

## Preface

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The material in this volume appears in the sequence in which it was presented at INFACON 74 — the opening speeches, the papers presented during the technical sessions together with the discussion on them, the proceedings of a panel discussion, and the closing speech. Apart from editorial changes, the papers are in the form in which they were submitted before the Congress. One exception is a paper that, as presented, differed materially from the paper submitted; only the modified paper is reproduced here.

Each of the other papers is followed immediately by any new points the author made during its presentation and by the discussion as recorded by the rapporteur for that particular session. The discussions are recorded in direct speech and, where possible, the rapporteurs have checked difficult or ambiguous points with the authors concerned.

Each technical section, or each session of the longer technical sections, closes with a summary by the chairman of that section or session. These summaries are as recorded by the rapporteurs or as provided by the chairmen.

Following South African practice, the comma is used as the decimal marker, and groups of three digits are separated by spaces. However, a space is not used for numbers consisting of only four digits unless those numbers occur in tabular columns together with numbers of more than four digits. Both the metric and imperial systems of nomenclature and units are used in the papers.

I extend my thanks to Mr L.F. Haughton, who helped with the preliminary editing of the papers and who, as Congress Manager, held a watching brief for the INFACON 74 Organizing Committee. My thanks are also due to the authors, chairmen, and rapporteurs for their cooperation, and to the printers, Messrs Frier & Munro (Pty) Ltd, for their patience during the preparation of this volume.

HELEN GLEN  
Editor

# Committees

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L.F. Haughton

# Foreword

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This publication is a record of the proceedings of the First International Ferro-alloys Congress, known as INFACON 74, which was held in Johannesburg from the 22nd to the 26th of April, 1974.

In the second half of 1969, the idea of a symposium on ferro-alloys was conceived at the National Institute for Metallurgy (NIM), and approaches were made to the South African Institute of Mining and Metallurgy (SAIMM) and the Ferro Alloy Producers' Association (FAPA) with the idea of joint sponsorship of such a symposium. Because of commitments of the sponsoring bodies, no action could be taken immediately, and a planning committee did not meet until late 1971. Contrary to some expectations, interest in ferro-alloys was not waning, and a date of April 1974 for the symposium did not appear to be too far ahead. The original idea of a symposium was changed to one of an international congress, and INFACON was born. The feeling at that time (strengthened by later events) was that the event should be made large enough and important enough to attract a large delegation from overseas, and that it should be made a continuing platform where ferro-alloy people (technical, managerial, and sales) could meet and discuss matters.

As a special attraction, five noted personalities in ferro-alloys were invited to give lectures on general topics. They also participated in a panel discussion and were prominent in the discussions on various papers. Some of the success of the Congress can surely be credited to their presence.

The Congress was opened on the 22nd of April, 1974, by Dr the Honourable P.G.J. Koornhof, Minister of Mines, in the new Carlton Hotel, Johannesburg. The proceedings consisted of technical sessions and tours; the technical sessions extended over five days, being broken by one afternoon's excursions: to the plant of Metalloys Ltd at Kookfontein and the new premises (still being built) of NIM.

After the technical sessions, delegates spent a further five days in the eastern Transvaal, where visits to the plants of Middelburg Steel, Rand Carbide, Highveld Steel and Vanadium Corporation, and Ferrometals Ltd were broken into by two days of animal-watching in the Kruger National Park. It is on record that this was the first time that South African ferro-alloy plants had opened their doors to visitors on such a large scale and in such an unreserved manner, and it augurs well for future congresses and future relations within the industry.

During the Congress, an *ad hoc* committee was convened and acted as the first International Committee on the Organization of Ferro-alloys Congresses. The main ferro-alloy associations of the world were represented on it, and a number of important and far-reaching decisions

were made. These were that the congresses would be continued, under the name of INFACON, at three-yearly intervals, that every third congress would be held in South Africa, and that NIM would provide the permanent secretariat. There was thus full agreement with the suggestion that ferro-alloy producers were in real need of some institution that would provide them with a platform and meeting place.

The registration for the Congress exceeded all expectations: 336 people from 22 countries attended, about half of them being South Africans. This indicated an interest in INFACON, which was reflected in the decisions of the International Committee and which it is hoped will be maintained in future years.

The social side was not neglected, and the thanks of the Organizing Committee go to all who contributed to the entertainment of the delegates and their wives: to the Mayor and Council of the City of Johannesburg, to the management of Amcor Ltd, to the management and staff of the Carlton Hotel and the Johannesburg Country Club, to the Ladies' Committee of INFACON, and to the many individuals who assisted in one way or another.

