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STEEL IN THE CHEMICAL INDUSTRY

FOURTH STEEL CONGRESS

(Luxembourg 9-11 July 1968)

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The behaviour of steels subject to extreme chemical and physical stresses

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SECRETARIAT GENERAL OF THE COMMISSION

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Address
by M. Jean Rey
President of the Commission of the European Communities

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Ladies and Gentlemen,

It falls to me in the first place, in opening the initial Session of the Fourth ECSC Congress on the theme of Steel in the Chemical Industry, to welcome the Grand Duke and Grand Duchess of Luxembourg, and to thank them for graciously consenting once again to be present at the commencement of this notable gathering.

The fact, Sir, that you are with us today signalizes the importance and the character of the occasion, and my colleagues and myself are impressed by this further token of the Luxembourg Sovereign's interest, not only in all matters directly concerning his own country, but also, from the very outset, in all that concerns the European Institutions and the advance towards the organization of our Continent. May I say, therefore, how greatly we appreciate Your Royal Highnesses' presence: our sincere and humble thanks.

Next I would address myself to the Prime Minister. Monsieur Werner, we are honoured to have you in our midst. Speaking both for my predecessors and for my fellow-Members of the present merged Commission, I should like to say how much we value the care and thought which you and your Government have given for so many years to everything connected, first, with the High Authority and the European Coal and Steel Community here in Luxembourg, and now to the three Communities in process of amalgamating. You have given every proof of friendliness and favour. You have been of the greatest assistance to us in the organizing of this as of the previous Congresses: thank you, and thank you, too, for your kindness in agreeing to preside at the reception for us this evening in the impressive and historic setting of the ancient Abbey of Echternach.

Next, a heartfelt tribute to the Executive whose place my colleagues and I now fill, the High Authority, set up in this city sixteen years ago, in 1952, as the first of the European Institutions, the first body to establish the interlocking of European Executive, member Governments and European Parliament — the Parliament represented here today by M. Wohlfart. For all the many notable new departures it initiated we owe a deep debt of gratitude to the High Authority and to its Members, both those who are still with us on the Commission and those who, for various reasons, are not. To each and all of them I would express our profound sense of the excellent work the High Authority did — including the convening of this series of Steel Congresses, an eminently worth-while idea, well carried out.

To Prof. Dino Del Bo, the last President of the High Authority and originator of the Congresses, our thanks must go for what he achieved during a difficult period. I am sure I speak not only for myself but for the rest of the Commission, including my friend Guido Colonna di Paliano, who is the Member with responsibility for the main industrial questions, when I say that the fact of our being here today is indicative of the Commission's resolve to proceed with the enterprising projects started by the High Authority. Naturally our approach will be somewhat different. The ECSC Treaty being framed as it was, the High Authority was concerned primarily with coal and steel: our approach must necessarily be broader, since we are concerned with all sectors of the economy. But even so, the High Authority, rightly venturing outside the limited domain prescribed for it, had begun the arranging of this Congress which, I would remind you, involves two sectors the one coming under the ECSC Treaty and the other under the Treaty of Rome. We for our part, required though we are to deal with a wider field than our predecessors, shall continue to give just as active attention to these major sectors of such importance to industry in our countries generally and to scientific research.

And finally, I thank my very good friend the Chairman, Dr. Campilli, for his willingness to serve in this capacity. The earlier Congresses were chaired, the first by M. Jeanneney, the second by Herr Etzel, the third by Count Moens de Fernig, and now at the fourth we have the good fortune to have Dr. Campilli, with his distinguished record of public service in his own country and his Community experience as first President of the European Investment Bank.

I should now perhaps turn to speak of the actual matters the Congress is to deal with, but I shall not do so, because I do not wish to make my opening remarks too long, or to anticipate what those directly in charge of the proceedings are going to say.

There are just three points I want to make. The first is that the Congress bestrides the border between two great industries, both growing yet with different parts to play and different futures before them. Likewise it is on the border between the world of research and the world of industry, and so has to do with questions that are, in this day and age, in the very forefront of our thoughts and of our wish to know more, intellectually, economically and politically.

My second point is that an adequate follow-up on the matters which are to be debated in the next three days cannot conceivably be accomplished on an individual national basis: it will need a European basis. For steel, the tariff walls have long been down; for chemicals, they were finally abolished a few days ago, on 1 July. But the mere fact of a large market is not enough: that market has to be organized, and it is with this task of market organization that the European Executive must in particular concern itself. We cannot afford to rest on our laurels of 1 July: we must see to it that our researchers and our industries are provided with organized facilities within the enlarged market we have established. To give only two examples from among many, it still remains, first — and perhaps foremost — to do away with fiscal barriers, and second, to institute the legal machinery for the formation of European joint-stock companies. In this latter respect, too little has been achieved up to now, and it is vital that real progress be made in the months ahead in order that Europe should at long last be properly equipped for economic and industrial development.

My last point concerns the timing of this Congress. The Congress is meeting a few days after the important date of 1 July, when the Community customs union was completed. The fact is no doubt a little — but I hope only a little — shadowed by the troubles of one of our members. In the last few days, restrictions have had to be imposed, or have had to be authorized, by the Commission among others, in matters having a very direct bearing on the economic affairs of the Community as a whole. I think I can say that, as we and Paris both see it, these measures are limited, unintended, temporary, not such as to interfere with the instrinsic operation of the customs union.

We very much hope that by the end of the year they will already be no more than an unhappy memory. At all events, the Commission will make sure that the barriers which have just had, unavoidably, to be reintroduced are kept to the absolute minimum.

Apart from this, 1 July stands out as a great day, the day of our attainment, eighteen months ahead of the Treaty's schedule, to the customs union, the common external tariff and the first Kennedy Round cuts — a major economic and political combination that must encourage us to yet further exertions, and to yet greater expectations.

On this note of confidence, I would conclude by wishing the Chairman, his helpers and all those attending, from a score of countries some of them in distant parts of the world, the very best of success in what they are setting out to do.

Address

by M. Pierre Werner, Prime Minister of Luxembourg

Institutions, like individuals, carry with them through life the imprint of the place where they were born. The Commission of the European Communities in sponsoring the Fourth Steel Congress in Luxembourg is at once paying tribute to the oldest of the three Communities, ECSC, and honouring the city and country where ECSC came into being. Inasmuch as Luxembourg received the pioneers of the Coal and Steel Community in its midst, and is a country whose economy centres upon steel, its Government and people are too keenly alive to the importance of everything relating to steel's prosperity not to welcome most warmly the succession of Congresses held in their capital on matters to do with this pre-eminent star among metals. In the presence and with the gracious permission of Their Royal Highnesses the Grand Duke and Grand Duchess, I take pleasure, on behalf of the authorities of this country, in offering our most cordial greetings to all those attending this Congress — to those leading figures from the worlds of government, science and industry whose wealth of ideas and experience and high public standing are making the occasion one of such lustre and importance.

The general line which your debates are to follow is, it seems to me, of much significance. The theme of the Congress calls to mind the stresses and strains to which technological progress in certain sectors now in vigorous and diversified expansion, such as chemicals, is exposing a traditional industry such as steel, accustomed to produce in bulk in order to meet a demand which was for long pretty well uniform. It brings home the point that in our economically developed countries today the production lines intended for a mass market have the greatest interest in enhancing their range and quality by taking in others focused more on the special requirements of certain ultra-advanced techniques.

We are now plunging into the full complex of problems presented by modern technology — scientific, economic and political. The present Congress, by firmly embarking on a dialogue with respect to the intricate problems of experimentation in one particular sector, is taking up one of the great challenges of the modern economy, that of ongoing and ever-restarting research. For there is a feeling that we are caught up in something that can never stand still. On the face of it, science is progressing from triumph to triumph. But the application of science's achievements at enterprise and national-economy level is another matter — more complex, more time-consuming, more uncertain in its results. Technological progress poses problems for the individual company, for the individual polity. Some countries, some parts of the world are lagging in development behind the rest — and these disparities in technological advance are at the root of grave political problems.

The Congress reflects, at the same time, Europe's desire for close co-operation and pooling of resources in the technological sphere. It is much to be hoped that its specific, carefully-thought-out programme will lead on to other ventures of a similar kind, and its example serve as a stimulus to joint action and joint achievement.

In the steel sector proper, I trust it may encourage those in positions of economic and technical responsibility in our different countries to bring all their resources of creative imagination to bear on remodelling current plans and systems so as to ensure that steel will retain its leading place in our economies.

As regards my own country, I take the opportunity to stress that we continue to attach the utmost importance to pursuing the aims of the ECSC Treaty. We are, I know, moving towards the amalgamation of the Treaties of Paris and Rome, and this is bound to involve some alterations to the provisions. Such alterations should be designed to make the provisions more relevant, more effective, more in line with the lessons of experience — to make them serve to strengthen the Community. It is also my view that market transparency and equal access should remain the operative principles in the steel sector, in accordance with the rules specifically pertaining to it.

It is true that the building of Europe is no longer proceeding by the sectoral approach. We have now reached the stage of working towards economic union, which involves broader issues — cyclical policy, commercial policy, energy policy, monetary policy.

Matters, these, in which the human element is very much to the fore. Now if ever is the time to recall the point — trite but true — that the economy and science exist for man, and not the other way about. Transposing your theme to the moral plane, I would add that care will have to be taken to see that the "extreme stresses" of the economy and science do not expose man to "irrational behaviour."

In conclusion may I wish your Congress the fullest success on the human side also, as an occasion both of constructive effort and of friendly fellowship.

Opening Address

by M. Pietro Campilli, Chairman of the Congress

As I rise to declare the Fourth International Steel Congress open, it is a pleasure and a privilege first of all to welcome Their Royal Highnesses the Grand Duke and Grand Duchess of Luxembourg, and to express our warm appreciation of the honour they have done us in consenting to be present at our Opening Session. I extend greetings also to the President of the European Commission, M. Rey, and his colleagues MM. Colonna di Paliano and Bodson, to the members of the Diplomatic Corps, and to the Prime Minister of Luxembourg, M. Werner. Welcome, finally, to all those met together here, university Fellows, research workers, engineers and industrialists, from more than twenty countries.

The present Congress is the latest in a by now established series launched some years ago by the then President of the High Authority of ECSC, Prof. Dino Del Bo, each of them a world event in this domain of such outstanding economic, technological and scientific importance, steel.

When I received the European Commission's invitation to serve as Chairman of the Congress, I was fully conscious of the tribute that was being paid to my country as well as to myself. I accepted with thanks, and I repeat those thanks publicly now. At the same time I have to admit to having felt a trifle uncomfortable at the prospect.

After all, to chair and address a gathering of such a highly specialized scientific and technological nature, convened to discuss so immensely technical a subject as the behaviour of steels under extreme chemical and physical stresses, is for someone like myself, from the world of economics and politics, decidedly out of the ordinary. However, I suppressed this natural sense of awkwardness, and I am consoled as I stand here to recall that, on the previous occasions too, what the Chairman was expected to do was rather to relate the technical matters explored by the Congress to the broader problems arising in connection with the economic and social development of the world today. I feel that this traditional arrangement by the Congress organizers is a sign of responsible alertness to the basic facts of present-day civilization.

The different aspects of that civilization are so closely interlinked that no political or economic issue can be ignored by those working in the field of scientific and technological research, even as it is becoming more and more apparent what tremendous opportunities modern science is able to offer for progress towards better living standards, and hence towards a better society.

The scale and tempo of change in our time is giving rise, as has been said, to "a global process of revolution affecting all of mankind today and so involving every individual, since it is not merely changing outward conditions and ways of life, but reaching from them into the inmost spiritual and structural recesses of being."

Now at these Congresses, I am happy to say, there has always been keen awareness that the problems posed by the advance of our modern technological civilization are global problems. Glancing through the published proceedings of the previous Congresses recently, I was particularly struck by a remark of Herr Franz Etzel, who was Chairman in 1965. In his opening address he said, "The challenge to our generation is the economic and ethical conquest of a future which, as we know, has already begun" — economic and ethical together, for (to paraphrase him) economics and ethics were

Siamese twins. He went on to express the hope that at a future Congress a philosopher or theologian should be invited to speak, along with the technologists and scientists, on the world of tomorrow.

To this call, springing from perception of the central problems of the contemporary world, has come a response at this Congress, which is in a few moments to be addressed by Prof. von Weizsäcker on the ethics of research.

To reach a true understanding of present-day civilization, then, we have to start by accepting that the problems are global, that technical processes are closely interwoven with economic ones, and research with ethics. In consequence, it is not merely allowable but obligatory for every one of us to take a knowledgeable interest in the problems and orientations of research and technology that will set their stamp on the world of tomorrow. On these grounds I felt justified in dismissing my doubts as to whether I should serve at this Congress. I derived further assurance from a quotation I happened to come across not long ago. It was written by a great metallurgist and outstanding researcher, Cyril Stanley Smith, who worked with Fermi at the first atomic pile in Chicago. "Metal physics today," he wrote, "needs new ideas, ideas of structure, hitherto a neglected field. And good, worth-while physics will have to call in the aid of the biologists, now that they have passed from the molecules to the organism. And I am convinced, too, that it will need the artist, who is best able to say significant, even if not precise things concerning highly complex interrelations."

So I said to myself, after all, if it is in order for an artist to talk about steel, why not a philosopher, or a politican, or a sociologist?

Thinking over the subject of this Congress, in appearance so esoteric, I was struck — this is the point I have been trying to make — by the openings it offers for reflection on the great themes of this human society of ours that is being thrust into the future.

Consider a moment. The Congress is an encounter between the steel and the chemical industries, dealing with the subject of extreme stresses. But the findings of our metallurgists, physicists and chemists are bound to open up new vistas for those now working on space research, on undersea research, on nuclear research, on research for the devising, with the aid of modern organic chemistry, of new synthetic materials.

A noted Italian scholar, Prof. Cotta, has said that the whole design for our future "can only stand provided it is solidly knit and carefully calculated to form a single integrated unit. Technological progress is thus becoming something organic. It is offered as a model the present methodological approach of the sciences, which have gone beyond the stage of strict specialization inasmuch as they have seen that, in order to advance, there must be co-operation among the different branches, common research hypotheses, access to one another's work, pooling of data. The world is one world for science, and one world likewise for progress."

