing, tuyere diameter and bridging between tuyeres. The results should supply data and guidelines for industrial practice.

Project P 155 is designed to obtain better utilization of pig-casting machines. It is a known fact that most pig-casting machines at present operate well below their maximum capacity. The aim is to reduce unproductive idle time and thus improve its casting yield.

The investigation is also expected to provide information on the optimum mould for a given pig form. The intention is to produce a mathematical model for the whole process which will enable the degree of efficiency to be ascertained, even in existing plants. Preliminary investigations indicate that if results are favourable a reduction in costs of 1.15 - 1.75 DM per tonne pig iron can be expected.

IV - "Steelw

IV. "STEELWORK" PROGRAMME

As usual, the research projects in the steel plant sector are extremely varied, ranging from theoretical metallurgy to the first application of a new technical process. The Commission proposes to aid a total of nine projects in this sector.

Theoretical metallurgy

The thermodynamic data required in ferrous metallurgy are generally available only in a very scattered form, if indeed they are known at all. This situation will be remedied by project P 148: Preparation of a data programme in the field of metallurgical thermochemistry.

Electrochemistry

Project P 154 (study of electrochemical deoxidation and desulphurization on a semi-industrial scale) is the continuation of earlier project that received ECSC aid. The first part established theoretical principles such as :

- determination of the most suitable slag composition
- investigation of electrochemical efficiency
- establishment of electrical parameters (current density, etc).

In the proposed phase, the laboratory results are to be tried out in a plant on semi-industrial scale. If the results obtained so far prove correct, it is possible to obtain sulphur contents as low as 0.001 % in a relatively short time (about 30 minutes). The process is also of interest because desulphurization is not tied to a specific part of the plant. Similar considerations apply to deoxidation. A further advantage in deoxidation is the fact that the addition of deoxidizers can be partly or completely abandoned.

Special ESR process

Project P 157 (production of a 1900 mm generator shaft by welding two parts together by the electroslog process) represents a practical application of electroslog technology. The European steel industry is here

trying to fill a technological gap that has existed for many years. All generator shafts for nuclear power stations of 800 MWe and over have at present to be made in Japan or America as the European steel industry is unable to supply the necessary ingots. The project is of immediate interest and great importance.

Project P 167 (novel slag systems for electroslag remelting (ESR)) is closely concerned with melting technology. It supplements the project P 080 recommended in the second research programme for 1974 which has the same aim: the development of slags that are non-polluting and non hygroscopic. However, different binary and ternary systems will be investigated. The technical and economic interest of the research lies in the intention to develop the ESR process to the stage where it will be possible to make steels with a very low hydrogen content.

Casting and solidification / continuous casting

Projects P 174, P 099 and P 173 centre mainly on the investigation of the metallurgical processes taking place in casting and solidification.

Project P 174 concerns segregation in wide-end-up ingots of 4-6.5 tonnes. The problem is particularly relevant to special steels and arises in connection with the move towards larger ingots. The purpose of the research project is to reduce segregation and rejects to a minimum by means of special ingot mould design measures and an optimum height to cross-section ratio.

Projects P 099 and P 173 are designed to investigate the effect of electromagnetic stirring of a continuous slab casting in the mould. The projects are coordinated, have similar aims, but adopt different methods. The main aim is to improve the surface quality and reduce the number of non-metallic inclusions.

Project P 173 also aims to influence the course of solidification in such a way that from the structural point of view a virtually unkilld steel is obtained. If good results are obtained, the market for continuously cast products would be greatly enlarged.

Automation

Project P 227 (automation of oxygen steelmaking plant) is a continuation and extension of research already in progress at ARBED.

It is now planned to test at ARBED other automation models developed by other steelworks and institutes (IRSID, CRM, Hoogovens).

Alongside work on ARBED's general aim of automatic process control by a dynamic model, based on reaction kinetics, tests will be carried out on a model to prevent slag foaming developed by CRM and a model to narrow the temperature range during refining prepared by Hoogovens. IRSID has developed its own dynamic model which will also be tested in Esch-Belval.

Continuous refining

Project P 230 (continuous oxygen refining process with solid charge) is the first technical application of the process developed by IRSID under an ECSC agreement. The process was originally developed for a hot metal charge. Instead, preheated granulated pig iron will now be charged. The CO gas produced by the refining process will be used for preheating. The heat balances prepared show that the process is self-sufficient as regards energy. However, it has not yet been tried in practice, and that is the purpose of this project.

From the economic aspect, this type of steelmaking represents an advantageous alternative to the melting of direct reduction pellets in the electric arc furnace.

V. "ROLLING MILLS AND PROCESSING" Programme

The quality of European rolled products is of very great importance in ensuring their success on the world market. With the current deterioration in the economic situation it is necessary to improve still further the competitiveness of European rolled products by maintaining our technological lead. Consequently the European rollers are presenting a research programme aimed specifically at obtaining better geometrical properties of wide strip. Four studies are designed to improve the thickness uniformity and accuracy of rolled products, with increased production and better flatness as complementary results.

One study is aimed at obtaining greater accuracy in the width of the product. One project, more in the nature of basic research, should enable better regulation of hot rolling mills to be obtained by increasing the knowledge of the phenomena governing metal flow in steel undergoing forming processes. Finally, the last project is related to contemporary problems (energy and environment) and aims to optimize slab reheating.

VI. "MEASUREMENTS" Programme

The activities that come under the heading "Measurement, Control, Examination and Analysis in Iron and Steel" include the analytical techniques, non-destructive testing, and any other method used in the inspection of components, or of assemblies, provided that it does not affect their ultimate use.

A very wide variety of techniques are employed, all of which have as their main objectives :

- improvement of product quality;
- rationalization of all sectors;
- reduction of production costs.

The development of these techniques is made necessary not only by changes in methods employed in the making, processing and fabrication of steel, but also by more exacting standards of quality. The research projects fall within the category of schemes aimed at evolving new methods and/or adapting existing ones to meet industrial needs.

VII. "USE PROPERTIES" Programme

a) Weldability

Maintenance of the mechanical properties of the parent metal in the heat-affected zone is a subject of constant concern to both the producer developing new grades and the user who has to meet increasing difficulty technological requirements.

b) Corrosion

It is not easy to find a solution to the problem of protecting thin sheet before forming and a number of complementary studies in related fields are needed.

c) Formability

Two major problems arise in the forming of sheet: to obtain a good surface finish and to ensure that the mechanical properties of the sheet used are inherited by the product, whose own properties may be improved by the forming operations.

d) Fatigue

Better understanding of fatigue behaviour by structural designers would enable safety factors to be better assessed and could then lead to a better evaluation of the design coefficient for structures.

e) Brittle fracture

The factors influencing the risk of brittle fracture in welded steel constructions have been studied throughout the world, resulting in various approaches to the problems of ensuring fracture safe design. Many current design standards utilize the Charpy test as a measure of material toughness in conjunction with experience and in some cases with laboratory type tests. More recently fracture mechanics approaches have been increasingly adopted and proposals to include the results of these tests in revision of standards are now being made.

f) Heat treatment

The study of the effects of heat treatment on welded structural steels is still of great interest, especially as increasing use is being made of steel grades with higher mechanical properties for technological purposes. The proposed research projects, such as the study of crack formation and investigation of the effect of the dimensions of the assembled parts, will enable progress to be made in this field.

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g) Electrical sheet

The most important commercial soft magnetic material is grain-oriented silicon-iron which is used in large quantities in the electrical industry. The amount of grain-oriented material produced is steadily increasing each year; in 1969 over 200,000 metric tons were produced in Europe. The total tonnage of electrical steel (oriented and non-oriented) made in the USA, Europe (the EEC countries) and Japan in that year was 657,000, 933,000 and 686,000 metric tons respectively, most of which was of non-oriented grades. In Europe, the major portion was consumed in home markets, although France and Belgium have important export markets. Another country with large export markets is Japan, whose production since 1959 has quadrupled, so that it is now probably the world's largest producer of electrical steel apart from the USSR.

As it seems that no new material is likely to replace grain-oriented silicon-iron in the foreseeable future, it is important to strive for a further understanding of and improvements in present-day material. Over the last few years economic considerations have tended to become increasingly important in large transformers and rotating machines, so users of the material are anxious for further progress.

VIII. "PHYSICAL METALLURGY" Programme

Research in the field of physical metallurgy has, as its ultimate objective, the generation of appropriate background information needed to bring about advances in the processing, service properties and utilization of steels. The research proposed below satisfies this requirement and deals with strengthening and precipitation mechanisms, the effect of hot deformation on structure and a basic study of the parameters governing the galvanizing of steel.

This research will contribute to advancing our current understanding of the factors governing such important aspects of physical metallurgy as :

- relationship between microstructure and mechanical properties (strength and toughness);
- influence of precipitates on texture development of sheet steel;
- precipitation phenomena and deformation stresses during hot deformation (rolling);
- role of base metal composition and process variables on the galvanizing of steel.

IX. "UTILIZATION" Programme

From studies carried out by the Steel Information Centres at the request of the Statistical Office of the European Communities, it appears that the construction industry accounts for about 25-35% of the total consumption of steel in the Community.

We continue to devote great attention to this sector, which is of considerable importance for steel utilization, mainly in order to encourage the idea (which it is hoped will be given practical expression in the near future) of the optimum use of steel in building.

This idea is reflected in the research proposals selected.

X. "MISCELLANEOUS" Programme

At present almost three million tonnes of granulated blast furnace slag are used in France as a binder for road foundations out of a total granulated slag production of six million tonnes.

The proposed programme makes an important contribution to the more profitable use of this by-product.

The proposed research is of great interest to the iron and steel industry in France and in the other Community countries.

CONCLUSIONS

The total budget for the selected research programmes amounts to 31.961,776 u.a. (at the conversion rates in the ECSC balance sheet for 1974). The ECSC's financial commitment will be 15.507.872 u.a., of which 15.056.185 u.a. will go to cover its participation in the research costs and 451.687 u.a. to cover the cost of disseminating information and related costs.

