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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
ECSC Treaty



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INTRODUCTION

The research proposals on iron and steel contained in this document have been selected from a total of 157 requests that were submitted to the Commission of the European Communities requesting aid under Article 55, 2 (c) of the ECSC Treaty. After detailed and lengthy examination by the Services of the Commission in collaboration with the Iron and Steel Technical Research Committee, 74 proposals have been selected as first priority and constitute the research programme in the iron and steel sector for 1977. In examining the aims of these proposals and assessing their importance to the steel industry particular attention was paid to research that would contribute to meeting the following needs :

- 1) to improve productivity in steel production and processing ;
- 2) to reduce production and processing costs ;
- 3) to improve the quality of steel products ; and
- 4) to extend the utilization of steel to new applications and, thereby, increase demand.

The priority given to these major lines of technological development is consistent with the long term objectives and forecasts for the Community's steel industry contained in the "General Objectives for Steel 1980 - 1985" (Official Journal, vol. 19, N° C 232, 4 October 1976).

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Before turning to the technical aspects of the proposed research, it is first necessary to comment on the preparation of this year's programme. The steady growth in the number of proposals submitted annually to the Commission over the recent past reached an unprecedented level during 1976 and the amount of aid requested greatly exceeded the funds available. The current general shortage of research funds coupled with what appears to be an overcapacity of facilities in certain areas of research have probably contributed to this situation. In addition, it should be noted that a significant proportion of the proposals involved a relatively small scale of effort while others were of little relevance to this Community programme of co-operative research.

One consequence of these developments is that the administrative and technical work involved in project selection and in programme planning has increased substantially. Furthermore, in the evaluation of requests it has become increasingly necessary to ensure that the available resources are concentrated effectively on problems of vital concern to the industry and not spread over too broad a field of activity. Clearly, the establishment of large projects in, for example, the fields of iron and steel production as well as in steel utilisation (e.g. offshore structures project) contribute in a valuable way to this intensification of effort in key areas ; however the scope for further progress remains.

The technical content of the proposed programme covers various aspects of iron and steel technology with the level of funding evenly distributed between process-oriented and product-oriented research in the following way : iron ores (1.2 %), iron making (10.7 %), steel-making (15.3 %), rolling mills and mechanical working (14.7 %) measurements and analysis (10.2 %), service properties of steel (31.1 %), physical metallurgy (8.7 %) and steel utilization (8.1 %).

In the production and processing sectors the problems associated with energy remain a major preoccupation of the industry. While technological advance has brought about some reduction in total energy consumption (through lower specific usage) there remains scope

for further advance particularly with regard to energy substitution, which in some instance would involve switching to alternative production routes. Aid is proposed, therefore, for a number of projects on this topic ranging from studies of production of iron by direct reduction and the properties of coke in relation to blast furnace performance to the massive injection of oil in the blast furnace to reduce coke requirements.

The continued growth in continuous casting within the Community (total capacity by 1980 is forecast to be 62×10^6 t) together with the energy saving that results from this process route make it an area of considerable technological interest. A large collective project is proposed, therefore, to assist in the improvement of product quality and the operation of continuous casting plant.

The projects on mechanical working include further studies of the rolling of strip products and of hydraulic extrusion for the production of steel sections. Also, a large collective project is planned to investigate the performance of rolling mill rolls with the aim of achieving cost savings through extending roll life in addition to improving product quality.

The continuing requirement for products of higher standards by the manufacturer and the customer is reflected by the work proposed on measurements and analysis ; the main themes relate to the assessment of the quality of rolled products e.g. shape, surface condition, and the further development of techniques for the rapid and accurate analysis (chemical and structural) of steel.

The aid requested for studies of the service properties of steel make this the largest section of the programme. A major part of the effort is devoted to collective projects on the properties of welded joints, marine corrosion, fatigue behaviour of high strength steels and brittle fracture. The quantitative knowledge to be generated in these projects will provide not only an essential base for the further development of steels but the design data will ensure that steels are used to the best advantage in engineering structures. Furthermore the research will help in establishing improved procedures for predicting the service life of steel components

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with obvious advantage to the steel producer and steel user alike.

The aims of the proposals in physical metallurgy are concerned mainly with advancing fundamental understanding on topics that are directly linked to areas of technological importance. The effort ranges from studies of the thermomechanical working of steels to the development of techniques in quantitative metallography and it is the relevance to practical needs that makes basic research of this type appropriate to the ECSC programme.

Finally in the utilisation sector, the studies range from further effort on the exploitation of steel in industrialised building to the application of steels in bridge construction and in marine technology; these latter two projects are complementary with Community programmes launched last year in these areas. Of particular significance is a collective project on the utilisation of steel bearing piles since current working practices in Europe seriously limit the competitiveness of steel against other foundation systems, particularly concrete piles. Where appropriate, the social implications of this and the other research contained in the programme are commented upon in the next section.

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THE RESEARCH PROGRAMME

I - "IRON ORE" Programme

The research under Agreement 6230-12/3/300 concluded in 1975 aimed at replacing the existing iron ore mining method by a continuous mining system. It appears that the technical improvements which can still be made to the non-continuous method in current use would not significantly increase output. However, if the iron mines are to continue working, their ores will have to be competitive in cost with foreign ores.

The research demonstrated that the new method was valid, but the machine used proved unsuitable for conditions in iron mines. Further funds are required to construct a cutter-loader for continuation of the research.

II - "DIRECT REDUCTION AND PIG IRON" Programme

The seven projects in this section relate to the following fields :

- direct reduction (P 335, P 403, P 402)
- coke research (supplement P 302/2)
- blast furnace technology (P 404, P 438, P 455)

(a) Direct reduction

The centrifuge ironmaking process (CIP) has been developed by BSC to the semi-industrial stage (P 235). It is based on the principle of using non-coking coals to reduce iron ore. The reaction takes place in a slightly inclined cylindrical vessel which rotates around its longitudinal axis at high speed. Theoretically this method is attractive as it offers the possibility of using cheap charge materials (untreated ore fines, cheap coal). The aim is to investigate the thermodynamic principles of the process. It should be possible to evaluate the productivity of an industrial plant from the thermodynamic data.

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The research has no foreseeable impact on labour and employment at the current development stage.

In project P 403, research will be done on the metallurgical conditions for a reduction process designed to obtain a fairly high-alloy steel melt directly in one operation. Plans are limited to the study of the technically attainable equilibria between the phases involved : liquid oxide, molten alloy steel, solid reducing agent and the gaseous phase. Of major interest are the contents of chromium, nickel, molybdenum, carbon, silicon, manganese, aluminium and oxygen that can be obtained in the molten steel with various oxide starting materials.

The long-term aim of the research is the continuous production of (alloy) steel with the lowest possible energy consumption.

At the present time, when work is concentrated on the theoretical principles, it is not possible to say whether the research will have any impact on employment.

The aim of project P 402 is to automate the direct reduction process in the rotary kiln.

Direct reduction of solids in the rotary kiln is gaining in importance, not only for iron ores but also for the recycling of metallurgical waste products containing zinc and lead. The processes taking place in the rotary kiln are so complex that they have not yet been fully described.

The project will use mathematical models to achieve the following aims :

- (1) better understanding of the course of the process ;
- (2) better selection of measuring and control points on the furnace ;
- (3) better process control, giving energy savings and increased output.

The construction of direct reduction plants using solid fuels will increase the demand for domestic fuels (brown coal or non-coking hard coal) and thus in the long term help to make coal mining jobs more secure.

(b) Coke

Project P 302/2 on the degradation of coke in the blast furnace and its relationship with coke properties and furnace performance is

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a supplementary application for an increase in the budget. In the first application, 15 blast furnace experiments were on the programme. However, Community steelworks showed such great interest that a further 30 experiments are now planned.

(c) Blast furnace

Investigation of the causes of pressure pulsation in combustion chambers, especially in hot-blast stoves, is the subject of project P 404. The trend towards larger hearth diameters in blast furnaces in the past ten years has brought in its wake an increase in the capacity of hot-blast stoves.

The energies released in the form of pressure fluctuations during pulsating combustion have frequently caused damage in practical operation.

The aim here is systematically to investigate the causes of pulsation so as to be able to take effective steps to remedy it in the future.

This research will help to improve plant safety and reduce down times and costs.

Research on stove coolers (P 438) is of great interest to all operators of large blast furnaces. Problems with stove coolers have caused blast furnaces to be shut down in several Community steelworks, generally as a result of local overheating, with the temperature at the hot spots being 300-400°C above the normal temperature.

The aim of the project is to devise a control model for stove coolers.

This would enable critical operating states to be prevented, or at least detected in good time.

The research should help to reduce blast furnace shutdown and increase operating safety.

An industrial-scale experiment with the injection of large quantities of oil into the blast furnace is planned in project P 455.

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With current techniques, 60-90 kg oil per tonne pig iron can be injected. The economics of oil injection into the blast furnace depends on the coke/oil price ratio at the time. At present it is highly desirable from the economic angle to increase the proportion of oil used in some European steelworks. The aim here is to increase the volume of oil to 180-220 kg/t pig iron in a 6 m blast furnace.

The European steelworks have always sought to introduce more flexibility into their energy supply. A wider choice of energy sources helps to stabilize prices, thereby increasing the competitiveness of the European steel industry and making jobs more secure.

III - "STEELWORKS" Programme

The seven projects in this sector relate to the following fields :

- theoretical metallurgy (P 275/1)
- casting and solidification (P 388, P 390, P 459)
- refractories (P 439)
- energy supply for steelworks (P 430) (covering the whole steelworks).

(a) Theoretical metallurgy

Project P 275/1 relates to the calculation of the physico-chemical properties of slags by the Monte Carlo method.

There are ECSC research agreements already under way on the compilation and critical assessment of thermochemical data on alloys and slag systems, in which the missing data are generally determined by experiment.

In this research project, a mathematical-statistical method of ascertaining such data will be tried out.

(b) Casting and solidification

Together with project P 265 that has already been approved, projects P 388 and P 390 from the third Community programme on casting and solidification, which is devoted entirely to continuous casting.

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Like earlier Community programmes on the subject, this research will help to improve product quality and to increase the profitability of continuous casting plant.

A better knowledge of the processes taking place in the mould and in the secondary cooling zone will help towards better and more reliable operation.

Project P 459 concerns electroslag remelting of powder electrodes for the production of cylinders, hollow cylinders or clad rolls. This is the continuation of another ECSC Agreement. In the first stage, powder electrodes manufactured by various methods were successfully tested on a laboratory scale. At the end of that stage, results were assessed from the technical and economic aspects to define the types of steel best suited to this technology.

These proved to be high-alloy chromium steels (for roll cladding) and high- and medium-alloy special steels (hot and cold forging steels, high-speed tools steels, etc.).

In the present stage of the research, it is planned to develop the method for industrial use.

(c) Refractories

P 439 aims to increase the life of fired refractory bricks. In most steel plant used for molten metals, severe local erosion of the refractory linings is observed at the phase boundaries. This applies, for example, to hot-metal mixers, submarine ladles and high-temperature distributing launders in continuous casting plant. The refractory costs per tonne crude steel for the principal applications covered by this project vary from DM 1 to about DM 7. It is known that the change in the wettability of the bricks the metal/slag interface and the porosity of the bricks play a very significant role in erosion.

In this project, an attempt will be made to close the pores by impregnation of the bricks in vacuum and subsequent drying, thus improving the life of the refractory linings.

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If the research is successful, it will reduce crude steel production costs as a result of lower refractory wear and better utilization of parts of the plant.

(d) Energy

Under project P430/2, a study is to be made of the feasibility of a dynamic energy control system for an integrated steelworks. The main aim is to ascertain whether in principle research results in this field can be applied in other steelworks.

IV. "ROLLING MILLS AND PROCESSING" PROGRAMME

Rolled products have always accounted for the major share of the output of first-stage processing in the steel industry. Because of their quantity, competition on the market is fierce and a sustained research effort is called for to make them more competitive in terms of quality and price. New techniques must also be studied to overcome certain disadvantages encountered in present production.

Improvement of product quality is the aim of project P 449 (Tension control on continuous long-product mills) and P 450 (Research on skin-passing). The former relates to dimensional accuracy in long products and the latter to the mechanical properties of flat products.

Two projects are planned to investigate new techniques: P 353 on the hydrostatic extrusion of sections in which the aim is to produce a finished section directly from the ingot in a single operation and P 405 on the semi-hot drawing of materials difficult or impossible to cold draw, which will endeavour to eliminate heat treatment following hot rolling for certain special steels.

Rolling mill roll wear accounts for a substantial share of the production cost of a rolled product. Projects P 277/2 and P 440 will study ways of reducing roll deterioration.

Projects P 346 (Optimization of the efficiency of hot strip mills) and P 406 (Performance tests on strip treatment plant) are designed to improve output and thus reduce production costs.

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Finally, Project P 470 on the use of blast furnace gas as fuel in high temperature furnaces of the steel industry will study the upgrading of blast furnace gas in the context of energy conservation and self-sufficiency.

V. "MEASUREMENT" Programme

In the steel industry, as in any other industry supplying worked materials, it is necessary to monitor at all levels the production, steelmaking and processing stages right up to quality control of the finished product. Consequently it is essential to seek new approaches for the design, practical use and optimization of instruments and techniques.

These activities generally have complementary aims:

1. At production level

The verification of certain parameters, such as the analysis of the various constituents, during the production process should make it possible to act in good time to correct any errors.