The applications of technology are by now part and parcel of our everyday life: we enjoy their benefits and take them for granted. We have attained to the "consumer civilization" — yet this consumer civilization is of its nature an uneasy thing, in that it is rich in material benefits badly maldistributed, and poor in the values that are the *raison d'être* of human society. Basically, science has never needed man so much as it does today. Debates on what the future may be expected to hold are very much in vogue, and practically nobody finds the incredible yet absolutely up-to-the-minute forecasts for A.D. 2 000 even startling any more. The world does not stand still, and it is well that science and technology should continue to level barrier after barrier and to change the face of the earth. But the real issue, in my view, is whether man has learned to develop along with his science, to know himself with the same degree of accuracy as he has achieved in exploring the mysteries of the sub-atomic world or the complex harmonies and disharmonies of cellular structure. The modern revolution that began at the end of the eighteenth century has brought us two hundred years crammed with change, and a science that has, by and large, worked for and not against man. What remains to be seen is whether this will continue to be the case in the years ahead.

The great and final aim of scientific and technical advance must be to conquer want and hunger and ignorance for ever, and to banish civil discord and war. It has been rightly said that "the technological society is a tremendous potential of love, but to turn it into an *act* of love needs the personal and conscious commitment of man." These are the real issues underlying our civilization and its potentialities for progress.

The theme the Congress is to discuss has a very real bearing on the challenges of technology which more than anything else will make their mark on human affairs in the coming decades. When the behaviour of steels under extreme chemical and physical stresses has been finally mastered, and the difficulties that still prevent steel from being used beyond the limits of today have been overcome, space research will undoubtedly be facilitated, and more practical opportunities afforded for systematic exploration of the ocean depths, and markets opened up for exciting new production lines. But will all this really profit man, if, even while we are shortening the distance to the moon and exploring outer space, whole nations and whole continents are struggling with desperate, life-and-death problems of starvation and disease? Will it really profit man that we are venturing into new fields of research, if the world is still bedevilled by bitter tensions arising out of blatant inequities, forms of segregation and oppression that are an offence to human nature as such? Will it really profit man that new materials and new products are continually being developed, if economic mechanisms and production systems are not focused first and foremost on meeting the primary needs of man, of all men without distinction of colour or race or creed? That is the real problem — to manage the great energies now at the disposal of modern science and technology, to enable them to be directed to establishing genuine wellbeing, to diffusing and defending, as has been said, "human life in place of sub-human and non-human." It is not in supine acquiescence nor in futile, nihilistic rebellion against the whole set-up of today that we must confront the potentialities which science and technology afford, but in the resolve to see the potentialities materialize, because both the realities of society and the facts reflect the truth of the matter, that man is the centre of the life of the world. That is the real challenge to us all, the real New Frontier on which our civilization must set its sights. It demands the commitment of scientists, researchers and technologists; it provides them with the guidelines and values that will be basic for the work they are called to do.

Still more, it demands the commitment of the politicians, in order that the patterns and the ordering of society in the different countries and beyond, in the world at large, be adapted to the mighty potentialities offered by the technological revolution. And, generally speaking, there will need to be a spurt in the quality of moral standards and of political life if man is to be able to handle what he has created.

When we say that a country's legislative, educational and social institutions are not in line with scientific and technological progress, we are saying in effect that the fundamentals of society are out of true, to the extent that the spirit of freedom itself is crippled. More vital still is that, even amid the most astounding achievements of science, man should keep himself and his inventions in hand, else the menace of the Robot, so much beloved of the writers of science fiction, will come to loom larger across the pages of human history. And the Robot, however elaborate and efficient, knows neither freedom nor moral travail: these are the attributes of man.

That is why it is necessary — more and yet more necessary — to progress that there should be men capable of facing the great risk of the new and unknown, all those new and unknown possibilities that science and technology have in store, as men responsibly fulfilling their mission to master all the energies and resources Nature affords.

I hereby declare this Congress open. In so doing, I would say that I hope and trust that research and technology will make this all-important and fundamental sector, steel, into an ever more effective means to the achievement of true civilization.

II. Addresses given at the opening ceremony

SCIENCE AS AN ETHICAL ISSUE

Address

by Professor C. F. Freiherr von Weizsäcker

Your Royal Highnesses,

Ladies and gentlemen,

I am to speak to you today on the subject of science as an ethical issue. I say "I am to," because that is what I have been asked to do, and the Chairman has just been good enough to explain to you what the idea was in asking me. I shall not deal primarily with the ethical issues the scientist has to face — these I intend only to touch on towards the end of my remarks — but with science as a whole, which constitutes an ethical issue for mankind. I propose to divide what I am going to say into four sections of unequal length. First, I shall try by means of a historical outline of the genesis of scientific thought to elucidate the points I have in mind. Next, I shall illustrate what I mean by reference to the one set of ethical issues in science of which, as a nuclear physicist, I have myself personal experience. In a third, rather shorter section I shall give a few further examples serving to show that nuclear physics is not an extreme case but a good and representative one. And lastly I shall speak of the ethical issues which actually confront the scientist. All this is, of course, a very wide-ranging subject. I shall do my best to condense it.

First of all, it may be asked, to what extent can science be an ethical issue? We all know science is morally detached, morally neutral. Twice two are four, and that has nothing to do with ethics: the good man and the bad both have to accept it once they understand it. If therefore I have to sum up in a very simple phrase what the issue of ethics in science boils down to, I can fall back on one that is as old as Western science itself. One of the earliest sciences to come into being in Europe was Greek medicine. The great name that is associated with it is Hippocrates, and to Hippocrates and his school goes back the oath that doctors have to swear to use the power their knowledge gives them solely for the purpose of saving and serving life, and not of destroying or injuring it. That is the nub of the whole issue. The problem is only, how does it work out in practice, how does it work out individually?

Now there are one or two points I would make here, still with reference to the ancient Greeks, which in themselves show the issue to be more complex in character. Plato in describing his Republic, his Ideal State intended as the yardstick against which all States actually existing should be measured, laid down in the first place that it must be ruled by philosophers. Not of course that he meant professors of philosophy: he meant people who were out to know, who were living embodiments of knowledge. What, we may ask, were they supposed to know? Plato answers, in the seventh book of his *Polytheia,* that they should learn arithmetic, geometry, astronomy and music — the classical Quadrivium. Now why should the rulers of a State learn arithmetic, geometry, astronomy and music, that is, a selection of mathematical disciplines? Because, Plato insists, this is a step on the way up to the highest perception, the perception of good, and at the same time a step in the descent from the abstract perception of good into sentient reality. That descent is what we call mathematical physics, mathematical "natural philosophy". And indeed Plato did, in his *Themaios,* propound such a schema of natural philosophy, though admittedly an old-fashioned one to us now. Thus, very early in Western thought there did exist a schema based on the view that from the highest principle, good, stems both the proper ordering of the State and the development of all science, and, it follows, of all individual human ethics. If I am now asked what relation science bears to good, I must turn from Plato himself to a later offshoot of his philosophy, Christian neo-Platonism, as represented by the great seventeenth-century scientist Johannes Kepler.

Kepler asked himself how it was possible for man, by means of mathematical laws, to work out for himself the course of natural events, and even to predict such occurrences as solar eclipses and the like. His answer was intentionally metaphysical and theological: it was that man is made in the image of God. God made the world in accordance with His creative concepts, and those concepts are, as in Plato, mathematical. Man, being made in God's image, carries within him creative concepts likewise in God's image, and for that reason he is able to discern the workings of Nature.

Such was the approach to science in former times. Since then, of course, it has entirely changed, and I cite these instances first in order to point the contrast with the direction taken later on. On the one hand, science — as indeed the Greeks too realized — has become a means to the mastery of the world. This was already fully and clearly recognized in the seventeenth century. The great Descartes, for example, who made it one of his chief aims as a philosopher to prove the existence of science, stated that the object of man's scientific exploration is to make himself the lord of Nature (*maître et possesseur de la Nature*). And on this object modern man has indeed increasingly concentrated, right up to our own time. Yet there was in science not only the urge to master the world, but also the urge to attain to a truth which should be distinct from the truths that the authorities, the churches and the kings, the rulers of the State, proclaimed and exploited.

Take the story of how the Royal Society originated in seventeenth-century England. A dominant idea of these men — who had initially in Cromwell's time had to meet in secret to discuss what could not be uttered in public — was perhaps best expressed by one of their number, Robert Boyle, when he compared the difference between a proposition based on authority and a proposition based on argument to the difference between the longbow and the crossbow: the distance the longbow (authority) will shoot depends on the strength of the archer who draws it, but the crossbow (argument) can be wound up and discharged to the same distance by anyone.

A democratic principle, if you like — though of course a democracy of those capable of perceiving the truth. But who the person is who perceives the truth, is immaterial: we learned as young physicists that the greenest student can defeat Einstein if he adduces the right argument, and any true man of science will admit it. It is the principle of the scientific spirit always involving acceptance of free debate — a principle Boyle, a man of his time, deliberately sets over against the principle of the control of opinion by authority.

Integral to this conception of science is the view that science must of necessity be public. This brings me on to ground that abuts on the ethics of science, in that scientists set out to formulate principles which must be adhered to in conducting scientific work. One of these is that such work must not be kept secret: it must be open to inspection. This principle — I saw it in the case of my own professors — is regarded by scientists as absolutely sacrosanct: to my teachers, as I realized immediately, it was one of their most strongly-held and deeply-felt ethical tenets. Now I am not, myself, setting this desire on science's part to have everything overseen by those with knowledge — and, of course, reasoning powers — over against the point I gave you first, from Plato, for those who were to rule Plato's Republic were at the same time those who sought to acquire knowledge and did accept free and frank debate. But the advance of science has been on such lines that all trace has been lost of the set, traditional images of society and the whole destiny of the human race progressively altered: discovery has followed discovery, dogma after dogma been overthrown, and as a result we are now, thanks to science, moving into an uncharted future which none of us can fully picture nor conceive. And here science does stand forth as an ethical issue, because it is problematical whether in pressing into the unknown we shall stay the course, and not topple into abysses we failed to foresee.

I now come to the second part of my talk: I do not wish to speak in abstractions, but to illustrate what I am trying to say by referring to a particular case that is staring us all in the face. I imagine all of us here have read a good deal about it, and some have actually worked on it, so it is a fair subject for debate. I mean, of course, the case of nuclear energy. I may perhaps mention that I have myself been closely involved, since pretty well at the outset of my career as a physicist, I embarked on the study — at that time the rather new-fangled study — of the atomic nucleus: consequently, along with a number of others, I realized from the start the importance of Hahn's discovery of uranium fission in December 1938, and immediately little groups of us began discussing the implications for humanity.

It came as a turning-point for which we were not prepared. When I first studied nuclear physics, with Heisenberg and later with Bohr, my personal reaction was, "How odd that I am apparently to be allowed to go on pursuing my hobby all my life at society's expense — and such a completely useless. academic hobby as nuclear physics!" Ten years later came Hahn's discovery, and out of the the blue we suddenly saw that this subject we had been delving into because we liked it, because it attracted us and somehow stimulated us to probe deeper into the mighty workings of Nature — this subject would utterly alter the whole face of the world.

That it would do so, we saw in February 1939. But in what way? We realized that, provided certain technical conditions were feasible (which in the event they were), nuclear energy could be put to peaceful uses, as now, in the present decade, it is at last beginning to be, on a significant world scale; at the same time we realized that it would be possible to produce weapons immeasurably more effective and more terrible than any ever seen before.

What were we to do? I remember many discussions when we argued and argued what a scientist ought to do in such a situation, and never came to a satisfactory conclusion. Well, never mind about our discussions: I would rather talk about what actually happened.

What actually happened was full of paradoxes. On the one hand, atomic weapons were devised. Rightly, they filled humanity with the profoundest dread. If they were ever used in a major nuclear war, that war would be the most appalling disaster in the annals of the human race. We still do not know that it will not happen. It may happen: it may happen in our lifetime. On the other hand, politicians and soldiers, and parliaments, and writers — not only scientists, that is to say — have become thoroughly convinced that it must not be allowed to happen, and the pattern of international politics has begun to change with the recognition that these weapons exist but that we dare not use them. I say "dare not," not "cannot" — for we can.

An ethical issue, this. What does it imply for the individual scientist? It is very tempting for him, in face of the terrifying possibilities, to say "I refuse to touch it."

And no one, I feel, should be blamed for taking that stance, for saying "I won't have anything to do with it, I'll do something else." I would only point out that, in a world so dominated by science as ours today, it is by no means easy to find something to do that has no bearing on the alteration of the world by science. As I shall show in a few minutes by quoting one or two examples, atomic energy is not an extreme case, only a clear case, of issues which also arise, rather less clearly, in every other field.

The endeavour to contain the perilous implications of science for human life has been dramatized, in comedy form, in Friedrich Dürrenmatt's play *The Physicists,* which I dare say many of you will have seen or read. In it, a physicist who has achieved the ultimate breakthrough in physics withdraws voluntarily into a madhouse in order to keep his discovery dark, since he knows its effects would mean the end of human life on earth. In the madhouse he meets a number of fellow-patients who are really agents of the Great Powers and try to pump him, but without success. In the end, however, it transpires that the woman alienist in charge of the institution has purloined his notes and is already running a flourishing arms business on the basis of his work. A comic version of the issue, but true enough in that it shows the impossibility of sparing the world the consequences of science.

What is really wanted is something quite different — to change the world through science in such a way that man can still live in it. It would of course be possible to take the line that all this is much too gloomy and pessimistic a way of looking at things: after all, science is progress, technology is progress, we are at peace because of the Bomb, and we are getting the benefits of nuclear energy as well, so what is all the fuss about? Well, as to that, I would say that this approach no more disposes of the problem than the other does.

I cannot bring detailed evidence to support the points I am going to make: in some cases I shall just make them, and each of you can decide for himself whether he thinks they will stand up or not. First, with regard to the question of peace and nuclear weapons, I would say this: to the best of my knowledge a technological world does not stabilize of its own accord in such matters as this. Equilibrium in major weapons does not guarantee us unqualified peace: all it guarantees us is peace until the next big new advance in technology. Whether the next big new advance in technology will restore the possibility of waging war or make war more difficult to wage, nobody knows.