Annex 1 : Summary table

Annex 2: Research projects

S U M M A R Y T A B L E

Propo- sal n°	Titel of the research	Proposed research		Financial Aid		
		Duration years	Amount in national currency	%	Amount in	
					national currency	u.s. (balance-sheet 74)
	<u>IRON ORE MINES</u>					
P 194	Trials of winning high-silica ore in longwall faces using cutter-loaders	2	FF 7.720.000	60	FF 4.632.000	775.358
P 195	Trials with the Jeffrey continuous miner in calcareous ore	2	FF 6.600.000	60	FF 3.960.000	662.871
	<u>DIRECT REDUCTION</u>					
P 082	New liquid phase direct reduction process	2	Lit 288.000.000	60	Lit 172.800.000	197.965
P 153	Adaptation of the Novalfer fluidized-bed reduction process of the bulk processing of pre-reduced ores	3 1/2	FF 896.000	60	FF 537.600	89.990
P 172/2	Practical possibility of pre-reducing oxidized pellets to sponge iron	2	Lit 670.000.000	44	Lit 294.000.000	336.815
	<u>BLAST FURNACE</u>					
P 126	Solid fuels for production of iron pellets	3	DM 498.000	60	DM 298.800	92.802
P 151	Relations between the morphology and quality of sinter in the blast furnace	2	FF 2.580.000	60	FF 1.548.000	259.122
P 156	Investigation of important metallurgical relationships in the sintering of iron ores	2	DM 623.983	60	DM 374.390	116.279
P 039	Injection of reformed gas in the blast furnace	4	FB 490.000.000	20	FB 98.000.000	2.014.091
P 130	Investigation of burden movement and the consequent gas pressure drop	3	DM 905.900	60	DM 543.540	168.813
P 155	Optimisation of the pig-casting machine process	1	FF 240.000	60	FF 144.000	24.105
	<u>STEELWORKS</u>					
P 148	Preparation of a data programme in the field of metallurgical thermochemistry	3	DM 660.000	60	DM 396.000	122.990
P 154	Electrochemical deoxidation and desulphurization on a semi-industrial scale	1	FF 1.050.000	60	FF 630.000	105.457
P 157	Production of a generator shaft with a barrel diameter of 1900 mm by welding two parts together by the partial electro-slag process	1	DM 1.400.000	60	DM 840.000	260.888
P 167	Development of novel slag systems for E.S.R.	2	£ 82.300	60	£ 49.380	86.259
P 174	Segregation in wide-end-up ingots	3	£ 302.800	60	£ 181.680	317.365
P 099	Electromagnetic stirring of a continuous slab casting in the mould	2 1/2	FF 3.721.000	60	FF 2.232.600	373.719
P 173	Electromagnetic stirring of steel during solidification with particular reference to continuous casting	2	£ 121.790	60	£ 73.074	127.648
P 227	Automation of oxygen steelmaking plant	2	FL 19.808.000 FF 285.000	60	FL 11.884.800 FF 171.000	244.256 28.624
			FF 1.700.000	60	FF 1.020.000	20.963
			FLH 50.000	60	FLH 30.000	8.942
P 230	Continuous oxygen refining process with solid charge	3	DM 9.032.000	60	DM 5.419.200	1.683.097

Propo- sal n°	Titel of the research	Proposed research		Financial Aid		
		Duration years	Amount in national currency	%	Amount in national currency	
	ROLLING MILLS AND PROCESSING					
P 124	Optimization of slab-reheating	5	FF 4.000.000	60	FF 2.400.000	401.740
P 147	Control of product width in wide-strip mills	3	DM 989.000	60	DM 593.400	184.299
P 158	Thermal variations in roll camber in a tandem cold-rolling mill	2	DM 416.000	60	DM 249.600	77.521
P 186	Thermal variations in roll camber in a hot strip mill	2	FB 5.400.000	60	FB 3.240.000	66.589
P 119	Adaptive set-up of a tandem cold rolling mill	4	Lit 728.530.000	60	Lit 437.118.000	500.774
	Thermal variations in roll camber in a tandem cold rolling mill	4	FB 4.270.000	60	FB 2.562.000	52.655
P 175/2	Mathematical model for the prediction of metal flow in steel undergoing hot forming processes	3	£ 133.300	60	£ 79.980	139.712
P 210	Vibration and friction in a cold tandem mill	4	FB 49.700.000	60	FB 29.820.000	612.859
	MEASUREMENTS					
P 168	Ultrasonic holography for the inspection of thick sections	3	£ 124.000	60	£ 74.400	129.965
P 181	Improvement of the surface quality of hot-rolled strip by automatic inspection on the strip mill	3	FF 1.985.000	60	FF 1.191.000	199.364
P 182	New industrial equipment for the detection of surface defects by Eddy currents	3	FF 1.500.000	60	FF 900.000	150.653
P 189	New developments in direct-reading optical emission spectrometry	2	Lit 45.000.000	60	Lit 27.000.000	30.932
P 200	Development and implementation of methods for the routine spectrochemical analysis of non-metallic substances	2	DM 250.000	60	DM 150.000	46.588
P 217	Application of the glow discharge source for the determination of metalloids	2	FF 450.000	60	FF 270.000	45.196
P 190	Estimate of boron in solid solution in steel and its effects on bainitic and martensitic hardenability	2	Lit 50.000.000	60	Lit 30.000.000	34.369
P 203	Study of the preparation of pearls for X-ray fluorescence	2	FF 424.000	60	FF 254.400	42.585
P 204	Isoformation of powder-samples for X-ray spectrometry	2	FB 5.520.000	60	FB 3.312.000	68.069
P 207	Detection of surface defects on sections and hot semi-finished products	3	FB 17.700.000	60	FB 10.620.000	218.262
	USED PROPERTIES					
	a) <u>Weldability</u>					
P 161	Hot embrittlement in the heat-affected zone of welds in austenitic steels	3	DM 450.000	60	DM 270.000	83.857
P 191	Possibilities and limits to the development of new structural steels	3	Lit 170.000.000	60	Lit 102.000.000	116.854

Propo- sal n°	Titel of the research	Proposed research		Financial Aid		
		Duration years	Amount in national currency	%	Amount in	
					national currency	u.a. (balance-sheet 74)
P 199	<u>b) Corrosion</u> Corrosion and metallurgical properties of Zn-Al based binary and complex alloys	3	Lit 191.000.000	60	Lit 114.600.000	131.289
P 187	<u>c) Formability</u> Definition of the surface morphology of cold reduced sheet	2 1/2	FB 10.000.000	60	FB 6.000.000	123.312
P 193	Surface quality of stainless steel sheet	3	£ 154.900	60	£ 92.940	162.351
P 208	Cold forming (joint programme)	3	FB 7.500.000 FF 1.300.000 DM 500.000 £ 80.700	60 60 60 60	FB 4.500.000 FF 780.000 DM 300.000 £ 48.420	92.484 130.566 93.175 84.582
P 162	<u>d) Fatigue</u> Influence of the degree of purity and production conditions on the behaviour of low-alloy steels when exposed to vibratory stress	3	DM 670.000	60	DM 402.000	124.854
P 163	Deformability of boiler-making steels under alter	3	DM 700.000	60	DM 420.000	130.444
P 164	Fatigue strength and fatigue limit of welded joints in hollow sections	3 1/2	DM 655.000	60	DM 393.000	122.059
P 165	<u>e) Brittle fracture</u> Design conditions for avoidance of brittle fracture	2	£ 110.000	60	£ 66.000	115.291
P 160	<u>f) Heat treatment</u> Cracking in the stress-relieving of ferritic steels	3	DM 950.000	60	DM 570.000	177.031
P 159	Relationship between strength, wall thickness and fracture behaviour in component-simulating test pieces of high strength steels in the welded and stress-relieved states	3	DM 960.000	60	DM 576.000	178.895
P 166	<u>g) Electrical sheet</u> Basic properties of grain-oriented electrotechnical steel	3	£ 370.300	60	£ 222.180	388.112
P 215	Losses in electrical sheet	3	Lit 240.000.000	60	Lit 144.000.000	164.971

Propo- sal n°	Titel of the research	Proposed research		Financial Aid		
		Duration years	Amount in national currency	%	Amount in	
					national currency	u.s. (balance-sheet 74)
P 177	<p><u>PHYSICAL METALLURGY</u></p> <p>Thermomechanical treatment of weldable medium-carbon steels</p> <p>Simulation of the metallurgical phenomena occurring during hot rolling of strip</p> <p>Ratio of concentrations of precipitating elements in steel</p> <p>Galvanizing of steel wires</p> <p><u>UTILIZATION</u></p> <p>Use of steel in housing</p> <p>Composite steel-concrete beams</p> <p>Steel components connected to concrete members in buildings</p> <p>Floor and roofing structures for industrialized buildings compounded with shape resisting unities</p> <p>Cold-rolled steel sections (joint programme)</p> <p>Ultimate static strength of welded lattice girder joints in structural hollow sections</p> <p>Buckling of thin-wall hollow sections axially loaded</p> <p><u>MISCELLANEOUS</u></p> <p>Granulated blast furnace slag for road construction</p>	3	FF 1.153.500	60	FF 692.100	115.852
P 179		3	FF 1.260.000	60	FF 756.000	126.548
P 188		3	FB 12.000.000	60	FB 7.200.000	147.974
P 216		3	FF 1.300.000	60	FF 780.000	130.566
P 143		1/2	DM 831.600	72	DM 598.752	185.961
P 149		2	Lit 32.866.000	60	Lit 19.719.600	22.592
P 140/2		2	Lit 79.200.000	60	Lit 47.520.000	54.441
P 141/3		1 1/2	Lit 44.660.000	60	Lit 26.796.000	30.699
P 192		3	£ 15.000	60	£ 9.000	15.722
			FF 270.000	60	FF 162.000	27.118
			DM 100.000	60	DM 60.000	18.635
			FIH 235.000	60	FIH 141.000	42.026
P 212		2	FIH 420.000	60	FIH 252.000	75.111
P 223		2	FF 1.450.000	60	FF 870.000	145.631
P 134/2		3	FF 3.750.000	60	FF 2.250.000	376.631
			FF 41.934.500		FF 25.160.700	
		Lit 2.539.256.000		Lit 1.415.553.600		
		DM 20.591.483		DM 12.454.682		
		FB 603.790.000		FB 166.274.000		
		£ 1.495.090		£ 897.054		
		FL 19.808.000		FL 11.884.800		
		FIH 705.000		FIH 423.000		
	T O T A L				15.056.185	

S U M M A R Y T A B L E

ECSC COMMITMENT

	Financial Aid	Cost of dissemination of information	ECSC Commitment
FF	25.160.700	754.821	25.915.521
Lit.	1.415.553.600	42.466.608	1.458.020.208
DM	12.454.682	373.641	12.828.323
FB	166.274.000	4.988.220	171.262.220
£	897.054	26.912	923.966
FL	11.884.800	356.544	12.241.344
FLH	423.000	12.690	435.690
u.a.	15.056.185	451.687	15.507.872
converted in u.a. at the rate applicable for the ECSC balance-sheet 1974			

Brussels, February 1975

THE RESEARCH PROJECTS

I. "IRON ORE" PROJECTS

P 194 - Trials of winning high-silica ore in longwall faces using cutter-loaders

Previous trials have shown that it is possible to control the roof of a short face by means of powered supports.

Present research is geared to industrial-scale tests to see whether ore in longwall faces can be worked under good safety conditions using cutter-loaders, powered supports and an AFC and whether output can be programmed and a yield obtained which is higher than that achieved by traditional methods.

The main parts of the programme are as follows :

- 1) Definition of the geometrical layout of the area to be worked
- 2) Determination of optimum characteristics of the cutter, powered supports and the AFC
- 3) Control of ground movements
- 4) Assessment of the ore recovery rate
- 5) Estimation of the economic returns

The two-year programme will be directed by the "Chambre Syndicale des Mines du Fer de France" in Paris (F).