2. The same applies to the steelmaking stage where chemical analysis enables direct action to be taken on the grade and quality of the steel. Quality is further defined by destructive or non-destructive testing (test pieces for analysis, mechanical tests, etc.) generally carried out on the production line.

3. At the processing stage, there is a vast number of means of checking the observance of certain criteria such as:

- geometrical shapes (mechanical, optical and physical methods of measuring dimensions)
- surface finish and/or texture
- flatness
- structures, etc.

These tests are carried out either at elevated or at ambient temperature.

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4. ~~The chain of operations~~ determining quality or nature of the product.

As this includes most of the techniques already used, the main points to check are structural defects and heterogeneities (by ultrasonic methods, non-destructive analyses of components, etc.) and abnormal appearance (surface defects, texture, etc.).

One of these techniques is atomic absorption spectrometry (projects P 380 and 465), a highly sensitive method giving a direct analysis without need for lengthy, uncertain and costly enrichment techniques.

The use of the plasma torch as a source of excitation in optical emission spectrometry is another advantageous method for the rapid analysis of solutions and liquids as it enables several elements to be determined simultaneously (projects P 385, 407, 431 and 473). Steel laboratories would benefit enormously from a method that would determine simultaneously the quantities of a large number of elements from a single specimen in solution. These applications will relate both to products directly connected with steel making and those of interest from the environmental protection aspect.

In a different context, one requirement for efficient sorting is rapid identification of the products in the stockyard. The main requirement is to be able to identify products from the angle of the chemical composition of the steel without damaging the product itself.

Consequently a simple and rapid non-destructive method is needed. The purpose of Project P 310 is, in the first stage, to design and develop a method based on rapid inspection techniques that are fast and easy to interpret and simple to use.

The recognized aim of non-destructive methods is the reliable and economic detection of defects. There has been definite and spectacular progress on these lines. However, this is merely a preliminary stage in the treatment of defects; equally important for the steel industry and metallurgy, but more difficult, is the observation of certain structural aspects of materials using ultra-sonic methods. In project P 409, this aspect of ultrasonic dispersion will be studied in order to obtain information enabling structural phases and elements to be defined.

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The observation and inspection of surfaces in general poses many problems for technicians while the inspection of hot surfaces adds a further difficulty. For example, it is current practice in the rolling of flat products to allow the slabs from the slabbing mill or continuous casting machine to cool to the ambient temperature before inspection (and repair if necessary) and then to charge them into reheating furnaces prior to delivery to the roughing mills. This whole procedure would be greatly simplified if the slabs were inspected and/or examined when hot. This would give more efficient working, operational economy and also appreciable savings of energy. Research project P 451 aims to devise a new and economical technical solution to this problem.

It will be based on the development of a device for displaying the slab surface using a television technique.

VI. "USED PROPERTIES" Programme

a) Weldability

The weldability properties of steels are always topical. The proposals presented here relate to:

1. The characterization of these properties: proposal P 383 aims to disseminate the users results obtained in the laboratory with the implant method, allowing simple and convenient testing, while proposal P 456 has the very useful aim for industry of defining the fusion zone.
2. Better evaluation of the qualities of welded joints: this is the aim of the joint programme, P 413, which by combining weldability and fracture mechanics should make it possible to compare simulation tests with tests on actual welds, to ensure that the tests are reproducible thus improving understanding between laboratories and to tackle the problem of the safety of welded joints in the context of presentday regulations.
3. The study of particular applications such as:
The development of a steel that is weldable with high heat input as in proposal P 442, which could lead to reductions in the cost of steel structures by increasing productivity during erection and enable producers to offer weldable stils under more economic conditions.

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The study of specific steels for low temperature use. Proposals P 351 and P 417 underline an economic problem that can only be resolved by overcoming major technological difficulties. The use of steels containing 5% instead of 9% Ni for low temperatures would reduce costs, but unfortunately fabricating problems, e.g. the welding of 5% Ni steels, have not yet been solved, which is why these research proposals are of such interest.

The welding of steels used for reinforced concrete, especially the higher-strength steels, calls for a good knowledge of their conditions of use, especially as the concrete reinforcing steel market is so vast.

As indicated in the proposal P 393, bars with too high carbon contents are difficult to weld as they require special methods not easily adaptable to on-site operation. Enhanced weldability will be sought in this research through a reduction in the carbon content of the steel. The economic implications of this approach will be carefully studied since the drop in strength (due to carbon reduction) will be compensated for in other ways which will increase production and/or processing costs (e.g. alloy additions, additional thermal and mechanical treatments).

b) Corrosion

In this field, two different but equally important activities are in progress: one relates to the behaviour of the steels used in prestressed concrete while the other concerns the corrosion resistance of steels and welded structures used in a marine atmosphere and/or environment.

The first aspect concerns the problem of stress corrosion cracking in prestressing steels which has become of increasing importance due to the general trend towards the utilization of higher strength alloys. Furthermore, current knowledge on the exact conditions under which stress-corrosion-initiated failures can occur in practice is quite rudimentary. There is, therefore, a need for a better understanding of the mechanism of this mode of failure which can assist in the forecasting of the long-term behaviour of these steels under service conditions.

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Two research proposals are presented:

- P 284/2: conditions causing stress corrosion cracking in the ducts of prestressed concrete structures prior to grouting
- P 352 : the stress corrosion cracking mechanism of prestressing steel

The second aspect of corrosion on which there is a need for action is the behaviour of steels in a marine atmosphere and/or environment: P 274/2.

The importance of research in this field relates to the increased use of steel in marine applications and, in particular, for offshore structures used in the exploitation of underwater gas and oil resources. The growing number of such structures being brought into use coupled with the recent movement towards their use in deeper and rougher areas (e.g. North Sea) have increased substantially the problem of safety. The influence of marine corrosion phenomena on the safe working life of these structures has become an aspect of vital concern and has highlighted the inadequacies in our current knowledge of the behaviour of steels in this type of environment. It is necessary, therefore, to carry out detailed corrosion studies with the following objectives:

- (a) to gather more complete information on the behaviour of available steels and, in particular, on selected alloy steels with a view to their wider utilization;
- (b) to develop suitable methods of protection for such steels, particularly against localized attack;
- (c) to explore the possibility of improving these steels or elaborating new compositions.

The ultimate objectives of the research cover technical aspects such as improving the properties of steels and their service performance, economic aspects relating to increasing the consumption and, therefore, the demand for steel and the social aspects that relate to enhancing the safety of advanced engineering structures where the danger to human life is a serious and ever-present hazard.

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c) Formability

During the work on the two previous joint programmes on drawability, a knowledge of the parameters defining the work hardening structure of sheet after cold rolling (deformation energy and its anisotropy) was found essential in order to analyse and understand the formation of recrystallization structures and textures during annealing and thus be able to specify acceptable limits to annealing conditions so as to obtain specified metallurgical properties (especially drawability).

The purpose of IRSID's current research is to determine the influence of the work hardening structure obtained after cold rolling on the texture and metallurgical properties (grain size, mechanical properties) of rimming or killed steel sheet after brief annealing.

As this research is limited in scope and entails a large number of tests, analyses and measurements, it will only be possible to study a very few types of sheet (obtained by varying the chemical composition or hot rolling conditions). Previous research has shown that the characteristics of work hardening after cold rolling, and in particular its removal during annealing, depend not only on the amount of reduction during hot rolling but also to a very great extent on the presence, absence, percentage volume or content of certain elements or precipitates (nitrogen, aluminium, titanium, $NaAl$, TiC , etc.).

Consequently, although the expected results will enable acceptable limits to the annealing conditions to be defined for the types of sheet studied, it will not be possible to extrapolate them readily to other sheet (or even to the same sheet in different states after hot rolling). Obviously it would be extremely advantageous to be able to define optimum annealing cycles for industrially-produced sheet whose chemical composition and hot rolling conditions can vary within certain limits. The study in progress would be of much greater interest if, alongside the planned experiments, it were possible to study the significance of certain variations in chemical composition or hot rolling conditions that result during annealing in changes in precipitation

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d) Fatigue

The study of fatigue in relation to steel structures and uses in the service behaviour of installations. This concern is reflected in the research projects presented here which relate either to welded structures or to the use of steel combined with concrete.

The study of fatigue problems in welded structures is the subject of three proposals concerning high-strength and quenched and tempered steels. The use of these steels should be promoted and consequently their behaviour must be studied.

The most common argument advanced in favour of the use of high-strength steels is the weight reduction allowed by the greater strength. It takes about the same amount of energy to make a tonne of steel, whatever the grade. Consequently the promotion of high-strength steels is a fashionable aim in the age of energy conservation.

A second important aspect is the safety of structures. In some dynamically loaded machines (crane jobs, for example) it is known that the steel is "occasionally" subjected to stresses exceeding its yield point, which in the long run can endanger the machine. Considering that the cost of the steel accounts for only about 10% of the total cost of such machines, it may be concluded that it would be advantageous to substitute high-strength steels for ordinary steels without reducing the component sections. Safety would be greatly improved, but the proof that its substitution is justified must be provided.

The programmes presented here (P 375, P 318 and P 378) are intended to provide answers to these questions by supplementing the data already obtained from research on welded assemblies as a function of stresses and the morphology of the steels, and on the influence of welding conditions.

Project P 343 highlights the problems encountered in using concrete reinforcing steels, with particular reference to mechanical testing.

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The use of reinforced concrete for dynamically stressed structures (e.g. bridges) calls for a knowledge of the fatigue strength of the reinforcing steel. The results of the beam test are generally used to assess the fatigue strength of reinforcing steel.

However, there is as yet no standardized method of determining the fatigue strength of reinforcing steel by using uncreted test pieces. Results of fatigue tests on straight uncreted test pieces cannot be transferred to the behaviour of the bent ccreted steel because of the different state of stress in such test pieces.

The beam test is costly, as the test pieces are difficult to produce. Consequently a simpler test with test pieces that are easier to prepare should be developed.

e) Brittle fracture

The development of fracture mechanics calls for basic and practical research to be carried out in parallel. This is the only way of ensuring that theoretical knowledge is properly disseminated and used in practice. The three research proposals presented here illustrate that fact.

The first proposal (P 376) has the aim of quantifying the risk of fracture in welded structures by using recent fracture mechanics concepts. Whereas linear elastic mechanics, making use of the fracture toughness parameter K_{IC} , can describe fracture conditions in a cracked structure under plane strain conditions (e.g. very thick gauge structures: pressure vessels, rotors, etc.), this concept cannot be applied without great care to structures subject to a non-plane state of strain (load-bearing structures). For such cases it would be useful to develop a method of predicting the risk of fracture under actual service conditions and, in theory, whatever the configuration of the structure.

Proposal P 418 also aims to clarify the concept of fracture resistance. Tensile tests will be carried out on large test pieces in order to obtain more significant results for thick plate. It has been found that in this case the use of small test pieces gives localized results

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that depend too greatly on the position of the test piece in the plate thickness.

This concern to combine basic and practical research also appears in proposal P 420 which is designed to study the mechanisms, metallurgical factors and conditions for arresting crack propagation, for example in large diameter tubes.

f) Creep

The behaviour of steels at high temperatures and above all the way it affects the residual life of energy-generating plant and its components is a constant source of concern to manufacturers and users who have to take account of both safety and economic requirements (planning of operating and maintenance conditions); this is all the more important as the size of units increases. This concern is reflected in five research proposals whose aims are complementary. For example, in proposal P 316 the aim is to compare the mechanical properties of steels for pressure vessels in the delivery state and after low-cycle fatigue testing and to ascertain whether the tests are sufficiently significant to predict the service behaviour of these steels. Proposal P 396 illustrates the need, difficult though it will be, to establish a link between existing knowledge obtained from costly high-temperature creep tests and the actual behaviour of steels in service.

Proposals P 423 and P 478 relate to the behaviour of turbines and are based on the same grounds of safety and performance. All efforts to increase the output of steam generating plant inevitably depend on the attainment of a higher turbine output. The properties required of steels used for steam turbine rotors are different from those needed in pressure vessel steels. This is partly due to the larger dimensions and different stressing conditions: operating transients, high dimensional stability of components throughout the life of the plant.

As emphasized in proposal P 271/2, low creep ductility is a critical problem in the design of components for high temperature applications.

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In fact, the creep strength of the commercial low-alloy ferritic steels generally used for equipment operating in the range of temperatures up to 565°C can be improved substantially but this improvement in strength is frequently accompanied by a reduction of the long-term ductility. The inadequate creep-ductility properties of high-strength low-alloy ferritic steels not only limit their use at high temperatures but can also cause manufacturing problems such as the formation of stress-relieving cracks during post-weld heat treatment.

Laboratory-based research has demonstrated that improved combinations of creep strength and ductility can be achieved in steels of enhanced purity. It is now necessary to examine whether these purity levels can be obtained on an industrial scale and, subsequently, to evaluate the effect of such reductions in residual element content on creep properties.

VII. "PHYSICAL METALLURGY" Programme

The research proposed in this sector of the programme is concerned essentially with the following two themes:

- studies of composition - structure - property relationships and
- development and application of quantitative analytical techniques.

In the first area, work is proposed (P 272/2) aimed at improving the properties of ferritic stainless steels (12-21% chromium content) so that they will compete more favourably with the more widely used austenitic alloys (e.g. 18/8 chromium-nickel); this research is prompted by the availability of a range of relatively new refining processes for the production of stainless steels of high purity (low interstitial content) and the benefits that would result from a reduction in nickel requirements.

