

COMMISSION OF THE EUROPEAN COMMUNITIES

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Proposals of financial aid for various types of
technical iron and steel research

JULY 1974

MEMORANDUM

on ECSC financial aid, under Article 55 (2c)
of the ECSC Treaty, for a research programme on
"BLAST-FURNACE TECHNOLOGY"

I. INTRODUCTION

The two main factors which are influencing the trend of applied research in blast-furnace technology are the cost and availability of energy sources which can be used for blast furnaces.

The scarcity and rising cost of blast-furnace coke together with the situation in the hydrocarbons sector are causing blast-furnace operators to reconsider the whole problem of energy for iron-ore reduction.

The proposed research topics include the following problem areas:

- (1) Study of reaction kinetics in blast furnaces in the temperature range of 950-1150 °C (P 102).
- (2) Study of the optimization of the properties of briquettes for use in blast furnaces (P 135).
- (3) Study of the behaviour of refractory substances in blast furnace runners (P 129).

II. NATURE AND AIMS OF THE PROPOSED RESEARCH

1. Influence of hydrogen on the reducing behaviour of iron oxides at a high temperature in the presence of reactive coke

The object of the research is to investigate more closely the phenomena which occur in blast furnaces at temperatures between 950 and 1150°C. This temperature range has been poorly explored in theory. It is the range in which coke gasification and wustite reduction take place.

Preliminary research has shown that a rise in the proportion of hydrogen in the blast-furnace gas greatly increases the kinetics of the process of direct reduction in the furnace. What now has to be established is whether this effect is observed when various types of coke and various ores are used. It is planned to inject proportions of hydrogen of up to 20% (remainder CO and N₂). The tests will be carried out in a test furnace. It is expected to obtain better knowledge of the reactive process in the well of the furnace. The results should provide a theoretical basis for large-scale use in blast furnaces of hydrogen (generated with the aid of cheaper nuclear energy). The results are naturally of particular interest to those Community countries which do not have large supplies of fossil fuels at their disposal.

2. Optimization of the shape and properties of briquettes for use in blast furnaces

In addition to the construction of large coking plants, the use of continuous coke-production processes will become increasingly important as regards energy for blast furnaces .

There is no need to underline the advantages which ensue from the ready availability of raw material. The briquettes which are to be used in the proposed research will be produced by the ANCIT method. Briquettes produced by this method are at present the only type available in quantities suitable for industrial use.

In the period 1970-1973 this type of briquette was tested in small quantities in four different blast furnaces. On the one hand the tests showed that the mechanical properties of the briquettes were very satisfactory. On the other hand, the permeability index declined in every case, probably owing to the fact that the briquette is less porous.

Consequently, the object of the proposed research project is as follows:-

- to determine the optimum shape for briquettes;
- to optimize the product from the point of view of abrasion and porosity.

Three different coke grades are to be used. Testing should last 3-4 weeks in each case. It is planned to use one of Thy Marcinelle et Monceau's blast furnaces with a hearth diameter of 5.3 m. A total of 25,000 t of briquettes will be involved.

3. Study of the behaviour of refractories in blast-furnace runners

The degree of automation and mechanization in blast furnaces is generally very high. The drawing of the ore, sinter and coke from the bunkers, the charging process and the control of the air blast generally take place without the use of human labour. Exceptions are the operations effected in the casting bay and on the furnace platform for which no more than partial mechanization has been achieved so far.

The object of the proposed research is to subject refractory substances used in the blast-furnace runners to systematic testing under the various essential structural conditions. It is hoped in this way to arrive at longer furnace life. This is desirable not only for economic reasons but also for ergonomic and metallurgical reasons, and to achieve production runs which are as trouble-free as possible.

The tests will be conducted on a mock-up plant. By using an electromagnetic runner it is possible to feed 5 t of pig iron to a circuit in which furnace-runner sections are incorporated in a size ratio of 1:1. Flow rates of up to 500 t/h can be achieved. Among other things the tests should show whether a mechanical leak and re-lining of the runners with refractories is more advantageous than the prefabrication and replacement of all the runners.

III. OPINION OF THE COMMITTEES OF EXPERTS

After examination by the sub-committees of experts and the Iron and Steel Technical Research Committee, it was decided to make this a top-priority project and to propose it for ECSC financial aid.

IV. DURATION AND COST OF THE WORK - FINANCIAL AID PROPOSED

Ref.	Title of Project	Duration Years	Total Budget	Financial Aid	
				%	Amount
P 102	Study of reaction kinetics in blast furnaces in the temperature range 950-1150°C	2	FF 522,000	60	313,200
P 135	Optimization of the properties of briquettes for use in blast furnaces	2	FL 32,150,000	60	FL 19,290,000
P 129	Study of the behaviour of refractories in blast-furnace runners	3	DM 1,885,000	60	DM 1,131,000

V. CONCLUSION

The aim of the research on reaction kinetics (P 102) is to investigate the theoretical bases of the behaviour of a blast furnace when hydrogen is injected in vast proportions. This technology will be of special interest to the Community countries which have little or no fossil fuels at their disposal.

Research into the behaviour of refractories in furnace runners (P 129) is geared to actual operating conditions. The object of the research is to increase the service life of the runners. In addition to its economic advantages this research is of ergonomic interest.

The use of briquettes in blast furnaces (P 135) has not yet been tested on a large scale. The object of the research is to put the supply of energy to blast furnaces on a broader basis. The capital costs of a briquette plant are only about 60% of those of a conventional coking plant of the same size. Furthermore, environmental problems are easier to cope with. Emission rates are comparable to those of a power plant and are therefore much lower than those of a coking plant.

The research will be carried out at the following establishments:

- P 102 - IRSID, Maizières-les-Mets
- P 129 - VDEh - BFI, Düsseldorf
- P 135 - ARBED, Luxembourg

The briquettes will be produced at the Eschweiler-Bergbau-Verein, and the blast-furnace testing conducted at Thy-Marcinelle et Monceau.

The Commission of the European Communities proposes granting financial aid to the programme of research on blast-furnace technology under Article 55 (2c) of the ECSC Treaty.

The funds required to cover the Commission's contribution to these three projects and to the costs of dissemination of information and incidental expenditure are estimated at 821,312 u.a.

COMMISSION
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Orig. D

JULY 1974

M E M O R A N D U M

on ECSC financial aid, under Article 55 (2c)
of the ECSC Treaty, for a research programme
on "STEELWORKS RESEARCH"

I. INTRODUCTION

The Steel Research Programme in the second train of research for 1974 is made up of eleven research projects which are to cover the following fields:

1. Continuous casting - (P 038, P 107, P 118);
2. Electroslag remelting (ESR) - (P 049, P 077, P 080);
3. Automation - (P 115, P 117);
4. Refractories - (PY, P 127, P 138).

In the field of continuous casting, two problem areas have been identified:

- (a) the problem of controlling the flowrate with an electromagnetic pouring device;
- (b) the problems of heat transfer at the casting.

In the field of electroslag remelting, detailed studies will be carried out on:

- (a) the structures in various operating modes;
- (b) the problems of the fusion phenomenon;
- (c) the composition of the slag.

In the field of automation, one proposal concerns the electric arc furnace and the other the AOD converter.

The field of refractories has only this year come within the scope of Community research.

- (a) In one particular case, different ladle linings will be investigated, in conjunction with various deoxidation techniques, for their standards of purity in non-metallic inclusions. This research proposal could equally well be incorporated in the field of pouring and solidification;
- (b) a further case concerns the oxygen converter;
- (c) the last case of all is fairly generally concerned with the iron and steel industry's problems regarding the rate at which plant and vessels can be raised to the working temperature.

II. NATURE AND AIMS OF THE PROPOSED RESEARCH

1. Adoption of electromagnetic pouring devices for continuous-casting plants

This research work will be carried out jointly by the Aachen Technische Hochschule and the Brescia firm Innocenti Santenstacchio SPA.

It consists of some theoretical scientific development work, which will be performed in Aachen, and the practical testing of the process in an industrial continuous-bloom-casting plant.

The aim of the Aachen end of the project is to test, and to optimize from experiments and theoretical exercises, a controlling or regulating device capable of being adopted for solving all pouring or flowrate-control problems. When the project has been completed, the aim will be to issue, on the basis of the results, some specifications for building such regulating plants for any given cross-section (blooms or slabs).

A prototype control device will be tested in a 30 metric ton experimental ingot continuous-casting plant concomitantly with this development. Should the trials have a successful outcome, the following benefits are expected:

- (a) With the need for regulating the stopper eliminated, no large launder is necessary;

- (b) multi-tapping casting presents no problems;
- (c) quantity control is straightforward because it stems from variations in electrical parameters only;
- (d) the height of the plant is less, the meniscus of the steel in the tundish is below the level of the meniscus of the casting in the mould;
- (e) the working safety is enhanced because leakage from the tundish due to an ill-fitting stopper has been rendered impossible;
- (f) casting at a lower temperature is metallurgically feasible;
- (g) moreover, the runner can be enclosed and put under an inert atmosphere, as and when necessary.

Even existing continuous casting plants of other types could readily be equipped with such a regulating system.

2. Determination of the distribution of the local material transfer coefficients relating to the melt during the continuous-casting process and devising of a mathematical model for the calculation of the temperature and concentration changes occurring within the mould

An appreciable percentage of the quantities of steel being produced today is already being made by the continuous-casting process. Throughout the world there are now 200 continuous-casting plants making slabs and 1,200 making ingots. The casting steel enters a water-cooled mould from above. Precise knowledge of the solidifying mode of the molten steel is of vital importance to the design of such plants, to the throughput of the steel, and also to the quality of the product.

The subject of flow conditions has been disregarded in the work on the solidifying mode that is to be found in the literature.

The effect that these flow conditions exert on the material transfer at the phase boundary, and consequently on the concentration field and the upwards migration phenomena, is largely unexplored territory and ought to be further studied in depth. In order to comprehend the whole phenomenon taking place in the mould, therefore, it is essential to link up the

solidification phenomenon with the local convective material transfer which occurs at the phase boundary and is affected by the flowrate.

The mode of flow and the convective material transfer occurring between the liquid phase and the solid phase will be investigated in a scaled-down experiment. Air will be used as the flow medium and the material transfer will be simulated with sublimable substances. The parameters used will be the length and geometry of the mould, the dimensions of the cast steel and the speed of casting. The ultimate aim is the devising of a computer model that can portray the solidifying mode in the mould quantitatively.