The official banquet was perhaps the main social event. This was a glittering affair held in the Ballroom of the Carlton Hotel, and was attended by the Mayor and Mayoress. The main speaker was Mr J.P. Coetzee, Managing Director of Iscor.

The Committee's thanks must go also to the constituent members of FAPA for their generous sponsorship of the Congress and especially to those who so willingly opened the doors of their plants to hordes of visitors, and to SAIMM for undertaking the preparation and publication of these proceedings.

The papers reproduced here represent a collection of technical information on different aspects of ferro-alloy production, and much of it is material that was made available in open publication for the first time. I believe that these proceedings are a very good example of what can be achieved by international cooperation and by the holding of congresses at which technical people can get together and discuss matters of common interest. It was particularly gratifying that, in a field where there is undoubtedly considerable competition, scientists and engineers were prepared to exchange technical information at the high level that was evident in the discussions.

It is therefore hoped that the proceedings of INFACON 74 will establish a pattern for all future congresses on ferro-alloys, and that this example of international collaboration will be continued for many years to come.

R.E. ROBINSON,  
Chairman: INFACON 74 Organizing Committee.

# Opening Session

# Introductory Remarks

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by Dr R.E. ROBINSON, Chairman of the INFACON 74 Organizing Committee

Mr Minister, honoured guests, delegates to the Congress, ladies and gentlemen, this is an historic occasion on which we officially open the First International Congress on Ferro-alloys, and I as the Congress Chairman, together with the organizing bodies, sincerely hope that this Congress will be the first of many. We are particularly privileged to have with us on the platform this morning the Heads of the various organizing bodies and sponsoring bodies for this Congress. We thus extend a particular welcome to Mr P.E. Streicher, Chairman of the Ferro Alloy Producers' Association of South Africa, Mr P. van Rensburg, President of the South African Institute of Mining and Metallurgy, and Dr A.J.A. Roux in his capacity as Chairman of the Board of Control of the National Institute for Metallurgy. We must thank, through these Heads of organizations, our various participants who have contributed in sponsoring and promoting this particular Congress.

One of the easiest tasks of the Organizing Committee was to decide who should perform this Opening Ceremony. One might argue whether ferro-alloy production is a matter that falls under the Department of Industries, or whether it is a follow up and part of our mining industry. But the Committee were unanimous and had very little hesitation in deciding that the most appropriate person to perform this Opening Ceremony was Dr the Honourable P.G.J. Koornhof in his capacity as Minister of Mines. Dr Koornhof has at all times shown a most enthusiastic interest as the Minister of Mines in all aspects of the exploitation of our mineral wealth in South Africa, particularly in those aspects that relate to the processing of minerals. He has made a very profound contribution to this aspect of the country's economy, not the least being the extent to which he has furthered the very close collaboration between industry and Government circles to develop our country's resources to the maximum extent. I am therefore very privileged and have very great pleasure in now inviting Dr the Honourable P.G.J. Koornhof to deliver his Opening Address to this Congress.

# Opening Address

by DR THE HONOURABLE P.G.J. KOORNHOF, Minister of Mines

Mr Chairman and gentlemen, thank you for the great honour you have done me in asking me to attend the opening ceremony of this, the First International Ferro-alloys Congress — INFACON 74.

The ferro-alloy industry in South Africa is still a comparative junior among the ferro-alloy industries of the world, but we feel that we have already made considerable progress, not only in the tonnage of alloys that we produce each year, but also in our technical proficiency and our ability to overcome the many problems with which our industry is faced. We are therefore very proud to act as hosts to the ferro-alloy producers of the world, and it gives me great pleasure to welcome the many delegates from overseas.

I see from the Congress programme that papers will be presented by delegates from no fewer than eight countries besides South Africa: Japan, Germany, Norway, the United States, Australia, Sweden, Great Britain, and Rhodesia. But that is not all. I have been informed that we have delegates from nine other countries — Switzerland, Spain, Brazil, Argentina, Mexico, the Netherlands, Finland, France, and Italy — who, although they are not specifically presenting papers, will probably contribute to the discussions during the Congress, both at the formal sessions and informally over the coffee cups and lunch tables.

To all of you, I bid a hearty and sincere welcome, and I hope that your visit to South Africa will prove both enjoyable and profitable.