The other projects range from obtaining a better understanding of the role of inclusions and the effect of trace impurity segregation on the deformation and fracture of steels (P 289, P 425) to a detailed

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investigation of the kinetics of precipitation in alloys under conditions typical of industrial scale production (P 374). This latter research should add to the striking progress already made in the thermomechanical treatment of steels where physical metallurgy (structure - property correlations) has been quantitatively integrated with process metallurgy (variables of time, temperature and deformation) to provide structural steels with enhanced combinations of properties.

The development and application of new high resolution instrumentation and sophisticated diagnostic techniques (e.g. electron microscopy, Auger electron spectroscopy) have contributed, in an indispensable way, both to advancing the understanding of fundamental processes in metallurgy and to improving inspection and analytical procedures in steel production. To sustain effort in this important area, two projects are proposed which are concerned with the techniques of small angle neutron scattering (P 349/3) and of quantitative metallography (P 466). The former project will explore the utility of neutron scattering as a means of obtaining detailed information on the structure of steels at sub-microscopic and microscopic levels and represents an extension of promising research already supported in the ECSC programme. The proposal on quantitative metallography represents a continuation of a collective project designed to develop new and standardized methods of metallographic examination that can be universally applied throughout the Community's steel industry; this proposed work will be specifically directed at adapting the results already generated with ECSC support to meet steel producer and user needs particularly in the field of quality control for the assessment of steel "cleanliness" (non-metallic inclusion content).

VIII. "UTILIZATION" Programme

a) Light application

The use of steel for the construction of buildings appears to be marking time at present. Leaving aside the economic aspects of competition from concrete, one of the reasons is the reluctance

of potential customers to use a product (steel) when there is insufficient knowledge on some aspects of its behaviour, e.g. its resistance to corrosion and fire.

Project P 427 on the use of steel sheet piling aims to remove obstacles in Europe to the use of steel piling by obtaining an exact knowledge of its behaviour during pile driving and when in position. Project P 472 (Fire resistance) is designed to supplement the extensive information already available on the reaction of steel to fire.

Project P 462, entitled Reaction of load-bearing steel structures to seismic phenomena, is a very topical subject in Italy (Frioul).

Project P 467 is designed to promote the use of steel in standardized non-residential buildings by providing potential purchasers with a catalogue of modular structures.

Finally, Project P 370 is a logical follow-up to the construction of the Berlin research station as it makes the facilities of the station available to architects and industrial companies.

b) Heavy application

When decisions were taken in 1974 on a joint programme on fatigue resistance of steel bridges and in 1975 on a vast joint programme on welded offshore structures, it was agreed that the Italian partners would submit their complementary programmes at a later date. As it proved impossible to make a coordinated start in all the laboratories at an early enough date, it was felt desirable to begin this research of interest to the Community as quickly as possible and to allow those laboratories whose work load prevented them from cooperating with the other at that time to prepare complementary programmes at a later date.

Consequently P 364/2 describes research that will complement Agreements 6210-KG/1/104, 2/204, 3/304, 6/604 and 7210-SA/8/802 relating to fatigue in steel bridges and P 386 covers research to supplement Agreements 7210-KB/1/102, 3/301, 6/602, 8/801, 8/802 and 8/803 on fatigue and corrosion fatigue in welded steel offshore structures.

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Research in both these fields have obvious social implications since one of the major objectives is to improve the safety of such structures and, thereby, reduce the danger to human life. Also the work in marine technology should help to reduce the risk of oil or gas spillage which constitutes a large environmental hazard in the exploitation of offshore gas and oil fields.

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CONCLUSION

The total budget for the selected research programmes amounts to 30,178,700 E.U.A. (conversion rates of 10.12.1976). The ECSC's financial commitment will be 18,709,500 E.U.A., of which 18,164,520 E.U.A. will go to cover its participation in the research costs and 544,980 E.U.A. to cover the cost of disseminating information and related costs.

Annex 1 : Summary table

Annex 2 : The research projects

SUMMARY TABLE

3/III-B-4/77-E
Annex 1

Project n°	Title of the Research	Proposed Research			Financial aid	
		by	Durat. years	Amount in EUA(10.12.76)	%	Amount in EUA(10.12.76)
194/2	<u>IRON ORE MINE</u> Trials of winning high-silica ore in longwall faces using cutter-loaders	Ch.Synd.M.F.	1 1/4	377.000	60	226.200
	<u>DIRECT REDUCTION AND PIG IRON</u>					
	a) <u>Direct reduction</u>					
335	Centrifuge ironmaking process	B.S.C.	2	424.000	60	254.400
402	Automation of the direct reduction process in the rotary kiln	B.F.I.	3	663.500	60	398.100
403	Investigation of the equilibria between liquid oxide, reducing agents and steel melt for the production of high-alloy steels by melting reduction	Thyssen	2	124.500	60	74.700
	b) <u>Coke</u>					
302/2	Degradation of coke in the blast furnace and its relationship with coke properties and blast furnace performance	B.S.C.	4	491.000	60	294.600
	c) <u>Blast furnace</u>					
404	Investigation of the causes of pressure pulsation in combustion chamber especially in hot-blast stoves	B.F.I.	3	432.000	60	259.200
438	Study of stove-coolers	C.R.M.	3	323.500	60	194.100
455	Large-scale oil injection at blast furnace tuyeres	IRSID } ARBED }	3	797.500	60	478.500
	<u>STEELWORK</u>					
	a) <u>Theoretical metallurgy</u>					
275/1	Calculation of the physico-chemical properties of steelmaking slags by the Montecarlo method	C.S.M.	1	83.000	60	49.800

Annexe 1

Project n°	Title of the Research	Proposed Research			Financial aid	
		by	Durat. years	Amount in EUA(10.12.76)	%	Amount in EUA(10.12.76)
	<u>b) Casting and solidification</u>					
388	Metallurgical bowders in moulds to improve continuously-cast semis	C.S.M.	2 1/2	372.500	60	223.500
390	Third joint programme on casting and solidification .	B.S.C. } IRSID } VDEh }	3 2 3	1.517.500 386.000 1.396.500	60 60 60	910.500 231.600 837.900
459	Electroslag remelting of powder electrodes for the production of compact ingots, moulds or clad rolls	C.S.M.	3	333.000	60	199.800
	<u>c) Refractories</u>					
439	Improvement of fired refractory bricks	C.R.M.	3	508.500	60	305.100
	<u>d) Energy</u>					
430/2	Dynamic energy control system for an integrated steelwork	B.S.C.	1	30.000	100	30.000
	<u>ROLLING MILL AND PROCESSING</u>					
277/2	Resurfacing of rolling mill rolls	C.S.M. } IRSID } B.S.C. }	3	538.000 538.500 299.000	60 60 60	322.800 323.100 179.400
346/2	Optimization of the efficiency of hot strip mills	B.F.I.	4	750.500	60	450.300
353	Hydrostatic extrusion of sections	B.S.C.	3	369.500	60	221.700
405	Semi-hot drawing of materials difficult or impossible to cold-draw	T.H. Aachen	3	175.000	60	105.000
406	Performance tests on strip treatment plant	B.F.I.	3	280.000	60	168.000
440	Lubrication of rolls for hot rolling	C.R.M.	3	298.500	60	179.100
449	Tension control on continuous long-product mills	IRSID	3	301.500	60	180.900
450	Research on skin-passing	IRSID	3	429.500	60	257.700
470/1	The use of blast furnace gas as fuel in high-temperature furnaces	Inst.Fl.Res.	1	327.000	60	196.200

Project n°	Title of Research	Proposed Research			Financial aid						
		by	Durat. years	Amount in EUA(10.1276)	%	Amount in EUA(10.12.76)					
<u>MEASUREMENT</u>											
310	Improvement of methods of sorting steel on the test bench and in stockyards	IRSID	3	438.000	60	262.800					
331	Analysis of sulfide inclusions in steel	M.P.I.	2	121.000	60	72.600					
385 } 407 } 431 } 473 }	New plasma-source spectrometric techniques for the steel industry	IRSID } HOESCH } BSC } CRM }	3	650.000	60	390.000					
408		Development and practical testing of a method of analysing steel without taking samples					Thyssen	3	324.000	60	194.400
409		Structural analysis of steels by ultrasonic dispersion					Inst.Zerst.Prüf.	3	358.500	60	215.100
411		Continuous testing of material properties of cold-rolled steel strip					Rasselstein	3	299.000	60	179.400
433/2	Continuous on-line measurement of gauge profile and shape of hot strip	B.S.C.	2	304.000	60	182.400					
451	Inspection of hot slab surfaces	IRSID	2	283.500	60	170.100					
460	Measurement of oxygen potential in liquid slags	C.S.M.	2	114.000	60	68.400					
465/2	Determination of certain oligo or trace elements by flameless atomic absorption spectrometry	Creusot-Loire } C.S.M. }	2	91.000	60	54.600					
				2	78.000	60	46.800				
X	Analysis of gas in steel	C.S.M.	-	12.000	100	12.000					
<u>USED PROPERTIES</u>											
a) <u>Weldability</u>											
351	Economy in the manufacture and utilization of cryogenic steels	B.S.C.	3	70.000	50	35.000					
383	Cold cracking on implants	Inst. Soud.	2	108.000	60	64.800					
393	Investigation of the weldability of concrete reinforcing steel type FeB 500	C.R.M. } T.N.O. }	2	115.000	60	69.000					
				2	113.500	60	68.100				

Project n°	Title of Research	Proposed Research			Financial aid	
		by	Durat. years	Amount in EUA(10.12.76)	%	Amount in EUA(10.12.76)
413	The possibilities of assessing the safety of welded joints	VDEh B.S.C. C.S.M. T.N.O. IRSID	3	1.961.600	60	1.176.960
417	Assessment of the safety of welded joints of 5,5 % Ni steel for cryogenic use	Thyssen	3	73.000	60	43.800
442	Development of steel weldable with a high heat input	C.R.M.	2	232.500	60	139.500
456	Molten metal in welding	IRSID T.N.O.	3	215.500 243.500	60 60	129.300 146.100
b) Corrosion						
274/2	Marine corrosion	B.S.C. Cebelcor Cent.Oc.Br. C.S.M. Hoogovens Breda IRSID SMOZ VDEh T.N.O.	2	1.196.100	60	717.660
284/2	Stress corrosion of prestressing steels	VDEh	3	597.500	60	358.500
352	The stress corrosion cracking mechanism of prestressing steel	Hoogovens	6	197.000	60	118.200
c) Formability						
336/2	Drawability of cold rolled sheets	IRSID	2 1/2	200.000	60	120.000

Project n°	Title of Research	Proposed Research			Financial aid		
		by	Durat. years	Amount in EUA(10.12.76)	%	Amount in EUA(10.12.76)	
	<u>d) Fatigue</u>						
318	Improvement of the fatigue strength of welds in high-strength water-quenched fine grained structural steels by thermal and mechanical treatment of the seams	VDEh	3	67.500	60	40.500	
343	Test method to determine the fatigue strength of steel reinforcing bars	VDEh	2	526.500	60	315.900	
375	Promotion of high strength steels	C.R.M.-ARBED FIAT IRSID Creusot-Loire C.R.I.F.	3	180.000 120.000 60.000 120.000 24.000	60 60 60 60 60	108.000 72.000 36.000 72.000 14.400	
378	Fatigue of welded joints in high-strength structural steels. European preliminary draft standards	VDEh C.R.M. IRSID Weld.Inst. C.S.M. T.H. Delft		1 1/2	25.000	100	25.000
	<u>e) Brittle fracture</u>						
376	Fracture mechanics of steels	IRSID		3	296.500	60	177.900
418	Assessment of the fracture behaviour of steels on the basis of large-scale tensile tests having regard to the results	VDEh		3	726.000	60	435.600
420	Mechanics and material behaviour as regards crack arrest	I.F.K.M. } T.N.O. }	3 3	198.000 195.500	60 60	118.800 117.300	
287/2	Fracture behaviour of gas transmission pipelines	VDEh	1	42.500	60	25.500	
	<u>f) Creep</u>						
271/2	Influence of steelmaking techniques on hot ductility of low-alloy ferritic steels	C.S.M.	4	548.000	60	328.800	
16	Tests of heat-resisting steels under periodically fluctuating stress	VDEh } T.N.O. }	3 3	455.500 233.000	60 60	273.300 139.800	

Project n°	Title of Research	Proposed Research			Financial aid	
		by	Durat. years	Amount in EUA(10.12.76)	%	Amount in EUA(10.12.76)
396	Collaborative research on the determination of the residual life of in-service steel components for high-temperature use	Dalmine	3	114.000	60	68.400
423	Improvement of the service properties of heat-resisting steels for turbines	VDEh	3	85.000	60	51.000
		Creusot-Loire	3	85.000	60	51.000
423/2	- Idem -	C.S.M.	3	57.000	60	34.200
<u>PHYSICAL METALLURGY</u>						
272/2	Ferritic stainless steels with low content of interstitials	C.S.M.	1 1/2	267.000	60	160.200
289	Influence of inclusion distribution and morphology on plastic deformation and fracture mechanisms in steel,	IRSID	3	215.500	60	129.300
349/3	Non destructive testing of steels by small angle neutron scattering	FIAT	2	305.000	60	183.000
		K.F.A.	2	103.500	60	62.100
374	Precipitation kinetics in the non-continuous cooling of sheet coils after accelerated cooling	C.R.M.	3	367.000	60	220.200
425	Concentration of foreign atoms at grain boundaries in iron and steel	M.P.I.	2	259.500	60	155.700
466	Quantitative metallography	B.S.C.		196.500	60	117.900
		C.R.M.		183.500	60	110.100
		C.S.M.	3	145.000	60	87.000
		IRSID		427.500	60	256.500
		M.P.I.		188.500	60	113.100
<u>UTILIZATION</u>						
a) <u>Light application</u>						
370	Research programme at the Berlin testing station for industrialised building in steel	F.I.B.	2	212.500	72	153.000
437	Use of steel sheet piling	GIRIA		132.500	60	79.500
		B.S.C.	3	167.000	60	100.200
		Arbed		484.000	60	290.400
		T.N.O.		21.500	60	12.900

Project n°	Title of the Research	Proposed Research			Financial aid	
		by	Durat. years	Amount in EUA(10.12.76)	%	Amount in EUA(10.12.76)
462	Reaction of load-bearing steel structures to seismic phenomena	Italsider	1 1/2	258.500	60	155.100
467	Conditions for the development of steel construction in typical non-residential buildings	CBLIA	1 1/2	70.000	60	42.000
472	Fire resistance of metal structures b) <u>Heavy application</u>	Experts	1	30.000	100	30.000
		Stg. Anw.	4	304.000	60	182.400
		C.T.I.C.M.	2	289.000	60	173.400
364/2	Measurement and interpretation of cumulative loads on bridges	I.S.C.Pisa	2	48.500	60	29.100
386	Static and fatigue behaviour of welded tubular joints in off-shore structures	Italsider	3	380.500	60	228.300
	Sub-total			30.178.700		18.164.520
	Cost of dissemination of information					544.980
	TOTAL					18.709.500

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THE RESEARCH PROJECTS

I - "IRON ORE" PROJECTS

P 194/2 Trials of winning high-silica ore in longwall faces using cutter-loaders

The research work has demonstrated that the new method with advancing face and powered supports is valid and could well give a significant increase in yield over the conventional method in current use.