I could go into a great deal of detail about, for instance, the well-known strategic problems of equilibrium through second-strike capability, but I do not propose to do so: I only wanted to mention at least one *terminus technicus* of present-day strategic thinking, in order to show that you have to think in pretty specific technical terms to realize that it is by reason of quite specific properties of modern weapons that the strategic position today is relatively stable. And, as I say, this can change: the invention of new weapons could offer a country such a head start that it would have great difficulty in resisting the temptation to start a war or to blackmail others with the threat of one.

So my own conclusion is that a world of science and technology does not stabilize of itself: it needs to be deliberately stabilized by political action, it needs world peace established on the political plane. Our Congress here today forms part of the drive to bring at least some of the nations of Europe to greater supranational unity, and part indeed of a drive which must some day be extended to take in the whole world, for otherwise there can be no assurance of stability.

I shall give you my other examples in a moment, but here there is a point I want to make. In what I have been saying, I have stated that science poses an ethical issue for humanity, but I have not actually offered an answer, in the form, say, of what I would consider the right ethical approach for the scientist. I have not tried to suggest how the scientist, a small cog in a vast machine (for it is not given to everyone to make the big discoveries), should act in this context. The problem is a hard one. All I have said is that we are facing a problem which we cannot evade and which will never solve itself unless we tackle it.

Next, the third section of my remarks, rather shorter than the others, in which I shall try to show, again by citing familiar examples, that nuclear energy is not an exaggerated instance of what I mean.

Now, and this is also a very important point, technological advance is certainly not everywhere revolutionizing armaments manufacture, nor, we may suppose, energy, necessary though an energy revolution is likely to be in face of the mounting demand ahead. But it is, on the other hand, everywhere inescapably transforming our lives. Take steel, the subject of this Congress, take physics and chemistry, the sciences the Congress is specifically concerned with: they all offer any number of examples — every one of us can think of examples from his own experience — of how life has changed, and will doubtless go on changing, in consequence of the technological advances in these fields, the outcome in most cases of scientific advances. Now these advances all have this in common, that while the research involved is directed to a particular end which the technologists are out to achieve, a great many side-effects, some of them dangerous, also result. The real object of a professional ethic in technology and science should be to take account also of the side-effects: after all, the atomic bomb was a side-effect of Otto Hahn's success in splitting a nucleus of uranium, which at the time we all welcomed warmly, from the scientific standpoint, as a notable new advance.

I should like to mention in particular two matters of especial topical importance today, of which we shall certainly be hearing a great deal in the next ten or twenty years, namely data processing by computer, and world nutrition.

Computerization is perhaps the branch of modern science-based technology which will most radically affect our lives in the coming decades. I do not propose to quote further examples: such examples will be familiar enough to those acquainted with the subject. I will just give one reason why I think computer technology will have particularly far-reaching effects.

If I may be permitted to introduce a little, shall we say, natural philosophy, in the form of three concepts, I should say, speaking as a physicist, or a natural philosopher, which is I think perhaps what I am today, that, by and large, in our physical world there are three realities: the one we call matter, the second energy, and the third information. Information is a particular way of apprehending conceptually the phenomenon of *form*; the word information, after all, contains the root *forma,* form. The processing of matter by technology has progressed further and further since the old days of artisan workmanship — steel technology today is still the processing of matter, the creation of new substances. To this has been added, more especially in the nineteenth century, the processing of energy by technology — energy technology put the energy resources of the world at man's disposal, and the technology of nuclear energy, to which I was referring just now, is the latest refinement so far reached in this direction. Information is yet a further stage beyond energy. Speaking in natural-philosophy terms, I would venture the hypothesis that in the ultimate analysis matter will turn out to be energy and energy to be information. The mere fact that this is a possible hypothesis at all — I am not setting out here to substantiate it — may perhaps serve to show how absolutely fundamental information is. Now the processing of information is what the computer is for, and I trust and believe that this is giving us a key which will open many doors hitherto closed to us. Nevertheless, nobody can tell how far our world will be rendered computable, nor how far we shall be faced with the problem — to mention only this one aspect — whether individual freedom can continue to exist in such a technologized world, whether we can remain independent of the control of anonymous forces. This is one of the great political issues of our time — a political and ultimately an ethical issue, which has become so clear-cut, has assumed the shape it has, as a consequence of technological advance.

Third on my list comes the peculiarly paradoxical question of world nutrition. The world's population today is growing by leaps and bounds. That fact is due primarily to one single cause, the astounding achievements of medicine and hygiene, and the achievements of science. But at the same time, as we all know, it poses the problem of feeding the people whom science's triumphs have — to put it brutally — condemned to live. I am not concerned here with what is to be done about it, and what, in practical terms, can be done about it: that is a matter that many experts have been working on and that still looks rather hopeless, because it is such a tough proposition to create the conditions that would be needed to provide all these people with enough to eat and — equally essential — to brake and eventually halt the increase in their numbers. I am simply saying that we have here an issue that is the result, in the main, of one of the finest and best of all science's fruits, the saving of human life by better medicine and better hygiene. And this demonstrates once again that it just is not possible to treat questions of scientific ethics as matters of individual conscience, to be approached from the angle that if this or that person satisfies certain requirements he is good and if not he is bad, that if his motives are decent and disinterested we applaud him and if not we censure him. Not that I mean disinterested motives are a bad thing: on the contrary. I mean that they are not enough, for who could be more disinterested than one who sets out to save life? —yet that saver of life, the doctor, is partly responsible for this new problem humanity is facing today. What is needed is that we should visualize and ponder the implications of what we do. For the ethical issues that science poses are always social issues and political issues that we cannot evade.

And this brings me to the fourth part of my talk. How should the scientist act in face of this situation? Can he cope with the tasks that confront him? — are they not rather altogether too much for him? My answer would be, in a sense, yes, they certainly are. History, as Hegel says, is not the soil of happiness: it was never foretold us that life would necessarily be a bed of roses. But the issues are there and we have to grapple with them, and my minimum basic article in the scientist's code of personal ethics would be that he should not blink those issues.

There, science is *not* morally detached. All right, you don't have to adopt a particular ethical stance to grasp that twice two is four. You do, to some extent, if you are conducting research in the way I was speaking of earlier on, prepared to let others see what you are doing, to allow your work to be public property. But that is not enough either: your ethical stance — and this would be my main point — must be such that you will scrutinize the implications of what you are doing with the same care as you do the conditions that are required for the work to be done at all.

It is firmly impressed on junior scientists that if they are careless in their work, make faulty calculations, mount their experiments wrongly they are no use to science and in fact not scientists at all: we are all trained to maximum accuracy, and anyone who fails to absorb this cardinal truth has no business to be there. My point is simply this: it is the scientist's basic individual duty — a pretty modest requirement surely — to devote equally scrupulous attention to the consequences of the scientific work he does, and never to imagine he can shrug off responsibility for those consequences.

Admittedly, very often he cannot be expected to foresee the consequences. Very often when they are beneficial he will not get credit for them: after all, he carried out his research from curiosity and the desire for knowledge, not in order to benefit humanity.

Conversely, very often when they are dangerous, he will not be legally answerable for the dangerous uses to which his work may be put, but he must consider himself at any rate morally answerable. He must make it his principle to be as alert to the consequences as is humanly possible, and, if he is a religious man, leave the rest to God.

All the same, religious people ought always to have been taught, and if they genuinely are religious they do realize, that they must not leave things to God too soon: God does not wish them to. So I feel that the counterpart for the scientist to the doctor's Hippocratic oath should be the resolve to bear always in mind the consequences of what he does. Whether we should go further and require him actually to give a corresponding undertaking — that he will never use his knowledge to injure but only to serve life — is, I think, a matter that could properly be debated at the present time. But not decided. To decide such a question, we should need to have the kind of society in which the scientist *could* adopt a responsible stance such as this, just as the Hippocratic oath is required of the doctor precisely because in his case that stance is recognized by all to be part and parcel of his professional ethics, and because he has to be protected against any efforts to induce him to engage in unprofessional conduct.

So far, no such professional code for the scientist and technologist has been evolved. There are certain rudiments of one, but there is as yet no general recognition that men must not be allowed to do all that they could do if they wished, since, were they allowed to, the bad that resulted would outweigh the good. Unless and until that general recognition comes, it is asking too much of the individual to require him to give an undertaking that society itself is not at all prepared to observe.

It is necessary, therefore, that we work up what I may call the ethics of technological research into a code of ethics recognized by society. Until then, it will be the individual researcher's own affair what line of conduct he adopts. He may be a radical, he may conform. To return then to the minimum requirement: I should say simply that he will be failing in his duty if he no longer troubles his head as to the consequences of his work. That he should consider these would be the core of any Hippocratic oath devised for him.

PROGRESS IN RESEARCH

Address

by Professor R. Zoja

After the lofty exposition we have just listened to of the ethics of research, it now falls to me to deal with some of the more down-to-earth aspects involved.

However, before I go on to offer my observations on the present state of steel research in Europe, and the prospects for pushing ahead with it more effectively, I must first define some of my terms, since in this field as in most others there can be quite a number of different basic approaches.

My subdivision will be as follows:

1) *pure research:* high-level scientific work not conducted with any application directly in view;

2) *applied research:* often on a high scientific level also, but usually on more specific subjects, and definitely intended for practical application;

3) *technological research:* on primarily technological matters, with no claim to be of general scientific interest, but carried out in order to solve particular practical problems;

4) *application and putting into effect of research findings:* the final stage, which while not really rating as research proper is so important and so intimately linked with research as to merit discussion in its own right.

As regards the time taken by research, from inception to completion, no period can be posited for the first type, which usually extends over many years. For the second and third types on the other hand, as a general rule it is possible to form a fair idea in advance how long they are likely to take — normally not more than five to ten years for applied and two to four years for technological research.

In view of the all-importance of research to human progress, I feel it is perhaps worth recalling the dictum laid down long ago by the famous metallurgist Prof. Henry Marion Hove, that it is possible to form a generally valid assessment of the level reached by the different industries in this exciting race to achieve progress by the methodical, step-by-step application of research results: in all fields, Hove pointed out, generally speaking technology has always preceded science, and, he emphasized more particularly, in the history of human progress there is always an evolution whereby science moves asymptotically from the position of a mere follower to the position of an absolute dictator.

Figure 1 shows this characteristic movement in diagram form: it plots, in function of time, the contribution of science in per cent., rising steadily from its initial extremely low level, or from nil, towards the upper asymptote of 100%.

The positions of the different industries in 1968 vary widely. Thus, for metal production, the asymptotic state is still far distant,[1] a circumstance which undoubtedly also applies to steelmaking (Fig. 2); on the other hand, for iron and steel products

[1] Prof. R. Piontelli, in his introductory address to the Milan Congress on Non-Ferrous Metals of 8-11 October 1967, referred to Prof. Hove's pronouncement of 1917 (quoted from the How Memorial Lecture by J. Chipman, Metal Trans. AIME, *185*, 349, 1949) concerning this asymptotic law, and expressed precisely this view with regard to extractive metallurgy in general.

(in particular, for instance, with regard to improvements in the chemical composition of certain steels and in their treatment) the contribution of science has already reached a considerably higher level (Fig. 3).

These diagrams, though given purely for guidance, make it sufficiently evident what a long way we have still to go in the steel industry, and how urgently necessary it is that we take more active steps to improve matters by an intensive stepping-up of research.

One or two further preliminary remarks first with regard to the first part of the steel production cycle, the making of the actual metal.

Since research in this connection is aimed, directly or indirectly, at improving present pig-iron and steel production plant, and often at developing new processes, it is unquestionably of tremendous potential importance from the business point of view: we have only to think of the LD process and those evolved from it and the way they have revolutionized steelmaking. Moreover, it is for the most part this kind of research that costs the most and occupies the largest number of trained researchers.

Bearing this in mind, if we look at the evolution of steel production processes since the middle of the last century, we can discern three successive and quite distinct periods.

First come the fifty years or so from 1856 on, which saw the progressive introduction of the modern types of plant — the acid Bossemer and basic Bessemer (Thomas) converters, the open-hearth and the electric furnace — by means of which it was possible to turn out molten steel in the enormous tonnages required by modern industry.

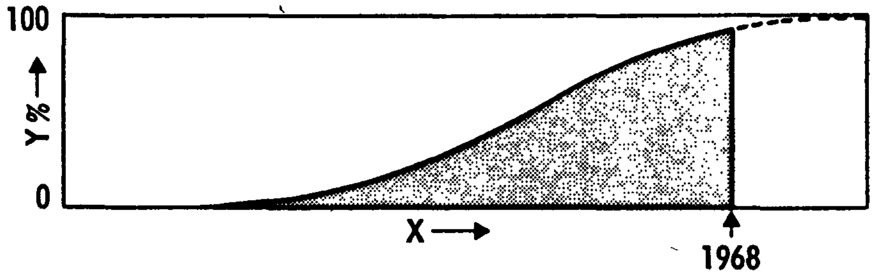
The fifty years after that represented in comparison a standstill, inasmuch as throughout this period, though improvements of all kinds were made to the existing plant, no new process was devised which became generally adopted in all or indeed in most countries. This is the conclusion suggested, for instance, by the volume on the processes for the direct reduction of iron ore brought out by ECSC in 1960, which deals with the most promising of the hundreds of patents and projects in being in different parts of the world, with the single exception, perhaps, of the Krupp-Renn process.

Lastly, we have our own time, beginning with the emergence of the first Linz-Donawitz oxygen converters in 1953-54. In addition to this amazing new process — which has swept the board all over the world — the last few years have witnessed a big burst of research activity, some of it on major improvements to the traditional processes (which would otherwise be doomed sooner or later to extinction), some on direct production of steel, some on the development of further new processes.