Providence, gentlemen, has blessed South Africa with a wealth of mineral resources. Some of these are very large — indeed enormous — like the gold reefs of the Witwatersrand and the Orange Free State, and the diamond mines of Kimberley. We are also fortunate in possessing large reserves of coal, which are conveniently situated and worked with relative ease. This was a most important factor in helping to establish the gold-mining industry in the early days of the Witwatersrand.

First diamonds and then gold served to develop South Africa. Their requirements led to the provision of the infrastructure of the country — the construction of roads and railways, the provision of adequate water supplies, and the establishment of a highly efficient and reliable electric power system — and finally led to the growth of large, modern cities such as Johannesburg.

Less obvious but equally important, the operation of the gold mines and, to a lesser extent, the diamond mines required men. The first people to come in any number to Kimberley and the Witwatersrand were the diggers and adventurers, who followed the lure of easy fortunes. These people played a valuable role, and many stayed on to found a more stable population. But the technical problems of mining to greater depths and on larger scales called for men of a different calibre — men of a high degree of technical skill — and they came too, very soon after the first initial rushes, and they stayed on to help build up a force of technical proficiency in the mining and metallur-

gical industry.

To supply the needs of the gold-mining industry, all manner of secondary industry grew, until now South Africa is largely an industrialized manufacturing country that has developed a technology matching that of most other countries. The gold-mining industry is still of immense importance to South Africa and will remain so for very many years to come; it will, however, become less and less predominant. This does not imply that the mining industry, or rather the mineral industry, will become less important. Far from it — the base-mineral industry in South Africa is growing faster and faster, to serve the needs both of our manufacturing industry and of export. Further, it is very definitely the policy of the Government that South African minerals should be exported in as highly processed a form as possible, and not just as crude ores or concentrates.

Two of South Africa's vast deposits are the chromium ore of the Bushveld Igneous Complex, amounting to about 74 per cent of the world's *known* resources, and the manganese and iron ore of the northern Cape Province, all of these being minerals of great concern to you gentlemen as ferro-alloy producers.

South Africa's desire to export her minerals in fully processed form does not mean that she will place any undue restrictions on the export of crude ores, except in those rare instances where it is considered necessary to conserve certain minerals that are vital to our local industry. In fact, we hope to export more and more of the ores of which we have an abundance. Where we can do so economically, we shall endeavour to process our minerals here in South Africa in order to sell the finished or semi-finished products, and this is what we are already doing with much of our chromium and manganese ore. We are converting them into ferrochromium and ferromanganese, and are exporting these alloys.

And that is why we are so very much concerned with the ferro-alloy industry, and why we have convened this present Congress — the first international congress specifically concerned with the technical problems of the ferro-alloy industry.

And, as the ferro-alloy industry is worldwide, it is indeed most gratifying to see so many visitors from overseas; and I believe that the discussion of the problems that are common to all of you can only be of mutual benefit.

We in South Africa have some rather special problems. One of the most obvious relates to the gold mines of the Witwatersrand. Our gold deposits are of low grade, and they occur as very narrow reefs and at great depths — one of Nature's less welcome practical jokes as far as South Africa is concerned. Nature here set us a real challenge; but we have met it successfully and now have developed the techniques of mining at depths of over eleven thousand feet. So, when Nature pulled a few more jokes on us with our chromium and manganese ores, we were prepared to face up to them and not to become too down-hearted.

The first of the problems to be solved concerned the manganese ores in the Postmasburg area of the northern Cape. These deposits occur in one of the most remote and arid parts of this country. We met this challenge by constructing a special railway line from Kimberley to Postmasburg in the early 1930s, and this line has since been extended to serve the more northerly manganese fields and the iron-ore deposits at Sishen.

After the War, as a result of increasing exports, the loading facilities at our ports became quite inadequate, and the freight terminal at Port Elizabeth was constructed in the early 1960s. Exports of iron and manganese ore increased still further, and the next step was the electrification of the railway line from Kimberley to Sishen and northwards, power being brought by transmission lines from generating stations on the coal-fields of the Transvaal and northern Orange Free State. Meanwhile the main railway line from Kimberley to Port Elizabeth was improved and can now handle unit trains of up to five thousand tonnes. It is expected that trains carrying up to seven thousand tonnes of ore will soon be in regular use.