Three problems arose during the trials :

- caving initiated by shots
- behaviour of the working face
- the cutter-loader.

The existing cutter-loader came from a potash mine and is unsuitable for iron mines. As there is no machine of the type required on the market, it is necessary to design and construct a cutter-loader of a larger capacity than the existing one, equipped with a different haulage system and capable of overcoming the problem of the flaking of the working face.

The additional funds proposed will allow construction of this machine, designed by the Chambre Syndicale des Mines de Fer de France in Paris (F). The time required is estimated at 15 months.

II - "DIRECT REDUCTION AND PIG IRON PRODUCTION" PROJECTS

(a) Direct reduction

P 335 Centrifuge ironmaking process

The following research programme is planned :

1. The experimental plant is first to be given a longtime test.
The critical part of the plant is the watercooled discharge ring.
2. Thermodynamic data, especially the heat transfer values between the gaseous phase and the molten phase (slag/metal) will be determined experimentally.

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3. On the basis of the thermodynamic data, the theoretical and practical limitations of the process will be determined, with particular reference to productivity.
4. Investigations will be carried out to determine the usefulness of the product (iron and slag).

The applicant is the British Steel Corporation.

The work will be carried out in the Teeside Laboratories, Grangetown (UK) and will take two years.

P 402 Automation of the direct reduction process in the rotary kiln

The following experimental programme is planned :

1. Collection from the literature and critical evaluation of theoretical data and practical experience with rotary kilns.
2. Evaluation of the data by means of regression analysis. Determination of existing gaps ; specific measurements on existing experimental and production plant.
3. Verification of the process descriptions by means of regression analysis.
4. Study of the influence of various parameters on energy consumption, throughput and product uniformity.
5. Optimization of plant and operation.

The research work will be carried out by the Betriebsforschungsinstitut of the Verein Deutscher Eisenhüttenleute, in cooperation with Krupp Industrie und Stahlbau AG and Lurgi Chemie und Hüttentechnik GmbH (D), and is expected to take three years.

P 403 Investigation of the equilibria between liquid oxide, reducing agents and steel melt for the production of high-alloy steels by melting reduction

The following research is planned :

1. Determination of the dynamic equilibria between molten iron - chromium - ore, reducing agents and steel melt.
2. Investigation of the relationship between reaction kinetics and temperature.

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3. Study of the reaction mechanism (direct reduction, indirect reduction, etc.).
4. Research on the effect of the presence of Ni and Cr on the C and O₂ content in the melt.
5. Behaviour of the refractory material.
6. Investigation of slag structure and material properties.

The experiments will be carried out in small experimental furnaces in a small ESR plant and in a small graphite bar furnace (300 kg).

Initially two materials will be melted : a low alloy structural steel and a stainless steel.

The applicant is Thyssen Edelstahlwerke AG in Krefeld (D) and the research is expected to take two years.

(b) Coke research

P 302/2 Degradation of coke in the blast furnace and its relationship with coke properties and blast furnace performance

The research programme is identical to that of the original application. (Coke samples of about 500 kg are taken at the tuyeres. The properties ascertained on these samples are related both to the cold properties of the coke and to blast furnace operating practice).

Number and distribution of blast furnace tests (main application and supplementary application)

1 Country	2 N° of blast furnaces	3 N° of experiments	4 Comments
F	4	4	-
I	2	2	-
B	5	20	Various charge materials are tested in different furnaces under identical operating conditions (coke, briquetted coke, various burdens)
UK	6	10	
NL	2	4	
D	4	5	
EC Total	23	45	

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The applicant and coordinator is the British Steel Corporation, London (UK) together with the British Carbonization Research Association and the research will extend over a period of four years.

(c) Blast furnace

P 404 Investigation of the causes of pressure pulsation in combustion chambers, especially in hot-blast stoves

The following programme is proposed :

1. Investigation of the causes of pulsation in hot-blast stoves of various designs.

Special attention will be paid to the parameters :

combustion gas composition
air factor
gas volume flow

2. Research on the extent of pressure and velocity variations along the gas, air and waste gas pipes.
3. Simulation experiments on models. Flow problems in particular will be investigated in these experiments. Cold and then hot experiments are planned.
4. Verification of the model experiments in practical operation.
5. Preparation of guidelines for the design of hot-blast stoves and study of the application of the results to problems in other combustion chambers.

The applicant is the Betriebsforschungsinstitut of the Verein Deutscher Eisenhüttenleute in Dusseldorf (D), and the research will last three years.

P 438 Study of stave coolers

The following research is planned :

1. Compilation and selection of characteristic measured data for stave coolers and blast furnace operation.

2. Construction of a mathematical control on the basis of the characteristic data which will allow the operator to detect abnormalities in the cooling system at an early stage.

The research will be carried out on two Belgian blast furnaces operating with :

- high top pressure
- oil injection
- oxygen-enriched blast
- high blast temperature

and in addition equipped with a gas analyzer at the throat and a neutron probe to determine the moisture content of the coke. One blast furnace also has a computer that enables the model to be tested in on-line operation.

The applicant is the Centre de Recherches Métallurgiques in Liège (B) and the research will take three years.

P 455 Large-scale oil injection at blast furnace tuyeres

The research will be carried out on a medium-sized blast furnace (6 hearth diameter) which is charged exclusively with Lorraine ore.

The blast furnace will first be equipped with the necessary apparatus (installation of special converging and diverging tuyeres operating in the ultrasonic range).

The quantity of oil injected will then be increased in stages from 80 kg/t pig iron to 200 kg/t.

After each stage the lowest acceptable flame temperature will be determined with a view to conserving pure oxygen.

In addition the thermal and material balances will be determined as will the blast furnace operating parameters (pressure drop, etc) and the respective quality of the pig iron and the slag.

The applicants are the Institut de Recherches de La Sidérurgie Française in Maizières-les-Metz (F) and Arbed in Luxembourg (L) and the research will probably take three years.

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III - "STEELWORKS" PROJECTS

(a) Theoretical metallurgy

P 275/1 Calculation of the physic-chemical properties of steelmaking slags
by the Monte Carlo method

The research is to be carried out on typical steelworks slag system and one typical blast furnace slag system.

The following programme is planned :

- (1) The activity of FeO will be calculated for various CaO/SiO₂ ratios at various temperatures.
- (2) The activity of CaO will be determined for various SiO₂/Al₂O₃ ratios, at two different temperatures.
- (3) The temperatures and the CaO/SiO₂ or SiO₂/Al₂O₃ ratios will lie in the range that is of interest for industrial purposes.
- (4) The consistency of the method in relation to the Gibbs-Helmholtz equation will be checked on very specific slag compositions.
- (5) The calculated data will be compared with data obtained experimentally.

The research will be carried out at the Centro Sperimentale Metallurgico in Rome (I) and is estimated to take one year.

(b) Casting and solidification

P 388 Metallurgical powders in mould ; to improve continuously-cast semis

The research programme described below will be carried out partly on a semi-industrial and partly on an industrial continuous casting machine :

- (1) investigation and development of the steel powder injection technique for submerged casting
- (2) model studies of the flow dynamics
- (3) casting experiments on industrial plant to test the technology
- (4) tests at a high casting speed on a billet casting machine
- (5) metallographic and mechanical tests on the product.

The tests will be carried out first on unalloyed and later on alloy steel. Amongst the alloy steels, special consideration will be given to grades containing easily oxidizing alloying elements.

The applicant is the Centro Sperimentale Metallurgico in Rome (I) and the research is expected to take two and half years.

P 390 Third joint programme on casting and solidification

The programme comprises the following research :

- (1) research in the ladle-tundish-mould area
 - problems of reoxidation of the molten metal stream
 - investigation of the flow conditions with a view to better separation of slag particles
 - influence of the refractory material on the degree of purity of the steel
 - determination of heat losses
- (2) research in the mould
 - research on mould powders
 - research on heat transfer in slab moulds
 - measurements of friction on the mould wall and temperature distribution and stresses in the continuous casting
- (3) research on heat transfer in the secondary cooling zone
 - basic research on heat transfer with film and bubble vaporization during spray cooling
 - measurement of the temperature distribution on the strand
 - effect of temperature changes on the surface of the casting (cracking) and on the structure
 - theoretical research on the optimum cooling and solidification conditions with subsequent practical tests on various strand cross-sections ; calculation of water volume as a function of operating conditions and steel quality.
- (4) research on segregation
 - research on core segregation and susceptibility to internal cracking
 - research on the influence of casting speed and casting temperature on core segregation

- computer calculations of segregation.
- (5) research on the effect of strand alignment
 - development and use of measuring instruments for roll gaps and movement
 - measurement of inter-roll bulging and surface temperature.

The applicants are :

British Steel Corporation, London (UK)

Verein Deutscher Eisenhüttenleute, Düsseldorf (D)

Institut de Recherches de la Sidérurgie Française, St-Germain-en-Laye (F)
and the research is expected to take three years.

P 459 Electro-slag remelting of powder electrodes for the production of compact ingots and clad rolls

The research programme will be carried out :

- (a) in an ESR laboratory installation on which ingots of 80-200 mm in diameter can be melted and
- (b) in an industrial ESR installation of 1 540 KVA on which ingots of up to 450 mm diameter can be produced.

The following research is planned :

- (1) production of ingots of
 - cold cutting tool steels of type D₃
 - stainless steels of type H₁₁
 - high-speed tool steels of type M₂.

The ingots will be investigated for homogeneity in the as-cast and forged states.

(2) Production of clad rolls

- production of hollow cylindrical powder electrodes, consisting of two concentric tubes, the space between them being filled with metal powder of the desired alloy
- manufacture of clad rolls by direct ESR hard facing on the roll
- as an alternative, manufacture of a hollow cylinder which can later be shrunk onto a core
- tests on the product, mainly in respect of the uniformity of the properties in the longitudinal and circumferential direction.

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The applicant is the Centro Sperimentale Metallurgico in Rome (I) and the research is expected to last three years.

(c) Refractories

P 439 Improvement of fired refractory bricks

The research programme comprises the following :

(1) in the laboratory

- selection of refractories suitable for impregnation
- selection of the impregnating agent according to technical, scientific and economic criteria (Ca, Mg, Zr and Si compounds)
- design of the impregnating method and testing of the properties of the impregnated bricks (heat conduction, corrosion behaviour, etc.)

(2) in practice

use of the refractories selected in laboratory experiments in hot metal mixers, torpedo ladles and distributing loundess of continuous casting machines.

The applicant is the Centre de Recherches Métallurgiques in Liège (B) and the research is estimated to take three years.

(d) Energy

P 430/2 Dynamic energy control system for an integrated steelworks

The study will take the following form :

- data collection and collation in various integrated steelworks
- selection and optimization of the available data
- investigation of a typical case to ascertain whether results are transferable to other steel works.

The applicant is the British Steel Corporation in London (UK) and the study will take one year.

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IV - "ROLLING MILLS AND PROCESSING" PROJECTS

P 277/2 Resurfacing of rolling mill rolls

Roll wear is an important item in rolling costs and even a small reduction in wear will have a very favourable impact on the production cost of the rolled product.

Project P 277/2 covers the following main aspects :

- (a) study of the basic phenomena governing the deterioration of rolls in service, having regard to both hot lubrication and the problem of roll cooling ;
- (b) study of the service properties of the various metallurgical structures that can be obtained by varying chemical analysis and production conditions both for the surface layers of the rolls that are in contact with the stock being rolled and for the roll core which is subject to special stress conditions.