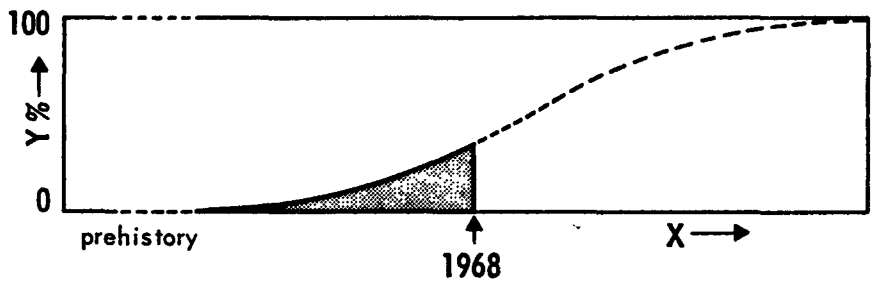
I should emphasize that this very rough sketch refers solely to processes which are not only completely new departures but also of such universal value and interest as to represent definite turning-points in steelmaking history: given these strictly limited terms of reference, it is understandable enough that, up to now anyhow, such epoch-making events have been few and far between, with, as I was saying, a whole fifty years in which practically nothing of this kind occurred.

The picture is of course quite different, and much fuller of outstanding developments, if we include all the many improvements and modifications to the traditional pig-iron and steel production processes which, without altering the fundamentals to any real extent, have so largely determined the industry's progress in the making of the metal itself, especially in the last few decades. Here, research at all levels has indeed made its essential contribution, which has become more and more indispensable with the rapid evolution of present-day science and technology. I cannot go into details here, but of the more important changes of recent times I would just mention the introduc-

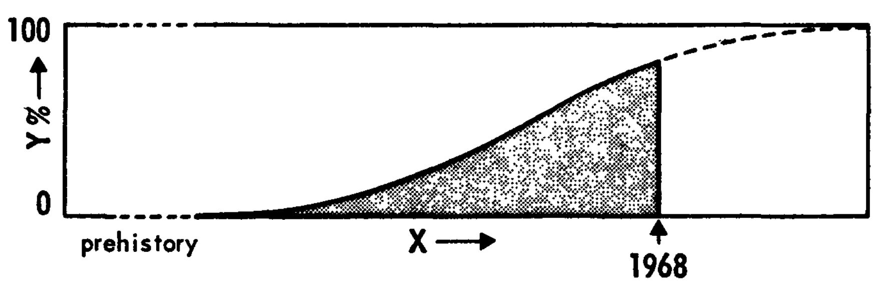
1 - THE GROWING CONTRIBUTION OF SCIENCE TO NEW INDUSTRIAL PROCESSES



2 - THE CASE OF STEELMAKING



3 - THE CASE OF THE DEVELOPMENT OF CERTAIN TYPES OF ALLOY



X = time
Y = contribution of science in per cent

tion of the oxygen lance for oxidizing the steel bath, the electromagnetic agitator for the electric furnace, vacuum steelmaking, vacuum tapping and remelting, continuous casting, and so on.

As regards research in connection with the second half of metal, and more particularly the steel production cycle, the position is, as I have already said, entirely different: in some fields at any rate the asymptote has pretty nearly been reached, as for instance in the development of new precipitation-hardening steels — a notable case in which the considerable volume of purely scientific research being carried on is of crucial importance to the ultimate achievement of the aims in view.

I now turn to the present state of steel research in Europe. Comparing this with the research position in other industries, also in Europe, and then making the same comparison for America — though expressing my views, of course, subject to all due reservations in face of so vast and complex a subject — I think I may briefly sum up the situation as follows.

1. Overall, expenditure on research by the steel industry in Europe is quite markedly smaller in proportion than similar expenditure in other European industries.

2. However, since in America too — where research expenditure as a whole is on the grand scale, especially in certain industries, such as electrical engineering, telephones and electronics — the steel companies have up to now invested only a relatively very modest proportion of their profits in research, the European steel industry's efforts in this direction can be considered, on the average, more or less equal to its American counterpart's.

3. It is generally agreed, in America as elsewhere, that it is high time these comparatively meagre appropriations for steel research were increased.

4. Viewed, however, taking steel production not as a single whole but as made up of two separate parts,[1] and comparing not research expenditure but research results (including interim results) at the present time, the picture undergoes a decided change.

a) I feel above all that so far as the making of the metal is concerned Europe is still quite clearly well in the van, especially if we include Britain and Sweden — as I most sincerely hope that it will be officially correct for us to do in the very near future. What is more, Europe too is showing all the forward-looking eagerness to innovate that I was speaking of just now.

b) On the other hand, as regards development of new steels and improvements to the traditional ones, and indeed product research in general, both pure and applied, it must be admitted that Europe, even though it has plenty of important achievements to its credit, is lagging behind.

Before discussing in somewhat more detail the burning question of research organization, I should like to take a quick look at the future prospects as to further advances in the steel industry.

I am well aware of our lag in various vital respects, but in view of the headlong pace of technological progress today, and perhaps above all the type of aim on which current research is concentrating, we must realize that there are openings for major new breakthroughs.

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[1] The making and the working of the metal.

In my own view, the most promising avenues are offered by the processes farthest away from the traditional ones, with their "revolutionary" kinetics and accompanying drastic shortening of production times. Examples are slag emulsion making, as for instance by the Perrin process, and the IRSID continuous-steelmaking process developed only the other day; treatment of ore and other fines in a fluidized bed with practically instant reduction by means of appropriate reducing atmospheres; and spraying of the molten metal, making possible ultra-high-speed treatment with an appropriate atmosphere, as in the new BISRA method of continuous pig-iron refining by oxygen jet.

Processes of this kind, quite apart from the enormous saving in time which they represent, could also afford solutions to some of the problems that have long harassed the technologists, such as production of pig-iron differing from the traditional type, direct production of iron or steel, continuous steelmaking, and so on, with all the additional business advantages that would result from the consequent simplification of the production cycle.

The perfecting of the many and varied techniques of vacuum steelmaking, and the introduction of new ones, will certainly pave the way for further improvements in the properties and qualities of the steels.

As regards finished products, by this time any fresh improvements in their performance depend primarily on the results of pure and technological research in the sphere of metal science, which is making tremendous strides, aided in its turn by advances in the sectors of chemistry and physics which are most closely allied to it.

Most of the estimates, even allowing for the recent development of mar-aging and austenite-formed steels, suggest that in future the tendency towards higher and higher strengths and yield points will proceed rather more slowly. No big new advances are to be expected in this direction, particularly as we must rule out any possibility of taking into account the exceptional properties of the ultra-fine monocrystalline filaments known by the name of Wischers.

Such is not the case with regard to high temperature steels where more important progress may be expected.

For instance, if one takes the melting temperature measured in Kelvin degrees as the approximate value of the maximum and if one takes as a level the useful temperature, also in Kelvin degrees, of the best alloy expressed in terms of a percentage of the absolute temperature, and if one takes into account that for certain metals such as aluminium, levels of between 90 and 95° have already been reached, then, with certain reservations as to such a comparison, the 65 % reached up to the present time with the best iron alloys should leave an ample margin for the research already mentioned to bear fruit.

At the time of the setting up of the Common Market in Coal and Steel, there existed in its constituent countries a vast multiplicity of various types of research bodies, from individual industrial laboratories to University laboratories, national and multi-national institutes, and from centres dealing with various metallurgical studies to those dealing exclusively with steel. There were privately and publicly financed research bodies as well as those financed by both.

This considerable diversity in the structure of research organizations in the various countries of the Community has without a doubt been a handicap, and is the probable reason why Community action with regard to technical research, with particular reference to steel research, and even though undeniably interesting and in some cases important results may have been achieved, has nevertheless been unable to achieve that which those who drafted Article 55 of the Paris Treaty had hoped for.

One may ask whether Community action could not have continued its attempt to bring greater homogeneity to national research work in this connection in the light of previous experience.

To this question it is today possible to give an affirmative answer and to state that with regard to research too, "a transitional period" for helping those countries such as mine, with a weaker structure and short of steel researchers, to start and develop their industry would have been useful.

On the other hand, it cannot be denied that there has been a certain tendency towards joint efforts in this field. For example, the Italian CSM is about to link up with existing organizations in the Federal German Republic, France and the Benelux, and one must recall that Community action has led to progressively increasing co-operation between the centres and laboratories of the various Community countries with undeniable advantage to many, especially those industrially weak.

Here I should like to draw your attention to the following.

Whereas in the more important Western European producer countries there is always a co-operative research centre in the steel sector, and whereas steel consumption per capita is around 200 kg (England with BISRA, France with IRSID, Belgium with CNRM, Italy with CSM, Sweden with the Lulea Experimental Research Centre), the pattern of steel research in Germany is rather of the North American type, where applied research is to a great extent carried out by individual firms or groups of firms, and where basic research is the responsibility of either public or joint public and private bodies.

It is also a fact that there are valid historical, social, economic and political reasons for this state of affairs. Furthermore, I should like to point out that Germany's technical scientific bodies work in co-ordination with a steel industry, the activities and publications of which are well known and highly regarded by experts all over the world. It is well known that the Max Planck Institute in Düsseldorf and certain University metallurgical institutes provide some of the most advanced contributions to the development of steel research and technology.

To develop the concept already referred to at the beginning of this talk, one may say that research in its true sense should continue up to a final stage, i.e. the practical *application of the research itself,* because if researchers pass on the results of their work too soon to the technicians, there could result failures which might completely jeopardize the success of the innovations. This is of the greatest importance because the results obtained will to a great extent depend on this rational attitude.

This is why experimental plants on a semi-industrial scale were introduced, constituting as they do an indispensable part of metallurgical research centres.

But production, even on a reduced scale, means, with regard to a typical metallurgical process, the displacing of considerable quantities of raw materials, means also a relatively large amount of liquid materials with all the problems concerning high temperature, refractory materials, products, by-products, etc. In other words, it means a process which is so costly to manage and involves such large investments that it is beyond the reach of anyone save financially sound organizations. One must also agree that full progress with regard to production (for example automation) would not be possible unless based on strictly controlled experimental work in pilot stations of research centres.

Here too, the Community could certainly play an important co-ordinating role. To my mind, a network of experimental stations of national research centres which would include specialized sectors and which would concentrate within itself the capacity, experience and requirements of all the enterprises and steelworks of the Community, would be an important achievement, in the sense that it would not limit itself to integration, specialization, co-ordination and co-financing of something which has already been achieved on a national scale in certain Western European countries and which the Italiam CSM intends to pursue in pilot plants of the new Castel Romano Centre. This is not the place to enter more deeply into this question. I will only limit myself to address an invitation to all those who are interested in these ideas to develop them in order to give them concrete form.

This Community network of research should also be combined with pure research and that part of applied and technological research which is normally carried out either fully or to a very great extent in university or industrial laboratories.

Thus the work carried out by the various types of organizations would give ample possibilities for achieving results of the greatest value from both the research and the business points of view, something which should not be neglected, nationally at least. The means for achieving this, however, are in general relatively limited.

Here I should also like to make an appeal for free research which appears to be neglected, but I should not like to be misunderstood.

Nobody more than I recognizes the need for planned research in all fields and at all levels, so that the best results must be achieved without waste and loss of time.

One should also not forget that there are research workers who, by temperament, do not adapt themselves very well, or who do not give of their best in planned and team work, and on the other hand, there are also subjects which either do not lend themselves to planned research or are not yet advanced enough for inclusion in such research.

To neglect all this would amount to forgoing the possibility of achieving results of the greatest importance.

Having come to the end of my talk on progress in research, I should once more like to emphasize the value, not to say the need, for complete Community co-operation in research with regard to the vast and fundamental sector of metal production processes in the steel industry.

Certainly, many obstacles stand in the way of full agreement on this matter. For example, there is the question of patents, and it is only natural that individuals, companies and indeed nations should wish to protect their own ideas and inventions.

Nevertheless it is in the general interest of all the countries of the Community, to work out procedures which may help in overcoming all the difficulties involved.

I should now like to draw your attention to another and specific aspect of the situation.

In the metal production sector, there is today the considerable research activity to which I have already referred, and vast amounts of capital have already been invested, especially if one also takes pilot plants and semi-industrial installations into consideration.

I have already expressed the view that, given the present technological level which is so different from that existing in the first half of this century and in the last century, the rate of progress in the future will no doubt increase.

Nevertheless, our extreme slowness in developing our steel industry to-date must not be disregarded, and I therefore make an appeal to be careful in your forecasts.

Not wishing to be accused of an excess of pessimism and therefore commit the sin of excessive optimism, I should say *a priori* that the probability of achieving a new industrial invention of vast and general application is not very high.

Naturally, and here again *a priori,* if one is satisfied with even a partial success, that is with an invention of a more limited industrial application, subject to particular conditions of place and possibly time, then the probability of success increases.

On the other hand, the fundamental formative and informative role played by research must not be overlooked.

In any case, the conclusions to be drawn from all this relate not so much, or I should say not only to the question of avoiding waste in energy and means, but rather to that of capital spent on such research.[1] The stakes are high and are worth the risk, but the effects of taking such a risk can be more easily borne if shared.

To consider the probability of a partial or total failure does not seem to me important only from the formal or psychological point of view, since in any case this would eliminate any possible future recrimination or criticism, but rather from the adverse effect it could have on the organization of the research itself.

If these ideas were to prove acceptable, they could very well result in discouraging individual industries and nations from any isolated efforts in the production of steel, and help towards the pooling of all available resources in a common and well-organized attempt to act progressively and systematically. And the co-ordinating centre for achieving this could well be the Community.

[1] This does not refer to immediately productive capital or capital giving short-term results.

III. From the Congress proceedings

WORKING PARTY I

STRESS AND STRAIN CAUSED BY HIGH POLYAXIAL PRESSURES

Report by M. H. Herbiet

Eleven papers were submitted for Working Party I. Several of them, it should be noted, departed to some extent from the subject set, namely "Stress and Strain caused by High Polyaxial Pressures."

It is proposed to group under a first head the only two papers to deal with steels to be used in chemical installations at very high pressures ranging from 2 000 to 3 000 atm. These are, first, the outstanding and very full paper by Dr. Spähn and Dr. Class, which treated the subject from all angles, *viz.* modes of calculation, characteristics of the steels used, fabrication and employment, and, secondly, the paper by MM. Deffet and Gouzou, which confined itself to a more specific aspect, deformation and rupture of thick-walled cylinders working under very high pressure, and showed by reference to tests carried out how far microdeformation in the steels used needs to be taken into account in calculating stress distribution. We may also include under this head M. de Leiris's short paper describing a method of expressing stress triaxiality under an elastic load as the proportion of the potential elastic energy corresponding to the elastic increase in volume.