The continuous-casting technique involves heavy capital investment and operating costs and its profitability is therefore dependent on the quality of its product. The proposed refined continuous-casting-technique computer model offers prospects of a more accurate planning of new plants and an improvement in quality.

3. Investigations into the heat-transfer economy of the metal casting when it is being continuously cast

Research proposals P 107 and P 118 have been harmonized by the proposers and supplement one another. Whereas proposal P 107 deals with the phenomena in the mould, proposal P 118 is directed towards investigating the heat transfer mode at the casting after it has left the mould.

The aim of the research project is the same as in the case of proposal P 107, i.e., the thermodynamic optimization of continuous-casting plants. A computer model will be devised which will take account of the whole heat-transfer economy of the continuous-casting plant and which will be applicable to all industrial continuous-casting plants.

With this end in view, it is planned first of all to carry out laboratory-scale trials to identify the hydraulic and also the thermodynamic characteristics of spray nozzles.

Subsequently, an investigation into the relevant heat-transfer coefficients will be made along the entire length of the casting.

Finally, the results obtained will be put to the test in some industrial plants, both ingot-casting plants and slab-casting plants.

4. Investigations into solidification structures with the ESR process

Proposals P 049, P 077 and P 080 have been harmonized as to their objective. The research should help to close the present technological gap in Europe where the manufacture of large castings is concerned.

The in-works investigations under research proposal P 049 should yield information on macrosegregation, primary-grain size and the nature and distribution of the inclusions found with electroslag remelting.

The investigations into primary-grain formation will be carried out in respect of both heat-treatability and forgeability.

The item of prime interest in the investigations into the distribution of the inclusions will be the non-oxide inclusions.

5. Theoretical and experimental investigations into the fusion phenomenon found with the electroslag remelting (ESR) technique

In the planned investigation the heat flow in the top electrode will be studied with particular regard to the fusion phenomenon. In this connection, a two-dimensional differential equation for the heat conduction will be assumed.

A particular objective in view is to be able to predict from theory the shape of the fusing tip of the electrode and the thickness and the speed of flow of the fusion film. In the ESR process, the metal is grain-refined at the molten metal/slag phase boundary. A knowledge of the extent of this reaction area and of the thickness and speed of flow of the film is therefore of major importance as regards the quantitative portrayal of the reaction modes.

Finally, the results should contribute to optimizing the power consumed in the remelting process and thus to reducing the specific remelting costs.

6. Optimization of the slag associated with the electroslag remelting technique

The main benefits accruing from the ESR project are:

- (a) a uniform solidification structure;
- (b) purity of the metal as regards oxide inclusions;
- (c) the possibility of achieving a proper desulphurization of the metal.

As slags, mixtures of $\text{CaF}_2 - \text{Al}_2\text{O}_3$ will in general be used.

In contrast with their admirable grain-refining action and their good electrical conductivity, such slags have the disadvantage of a great affinity for hydroxyl ions, as a result of which the metal takes up hydrogen.

This is one of the main problems in metallurgy which still hamper the manufacture of larger forgings.

The chief aim of the research is to reduce the amount of hydrogen taken up in the unfused metal. In addition, the slag should absorb the oxide and sulphide inclusions to the greatest possible extent. The surface of the forging must be smooth.

The starting point in the test series will consist of binary mixtures of Al_2O_3 and CaO , to which other oxides will be systematically added.

7. Conceptual model for optimizing the electric-arc steel process

Proposal P 115 provides for the continuance of research that has hitherto been carried out with success. Many of the results obtained in the research accomplished to date are already being applied industrially.

The research programme has been executed jointly by the Betriebsforschungsinstitut (Operational Research Institute) of the VDEh, where the first part of the research was carried out, and BISRA (Round Oak Steel Works Ltd.), where a research project with a similar objective had been scheduled.

It is planned to devise the following five computer programmes:

- (a) Programme No. 1 will deal with the problem of optimizing the power consumed in the steelworks.
- (b) Programme No. 2 is concerned with the distribution of the load between the three arcs in the arc furnace.
- (c) Programme No. 3 provides for the devising of a model for working the electrodes above the nominal impedance-regulating values.
- (d) Programme No. 4 provides for improving the programme for calculating alloying materials that was devised in the previous research programme, by introducing direct data-transmission between the analytical laboratory and the process computer.
- (e) Programme No. 5 is the programme in which it is planned to correct not only the energy balance but also the alloying calculations continuously by evaluating data stored in the magnetic memory. Further work in this connection is directed towards the computer-controlled oxygen supply and the conduct of the slag metallurgy.

The ultimate objective is to discover the optimum conditions for operating an electric arc furnace, in respect of both the energy consumed and the quantities of alloying materials used.

8. Automatic control of the AOD (Argon-Oxygen-Decarburization) process

The AOD converter is the third steel-producing facility, after the electric-arc furnace and the LD converter, to have its automation problems put forward for solution under an ECSC research project.

Oxidation with an argon-oxygen mixture (AOD) in place of pure oxygen (LD, etc.) has the advantage of a lower chromium oxidation loss. This technique is therefore mostly applied to the manufacture of alloy steels. The ratio of oxygen to argon is about 3 : 1 at the beginning of the "blow" and about 1 : 2 at the end. The process is conducted stepwise and is based on the analysis and temperature of the charge.

The objective of the research is first to obtain the required data continuously and then to subject them to dynamic-process updating.

For this objective to be achieved, continuously operating measuring devices will have to be installed and tested during the initial stage.

In the second stage a correlation between the aforementioned data and the carbon content of the charge will then be established mathematically or by comparative methods.

Finally, in the third stage, an experiment will be performed on dynamic control system, with the data automatically adjusting the actual gas composition.

The currently inevitable - and somewhat lengthy - pauses due to the stepwise operating mode for blowing would be eliminated with the automatic control of the oxidizing gas composition. This would mean the plant having an appreciably higher load factor.

9. Investigations into the types of non-metallic inclusions in forgings versus the ladle lining

The research proposal has been harmonized not only with the work of the first and second "Casting and solidification" programmes but also with the research projects starting up on refractories.

Under this research proposal, forgings of 20 to 50 metric tons will be examined as to the nature and quantities of their non-metallic inclusions.

Various ladle linings will be the first experimental parameters used. The choice of the refractories has been harmonized with the CRM (Liège) refractories programme now starting up. Studies will be carried out on:

- (i) a fireclay containing 55% Al_2O_3 ;
- (ii) a fireclay containing not less than 70% Al_2O_3 ;
- (iii) chrome-magnesite firebricks.

As additional parameters it is proposed to use various deoxidation routes in which either a vacuum treatment in accordance with the RH process or flushing with argon is planned as well as adding the deoxidant. The proposed routes are:

- (i) FeMn, FeSi + Al + vacuum;
- (ii) SiMn, FeMn + Al + vacuum;
- (iii) FeMn + vacuum + FeSi + Al;
- (iv) FeMn + FeSi + Al + argon;
- (v) SiMn + FeMn + Al + argon.

The various techniques for the treatment of the molten steel in the ladle offer forgings some significant possibilities as regards improving their quality. Vacuum metallurgy and argon-flushing techniques play an important part in these processes.

10. Measuring with radioactive tracers the abrasion sustained by refractory linings in oxygen converters

The research will be pursued in three different directions.

First, it will aim at providing data on the repercussions of the properties of refractories on integrity in operation. By carrying out a study of the abrasion mechanism in greater depth it should be possible to predetermine which materials are the best suited to which zones in the converter.

Secondly, a study of the repercussions of the various steel-making techniques on the abrasion of the refractories will be carried out in greater depth. In this way the steelmaker should be enabled to choose within his given metallurgical ambit the manufacturing technique with the lowest abrasion.

Thirdly, the optimum profile of the lining should be ascertained for various facilities. The aim is to offset the different rates of abrasion found in the various zones in a converter by installing refractory materials of different thicknesses and different grades.

All in all, the useful life of a converter lining should thereby become appreciably lengthened.

Reliable and thoroughly proven radioactive measuring methods will be used for carrying out the trials. Radioactive point sources will be installed in the refractory material at varying depths from the surface in different sites in the converter. It will be possible to detect the nuclide in question in the molten steel when the abrasion has reached a given value. In other instances an activated wire will be embedded with the aim of deriving from the amount passing into solution the abrasion sustained per charge.

11. Determination of the maximum rate at which refractory linings in the iron and steel industry can be brought up to the working temperature

Many refractory-lined facilities in the iron and steel industry have undergone tremendous capacity expansions over recent years.

In the steel industry, submarine ladles holding 400 to 600 metric tons, pig-iron mixers holding 2,500 metric tons and 400 metric ton T-converters are no longer rarities today. In addition, there are the high-capacity soaking pits and pusher-type furnaces that are tailored to present-day rolling mill outputs.

With such capital-intensive development, a high plant availability is naturally of even more importance than before.

The enhancement of the durability of the refractories has not invariably resulted in the desired extension of the useful life of the facilities. Considerable store is accordingly set by rapid repair techniques and ease of replaceability in the design of the refractory lining.

All these efforts not only at enhancing the quality of the refractories but also on the design side are in many instances frustrated by the fact of being obliged, in the absence of precise information on the stress patterns occurring not only in the individual bricks, but also in the brickwork bond, to take as long as possible to come up to the working temperature. A submarine ladle will accordingly remain out of action for ten days after being relined. A pig-iron mixing vessel will need preheating for about thirty days before being taken back into service. Even so, there are some firms which will take such vessels back into service again - albeit at their own risk and peril after preheating for ten days.

The research proposal represents an attempt to transpose the pre-heating requirements from the rule of thumb to scientifically founded principles. Experiments will therefore be carried out first on individual bricks. A testing procedure needs to be developed in which it will be possible to deduce the stress pattern by reference to the temperature gradient. At a later stage the studies will be switched from individual bricks to brickwork bonds, to embrace bricks made of silica, fireclay, magnesite, bauxite, mullite and corundum. The onset of cracking will be detected by sonic emission analysis.

The iron and steel industry's interest in such investigations is manifest. The iron and steel industry will in no way, however, be the sole beneficiary of such research.

III. COMMITTEE OPINIONS

After examination by various committees, including subcommittees and the Iron and Steel Technical Research Committee, it was decided to make these top-priority projects and propose them for ECSC financial aid.