This research programme lasting three years will be carried out jointly by the British Steel Corporation in London (UK), the Centro Sperimentale Metallurgico in Rome (I) and the Institut de Recherches de la Sidérurgie Française in Maizières-Les-Metz (F).

P 346/2 Optimization of the efficiency of hot strip-mills

This research project is part of a wider programme that started a few years ago with the general aim of obtaining further knowledge of and systematically improving the components and ancillary installations of wide strip mills.

This project will tackle the optimization of these components and study point by point all the parameters that have an individual influence on the "rolling mill" system considered as a whole. It will cover the following aspects :

- plant techniques
- process techniques
- economy

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and will devote particular attention to the following components :

- furnace with its stock charging, transport and delivery devices
- scale breakers
- roughing stands
- finishing stands
- entry, transfer and run-out tables
- shears
- coilers
- auxiliary installations.

This research will take four years and will be carried out by the Betriebsforschungsinstitut of the Verein Deutscher Eisenhüttenleute in Dusseldorf (D).

P 353 Hydrostatic extrusion of sections

The aim here is to improve the output of the hydrostatic extrusion operation for the economical production of high-strength steel sections. The research will follow three lines :

- (a) the optimization of die design and lubrication practice of multi-aperture dies ;
- (b) the reduction of press cycle times by the use of augmentation control and process automation equipment ;
- (c) the production of close-tolerance carbon and stainless profiles at intermediate temperatures using preformed feedstock.

If this research is successful, hydrostatic extrusion could be used to produce all light steel sections, which currently exceed two million tonnes per annum within the Community. The production cost could be reduced by about 25 % with a considerable improvement in quality.

This research will be carried out by the British Steel Corporation in London (UK) and will last three years.

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P 405 Semi-hot drawing of materials difficult or impossible to cold-draw

Sections of some steels (including high-speed steels for cutting tools) are impossible to cold-draw because of the hardness of the product and are difficult to hot-draw because of oxidation, increase in friction coefficient, high die wear, impossibility of transferring traction forces to the hot section, etc.

Semi-hot drawing (below the recrystallization temperature) appears an advantageous compromise : as drawing, impossible cold becomes feasible at that temperature, while the difficulties of hot drawing are reduced.

This process, which calls for a number of technological improvements to drawing installations (automation, heating, lubrication, etc.), could possibly be combined with hydrostatic extrusion for economic production of parts such as valves for internal combustion engines, roller bearings, turbine blades, etc. thus having a large market.

The Institut für Bildsame Formgebung of the Technische Hochschule in Aachen (D) will carry out this research over a three-year period.

P 406 Performance tests on strip treatment plant

Crude steel production has increased 1.6-fold in the last fifteen years. Over the same period the volume of flat rolled products with treated surfaces has increased fourfold. This would not have been possible without high-capacity surface treatment units. As yet, insufficient attention has been paid to production capacity for these treatments, which include pickling, continuous annealing, tinsplating and galvanizing. Mathematical modelling of these operations would make it possible to calculate in advance the production capacities of these installations in various configurations and under varying conditions. This would show whether the conversion of existing installations to meet new conditions or the construction of new installations would be better suited to production requirements and therefore more economic.

This project aims to study all aspects of this subject and will be carried out by the Betriebsforschungsinstitut of the Verein Deutsche Eisenhüttenleute in Dusseldorf (D).

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P 440 Lubrication of rolls for hot rolling

This research project usefully supplements Project P 277/2 as it devotes particular attention to hot lubrication. Some oil lubrication methods that are technically valid have had to be abandoned because of the excessive atmospheric pollution they cause.

This study will systematically explore the question of oil lubrication as it affects the rolling of long products, with particular emphasis on the pollution aspect. In a second stage, the feasibility of using products other than oil as hot lubricants will be examined.

Graphite with a binder and in particular molten oxides appear to be promising techniques.

If successful, the research will terminate with tests on an industrial scale.

The research work will take three years and will be carried out by the Centre de Recherche Métallurgique in Liège (B).

P 449 Tension control on continuous long-product mills

Rolling on a continuous mill necessitates synchronizing stand speeds so as to avoid clogging of stock between stands or breakage owing to excessive tension. This difficulty does not arise with small-section products as they can be looped between stands.

Long products of larger section call for the use of other technique that will be explored and developed under this project. The two main results expected from this research are a substantial improvement in the dimensional quality of the products and an increase in rolling speeds.

The research will embrace all existing continuous long-product mills, accounting for about one quarter of steel output.

The work will last three years and will be carried out by the Institut de Recherche de la Sidérurgie Française in Maizières-les-Metz (F).

P 450 Research on skin-passing

The purpose of skinpassing is to eliminate the plateau in the yield point diagram of the steel in rolled strip. It is also used to produce a given surface finish (roughness) and to improve flatness. For some grades of steel, skin-passing increases the hardness of the product. Insufficient is known of all these phenomena and although the desired strip qualities are generally obtained in a single pass a fairly large part of the production requires 3, 5, 7 and sometimes even 9 passes to attain the required result. The aim of the research is to gain a better knowledge of the metallurgical and mechanical phenomena governing the process so that the skin-pass operation can be used more effectively, enabling the required result to be obtained in a single pass on any product. The expected results will obviously be chiefly of an economic nature. The research will take three years and will be carried out by the Institut de Recherche de la Sidérurgie Française at Maizières-les-Metz.

P 470/1: The use of blast furnace gas as fuel in high-temperature furnaces of the steel industry

The future electricity generating programme indicates that the consumption of blast furnace gas for this purpose will drop. It will therefore be necessary to use it for steelmaking processes proper. These call for very high temperatures (1300°C in soaking pits and reheating furnaces preceding rolling) which cannot be obtained under normal consumption conditions owing to the low calorific value of blast furnace gas.

This project aims to upgrade blast furnace gas to allow high-temperature combustion by enriching the combustion air with oxygen or enriching the fuel with hydrocarbons (natural gas or oil products) or combining both techniques. A reduction in atmospheric pollution is also expected as a result of better control of combustion and reduction or elimination of the use of excess gas burners.

The work will be carried out by the International Flame Research Foundation in IJmuiden (NL) and will take one year.

V. "MEASUREMENT" PROJECTS

P 310 - Improvement of methods of sorting steel on test bench and in stockyards

Despite precautions taken during production, different grades of steel are bound to be mixed together at some production stage in all steelworks. Consequently sorting operations are necessary. The main point is to identify steels from the aspect of chemical composition. Simple and rapid non-destructive methods that are easy to interpret must therefore be used for sorting.

The project is designed to meet this general requirement for the development of new and rapid identification techniques on storage rocks and in the stockyard.

This method will have the advantage of simplifying and rationalizing the work involved so that highly skilled labour will no longer be required.

This project will take three years and will be carried out at the Institut de Recherches de la Sidérurgie Française, St Germain-en-Laye (F).

P 331 - Analysis of sulphide inclusions in steel

To measure the sulphide phase content and chemical composition in steel, it is necessary to isolate these phases almost completely. It is not known how far finely separated sulphide particles are decomposed during the isolation process. The research project is designed to fill this gap, making use of potentiostatic measurements on high-purity sulphide electrodes produced by synthesis. It is planned in this way to determine the chemical and electrochemical dissolution rate of the sulphides.

Use of this technique for separate determination of the various sulphides will facilitate the study of the metallurgical processes peculiar to the precipitation of these sulphides. These techniques could also be very useful in research on the influence of sulphide inclusions on steel corrosion. This work should help to improve steel quality and also appears acceptable on the grounds of economic efficiency.

This project will take two years and will be carried out by the Max-Planck-Institut in Düsseldorf (D).

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P 385)
P 407) New plasma-source spectroscopic techniques to the steel
P 431) industry
P 473)

The use of the plasma torch as a source of excitation in analysis by optical emission spectrometry is a useful method for the rapid analysis of solutions and liquids as it allows simultaneous determination of several elements.

This technique makes use of the "inductive plasma" method. A development study will be carried out on this process in order to resolve analytical problems in the steel industry.

From the economic angle, chemical analyses and other individual determinations are extremely costly. Inductive plasma source spectrometry holds out prospects of substantial savings.

This programme will include:

- Research on the most suitable methods of preparing the solution.
- Research using spectrography with photographic recording on the most suitable spectral lines for the analysis of steel solutions.
- Choice of the optimum dilution for simultaneous determinations of minor and major elements.
- Research on the most suitable flame zones for the determination of elements.
- Research on interactions between residual elements (possibly internal standards).
- Selection of the best method of calibrating the apparatus.
- Development of analytical methods applicable to the environment.
- Comparative study to determine whether a generator with (a) frequency stabilization or (b) power stabilization is preferable.
- Research on an atomizer/burner system for the production of an aerosol and combination of this source with an optical quantity determination system.
- Transfer of the data obtained and experimental verification of the results.

This research is estimated to take three years.

The work will be coordinated by the Institut de Recherches de la Sidérurgie Française in Maizières-les-Metz (F) and will be carried out by the following beneficiaries, who will contribute equal shares to the budget:

- Institut de Recherches de la Sidérurgie Française, Maizières-les-Metz (F)
- Centre de Recherches Métallurgiques, Liège (B)
- Hoesch-Huttenwerk AG, Dortmund (D)
- British Steel Corporation (Teesside Laboratories), London (UK)

P 408 - Development and practical testing of a method of analysing steel without taking samples

Apart from the required mechanical and technological parameters, one vital condition for the use of rolled steel products is correct material composition. Consequently it is normal practice to take samples, send them to the laboratory and have a chemical analysis made. The measurements involved are generally very costly and time-consuming. It would therefore be very useful to have a method of the kind to be developed in this project, allowing direct verification of composition on the product, without taking samples and by non-destructive methods. The method developed will make use of aerosol techniques.

The main feature of this method is the separation in space between the vaporization of the material being tested and the excitation of the optical spectra. Apart from its technical advantage, this project could have an economic incidence as the above facts indicate.

The project will be carried out by Thyssen Niederrhein AG at Oberhausen (D), and is estimated to take three years.

P 409 - Structural analysis of steels by ultrasonic dispersion

Extensive theoretical and experimental research on ultrasonic dispersion and absorption in steel structures has been carried out in recent years. The common aim is to obtain by ultrasonic dispersion methods data for the qualitative and quantitative characterization of structural phases and elements. Steelmakers and above all metallurgists are extremely interested in the practical application of grain size determination by ultrasonic methods. This is the aim of the research project which is broken down into three separate parts:

1. Development and construction of a prototype instrument.
2. Physical study of ultrasonic dispersion in a multi-phase system.
3. Development work on multi-phase structures and other problems involved in measuring ultrasonic dispersion.

The work will be carried out by the Institut für Zerstörungsfreie Prüfverfahren in Saarbrücken (D) over an estimated period of three years.

P 411 - Continuous testing of material properties of cold-rolled steel strip

The aim of this research project is to study the possibility of continuous and non-destructive measurement of the properties of steel strip. The work will be carried out on non-alloy steel and application of the method to steel sheet will also be studied.

The research will be carried out with two different appliances operating on a magnetic principle. The measured values will be combined, thus making them more significant than the results of known methods at the present time.

The programme may be summarized as follows:

1. Precision and reproducibility of the process.
2. Influence on measurement signals at the measuring points before and after the furnace.
3. Precision and results of the measurements
4. Research to determine the systematic influence on the measurement results of work hardening, strip tension, speed and temperature.

The work is expected to take three years and will be carried out by Rasselstein at Neuwied (D).

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P 433/2 - Continuous on-line measurement of gauge profile and shape of hot strip

In modern wide strip hot-rolling practice, the control of gauge profile across the width and of strip flatness to within close tolerances is of considerable economic significance and is receiving increasing attention. The aim of this research is to develop a technique for monitoring the profile across the width of the strip in a very brief time (a few seconds) and to within a few millimetres of each edge, to detect significant ridges of about 1 cm in width and to indicate crown and wedge as the strip leaves the finished stand. The method will make use of the gamma radiation emitted by a radioisotope of Americium 241 and the detection system will be suited to the industrial environment so as to avoid any parasitic effects.

The programme may be summarized as follows:

1. Theoretical studies in the laboratory
2. Design of a gauge
3. Construction of equipment
4. Installation on a hot-rolling mill
5. Series of tests and measurements for final development.

This work will extend over a two-year period and will be carried out by the Research Department of the British Steel Corporation in London (UK).

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P 451 - Inspection of hot slab surfaces

Normal practice in the rolling of flat products is to allow the slabs coming from the slabbing mill or continuous casting machine to cool to ambient temperature. These slabs are inspected and repaired cold, either completely or selectively, then charged into reheating furnaces prior to delivery to the roughing mills. A number of technical constraints are at the root of this practice, not least the current impossibility of making a good evaluation of the surface condition of semi-finished products when they are hot.

The costs of this practice are substantially increased by rising fuel prices. The research project therefore aims to provide a technical solution to the problem that will also be economic, if only because it will give metal savings that can be put at 10 kg per tonne - the normal loss in reheating furnaces.

The method will be based on the development of a device to display the slab surface in the first stage, followed in the second stage by a study of automatic recognition of defects by means of suitable mathematical tools, combined with metallurgical research.

The project is expected to last two years and will be carried out by the Institut de Recherches de la Sidérurgie Française in St Germain-en-Laye (F).

P 460 - Measurement of oxygen potential in liquid slags

The measurement of oxygen potential has never yet been extended to metallurgical slag systems despite the considerable scientific and practical advantages in such an application.