Under a second head come four papers dealing with pressure vessels used in the chemical and petrochemical industries at pressures of between 100 and 250 atm. First, there was that by Messrs. Lancaster and Nichols, which gave a very full account of the selection criteria for the steels to be used in this type of plant (more particularly with respect to weldability and brittle fracture) and of the fabrication and quality-control techniques employed for these heavy structures. Dr.. Montechiaro and Dr. Somigli's paper described the results of experiments with prototype vessels for the purpose of comparing quenched and hardened with normalized steels as regards the technical and economic criteria to be adopted in the calculation of pressure vessels. M. de Cadenet's paper dealt exclusively with stainless austenitic steels: he showed from their tensile behaviour that the conventional 0.2% yield point is not really appropriate, and that it would be preferable to base the calculation of permissible stress on the maximum permissible deformation in testing, which in the case of these steels may be as much as 2-3%, and still leave an ample safety margin before fracture. Lastly, perhaps the main contribution under this head was the paper by Prof. Schaar, who sought by comparing the existing European national safety regulations for high-pressure installations to establish the true significance of the safety coefficient: he emphasized that a great deal of investigation of the various possible causes of damage would still be needed to enable us to revise and standardize the present regulations with respect, more especially, to vessels and installations subjected to particularly rigorous stresses.

Under a third head we may include two strongly contrasting papers which had, however, this in common, that they dealt, the one with a particular application, and the other with a particular mode of fabrication, of pressure vessels. The first, by Dr. Inagaki, described in minute detail the fabrication of spherical gas storage vessels operating at comparatively low pressures (5-25 atm.) and at service temperatures ranging down to — 30°C, made from quenched and tempered steels with yield points of 80 and 100 kg./mm^2 and between 19 and 36 mm. in thickness. Dr. Inagaki also described the results of fracture tests on prototype spherical vessels, which showed that the fracture surface was fully ductile in all cases, and the fractured stress over 100 kg./mm^2. M. Noel's paper dealt exclusively with the design and fabrication of "Multiwall" pressure vessels, setting forth the advantages of this process for thick-walled high-pressure vessels with an internal diameter of over one metre, and discussing the material selection for the component walls and the appropriate fabricating and inspection techniques.

Under the fourth and last head come two papers devoted to the main types of high-strength steels and their respective chemical, mechanical and structural characteristics. Dr. Brühl's paper was concerned primarily with steels having yield points of up to 70 kg./mm^2: the author listed clearly the advantages of particular alloying additions and heat treatments for the purpose of meeting the special requirements of pressure vessels for the chemical and petrochemical industries, and offered tentative suggestions as to standardization. Finally, the paper by Prof. Verbraak and Messrs. Van Elst and Schinkel dealt with all high-strength steels, including the Maraging steels with yield points of 180-200 kg./mm^2, even where not used for pressure vessels. An account was given of the hardening mechanisms operating in these and their usual mechanical characteristics; the interesting point was made that, according to fatigue tests at 50 000 pressure cycles, very high yield points bring the permissible design stress dangerously close to the fatigue limit, whereas, as regards the mechanics of fracture, the risk of unstable fracture is less with these steels even though the plasticity reserve is usually low. The paper also mentioned the problem of weldability and behaviour under neutronic irradiation.

For the delegates' guidance, the Rapporteur offered the Working Party a preliminary summing-up of these interesting contributions from the angles of

1) design and calculation;

2) characteristics and selection of steels;

3) application.

All three aspects were the subject of constructive and on occasion lively debates. We would suggest that the following points, which are highly important in the construction of pressure installations for the chemical industry, merit special attention at Community level.

1. Fatigue after a small or large number of pressure cycles, according to the service conditions. Often found in combination with corrosion phenomena, likewise depending on service conditions. Relative merits in this connection of high-strength and traditional steels.

2. Correct selection of high-strength (austenitic) steels, as regards *inter alia* dimensioning, application, control, and — the most important point in the chemical industry's case — operational behaviour, allowing for all environmental factors.

3. Post-weld stress-relieving or thermal treatment. Practical object to be considered in each case taking into account (*a*) ductility of the welded joints and base metal, (*b*) reduction of residual tensile stresses for corrosion resistance, (*c*) the special case of cladded vessels and "multiwall" vessels where the residual fabricating stresses are compression stresses in the inner wall.

4. Significance of the final pressurized test; in particular the new view concerning its employment as the last stage in fabrication, to reduce peak stresses or improve the properties of the metal, more especially in the case of austenitic steels. This recent change in approach to the superatmospheric-pressure test is in line with the well-known and well-tried process of autofrettage.

It is evident from the debates that there is a certain dichotomy between progress in the study and application of new qualities of steel and the interest of their employment by users in accordance with present regulations and practical experiences with the traditional steels.

This is due primarily, as Prof. Schaar has pointed out, to the complexity of the phenomena involved and the lack of experimental data, but also to the absence of reports analysing and synthesizing the work that has been done. In addition, it is time existing regulations were adjusted to the use of the steels the producers have been developing, with respect to design, to fabrication and to inspection.

As a basis for this, we would submit the following Working Party resolution:

"Specialized Community-level committees should be set up to conduct this work of analysis and synthesis, and to plan and co-ordinate in a logical manner the research programmes suggested thereby."

These committees should comprise representatives of all those concerned, *viz.* the steelmakers, the manufacturers, the inspectorate, and above all the users, in co-operation, also, with the research centres and the major specialized planning and design bureaux. On the basis of information supplied by users, pressure vessels should be classified in groups according, first, to service conditions and secondly, to possible causes of damage. The committees should study in detail the specific damage factors for these different groups. Thanks to their work, which should be conducted in depth and could include joint Community-level research, it would no longer be necessary to assess all these factors individually for every application. This would furnish a sound basis for improving and streamlining the regulations at Community level.

In the United States a body of this kind, the Pressure Vessel Research Committee, was set up over ten years ago. It is an independent agency which sponsors co-operative research programmes for the purpose of improving the design, fabrication and materials of pressure vessels. It works in conjunction with the American Society of Mechanical Engineers' Special Committee which deals with the revision of regulations. Mention should also be made of the British Ministry of Technology's recently-announced plans to provide grants to encourage the use of new welding materials and techniques in the construction of pressure vessels for the chemical and allied industries.

As Rapporteur to Working Party I, with the endorsement of the Chairman and members, I suggest that the institution of such committees would be a desirable follow-up to this Congress, which was convened, like its predecessors though in a much more specialized domain, to promote the harmonious development of two very important industries.

WORKING PARTY II

STRESS AND STRAIN CAUSED BY LOW AND HIGH TEMPERATURES

Report by Mr. A. Randak

Mr. Chairman,

Mr. President,

Ladies and Gentlemen,

All frequenters of big assemblies like this year's Steel Congress are familiar with a phenomenon that develops with quite astonishing regularity towards the end of such occasions — the onset of what I might call "Congress fatigue". Since we all have a good many meetings behind us, some of them decidedly arduous, I think this is very natural. So that those with sufficient endurance to attend to-day's Closing Session shall not turn up too worn out at the final reception in Mondorf-les-Bains, I shall try, in accordance with the organizers' directives, to keep my summing-up brief and confine it to the essentials.

I propose to divide my remarks into two parts: first, I will summarize the proceedings of Working Party II, and I will then go on, as M. Herbiet has just done, to cast up the balance-sheet and offer a few suggestions for future activities.

The Working Party's agenda covered a considerable number of very widely differing steels intended to withstand stresses and strains at ultra-low and at high temperatures. To make the debates as constructive and to-the-point as possible, we subdivided the aspects to be discussed under the following four heads:

1) steels exhibiting toughness at sub-zero temperatures;

2) heat-resistant low-alloy steels;

3) heat-resistant 12% Cr steels and special steels;

4) points of theory in connection with the creep behaviour of steels and alloys.

1. This part of the proceedings was devoted to steels for use at temperatures down to that of liquid helium, — 269°C.

Herr Barth's and Mr. Derungs' papers discussed in considerable detail which steels could and should be used in the different temperature ranges given the stresses and strains liable to occur there, adding further particulars concerning the testing of the different steels and the conclusions to be drawn from the results in assessing them. In the course of the debate we found ourselves substantially in agreement as to which steels could appropriately be used in the different temperature ranges, but not, although the matter was gone into very thoroughly, on the question of testing and assessment. We did agree that it is necessary to distinguish in testing whether the object is to establish the merits of a new steel or simply to check the commercial quality of one whose merits are already proven. In the former case, special tests such as the wide plate test can undoubtedly be very helpful, but it is more difficult to be sure as regards routine testing, as frequently quite different types of test piece are used and this very considerably affects the calculation of the notch impact strength. Some recommend Charpy V and round notches for routine testing: others point out that Charpy V-notch specimen tests can lead to the downgrading of steels which have been found perfectly reliable in practice. It would appear, therefore, that it is high time an international convention was concluded on the testing of steels for use at low temperatures.

Even here, in the discussion on steels exhibiting toughness at sub-zero temperatures, it emerged clearly that close attention will need to be devoted in the future to fracture mechanics, with respect to this category as well as to the very high-strength steels. To this end it will be necessary in the first place to assemble experimental data in order to provide the basis for evaluation. This new and important field would seem to me to be one lending itself particularly well to international co-operation.

Reference was made in the debate to the nitriding austenitic steels, which it is thought will assume increased importance in the coming years. It is greatly to be hoped that international co-operation will enable a small number of them to be standardized in the near future, rather than allow a whole multitude to be developed which will all be very much of a muchness.

With austenitic steels there is, as we know, the advantage that the strength properties can be enhanced by cold-straining whole vessels. Unfortunately, the potentialities of this process are not everywhere accepted. It was instructive to learn in the course of the debate that it has been employed in, for instance, Sweden, with excellent results, for over ten years; in various other countries on the other hand, such as Germany, it has not been adopted as doubts continue to be entertained of its value. To my mind it would be a very good thing to pay more attention to the successful practical applications in this connection.

Of the ferritic steels, only those with a 9% nickel content are, of course, suitable for low-temperature applications. Unfortunately, it has only been possible up to now to make limited use of their high yield point for welding purposes. High hopes were voiced in this regard during the debate, but the fact remains that in the case of repeated quenching and tempering following welding the limitations referred to still apply.

MM. Caillaud and Waché described the great advantages of the 36% Ni-alloy Invar in the construction of liquefied gas holders, including in particular its low coefficient of expansion and its excellent toughness values at temperatures down to — 196°C. Large-scale production, the steel being if necessary teemed in large blooms or slabs, can now be considered perfectly practicable, and weldability is also described as satisfactory provided certain precautions are taken. I feel, all the same, that careful account should be taken of the possibility of stress corrosion cracking which was mentioned in the discussion.

Dr. Cattro and Dr. Cesti dealt in their paper with the influence of production methods on toughness values at temperatures down to — 180°C, and in particular with that of vacuum processing on the properties of steels not produced specifically for low-temperature applications. It was stated that vacuum treatment could bring about a displacement to lower levels in the sharp fall to the impact-temperature curve. This increased toughness at low temperatures was ascribed by the contributors to improved micro-purity resulting from deoxidation.

2. Dr. Felix and Dr. Geiger had some interesting information to give us concerning the effects of chemical composition and structure on the creep properties and embrittlement of CrMoV cast steels. The experiments described were carried out with melts having a maximum carbon content of 0.15%, in accordance with British and American specifications. In long-time (100 000-hour) tests at 550°C, very good properties were recorded in small test pieces after oil quenching from 970°C, though it is doubtful whether equally good core characteristics can be obtained with larger test pieces.

In some countries of course, such as Germany, it is considered preferable with this category of alloys to have higher carbon contents and also larger proportions of chromium and molybdenum, a view supported by the results of a great many long-time tests. It is therefore particularly interesting to hear from Dr. Felix and Dr. Geiger that such excellent values can also be obtained using less carbon and smaller amounts of alloying elements, even though, as I say, some points remain in doubt as regards behaviour in the case of thicker dimensions.

The research described by these contributors also confirmed that the toughness values are adversely affected by higher austenitizing temperatures.

Dr. Rinaldi and Dr. Biraghi gave an account of the effects of post-weld heat treatment of thick-walled pipes on the properties of the joints. The experiments they described were carried out on pipes of 460 mm. diameter and up to 60 mm. wall thickness made of low-alloy CrMoV steel 14 MoV 6 3. Two welding techniques were used, namely manual arc-welding with coated electrodes and automatic submerged arc-welding. In the latter case embrittlement developed after normalizing and tempering: this was attributed to carbon migration between the weld and the base metal, resulting in carbon enrichment and increased microhardness. The phenomenon was favoured by the higher temperatures applied in submerged arc-welding.

M. Wagener's paper dealt with forged and cast heat-resistant ferritic steels for use in temperature ranges of below 580°C, setting forth the advantages and disadvantages of various steels with respect to particular stress and temperature conditions, and adding some observations on remelting, processing and, more especially, the importance of really appropriate heat treatment.

Dr. Yukawa went in detail into the considerations determining the selection of steels for steady and cyclic service at temperatures up to around 550°C — primarily the low-alloy heat-resistant grades and the 12% chromium grades. He listed as of special importance with regard to the mechanical stresses occurring:

a) high-temperature properties, including in particular creep and rupture strength, rupture ductility, stress relaxation behaviour and notch sensitivity in creep rupture;

b) low-temperature properties, principally adequate yield strength and fracture toughness;

c) vibration resistance, the conditions to be withstood including both high-cycle fatigue and low-cycle plastic strain fatigue.

To understand the alterations taking place in the material under stress it was necessary to pay careful attention to the carbide and other phase reactions. Dr. Yukawa went on to emphasize that, with these grades too, it was necessary to take account of fracture mechanics in seeking to understand material defects and to develop the metals further. He also had some interesting observations to make on special techniques for testing the behaviour of the material and the progressive changes and damages occurring in it as it was exposed to steady and cyclic loading conditions; in this connection he gave various details concerning measurement of density changes and low-cycle fatigue tests.