IV. DURATION AND COST OF THE WORK -- FINANCIAL AID PROPOSED

Ref.	Subject Title	Duration Years	Total Budget	Financial Aid	
				%	Amount
P 038	1. <u>Continuous casting</u> Use of electromagnetically controlled pouring devices in continuous-casting plants	3	Lit 69,360,000 DM 450,000	60	Lit 41,616,000
				60	DM 270,000
P 107	Distribution of the local material transfer coefficients at the solidification front in continuous casting and the devising of a mathematical model	3	IM 522,900	60	IM 313,740
P 118	Investigations into the heat-transfer economy of the metal casting	3	FB 8,000,000	60	FB 4,800,000

Ref.	Subject: Title	Duration Years	Total Budget	Financial Aid	
				%	Amount
	<u>2. Electroslag remelting</u>				
P 049	Investigations into solidification structures with the ESR process	2	FB 6,000,000	60	FB 3,600,000
P 077	Investigations into the fusion phenomenon	2	DM 218,250	60	DM 130,950
P 080	Optimization of the slag	2	DM 400,200	60	DM 240,120
	<u>3. Automation</u>				
P 115	Conceptual model for optimizing the electric arc steel process	2½	DM 1,783,000	60	DM 1,069,800
P 117	Automatic control of the AOD process	2	£ 58,300	60	£ 34,980
	<u>4. Refractories</u>				
PY	Investigations into the types of non-metallic inclusions in forgings versus the ladle lining	3	U.A. 606,000	55 ⁽¹⁾	U.A. 333,300
P 127	Measurements of abrasion in oxygen converters	3	Fl 10,200,000	60	Fl 6,120,000
P 128	Determination of the maximum rate at which refractory linings in the iron and steel industry can be brought up to the working temperature	3	DM 1,301,870	60	DM 781,122

(1) The Commission suggests that the borrower's own contribution should be 45%. This is in line with what the Commission has decided in similar instances where the other contracting party is not in a member country of the ECSC.

V. SUMMARY

1. The benefits expected to accrue from introducing electromagnetic flow control into continuous-casting plants are a higher plant-load factor and greater operating safety. This could also be regarded as being a first step towards automating these plants.

2. Proposals P 107 and P 118 are primarily concerned with the optimization of the thermodynamic problems inherent in the mould (P 107) and in the casting (P 118). The results of this work are expected to make it easier to plan continuous-casting plants and to operate them more efficiently.

3. The proposals regarding electroslag remelting cover not only the fields of structure and upwards migration but also the effects these phenomena have on the forging process (P 049); the investigation of the fusion phenomenon with regard to an optimum energy economy (P 077) and the search for new less hygroscopic slags (P 080). The chief metallurgical problem at present in the melting-down of large ESR ingots is the relatively high hydrogen content of the metal.

4. Proposal P 115 is aimed at optimizing the energy consumption and the most economical usage of alloying additives. The results of programmes forming part of the first train of research are already being supplied industrially with success. Proposal P 117 is aimed at automating the AOD process. The aim is to switch from the current stepwise blowing and various A/O₂ conditions to a continuous mode of blowing where the required A/O₂ ratio is continuously matched to the demands.

5. Proposal FY lies, by virtue of its subject matter, between the fields of "Casting and solidification" and "Refractories". In both fields it closes a technically important gap, namely, the area of ladle metallurgy, which has so far gone unheeded in ECSC research work.

6. Proposals P 127 and P 128 relate to top-priority problems, the solving of which will have direct economic repercussions. Where Proposal P 128 is concerned, its interest far transcends the iron and steel industry.

The Commission of the European Communities therefore proposes granting the eleven research proposals financial aid under Article 55 (2c) of the ECSC Treaty.

The work will be carried out by the following undertakings or establishments:

- P 038 - 1. VDEh - Technische Hochschule, Aachen
2. Innocenti-Santenstacchio, Brescia
- P 107 - VDEh - Technische Hochschule, Aachen
- P 118 - CRM, Liège
- P 049 - Cockerill, Seraing
- P 077 } - VDEh - Max-Planck-Institut für Eisenforschung, Düsseldorf
- P 080 }
- P 115 - VDEh - Betriebsforschungsinstitut, Düsseldorf
- P 117 - BISRA, Spartan Steel and Alloys Ltd., London
- PY - Metalurski Institut "Hasan Brkic", Zenica, Yugoslavia
- P 127 - ARBED, Luxembourg
- P 128 - VDEh, Düsseldorf

The funds required to cover the ECSC contribution to the work and to the costs of the dissemination of the information and incidental expenditure are estimated at approximately 1,667,687 u.a.

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M E M O R A N D U M

on ECSC financial aid, under Article 55 (2c)
of the ECSC Treaty, for a research programme on
"STEELWORKS RESEARCH"

I. INTRODUCTION

The programme for which aid is sought is in the field of electroslag remelting. Three applications for aid have already been made in this particular field under the second train of research.

This application is complementary to the others mentioned in as much as an attempt is to be made to use electrodes of a different kind, manufactured by a powder metallurgy process.

II. NATURE AND AIMS OF THE PROPOSED RESEARCH

The aim is the manufacture of a novel type of completely segregation-free electrodes for the ESR process. The electrodes would consist of a metal tube filled with a compacted powder.

The method is particularly suitable for the manufacture of electrodes for special alloys which cannot be manufactured by normal methods (e.g., alloys with 15% Al or 7% Ti).

It is first planned to carry out a feasibility study. The first stage of this study would be an investigation of the usability limits of such electrodes, seen from both the process engineering and economic angles.

III. OPINION OF THE COMMITTEES OF EXPERTS

After examination by a Committee of Experts and the Iron and Steel Technical Research Committee, it was decided to make this a top-priority project and to propose it for ECSC financial aid.

IV. DURATION AND COST OF THE WORK

Ref.	Title of the Research	Duration Years	Total Budget	Financial Aid	
				%	Amount
P 132	Manufacture of ESR electrodes by a powder metallurgy process	2	Lit 100,000,000	60	Lit 60,000,000

V. SUMMARY

The research project covers the development for the electroslag remelting process of a new electrode having a metal mantle and a metal powder core.

Laboratory trials have established that this technique is very appropriate for the manufacture of segregation-free small ingots of special alloys.

It remains to be established how far the principle of the technology is applicable to the manufacture of large forgings and how far electrodes manufactured by a powder metallurgy process can compete with those which have been cast.

Should these problems be successfully solved, such a technique would represent an advantageous variant of the conventional electroslag remelting method.

The work is to be carried out at the CSM.

The work is expected to take two years. The funds required to cover the Commission's contribution to the work and to the costs of dissemination of information and incidental expenditure are estimated at 75,483 u.a.

JULY 1974

COMMISSION
OF THE
EUROPEAN COMMUNITIES

MEMORANDUM

on ECSC financial aid, under Article 55 (2c)
of the ECSC Treaty, for a research programme on
"ROLLING MILLS"

I. INTRODUCTION

The largest share of the EEC's annual crude steel production of 150 million tons is accounted for by rolled products with about 100 million tons. At present, the main problems facing the rolling industry are:

- (a) to reduce production costs;
- (b) to reduce energy consumption;
- (c) to improve the quality of flat products.

The research projects outlined below are aimed at solving these problems and are designed mainly to save water and energy (three projects) and to improve the geometrical properties of flat products (two projects).

II. NATURE AND AIMS OF THE PROPOSED RESEARCH

1. Counter-deflection of rolling mill rolls

The roll separating force tends to cause deflection and flattening of rolling mill rolls. The major effects of this are:-

- (a) to give the sheet or plate a profile different from the active generator of the roll at rest, in most cases making it thicker at the centre line than at the edges;
- (b) to make it difficult to control the rolling process in order to obtain dead flat sheet or plate.

The idea of regulating the profile of the active generator of the work rolls as required by deforming the rolls elastically by means of counter-deflecting forces applied by hydraulic rams was studied in theory in a first research phase, for which ECSC financial aid was granted under convention No. 6210/71/3/031.

The very encouraging results of this theoretical study and of the first tests make it essential to check out the theories in the rolling mill and to incorporate in an automated control system the algorithm and strategy defined in the first phase.

The new research project will be devoted to this industrial application.

2. Study and verification of sheet flatness

Sheet production (hot and cold) is of growing economic importance. The need to obtain high output and to improve the precision, gauge uniformity and surface properties of the sheet has led to a number of research projects. Some have been directed towards the study of complete physical models to describe the phenomenon (force, torque, etc.) which enable the rolling train to be automated by prior regulation (i.e., before the sheet has entered all the stands). However, this regulation is not a once only process and the usual indeterminacy is relative to the distribution of the total reduction to be obtained over the various stands, i.e., the plan of intermediate thicknesses. This indeterminacy generally causes flatness defects in the sheet, making additional rolling necessary to obtain dead flat sheet. The use of flatness constraints largely eliminates this indeterminacy and obviates the need for additional rolling, currently required for 7% of production. This research project is designed to study the complete physical model of the flatness of sheet and its application to automatic rolling mill control.

3. Optimization of cooling devices in rolling mills

In recent years, cooling problems in rolling mills have increased in urgency and scope. The reasons for this include:

- (a) the constant increase in rolling speeds, leaving less and less time available for cooling and involving the use of ever-increasing quantities of water (up to 15,000 m³ per hour in some cases);
- (b) the current tendency to make increasing use of heat and the thermo-mechanical treatments in rolling mills.

The purpose of this research project is:

- (a) to develop cooling systems able to dissipate large quantities of heat in the shortest possible time;
- (b) to reduce to a minimum the quantities of cooling fluid required while ensuring homogenous properties;
- (c) to solve the technological problems involved in adapting cooling systems in rolling mills.

4. Accelerated cooling of strip at the exit of a wide strip mill

A modern wide strip train is generally 800 m long, 150 m of which is taken up by the delivery table, which is equipped with cooling systems over a length of 100 m. Typical specific water consumption by these systems is at present 1 m³ per minute per m² for a heat transfer coefficient of 2,000 kcal/m²/h/°C and an average efficiency of 10-20 kcal/kg cooling water.

In this research project, it is proposed to study a cooling system of the "guided jet" type with a performance of 10,000 kcal/m²/h/°C and an efficiency of 20-30 kcal/kg cooling water. The expected advantages are:

- (a) a reduction in capital costs, as the rolling mill can be shortened;
- (b) a reduction in water and energy consumption;
- (c) easier control of strip coiling temperature.

III. OPINION OF THE COMMITTEE OF EXPERTS

After examination by sub-committees of experts and by the Iron and Steel Technical Research Committee, it was decided to make these top priority projects and to propose them for ECSC financial aid.