P 195 - Trials with the continuous miner in calcareous ore

Earlier trials in France and West Germany have shown that it is technically possible and economically profitable to win high-silica ore using a continuous miner. Calcareous ore is harder and less homogeneous than high-silica ore and has different abrasion properties. In France for example, it accounts for 80 % of the normal extraction from the Lorraine Basin.

It would therefore be worthwhile trying to win such ore by mechanical means, and this technique could also be used to work average seams.

Trials would consist of :

- 1) Determining the optimum cutting characteristics of a Jeffrey miner in more than one calcareous seam using several cutting heads and several types of pic-lacing patterns.
- 2) Developing a system for withdrawing the ore extracted by means of belt conveyors.
- 3) Assessing the economic returns of this method of extraction.

The two-year research project will be carried out by the "Chambre Syndicale des Mines de Fer de France" in Paris (F).

II. "DIRECT REDUCTION" PROJECT

P 082 - New processes for direct reduction in liquid phase

The Rotored process is a smelting reduction process that is in many respects comparable with the Ecketorp or Dored processes.

The main component of the installation is the rotating cylindrical reactor. The ore and reducing agents are charged and the oxygen and additional fuel injected through rotating, vertically displaceable lances inserted from above. The ore and fuel are alternately projected against the cylinder wall.

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The existing 1 m high plant is to be enlarged so as to provide valid data on :

- the iron yield (establishment of material balance)
- the energy consumption with various types of energy
- the refractory wear
- the uses of the molten metal.

The work is being done at the Centro Sperimentale Metallurgico in Rome, Italy, over a period of two years.

P 153 - Adaptation of the Noval for fluidized-bed reduction process to the bulk processing of ores

In previous experiments (ECSC Agreement 6210.76 with IRSID and CSM) quantitative data have been obtained on the influence of the ore in the fluidized bed and the optimum service pressure for hydrogen.

In the current phase, experiments with three fluidized beds operating in series are to be carried out. Prereduction to wustite will be done in the first reactor with partially oxidized gas. The main reduction will be done in the second reactor and the final degree of reduction will be obtained in the third.

The current plant consisting of one reactor will therefore be enlarged by the addition of another fluidized bed. A gas cleaning plant must also be installed.

The work is to be done at the Institut de Recherche de la Sidérurgie Française in Maizières-les-Metz, France, over a period of 3 1/2 years.

P 172/2 - Production of pellets by direct reduction of calcined pyrites containing Zn and Pb

Rotary kiln processes, such as the Krupp rotary kiln or the SL/RN, process, are the most suitable for the direct reduction of pellets containing Zn and Pb, and consequently the research is limited to them. The following

are planned :

- (a) preparatory laboratory experiments, particularly of a physical and chemical nature, to investigate the reactions between zinc and lead oxides and the iron oxides and the gangue;
- (b) experiments in a pilot rotary kiln, first to try out various fuels and then to investigate operating conditions such as throughput rate, reduction temperature, temperature profile in the kiln, etc. The distribution of Zn and Pb will also be ascertained (in the pellet, in the waste gas and possibly in accretions or refractories);
- (c) experiments with the reduced pellet. In addition to the normal pellet tests, melting tests in the electric arc furnace will be carried out.

The work is to be done by the Centro Ricerche e Sviluppo Solmine in Rome, Italy, over a period of two years.

III. "BLAST FURNACE" PROJECTS

P 126 - Solid fuels for production of iron pellets

In a number of scattered experiments it has been found that an increase of about 20 % in production can be obtained by adding solid fuel when firing hematite iron ore pellets. Energy consumption in making hematite pellets is about 100 000 kcal/tonne higher than for magnetite concentrates. It appears possible to replace about 85,000 kcal/tonne by adding solid fuel. This means that by adding 1.0-1.5 % solid fuel to hematite pellets the energy consumption in the form of natural gas or oil would remain the same as for the firing of magnetite pellets. The experimental programme is designed to supplement the tentative experiments carried out so far by a systematic investigation. A variety of solid fuels such as coke breeze, charcoal, lignite, coal of high and low volatility and petroleum coke will be systematically investigated to ascertain the optimum quantity and sizing.

Annex 2

The ores investigated will be hematite, hematite-simonite and hematite-magnetite mixtures.

The firing experiments will extend primarily to simulation of the travelling grate process and later the grate-kiln process.

The possibility of firing in the shaft furnace will also be explored. The pellets from the best experiments will then be tested for their chemical physical and metallurgical properties.

The research will be carried out by the Studiengesellschaft für Eisenergaufbereitung in Siebenburg, Germany, over a period of three years.

P 151 - Relations between the morphology and quality of sinter

The texture analyser developed by the Institut de Recherches de la Siderurgie Française (IRSID) and made by Leitz is the main instrument for this research. It analyses and records quantitative data on the following components simultaneously: magnetite, hematite, wustite, gangue, voids and ferrite.

A wide range of sinter mixtures will be made under varying operating conditions in an experimental shaft furnace in order to obtain a broad spectrum of sinter qualities. These will then be systematically investigated with the structure analyser and at the same time the conventional sinter tests such as cold strength, reducibility and decomposition on reduction will be carried out. In the most characteristic cases the sinter specimens will be reduced in counter current operation so as to monitor with the analyser the changes in structure during reduction.

Sinter tests in industrial plant are to be carried out at the same time to investigate the influence of the composition of the blending beds on the morphology of the sinter. The industrial results will then be compared with those obtained in the pilot plant.

This work is to be done at the Institut de Recherches de la Sidérurgie Française in Maizières-les-Metz, France, and is expected to take two years.

P 155 - Investigation of important metallurgical relationships in the sintering of iron ore

In this research project it is planned to investigate systematically once again the metallurgical relationships connected with sinter. The reason for this is that sinter is exposed to very much greater mechanical stress in new plants than in old ones. The following experiments are planned :

- (a) The investigations will be carried out on sinter from high-grade ore with an average Fe content of 60 %. Coke breeze of properties remaining constant throughout all the experiments will be used as supplementary fuel, the volume being varied.
- (b) The basicity will be varied in stages from 0.25 to 3.5. Limestone will be used as the basic material in one series of experiments and magnesite in the other.
- (c) Mechanical stress will be determined at four stress levels in the tumbler test (10, 20, 70, 250 revolutions).
- (d) The proportion of returns will be kept constant in each series of experiments (two proportions, 30 % and 60 %)
- (e) The factors to be determined or measured are size grading, sintering efficiency, fuel consumption, tumbler strength, degree of oxidation, reducibility, resistance to degradation and structure.

The structural analysis is to be carried out at the Institut de Recherches de la Sidérurgie Française (IRSID) with the texture analyser described in connection with P 151.

The work will be carried out by Mannesmann, Düsseldorf, Germany, over a period of two years.

P 039 - Blowing of hot reformed gas into the blast furnace

The preliminary work will take about three years; during that time the following will be done :

- (a) preparation of the project study, estimate of prime costs, conclusion of the necessary contracts;
- (b) supervision of the construction work in Annaba and acceptance of the plant;
- (c) training of the necessary personnel in the Community. The experiments will be carried out with engineers and technicians from the Community. The experiments proper will take about one year.

First oil will gradually be replaced by reformed gas until the injection technique is properly mastered.

Only then will coke gradually be replaced by reformed gas.

In the final phase experiments to increase efficiency will be carried out.

In all the experimental phases the substitution relationships will be precisely determined and chemical and physical measurements carried out. On completion of the experiments a critical economic study will be made.

The contract is to be concluded between the Commission and the Centre de Recherches Métallurgiques (CRM) of Liège, Belgium, which will manage the whole research project. The actual experiments will be carried out on the 2000 tonne blast furnace of the Société Nationale de Sidérurgie in Annaba.

The total duration of the research will be about four years.

P 130 - Investigation of burden movement and the consequent gas pressure drop

With increasing hearth diameters, the gas flow problems in the blast furnace are increasing. Individual phenomena such as the descent of the stock can very well be investigated on a model. Experiments of this kind are planned in two experimental plants:

(a) Experiments with sublimating particles

A three-dimensional blast furnace model is to be constructed on which the number, angle of inclination and diameter of the tuyeres can be varied. It will be charged with paradichlorobenzene pellets which sublime when air is blown through them. Decomposition therefore occurs in particular in front of the tuyeres. The burden movement is monitored optically by colour-tagged particles or by means of X-ray absorption measurements. The parameters in the measurements are volume of blast, particle diameter and size distribution.

(b) Experiments with non-sublimating particles in an experimental plant with mechanical discharge

These experiments will be carried out with one sublimating and one non-sublimating component (coke, formed coke or lime). Again the descent of the stock will be monitored by means of marked layers.

In all the experiments pressure drop measurements will be carried out over the full height.

The results will be stored and analysed by computer. They will be described by means of a mathematical model.

The research will be carried out at the Institut für Wärmetechnik und Industrieofenbau of the Technische Universität Clausthal, Germany, over a period of three years.

P 155 - Optimization of the Pig Casting Machine Process

Pig casting machines are generally used well below their maximum capacity and it has been estimated that over a 20 % increase in efficiency could be realized by reducing unproductive non-operating times and improving the casting yield. Such an improvement in operating efficiency would lead to important economic gains for pig iron producers. To establish the scope that exists for such a development, a test programme has been proposed aimed at the optimization of various operational parameters including casting temperature, method of mould cooling and iron composition for different pig forms and different types of moulds. The project will consist of four parts :

- (1) direct analysis of machine characteristics
- (2) thermal balance studies of the mould
- (3) development of a mathematical model and
- (4) application of the model to determine maximum permissible strand speeds.

This project will be carried out jointly by Société Saulner at Uckange (F) and Institut de Recherche de la Sidérurgie Française à Maizières-les-Metz (F), over a period of 1 year.

IV. "STEELWORK" PROJECTS

P 148 - Data programme in the field of metallurgical thermochemistry

The application of thermochemical principles and data to industrial problems involving metallurgical equilibria is a relatively new field of technology. There is not as yet a general technical awareness of the prospects for development that it offers. Although a few laboratories in various countries are very active in the field of thermochemistry, the practical man suffers the disadvantage that the available information is very widely scattered in the literature. In addition, there are still appreciable gaps that inhibit practical application.

Annex 2

In this research project, it is planned to remedy the last two disadvantages. The most important data for the ferrous metallurgist will be collected in the form of a reference work and much of the data will have to be reexamined. Special attention will be paid to iron alloying systems of the binary and ternary type, with the emphasis on elements Ni, Co and Cr. The research will be carried out at the Institut für theoretische Hüttenkunde of the Rheinisch Westfälische Technische Hochschule Aachen, Germany, over a period of three years.

P 154 - Electrochemical deoxidation and desulphurization on a semi-industrial scale

This work is a continuation of the results obtained in an earlier ECSC research project.

The research again covers pig iron and steel. Both solid and liquid slags are considered as electrolytes. Lime or dolomite with 3-8 % CaFe_2 are to be used as solid slags and the liquid slags will be those of the $\text{CaO} - \text{CaF}_2 - \text{Al}_2\text{O}_3$ system.