The research project plans to do this by devising a method and equipment for this type of measurement and verification. A knowledge of the oxygen potential of slag is extremely useful for correct interpretation of the deoxidation and desulphurization reactions occurring in metallurgical processes between liquid slags and the molten metal bath. This work will have an impact on a number of industrial techniques used in the blast furnace and also, for example, in submerged arc welding.

The programme includes:

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1. Tests on the reproducibility of oxygen potential measurements with different types of zirconium
2. Study of the behaviour of certain reference substances
3. Study of variations in time of the reference value of the O₂ potential
4. Influence of each slag component
5. Measurements of the correlation between potentials of different origins.

All the work will be carried out in the laboratories of the Centro Sperimentale Metallurgico in Rome (I), over a two-year period.

P 465P2: Determination of certain oligo or trace elements by flameless atomic absorption spectrometry

The purpose of this research is to evaluate the possibilities of atomic absorption spectrometry. In particular, the technique will be developed with a view to replacing conventional atomization by flameless atomization systems. Research will be done into the analytical possibilities offered by the method for both steel products and pollutant waste from the steel industry (dust and waste liquids). The results will be compared with those obtained by conventional methods to assess the accuracy and reliability of the values.

The programme will follow three lines:

1. Development of analytical methods in a graphite furnace
2. Equipment and technical improvements
3. Comparison of results with other techniques - conclusions.

The work is planned to take two years and will be carried out jointly by the Centre de Recherches d'Unieux-Firminy, Creusot-Loire (F) and the Centro Sperimentale Metallurgico in Rome (I).

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PX - Analyses of gas in steels (supplement)

Under agreement 6210-17 on research into methods for the analysis and determination of oxygen, hydrogen and nitrogen and the development of efficient apparatus for the purpose, much work has been carried out and very favourable results have been obtained. The work undertaken by the Centro Sperimentale Metallurgico in Rome (I) was more extensive than anticipated and therefore additional aid is required.

VI. "USED PROPERTIES" PROJECTS

a) Weldability

P 351 Economy in the manufacture and utilization of cryogenic steels

It is proposed to examine the properties of 5% Ni steels. The main aims of the research are:

- (a) to determine the fracture toughness of thick plates produced commercially and if necessary to improve it;
- (b) to study heat treatment to decrease steel costs;
- (c) to determine the fracture toughness of weld heat-affected zones and if necessary to improve it, particularly at high weld heat inputs.

The work which will take three years, will be carried out by the British Steel Corporation in London (UK) and will be coordinated with the work on projects P 413 and P 417.

P 383 - Cold cracking on implants

In this programme, it is planned to study the influence of test conditions such as the selection of the test criterion (cracking or rupture), the notch arrangement and the method of crack detection and also to attempt to demonstrate the significance of the cracking stress. It is hoped to obtain the following results:

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- (a) knowledge of the variables of the cold cracking test on implants and more economical operation of the test;
- (b) quantitative evaluation, through the "equivalent stress", of the risk of cracking in terms of the type of assembly, allowing a more accurate interpretation of implant cracking curves for a specific case;
- (c) possibility of extrapolating the results to other types of assembly.

The work will take two years and will be carried out by the Institut de Soudure in Paris (F).

P 393 Investigation of the weldability of concrete reinforcing steel type FeB 500

The research proposal has the aim of assessing the weldability of the different FeB 500 bar types now available on the market of the European Community.

Weldability will be assessed for typical types of joints currently produced (tack welds, butt and overlap welds) by different welding processes with electrical, mechanical or chemical energy sources.

Weldability will be determined on the basis of results obtained from practical tests. Simulation tests will be made in order to characterize the structures in the heat-affected zone. The fatigue resistance of typical welded bars will be compared with that of bare ones.

The work will take two years and will be carried out by the Centre de Recherches Métallurgiques in Liège (B) and the Toegepast-Natuurwetenschappelijk Onderzoek in Apeldoorn (NL).

P 413 - The possibilities of assessing the safety of welded joints

In this joint programme, it is planned to use various methods of brittle fracture testing (including fracture mechanics) ranging up to tests on structural components subject to a wide variety of loading conditions in order to investigate both the brittle fracture behaviour and the fatigue behaviour of welded joints in the major weldable structural steels. The full results should eventually help the fabricator to make a reliable choice of material and fabricating conditions depending on the relevant service stresses.

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The general aim of the work is to increase knowledge of the relationship between the toughness properties of the welded joints and the behaviour of the structural component so that it is possible safely to specify minimum requirements for the toughness of the welded joints taking all parameters into consideration.

The experiments in this joint programme will be carried out by:

- Centro Sperimentale Metallurgico, Rome (I) 14 months
- Institut de Recherches de la Sidérurgie Française, St Germain-en-Laye (F) } 3
- Toegepast-Natuurwetenschappelijk Onderzoek, Apeldoorn (NL) } years
- Verein Deutscher Eisenhüttenleute, Düsseldorf (D) }

P 417 - Assessment of the safety of welded joints of 5.5% Ni steel for cryogenic use

The purpose of the planned research is to study the deformation and fracture properties of welded joints in comparison to the parent metal in the temperature range from -100 to -200°C and to specify limits for the use of the steel. In addition to large tensile tests, tests on medium-sized notched test pieces, including COD measurements, and the usual tensile and notched bar impact tests are planned. Joints welded with various degrees of heat input (representative of manual arc welding and submerged arc welding) will be used.

The experimental material will be a commercially quenched and tempered heavy plate X 7 NiMo 6, 30 mm thick, with the properties shown in Table 1. Double V joints welded under conditions similar to industrial practice (manual and submerged arc welding) without preheating or post-weld treatment will be used.

The work will take three years and will be carried out by Thyssen Niederrhein AG in Oberhausen (D); it will be coordinated with the work on projects P 413 and P 351.

P 442 Development of a steel weldable with a high heat input

In view of the changes in the mechanical properties of steel in the heat affected zone, it is necessary to determine the causes and metallurgical means of overcoming the limitations on welding with a high heat input.

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It is planned to make a complete experimental description of the thermal fields corresponding to the heat inputs normally used in the electrogas and electroslog methods and their changes with time, and to define these fields by a limited number of parameters.

Subsequently, it is planned to:

- (a) establish on the basis of the mechanical properties measured on welds the factors responsible for deterioration; the deterioration will be quantified in terms of the factor(s) responsible, in particular grain growth;
- (b) verify the possibilities of improving weld properties by local annealing;
- (c) examine the possibilities of adapting the composition of the parent metal.

This work will take two years and will be carried out by the Centre de Recherches Métallurgiques in Liège (B).

P 456 - Molten metal in welding

In the submerged arc welding of medium- and high-strength heavy steel plate, it is sometimes difficult to meet the requirements of the inspection bodies regarding mechanical properties.

Work already carried out (study of the interactions composition/micro-structure/mechanical properties of the molten metal) indicates not only that the type of flux and of electrode is of great importance but also that the combined effects of the alloying elements must be examined.

In the proposed research, three types of steel (A 42, A 52 and X 70) will be used in two thicknesses (20 mm and 35 mm), together with both bare and coated electrodes under different fluxes (it appears possible to find a flux of optimum composition selected on the basis of the required physical properties and transfer capacity of the alloying elements).

The possibility of making recommendations regarding selection of electrodes and fluxes for submerged arc welding will be examined.

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The work will take three years and will be carried out jointly by the Institut de Recherches de la Sidérurgie Française in St Germain-en-Laye)F) and the Toegepast-Natuurwetenschappelijk Onderzoek Metaal instituut in Apeldoorn (NL).

b) Corrosion

P 274/2 - Marine corrosion

The aim of the research is to gather information on the corrosion behaviour of and on means of corrosion protection for:

- a number of selected commercial low-alloy steels produced both in the Community countries and outside them;
- experimental low-alloy steels, especially designed for resistance to a marine environment;

in order to allow

- (a) a better use and proper selection of the steels available for service in a marine environment;
- (b) the development of new alloyed steels with improved corrosion resistance to a marine environment.

For the proposed research, the following general methods of investigation are planned:

- observation of the behaviour of steels "in situ";
- simulation of particular conditions of exposure to sea water by means of accelerated laboratory tests and fundamental laboratory studies.

This research programme also takes into consideration work currently in progress under an extensive Community programme for the study of the corrosion fatigue resistance of offshore welded steel structures.

The work will take two years and will be carried out by the following laboratories:

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- BSC	United Kingdom
- CEBELCOR	Belgium
- Centre Océanographique de Bretagne	France
- Centro Sperimentale Metallurgico	Italy
- Hoogovens	Netherlands
- Instituto Recherche Breda	Italy
- IRSID	France
- SMOZ (Stichting Materialonderzoek in de Zee)	Netherlands
- VDEh	Germany
- TNO	Netherlands

The research will be coordinated by the following laboratories:

- SMOZ : behaviour "in situ"
- CSM: (with the assistance of IRSID for the coordination of steel selection) : simulation
- IRSID: Accelerated tests and fundamental laboratory studies.

P 284/2 - Stress corrosion of prestressed steel

Experiments under practical conditions will provide data on the causes and progress of stress corrosion cracking on prestressing steels under tension prior to grouting of the ducts. These would be the basis for recommendations on fabricating specifications for prestressing steel in post-tensioned prestressed concrete design and on production methods (heat treatment, structure) for the prestressing steels. In addition standard practical procedures to test the resistance of prestressing steels to the corrosion conditions prevailing during fabrication will be designed and tried out in the course of on-site and laboratory research.

The programme for this research project has been prepared in coordination with that for project P 352.

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The research will take three years and will be entrusted to the Verein Deutscher Eisenhüttenleute in Düsseldorf (D), which will coordinate the work of the following laboratories:

Max-Planck-Institut für Eisenforschung (MPI), Düsseldorf

Bundesanstalt für Materialprüfung (BAM), Berlin

Institut für Werkstoffe im Bauwesen, University of Stuttgart

Versuchsanstalt der Friedr. Krupp Güttenwerke AG, Rheinhausen Works

Institut für Werkstoffwissenschaften of Erlangen University, Nuremberg.

P 352 - The stress corrosion cracking mechanism of prestressing steel

The following research programme is proposed:

- (a) Literature review regarding the known influences on the stress corrosion cracking of prestressing steel;
- (b) characterization of ruptures in practice and simulation of rupture in practice and laboratory scale;
- (c) research into the mechanism of the stress corrosion cracking of prestressing steels on the basis of pints (a) and (b) and existing models.

The main investigations proposed are:

- characterization of passive areas
- characterization of corrosive media
- influence of harmful ions
- characterization of the solution in the crack
- electrochemical behaviour of the steel in the crack solution
- hydrogen investigations concerning diffusivity, permeability and solubility.

The programme for this research project has been prepared in coordination with that for project P 284/2.

The work will take 6 years and will be carried out by Hoogovens in IJmuiden (NL).

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c) Formability

P 336/2 - Influence of chemical composition and hot rolling conditions on workhardening properties and their removal

The research is designed to clarify the metallurgical mechanisms involved in short annealing operations (removal of work hardening, precipitation) and to interpret in general terms the changes in texture and mechanical properties resulting from modifications to the production cycle for steel sheet. This should help towards a better definition of short sheet annealing cycles which will be optimum in relation to the complete production cycle.

This research, supplementary to a project already under way, will include:

- an extension of the current research to sheet in which some properties have been modified;
- an analysis of the changes in work hardening structures during annealing.

The work will take $2\frac{1}{2}$ years and will be carried out by the Institut de Recherches de la Sidérurgie Française at St Germain-en-Laye (F).

d) F a t i g u e

P 318 - Improvement of the fatigue strength of welds in high-strength water-quenched fine-grained structural steels by thermal and mechanical treatment of the seams.

The purpose of the planned project is to ascertain the possibilities of improving the fatigue strength of welds in high-strength water-quenched fine-grained structural steels, with particular reference to post-weld heat and mechanical treatment. The results of the planned fatigue tests should also provide designers with data on the dimensioning of structures exposed to cyclic stress.

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For this research, the use of steel grades StE 51 V (MnMoTi), StE 70 V (CrMoZr) and StE 90 V (CRNiMoV) is proposed, although the research will focus mainly on steel StE 70 V; comparative tests only will be carried out on steels StE 51 V and StE 90 V, in order to ascertain how far the data obtained with StE 70 V can be applied to other quenched and tempered structural steels with different chemical composition and yield strength. The materials will be water-quenched.

This work, which will last three years, will be entrusted to the Verein Deutscher Eisenhüttenleute in Düsseldorf (D) and will be carried out at the Thyssen Laboratory.

P 343 - Test method to determine the fatigue strength of steel reinforcing bars

The research programme comprises the comparison of S/N diagrams obtained with concrete-embedded reinforcing bars by the beam test with S/N diagrams obtained in tests on various unconcreted test pieces. Reinforcing bars with a minimum yield strength of 410 and 490 N/mm² will be used in the states N (natural hardness) and K (cold formed) in each strength category. For N, the most commonly used cross-sectional shape will be tested and for K the twisted bar.

One current cross-sectional shape for each type of steel, with a diameter of 16 and 18 mm, will be used.

The work, which will take two years, will be entrusted to the Verein Deutscher Eisenhüttenleute in Düsseldorf (D) and carried out by

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P 275 - Promotion of high-strength steels

The opinion of expert study groups was taken into account when this research program was drawn up and the following subjects have been selected:

- (a) Continuation of the general characterization of high-strength steels and welded joints in these steels; evaluation of their fatigue behaviour under varying loads.

