Indigenous substitution of imported materials on Indian Railways

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THE psychology of import substitution is based on the concept of dispensing with as much import as possible by providing alternative indigenous resources.

In a developing country like India, it is essential to stress on research, development and trials through different research laboratories/Institutes by suggesting substitutes of imported materials for the avoidance of use or conservation of the imported materials in our country, particularly in the emergency which has highlighted the necessity for intensifying efforts in this direction.

The subject of substitution has always tended to be somewhat controversial, judged as it is on the basis of availability of particular raw materials not only in relation to metallurgical acceptability of the substitute alloys but also on the economics of their production and service life. As such, the diverse substitutional factors have to be rationally and scientifically examined to establish their industrial acceptance, particularly in the background of Indian conditions.

Non-ferrous metals, in which India whilst possessing some resources is highly deficient, are copper, zinc and lead. The metals in which we are potentially rich are aluminium, titanium, magnesium, beryllium, manganese, etc. Metals such as nickel, tin, molybdenum and tungsten either do not exist or are perhaps found in isolated uneconomical pockets even though with more intensified exploration and prospecting etc., some economic deposits thereof may yet be discovered. The one metal whose resources are abundant in India is aluminium; its applications and potentialities as a substitute metal have been examined by the National Metallurgical Laboratory and have shown great promises.

The demand for aluminium has risen during the four years of the current plan by 140 per cent and in terms of tonnage from 50 000 to 120 000 tonnes per annum, for copper by nearly 80 per cent from 80 000 tonnes to 140 000 tonnes, lead by nearly 90 per cent from 35 000 tonnes to 65 000 tonnes, tin by 58 per cent from 6 500 to 10 000 tonnes and zinc by nearly 120 per cent from 85 000 to 187 000 tonnes.

Railways' role in the development of our country is not small and in fact railways are the main tools used for the rapid industrialisation of the country and its importance in our country is in the increase.

Railway system in India is the largest in Asia and the second largest single system in the world. The Indian Railways at present embrace a route kilometerage of about 57 000 and possess in the form of assets about 11,000 locomotives, (including Diesel and Electrical locomotives), 350 000 units of wagons or freight cars and 30 000 units of coaching vehicles. Provision of further assets, in addition to the above, is made through Five-Year Plan Programmes since importance of Railways is in the increase in our country. The effective running of Indian Railway system has a major part to play for the development of the country through planned programmes. Any disruption in the system may cause delay in achievement of planned development programmes. As such, it is necessary on the part of Railway Engineers including Metallurgical Engineers to maintain rolling stocks, track, signalling equipment, etc. efficiently for smooth running of the trains round the clock. For the maintenance of vast railway system and its assets, quite a good amount of imported materials is required. The railways are trying, with a view to attaining self-sufficiency, substitution of imported materials with indigenously available ones and as such, so far, in the railways and the railway research laboratories, and other National Laboratories considerable work has been done. Some indigenous substitutes of foreign materials have been found out and some problems are being still processed for finding out the suitability of indigenously available substitutions. With the effort of last five years the Railways have achieved self-sufficiency to the extent of about 90 per cent of their total requirements. The three-fold objective now is to conserve the existing stock of imported items, to find out indigenous substitutes for imported ones and to cut down to the barest minimum the requirement of these items which have to be imported.

The main purpose of this article, is to give an idea of the work done or being considered by the Railways and for the Railways by outside institutions for finding out suitable substitutes for imported ferrous and non-

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ferrous materials and components, which are in short supply, or for developing new methods of production with a view to attaining self-sufficiency.

Indigenous substitutions

Some of the important items for which work has been done or has been planned for finding out indigenous substitutes are as follows :

Non-ferrous metals and alloys

(i) Use of spheroidal graphite cast iron bearing shells in place of bronze bearing shells of carriage and wagon bearings.
(ii) Substitute for leaded bronze solid axle boxes of the steam locomotives.
(iii) Substitute for other non-ferrous components of steam locomotives, carriage and wagons.
(iv) Development of electrodes for spot welding.
(v) Development of aluminium base bearing alloys to replace bronze and antifriction metals.
(vi) Development of electrical contacts, based on indigenous material, used for signal relays.
(vii) Development of contact springs, based on indigenously available materials, for use in signal equipment.
(viii) Use of insulated aluminium cables in place of copper cables for train lighting and signalling.
(ix) Substitution of red lead primer by zinc chromate, zinc chromate red oxide primers and aluminium zinc oxide composite primer.
(x) Substitution of galvanising by aluminising.