IV. DURATION AND COST OF THE WORK - FINANCIAL AID PROPOSED

Ref.	Title of Research	Duration Year	Total Budget	Financial Aid	
				%	Amount
P x	Counter-deflection of rolling mill rolls - second phase	3	FF 3,880,000	60	FF 2,328,000
P 052	Study and verification of sheet flatness	3	FF 2,294,000	60	FF 1,376,400
P 083	Optimization of cooling devices in rolling mills	3	Bfrs17,000,000	60	Bfrs10,200,000
P 121	Accelerated cooling at the exit of a wide strip mill	2½	Lit 82,397,000	60	Lit 49,438,200

V. CONCLUSIONS

In view of the marked interest in these five research projects, the Commission of the European Communities plans to grant, under Article 55 (2c) of the ECSC Treaty, financial aid for a research programme in this field.

The programme would be carried out by:-

- II 1 - (Px) - IRSID, Maizières-~~lez~~-Metz
- II 2 - (P 052) - IRSID, Maizière-~~lez~~-Metz
- II 3 - (P 083) - CRM, Liège
- II 4 - (P 121) - CSM, Rome

The funds required to cover the ECSC contribution to the work and to the costs of dissemination of information and incidental expenditure are estimated at approximately 883,273 u.a.

JULY 1974

MEMORANDUM

on ECSC financial aid, under Article 55(2c) of the
ECSC Treaty, for a research programme on

"MEASUREMENT, TESTING AND ANALYSIS"

I. INTRODUCTION

In the metallurgy of iron and steel, the range of activities that come under the heading of "Measurement, Testing and Analysis" includes the "non-destructive tests", i.e. tests in which components or assemblies are examined by a method which will not prevent their subsequent utilization.

The techniques mainly employed are:

- ultrasonic testing;
- acoustic emission;
- neutron radiography/spectrometry (by way of simple example).

The need to develop techniques of this kind arises partly from the changing methods and techniques employed in the making and processing of steel, but even more from the increasingly stringent requirements with respect to quality. Hence the research programme outlined in this paper is wholly in keeping with the aim of investigation into new methods and/or adaptation of existing methods to satisfy the requirements of industry.

II. NATURE AND AIM OF THE PROPOSED RESEARCH

1. Sound emission for non-destructive testing

Among the most insidious causes of fracture in metallic materials are fatigue and stress corrosion. Both these types of fracture show a characteristic progression in which three phases can be distinguished:

- (a) by incipient cracking;
- (b) by slow propagation, and
- (c) by final fracture.

During phases (a) and (b), the damage to the test piece is often hard to detect by the usual methods of non-destructive examination and, even when it can be detected, there is still the problem of defining the damage in terms that indicate the proximity or otherwise of the critical phase(c).

Acoustic emission seems today to be the most promising approach, as it is the one likely to be most fruitful as regards practical applications. Since the development of this method is a matter of considerable practical importance, particularly in connection with the safety of machines and structures, it is proposed that the following programme of research be carried out:

- analysis of flaw-detection characteristics;
- tests to correlate the sound emission process with conventional test methods;
- application of the method to an experimental pressure vessel of great thickness.

2. Metrological study of preferred orientations in cold-rolled strip

The cold-rolling of low-carbon steels gives rise to preferred orientations which have a decisive influence on the coefficient of anisotropy, and hence on the technological properties of the steels. It is important, therefore, to be able to measure the change in these orientations throughout the cold-rolling process so that they can, if appropriate, be influenced in a given manner.

The usual procedure for radiographic measurement of preferred orientations consists in examining the reflections projected on a polar hemisphere. The information obtained by this method requires relatively substantial equipment for the generation and measurement of monochromatic x-rays, and

there is also the time-factor. The intention behind the research programme, therefore, is as follows:

- to obtain textures suitable for x-ray transmission using a system of detectors based on energy dispersion;
- to determine the optimum parameters, such as voltage, current strength and angle of diffraction;
- preparatory work on the development of an industrial-scale device which will afford continuous measurement.

3. Analysis of ultrasonic fields by the echo method, using transverse waves

Many tests and a number of theoretical studies - some of them based on very simple hypotheses - have shown that there is not necessarily a constant relation between the size of the flaw and the intensity of the echo. Hence any conclusion as to the size of the flaw which is based solely on the intensity of the echo in ultrasonic testing involves an element of uncertainty the significance of which has not so far been satisfactorily determined.

The aim of the research in this connection is to provide an answer to three questions:

- (1) What are the conditions that a reference reflector must satisfy in order to ensure constant sensitivity to an echo of the same intensity;
- (2) How can a reference reflector of this type be used to select a level of sensitivity which is adequate for the detection of dangerous flaws?
- (3) What limitations and sources of error have to be taken into account in the interpretation of the echos, and what is the correlation between these limitations or errors and the geometry of the flaws?

In order to clarify these three points, it will be necessary to examine the reflection characteristics of interfaces with different geometry (finish flat reflection surface notch, edge, cylindrical borings, etc.) in the presence of transverse waves.

4. Non-destructive ultrasonic testing

A very important consideration is that there has been a remarkable advance in knowledge in the field of in-service behaviour of structures, and the effect the various types of flaw will have under specified conditions of use is beginning to be fairly well known.

As a result of these new insights into the fracture hazard, specifications are becoming more and more exact in their requirements, and it is clear that the non-destructive test will carry a considerable burden of responsibility. It will have to be capable of determining the exact shape and dimensions of the defect. The test methods that are being used at the present time, however, do not always provide a satisfactory solution to this problem.

The purpose of this study is to apply focussed sensors to actual flaws in structures which are permeable or not so permeable to ultrasonic waves, in order to estimate the accuracy of detection of such flaws. The procedure will be as follows:

- development of focussed sensors;
- investigation of the actual geometry of different types of flaw: determination of the dimensions by means of --
 - (a) longitudinal waves;
 - (b) transverse waves,using the echo or transmission techniques;
- construction of a partial-immersion device.

It is hoped that this will result in ability to:

- determine the contours of actual flaws to within a few millimetres;
- deal individually with discrete flaws of only a few millimetres;
- examine test pieces with high ultrasonic absorption rates.

5. Application of "hot" ultrasonic probe tests to the examination of slabs

A major effort has been made on research into and development of a new process for the ultrasonic testing of products at high temperature.

At the present time it is necessary to carry out shop tests using this method, which should provide the answer to a major problem of productivity in the slabbing unit. It is a process, for the automatic detection of shrinkage cavities, which will result in an appreciable stepping-up of productivity in the hot shearing of effervescing steel slabs. The practical study is to be carried out at the Hoogovens Ijmuiden works, where the conditions are particularly favourable as the slabs undergo a scarfing operation on leaving the slabbing mill, and therefore show a free scale-surface.

In a first stage, IRSID proposes to carry out a series of laboratory tests on appropriate samples, followed by a series of probe tests on a slabbing line.

6. Sampling of molten pig iron or steel (extension)

Under Convention 6210-78/2/021, the CRM has embarked on an investigation of the sampling of molten steel in a tilted converter, and the progressive mechanization of this operation. This work has been virtually completed and the success achieved has been remarkable. So far this success is still only partial as there are several adjustments to be made: in particular, the speed of lowering the probes has to be carefully regulated to take account of the sensor in the time-lag. This time-lag, moreover, will have to be reduced to a minimum, and there are also a number of technological problems which will have to be solved in order to obtain an instrument reliable enough to be handled by personnel without much training in the art.

II. OPINION OF THE COMMITTEE OF EXPERTS

After examination by the sub-committees of experts and the Iron and Steel Technical Research Committee (CRT), these projects were given top priority classification and it was proposed that they should receive ECSC financial aid.

IV. DURATION AND COST OF THE WORK - PROPOSED FINANCIAL AID

Ref.	Nature of Research Project	Duration in Years	Total Cost	Financial Aid	
				%	Amount
P 075	Sound emission for non-destructive tests on structures and machines	3	Lit. 195,000,000 Lit. 125,045,000	60 60	Lit. 117,000,000 Lit. 75,027,000
P 078	Metrological study at preferred orientations in cold-rolled strip	3½	DM. 422,000	60	DM. 253,200
P 079	Analysis of ultrasonic fields by the echo method using transverse waves	2½	DM. 207,518	60	DM. 124,511
P 085	Non-destructive ultrasonic testing	3	FF. 399,200	60	FF. 239,520
P 133	Application of "hot" ultrasonic probe tests to optimize the examination of slabs	1½	FF. 465,000 FLH. 151,000	60 60	FF. 279,000 FLH. 90,600
P 138	Sampling of molten pig iron and steel	½	FB. 1,175,000	60	FB. 705,000

V. CONCLUSIONS

In view of the keen interest in this research, the Commission of the European Communities proposes to grant financial aid under Article 55 (2c) of the ECSC Treaty to further a programme of research in this field.

This programme will be carried out by:

- II.1. (P 075) - (a) Istituto di Ricerche Breda - MILANO
(b) CSM - ROMA
- II.2 (P 078) - HOESCH HÜTTENWERKE A.G. - DORTMUND
- II.3 (P 079) - Fachgruppe "Zerstörungsfreie Materialprüfung"
- II.4 (P 085) - Sté CREUSOT-LOIRE - LE CREUSOT
- II.5 (P 133) - IRSID - ST. GERMAIN-EN-LAYE
HOOGOVENS - IJMUIDEN
- II.6. (P 138) - CRM - LIÈGE.

The appropriations which will be required to cover the ECSC's share in the research and in the costs of disseminating information and related expenditures are estimated at approximately 489.856 u.a.

July 1974

MEMORANDUM

on ECSC financial aid, under Article 55(2c) of the ECSC Treaty,
for a research programme on WELDABILITY

I. INTRODUCTION

Community research contracts for welding projects have so far related principally to fusion welding using filler metal (coated electrodes, MAG, submerged arc welding) and have not covered electron-beam welding. It is true that, at the time the research on weldability started, the process appeared limited as regards both its applications and the materials for which it could be used.

In only a few years, however, electron-beam welding has developed considerably, especially since the appearance on the market of welding equipment with pressure-reducing devices, making it unnecessary to enclose the object to be welded in a vacuum chamber. Plates up to 50 mm thick can now be welded with this equipment. The heavy plate fabricating industry is very interested in the process, which also has extensive applications in welded steel frames.

Published studies are not very informative on the subject of weldability and non-destructive testing in relation to the harmfulness of defects because no very advanced research has been done, priority always having been given to work on welding equipment (electron guns, vacuum chambers, etc.). It is therefore desirable to take stock of the properties the steel should have, the optimum conditions for the execution and heat treatment of welded joints, the assessment of mechanical behaviour and finally methods of weld inspection.