The work will relate to two high-strength steel grades of a thickness between 6 and 8 mm. After characterization of the parent metals, tests on butt-welded and double-V joints will be carried out. Special attention will be paid to optimum welding conditions and crack propagation in the various heat-affected zones.

- (b) Behaviour of welded joints in high-strength steel under low-cycle fatigue and special loading programmes.

This research relates to steels of the type Fe, E 355 (up to 700 N/mm² yield strength).

Low-cycle fatigue tests will be carried out on the parent metal and on butt-welded joints. Special loading programme such as a combination of plastic cycles followed by a large number of elastic cycles will also be used.

Some methodological aspects will also be tackled; it is planned to simulate the structures observed in welded joints on cylindrical test pieces and to test their fatigue resistance. The influence of the filler metal and stress-relieving treatment on the fatigue resistance of welded joints in the steels studied will also be examined.

- (c) Study of the fatigue behaviour of steels having a controlled inclusion morphology and of standard joints in these steels.

Using steels of grades Fe E 235, 355 and 455, it is planned to study the influence of controlled sulphide morphology on the reduction of the anisotropy of the fatigue properties of the parent metal and of standard welded joints, and on the crack propagation rate. The influence of methods of improving fatigue

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resistance will be studied on welded joints in the same steels containing artificially induced residual stresses. This research will enable a systematic study to be made of the anisotropy of fatigue properties and the way it is influenced by certain additions and will enable methods of improvement to be used in the case of residual stresses.

(d) Influence of the heat input on the fatigue resistance of welded joints in parts of quenched and tempered steel

The intention here is to obtain additional knowledge on the influence of the welding process on the fatigue strength of welded joints in quenched and tempered steel, taking into consideration the low heat input.

(e) Determination of the critical dimensions of fillet weld beads in assemblies of high-strength steel components under fatigue stress

In this research, it is planned to study the influence of various geometric factors on the fatigue strength of transverse and longitudinal fillet joints. A steel with a yield strength of 700 N/mm^2 has been selected for this work.

This two-year programme will be carried out jointly by the following:

FIAT in Turin (I), Institut de Recherches de la Sidérurgie Française in St. Germain-en-Laye (F), Creusot-Loire in Creusot (F), ARBED in Esch-sur-Alzette (L), Centre de Recherches Métallurgiques in Liège (B) and Centre de Recherches Scientifiques et Techniques de l'Industrie des Fabricateurs Mtalliques in Brussels (B).

P 378 - Fatigue of welded joints in high-strength structural steel
European preliminary draft standards)

The purpose of this research, which will be carried out jointly by the laboratories of the VDEh, CRM, IRSID, Welding Institute, CSM and University of Delft, is as follows:

The working stresses admissable in welded structures exposed to fatigue stress will be reviewed in the light of the test results from ECSC

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programmes and data in the literature; on this basis, a concept will be developed for the dimensioning of fatigue-stressed welded structures.

The work will last one and a half years.

e) Brittle Fracture

P 287/2 - Fracture behaviour of gas transmission pipelines

To complete the project already in course, three additional full-scale pipe fracture tests will be carried out under the supervision of the VDEh. A complementary aid of 25 500 EUA is requested for this work.

P 376 - Fracture mechanics of steels

The following techniques will be used in this research:

- notch impact tests
- slow tensile or bend tests on small test pieces with induced fatigue cracks
- slow tensile tests on thin, wide test pieces with induced fatigue cracks.

These measurements will require the development of a test technique suited to steels with a yield strength between 360 and 500 N/mm².

A study will be made of the structures of the parent metal (longitudinal and transverse directions), the weld metal and the heat-affected zone.

The work will take three years and will be carried out by the Institut de Recherches de la Sidérurgie Française, St. Germain-en-Laye (F).

P 418 - Assessment of the fracture behaviour of steels on the basis of large-scale tensile tests having regard to the results

It is proposed systematically to investigate the effect of the following parameters on the fracture behaviour of large tensile test pieces as a function of temperature:

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1. Plate thickness
2. Ratio of plate thickness to test piece width
3. Type of notch and radius of notch root, i.e. saw cut and incipient fatigue crack
4. Notch length
5. Structure and strength of the experimental material
6. Loading rate, e.g. 1 mm/min and 1000 mm/min.

The selected experimental materials are plates of commercial steel grades (e.g. FC E 460 normalized and 20 MnMoNi 55 or HY 130) in various heat-treated states. Taking as many measured values as possible, an effort will be made to develop new possibilities for the interpretation of experimental results. The results of various interpretation procedures will be compared with the widest possible interpretation of fracture mechanics tests on laboratory test pieces and also related to the conventional values for material properties. It is expected that the comparative study of the behaviour of various structures will provide valuable data that could be useful in assessing the behaviour of welded test pieces. This work will take three years and will be carried out by the Verein Deutscher Eisenhüttenleute in Düsseldorf (D).

P 420 - Mechanics and material behaviour as regards crack arrest

In the proposed programme the first step would be to develop a specimen configuration for which the complicating effects of kinetic energy either do not occur or may be neglected, so that straightforward and accurate determination of crack arrest toughness R_a may be made. Following the development of the method, it will be used to determine values of the crack arrest toughness of different steels at different temperatures.

On the basis of the results of these measurements the relationship with the crack arrest temperature approach will be investigated. Finally the crack arrest toughness R_a and the conventional crack initiation toughness

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G_{IC} will be compared. It is expected to find R_a G_{IC} as a consequence of the strain rate embrittlement of the material in front of a running crack. Then R_a , which can be determined more cheaply and more exactly than G_{IC} , could also be used as a safe limit in a crack initiation safety analysis.

This work, planned to take three years, will be done jointly by Metaal-instituut TNO, Apeldoorn (NL) and IFKM, Freiburg/Breisgau (D).

f) Creep

P 271/2 - Influence of steelmaking techniques on hot ductility of low-alloy ferritic steels

The purpose of the present research proposal is to evaluate the influence of residual element content and distribution on the creep-ductility properties of high-strength low-alloy ferritic steels.

The investigation will also aim at acquiring further and more detailed knowledge on the correlation existing between the two criteria at present most commonly used for evaluating the ductility of a material, i.e. information given by tests on smooth test-bars only, and information given by tests on smooth and notched test-bars.

Typical low-alloy ferritic steels which are widely used for components operating at high temperatures and which therefore lend themselves to improvement in terms of creep strength-ductility compromise will be investigated.

This work will take four years and will be carried out by the Centro Sperimentale Metallurgico in Rome (I).

P 316 - Tests on heat-resisting steels under periodically fluctuating stress

In this research project it is planned to carry out creep tests with low-cycle variations in stress and temperature up to about 20 000 hours on several commercial heat-resisting steels in the initial state (heat-resisting molybdenum and chromium-molybdenum steels and austenitic

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chromium-nickel-molybdenum steel in the delivery state).

Various conditions typical of service stresses are to be taken into account. To ascertain the effect of structural changes on sensitivity to cyclic stressing, creep rupture tests under constant and cyclic loading will also be carried out, together with strain cycling tests on structural components that have been prestressed for different periods of time, as this appears to be the easiest way of obtaining experimental materials in sufficient quantities in structural states that have developed under service conditions and are therefore also of particular interest for practical applications.

The possibility of defining the sensitivity of materials to fast and slow stress variations by comparatively simple short-term tests will also be investigated, together with the possibility of obtaining sufficiently reliable results on the long-time behaviour under non-constant stressing by taking account of the known values for creep rupture strength.

The research work is expected to produce, for structural components having to withstand fluctuating creep stress and cyclical strain, design rules that are easy to apply and have been verified by long-time tests on typical heat-resisting steels. The results will therefore contribute towards greater reliability in the dimensioning and operation of energy-generating and chemical plant.

This three-year research project will be carried out jointly by TNO Metaal Instituut, Apeldoorn (NL) and the Verein Deutscher Eisenhüttenleute, Düsseldorf (D).

P 396 - Collaborative research on the determination of the residual life of in-service steel components for high-temperature use

Estimates of residual life based on the hypothesis that the materials will be used under static conditions with constant temperature or stress and on the law of the accumulation of creep damage can be hazardous in that they do not take account of the effects of start-up and shut-down operating transients and load variations.

It is therefore thought essential to include in the aims of this project determination of the influence of heat and stress cycles on the

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deterioration of the steels of which the component examined is made, whilst referring basically to evaluation criteria based on the traditional creep tests.

The proposed programme is as follows:

- collection of in-service data
- regeneration treatments
- definition of materials
- metallographic examinations
- creep tests
- study of the deterioration of properties.

Samples from used piping will be studied.

The three-year research programme will be carried out by Dalmine in Milan (I).

P 423 - Improvement of the service properties of heat-resisting steel for turbines

The aim of this research project is to study the causes of temper brittleness and to monitor their influence on creep behaviour and on long-term hot ductility. By means of comparative studies, the following parameters must be studied:

- influence of a decreasing carbon content with increasing chromium and nickel contents:
- influence of deoxidation by carbon in vacuum
- effect of segregation phenomena.

All the research is to be carried out on internationally known steels currently used in the manufacture of turbines.

The results of this research are expected to help to define more reliably the effect of embrittlement on the creep resistance of Ni-Cr-Mo-V steels. It is probably that useful data will be obtained on ways of reducing the tendency to brittle fracture of these steels.

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The stringent and high requirements for dimensional stability of turbine rotors mean that reliable values for the 0.2% permanent set must be determined in the creep test.

Even in the temperature range where permissible stresses are normally calculated from the 0.2% proof stress, appreciable creep deformation must be expected.

The economic advantages of the project are as follows:

- (1) for the steelmaker, elimination of the uncertainties regarding the effect of alloying elements and trace elements and the influence of deoxidation processes;
- (2) for the turbine designer and user, the establishment of extensive back-up data necessary for the definition of permissible working conditions. In particular, it will allow permissible service temperatures to be defined much more precisely than at present. It will thus become possible to improve both the capacity and the safety of plant.

It must not be forgotten that all efforts to increase the capacity of steam generating plant inevitably depend on a higher turbine capacity.

This work, which will take three years, will be carried out jointly by Creusot-Loire in Creusot (F) and the Verein Deutscher Eisenhüttenleute in Düsseldorf (D).

P 423/2 - Improvement of the service properties of heat-resisting steels for turbines

Following the proposal put forward by Creusot-Loire and the VDEh, and with the intention of extending participation within the Community, it seems useful to develop the research described below concerning a Ni Cr Mo V material made in the electric furnace with a charge consisting partly of scrap mixed with pre-reduced pellets.

The project is designed to study the phenomenon of temper brittleness and the loss of hot ductility in a material used in the construction of low-pressure turbines with a very low impurity content.

The results will enable the effects of the trace elements on steel behaviour to be assessed and permissible service conditions to be defined for turbines constructed of that type of steel.

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In addition, useful information will be obtained with a view to the wider use of pellets as a charging material so as to obtain in the electric furnace a steel with a limited impurity content.

The work will be carried out on the lines of the programme submitted by Creusot-Loire and the VDEh, using the tests selected as being best suited for the evaluation of the influence of trace elements on the mechanical properties of the material.

The work will take three years and will be carried out by the Centro Sperimentale Metallurgico, Rome (I).

VII. "PHYSICAL METALLURGY" Projects

P 272/2 - Ferritic stainless steels with a low content of interstitials

The aim of the research is to obtain information on the ferritic stainless steels of the Cr-Mo type with a low C + N content.

These materials, which in terms of properties help to close the gap between the ferritic steels and the better-known austenitic ones, will be studied to identify any possibilities of improving certain service properties at the 18 and 21% Cr levels by optimizing the ratio and type of stabilization of the interstitials and by the addition of a third element. The third element and its level will be selected on the basis of pitting resistance properties. The content of C + N will be compatible with existing industrial refining capabilities (AOD).

The research programme is divided into three parts:

- (a) critical analysis of the existing refining processes with particular reference to the potential of AOD plant in refining steel compositions of the 18-2 and 21-3 CrMo type in the presence of interstitial stabilizers of the type Ti, Nb and Al;
- (b) industrial production of two melts of the 18-2 and 21-3 CrMo type by the AOD method and definition in the laboratory of the properties of the products obtained;

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- (c) basic laboratory research on products to ascertain amongst other things the influence of (C + N), stabilizing elements (Ti, Nb, Al, Zr) and ternary alloying elements on the in-service mechanical and corrosion properties.

The work will be carried out by the Centro Sperimentale Metallurgico, Rome (I) and is expected to take 1½ years.

P 289 - Influence of inclusion distribution and morphology on plastic deformation and fracture mechanisms in steel

The influence of inclusions on the ductility properties of steels is a problem of great importance at the present time. It is now possible, for example, to relate certain inclusion parameters to mechanical properties, but there is a lack of basic data concerning cold forming operations.

The planned programme allows new methods to be applied and includes direct observations during deformation of test pieces in which the type and morphology of the inclusions can be varied. The variations in the shape and distribution of the inclusions (especially sulphides) are obtained by selecting steels with different types of inclusion and using different rolling and sampling processes.

With four steels of compositions specially selected so as to give different matrices, and with different inclusion systems obtained by additions and appropriate rolling, samples taken in different directions will be examined by the semi-continuous method. The steels are:

1. CMnNb structural steel killed with Al, high sulphur + elongated sulphides
2. CMnNb structural steel killed with Al, low sulphur + globular sulphides
3. mild rimming steel
4. mild killed steel.