The experiments will be carried out in a 300 kg crucible. The electrode material is graphite. The anode is in contact with the slag, and the refractory-protected cathode with the metal.

After installation of the necessary electrical equipment, the metallurgical possibilities will be investigated, having regard to Faraday efficiency and attainable current densities.

The costs of electrolytic deoxidation and desulphurization will also be determined. Then the agitation effect, the heat transfer through the Joule effect and the purity of the metal will be investigated.

The research will be carried out by the Institut de Recherche de la Sidérurgie Française, Maizières-les-Metz, France, and the estimated duration is one year.

Annex 2

P 157 - Production of a generator shaft with a barrel diameter of 1900 mm by welding two parts together by the partial electroslag process

The research embraces three different problems :

- (a) Two parts of 2100 x 2100 mm and a generator shaft of 1900 mm diameter are to be welded together by the partial electroslag process developed by the applicant.
- (b) First of all, preliminary tests are to be carried out to ascertain what seed charge is necessary to obtain a fine-grained primary grain in the weld metal.
- (c) The weld seam must be forgeable and heat-treatable. To determine these properties specimens will be taken after the first welding operation (but before quenching and tempering). The remaining parts will then be welded together again, quenched and tempered and tested.

The research will be carried out by Rheinstahl Hüttenwerke AG at Hattingen, Germany, over a period of one year.

P 167 - Novel slag systems for electroslag remelting

Slag used in the electroslag refining process are conventionally based on calcium fluoride. This family of slags has been widely developed to meet electrical, thermal and chemical requirements for almost all ferrous or high melting point metal applications. Preliminary experiments carried out by BSC have shown, however, that important advantages may be obtained from the use of fluoride-free compositions of electroslag remelting. It is proposed, therefore, to extend this initial work to optimize the observed advantageous features and to establish the limitations of low-fluoride or fluoride-free slags. Compositions will be selected from combinations of $\text{CaO-Al}_2\text{O}_3$ and $\text{CaO-MgO-Al}_2\text{O}_3$ and similar slags containing up to 10 % CaF_2 . Some of the trials will be carried out on large ingots, e.g. 300 - 400 mm diameter, to ensure that conclusions obtained from pilot plant work apply on a commercial scale.

Annex 2

The proposed research will be carried out by British Steel Corporation United Kingdom, over a two-year period and will be closely co-ordinated with a number of projects in this technological field that are currently receiving ECSC support.

P 174 - Segregation of wide-end-up ingots

The objective of this research is to assess the influence of ingot design variables on the centre segregation pattern obtained in wide-end-up ingots used in the production of special steels. From a better understanding of the effects of the specific variables of ingot height to cross-section ratio and ingot taper it should be possible to cast bigger ingots; such a development would lead directly to improvements in steel-works productivity and reduce throughput costs. The mean cross-section of the ingots would be 0.54 m, 0.6 m and 0.65 m and ingot heights would be chosen to produce ingot weights in the range of 4 to 6 tons.

This proposed research will be carried out by British Steel Corporation, United Kingdom, and the estimated duration of the programme is 3 years.

P 099 - Electromagnetic stirring of a continuous slab casting in the mould

In a previous research project supported by the ECSC, preliminary tests were carried out on electromagnetic stirring in continuous casting. They related to billets and were intended solely to establish efficient flow conditions by electromagnetic means and to determine the optimum electrical parameters.

In the current research project, it is proposed to design a special mould with a wall thickness of only 30 mm. Attempts will then be made to obtain an efficient stirring effect with relatively small current intensities, so as to improve the surface quality of the continuous casting and reduce the number of inclusions.

The work will be done by the Institut de Recherche de la Sidérurgie Française in Maizières-les-Metz, France, and is expected to take two and a half years.

P 173 - Electromagnetic stirring of steel during solidification with particular reference to continuous casting

Improvement of surface quality and reduction of inclusions are also the aims of this project. Another special aim is to obtain the structure of a virtually unkilld steel by means of electromagnetic stirring.

Unlike project P 099, it is here planned to use normal, commercially available moulds. The electromagnetic equipment will be adapted to requirements. Whereas project P 099 will be carried out in a pilot plant, this research will be done on an industrial scale.

The research is proposed by the British Steel Corporation, United Kingdom, and is expected to take two years.

P 227 - Automation of oxygen steelmaking plant

Since 1970 ARBED has been engaged in research on the automation of oxygen steelmaking plant (ECSC Agreement No. 6210.58).

Under this agreement, ARBED was to equip its steel plant with a computer, a mass spectrometer and the necessary interfaces for data collection and regulation of the control circuit. It was also planned that ARBED would put into operation other automation models or control systems supplied by other institutes or companies. IRSID, CRM and Hoogovens-Estel expressed their interest in cooperating in the project.

(a) IRSID

IRSID would be interested in testing the dynamic automation models resulting from its own research. The experiments could cover the following points :

- use of a suitable metallurgical relation between rate of carbon drop and carbon content and a control algorithm for stopping the blow;
- use of continuous argon measurement in the waste gases (and if necessary in the blowing oxygen) to calculate the gas flow escaping from the converter and slag decarburizing and oxidation rates.

(b) CFM

CFM will investigate :

- 1) the causes of the overflows currently observed and
- 2) the relationship with reaction paths and charge characteristics. A mathematical model will be designed for continuous calculation of the carbon and oxygen reaction paths. Off-line processing will be carried out to investigate the parameters accounting for an overflow. At a later stage on-line operation will be used to minimize overflows.

(c) Hoogovens-Estel

Hoogovens will test its LD automation model using an off-line process. It is mainly interested in studying the possibility of narrowing the temperature range at the end point by recalculation of the heat balance a few minutes before tilting of the converter. The calculation would be based on the gas oxidation rate in the converter and the iron content of the slag.

(d) ARBED

For its part, ARBED would :

- 1) make all its equipment and programmes available for the studies;
- 2) extend the equipment so the research could be carried out under optimum conditions. ARBED plans to put the converter on balances and acquire a mass spectrometer with single collector plate for determination of argon in the blowing oxygen;
- 3) make its team available to cooperate in the measurements, statistical analyses, model design and programming.

The research will be carried out by ARBED, Esch-Belval, Luxembourg, the Institut de Recherches de la Sidérurgie Française, Maizières-les-Metz, France, the Centre de Recherches Métallurgiques, Liège, Belgium, and Hoogovens-Estel, Ijmuiden, Netherlands, over a period of three years.

P 230 - Continuous oxygen refining process with solid charge

The research programme will be carried out in a 35 t plant to be newly built at the works of ARBED-Felten & Guilleaume in Cologne-Mulheim. This plant will be the first of its kind on an industrial scale and consists of a rotary kiln to preheat the granulated pig iron, a continuous charging device, the IRSID-developed plant for continuous refining, a waste gas cleaning system and measurement and control equipment.

Long-term testing of the plant will be carried out first, with a gradual move towards the charging of solid materials only.

Then optimization tests will be conducted, special attention being paid to heat losses at the reactor, afterburning of waste gases and preheating of the granulated iron.

Finally, various charging materials will be tried out, including sponge iron.

The research will be done by ARBED-Felten & Guilleaume, Germany, and the Institut de Recherches de la Sidérurgie Française, France.

The expected duration of the research is three years.

V. "ROLLING MILLS AND PROCESSING" PROJECTS

P 124 - Optimization of slab reheating

Changes in the respective costs of electric power and fossil fuels and the constraints imposed by the need to avoid pollution militate in favour of the substitution of electricity for combustible fuels wherever the conditions for substitution are propitious.

A case in point is the reheating of slabs, where it is possible to couple a flame furnace for the lower heat levels with an electric induction furnace to attain the higher levels.

The present research project proposes to examine this combination of furnaces with a view to determining the configurations that are most advantageous for the purpose of obtaining less atmospheric pollution, a greatly reduced noise level, higher output with lower energy consumption, and finally more even heating with a lower rate of oxidation.

The implementation of this project, which will take five years to complete, is to be entrusted to the French Institut de Recherches de la Sidérurgie, Maizières-les-Metz.

P 147 - Control of product width in wide-strip mills

Euronorm standards 29-69 for hot-rolled plate do not permit any minus tolerance in the product width. To allow for normal variations in width, therefore, the producers of hot-rolled strip are obliged to supply products that are 12 to 18 mm too wide along the whole length of the strip. This involves a loss of production in the order of 30,000 tons annually for a plant producing 2,000,000 tons a year.

This research project is aimed at achieving an appreciable reduction in this loss of output by :

- 1) investigating the causes of the variation in the width of the strip;
- 2) working out an improved rolling technique based on the information acquired;
- 3) finally, applying the new methods on a modern wide-strip mill.

The implementation of this project, which will cover a three-year period, is to be assigned to Betriebsforschung VDEh., Düsseldorf.

P 158 - Thermal variations in roll camber in a tandem cold-rolling mill

To ensure the flatness of cold-rolled strip, it is essential that uniform thickness be maintained over the whole width of the product despite deflection and wear on the working rolls. This result is obtained with difficulty by various means (machined camber, natural thermal camber or counter-deflection), usually in combination. An original new method has

recently been suggested, namely, that of controlled thermal camber obtained by the differential distribution of heat over the width of a roll. This method, which in theory is promising, is the subject to be studied in this project. It will be applied to a research rolling mill with a view to developing a method that can be used on modern tandem mills for cold-rolling.

The implementation of this project, which will cover a two-year period, is to be assigned to the Max-Planck-Institute, Düsseldorf.

P 186 - Thermal variations in roll camber in a hot strip mill

The transverse profile of the strip leaving a rolling mill is an important factor in the quality of the product. One of the techniques that are used to obtain the desired profile is that of adjusting the roll camber. A convenient way of achieving this end is that of counter-deflection, which is at present the subject of an ECSC research project. Since this method is not widely used, however, it seems expedient to study the possibility of controlling the thermal camber by adjusting the roll cooling sprays. The proposed research will be directed towards :

- 1) The development of mathematical models for forecasting the thermal camber of the working rolls of a continuous hot-rolling mill.
- 2) The study of dynamic variations of the thermal camber resulting from adjustments to the roll cooling system, and the development of a technique for controlling the cooling system.

The implementation of this project, which will cover a period of two years, is being assigned to the Centre de Recherche Métallurgique, Liège.

P 119 - Adaptive set-up of a tandem cold rolling mill

Modern cold rolling mills are generally regulated before the strip enters them by means of an off-line mathematical model that is often simplified and always imperfect because of the complexity of the phenomena involved in cold rolling. This method results in a certain degree of scatter in properties of the finished product. Feedback (adaptive) control techniques

Annex 2

provide an answer to this problem by enabling the mill to be continuously adjusted to the properties of the strip during rolling.

The state of the rolls must also be known for calculation of the optimum set-up for entry of the strip. Consequently models must be developed to predict thermal variations in roll camber and adapted to on-line adjustment of a rolling mill.

The proposed research project involves a study of these two subjects in order to reduce scatter in the thicknesses of cold-rolled strip and improve its flatness.