3. M. Caubo described intensive research conducted on a modified 12% CrMoVNb steel for the construction of turbines to operate at temperatures up to about 600°C. While the B2 grade differed only marginally in composition from several other current steels of this type, it was, M. Caubo said, essential to stick to certain composition limits with regard to particular elements: for instance, an Mo content in excess of 0.5% was liable to cause a reduction in toughness even if there was no delta ferrite. In the debate, German members stated that there were any number of research results on the

12% Cr steels proving the satisfactory properties of the existing grades, so that it was pointless to develop new ones differing only in minor respects; they also considered that M. Caubo's steel was no improvement on those already available. The weldability of the 12% Cr steels was discussed in detail: German members contended that if the proper precautions were taken there was no real problem nowadays, but it seems doubtful whether their opinion was altogether shared by the delegates from other countries, either as to the chemical composition which might help to make the B2 grade freer from delta ferrite in thick sizes, or as to weldability.

Dr. Dulis and Prof. Habraken described in considerable detail the results of research on the martensitic stainless cobalt steel AFC 77. to which very high strengths can be imparted by aging, tensile strengths of up to 200 kg/mm² having been recorded for the bar form and around 350 kg/mm² for drawn-plus-aged wire. The properties and practical potentialities of these new steels were very fully gone into; it is considered that technical application would be feasible at up to about 590°C, but there is no saying as yet what compositions will become standard for this type of steel, nor in what fields it could in fact suitably be used. Moreover, no long-time values are at present to hand. The steels' weldability is obviously first-class; their corrosion resistance is comparable with that of the traditional 12% Cr steels.

Dr. Edeleanu in his paper surveyed and commented on the present position regarding the use of heat-resistant austenitic cast steels for chemical plant, with special reference to centrifugal cast tubing, which had done excellent service in the petrochemical industry in connection with the production of town gas, ammonia, ethylene and so on. The fact that larger quantities of carbon could be used than with hot-worked steel made it possible to obtain major improvements in heat resistance, resulting not only in lower costs but also in better creep properties. Dr. Edeleanu considered a carbon level of 0.4% to be quite suitable and not liable to involve any serious loss in ductility. On this point opinion in the Working Party was divided. However, the fact remains that the tubes have performed well in service, whereas shaped casting continues to present problems with steels of this type. At all events it is evident that the prospects for this 18-25% Cr 20-40% Ni centricast tubing are most promising.

4. Mr. Henderson and Dr. Siegfried contributed various observations and research findings of relevance for the purpose of working out the physical and mathematical explanations of the creep behaviour of steels and alloys. The many speakers in the debate fully agreed with them that these important studies must be continued; at the same time it must be said that, although the lines pursued seem most hopeful and a number of highly encouraging interim results have been obtained, a great many question-marks still remain.

So much for the substance of the proceedings. I must now place it on record that, owing to the enormously wide field we were expected to cover, the Working Party found it impossible to thrash out in full all the points that arose. It must be admitted indeed that many points which members had stated they wished to raise simply could not be considered at all, for lack of time. It would be well if the members concerned would submit their points afterwards in writing, and I would also suggest that an effort be made by the authors of the papers to which these queries relate to reply to them.

May I be allowed to add a few words of criticism. M. Herbiet's summing-up shows me that he and I have come to pretty much the same conclusions concerning the Congress proceedings. In the first place, I would say — and so, I think, would most of the delegates I have talked to — that the organizers' decision to make the Congress primarily an occasion for debate and discussion was undoubtedly absolutely right. But I must immediately qualify that. Our Working Party had, as you know, to debate thirteen papers. And it was obvious that many delegates just had not had time to read through the papers carefully in advance of the Congress. As a result, it was impossible to get through all the material up for debate, so that a number of debates had to be guillotined. The conclusion I would draw is similar to M. Herbiet's. I think the course adopted this year was the right one and should be pursued consistently. But it would be a great help, and certainly assist the technical discussions, if small sub-committees could be set up with very strictly limited terms of reference, each to be provided with not more than one or two covering introductory papers establishing the precise scope of the subject to be dealt with, so as to leave adequate time for debate.

For myself, I am convinced that it is most important to get the different countries' approaches to the assessment and application of steels lined up as soon as possible. You may say that there already are international bodies for this purpose, working on standardization under the aegis of ISO and Euro. All the same, I feel there are many problems on which these bodies cannot help us. Once different approaches develop in individual countries on such matters as, for example, the assessment and possible applications of certain steels, it is extraordinarily difficult when discussing standards to get back to a single uniform standpoint. The conclusion is, to my mind, that so far as many issues are concerned discussions cannot take place soon enough, and I am sure that such discussions by international committees of the kind I suggest could be extremely constructive. Of course it would be necessary to make sure that such committees were made up of members really competent to deal with the subjects concerned. I can imagine that it would be most valuable for the findings of various small committees of this nature to be submitted periodically to a larger body.

Ladies and gentlemen, before closing I must express our thanks to the Congress organizers for their admirable staff work and for all the trouble they have taken. Thanks, also, to all those who spoke in the debates and so contributed to the success of the occasion, and last but not least to M. Heurtey, the Chairman of the Working Party, for his eminently capable and impartial handling of the proceedings.

Thank you for your attention.

WORKING PARTY III

STRESS AND STRAIN CAUSED BY CHEMICAL ATTACK (THEORETICAL STUDIES)

Report by Professor R. Piontelli

Mr. Chairman,

Ladies and Gentlemen,

I should first like to thank the organizers of this Congress for having entrusted me with the difficult, if complimentary, task of summing up the work of the Third Working Party.

This work was to examine the theoretical aspects of the behaviour of steels in the presence of chemical agents. Those dealing with the aspects of corrosion, will recognize the usefulness of any encouragement and progress, even if only theoretical, in the study of a subject bristling with difficulties and disappointments. The results of our work are without a doubt of great importance and we must be thankful for the eminent specialists in the various fields who have contributed not only valuable ideas and up-to-date information but also suggestions of the greatest assistance to technologists. The eleven papers which were submitted to our Working Party and so thoroughly discussed concern the many types of corrosion affecting ferrous materials of major practical interest which are still open to discussion and controversy.

I will abstain from going into a detailed survey of these papers as many of us have already had the privilege of being present when they were submitted by their authors. I will limit myself therefore to giving you an overall summary of our work.

The subjects dealt with include: the general aspects of the behaviour of high and low alloy steels used in building structures embedded in concrete or in the ground, weathering steels (oxide coated) used for architectural purposes, steels used in central heating installations, passivatable steels; intercrystalline corrosion, stress corrosion, and local corrosion; inhibitors; the influence of flow rate, methods of inspection, behaviour at high temperature in water, water vapour and in the air. This will give you an idea of the range covered.

At present it is not possible to give anything but a preliminary evaluation of the present and future importance of our work, but it is, however, possible to analyse the gaps in our knowledge and to propose a few directives for improving the situation. Present progress in the study of corrosion phenomena is, generally speaking, part of what one may call "rational technology", meaning by this more than just empiricism or the collation of practical rules. The corrosion expert, like a doctor, is required to prevent or cure one of the most insidious diseases affecting metals. His main job is to:

1. correlate the characteristics of the composition, the structure, and the surface conditions of metals together with their behaviour;

2. establish points of compatibility, anticipate the occurrence, type and duration of corrosive phenomena. By type we mean nature and distribution;

3. diagnose the causes of the phenomena;

4. suggest means for preventing and limiting corrosion phenomena.

In the field of an industrial activity where any interruption or slow-down represents not only risks but a heavy economic burden, it is above all necessary to avoid the deleterious forms of corrosion. The corrosion expert must therefore be able to create conditions whereby his materials suffer only negligible and gradual deterioration in order to preserve their service life in conditions of adequate working safety. In order to tackle this most exacting challenge, he must not hesitate to draw on thermodynamics so as to know beforehand of the conditions in which dangerous phenomena may occur; he must also draw on structural research (relating to both internal structure and surface areas) no longer limited to metallography, as well as on radiography. For this purpose he must utilize the most up-to-date equipment and knowledge, such as the electron microprobe, the Mössbauer effect, neutron diffraction and slow electrons, and the most complex kinetic electrical chemical research apparatus. With the help of all these, if available naturally, the corrosion expert must patiently work out his own "pathological anatomy" of metals which are exposed to a multitude of aggressive media and build up the "corpus" of his diagnosis. He must in fact develop an ever more effective anti-corrosion pharmacology.

We have obviously moved from empirical to rational medicine. What is, however, missing is the equivalent of molecular biology. Am I right in stating that the corrosion expert must try to elaborate solid and general principles in order to turn his knowledge into a genuine science? At a glance, this would seem obvious, i.e. since corrosive phenomena are of an essentially electrochemical nature, the knowledge which we are seeking cannot come from that direction alone. But would it not be possible to develop an atomic and molecular electrochemistry which would be analogous to the molecular biology of living things? Or maybe such a science exists already? It is this doubt with regard to our own field which seems to justify the pessimism which I do not believe should be concealed before a highly qualified gathering such as this. It is true that an atomic and molecular electrochemical science is claimed to exist, although, up to the present time, it has only led to sterile and more or less elegant formalistic theories. It is not astonishing, therefore, that the metallurgist, whether corrosion or, to take an example, electrogalvanizing expert, facing practical problems and difficulties, has so far desisted from using this science, which he finds so insecure and devoid of promise, as a basis for his research.

We must also understand the reason why technologists in our field believe that any financial and human effort devoted to basic research in this direction is wasted.

In my humble opinion, molecular electrochemistry, instead of constituting, as at present, a starting point which can only be based on innumerable hypotheses which are but rarely enunciated and cannot generally be proved, should constitute an aim which must be approached by means of a patient and systematic progression of approximations, while methodically and gradually stripping the phenomena of all ancillary and incidental aspects. This is obviously a long-term aim, and one should not really be surprised at this if one considers the slow rate of progress in all the physico-chemical sciences in which phase interface phenomena are of vital importance.

The existence of boundaries is in fact a source of anxiety to scientists as well as politicians. Even though the aim may be sufficiently well-defined, the difficulties facing the theoretical scientist are nevertheless numerous. One need only think of the confusion which still exists in the case of thermodynamics concerning the possible effects of crystallographic orientation on the relative tensions of equilibrium electrodes, or of the lack of certainty regarding the causes and distribution laws of corrosive attacks in conditions of apparent contact of phase uniformity, or of the fact that we are not yet in a position to evaluate adequately, in chemical potential terms, the influence exerted on the various aspects of elastoplastic behaviour of metal atoms, which will in fact be the elements involved in corrosive phenomena, by their being associated with the interface between crystal grains of different orientation or with the phase interfaces, or by the state of deformation.

I should also like to point out how far removed are the actual phases of the products of corrosion reactions from the ideal phases to which all the available thermodynamic data refer. I believe that, in order to achieve real progress in this direction, it is above all essential to lay down a number of general methodological norms.

Initially, the development of the electrochemical theory will have to be of a practical nature, i.e. based on concepts and methods which are met with experimentally. Any theory on corrosion will, in any case, have to be based on both thermodynamic and kinetic concepts and laws. When listing the factors connected with these two branches of science, a sufficiently important place will have to be given not only to environment but also to structure, in the widest meaning of the word, that is to say taking in the macroscopic geometries of the systems under investigation, the distribution laws of the constituent phases, the nature and distribution of the lattice effects, the microstructural characteristics of the grain shapes, the surface conditions and the results of mechanical or thermomechanical stresses. There is no doubt that this rather long list will, in a relatively short time, also include such things as magnetization states. In the field of electrochemistry, theoretical hypotheses are much more numerous than really reliable experiments, and most of the latter concern either mercury or polycrystalline platinum. We must, therefore, not be surprised at the fact that, in order to prove the kinetic laws of electronic processes, the most recent work on corrosion related to cadmium amalgams. To overcome this major obstacle to an ordered and effective development of the electrochemistry of solid metals, we must above all systematically assemble phenomenological data and laws relating to the electrochemical behaviour of metals of extreme purity under maximally controlled structural and surface conditions.

We now come to oriented single crystals, whose surface defects and conditions are the easiest to control, which will have to be studied with regard to all the aspects of electrochemical behaviour, namely exchange of ions, hydrogen or oxygen, passivation phenomena including the aspects of instability and self-healing capacity. One would then be in a position to tackle the as yet unsolved problems of the conditions under which passivation phenomena occur, of the base metal's influence on the structural properties of the coating layers, of the seats of localized corrosion processes, of the electrochemistry of mixed metal phases, of the behaviour of metals in the face of alternating currents or in fused salt media and of many other theoretical and practical aspects. It is very often extremely difficult to carry out this type of investigation with polycrystalline materials.

In all this work, the electrochemical expert will have to co-operate closely with specialists in metallurgy, solid-state physics and physico-chemistry of aggressive media. The metallurgist will be able to help with the results of his theoretical and experimental studies connected with ideal and real metal structures and will also be able to help in solving the question of the influence of deformation conditions, of the effects of radiation and of very many other phenomena. The solid-state physicist will be able to provide valuable suggestions on questions relating to coating layers, such as composition, the epitaxial relationship to the base metal, structure, distribution, all factors which often influence the corrosive behaviour of metals. It is very probable that the vital influence exerted by the lattice state (defects, traces of other constituents) on the behaviour of oxides and similar semi-conductor phases, is also exerted on electrochemical behaviour. The anion's influence, which our Working Party has shown to be one of the major factors of corrosive phenomena, must still be studied in all its aspects regarding the kinetics of various types of ion exchange, competitive absorption, the colloidal chemical relationship to corrosion products, etc. In this field, too, the use of radioactive indicators and the co-operation of the colloidal chemical experts will be of the greatest assistance. Thus, the electrochemcial expert will be in a position to improve also his knowledge of the significance and validity of the methods of diagnosis and control, which now form part of industrial practice and the results of which are not always easy to interpret. It is quite a long time since the corrosion expert could rely almost exclusively on statistical research relating to the results of a large number of tests. Here too, a statistical list might be most useful.

The statistical method is certainly of the greatest help in all fields where the lack of data on original conditions and the complexity of the phenomena due to the vast number and to the nature of the factors involved, incidental and fluctuating for the most part, prevent the formulation of laws and forecasts. In this connection, the position of the corrosion expert, disposing as he does of a large number of results, might, at first glance, seem analogous to that of the physicist, who applies statistical methods for the purpose of forecasting or interpreting the macroscopic behaviour of a system. In reality, however, the corrosion expert's position is much closer to that of the scientist who applies statistical methodology to the study of biological phenomena.