Ferrous metals

(i) Indigenous manufacture of super heater elements used in steam locomotives.
(ii) Development of suitable indigenous substitute for ARMCO Iron used in reverses and relays of signal and tele-communication equipment.
(iii) Development of indigenous substitute for manganese steel liners used in steam locomotives.

Non-ferrous metals and alloys

Use of spheroidal graphite cast iron bearing shells in place of bronze bearing shells of carriage and wagon bearings

Carriage and wagon bearing shells used on the Railways are manufactured either from bronze, Cl. V to IS : 1458 with 85% copper, 5% zinc, 5% tin and 5% lead or from Cl. III leaded bronze alloy containing 14–16% lead, 6–8% tin and balance copper. Our country is in short supply of these costly non-ferrous materials which constitute the manufacture of these alloys. As a substitute for this alloy spheroidal graphite cast Iron to BS : 2789–59 type 2A was considered, since this grade of SGCI has superior strength and ductility compared to bronze alloys used.

Tinning of SGCI bearing shells, however, require special technique. This has been developed by the Metallurgical and Chemical Engineering Wing of the Research Designs and Standards Organisation of the Railways. Bond test carried out on new and impact tested SGCI bearings, lined with lead base antifriction metal following the technique developed, showed better results compared to conventional bronze bearings tested under similar conditions. Service trials conducted with the spheroidal graphite cast iron bearing shells lined with antifriction metal also proved to be fairly satisfactory. In addition, it has been found that the use of spheroidal graphite cast iron bearings have the advantage of reducing the chances of pilferage and failure of journal, due to penetration of copper base materials into the axle material under condition of elevated temperature and pressure, resulting from hot-boxes.

On the basis of a rough calculation, taking into consideration the scrap values, it is claimed that use of spheroidal graphite cast iron bearing shells will amount to a saving of about Rs 9 per bearing compared to conventional bronze shells lined with antifriction metal. It is further expected that if the railways fully adopt the use of spheroidal graphite cast iron bearings they would be effecting a saving of approximately two crores of rupees.

Further, the conventional bearings in the new design of rolling stock are slowly replaced by roller bearing which has also resulted in conservation of some non-ferrous metals.

Substitute for leaded bronze solid axle boxes of the steam locomotives

In the manufacture of W. G. steam locomotives, solid axle boxes of leaded bronze were used. These axle boxes were substituted by composite steel axle boxes having pressed-in non-ferrous bearings with a view to conserving non-ferrous metals. Composite axle boxes have since been substituted by roller bearings. In the roller bearing axle boxes the axle box housing is available indigenously while the bearing is imported. In a W.G. locomotive, bronze Cl III alloy weighing about 2 896 kg costing approximately Rs 17 376 was used which has been replaced by roller bearing axle boxes costing about Rs 16 418 taking the cost of indigenously made axle box housings to be approximately Rs 8 000. Thus not only bronze Cl. III has been conserved but also a lowering down of cost per W.G. locomotive by approximately Rs 958 has been effected.

Substitute of other non-ferrous components of steam locomotives, carriages and wagons

In the construction of locomotives, carriages and wagons different non-ferrous components are used. These are receiving or have already received due consideration for replacement by suitable substitutes of ferrous metals indigenously available. Non-ferrous castings such as number plates, window frames, some boiler mountings of locomotives and a few valves with its accessories of carriage and wagons which were primarily selected to be of non-ferrous metals due to their highly anti-corrosion properties are being substituted or under consideration for replacement by ferrous castings, spheroidal graphite cast iron or malleable iron or by fabrication from wrought steel with appropriate protective coating.

Development of electrodes for spot welding

In the manufacture of coaches at Integral Coach Factory, Madras, a considerable amount of spot welding is involved on the panel plates requiring 9 spot welding machines consuming about 312 kg of electrode tips per year. A notable contribution of developing an indigenous substitution by Integral Coach Factory, Madras, is of electrodes (tips) for spot welding. These were previously obtained by import involving foreign exchange, to the chemical composition as 99·5% copper and 0·5% chromium. A suitable substitute with 99% copper and 1% cadmium which can be forged easily, has been developed by Integral Coach Factory and is now being manufactured indigenously from imported raw materials and used successfully. This has effected a saving of approximately Rs 4 193 in foreign exchange annually.