This four-year programme will be carried out at the Centro Sperimentale Siderurgico in Rome, Italy.

The more specific problem of roll camber will be studied at the Centre de Recherche Métallurgique in Liège, Belgium, over a period of two years.

P 175/2 - Development of a mathematical model for the prediction of metal flow in steel undergoing hot forming processes

Much work has been done in an effort to describe metal flow during hot forming by rolling and, to a lesser extent, by forging. Most of the existing models study the phenomenon on the assumption that the temperature distribution in the material being worked is uniform. This hypothesis is never correct in practice and the models therefore calculate operational parameters (force, torque, power) with a degree of approximation that can be very disturbing. This project aims to provide a more exact calculation using the method of finite elements to determine the distribution of stress and resultant strain during the forming process, the temperature distribution (as a function of time) being calculated during the heating and forming processes.

The model will be tested on a variety of specimens exposed to varying temperature and forming conditions.

The expected results will allow better prediction of the exact operational parameters for hot rolling and consequently will improve rolling efficiency in both qualitative and quantitative terms.

This study will be carried out at the Swindon Laboratories of the British Steel Corporation, United Kingdom, over a period of three years.

P 210 - Vibration and friction of a cold tandem mill

In the cold reduction of very thin sheet, vibration and a chattering phenomenon appear above a certain speed. These cause thickness defects in strip that necessitate rejection. At present, reduction of rolling mill speed is the only course open to the roller, with the consequent loss of production. The reasons for the occurrence of this vibration are not yet known.

The purpose of this research project is to demonstrate the factors involved in the occurrence and continuation of vibration and then to define ways of avoiding it.

This study will be carried out at the Centre de Recherche Métallurgique at Liège, Belgium, over a period of four years.

VI. "MEASUREMENTS" PROJECTS

P 168 - Ultrasonic holography for the inspection of thick sections

The use of ultrasonic holography as an improved method of examining the dimensions and shape of a defect will be studied more particularly in connection with very thick steel plates, the aim being to make it easier to assess the importance of a defect from the point of view of the use and service life of the component.

Annex 2

The first part of the research will investigate the utility of ultrasonic holography with diffraction wave scanning, both for general inspection purposes and for the more specific purpose of examining welds in thick plates. The second part will be concerned with its usefulness in improving the resolution of the B scanners which are being used more and more for examining thick sections. The study should result in an improved cost/efficiency ratio for the quality control of thick steel components by permitting a more accurate assessment of the need to remedy a particular fault either at the time the component is placed in service or during operational use. Having a better knowledge of the dimensions of the defect will make for better judgement of its repercussions and the avoidance of premature wear on the part in question.

The work is scheduled to last three years and will be carried in the U.K., at the Harwell Atomic Energy Research Establishment and the British Steel Corporation.

P 181 - Improvement of the surface quality of hot-rolled strip by automatic inspection on the strip mill

If full advantage is to be taken of the very high productivity of modern strip mills, there must be facilities not only for continuous checking of the geometrical and metallurgical parameters such as we have at present, but also for controlling the quality of the plate. The first problem has been solved by the combined use of measurement recorders, mathematical models and control loops, which together form the process control aspect of rolling. At present, however, the control of quality (considered in the normal sense as the presence or otherwise of internal or surface defects in the plate) continues to elude automatic control, and it is this gap which the proposed research is designed to remedy - at least as regards the surface defects - by developing a visual method based on the use of integrated photodiode batteries in conjunction with a high-speed electronic scanner depending on the width. This work, which is expected to last three years, will be conducted at the Institut de Recherches de la Sidérurgie Française at St.-Germain-en-Laye, France.

Annex 2

P 182 - Development of new industrial equipment for the detection of surface defects by eddy currents with a view to improving performances in the automatic control of iron and steel products

Although the quality control of iron and steel products has made great strides in regard to the automatic detection of internal defects, notably by the use of ultrasonic techniques, the same cannot be said of the methods of detecting surface defects. These are highly detrimental to the majority of products, and may also cause incidents during fabrication. Not surprisingly, therefore, there is felt to be an urgent need for a method of revealing surface defects at any stage in the fabrication of steel. The most suitable technique for solving these crack-detection problems is that of non-destructive testing by eddy currents, which is better suited to the production rhythms of the iron and steel industry than techniques such as dye penetrant testing or magnetic particle testing, which are harder to automate. During the last few years, however, it has been found that, in its present state of development, the eddy current test method is not entirely satisfactory as applied to iron and steel.

Aware of the importance of this inspection problem and the difficulty of finding a satisfactory answer, the IRSID has been engaged for several years in a major laboratory project involving a re-examination of the basic principles of this technique of testing by eddy currents. Judging by the favourable results obtained in the laboratory, this research, which has been subsidized by the ECSC, appears to have born fruit, and the task that now remains is to apply to industrial practice the theoretical knowledge already acquired. This is what it is hoped to accomplish in this research project, which will be carried out over a three-year period by the Institut de Recherches de la Siderurgie Française at St.-Germain-en-Lay.

P 189 - New developments in direct-reading optical emission spectrometry

With a view to speeding up and rationalizing the necessary process of change in analytical chemistry, past Community research programmes have included subjects designed to try out techniques and equipment in course of development, and ascertain the advantages of applying them for the inspection of iron and steel materials. The development of emission

sources for spectrometric analysis comes within this category. Lately, there has been a trend towards replacing the traditional sources (arcs and sparking devices) by sources of hollow-cathode type. What still has to be done, however, is to study the possibilities they offer in regard to both the equipment and the various materials that have to be analysed (castings, alloy or non-alloy steels, stainless steels, ferro-alloys, etc); this is the purpose of this project, which is being conducted over a three-year period by the Centro Sperimentale Siderurgico in Rome (Italy).

P 200 - Development and implementation of methods for the routine spectrochemical analysis of non-metallic substances using a grimm lamp

The aim of this research is to apply and develop the Grimm lamp principle in the spectroanalysis of non-metallic substances. In the first instance, efforts would be directed to evolving a general-purpose procedure specially geared to the requirements of the iron and steel industry, e.g., for analysing any kind of oxide. This might be followed by work to determine the accuracy, fitness and speed of the procedure - research into the best way of preparing the test-pieces, with special attention to certain techniques such as crushing, treatment with tannin, and compaction. Determination of the granular structure required to obtain a high level of accuracy where concentrations of homogeneous and heterogeneous mixtures are present.

This project is to be carried out by the Dortmund Institute of Spectrochemistry and Spectroscopy (West Germany) in association with the Verein Deutscher Eisenhüttenleute in Düsseldorf (West Germany). It is scheduled to take two years.

P 217 - Study on the application of the glow discharge source for the determination of metalloids, with special attention to their surface distribution

The metalloids in steel are analysed by a number of methods involving classical and instrumental chemistry and spectrometry. In regard to the last-named, classical optical emission spectrometry permits the simultaneous analysis of carbon, sulphur, phosphorus and boron in addition to the metallic elements. A new source of excitation based on glow discharge has come to light.

The IRSID will endeavour to develop spectrometric glow-discharge analysis of the metalloids in steel, and to show that in this way valuable information can be obtained on the distribution of these elements on and below the surface.

The work will be assigned to the Institut de Recherche de la Sidérurgie Française at St.-Germain-en-Laye (France). It is scheduled to cover a two-year period.

P 190 - Estimate of boron in solid solution in steel and its effects on bainitic and martensitic hardenability

It has long been known that boron can improve the hardenability of steels, so far, however, it has not been possible to determine its exact effect before and during hardening, and its general behaviour from the molting bath to the last thermal treatment carried out by the user of the boron steel. It is assumed, therefore, that boron is responsible for both the favourable and the less favourable behaviour of these steels with respect to their hardenability and final mechanical properties. To establish the existence of such a correlation, it was essential to develop a specific method for determining the boron in austenitic solution. This is the aim of this research, which will be performed by the Centro Sperimentale Sidérurgico, Rome, (Italy), over a period of two years.

P 203 - Study on the preparation of pearls for X-ray fluorescence

It ought to be possible to apply the X-ray technique to any non-metallic iron and steel product with the exception of certain volatile elements. This technique, i.e., the preparation of non-metallic samples by solution in a vitrifying mixture for analysis by X-ray fluorescence, is relatively widely used. However, although the technology is far enough advanced to produce pearls with a reasonable chance of success, the analytical consequences of the preparation for the iron and steel sector have still to be investigated.

The main aim of the project is to adapt the fabrication control techniques to the requirements of X-ray fluorescence. An attempt will also be made to extend the method for use with pre-reduced products and products with a high ignition loss, as well as with ores, sinter, slag, dust and refractories. The research will be carried out at the Institut de Recherche de la Sidérurgie Française (France) at Maizières-les-Metz over a two-year period.

P 204 - Study of the isoformation of powder samples for X-ray spectrometry

X-ray fluorescence has become an established process in all modern laboratories for the inspection of iron and steel products, but there is still a need for improvement in the preparation of samples. Measurement of the ignition loss in each sample is impracticable for the purpose of rapid inspection of fabrication. What is required is a method that automatically takes account of the loss or gain by ignition of both the samples and the flux itself. To achieve this end, it is proposed that a reference element be introduced into the flux, e.g., oxidizing cobalt salts.

The following work is planned :

- investigations into optimum concentrations of the reference element in the flux; study of the efficacy of the method;
- development of a general method of analysis for iron and steel powder products for use with the following elements: Fe, Mn, Ti, Ca, K, P, Si, Al, Mg.

The research will be conducted by the Centre de Recherche Métallurgique, at Liège, (Belgium). It is scheduled to take two years.

P 207 - Detection of surface defects on sections and hot semi-finished products

The need for quality control of the surface of iron and steel sections and semi-finished products is becoming increasingly evident, especially in the case of blooms, billets and slabs. This research proposal is aimed at filling a few of the gaps in this field by measuring the quality of sections and semi-finished products, using objective criteria, and by developing and placing in service in industry equipment for the detection of cracks appearing on the surface after the hot-rolling process and before shearing.

The primary task will be :

- selection of an optical crack-detection method;
- characterization of the defects and their degree of seriousness and harmfulness;
- use with making devices compatible with the rolling speed.

The Centre de Recherche Metallurgique at Liège, (Belgium), is allowing three years for this work.

VII. "USE PROPERTIES" PROJECTS

a) Weldability

P 161 - Study of hot embrittlement in the heat-affected zone of welds in austenitic steel

The research programme is designed to ascertain the conditions that foster the occurrence of embrittlement phenomena at critical service temperatures around 550°C. Various alloyed austenitic steels will be given normal or weld-simulating heat treatment and in those states will be exposed to the normal service temperatures with and without simultaneous mechanical stressing. By comparison of the changes in mechanical properties in the two states, the extent of any embrittlement phenomena that occur will be determined and related to the interaction of the various factors involved. The purpose of the research project is to obtain information on fabricating measures that could for the service life of the steels obviate any reduction in formability detrimental to their use.