These improvements are still inadequate for what we estimate as the future demand. So the next step is to construct a special ore-carrying railway over the 860 kilometres from Sishen to Saldanha Bay, where a special deep-water ore terminal will be constructed. Work is already in progress on the Sishen—Saldanha Project. The construction of the port at Saldanha Bay and the railway through the northwestern Cape will offer an infrastructure that will make the whole development of mineral deposits in this part of our country an economic feasibility, and the prospects are tremendously exciting.

Soon after the early development of the manganese deposits at Postmasburg, the demand for manganese in South Africa increased. This arose from increasing demands for ferromanganese by Iscor and the demand for wear-resistant manganese alloy steels for scrapers, ball-mill liners, and crusher parts used by the gold mines. It was not surprising, therefore, that the first ferro-alloy to be produced in South Africa was ferromanganese.

At first, quite naturally, ferromanganese was produced for the local iron-and-steel industry. Soon, the advantages of low-cost fuel, ore, and electric power, together with increasing experience in the smelting of South African ores, made the production of ferromanganese for export a profitable venture. It is interesting to note that the first vessel under the South African flag to sail up the St Lawrence Seaway was the 'S.A. Transporter' in 1968, carrying a bulk cargo of six thousand tonnes of ferromanganese right into the heart of the iron-and-steel producing region of the United States.

As might be expected, the first manganese ores to be mined in South Africa were high-grade material and presented no particular metallurgical problems. However, the reserves of really high-grade manganese ore are somewhat limited. The majority of our ores are of the braunitic type, the so-called Mamatwan ore, which is rather lower in manganese content and contains appreciable amounts of lime and magnesium. This type of ore is an excellent self-fluxing ore for smelting in a blast furnace, but was regarded as quite unsuitable for use in a submerged-arc furnace. Our local metallurgists have disproved this theory and, by suitable smelting practice, are producing ferromanganese quite successfully from Mamatwan ore.

With chromium ores the situation is rather different. In general, they are situated appreciably nearer to the ports

than our manganese ores, and not too far from a railroad. Thus, transport is not a particularly serious problem. However, until recently, Transvaal chromium ores were regarded as chemical-grade ores – quite unsuitable for smelting to ferrochromium – and so fetched a very low price, the result being that the cost of transport, even at very low railage rates, was a major item.

The problem with Transvaal chromium ores is that they all occur as pseudo-stratified seams in the Bushveld Igneous Complex. Being typical stratified deposits, they are of comparatively low grade; they have a low chromium-to-iron ratio and are friable; in fact, at least 50 per cent of the Transvaal chromite occurs in the form of fines. These are suitable for so-called chemical-grade ore and for the production of foundry sands, but prove extremely troublesome during smelting to ferrochromium.

What success we have achieved in overcoming the problems inherent in the smelting of Transvaal chromium ores to ferrochromium, and even to producing stainless steel, I hope you will be able to see for yourselves when you visit the various ferro-alloy plants during this Congress and when you attend the presentation of the papers by the South African delegates.

We still have a very long way to go, and our industry is not just relying on the large and conveniently situated deposits of raw materials. Just as the gold miners had to develop their techniques for mining at great depth or else close down, so our ferro-alloy producers have to continue a very active policy of research and development to get into the business and to remain competitive. In this respect, I am very pleased to say that we have a very happy marriage between our Government-sponsored research organizations such as the National Institute for Metallurgy (NIM), our universities, and industry itself. This research covers a wide range of investigations from the fundamental characteristics of the reactions that take place in the furnaces, and the properties of alloys and slags and their interrelationships, through to the practical and economic problems connected with the agglomerating of chromite fines for use in very large electric furnaces. All the research by NIM and the universities is being carried out in very close collaboration with the industry, and there is close coordination between the work being carried out in the laboratory and what actually occurs under commercial plant conditions.

I most certainly do not want to give the impression that research is being carried out only by NIM and the universities; for the industry itself is probably doing even more than those institutions. The point that I wish to make is that the success attained so far has been through the close liaison between plant and laboratory.

So far, Gentlemen, I have spoken as though the ferro-alloy industry produced only two commodities – ferromanganese and ferrochromium – though it is true that these two ferro-alloys are at present attracting most of our attention, probably because they give their producers the most headaches.

Ferrosilicon is another major product of our local ferro-alloy producers. A fair amount is produced as an adjunct to the production of certain grades of ferrochromium, more is used in the local iron-and-steel industry, and a large amount is exported on a highly competitive market. In South Africa, we make all grades of ferrosilicon. These range from the types of low silicon content that are specially produced for heavy-medium-separation plants, right up the scale. Very shortly, in a plant near Pietersburg, we shall be producing pure silicon

metal from a deposit of almost pure quartz.