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II. NATURE AND AIMS OF THE PROPOSED RESEARCH

The following programme is proposed for electron-beam (EB) welding:

(a) Review of existing knowledge on the EB weldability of steels

One of the conclusions of this survey will concern the selection of steels for the experiments, not only by grade, but also by steelmaking method, in view of the fact that EB welding involves vacuum melting.

(b) In a second stage, study of the operational and thermal characteristics of the process applied to products about 40 mm thick. The settings (current, voltage, speed) providing the best joint properties will be determined.

The problem of cracking will also be tackled: the type to be studied is hot cracking in the weld metal zone.

After this stage of the study, it will be possible to select, for each steel tested, the optimum welding setting to ensure sound, crack-free deposited metal.

(c) The properties of the weld in the as-welded and treated state will then be studied, in particular:

- the microstructure in the weld metal and heat-affected zones (optical and electronic micrography);
- the range of hardnesses through the joint at different levels, to supplement the micrographic study and facilitate the positioning of notches or cracks for brittle fracture tests;

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- the tensile strength on transverse and longitudinal test pieces, and the impact strength;
- the brittle fracture properties by measurement of KIC or COD, whichever is valid, in the weld metal and heat-affected zones.

(d) The non-destructive testing of welded joints will be studied with a dual aim: the possibilities and limits of defect detection (cracks, fine porosity and above all lack of fusion and an assessment of the dimension of these defects in relation to the fracture toughness of the metal in which they are found.

(d1) Establishment of a list of defects (with position and direction).

(d2) Assessment and comparison of the sensitivity with which the various test methods can detect the defects listed. Possibility of determining the size of these defects by non-destructive testing.

(d3) Comparison of the results obtained with those of the study of the fracture toughness of the metal in which the defects are found (weld metal and heat-affected zones).

The main test methods used (radiography, ultrasonic testing using L and T waves, magnetic techniques) will be applied to both faces of the assembled plate and to longitudinal testpieces. The results will be compared with those of macrographic examinations.

III. OPINION OF THE COMMITTEES OF EXPERTS

After examination by a Subcommittee of Experts and the Iron and Steel Technical Research Committee (TRC) it was decided to make this a top priority project and to propose it for ECSC financial aid.

IV. DURATION AND COST OF THE WORK

Ref.	Title of the research project	Duration	Total budget	Financial aid	
				%	Amount
P111/2	Electron-beam welding	2 years	FF 850 000	60	FF 510 000

V. CONCLUSIONS

In view of the interest shown by the heavy plate fabricating industry in the development of electron beam welding, the Commission of the European Communities plans to grant financial aid, pursuant to Article 55(2c) of the ECSC Treaty, for a research programme on this subject.

This programme will be carried out by the Institut de Soudure, Paris.

The funds required to cover the ECSC contribution to the work and to the costs of dissemination of information and incidental expenditure are estimated at approximately 83.315 u.a.

JULY 1974

MEMORANDUM

on ECSC financial aid, under Article 55(2c)
of the ECSC Treaty, for a research programme on
"WELDABILITY"

I. INTRODUCTION

In many applications, the plate thicknesses and the lengths that have to be welded are constantly increasing, with the result that it is necessary, for economic and technical reasons, to employ welding techniques that cut the number of welding operations to a minimum by dint of a high melting speed.

If this were not done, shrinkage distortions would occur and it would be necessary to resort to preheating, which in applications such as ship-building, bridge construction or the manufacture of welded tubing is regarded as virtually inadmissible.

For plate thicknesses of less than 25 mm, wire-flux combinations are available. The tensile strength and impact strength of the deposited metal satisfy even the most stringent requirements, such as those of the ship classification societies.

For plates of greater thickness, however, it always seems to be more difficult to meet the requirements with respect to welding metal's impact strength.

IV. NATURE AND AIMS OF THE PROPOSED RESEARCH

In the first instance the research consists of a number of welding tests on Si-Al killed 52 steel 35 mm thick conforming to the EH quality specification with respect to composition. The test plates are 1.5 m in length. The width is selected so that the cooling conditions in the weld are the same as for the very large plates which are welded in practical

application (approx. 0.5 m). The test welds are performed by submerged-arc welding, using two wires through which an electric current is passed.

The tests are carried out with several wire-flux combinations which have been approved by the classification societies subject to a limitation on the plate thickness for which the technique can be employed (Class III) (minimum three combinations). Along with the combinations specified by the manufacturers, further tests are performed (approximately six) using interchanged wires in order to determine which wire-flux combination produces a result that can be provisionally regarded as optimum. The flux for this combination will be employed preferentially in the subsequent welding tests, the aim of which is to determine the effect of varying the content of the alloying elements C, Mn, Si, Mo, Al and Nb (or V), (and where appropriate O, P and S) on the structure and mechanical properties of the weld metal. In the course of the programme, 45 test welds will be performed and examined.

III. OPINION OF THE COMMITTEES OF EXPERTS

After examination by a sub-committee of experts and the Iron and Steel Technical Research Committee, it was decided to make this a top-priority project and to propose it for ECSC financial aid.

IV. DURATION AND COST OF THE WORK -- FINANCIAL AID PROPOSED

Ref.	Nature of Research	Duration Years	Total Budget	Financial Aid	
				%	Amount
P 144	Influence of structure and composition on mechanical properties in two-pass flux welding	1	Fl. 235,000	60	Fl. 141,000

V. CONCLUSION

In view of the interest in this research programme, which will afford a fairly comprehensive idea of the influence of the various alloying elements and the optimum composition of weld metal, the Commission of the European Communities plans to grant financial aid for this research programme under Article 55 (2c) of the ECSC Treaty.

The programme will be carried out by the Metallinstituut TNO, Apeldoorn.

The funds required to cover the ECSC contribution to the work and to the costs of dissemination of information and incidental expenditure are estimated at approximately 43,287 u.a.

COMMISSION
OF THE
EUROPEAN COMMUNITIES

July 1974

M E M O R A N D U M

on ECSC financial aid, under Article 55(2c) of the
ECSC Treaty, for a research programme on "CREEP"

I. INTRODUCTION

Work within the European Community to promote the collection and presentation of data on the behaviour of steels at high temperatures on behalf of the steel industry has been carried out for a considerable time by individual countries. From 1966, work has also been carried out on an international basis by the British Standards Institution in assessing and extrapolating data on behalf of ISO/TC 17. This Property Evaluation Unit is now located at the Swinden Laboratories of the BSC, Rotherham.

As a result of the work carried out, internationally agreed minimum yield and proof stress values, and creep rupture properties, have now been agreed for the most common steels for use at high temperatures, some albeit on a tentative basis. In time it is anticipated that these properties will also be incorporated in national standards for these steels, particularly in Europe, and it is generally accepted that future developments must, of necessity, be undertaken on an increasingly collaborative European and international basis.

Thus, the Property Evaluation Unit has available to it completed test data on standard boiler and pressure vessel steels, and it is evident that there are deficiencies in this data that must be remedied by further testing. To meet these deficiencies, therefore, it will be necessary to ascertain what programmes of testing are in progress or planned in the European Community.

II. NATURE AND AIMS OF THE PROPOSED RESEARCH

The object of the proposed research is to establish authoritative properties which are required for the design of plant operating at elevated temperatures. In the case of creep, and creep rupture properties in particular, it is generally not possible for any single organisation to mount and maintain the necessary number of tests, and the quantity of data needed can only be obtained on a collaborative basis. Collaboration exists both on a national and international basis but it is desirable that the ECSC countries should have a common approach to work in this field. A Property Evaluation Unit is needed to collect and analyse the data and it is proposed that the staff and facilities established by the UK steel industry for their national activity should be adapted for this purpose. There is the added advantage that the staff also provide the Technical Secretariat for ISO TC 17.

III. OPINION OF THE COMMITTEES OF EXPERTS

After examination by a Sub-Committee of Experts and by the Iron and Steel Technical Research Committee (TRC) it was decided to make this a top priority project and to propose it for ECSC financial aid.

IV. DURATION AND COST OF THE WORK

Ref.	Name of Research Project	Duration in Years	Total Cost	Financial Aid	
				%	Amount
PO57/2	Properties of steels for high-temperature use	3	£196,200	60	£117,720

V. CONCLUSION

The Commission of the European Communities wishes to encourage efforts to disseminate information and to speed up the exchange of existing technical data between the Members of the Community, and to this end it plans to grant financial aid to a research programme in this field, under the terms of Article 55 (2c) of the ECSC Treaty.

The programme will be carried out by the British Independent Steel Producers Association, London.

The funds required to cover the ECSC contribution to the work and costs of dissemination of information and incidental expenditure are estimated at about 225,845 u.a.

JULY 1974

M E M O R A N D U M

on ECSC financial aid, under Article 55 (2c)
of the ECSC Treaty for a research programme on
"BRITTLE FRACTURE"

I. INTRODUCTION

At its 1973 meeting, the European Pipe Research Group decided that there was a need for a European research programme designed to gather basic information on brittle fracture in steel gas pipe lines for the benefit not only of producers and users but also of the authorities and bodies responsible for inspection.

The full programme consisted of three phases of investigation to meet the needs of the various groups concerned.

II. NATURE AND AIMS OF THE PROPOSED RESEARCH

The joint programme was set out in Doc.III/a-814/73 of June 1973. The main aim is to determine appropriate steel properties from which the fracture behaviour of large-diameter pipes can satisfactorily deduced in practice.

The research is divided into four parts:

- (i) laboratory tests on model tubes;
- (ii) laboratory tests on flat plates;
- (iii) tests on large-diameter tubes;
- (iv) a study of fracture mechanics with a view to characterizing steels.

A supplementary programme, proposed in doc.78/III-A/74 of February 1974, is for the study in greater detail of a number of anomalies which were brought to light during previous tests.

It emerged that modifications and improvements were needed to the existing test rig before full-scale bursting tests on large-diameter gas pipes could be carried out. To achieve this, additional financial aid is requested for this modification.

III. OPINION OF THE COMMITTEES OF EXPERTS

After examination by the Iron and Steel Technical Research Committee it was decided to make this a top priority project and to propose this research for additional ECSC financial aid.

IV. DURATION AND COST OF THE WORK - FINANCIAL AID PROPOSED

Ref.	Title of Research	Duration Years	Total Budget	Financial Aid	
				%	Amount
P 063	Fracture of gas pipes	1½	DM 345,176	30	DM 106,253

V. SUMMARY

There is clearly a technical and economic need for a proper understanding of brittle fracture phenomena particularly as the size of structures being used is increasing. The Commission of the European Communities plans to grant additional financial aid under Article 55 (2c) of the ECSC Treaty for a research programme in this area. The programme will be carried out by VDEh, Düsseldorf.