Special attention will be paid to the carbon content of the steels, and to the type and quantity of any carbide-forming alloying elements that may also be present. Because of the increasing use being made of steels alloyed with nitrogen, the effect of nitrogen additions will also be investigated. The behaviour of understabilized steels will be studied.

This programme will be carried out by the Verein Deutscher Eisenhüttenleute at Düsseldorf, Germany, over a period of three years.

P 191 - Possibilities of and limits to the development of new structural steels

This research project is designed to evaluate, by systematic study, the effects of various alloying elements on the weldability of low carbon steel (C 0.10 %); the final aim is to obtain useful information for the definitive development of new types of high strength steels already optimized as far as possible from the aspect of weldability. In the structural steel sector a new trend has emerged towards the development of high strength steels that can be used in the as-rolled state to replace steels which, for the same strength levels, traditionally have to be quenched and tempered. The procedure adopted is, in brief, to reduce the carbon content more and more and at the same time to increase the content of alloying elements, some of which (Mn, Cu, Mo, Ni) can in principle be selected on the basis of cost considerations, while an element from the group Nb, V and B is always present to obtain the required austenite transformation characteristics.

This programme will be carried out at the Centro Sperimentale Siderurgico in Rome, Italy, over a period of three years.

b) Corrosion

P 199 - Study of the corrosion and metallurgical properties of Zn-Al based binary and complex alloys

New trends in hot dip zinc and aluminium coating have been moving towards experiments with Zn-Al based alloys which as compared with zinc coatings have better adherence properties, resistance to electrochemical corrosion and to corrosion at high temperatures and, as compared with aluminium coatings, more efficient sacrificial protection. It is possible that there are Al concentration thresholds which are critical for the metallurgical and corrosion properties of the coating and, since the proper choice of secondary alloy may make it possible to reduce the Al content, there is a good case for carrying out a systematic study of the basic properties of Zn-Al based binary and ternary alloys and of coatings of such alloys on steel, in order that the best alloying method may be selected.

A research study comprising three stages is proposed :

- i) Study of the effect of increasing Al contents (5-60 %) on the chemical and electrochemical properties of Zn-Al alloys.
- ii) Study of the interaction between steel and the alloy melts
- iii) Assessment of the chemical, electrochemical and mechanical properties of alloy coatings.

The research will be carried out by the Centro Sperimentale Metallurgico, Rome and will last for a period of three years.

c) Formability

P 187 - Definition of the surface morphology of cold reduced sheet

The surface morphology of cold reduced sheet is of considerable importance to both producers and users. Surface roughness is a far from negligible factor in drawing operations. It is always modified to some extent during the process.

The ultimate surface finish of the part will depend on the initial roughness of the sheet to be drawn, the intrinsic properties of the steel and the sheet and finally the drawing conditions.

The surface morphology after a part has been drawn should be such that it can be painted under optimum conditions.

Consequently it is important to know the surface finish criteria that will reduce the risk of scoring during forming operations and enable a painted finish absolutely reproducible in appearance to be obtained.

The analysis of roughness profiles has been used for this purpose. However, this method is artificial and conventional and it appears from preliminary tests that analyses using the quantitative television microscope hold out interesting prospects for the determination of sheet behaviour with regard to scoring.

These measurements with the QTM must therefore be made as discriminating as possible and to do this it is necessary to define absolute parameters, establish ranges for the new surface finish parameters to enable the risk of scoring to be averted and study the influence of final roughness on the appearance of the coating.

This programme will be carried out by the Centre de Recherche Métallurgique at Liège, Belgium, over a period of 2 1/2 years.

P 193 - Surface of stainless steel sheet

At the present time, the assessment of surface finish in stainless steel sheet is purely subjective. As a result, unrealistic statements are made with regard to the relative appearance of material produced in different works. Additionally, although various types of finish are recognized, e.g. bright annealed and electrolytic polished, these definitions are based on the method of production rather than the true nature of the quality of the surface. On the other hand, the aluminium industry has developed methods of assessment which define surface finish in quantitative terms.

In addition to intrinsic surface characteristics such as reflectivity, colour, lustre etc., the surface quality of stainless steel sheet is also governed by imperfections that are produced during the manufacturing process. On-line monitoring devices are becoming available which could be applied to the evaluation of manufacturing defects such as scratches and gouge marks.

The objective of the research project is to develop quantitative methods of measurement and standardized test procedures for evaluating and comparing the surface quality of stainless steel sheet.

The programme concerns the evaluation of surface aspects such as total and specular reflectivity, colour, lustre and image clarity. Instruments have been developed for the measurement of these characteristics and preliminary work at instrument manufacturers' works has indicated that these facilities are suitable for the evaluation of stainless steel sheet. Attention will be

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directed mainly towards the popular grades of stainless steel such as 18 % Cr 9 % Ni austenitic steel and 17 % Cr ferritic steel. Measurements will be taken on a large number of samples from UK sources and from other producers within the Community. As well as obtaining basic data on these materials, an attempt will be made to seek the co-operation of European producers in drawing up draft standards for surface finish.

The proposal relates to the study of methods for quantifying surface damage and imperfections, such as those produced in the manufacturing process. On-line scanning equipment has been developed and used on a limited basis for the evaluation of stainless steel sheet. A detailed survey will be made of the available systems and the most suitable system will be installed at the Shepcote Lane Works of British Steel Corporation for evaluation under production conditions. This would relate to the production of stainless steel sheet up to 1 1/2 m wide.

This programme will be carried out by the British Steel Corporation, United Kingdom, over a period of three years.

P 208 - Cold forming (joint programme)

This joint programme is designed to supplement and extend to an industrial scale knowledge obtained in the laboratory during research projects, some of them aided by the ECSC. Three different areas of activity have been defined :

- (a) Search for criteria enabling the suitability of a metal for cold forming to be assessed

Special attention will be paid to the influence of metal ductibility on the bent sections. An attempt will be made to define precisely a general work-hardening coefficient and ascertain how it affects the risk of removal of workhardening. It is also planned to determine the correlation between the degree of softening and cold forgeability in extrusion under experimental and industrial forming conditions.

(b) Metallurgical studies

The influence of various elements on spheroidizing kinetics and on ductility will be investigated. In steels with 0.15 - 0.4 % carbon, manganese, chromium, silicon, molybdenum boron and elements containing dispersoids will be studied.

In addition, as the origin and nature of the hardening of wire together with its importance and influence on the subsequent forming process are not known at present, the cause and method of hardening of ferritic structures and the importance of hardening as a function of cooling kinetics will be studied in particular.

(c) Properties of work hardened materials

An attempt will be made to measure mechanical properties and correlate their values with forming conditions and the original properties. A special study will be made of the properties after low-temperature tempering to determine the effect of this process.

An endeavour will be made to define a final state in which the product can still withstand some deformation.

This joint programme, which will take 3 years, will be carried out by the Centre de Recherche Métallurgique at Liège, Belgium, the Institut de Recherche de la Sidérurgie Française at St.-Germain-en-Laye, France, the Verein Deutscher Eisenhüttenleute at Düsseldorf, Germany, and the British Steel Corporation, United Kingdom.

(d) Fatigue

P 162 - Study of the influence of the degree of purity and production conditions on the behaviour of low-alloy steels when exposed to alternating stress

The aim of the research project is to extend existing knowledge of the influence of :

- (a) the degree of purity,
- (b) small degrees of work hardening normally occurring during fabrication, and
- (c) the application of heat during welding

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on the fatigue strength of steels. Stress- and strain-controlled fatigue tests will be carried out on two low-alloy steels of different strengths to provide coefficients for behaviour under cyclic stress that could also be used where appropriate for the design of components. To facilitate a comparative assessment of the material conditions and the effect of the various factors, it is intended to plot cyclic stress-strain curves under both tensile and cyclic stress. Notched test pieces will be used to determine the deformation conditions at the notch root as a function of nominal stress.

For welded connections, strain-controlled fatigue tests will be carried out on test pieces taken along the weld seam, in such a way that they contain all the structural zones between the weld metal and the unaffected parent metal and the same strain is imposed on all the structural zones in the test. The conditions for crack formation and propagation in materials with non-homogenous stratification will be investigated more closely in this way.

This programme will be carried out by the Verein Deutscher Eisenhüttenleute, Düsseldorf, Germany, over a period of three years.

P 163 - Study of the deformability of boilermaking steels under alternating load at moderately increased temperature

The proposed research will help to increase existing knowledge of deformability and thus make a substantial contribution to the attainment of greater safety in boilers and pressure vessels.

The materials tested will be steels for elevated-temperature service at up to about 400°C in three different categories :

- (a) an unalloyed steel
- (b) two different fine-grained alloy structural steels
- (c) two quenched and tempered steels for particularly thick-walled components.

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The materials will be tested in the following conditions :

- 1) The basic materials will be tested in the commercial delivery condition and random tests will be made after 5 % cold working, in the stress-relieved state and after long exposure to service temperature
- 2) Plate lengths of the basic materials in the delivery condition will be welded together, preferably by submerged arc welding, and will be tested in the stress-relieved condition, random samples also being tested in the non-annealed condition for comparison purposes.

The test methods will be as follows :

- 1) Preliminary tests of the usual kind to define the state of the material, for example tensile tests and notched bar impact tests.
- 2) Stress-controlled fatigue tests under pulsating tensile stress or strain-controlled alternating compression-tension tests up to about 2×10^4 load cycles with alternating stress amplitudes just above the yield point and a test temperature of 350°C .
- 3) Metallographic investigations to clarify the relationships between grain structure, strength under tensile stress fracture surface appearance and ability to withstand alternating deformation.

This programme will be carried out by the Verein Deutscher Eisenhüttenleute at Düsseldorf, Germany, over a period of three years.

P 164 - Fatigue strength and fatigue limit of welded joints in hollow sections

Extensive test results and other information are available for estimating the behaviour and for designing welded joints between circular and rectangular hollow sections in the case of static loading. Comprehensive data is however lacking regarding the application of such results to the field of structures under dynamic load (oscillatory or reversal). A comparison between the availability results (related in particular to tests carried out abroad on such tubular connections) with the established stress/cycle curves for basic types of welded connections (i.e., DV 848 of the German railways dealing with fillet welds for notched bars) shows

first of all that similarity or proportionality is not directly apparent. This applies to an even greater extent in the case of joints with rectangular hollow sections for which only typical results are known.

Further information can only be obtained at the present time by means of suitable fatigue tests on specimens used in practice. The knowledge of these test results may be extended for other structural variations.

The tests which would be undertaken in this connection should make it possible to determine the dimensions and structural configuration pertaining to structures with welded tubular joints and do this for both the region of "endurance limit" (i.e. about 2-3 times 10^6 cycles) and the "fatigue strength for finite life" (up to about 6 times 10^5 cycles). The information in the latter field (i.e. that of "fatigue strength for finite life") is principally aimed at expected design methods for "mainly statically" loaded structures and for the application of high strength steel. In this region of "fatigue strength for finite life" the application of high strength steel could possibly yield variations in the results from those of steel grades St 37 and St 52.