Micrographic examinations will be carried out by optical and electron microscope and sections will be studied to verify the validity of the surface observations. The structural parameters will then be measured by quantitative metallography.

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Conventional mechanical tests (tension on normal-sized test pieces, impact, Charpy V and variable notch) will also be conducted to relate the observations under the microscope to the conventional properties (elongation, reduction in area) and forming tests (bending, deep drawing, extrusion, etc.) will be carried out.

It is planned to carry out examinations and measurements on test pieces and specimens both on a macroscopic scale (grids, etc.) and on a microscopic scale to follow strain in the proximity of inclusions.

The work will be carried out by the Institut de Recherches de la Sidérurgie Française at St. Germain-en-Laye (F) and will take three years.

P 349/3 Non destructive testing of steels by Small Angle Neutron scattering

This research proposal concerns the application of the technique of small angle neutron scattering to study:

- (1) the structures produced in steels following various heat treatments and
- (2) the structural damage developed in steels subjected to different deformation processes (creep, fatigue).

The research represents the extension of earlier ECSC supported work directed at developing the technique itself where it was demonstrated that the method is potentially a most valuable means of providing information on structural "long range order" heterogeneities in steels (the different phases, precipitates, dislocations).

It is now proposed to apply the technique to the detailed study of specific metallurgical phenomena and the programme of work will cover the following:-

1. Fundamental studies: These will concern a systematic examination of the influence of magnetization on scattering so that its contribution can be assessed and, therefore, separated from other scattering effects of interest.

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2. Thermal treatment studies: The contribution made by grain boundaries in ferritic and martensitic steels and precipitates to the scattering of neutrons will be investigated and related to quantitative metallographic data of the structures.
3. Creep and fatigue: The structural damage generated during creep and fatigue will be quantitatively determined by small angle neutron scattering; these studies will be carried out on high-temperature ferritic alloys (creep) and high-strength steels (fatigue).

The creep experiments will be concerned partly with developing a better procedure for estimating the residual life of components exposed to high temperatures in service. For steels subjected to fatigue loading, small angle neutron scattering may provide a suitable means of assessing cumulative damage.

The project will be carried out jointly by the FIAT Research Center, Turin, and the Institut für Festkörperforschung der Kernforschungsanlage Jülich; over a period of two years.

P 374 - Precipitation kinetics in the non-continuous cooling of coils after accelerated cooling

The parameters of the thermomechanical treatment to which hot-coiled sheet is subjected after accelerated cooling are many: hot rolling conditions (reheating, pass sequence, final temperature), cooling speed and coiling temperature. The governing factor for the progress of precipitation and its effect on the final properties is the coiling temperature (500 -700°C). The conditions under which the precipitates form are completely different from those prevailing during conventional coiling as precipitation in the coil occurs in the ferritic phase.

Precipitation and the final properties depend not only on cooling and subsequent coiling but also on:

- the state of the austenite at the beginning of cooling (recrystallized or work hardened),
- the special conditions for allotropic transformation.

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Knowledge in most of these fields is unfortunately still totally inadequate. Precipitation in hot-coiled sheet after accelerated cooling will be studied by concentrating on the influence of the solution process during reheating prior to hot rolling, the temperature after rolling, the cooling rate (variable between 5 and 20°C/sec) and the coiling temperature (500 - 700°C).

Steels of a composition close to

0.05 - 0.15% C, 1.3% Mn, 0.3% Si, 0.02% Al, 0.02% Nb, 0.06% V, 0.5% Mo will be examined.

The research will be conducted both on laboratory melts and on specimens taken from industrial products.

The conditions for mechanical and heat treatment will be selected so as to embrace those prevailing in industrial practice.

The experimental programme will include a study of the influence of the parameters of the process on the resultant microstructure and an evaluation of the elastic and hardness properties.

The work will be carried out by the Centre de Recherches Métallurgiques, Liège (B7) and will take three years.

P 425 - Concentration of foreign atoms at grain boundaries in iron and steel

This proposal represents an extension of a recently completed project supported under the ECSC programme which has been concerned with gaining a better basic understanding of equilibrium segregation phenomena relating to sulphur, nitrogen and carbon in steels. The experimental work now proposed will involve the further application of advanced and sophisticated quantitative techniques such as Auger electron spectroscopy and will cover an investigation of the following aspects:-

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1. Study of the concentration of elements at grain boundaries under non-equilibrium conditions of segregation (characteristic of industrial processing conditions). Of particular interest will be the behaviour of substitutional atoms such as boron and silicon as well as trace impurity elements.

It will be necessary to start this stage of the work with a literature study of the diffusion behaviour of alloying elements.

2. Examination of the segregation behaviour of impurities and alloying elements in the austenite region. While there is evidence indicating that grain boundary segregation can occur and may lead to intergranular fragility, little is known about the controlling mechanisms.
3. Generation of experimental evidence to establish the influence of various atom species (e.g. carbon, sulphur and nitrogen) and concentration levels as well as the role of grain boundary orientation or grain boundary cohesion in steels. This will involve the tensile testing of specially prepared specimens to provide quantitative data on the degree of grain boundary embrittlement.

This study is proposed by the Max-Planck-Institut für Eisenforschung, Düsseldorf, and will cover a period of 2 years.

P 466 - Quantitative Metallography

Two collective programmes have already been supported by the Commission on the subject of quantitative metallography which have contributed significantly to establishing a common approach within the steel industry to the development and application of new techniques in this field. This research has included studies of various methods of specimen preparation, correlations between microstructural parameters and properties, the application of automatic analysing equipment together with the standardization of measuring procedures. It is now necessary to adapt the results of this work to meet the needs of both the steel producers and steel users, where, in the field of quality control, there are increasing demands for improved metallographic assessment procedures.

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A third co-operative programme of research has been proposed, therefore, which will concentrate on the following two aspects of quantitative metallography:

- (a) Practical application of the various methods so far developed;
- (b) Extension and further development of measurement techniques.

The programme consists of the following five points:

1. BSC Project

The first part of the proposed work will involve, in co-operation with the other participants, the preparation of recommended procedures for specimen sampling, preparation and instrument operation followed by the application of the findings.

In the second part, particular components of variance will be examined in detail to establish the extent to which sampling procedures may contribute to the variance.

2. CRM Project

It is proposed to study:

(a) Metallographic etching

A phase to be measured can be revealed by selective etching of the phase. The qualitative effect of etching is often satisfactorily known, but the same cannot be said of its quantitative effect.

(b) Use of image analysers

Study of the limiting conditions for the use of an image analyser with an optical microscope.

Study of the possibilities of using a computer to control the image analyser and evaluate its results.

(c) Description of specific structures

Bainitic structure: search for measurable and representative parameters.

Non-metallic inclusions (sulphides): influence of the shape, size and number of sulphides on the anisotropy of the impact strength properties-

3. CSM Project

It is planned to extend the earlier work on automatic image analysis

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to instruments of higher resolving power (scanning electron microscope, transmission electron microscope), concentrating on the study of non-metallic inclusions in high-strength steels.

The influence of small inclusions on ductile fracture will also be investigated.

4. IRSID Project

The proposed research covers the following aspects:

(a) Specimen preparation

Determination of the optimum conditions for automatic polishing and development of techniques for increasing contrast in multiphase microstructures.

(b) Image analysis (TAS and QTM 720)

Use of a minicomputer for the quantitative analysis of structures.

(c) Description of microstructures

The main aim will be to continue the work undertaken at IRSID on the application of mathematical morphology to metallography and to make wider use of results already obtained. The aims are:

- to establish and test measurable parameters on flat sections so as to define in space a system of inclusions or a grain structure;
- to link these definitions to the mechanical properties of the structures that they describe;
- to measure these parameters with a knowledge of their accuracy and representativeness.

5. MPI Project

For a practical application, use is to be made of the method developed during the existing research project to determine the relationship between the measuring error and the particle size for sulphides and oxides in steels for various parameters such as area and length. Particular consideration will be given to the varying shape of the particles. The automatic analyses are to be extended from optical to electron microscopy.

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This method will be used to study the influence of transformation on pearlite formation. The shape of the lamellae will be described quantitatively and correlated with the transformation. The results should help to speed up spheroidizing processes.

The work will take three years and will be carried out by the British Steel Corporation in London (UK), the Centre de Recherches Métallurgiques in Liège (B), the Centro Sperimentale Metallurgico in Rome (I), the Institut de Recherches de la Sidérurgie Française in St. Germain-en-Laye (F) and the Max-Planck-Institut in Düsseldorf (D).

VII. "UTILIZATION" Projects

a) Light application

P 370 - Research programme at the Berlin testing station for industrialised building in steel

The first stage of the research station designed to allow components of an "open" system to be tested ended in Berlin on 30 September 1975 when the construction of the experimental building was completed. In the second stage, covered by this research project, the building and financial aid are being made available to architects and companies interested in structural steelwork so as to allow them to design and experiment with new components. The proposed budget also covers the maintenance costs and legal charges payable in respect of the building. The research programme extends over a two-year period from 1 October 1975 to 30 September 1977. It will be carried out by the Forschungsgesellschaft für Industrielle Bausystem mbH in Berlin (D).

P 437 - Use of steel sheet piling

Although sheet piling is very widespread in the USA and Japan, it is used to a very limited extent in Europe. This difference is mainly due to the discrimination in European regulations between its steel pile and the concrete pile. If it were possible to remove the barriers to the use of steel, mainly in respect of working stress, load-bearing capacity and

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corrosion, there would be a potential market of several hundred thousand tonnes in Europe. This research project aims to overcome these handicaps by obtaining a better knowledge of the behaviour of steel piling when used for foundation works.

The research will take three years and will be carried out by:

- Construction Industry Research and Information Association, London (UK)
- British Steel Corporation, London (UK)
- Arbed, Luxembourg (L)
- TNO Institute for Building Materials and Building Structure, Delft (NL).

P 462 - Reaction of load-bearing steel structures to seismic phenomena

Steel is already widely used in Japan for the construction of buildings that have to withstand earthquakes. The consequences of the Frioul catastrophe highlights the lack of knowledge of this technique in Europe. This project aims to fill this gap and to promote the use of steel in earthquake zones by improving knowledge of the existing situation as regards the structural safety of steel buildings. In addition, a programme of experiments will increase the knowledge of fatigue due to a limited number of stress cycles.

This research has obvious social implications.

It will be carried out by Italsider in Genoa (I) and will take 18 months.

P 467 - Conditions for the development of steel construction in typical non-residential buildings

Social and industrial progress combined with economic and cultural development in Europe are creating an increasing and often urgent demand for buildings of the following types: workshops for small and medium-sized industrial companies, farm buildings, storage sheds, exhibition rooms, recreation centres, hangars, garages, shops, etc. These are single-storey non-residential buildings of small or medium volume.

The recurrence of very similar requirements on the part of clients for buildings in the sectors indicates that it would be advantageous to design buildings composed of elements prefabricated in the factory, available from catalogue in a standard range, which can be assembled to form a complete

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"standardized" buildings. In the present project it is intended to conduct surveys to ascertain the factors governing the choice of a standardized building, and in particular a standardized steel building, over other methods of construction. The potential market for the steel industry will also be ascertained. Similar surveys will be conducted throughout the European Community if the results of the present study, which is limited to Belgium and Italy, are sufficiently encouraging. The first stage of the research will take 18 months and will be carried out by the Centre Belgo-Luxembourgeois d'Information de l'Acier in Brussels (B) and the Centro Italiano Sviluppo Impieghi Acciaio in Milan (I).

P 472 - Fire resistance of metal structures

There is no need to emphasize the importance of this type of research in the context of the use of steel for building. This project is a logical extension of the previous research on the fire resistance of metal frameworks under an ECSC agreement and will help to harmonize European attitudes on the subject.

The project relates in particular to the fire resistance of solid metal columns and composite steel-concrete columns, exterior columns (the only protection of which is their relative remoteness from the source of a fire) and structures. In addition, an exhaustive survey will be carried out by two internationally known experts to determine future guidelines for research on the fire resistance of steel structures.

Miss Law in London (UK) and Mr. Bourguignon in Brussels (B) will be commissioned through their respective organizations to carry out this survey, which will take one year.

The research will be carried out by:

1. The Studiegesellschaft für Anwendungstechnik in Düsseldorf (D)
(four years).
2. The Centre Technique Industriel de la Construction Métallique in Puteaux (F)
(two years).

b) Heavy application

P 364/2 - Measurement and interpretation of cumulative loads on bridges

The proposed research programme comprises traffic surveys and strain measurements to be carried out on some bridges in Italy and subsequent processing of the data obtained. It is planned to investigate on three recently constructed wide-span steel bridges with light gauge decking: means of transport, loads, type of vehicle flow, strain-gauge measurements, two-directional measurements.

This programme, which will last two years, will be carried out at the Istituto de Scienza delle Costruzioni, Pisa University, in Pisa (I).

P 386 - Static and fatigue behaviour of welded tubular joints in offshore structures

It is proposed to study both theoretically and experimentally the static and fatigue strength of large-scale tubular joints. Ring-stiffened joints will be examined and comparisons will be made between stiffened and unstiffened members. Specimen size and dimensions will be reasonably representative of real joints in offshore structures. Each specimen will be strain-gauged for stresses to be checked against theoretical calculation.

This work, which will take three years, will be carried out by Italsider in Genoa (I).

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