We produce only limited quantities of ferronickel, entirely for local consumption. Although we have large reserves of nickel ores in South Africa, nickel is being worked only as a co-product from the production of the platinum-group metals. Thus, the production of nickel is directly related to that of platinum.

South Africa almost certainly has the largest reserves of vanadium in the world. Again, these deposits are unusual and, like so many South African mineral deposits, they are of low grade. Our local producers have had to develop special processes for recovering the vanadium, most of which is obtained from the titaniferous magnetite iron ores of the Bushveld Igneous Complex. One producer, Highveld Steel and Vanadium Corporation, recovers the vanadium as a co-product from the production of iron and steel by a unique process that was devised entirely in South Africa.

We produce only very small quantities of ferro-vanadium as yet, but one company is already manufacturing a proprietary vanadium-containing additive for steel.

The output of other so-called 'minor ferro-alloys' in South Africa is still small, being produced on an 'as required' basis for local consumption. With the development of known or possible deposits of other metals, it is certain that we shall begin producing the alloys ferro-niobium, ferrotitanium, and ferrotungsten.

As for the future of the ferro-alloy industry in South Africa, it certainly seems to be rosy.

I have already mentioned one major principle that we are following: that is the policy of exporting our minerals in as fully processed a form as is economically feasible. A second major point is that we propose to develop our mineral heritage to the best long-term advantage of the nation as a whole.

To this end, the Government regard the ferro-alloy and special-steels industry as one of the major areas of expansion in the future. We have the ores, and we are developing the specialized 'know-how' to treat these ores. We also believe that we shall be able to supply adequate electric power at a cost that will be competitive with those in other countries.

Here, I should like to expand a little bit.

It has frequently been claimed that South Africa has very large reserves of low-cost coal. This is not entirely true. Our known reserves of coal are indeed high, but they are not, I repeat NOT, so great that we can afford to use them wastefully. One way in which we can avoid wasting our coal resources is the use of mining techniques that will ensure the maximum extraction of the coal, and another is the utilization of lower grades of coal that are at present left in the ground. The result must inevitably be an increase in the cost of coal in South Africa, and consequently an increase in the cost of power – and that means an increase in the cost of power to ferro-alloy plants.

No one likes increases in costs – they inevitably lead to a greater or lesser degree of inflation. But in this instance some measure of increase is fully justified if we are to avoid wasting an irreplaceable national asset.

South Africa can boast one of the cheapest electric-power supply systems, certainly for a thermally generated system. This has been achieved by the availability of low-cost coal that is won by modern and efficient mining techniques from shallow, thick seams. Even if the cost of this coal does increase, the cost of electric power should not increase unduly. This is because of the forward thinking of the Electricity Supply Commission (ESCOM), who have adopted a policy of siting their generating stations on the coal-fields so that the coal can be fed straight from the working face to the power-station bunkers by conveyor belts. ESCOM have also developed a highly efficient distribution network.

Just what this means to the ferro-alloy industry can be seen from the fact that certain of ESCOM's new generating stations have been located with the requirements of this industry in mind – for example, the Komati and Hendrina stations. Over the past two years ESCOM have increased the electric power available to the ferro-alloy industry from 350 to 550 MVA.

The ferro-alloy industry does not require very large quantities of water, which is fortunate because water supply is always a problem in South Africa. However, steps are being taken to ensure sufficient water for all reasonable future requirements, even in times of drought.

So far, pollution by industry in general and the ferro-alloy industry in particular has not been a serious problem in South Africa, at least not as serious as in many other countries; but the pollution problem is being watched very closely by the responsible authorities. No pollution of water resources whatsoever will be tolerated. The requirements of our air-pollution control will be found to be reasonable and not crippling to the industry. Basically, these regulations require that the best available means of preventing air pollution must be adopted by all possible offenders, and I am afraid that that includes the ferro-alloy producers. I am most gratified to learn that the latest ferro-alloy furnaces to be installed have been equipped with most effective gas-cleaning equipment. This shows a commendable sense of public responsibility.