The funds required to cover the ECSC contributions to the work and to the costs of dissemination of information and incidental expenditure are estimated at 33,992 u.a.

JULY 1974

M E M O R A N D U M

concerning ECSC financial aid, under Article 55 (2c)
of the Treaty, for a research programme in the field of
"HIGH-STRENGTH STEEL PLATES" of medium thickness
(10 to 60 mm)

1. INTRODUCTION

Within the last decade, there has been considerable growth in the new family of structural steels for making plates of quenched and tempered steels.

The market of interest is centred to a large extent on such activities as the fabrication of pressurized tanks, storage tanks, pressure-resistant piping and also special frame structures such as long-span bridges and crane booms.

Production in the Community is behindhand in comparison with that in the United States and, particularly, in Japan, which alone produces about five times (500,000 t) the tonnage produced in the Community. Competition is extremely keen and is liable to become more and more intense on this market, from which the Community may find itself ousted.

The Community is currently importing 100,000 t of quenched and tempered steels and will probably consume 250,000 t in 1978. If no effort is made as regards production, this will only amount to 150,000 t for the Community.

This market will be completely open to competition from Japan, since, although America is a large producer, its production is entirely absorbed by its own domestic market. (America even has to import from Japan as well).

It is therefore desirable, for a Community-scale effort to be made in this field, both in investing in production and in studying means of utilization.

From the technical point of view, numerous specifications and codes now define the characteristics of the existing grades of steel.

We are, however, witnessing a significant phase of development in the market; constructors have not only overcome their reservations about using these steels but have become aware of the benefits to be derived as regards creating structures to meet increased requirements, particularly from the point of view of load capacity. It is now becoming necessary to advance beyond this first "generation" of quenched and tempered steels and develop a second "generation", better suited to current needs.

II. NATURE AND AIMS OF THE PROPOSED RESEARCH

The proposed research is divided into two main parts:

- (a) research on improving existing grades; this work would be assigned to BSC, CSM and VDEh;
- (b) development of new grades (i.e., new as far as the Community is concerned) to provide a means of combating the virtual world monopoly of the Japanese in this field; this work would be assigned to VDEh and Creusot-Loire.

(a) Research on improvement of existing grades

(1) Work proposed by BSC

The programme proposes that only weldable steels with a strength from 420 to 490 N/mm² be included, since they represent both the greatest growth potential and the area in which competition from outside will probably be strongest.

It is assumed that the basic types of steel are already known and produced, and in consequence the work should focus mainly on the steel plates commercially produced by a number of European sources using available steels of all strengths made by different manufacturing processes. An important characteristic of this programme is that it groups steels according to strength and not according to process. In this way normalized, rolled, controlled and refined (fully killed) steels with a strength of 420-490 N/mm²

could be supplied according to thickness. Considering the limited quantities currently being supplied by European steelworks for structural applications, it would be highly desirable to compare these three processes in order to be able to determine the advantages and the performance characteristics of each of them.

The types of grade that it is hoped to study come under the following basic categories:

<u>Grade</u>	<u>Manufacturing Method</u>	<u>Type of Steel</u>
420 N/mm ²	Normalized steels	V/N steels; V alloyed steels
	Control-rolled steels	Nb-(V) steels; Nb-V-(Mo) steels
	Refined steels	V-N steels; Mo(V) steels Nb-(V) steels; boron steels
490 N/mm ²	Refined steels	V-N steels; Mo-(V) steels
	Control-rolled steels	Nb-(V) steels; boron steels
	Normalized steels	Nb-V-Mo steels Alloyed V steels

Thickness

It is proposed that a study be made of the three current thicknesses, i.e., 25 mm, 40 mm and a range of thicker steel plates, varying from 50 to 63 mm. These thicknesses represent the main tonnage used for structural applications such as tanks, bridges and marine platforms. It is thus hoped that, at a strength of 420 N/mm², normalized steels and refined steels will be available in all thickness ranges and that control-rolled steel will be available in thicknesses up to 40 mm. At a strength of 490 N/mm², refined steels and, in certain cases, control-rolled steels (of limited thickness) will fulfil the criteria and normalized steels of relatively high CEV (Charpy Energy Value) will also be available.

Aim of the proposed programme

Steels - The aim of this programme is summarized in the table below, which gives the figures to which the basic grades, the manufacturing methods and the thicknesses have to correspond.

Grade	Normalized	Thickness levels	Control-rolled	Thickness levels	Refined	Thickness levels	Total
420	2	3	2	2	4	3	22
490	2	2	1	2	4	3	18
10 m ² by sheet test				Basic grades, etc.			40
				Number of steel plates tested			50

A further feature of this programme is that steels from several European sources may be examined within the 40 different basic forms from the point of view of grade and thickness. Accordingly, at certain basic grade/thickness levels, steel plates will be provided in duplicate so that, where necessary, nominally equivalent plates can be tested - for example, a plate from one rolling mill in comparison with another from a second rolling mill. The precise origin and the distribution of the samples to be tested will be decided by agreement with the manufacturers involved.

(2) Work proposed by CSM

The research will concern steel plates 40 mm thick with a strength of 40-50 kg/mm² used to construct pressure boilers and petroleum storage tanks.

This should enable a direct comparison to be made between the actual behaviour of the material in service and its behaviour during the acceptance-testing operations required in order to check the quality of the steel plates supplied. The results of these tests could also be used by the ECSC W.G. on the standard code for greater precision in the current definitions of the code.

The influence of the manufacturing conditions, i.e., cold-working, welding and attenuation treatment, will be determined as a function of the final mechanical properties and of the crack-corrosion resistance of steel plates of different original metallurgical structures (refined, normalized, control-rolled).

The main characteristics of the steel plates to be studied are: thickness - 40 mm; strength - 40-50 kg/mm²; manufacturing conditions - refined, normalized, control-rolled.

Samples of these plates will be subjected to work cycles similar to actual manufacturing conditions. The comparison will be established on the basis of ordinary mechanical characteristics, lamellar tearing resistance and fracture toughness tests (initiation and propagation) in the temperature range between -20 and +250°C.

As already mentioned, resistance to crack corrosion in H₂S will also be calculated.

(3) Work proposed by VDEh

It would thus seem to be particularly desirable to carry out systematic studies on these high-strength steels for which minimum limit-elongation values are guaranteed, these being in the upper region of the values known at present for the fine-grained structural steels normally used, i.e., about 420-490 N/mm². This would, on the one hand, provide answers to questions of general importance and, on the other hand, afford wider experience on the basis of which to master the economic processes of converting steels of this degree of strength, to reinforce the confidence of those who work the steel, and to open up new ways of utilizing steels.

It is accordingly proposed that testing materials be used consisting of two ordinary fine-grained structural steels with a minimum limit-elongation value of 480 N/mm² for a thickness of 30 mm, one having a chemical composition based on Ni-V, normalized and tempered at delivery, and the other with a chemical composition based on Cr-Mo-B, quenched and softened in their as-delivered condition. These two steels should reach the following minimal values with regard to their mechanical properties at ambient temperature:

Steel	Heat Treatment	Elongation Limit	Tensile Strength	Elongation at break	Impact strength	
		For 30 mm thickness (N/mm ²)		(L ₀ = 5 d ₀)	Longitudinal	Transversal
					J	J
A	900°C/ air ₀ +600 C	400	560	17	51	31
B	900°C/ water ₀ +650°C	480	560	17	63	39

Identical testing materials will be available in sufficient quantity for the studies to be performed within the framework of the British Steel Corporation's research project.

(a) Development of new grades

(1) Work proposed by VDEh

The use of high-strength weldable steels is gaining in importance in the construction of superstructures and bridges, of cranes and pressurized tanks, as well as in the technique of off-shore drilling. At present, there is a preference for using fine-grained steels, which, when normalized, have minimum elongation limit values of up to 500 N/mm². Nevertheless, the necessity of having weldable steels available which, for such a high strength, have even better hardness is becoming urgent. In addition, in numerous steel-using fields there is a growing interest in fine-grained, weldable structural steels of greater strength which, however, have not suffered any appreciable decrease in hardness.

This condition seems capable of being fulfilled if the steels are first quenched in water or oil and then tempered. The increase in strength, by acting on the structures, has the particular advantage that a high level of hardness is also obtained.

During the quenching and tempering treatment, however, account must be taken of the fact that the strength properties depend more on plate thickness than in the case of normalized steels. The effect of the plate thickness is related to the fact that adequate quenching and tempering are only obtained

on the parts of the section where the abrupt cooling of the surface by the quenching liquid still permits an adequate cooling rate. With increasing plate thickness, complete through hardening followed by tempering can only be achieved if there is a high alloying elements content. On the other hand, however, the content of carbon and alloying additives is limited by the degrees of weldability required.

We are thus faced here with two contradictory requirements which, having regard to the desirable plate thicknesses, necessitate the manufacture of steels of optimum chemical composition. In the present state of knowledge, it would be advisable to study the influence of the content of carbon, chromium, molybdenum, nickel and vanadium. It seems both indispensable and urgent to undertake systematic research along these lines.

It is proposed that within the framework of this research programme studies be performed on three experimental batches with three different basic compositions having progressively modified contents of molybdenum and vanadium.

(2) Work proposed by Creusot-Loire

This involves carrying out research, within a thickness range between 10 and 60 mm, to find a class of products which will make it possible to comply with the new requirements from the economic standpoint. The main requirements are: an increase in the tensile strength properties (an elastic limit of 60-80 kg/mm² is aimed at), better resistance to embrittlement, better fatigue resistance and greater ease of working, especially in welding.

The proposed research is divided into three phases:

- First of all, study will be made of the characteristics of a quenching facility operating in a laboratory and enabling products to be obtained which meet the tolerances defined by the standards.
- The second phase will consist in using 20 kg experimental castings to understand the development of tensile characteristics and also service properties such as brittleness and weldability.
- The last phase will require the industrial production of a small number of castings for the characterization of these grades, in order to verify the quality of the simulations, and a study in depth of the service properties.

The research will be performed mainly in the laboratories and work-shops of the Creusot plant, particularly as regards steel production and platemaking. Plenty of equipment is available in the laboratory for all fields of the research under consideration. The laboratory specializes in the study of structural steels and their various uses. If necessary, assistance can be requested from the Imphy and Unieux research centres for certain special investigations such as electron microscopy.