Development of aluminium base bearing alloys to replace bronze and anti-friction metals

The bearing alloys at present used in Indian Railways contain a large quantity of imported non-ferrous metals such as tin, lead, copper and antimony. Since it is expected that by the end of the Fourth Five-Year Plan our country will be self-sufficient in respect of aluminium, a systematic investigation into the evolution of suitable alloys of aluminium for use as a solid bearing as well as anti-friction metal, which could be bonded satisfactorily on bronze bearing shells and also spheroidal graphite cast iron bearing shells is necessary. As such, this problem has been allotted to the National Metullurgical Laboratory with the object of substitution of imported non-ferrous metals by aluminium base alloys for which studies are in progress.

Development of electrical contacts based on indigenous materials for use in signal relays

Electrical contacts used in various circuits controls and relays are not available in the country. Some of the contact materials that could be considered are silver, cadmium-silver, palladium silver, graphite, platinum silver-gold-tungsten, copper tungsten, etc. This problem has been allotted to the National Metallurgical Laboratory and it is understood from them that the sample tested by them were from simplest ingredients such as graphite and silver powder made by powder metallurgical technique. As such, according to them, no substitution can be economically possible, neither any further work on this subject is intended. They have however, suggested to explore the possibility of procuring these electrical contacts from indigenous industries.

Development of contact springs based on indigenously available materials for use in signal equipment

Phosphor bronze to BS 407/3, hard and extra hard for various signal equipment is not available and has to be imported. The problem for the substitution of imported contact springs to save foreign exchange was thus taken up at the National Metallurgical Laboratory at the instance of Indian Railways. A suitable substitute has been developed and the report containing the know-how will shortly be available to the Railways.

Use of insulated aluminium cables in place of copper cables for train lighting and signalling

Copper cables are generally used for train lighting and signalling. The requirement of this item is not met with the resources available in India and are imported. Although aluminium conductors have slightly less electrical conductivity compared to copper, considering that aluminium is indigenously available, use of aluminium cables has been introduced on the railways effecting saving in foreign exchange.

Substitution of red lead primer by zinc chromate, zinc chromate red oxide primers and aluminium oxide composite primer

Red lead primer is used for painting of wagons, bridges and structures. Red lead paint contains about 80% of red lead in its composition and red lead contains about 93% of metallic lead. One gallon of red lead paint weighing about 30 lb contains 24 lb of red lead or 22 lb of lead metal. According to the 1958–59 Annual Report of the Development Wing of Ministry of Commerce and Industry, red lead produced in 1958 for various purposes was 4 943 tons containing about 4 533 tons of imported lead and hence involving a foreign exchange of about 0·65 crores of rupees. In 1963 the production of lead oxide pigments was 9 170 tons (paint India Annual, April 1965, p. 54). The requirement of lead for pigments and compounds is estimated to be 14·2, 21·0 and 40·0 thousand metric tons for the years 1965–66, 1970–71, and 1975–76 respectively.

Taking into consideration the great difficulty in obtaining red lead primer, use of one coat of zinc chromate primer to IS:104, followed by another coat of red oxide zinc chromate primer to IS : 2074 in place of two coats of red lead primer has been introduced for wagon paintings. In this connection it may be mentioned that zinc chromate primer to IS : 104 contains about 8% of metallic zinc and red oxide zinc chromate primer to IS : 2074 about 3% of metallic zinc which constitute a very small amount of foreign exchange compared to red lead.

Another substitute for red lead primer is aluminium zinc oxide composite primer which has been developed by the Regional Research Laboratory, Hyderabad. It contains about 11% imported metallic zinc. Since no experience is available on service performance of aluminium zinc oxide composite primer, trials on one hundred 'O' type wagons with this primer are being planned. Trials with this primer on bridge girders are also being planned.

While all the primers mentioned above contain amount of imported ingredients, there is one rust inhibitive pigment, namely barium potassium chromate which can be manufactured entirely out of locally available raw materials. Work on standardisation of method of manufacturing this pigment and studying its properties is being planned on priority basis.

Substitution of galvanising by aluminising

On the Indian Railways, a galvanising plant is functioning in Chittaranjan Locomotive Works since last six years and another plant at Raipur on the South Eastern Railway is under construction.