In conclusion, Gentlemen, I must remind you, as ferro-alloy producers, that your product is *not* an end in itself. Your products can be sold only because they are required by a very much larger industry, namely the iron-and-steel industry. No matter how great your problems may appear to you, remember that you yourselves are really only serving another industry that has its own problems – and much greater ones too. One way in which you can expand your industry will be to increase the demand for chromium, manganese, vanadium, and all the other metals that you provide for the steelmaker. You must look beyond the ferro-alloys that you manufacture and must develop new end-uses for these metals – and most of those end-uses will be in the production of improved and longer-lasting iron and steel.

Mr Chairman and Gentlemen, I now have great pleasure in declaring this International Ferro-alloys Congress officially open.

And may you all have a profitable and enjoyable conference.

# Reply to the Opening Address

by DR A.J.A. ROUX, Chairman of the Board of Control, National Institute for Metallurgy

Mr Minister, honoured guests, ladies and gentlemen. If I had known in good time what the Minister was going to say in his opening address, I would have tried to persuade Dr Robinson to allow me to thank the Minister before he spoke, so that his address could serve as the climax to this opening session, instead of mine now providing the anti-climax. Be it as it may, I should like, on behalf of you all, to thank the Minister for accepting our invitation to deliver this opening address. To those of you who have not met him before, I can explain that our Minister is a very active man, and for that reason is very busy, particularly in these days when he, with other politicians in the country, is fighting an election. The Minister has certainly given us a very excellent review of the raw materials that this country is fortunate to have in abundance. It is well known that he takes a lot of interest in every activity, but he is never satisfied until he knows a lot of detail about each one of those activities. And that is why he was able this morning to give us this excellent review.

I think that it is true to say that the success of an organization depends very largely on its leadership. I think it is also true of a State department. With our resources for the production of ferro-alloys, with the expertise that the country has developed to exploit these raw materials, and, for that matter, with the mineral resources South Africa has outside the ferro-alloy industry, I am sure that there would be a great future for this country if we could always have Minister Koornhof as Minister of Mines. If I had a little influence with the Prime Minister, I would certainly ask him, if he should find a reshuffle of the Cabinet necessary after this election, not to worry too much about changing the Minister of Mines.

I should like, in the few minutes at my disposal, to highlight some of the very important matters to which our Minister has referred. Forgive me for starting with coal. As Dr Robinson has indicated, power generation is close to my heart, and, seeing that he has said so, I don't mind admitting that I obtain a lot of satisfaction from the fact that we have so much coal in this country and therefore have cheap power on which we can base our industrial development.

We are in the fortunate position – for reasons that the Minister has indicated – of not only having cheap coal and large reserves (with certain limitations, to which he has also referred); but we also have cheap uranium and large resources. I emphasize this point only because it is important. As the Minister has indicated, developments of the kind in which we are interested depend on power,

particularly cheap power. We are fortunate in having that, and I think we shall have it for a long time to come.

I should like to mention another very important matter to which the Minister referred – namely, the policy of the Government in regard to the exploitation of our raw materials. I think it is reasonable for any country, particularly a young country that is developing, to adopt a policy of exporting its raw materials in a more and more refined form. But I think it is a very wise policy of our Government, as the Minister has emphasized, to maintain that balance and not to refuse to export those raw materials of which we have an abundance. The proof that this is so is evident in many areas of this country. Here, I want to refer only to uranium, and to mention the long period during which we have exported uranium as a concentrate. I think that we shall continue to export uranium as a concentrate, in spite of our developments in the production of enriched uranium.

I wish to refer to another important point that the Minister made, and that is the importance of research work in the development of raw materials, and the importance of carrying out that research work in close collaboration between the national research organizations and industry. If I look back over the years that I have been engaged on research and development in this country, I think that this is the most important lesson I have learnt: if you want your research results to be applied, the only way is to establish those research results in the first instance in close collaboration with industry; if they have good results – and the results will be good if you work with industry – the results will be applied again and again. And this, I feel, is very important. In this country we are fortunate in that our National Institute for Metallurgy – to mention only one of several organizations – is working in very close association with industry, and the credit for the advances that have been made must go to them jointly. The universities, too, are drawn into these research activities through the National Institute for Metallurgy.

But the Minister made so many important points that, if I tried to emphasize them all, my speech would be double the length of his because I cannot put the points across as concisely as he has done. I should like to say, in conclusion, that the Minister over the years has served as an inspiration to the Department of Mines. He has this morning, I'm sure, served as an inspiration to this gathering, and I hope that you will find his words an inspiration in your further deliberations. Thank you very much, Mr Minister.