The importance of this investigation becomes apparent considering the fields of application where structural fatigue is involved: structures under dynamic load, specially cranes, conveying or rubble clearing equipment, bridges, tracks for high-speed trains, offshore installations and aerial masts and structures.

The basis of the investigation consists of comparative tests with standard specimens of the materials, as well as tests on notched specimens variously welded (fillet or butt). A comprehensive literature survey is to be carried out in parallel with this investigation. This should give, inter alia - and by further analysis of the fatigue behaviour of circular tube joints - detailed guidelines for the tests with rectangular hollow section joints. The experimental work on tubular joints will first of all concentrate on W- and N- joints with a gap between the toes of the bracing members and with overlapped bracing members and, in addition to building methods based on the exclusive use of circular hollow section, will also consider the utilization of rectangular hollow sections or alternatively a combination of

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of rectangular and round sections. Tests on joints consisting of rectangular hollow sections and H-sections are also planned.

The steel grades St 37, St 52, StE 47 and StE 70, partly in cold formed condition, are to be tested.

This programme will be carried out by Mannesmann, Germany, over a period of $3\frac{1}{2}$ years.

e) Brittle fracture

P 165 - Design conditions for avoidance of brittle fracture

The factors influencing the risk of brittle fracture in welded steel constructions have been studied throughout the world, resulting in various approaches to the problems of ensuring fracture-safe design. Many current design standards utilize the Charpy test as a measure of material toughness in conjunction with experience and in some cases with laboratory-type tests. More recently fracture mechanics approaches have been increasingly adopted and proposals to include the results of these tests in revision of standards are now being made. The aim of the present project is to examine, in detail, the interpretation of large-scale laboratory wide-plate tests with reference to a number of applications and design conditions in order to provide data for a unified approach to European design standards for containment and support structures.

The programme will be carried out by the British Steel Corporation, (U.K.)

f) Heat treatment

P 160 - Study of cracking in the stress-relieving of ferritic steels

The research programme is designed to provide further knowledge of the metallurgical causes of cracking and prepare the way for measures for the reliable and economical working of steels which in the present state of the art and of production techniques are considered liable to cracking.

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The following will be investigated :

- 1) The influence of chemical composition
All experimental materials will be tested after weld-simulating heat-treatment.
 - a) Hot tensile tests after very rapid heating on a Gleeble machine to determine reduction of area as a function of test temperature at low strain rate
 - b) Relaxation tests by the Murray method in the temperature range of normal stress-free relieving
 - c) Metallographic investigations and examination of precipitation processes by the isolation of residues on test pieces having undergone prior thermal stressing.
- 2) The influence of grain structure and temperature application in stress-free annealing.
 - a) Hot tensile tests after very rapid heating on a Gleeble machine to determine reduction of area as a function of test temperature at low strain rate
 - b) Relaxation tests by the Murray method at 500-675°C in steps of 25°C.
- 3) The influence of the weld deposit properties
 - a) Determination of the mechanical properties at ambient temperature, with and without prior exposure to stress-free annealing temperatures and where appropriate in the range of the expected service temperatures.
 - b) Hot tensile testing after very rapid heating to determine mechanical properties, especially reduction of area, at high temperature.
 - c) Relaxation tests by the Murray method in the temperature range of 500-675°C, in steps of 25°C.

This programme will be carried out by the Verein Deutscher Eisenhüttenleute at Düsseldorf, Germany, over a period of three years.

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P 159 - Relationship between strength, wall thickness and fracture behaviour in component-simulating test pieces of high-strength steels in the welded and stress-relieved states

Until a few years ago it was customary to use steels in the normalized state with yield points up to about 350 N/mm^2 and a yield point/tensile strength ratio of about 0.7 for the construction of welded pressure vessels, especially vessels to hold gaseous or liquid substances both at ambient temperature and at elevated temperature. Non-alloy and low-alloy steels of this type have proved excellent for the purpose and extensive experience is available on their processing and reliability in service.

The rapid development in process engineering, especially in the chemical industry and in the energy generating sector, has produced a demand for :

1. higher safe working stress and
2. larger vessels

The research programme should help to provide more information on this subject and thus to establish a more reliable basis for the evaluation of the safety in welded structures of high-strength steels than is provided by existing experience. As there is not yet a watertight safety concept based on quantitative evaluation of the usual parameters for the mechanical properties of steels, it will be more or less necessary to relate the behaviour of more recent materials in the fabrication states found in practice to the behaviour of the well-known steels in the lower strength categories.

Comparative tests on steels in three strength categories are proposed :

- 1) an unalloyed fine-grained structural steel in the normalized state with a yield point of about 350 N/mm^2 ;
- 2) two or three low-alloy fine-grained structural steels with differing alloy additions in the normalized state with a yield point of about 500 N/mm^2 , including one steel suitable for use at moderately high temperatures up to about 400°C ;
- 3) one or two low-alloy steels in the water-quenched and tempered state with a yield point of about 700 N/mm^2 .

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The wall thicknesses to be tested should be in the 30-50 mm range, depending on the strength of the materials selected for testing. At least two wall thicknesses for each steel are to be tested.

This programme will be carried out by the Verein Deutscher Eisenhüttenleute, Düsseldorf, over a period of three years.

g) Electrical sheetP 166 - Basic properties of grain-oriented electrotechnical steel

The most important commercial soft magnetic material is grain-oriented silicon-iron which is used in large quantities in the electrical industry. The amount of grain-oriented material produced is steadily increasing each year: in 1969 over 200,000 metric tons were produced in Europe. The total tonnage of electrical steel (oriented and non-oriented) made in the USA, Europe (the EEC countries) and Japan in that year was 657,000, 933,000 and 686,000 metric tons respectively most of which was of non-oriented grades. In Europe, the major portion was consumed in home markets, although France and Belgium have important export markets. Another country with large export markets is Japan, whose production since 1959 has quadrupled, so that it is now probably the world's largest producer of electrical steel apart from the USSR.

As it seems that no new material is likely to replace grain-oriented silicon-iron in the foreseeable future, it is important to strive for a further understanding and improvements in present-day material. Over the last few years economic considerations have tended to become increasingly important in large transformers and rotating machines, so users of the material are anxious for further progress.

The major aims of the proposed investigations will be to obtain improvements in the magnetic characteristics of the material itself, and improvements in the way in which the material is used in electrical equipment as an aid to the competitiveness of ECSC steel. This will be done through specific projects which will relate the magnetic behaviour to various metallurgical characteristics of the material itself and study, scientifically,

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some design and operating principles appropriate to electrical equipment for which oriented electrotechnical steel is produced in large quantities.

The work will be divided into three parts :

- power loss, domain wall motion and the nature of the anomalous loss;
- flux distribution and localized loss in silicon-iron cores and equipment, particularly when complex wave forms are present;
- dependence of the magnetic properties of silicon-iron as used in both machines and transformers on stress and temperature.

This programme will be carried out by the British Steel Corporation, United Kingdom, over a period of three years.

P 215 - Losses in electrical sheet

The problem of anomalies in power losses is of considerable interest not only from the scientific point of view but also as regards applications since by definition an abnormal loss implies a higher power loss than calculated on a conventional model, where the induction is assumed to be uniform throughout the cross-section. Any research designed to throw light on the origin of this abnormal loss could in principle provide useful information on the possibility of reducing total losses and hence obtaining appreciable savings.

In the research already done by the Istituto Elettrotecnico Nazionale on these problems, it was decided to study abnormal phenomena in a general fashion by means of measurements on macroscopic specimens of different materials.

The main results obtained to date concern the development of instruments for the exact measurement of power losses as a function of frequency and under specific working conditions.

The instruments produced have enabled precise measurements to be made, in a very low frequency field and under controlled conditions, of the envelope of the induction flux. Measurements on variety of materials, both directional and isotropic, have demonstrated that the anomaly of non-linearity is a fairly general phenomenon.

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Experiments show that this anomaly becomes more pronounced with high values of working induction, which appears to indicate that domain nucleation phenomena may influence the anomaly, while the part played by other effects that are present, such as block wall motion, may be of less importance.

Research over the next two years could therefore start here and follow the lines given below :

Firstly, it is proposed to continue the precision measurements on various materials to verify whether the anomaly of non-linearity is general or typical of certain materials.

Secondly, it is proposed to measure the variation in form of dynamic hysteresis cycles as a function of frequency, to see what parts of the cycles contribute most to the anomalies observed.

Thirdly, it is proposed to measure losses as a function of the surface finish of the electrical sheet, as this appears, in the final analysis, to have a very considerable effect on domain structures, magnetization processes and hence most probably on losses and their anomalies.

This programme will be carried out by the Istituto Galileo Ferrario in Turin, Italy, over a period of three years.

VIII. "PHYSICAL METALLURGY" PROJECTSP 177 - Thermomechanical treatment of weldable medium-carbon steel

Recently, the market for high-strength steels has expanded considerably. This increase has been particularly marked in the oil industry for tube plate and plate for offshore platforms. It has created a continuous demand for high-performance steels (high yield point and toughness) which also have good weldability.

Thermomechanical treatment (controlled rolling) provides an advantageous method of obtaining these properties. Research on the application of this method to certain steels (C, Mn, Nb, C equivalent 0,32-0.36) has been

proposed, with particular attention paid to the following parameters :

- Austenitizing temperature
- Rolling programme
- Cooling speed

This research has been proposed by the Institut de Recherche de la Sidérurgie Française, St.-Germain-en-Laye and would take three years.

P 179 - Simulation of the metallurgical phenomena occurring during hot rolling of strip

A knowledge of the metallurgical phenomena occurring during hot rolling is essential for prediction of the mechanical properties of the product and important for the evaluation of the rolling stresses necessary for mill automation.

Full-scale measurements are impossible because of their cost and the loss of output.

Consequently a method of simulation using a torsion machine and experimental rolling mill has been developed and tested successfully for a heavy plate reversing mill.

The purpose of this research is to carry out a similar study, but for hot wide-strip mills, in which the deformation conditions and temperatures as a function of time differ very greatly from those in the rolling of heavy plate.

The following four points will be studied in particular :

- (a) Study of austenite recrystallization phenomena and any precipitation occurring very close consecutive rolling passes
- (b) Simulation of the strip mill cooling table

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- (c) Complete simulation of a strip mill with an assembly consisting of No 1 furnace, experimental rolling mill, hardening machine, No 2 furnace.
- (d) Study of the mechanical properties of the simulated strip.

This study will be carried out by the Institut de Recherches de la Sidérurgie Française at St.-Germain-en-Laye, France, over a period of three years.

P 188 - Ratio of concentrations of precipitating elements in steels

Increasing use is being made in steels of elements that form carbides or nitrides because of the many effects they have on the structures and mechanical properties of the products obtained. Despite the number of research projects devoted to this subject, some points still need further clarification.