Atomic and molecular physics provide the physicist with a thorough knowledge of basic phenomena. In physics, normal behaviour is none other than macroscopic behaviour which can be observed daily. It is different for the corrosion expert, since the use which he makes of statistical methodology based on insufficient knowledge of actual basic conditions can only rarely provide him with more than an indication of average behaviour, owing to the fact that experimental conditions are in most cases different from the kind of conditions which the materials will have to contend with in practice.

The present trend whereby laboratory electrochemical methods are used is therefore quite justified, although the interpretation, the generalization or the extrapolation of results obtained is continually hindered because of the inadequacy of our knowledge of the basic phenomena. It is always to these phenomena that we must return, although, may I repeat once again, we must not necessarily consider them as starting points.

May I be allowed to say that, in order to solve all the main problems which condition the development and the very future of humanity, namely sources of energy, water, the conquest of space and possibly of the ocean depths, the question of materials is among the most essential and difficult, because these are subjected to ever greater and more varied requirements. In a Congress dealing with the use of steel in the chemical industry, it is certainly not necessary to remind you that both past and present history of chemical technology demonstrates the part which the availability of suitable materials has played, plays and will most probably play in deciding the industrial uses of chemical processes. In all this, where the corrosion expert is often required to forecast that which cannot be forecast, competition is becoming tighter among the various materials which aspire to new duties and which hope to displace their competitors from their traditional fields of activity.

Obviously, the kind of basic research which I am suggesting should be encouraged is not likely to increase the short-term turnover figures of steelmakers. On the other hand, an excessive effectiveness of anti-corrosion measures is not likely to reduce this turnover.

On the other hand, I believe that a more thorough knowledge of electrochemical and corrosive behaviour, increasingly necessary to both researchers and users, is bound to lead to an orderly, rational and safe extension of applications.

It now remains for me to touch briefly on a rather delicate subject. I wonder whether this is the type of gathering to undertake the task of elaborating methods of research, and of assembling, interpreting and collating truly reliable phenomenological data for the purpose of forming the basis of an up-to-date theory of the electrochemical behaviour of metals.

I think that one should consider in the first place university research centres, not only because these are the natural centres for basic research and for the essential preliminary work of revising general and methodological concepts, but also because the research itself is an invaluable and essential part of the training of future teachers and research workers, and because a university is an uninterested party.

In addition to this activity, there could be co-ordination with individual research centres, which could be entrusted with work on specific subjects. It is certainly desirable that there should be co-operative work on a national scale which would be more closely linked with the more practical aspects of the problem.

This Congress has amply shown (thanks not only to the marvellous efficiency of the translation services) that, where there are common interests, it is easy to understand and co-operate with people of different nationalities, traditions and mentality.

The corrosion expert, who, in his daily work, has to tackle problems connected with the instability of the electrode phenomena of inertia and passivity and who realizes the ease with which barriers and inhibitions can be overcome, is not the man who ought to fall back on *a priori* prejudices with regard to the possibility of co-operation.

Before closing, may I express the hope that the subject of this Congress, which could not be gone into as thoroughly as one would have wished owing to lack of time, will be gone into once again in the near future in order to be examined in the light of new developments.

I should like to apologize for the length of this talk which should have been a summary, and may I thank once again all those who have participated in our work, the Chairman of the Congress for having given us the possibility to spend some time on these topical and important problems, and all of you for your kind attention.

WORKING PARTY IV

STRESS AND STRAIN CAUSED BY CHEMICAL ATTACK (PRACTICAL STUDIES)

Report by M. R. Castro

Working Party IV, which dealt with "Stress and Strain Caused by Chemical Attack (Practical Studies)", sought first of all, despite the very widely varying nature of these studies, to define, within the general sphere of the corrosion resistance of ferrous materials, the concept of "extreme stress." It was clear that this was in no sense an absolute, but always a purely relative concept, since the aim is necessarily, in corrosive environments, to strike an acceptable mean between operational requirements and ease of maintenance on the one hand and capital costs and depreciation on the other. Accordingly, where a given industrial application presents an obvious corrosion hazard, as happens in particular in the chemical and para-chemical industries, it becomes necessary to seek the most economical possible material with a corrosion resistance that is the maximum obtainable for that material and at the same time adequate to withstand all sorts of eventualities in the way of environmental variations. The selection process moreover covers, as we shall see, not only the actual material, but also the modification or control of the corrosive surrounding medium, and/or the use of protective coatings.

In certain special cases this limitation as concerns maximum resistance may be deliberately disregarded. It may be found preferable to use a comparatively cheap corrodable material in which the rate and uniformity of corrosion can be kept under observation and which it is intended to replace at pre-ordained intervals, rather than a more resistant and expensive one liable to more insidious and less detectable corrosion resulting in sudden unforeseeable breakdowns.

The corrosion processes discussed by Working Party IV varied widely, from corrosion in aqueous media to dry corrosion, from corrosion at ambient to corrosion at high temperatures, and also taking in flame corrosion and corrosion by abrasion and erosion. But these are none of them wholly separate categories. While many of the cases of aqueous corrosion cited come under the broad heading of electrochemical reactions in dilute media, corrosion by saturated fluids deriving from the degeneration of hygroscopic solids as a result of moisture is more akin to corrosion in molten or combusting media. Similarly, dry corrosion either at ambient temperature, such as atmospheric corrosion, or at high temperatures, such as the action of water vapour or combustion gases, is considerably complicated and aggravated where accompanied by liquid condensation, or formation of a molten phase, or erosion steadily modifying the conditions promoting chemical development of the metal/medium interface. Considering these various practical instances, it is obvious how difficult it can be to predict the behaviour of metal materials from experience gained beforehand with a number of straightforward cases. The cases discussed by the Working Party confirmed that there are, broadly, three ways of combating corrosion of ferrous materials:

a) by acting on the composition of the base metal and impurities (deliberately introduced or accidental), its geometry, its surface state, the nature of the metals with which it is in association in the corrosive media, and the electrochemical relationships with these media;

b) by acting on the corrosive medium wherever possible, i.e. by modifying its temperature, concentration or agitation, or adding corrosion-retarding impurities or bodies, or obviating other corrosion-activating impurities;

c) by interposing a permanent or temporary protective substance between the metal and the medium to prevent or retard their reaction on one another.

It is of course possible to use two or all three of these methods in combination, for instance by adding a coat to a metal which is fairly corrosion-resistant already, or employing an organic coat containing a corrosion-inhibitor. Anyhow, practical corrosion problems are always tackled by recourse to one or more of these three techniques, and I propose in my summing-up to discuss each of them in turn.

First, the metal.

As regard the composition of the base metal, we have to distinguish between the cases where, for costing reasons, the metal has to be unalloyed or low-alloyed, and those where costs allow and obvious technical reasons compel the use of high-alloy materials. In cases of the first kind, the debates confirmed that, in dealing for example with atmospheric corrosion, small amounts of certain elements can reduce the kinetics of corrosion and, in combination with surface protection of various kinds, enable metal structures to stand up better to the action of industrial atmospheres. Small amounts of these or other elements commonly added to iron can also alter, sometimes for the better but more usually for the worse, the kinetics of iron oxidation at high temperatures by interfering with the diffusion and adhesion to the metal/oxide interface, and so influence the total fire waste between the ingot and the finished-product stage in the course of the successive heating operations before the plastic transformation of the metal.

With regard to high-alloyed materials intended to withstand exceptionally corrosive environments, attention was drawn to two particular courses which can be adopted in the choice of chemical composition. First, certain modifications can be made which, while maintaining or even improving the corrosion resistance of stainless steels, push up their mechanical characteristics, and more especially their yield point, thus enabling them to be more economically utilized. In the instances described by members, this was done either by substantially increasing the nitrogen content of the traditional austenitic steels, or by so conducting the production, processing and treatment of mixed austenitic/ferritic steels as to give them greater resistance, elasticity and ductility. In some cases, however, corrosion resistance can only be combined with some other service property such as hot creep resistance by compromising to some extent. For instance, the addition of certain elements such as molybdenum and vanadium, while admittedly increasing the steels' rate of softening at high temperature, at the same time, by fusible non-protective oxide-phase formation, reduces their resistance to hot gases containing excessive amounts of oxygen. Another technique consists in controlling certain impurities, either accidental and harmful (copper, silicon, manganese) or intentional and useful (rare-earth metals, zirconium, thorium, lithium and so on), whose influence on certain factors in dry corrosion, such as grain growth and adhesion of oxide weathering layers, is coming to be well known.

Geometry — both the macrogeometry or general design of metal installations and equipment and the microgeometry of the metal in relation to its surface condition — is turning out to have more and more to do with corrosion as actually occurring than can usually be worked out in advance by laboratory experimentation. Macrogeometry is primarily connected with corrosion caused by differential aeration or cell formation and with interstitial corrosion, which are among the most dangerous kinds inasmuch as they are insidious, localized and hard to detect. It also plays a part where, as a result of faulty design, abrasion or erosion develops and makes the metal less self-protective *vis-à-vis* the medium, or where dry corrosion is speeded up by condensation. This underscores the vital need for co-operation between the engineer and the corrosion expert in the designing and construction of plant for the chemical industry, since any defect in geometry can lead, in liquid media, to heterogenization of the concentration of oxygen or other ions in solution or to settlement, or alternatively turbulence, of scums or deposits, and, in gaseous media, to temperature gradients favouring condensation.

As for the microgeometry connected with surface treatments such as passivation, the Working Party discussed a number of examples illustrating the part played by surface irregularities or "stress raisers" in setting off pitting or stress corrosion. Here again both the producer and the user must be made to realize how vital it is that steel intended for employment in a corrosive medium should be delivered in good surface condition and kept that way during storage and in the process of final installation, whether the latter is effected by forming operations or welding. The association of different metals in the same conductor medium can produce galvanic phenomena causing the metal acting as anode to corrode. The Working Party was told of various cases that had occurred with heterogeneous welds and assemblies used in mining. At the same time, the relative surface area of the anodes and cathodes is of great importance in such association — yet another case where co-operation between designer and metallurgist is essential if there is not to be the risk of miscalculations and disappointments. Several examples were described where the persistence of stresses in welded or other assemblies had in certain media given rise to very dangerous cracks, a possibility which could be substantially guarded against by stress-relieving or by choosing special materials.

Next, the reactive media. How can these be modified by those operating the plant in question so as to reduce corrosion to a minimum? In some cases, particularly with aqueous media, substances can be added which modify the nature or kinetics of the anodic and cathodic reactions at the metal/medium interfaces. The inhibitors which are extensively used for this purpose have up to now been selected much more by rule of thumb than on the strength of electrochemical studies conducted in advance: rather, modern electrochemistry has made it possible to understand their workings correctly and to investigate and elaborate them on a properly scientific basis. In this connection, the Working Party was given an account of electrochemical research which had brought to light the good and bad effects of small amounts of certain impurities in sulphuric acid: these might either ensure the proper behaviour of the stainless-steel containers in which the acid was stored, or suddenly trigger off serious and rapid corrosions, and this fact had enabled hitherto unexplained accidents to be elucidated and so prevented for the future.

This grasp of the significance of impurities in the reactive medium has since been extended to the non-aqueous media. The Working Party was given examples of the undesirable effects of traces of acid in combustion gases, of sulphuretted salt or metal impurities in fuel oils sending down the melting point of the slag, of impurities in the feed water of exchangers producing noxious deposits, and of traces of oxygen in molten alkaline metals. All this makes clear the importance of the work being done to purify these media. But quite apart from the action of impurities in general, the engineer can also exert influence on the thermal and mechanical factors relating to the reactive media. Local rises in temperature, or the sizeable temperature gradients of liquid or gaseous turbulences, or saline or acid condensations, are practically always harmful, and, if they can be corrected by altering the design or the insulation and cooling arrangements, it should be possible to prevent accidents in this connection.

The third means of coping with corrosion, namely by interposing a low-reactive protective layer between the metal and the medium, is among the most economical, and must always be considered where the environment is only moderately corrosive and the surface to be protected very large. The Working Party was not able to go exhaustively into all the protection techniques available, but a number of examples were discussed, ranging from viscous greases, with or without inhibitors added, to metal cladding, and also including ceramic coatings and paints, as well as special forms of protection where there is a risk not only of corrosion but of abrasion and erosion.

The discussion, with practical illustrations, of the criteria for selecting a steel for a particular application, and of the factors which have caused difficulties and accidents to occur notwithstanding what looked on the face of it a perfectly sensible choice, showed clearly that to rely purely on corrosion tables indicating such and such a metal for such and such an aggressive medium is unwise if these are used as the sole guide in the complex business of installing plant which may be exposed to corrosion.

Laboratory tests followed by pilot or shop trials are in fact indispensable in all cases where the service conditions are to be exceptionally heavy. Account must be taken in these experiments of all the parameters I have mentioned, some of which, as we have seen, are physical and physico-chemical and not only chemical in character. As regards the physico-chemical side, the tremendous strides that have been made recently in electrochemical analysis merit the closest attention, since, thanks to them, the study and interpretation of corrosion processes — especially the processes of aqueous corrosion — are now no longer done empirically, but enable these processes to be not only explained but guided and predicted; consequently, electrochemistry is more and more superseding many of the empirical tests, as it is showing up the danger of using them under any but the conditions for which they were originally intended.

Electrochemistry is thus a first-class example of the assistance which pure research can afford to technology, and hence to economy generally. The Working Party accordingly expresses the hope that action will be taken at international level to promote co-operation between pure research, applied research and industry in the field of corrosion control.

IV. Addresses given at the closing session

Closing Address
by M. Pietro Campilli
Chairman of the Congress

And so we come to the end of the Fourth Steel Congress. As Chairman, I have first of all to thank the distinguished scientists and technologists who have buckled down with such success to their task of exploring various matters in detail, describing particular experiences of their own, and engaging in thorough and thoughtful debate. More especially I must thank the chairmen of the working parties, upon whom fell the main burden of conducting the Congress proceedings, and with them the rapporteurs, who with their learning and experience occupied a quite distinctive position as pacesetters and activators of the discussions.