III. OPINION OF THE COMMITTEES OF EXPERTS

After examination by a sub-committee of experts and by the Iron and Steel Technical Research Committee (CRT), it was decided to make this project a top-priority in a collective programme and to propose it for ECSC financial aid.

IV. DURATION AND COST OF THE WORK - PROPOSED FINANCIAL AID

This collective programme (P 050), with the title "Industrial development of high-strength steel plates of medium thickness", will be implemented over a period of three years.

The breakdown of the budget will be as follows:

	Total Budget	Duration (Years)	Financial Aid	
			%	Amount
BSC	£ 210,894	3	60	£ 126,537
CSM	Lit 142,280,000		60	Lit 85,368,000
VDEh Part A	DM 867,500		60	DM 520,500
Part B	DM 716,400		60	DM 429,840
Creusot-Loire	FF 2,337,500		60	FF 1,402,500

V. SUMMARY

To defend the Community's position in world competition in the field of producing and utilizing high-quality steel plates (quenched and tempered steels), the Commission of the European Communities intends to accord financial aid, under Article 55 (2c) of the ECSC Treaty, for a research programme in this field.

This programme will be implemented by:

- 2 (a) (1) - BSC
- 2 (a) (2) - CSM
- 2 (a) (3) - VDEh
- 2 (b) (1) - VDEh
- 2 (b) (2) - Creusot-Loire

The funds required to cover the ECSC contribution to the work and to the costs of dissemination of information and incidental expenditure are estimated at 883,286 u.a.

JULY 1974

M E M O R A N D U M

on ECSC financial aid, under Article 55 (2c)
of the ECSC Treaty, for a research programme on
"PHYSICAL METALLURGY"

I. INTRODUCTION

The three proposals submitted for aid in this research field relate to:

- precipitation hardening steels;
- structural and mechanical properties of low-carbon bainitic steels;
- carburization and decarburization of alloy steels.

The first two proposals will provide valuable background information on the influence of dispersion strengthening additions and of bainitic microstructures respectively that is needed for the further development of improved weldable high-strength steels. The third project deals with the carburization and decarburization problems that occur in case hardening steels and in the heat treatment of constructional and various alloy steels.

II. NATURE AND AIMS OF PROPOSED RESEARCH1. Precipitation hardening steels

Research on precipitation hardening steels has been supported by the Commission since 1966 and this proposal forms the basis of the third cooperative programme in this field. The work to date has shown the value of dispersed phases on mechanical properties and it is now necessary to rationalise the use of these additives. A systematic study has been proposed to investigate the properties of a range of steels to examine the effect of such factors as composition with respect to interstitial content and microalloying addition and heat treatment. The proposed cooperative programme consists of five parts, to be carried out by the BSC, CRM, MPI, IRSID and CREUSOT-LOIRE respectively.

1.1. BSC Project

It is proposed to study high-strength structural steels over a range of carbon contents with a matrix composition of 1.5% Manganese and controlled additions of niobium (0.05 - 0.18 wt.%) and titanium (0.15 - 0.22 wt.%).

In addition to examining the influence of austenitising temperature, the microstructural changes during hot rolling will be studied to assess precipitation and grain-size changes. The effects of varying the cooling rate to room temperature after hot rolling will be investigated.

Tensile and impact properties will be evaluated together with a detailed optical and electrometallographic study of the resulting microstructures.

The steels and heat treatments selected for investigation are expected to give properties required in applications for high strength strip and high gauge plate.

1.2. CFM Project

It is planned to study the effect of elements that form dispersoids on the mechanism of ductile and brittle fracture in structural steels.

A series of carbon-manganese steels with controlled additions of niobium (0.02 - 0.03 wt.%) and vanadium (0.04 - 0.08 wt.%) will be investigated.

The experimental programme will include:-

- hot rolling and various thermal treatments to produce a range of microstructures and ferrite grain sizes;
- instrumented Charpy impact tests to assess toughness;
- tensile property evaluation;
- optical and electron metallographic study using scanning electron and transmission microscopes.

The results should enable quantitative relations to be established between microstructure (grain size, precipitate distribution) and tensile and impact properties.

1.3. MPI Project

It is proposed to investigate two main aspects of precipitate behaviour in steels:

- to determine the maximum content of AlN, TiN and TiC required for grain refinement and the maximum temperature at which grain growth can be prevented;
- to study model alloys to determine the mechanism whereby particles hinder grain growth with the aim of evaluating the influence of various phases on grain growth.

The experimental work will include a study of carbon-manganese steel (0.2 wt. % C, 1.5 wt. % Mn) containing controlled additions of Ti, Al and N. In this way the influence of the austenitising temperature on austenite grain size will be investigated in a range of alloys containing varying amounts of TiN, AlN and TiC.

A study will also be made of model alloys in which the austenite is stable at room temperature so that the role of specific precipitates on grain growth can be unambiguously assessed.

1.4. IRSID Project

The proposed investigation will consist of two parts:-

- a study of the influence of elements that influence hardenability, such as molybdenum, on the precipitation of niobium and vanadium in carbon-manganese steels (0.1 wt. % C, 1.4 wt. % Mn), together with a study of resulting mechanical properties and
- a study of the influence of copper (0.2 - 1 wt. %) on the mechanical properties of carbon-manganese steels to include an examination of the precipitation mechanism.

Subsequently, additions of elements which increase hardenability will be made, if necessary, to study the effects of copper in bainitic and martensitic microstructures.

1.5. Creusot-Loire Project

The results already obtained have shown that the precipitation of carbonitrides of vanadium during the cooling of a carbon manganese steel (16Mn 4 type) has a maximum at a specific cooling rate, leading to a mixed ferrite-bainitic microstructure.

It is now proposed to examine this phenomenon further in steels of varying hardenability with or without additions of vanadium. The influence of other dispersoid-forming alloying elements, e.g., niobium, on kinetics of precipitation of these carbo-nitrides will be studied along with an evaluation of the resulting mechanical properties (tensile and impact tests).

2. Structure and mechanical properties of low-carbon bainitic steels

During the course of the last ten years, much research has been carried out for the purpose of optimizing the properties of steels of ferrite-pearlite structure. A particular aspect of the demands of weldability and toughness has been to cause contents of carbon and alloying elements in this type of steel to bend downwards.

In view of the importance of these demands, a joint research programme has been drawn up by ARBED, CRM and IRSID.

The aim of this research is to develop some of the potential applications of low-carbon bainitic structures in their various fields: tube plate, deep-drawing sheets, general-purpose weldable structural steels.

2.1. Programme IRSID

The aim of the proposed study is to evaluate the development structure/mechanical properties relationships in connection with the morphology of bainite and bainite-martensite structures.

In order to vary appreciably the fineness and morphology of bainite and bainite-martensite structures in the thermomechanical treatments laboratory will likewise have to be employed.

The programme includes three main sections:

- characterization of the hardenability and bainitic conversion kinetics as a function of the composition studied;
- comparative study of the microstructures obtained under isothermal conditions, during continuous cooling and after thermomechanical treatment;
- study as tempered of the behaviour of the structures previously characterized.

The basic composition will be of the type C-0.07%, Mn-1.4%, Mo-0.5%. The hardenability will be modified by the addition of either or both of chromium and nickel up to 2%.

2.2. CRM Programme

A study will be made of the effects on the formation and properties of bainite or acicular structures (with the exception of martensite) of the following factors:

- the effect of a deformation occurring before allotropic conversion during the final cooling-down. Here two aspects may be considered - hot deformation (in the austenite phase), or cold deformation before reheating in the austenite phase;
- The effect of the heating speed and the temperature reached. These two factors are capable of considerably modifying the condition of the austenite (chemical homogeneity, dissolving of precipitates, grain size, work-hardening distribution, etc.);
- effect of the cooling speed and the chemical composition of the steel. These two factors are capable of being modified to some extent in order to allow the formation of the required bainitic structures.

The basic composition will be of the type 0.050% max. - C, 0 - 1% Mn and, where applicable, 0.5% max. Cr and B.

2.3. ARBED Programme

A low-carbon steel with Mn-Mo-Nb which forms an acicular ferrite or bainite structure, and which is used for the manufacture of large-diameter tubes from hot-rolled strip, will be studied. As in the case of long products, it will not be possible to exploit the possibilities offered by controlled cooling of coils. Various ways and means of achieving a high tensile strength will be studied:

- as regards the Mn-Mo-Nb basic formula, the incidence of increasing carbon contents, 0.05, 0.10 and 0.15%, will be examined;
- As regards the lowest carbon content, an investigation will be conducted into the effect of the addition of B, either alone in combination with titanium, which, where appropriate may replace niobium.

3. Effect of alloying elements on the carburization and decarburization processes in steels during heat treatment

Heat treatments have a decisive effect upon the grade of many steel types.

Thus for the case-hardening group of steels, a high surface hardness with a corresponding core toughness is increasingly achieved via gas carburization and subsequent direct quenching. Mention should also be made of the hardening and tempering of structural mar-aging steels and the hardening and solution heat-treatment of mar-aging steels.

In all these technical annealing processes, reactions take place between the gas phase and the steel which may engender to some extent desirable but to some extent undesirable steel properties.

Carbon plays a dominant role in these interactions.

By means of a controlled gas-metal reaction, it is possible to regulate the quantity and also the distribution of the carbon as desired. As a rule, however, it is not sufficient to know merely the concentration where carbon diffusion is concerned. The carbon activity, as a function of the temperature and concentration of the other elements present, must also be known.

The purpose of this research is thus to establish exact working conditions, based upon thermodynamic parameters and phase diagrams, for the heat treatments of various types and grades of steel. The results should give rise to a better yield and improved adaptation of steel to its service conditions.

The research includes an investigation of steels with additions in controlled amounts of the elements Ti, Nb, V, W, Cr and Mo.

III. OPINION OF THE COMMITTEES OF EXPERTS

After examination by sub-committees of experts and by the Iron and Steel Technical Research Committee (CRT), it was decided to make these top priority programmes and to propose them for ECSC financial aid.

IV. DURATION AND COST OF THE WORK - PROPOSED FINANCIAL AID

Ref.	Title of Research	Duration Years	Total Budget	Financial Aid	
				%	Amount
P 096	Precipitation hardening steels	3	IM 520,000	60	IM 312,000
			FB 10,000,000	60	FB 6,000,000
			FF 833,000	60	FF 499,800
			FF 850,000	60	FF 510,000
			£ 83,750	60	£ 50,250
P 105	Structure and mechanical properties of low-carbon bainitic steels	3	FF 1,100,000	60	FF 660,000
			FL 3,000,000	60	FL 1,800,000
			FB 5,000,000	60	FB 3,000,000
P 106	Influence of alloying elements on the carburization and decarburization of steels during heat-treatment	3	IM 243,500	60	IM 146,100

V. CONCLUSIONS

The proposed research into precipitation hardening and low-carbon bainitic steels will provide the necessary basic information required for the further development of these two important classes of high-strength structural steels. While steels based upon these strengthening mechanisms are already used in a wide variety of engineering applications, there is a continuing need to improve properties and to optimize compositions, particularly in weldable grades. The close relationship between these two proposed studies is recognized and it is envisaged that the work on both projects will be closely co-ordinated.