The Indian Railways are using a number of galvanised items. These include masts and fabricated structures required for Railway Electrification, vacuum brake equipment (cylinder as well as brake piping) for wagons and a number of signal fittings. Since the durability afforded by paints is inferior to that provided by galvanising, painting has to be done at regular intervals and cannot be done for stakes which are driven into the ground. Similarly, steel structures carrying overhead wires in electrified sections, cannot be frequently painted due to risks involving in the work of painting when lines are live and the heavy intensity of traffic does not permit the lines being rendered dead for painting of structures when necessary. Therefore, a suitable alternative to galvanising, not requiring imported material and equally efficient is required to be developed.

The advantages of aluminising as compared to galvanising are : (i) aluminium is manufactured indigenously (ii) for a given coating thickness aluminium layer is approximately half the weight of zinc (iii) in industrial atmospheres aluminising affords better protection than zinc coating (iv) resistance of aluminised coating to flaking on deformation is better than that for galvanised coating. The disadvantages of aluminising are (i) it has higher cost compared to galvanising (ii) the higher dipping temperature (710° to 760°C) as compared to galvanising (450° to 460°C) may cause distortion of the article. Aluminising has great prospects for application to steel sheet, strip and wire product industries for replacing galvanising.

A small plant for carrying out experiments on aluminising was put up in the premises of the galvanising plant of Chittaranjan Locomotive Works in the beginning of 1963. Some aluminised samples have been sent by the galvanising plant, Chittaranjan Locomotive Works to the Railway Electrification, Calcutta, for field tests and the report is awaited.

Accelerated corrosion tests in a salt spray cabinet on samples of aluminised and galvanised plates received from the galvanising plant, Chittaranjan Locomotive Works were carried out in the Metallurgical and Chemical Wing of Research Design and Standards Organisation, Chittaranjan, in October 1963. The results of salt spray tests showed that aluminised coatings are not suitable for saline atmosphere. The galvanised coating gives better performance under these conditions. Aluminised steel is not considered suitable for use in a location within about 5 miles of sea shore.

Work for considering aluminising as a substitute for galvanising is in progress.

Ferrous metals and alloys

Indigenous manufacture of super heater elements used in steam locomotives

Super heater elements are indispensable items to the efficiency and economic operation of steam locomotives. These super heater elements are placed in the flues of boilers and encounters hot gases passing through the flues on their way from fire box to the smoke box. The total annual requirement of super heater elements for Indian Railways, inclusive of broadgauge and metergauge locomotives, built by Chittaranjan Locomotive Works and Tata Engineering and Locomotive Works Co. Ltd., respectively amounted to about 22 000 valued at Rs 55 lakhs approximately. The entire amount was spent in foreign exchange as this item was not manufactured in the country prior to 1961. Considering that these element tubes were not available indigenously, steps with a view to attaining self-sufficiency for this item was taken for promoting manufacture of this item under the direct guidance of Metallurgical and Chemical Engineering Wing of Research Designs and Standards Organisation.

The super heater elements are of the long loop type and can be manufactured by one of the following two methods :

1. Gas welding separately forged return bends and ball ends to the tubing.
2. Integrally forged return bends and ball ends.

Two firms in Calcutta have been manufacturing super heater elements, one adopting the first method and the other the second method. Their products are meeting the entire demand of the railways and thus the country is self-sufficient in respect of super heater elements, effecting saving in foreign exchange.

Development of suitable indigenous substitute for ARMCO steel used in reversers and relays of signal and telecommunication equipments

For the substitution of imported ARMCO steel (magnetic soft iron), used in reversers and relays of signal and telecommunication equipment for the cores of various electromagnets, the problem of development of a suitable method for production of ARMCO iron indigenously was entrusted to National Metallurgical Laboratory.

Experiments were carried out in the National Metallurgical Laboratory in their electric furnace using various methods of deoxidation and the chemical composition of the following ranges were obtained, which are considered by the Railways to be quite suitable to substitute ARMCO iron.

Carbon%	Less than 0·03
Silicon%	0·01–0·02
Manganese%	Trace–0·04
Sulphur%	0·0095–0·02
Phosphorus%	0·004–0·01
Aluminium%	Trace to 0·21

A report detailing the 'know-how' of the process developed by the National Metallurgical Laboratory has been issued. This item will be manufactured by the Alloy Steel Project of Messrs Hindustan Steel Ltd., Durgapur, in their future programme according to the recommendations made in the report.

Indigenous substitute for manganese steel liners for steam locomotives

These steel liners having manganese content ranging from 11·0% to 14% possesses long wearing quality and are used for the manufacture of axle box guides, wear plates, tender rubbing blocks, etc. Steel liners, in the order of about 21 000 units are being imported annually at a cost of over 1½ lakhs of rupees as no steel manufacturer in India could roll this quality of steel into plates of 3/16″ and ¼″ thickness required for the manufacture of these liners.