The CRM proposes to study two of these points in particular :

- (1) Production of an extra mild steel with improved drawability which has simultaneously a high normal anisotropy and a low planar anisotropy as a result of the modification of the recrystallization kinetics of mild steel in the controlled presence of dispersoid-forming elements.
- (2) Production of structural steels having increased tensile and impact strength and improved forgeability by making maximum use of the possibilities of aluminium deoxidation. A special study will be made of the systematic precipitation of aluminium nitride :
 - either in the form of very fine particles producing hardening comparable to that obtained by columbium or vanadium carbides
 - or in the form of particles that are sufficiently large and in sufficient quantity to produce extensive grain refining.

The research has been proposed by the Centre de Recherche Métallurgique at Liège, Belgium, and will take three years.

Annex 2

P 216 - Galvanizing of steel wire

The purpose of the research project is to study the galvanizing mechanisms and pinpoint the origin of the difficulties encountered in this operation so that they can be overcome, especially in the case of wire rod.

IRSID will therefore study the influence of the type of steels used, the nature and finish of the surfaces and the operating conditions on the nature, appearance and adhesion of the coatings. The reactions will be studied simultaneously on pure iron and iron alloys containing a very low level of impurities and on synthetic steels prepared specially by vacuum melting, with subsequent verification on industrial steels. The structures of iron-zinc alloys will also be studied. The results of this research would help to overcome the difficulties arising in the galvanizing of wire rod owing to changes in the properties, to extend the knowledge obtained to other galvanizable steel products and to secure better zinc utilization.

This research has been proposed by the Institut de Recherche de la Sidérurgie Française, St.-Germain-en-Laye, France, in conjunction with the Syndicat National du Tréfilage de l'Acier and is planned to take three years.

IX. "UTILIZATION" PROJECTS

P 143 - Use of steel in housing

The construction of the Berlin station where European comfort criteria are to be determined is continuing.

Experts who visited the site at the end of 1974 unanimously agreed on the usefulness of this demonstration and were eager to see the research attain the aims set some years ago.

This confirmed the advantage to the Community of this station.

It is proposed to grant Brandi an additional six months to complete the project. This brings the final date for the research to 30 June 1975.

Annex 2P - 149 - Hybrid steel-concrete beams

The fabrication of composite welded beams is developing rapidly in countries such as Sweden and Japan. Production lines for these beams are being or will be set up in the Community. There are three main reasons for this development : the first is that very commonly produced products, generally flats, are used as the starting material; the second, which follows on from the first, is the flexibility of the process, much greater than that of rolling, which makes it possible to offer constructors a continuous range of product shapes and sizes and sections of varying forms and complexities (symmetrical and asymmetrical double tees, box girders, etc.), and the third is the possibility of supplying small tonnages at prices justified by short delivery periods.

Although these three reasons are sufficient to account for the profitability of the production lines, it is nevertheless true that an increase in the utilization factor of the steels involved would further reduce the cost of the process; this can be obtained by using different steels in the same section in such a way that the further they are from the neutral axis the higher their yield point. In these hybrid beams, low yield point steels can be loaded in the plastic range as a result of the presence of high yield point steels surrounding them and providing rigid support.

The research will include static tests on composite beams that are prebent but not stressed during curing of the concrete, prebent and stressed during curing of the concrete or prebent with a temporary top plate, together with creep and fatigue tests and tests to evaluate the adhesion force between the steel and the concrete.

This programme which will take two years, will be carried out partly by the Centres de Recherches scientifiques et techniques de l'Industrie des fabrications métalliques (CRIF) at Liège, Belgium, and partly by the Centro Italiano Sviluppo Impiego Acciaio in Milan, Italy.

Annex 2

P 140/2 Steel components connected to concrete members in buildings

The following research proposal is based on realistic and fundamental considerations :

- (1) Throughout Europe there are (and will be for several years) tens of thousands of "traditional" building firms which because of their mental attitude, need to use existing equipment or lack of preparation for the adoption of new building techniques based on metal structures, will most probably prefer to continue to build in reinforced concrete.
- (2) It is known that in a structure entirely of reinforced concrete, if the cost of the columns is 1 (per cubic metre), the cost of the horizontal beams is 3 (they necessitate special bending of concrete reinforcing rounds, the cost of formwork is higher, etc.).
- (3) By definition, reinforced concrete must be loaded in compression, while steel can withstand bending stress.

The aim of the proposed research is to encourage the "traditional" firms to use steel at least for horizontal structural components, without too much modification to the construction equipment of the firms themselves.

Obviously if such an effort were to succeed, the additional quantities of steel used would be incalculable.

It is proposed to study and carry out scientific experiments on :

- (a) the most efficient ways of fixing horizontal steel beams in conventional reinforced concrete columns;
- (b) the steel beam sections that are most suitable for this type of mixed structure (examining either hot-rolled or cold-rolled beam sections);
- (c) erection systems.

This programme will be carried out by the Centro Italiano Sviluppo Impiego Acciaio (CISIA), in Milan, Italy, over a period of two years.

P 141/3 - Floor and roofing structures for industrialized building compounded with deformation-resisting units

For horizontal structures (floors and roofs), use is made either of conventional reinforced or prestressed concrete systems or systems based on ribbed plate. The former are very heavy and hence unsuitable for construction in the factory and transport to the site (i.e., not in keeping with the new requirements for industrialized building) while the latter are not very economic since for every square metre of ribbed plate flooring, a plate surface area of about 1.80 m^2 is required. As a result, ribbed plate floors are used very little.

From the static point of view, too, it must be remembered that ribbed plates are orthotropic, i.e., they have monidirectional bending strength and consequently need a line of support at their ends.

The above considerations indicate the need to design components for horizontal structures that can be made of thin plate pressed or stamped with geometrical forms (ribs, spherical indents, truncated pyramids) so as to obtain, in addition to the necessary load resistance and minimum ratio of weight per m^2 of permissible load per m^2 , isotropic characteristics or the elimination of preferential bending lines; in other words to accept in theory that the rectangular (or square) plate can be supported, not on lines, but on only four points forming the corners of the rectangle.

Since industrialized building by assembly of components is an innovation still in the trial stage, it is also logical to believe that an isotropic horizontal component could make a valuable contribution to overcoming numerous structural difficulties, and also that the shape of the pressing could have interesting esthetic effects as well as fulfilling load-bearing functions.

The research aims to define a horizontal structural component of pressed plate having the following basic properties :

- (a) minimum plate thickness (depending on load)
- (b) high strength derived from its form

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- (c) large-scale industrial production
- (d) continuity of form between two adjacent components
- (e) components suitable for use either alone or in conjunction with a concrete slab
- (f) components suitable for easy erection on site.

The research will be carried out by the Centro Italiano Sviluppo Impiego/Acciaio in Milan, Italy, over a period of one and a half years.

P 192 - Cold-rolled steel sections (joint programme)

The previous research projects, carried out with ECSC aid, made it possible first of all to study the influence of the metallurgical and mechanical properties of cold formed steel on the stability of light structures made up of sections and then to incorporate the practical results obtained into a European recommendation, and to design the necessary software for modern calculation of the performance of cold-rolled sections.

The importance of this research, which relates mainly to structural steelwork, justifies its extension to other fields.

The purpose of the proposed programme is to investigate :

- (a) the internal stresses resulting from the cold rolling of sections in order to ensure greater accuracy and better product performance;
- (b) the fatigue behaviour of thin sections under vibratory stress;
- (c) the welding of thin elements so as to obtain a full understanding of the techniques and design methods applicable to the assembly of cold rolled sections;
- (d) cold rolling of steels with a higher yield point.

The programme will take three years and will be carried out jointly by :

Fachverband Deutscher Kaltprofilhersteller in Düsseldorf, Germany;
Syndicat national des profilages des produits plats en acier in Paris, France;
Cold Rolled Sections Association in Birmingham, United Kingdom;
Stichting Staalcentrum Nederland in Amsterdam, Netherlands.

Annex 2

P 212 - Ultimate static strength of welded lattice girder joints in structural hollow sections.

Due to the growing interest in tubular structures the demand for uniform design criteria and specifications has increased.

Last year a research programme was proposed by the Staalbouwkundig Genootschap and approved by CIDECT.

This research programme was based on the then available test results and the adopted method of analysis. Furthermore, it was set up for joints in square and rectangular hollow sections. The aim of this programme was to check the design criteria for parameters which were not taken into account previously.

During the execution of the above-mentioned research programme it became apparent that the design parameters in the usual method of analysis for joints in rectangular hollow sections were not representative. This was further substantiated by research carried out in Germany. It is unavoidable, therefore, to carry out an additional programme to complete the test data for joints in rectangular hollow sections.

This programme will be carried out by the Stichting Staalcentrum Nederlands, over a period of two years.

P 223 - Buckling of thin-walled axially-loaded hollow rectangular sections

The optimization of the use of thin-walled hollow sections as a result of this research will greatly increase the potential applications of this type of section and consequently will increase steel consumption by extending it to new areas, in particular the economic construction of :

- blocks of flats
- office buildings
- school and hospital buildings.

Because of their lightness and ease of erection, these sections are particularly suitable for industrialized building systems.

Annex 2

The problem of the buckling of thin-walled hollow sections is an extremely vast one because of the very varied cross-sections of these products may have.

This project is limited to the case of :

rectangular sections
under axial load

Research programmes of a similar type are planned to explore other cases (different cross-sections and types of loading).

These future programmes will profit from the experience gained in this research project.

The purpose of the research is to demonstrate and clarify the interaction of three phenomena :

- (a) general buckling of the prismatic section;
- (b) non-linear bowing of the walls of the section;
- (c) progressive plastification resulting from the variation along the cross-section of the combinations of residual stresses and elastic limits in compression.

Although it is true that :

- (a) the buckling of prismatic sections in relation to the distribution of residual stresses has been very thoroughly studied by CECM (European Convention of Constructional Steelwork Associations) with ECSC aid;
- (b) non-linear bowing of thin-walled sections has been studied by Professor Winter in the United States and by Professor Shearer Smith in the United Kingdom;
- (c) some progress has been made towards determining the interaction of the two phenomena in thin-walled sections (but without taking account of variations in the elastic limits and residual stresses) in the work done by Professor Skaloud in Czechoslovakia and experiments carried out in Belgium (SERCOM) and Germany, with ECSC aid,

it has not yet been possible to formulate the interaction of these phenomena in a general fashion.

This programme will be carried out by Société Cométube in Paris, France, over a period of two years.

X. "MISCELLANEOUS" PROJECTS

P 134/2 - Use of granulated blast furnace slag for road construction

The use of granulated blast furnace slag as a binder for road foundations has developed very rapidly in recent years, especially since the increase in the cost of bituminous petroleum products, transport and road works.

A new technique involving the precrushing of granulated slag should, if this research proves that it can fulfil expectations, make it possible to reduce by 30 % the quantities of granulated slag required.

The proposed research project will consist of two relatively independent phases :

- (a) study of granulated slag and the possibility of using it to treat local materials (precrushing and treatment of local materials with precrushed slag);
- (b) study of the fatigue behaviour of slag gravels.

It will be carried out by the Laboratoire Central des Ponts et Chaussées, Paris, France, over a period of three years.