The third proposal will provide a better understanding of the carburization and decarburization process which will be most valuable in relation to the improvement of both heat-treatment practice and the resulting properties of a wide range of engineering steels.

In view of the importance of such potential developments, the Commission of the European Communities plans to grant financial aid for this research under Article 55 (2c) of the ECSC Treaty.

This work will be carried out by:-

- P 096 - BSC (Rotherham)
CRM (Liège)
MPI (Düsseldorf)
IRSID (Paris)
CREUSOT-LOIRE (Le Creusot)

- P 105 - IRSID (Paris)
CRM (Liège)
ARBED (Luxembourg)

- P 106 - DEUTSCHE EDELSTAHLWERKE (Krefeld).

The funds required to cover the ECSC contribution to the work and to the costs of dissemination of information and incidental expenditure are estimated at about 744,359 u.a.

COMMISSION
OF THE
EUROPEAN COMMUNITIES

JULY 1974

MEMORANDUM

on ECSC financial aid, under Article 55(2c)
of the ECSC Treaty, for a research programme on
"USES OF STEEL: METAL STRUCTURES"

I. INTRODUCTION

The development of the uses of high elastic limit steels in metal structures calls for a definite effort to acquire a better knowledge of these steels for the purpose of achieving better performances in metal frameworks.

Moreover, the question of thin walls in box girders and I-beams still lacks any systematic treatment at the international, or at least at the European, level.

On the theoretical side, the literature of the subject is very extensive, but it can be classified under three main headings:

- the German group, which, thanks to the work of Kloppel and his school, presents a vast collection of cases in the context of the linear theory of wall panels and stiffeners;
- the American group, exponents of the Balser and Thurlimann calculation method, which tends to space the longitudinal rigidities of the walls as widely as possible;

- the Swedish group, which has compiled rules enabling thin walls to be made without stiffeners with web slenderness ratios exceeding 300.

II. NATURE AND AIMS OF THE PROPOSED RESEARCH

1. The stress-strain diagram for metal frameworks

This coordinated programme comprises:

- (a) A theoretical study in the form of a numerical computer simulation of the behaviour of structures in the elastoplastic zone. It consists of an approach by finite elements, account being taken of the residual stresses in the sections, for the purpose of determining the quantitative effects of the main parameters derived from the stress-strain diagram on the plastic redistribution capacity of the stresses and, on the instability behaviour of steel sections.

In addition, an experimental programme will be launched on a range of products with elastic limit/tensile strength ratios varying from 0.65 to 0.90. The experimental part is aimed at verifying throughout the theoretical study the validity of the models under investigation.

- (b) Study of the interaction between the elastic limit/tensile strength ratio and the total plastic deformation in the presence of polyaxial stresses. It should thus be possible to determine the minimum elongation-at-break requirements as a function of the R_e/R_r ratio and the stress concentrations in the vicinity of cross-sectional reductions.

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The research consists in an analytical study designed to analyse by computer the elastoplastic zone in perforated or notched plates. The experimental part is aimed at determining the tensile behaviour of rectangular plates containing stress-raisers. Different thicknesses and types of steel will be examined.

2. Optimization of the stiffeners in beams with thin solid walls

As regards the theoretical aspect of the problem, the research programme comprises:

- (a) systematic collection of the more recent and significant theoretical works, in cooperation with all the countries concerned;
 - further theoretical study of post-critical behaviour with a view to introducing, as in Sweden, regulations on ribless girders with thin webs for roofing structures which are not subjected to dynamic loads or to force phenomena. This process may be extended to post-critical behaviour, and this type of application is at present being studied.
- (b) From the experimental point of view, even though a number of interesting studies exist (some of them already considered classical: American, Swedish, Belgian), a more systematic study is proposed. This would be carried out on standard wall panels, and would embrace the following activities:
 - research on the static behaviour of the plane wall in the critical and post-critical range up to the point of collapse, after single and combined stresses (respectively pure bending and bending plus shearing), as a function of its flexibility and initial configuration;

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- evaluation of the effect of welded stiffeners (vertical and horizontal) on the linear and non-linear critical behaviour and recording of the stresses in these stiffeners;
- to experiment with new types of stiffener such as X-shaped indentations, flanged holes, etc., which offer economic advantages over the traditional solutions even though they are limited to the field of very thin walls.

III. OPINION OF THE COMMITTEES OF EXPERTS

After examination by the Sub-Committee of Experts and the Iron and Steel Technical Research Committee (CRT), it was decided to make this a top-priority project and to propose it for ECSC financial aid.

IV. DURATION AND COST OF THE WORK - FINANCIAL AID PROPOSED

Ref.	Research project	Duration	Total cost	Financial aid	
				%	Amount
P.110	Stress-strain diagram of steels for metal frameworks				
	(1a)	2 yrs	FL 4 400 000	60	FL 2 640 000
	(1b)	2 yrs	FL 200 000	60	FL 120 000
p.136	Optimization of stiffeners in beams with thin solid walls	2 yrs	Lit 40 950 000	60	Lit 24 570 000

V. CONCLUSION

In view of the importance of this research in promoting the use of higher-performance steels and of thin-walled beams in metal structures, the Commission of the European Communities proposes to grant financial aid, under the terms of Article 55(2e) of the ECSC Treaty, for a research programme in this field.

This programme will be carried out by:

II(1a), p 100 : ARBED, Esch sur Alzette

II(1b), p 110 : TNO, Delft

II(2), p 136 : CISIA, Milan.

The funds required to cover the ECSC contribution to the work and to the costs of dissemination of information and incidental expenditure are estimated at about 123,637 u.a.

JULY 1974

M E M O R A N D U M

on ECSC financial aid, under Article 55 (2c)
of the ECSC Treaty, for a research programme on

"DIRECT REDUCTION"I. INTRODUCTION

About two-thirds of today's steel production is based on pig iron and about one-third on scrap. Apart from the increasing costs of metallurgical coke, scrap prices in particular are pushing up crude steel production costs. Consequently, growing significance is being attached to direct reduction as an alternative to the blast furnace.

Due to the availability of primary energy sources, direct reduction processes which use a solid reducing agent or are based on the conversion of solid fuels offer the best long-term prospects in Europe. The SL/RN process is based on the use of unconverted solid fuel.

To date, the SL/RN process has not been tried out on an industrial scale in Europe. Existing plants in Brazil, South Africa and New Zealand use either a completely different type of fuel or special ores such that the results are not valid for European conditions.

II. NATURE AND AIMS OF THE PROPOSED RESEARCH

In 1970 energy consumption in the European Community was 1,164 million tce. The expected energy consumption for 1980 is 1,891 million tce. It should be remembered, however, that dependency on imports will continue to grow and will even reach 98% for some energy sources (e.g. oil).

The proposed research is therefore designed to investigate whether highly volatile indigenous coal can be used as a reducing agent in the direct reduction process. The proposal is to use brown coal from the Rhine area, the double advantage of which is its availability (55,000 million t) and its cost (approximately DM 11/Coal when dried and briquetted).

In preliminary experiments which were carried out in a pilot plant by the Lurgi company in Frankfurt, pellets and lump ore have been reduced with brown coal. From the point of view of both the sponge iron quality and energy consumption the results were generally very encouraging. The results cannot, however, be extrapolated for a full-scale plant.

There is now the opportunity for a full-scale trial using the SL/RN rotary furnace belonging to ACOS FINOS PIRA TINI in Brazil which is designed to produce 65,000 t sponge iron/year, as one of the associated melting plants used for steel-making is out of action.

Under the research proposal, therefore, 2,000 t sponge iron could be produced; the existing pellets would continue to be used but the fuel would be replaced by highly reactive brown coal briquettes from the Rhine area. To produce 2,000 t of sponge iron requires an experimental campaign lasting from fourteen days to three weeks. In particular, the following points should be investigated:

1. The transportability of highly volatile brown coal.
2. Metering the coal in the rotary furnace.
3. Maximum throughput to produce sponge iron at 93% metallization.
4. Energy consumption in steady operation.
5. Fe-yield and decomposition behaviour of the coal and ore.
6. Desulphurization in the rotary furnace.
7. Temperature and reduction profile throughout the furnace length.
8. Waste gas and dust measurements.
9. Reoxydation behaviour of sponge iron produced with highly volatile reactive coal during storage, handling and transportation.

The reduced pellets are to be finally melted down on a "Contimelt" plant in Bous (Saar area).

The results should also be interesting in connection with the use of other cheap highly volatile coals in direct reduction; from an economic point of view, English steam coal (approximate price DM 10/G cal) and American low-grade coal (approximate price DM 15/G cal) are worth particular mention.

III. OPINION OF THE COMMITTEES OF EXPERTS

After examination by the Iron and Steel Technical Research Committee, it was decided to make this a top priority project and to propose it for ECSC financial aid.

IV. DURATION AND COST OF THE WORK - FINANCIAL AID PROPOSED

Ref.	Research	Duration Years	Total Budget	Financial Aid	
				%	Amount
P 146	Use of brown coal for direct reduction in a SL/RN plant	1	DM 2,144,780	60	DM 1,286,868

V. SUMMARY

Due to the growing shortage and increased cost of coke and scrap the direct reduction process is becoming more and more significant.

In this context an investigation should be carried out to ascertain whether cheap indigenous energy i.e., brown coal can be used in the SL/RN process.

The total energy consumption is estimated at 4.6Gcal/t sponge iron. If the waste gas is exploited, approximately DM 12 to 13/t can be recovered (based on European locations).

The Commission of the European Communities recommends this research for supply and energy policy reasons and proposes financial aid under Article 55 (2c) of the ECSC Treaty.

The research is to be coordinated by Mannesmann AG, Düsseldorf.

Direct reduction tests are to be carried out in Brazil by the ACOS FINOS PIRANTINI Company and sponge iron melting tests by the Bous Steel and Tube Works on the Saar.

The funds required to cover the ECSC contribution to the work and to the costs of dissemination of information and incidental expenditure are estimated at 411,667 u.a.