I would also thank the European Commission, and in particular President Rey and Signor Colonna di Paliano, for the decision to carry on with the series of ECSC Congresses, each of which in succession proves just as good and valuable an occasion as its predecessors, if not more so.

For this, credit must also go to the Commission's staff, and especially to Director-General Peco, who has worked so hard in the organizing of this Congress as of the previous ones.

And no Chairman at an ECSC Steel Congress could close it without recalling that these occasions are now indissociably linked in every mind with the courteous and efficient hospitality of the Grand Duchy of Luxembourg. It is with the truest pleasure that I extend our thanks once more to Their Royal Highnesses the Grand Duke and Grand Duchess, who honoured our opening session with their presence, and to the Prime Minister, M. Werner, and all others in authority in this country who have followed our work with such interest. To them I would say how greatly all of us present have appreciated the charming welcome given us, which touched a special peak in the reception at Echternach Abbey.

Having thanked all those to whom thanks are due, a Chairman should next cast up the balance-sheet of the proceedings. I think, however, that I can fairly dispense with this duty, firstly because it has already been performed most capably and authoritatively by the working parties' rapporteurs, and also, of course, because the debates were so specialized as to be quite outside my range.

I should like on the other hand to offer some very brief general comments appropriate to the Chairman at such an occasion, taking my cue from the accounts we have heard of the working parties' discussions and conclusions.

In the first place, I think the Congress has sharply underscored the fact that science and technology are tending away from rigid specialization and towards a broader and more comprehensive conception of the progress of human civilization. This is a trend which I referred to before, in my opening address. Now it seems to me that one of the most striking points about this Congress has been the emphasis laid on the need for the steel industry to get away from the strict compartmentation that has existed up to now. The sense that progress in the steel industry, and in technology generally, necessitates a new, joint approach in research and experimentation, in planning and application, between the steel-producing and the steel-consuming industries has, I feel, been very much in evidence during the Congress. In particular there has been the call for the steel and chemical industries to work more closely together, since only so can the latter turn its growth and innovation potential to full account and do something really effective to help meet the needs of the world's ever-expanding population. And in this way the enormous driving-power of the chemical and petrochemical industry could communicate itself to the steel industry also, and stimulate it to undertake major innovations in its production technology and range of products.

It is not only between industries, as the Congress stressed, that this pooling of experience and effort is wanted: what is also wanted is better surmounting of the continuing geographical, political and administrative barriers that are impeding freer interchange of research results, and hence impeding the full attainment of the growth rates that can and must be achieved in order to cope with the many grave problems still confronting the world as a whole. Occasions such as the Steel Congresses are undoubtedly a very valuable means to this end, yet at the same time they show us how much remains to be done. We are seeing how vital it is to enable full use to be made of scientific talent and research potential wherever they are to be found. World development must not proceed on the basis that some countries' research work is treated as the mere underling of others': it is unthinkable that the "junior partner" and "brain drain" relationships should go on for ever. Research work is bound of course to involve some specialization, so as to enable the true bent of a particular people or group or individual to be used to the best advantage. But by the logic of modern scientific progress that specialization requires to be offset by a corresponding element of openness and co-operation. And there, clear to see, is the great part that Community-level action can play. The Community's activities, even if they did stem originally from the Six themselves, should be opened wider and wider, within Europe primarily and *vis-à-vis* Britain in particular with her immense scientific and technological sophistication: they should be directed not to dividing and shutting-off but to uniting and opening-up, to allowing co-operation with everyone, in West and East alike. The logic of technological progress and the need to make efficient use of available research potential in all the different countries constitute an incentive — not conflicting but combining — for the closer interknitting of the world's economies and stronger bonds of solidarity among the world's peoples.

This movement towards greater co-operation among the different sectors of research, towards placing the emphasis on the factors making for unification as well as on those making for specialization, has been thoroughly gone into during the Congress, and the important conclusions that have been reached do, as I say, lend themselves to comments of a general nature. In this connection, I feel I should touch on two other problems of major interest, on the tackling of which it will very largely depend whether or not scientific and technological research does in fact succeed in forging ahead in its own field and in enabling steady progress to be made in the economic and social development of the whole world.

The co-operative approach that is so much a part of present-day science should not be confined to relations between the different fields of research and the dissemination of the research results obtained in the different countries: it must involve a rethinking of some of our traditional patterns. I would stress in particular the need for close and effective co-operation in the promotion and conduct of research between the Governments and the private sector of the economy. This is not a matter purely for public grants and loans, important though we know from experience that these are in getting research carried out in all countries. It means something more — the stepping-up of the State's co-ordinating role so as to ensure that public funds are channelled in accordance with criteria and values genuinely in line with the deepest needs of the society concerned and of the people living in it.

Now, with the role of the Government in the promotion and co-ordination of research thus enhanced, it becomes necessary, for the same reasons as I have just given you, that Governments should show themselves prepared to line up their respective research policies at international and supranational level. This is a field in which the Community would do well to be active, making it possible on the strength of past experience — sometimes negative but always instructive — to work in research as in other matters for the evolvement of common policies which will be the great distinguishing feature of a group of countries moving on from the customs union now completed towards the establishment of a full-scale economic and political Community .

The other important point I would make in my closing remarks, of which much was made in the discussions, is that it is vitally necessary to establish new and more effective links between researchers and producers, and in particular, as has come to be widely recognized, to establish closer relations between the universities and industry. I should like to explain briefly how I feel about this in the light, more particularly, of the importance which university organization has latterly assumed in all countries. When I say we need this closer co-operation, I do not in the least mean that the universities should exist to serve industry, for unquestionably there can be no hope of dealing with the present difficulties if true freedom of education and the independence of the universities as educational institutions are not preserved. What I mean is that the universities, to be viable, must be able to keep in continuous touch with the real problems of the world of today, and must devote their energies to seeing that their cultural heritage and intellectual values can afford guidance for human development and progress. In honesty we have to admit that there were good and sound reasons behind the student unrest: it was not purely the work of the lunatic fringe. The universities have not always kept pace with the march of events: they have often been the prisoners of outdated institutional traditions. So to say that closer relations are needed between them and industry does not mean merely that university studies should be a preparation for future employment, though of course they should be that too: it means also that scope should really be offered for translating learning and research into practical steps forward.

One general observation seems to me especially worth making on this occasion. Science and technology have now taken over every side of human life, and they are continuing to innovate faster and faster. It might indeed be said that, in this technological civilization of ours, the whole concept of time has altered, since today the space of one brief year witnesses more changes than did a decade not so very long ago. This ceaseless onward drive is affecting customs and traditions, often carrying them along with it, sometimes sweeping them away altogether. Science and technology have moved into an age in which the dividing-lines between discipline and discipline are being transcended and co-operation is seen as affording the only chance for extending their frontiers further. Now all this is offering our present-day political systems too a chance we cannot let slip. With science and technology seeking increased integration and new modes of co-operation, our political set-ups too are having to progress towards forms of community both more extensive and more intensive, inwardly and outwardly, with the rest of the world.

This Steel Congress of ours is an adumbration, both in the manner of its holding and in the course that it has taken, of this future approach. It was convened by the

European Economic Community, but it has been an encounter full of stimulating debate and mutual profit for researchers from many countries outside as well as inside the Community fold.

At the close of the Congress, then, may I express my most heartfelt hope that the European Community, with its organizational framework and its policies gaining in strength as time goes on, will more and more adopt a position of openness towards other countries, and will help to bring about genuine and fruitful co-operation with all peoples everywhere.

Closing Address

by M. G. Colonna di Paliano
member of the Commission of the European Communities

It has become a tradition of the ECSC Congresses that a Member of the Community Executive — formerly the High Authority, now the European Commission — should say a few words at the close of the proceedings.

This Congress, a notable occasion in itself for the professional eminence of its rapporteurs, contributors and delegates and for the experience and authority of its Chairman and Vice-Chairmen, has the further special feature that a point was made of asking all those attending not simply to listen, but to put forward for the benefit of the rest the fruit of their own learning and knowhow.

The lively debates in the working parties and the summings-up which we have just heard from the Chairman and the rapporteurs make it clear that the point was taken. The Congress can thus be seen to have served not only as an exchange of information at an extremely high level, but also as a springboard for new ideas and new studies calculated to extend still further man's mastery over matter, and to afford man still greater opportunities for turning the matter at his disposal to account in line with his particular needs in this day and age.

We were all, I feel sure, deeply moved by Dr. Campilli's and Prof. von Weizsäcker's opening addresses. Both speeches, delivered before this distinguished gathering of scientists and technologists, gave pride of place to the question of what the relationship of research and industry should be to the end purpose of humanity — that relationship which is the sole warrant for human action, whether by scientists, researchers, industrialists or statesmen.

Prof. von Weizsäcker closed by suggesting that scientists and researchers take an oath of loyalty to humanity, similar to the oath which Hippocrates framed for the first scientists in history, the medical profession. It seems to me that a like oath should be required of every politician who is alive to the responsibilities he is assuming in seeking to influence the course taken by a people. For while scientists and researchers do indeed nowadays have to realize the risks which scientific and technical progress may involve for mankind, it is for the politicians to promote the growth of a society in which mankind can derive the benefits of this wonderful age, the second Industrial Revolution, without having to encounter new and terrible dangers.

I think I can say that we Members of the European Commission have already sworn that oath. Our work is purely for the common good, the good of the peoples of the Community. Everything that is done at Community level on the responsibility or at the instance of the Commission, whether concerned with research, with trade or with the economy at large, is aimed at economic and social objectives shared by six nations — objectives of lasting prosperity in justice, equality, freedom and peace.

We all know that for industrialized countries like those of the Community, the market as regards most of our products is now the world.

And what do we find in this world market where we want to sell on a basis of increasingly free competition? We find enterprises which, having expanded to national and then to continental scale, enjoy the prerequisites for making full use of innovation as understood today — a process whereby the lapse of time between the making of a discovery and its industrial and commercial exploitation is shortened, as is the lapse of time between one discovery and another. The fact that there are enterprises in the world which are in a position to do this poses a problem for us in the Community. For it means that the competitive capacity of those of our enterprises which are not in that position is liable to be undermined, and, what is worse, the aggregate competitive capacity and growth potential of our countries is liable to go downhill in consequence.

Only continental-scale enterprises, willing and able to stand up to competition in the world market, are capable of actually influencing that market in favour of new products. It is said — and I think it is very likely a fact — that in a few years' time 50% of the products on offer from American industry will be products that do not exist today.

Where will those products come from? From the research laboratories, and also from the venturesome habit of mind of American industrialists, operating in a country where the authorities see to it that the scope for taking decisions freely, and bearing the responsibility for those decisions, is not unduly restricted.

And what else do we find? We find the have-nots, the peoples who, in the search to achieve a decent future, have in many cases to start practically from scratch. Who with any political, any human awareness could look on the spectacle of a growing part of the human race doomed to starve indefinitely as being "in the nature of things"?

To help those countries develop, to give them what they need, the industrialized countries will have to work, and work hard, in line with the particular demands upon them of their own social conscience. Now, to work to our own advantage as well as, of course, to the advantage of those we are out to help, it will be necessary for our six countries to become receptive to innovation: that is, to abandon all conservatism in the management of affairs — which is a matter of mental approach — and establish the sort of set-up that will encourage innovation — which is primarily a matter of policymaking and the concern, very largely, of the authorities.

Independence in the pursuit of our lawful aims of economic growth, equality with the other major developed regions of the world, devotion to the cause of bettering the lot of the have-nots — these to my mind are the concepts which research should morally and humanly reflect to the full.

If I were asked to describe the role of this Fourth ECSC Congress in the context of European policy, I would say, first, that it bears witness to the Commission's resolve to recognize that science is world-wide.

I would say, further, that with the customs union now completed, we have to work towards economic union, as the only thing that can turn Europe into an organized society with a continental-scale economic policy.

To do this we shall have to push ahead vigorously on many fronts, such as fiscal policy — so diverse today that conditions of competition cannot but suffer — or a monetary co-operation which would demonstrate that the Six have adopted common economic and social objectives without limit of time.

But at the same time we shall have to make a really big push in research and technology to bring Europe abreast of the other main economic areas of the world. For this reason, indeed, the Commission has assigned to research and development a key role in the building of Europe, and accordingly is looking forward to establishing this common legal, fiscal, financial and institutional framework so essential to ensure that research results are quickly absorbed and applied in industry.

The Commission's own facilities for launching a European research programme are limited. But we do not consider this an insuperable obstacle, nor even grounds for discouragement, since in technological progress the determining factors are the mental approach of industrialists and close co-operation between them and the Governments, the Community playing a *direct* part only in exceptional cases.

The Congress just over has produced ideas and suggestions for the attention not only of the authorities but rather more, probably, of research and industrial circles. In addition, having expressly focused on progress — stressing the need to line up technical regulations, drawing up guidelines for further research — it has made a particularly valuable contribution thereto. And we should note that that contribution was the outcome of co-operation among different branches of science, different countries, and different continents.

Action ought to follow, with respect both to actual research and to industrial organization.

The Commission, as the High Authority's legatee, takes pride in having carried through the holding of this Congress, the arranging of which was begun by the High Authority before the merger.

On behalf of the Commission, I should like, as President Rey has already done, to thank all those who have had a part in the organization and the success of the occasion. A special word of appreciation must go to the staff members responsible, and also to the City of Luxembourg, which has once again shown a true sense of its position as a European capital, and a warmth and courtesy which will long remain in the memories of all who were at the Congress.

I would say also that the Commission will make and maintain all such contacts as may be found necessary for the purpose, first and foremost, of lining up the various economic and legal infrastructures and so promoting the forward movement of research, but also of making industry more receptive to scientific and technological progress and quicker in applying the findings operationally. It has duly noted the suggestions offered in the summings-up, and the criticisms also.

Firmly believing as I do that occasions like this Congress, when held at the requisite professional level and with specific, carefully-chosen aims, are for a host of reasons thoroughly in line with the great overriding aim of the Community — to cast aside the ancient and fatal error of engaging in national quarrels and work instead for active world-wide co-operation — I, for my part, consider not only that *practical steps must be taken to follow up the Fourth Congress,* but also that this Fourth Congress must not be the last joint Steel Congress.

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