Resurfacing of plain carbon steel liners using indigenous brand, hard facing electrodes followed by surface grinding may be a possible substitute. Alternatively castings of the liners by carbon dioxide or shell moulding process to a thickness required for castability may be used after redesigning the axle box assembly. Suggesting of suitable substitute of these manganese steel liners is receiving due consideration with a view to effecting saving in foreign exchange by stopping the import.

Conclusion

The question of progressive replacement of imported items of railway stores by indigenous production has claimed prior attention in which field encouraging results have already been achieved, and scope for further substitution is still in view.

An idea to the extent of progressive use of indigenous materials by the railways in place of imported ones can be had from the curtailment in use of imported materials for the manufacture of steam locomotives at Chittaranjan Locomotive Works of the Indian Railways. In 1951–52 imported accessories worth about 38·4% of the total cost of a locomotive was used for the manufacture while in 1964–65 imported items worth about 1·0% of the total cost of the locomotive has been used. Thus, within a span of about 12 years use of imported accessories worth about 37·4% of the total cost of a locomotive has been curtailed by substitution with indigenously available accessories, which is really encouraging.

In the production of coaches in the Integral Coach Factory, Perambur, Madras, steady reduction in the use of imported components has been achieved. Save for some specialised items, the raw materials of all coaching stock other than electric motor coaches and diesel rail cars are procured indigenously and considerable development work has been organised by the factory in order to widen the range of ancillary industries. As production of traction motors comes to be established in Bhopal and diesel engines for rail movements in other factories in India, the present dependence will be further reduced in the production of coaches, electric motor coaches and diesel rail cars.

It is expected that it would be possible to tide over the present dependence on imported materials by gradual substitution with indigenous ones.

Discussions

Mr **T. K. Roy** (W. S. Atkins Pr. Ltd., Calcutta) : Referring to the paper on utilisation, recovery and substitution of strategic non-ferrous metals I would like to know if the corrosion resistance of the aluminised article is the same as that of the galvanised article.

The authors have also pointed out that we have some deposits of Ni ore and that they were able to produce some Ni-oxides. What would be the cost per ton of Ni thus produced ? Finally I would like to know why aluminised wire cannot be used in transformer windings ?

Mr **R. N. Misra** (Author) : Aluminised articles have, as a matter of fact, better corrosion resistance to sulphurous atmospheres than galvanised articles. Various aspects of aluminising as a substitute for galvanising will be discussed in detail in a subsequent paper to be presented in this Symposium. Regarding the use of aluminised steel wires for transformer windings, I have my own doubts; a material with high electrical conductivity is essential for the purpose. I believe, however, that aluminium wire can be used as a possible substitute for copper in windings of this nature. This surely needs experimentation.

Some low grade nickel ore deposits of serpentinous and lateritic nature are found in Assam, Rajasthan and Orissa. Such low grade ores scattered around the tropic and sub-tropic regions of the world are considered to be a potential source of nickel for the future, with gradual depletion of the high-grade sulphuric nickel ores. High grade nickel ores do not exist in India. In view of the very low nickel content in the indigenous ores, smelting methods cannot be applied profitably to these ores. Irrespective of cost factors, the process we have developed is the only feasible one known today for extracting nickel out of these lean ores. We have therefore no choice and nickel being a strategic material we will have to extract it from these low grade ores by the method as described in our paper. Incidentally, nickel produced by hydro-metallurgical method from Cuban ores at Nicaro competes well with the metal produced by the well-known pyro-metallurgical methods. We need not therefore have any apprehension about the economics.

Mr **Sundaram** (Cooper Engg. Ltd.) : Mr Choudhuri referred to the use of S. G. iron bearing shells for railway axle bearings; I would like to know the bond strength between S. G. iron and the babbits as compared to that between bronze and the babbit liner. Was the same lining thickness used and were special steps taken to obtain a better bond strength?

Mr **K. C. Choudhuri** (Author) : Bond strength is practically the same in both cases. Lining thickness is also the same, in fact there is no difference whatsoever in the design of the shell.

Mr **W. E. Duckworth** (Bisra, London) : Some years ago the United Steel Companies in England went quite a long way to develop a process for leaching iron out of iron ore, using fluoride and it was called Flocks in England, standing for fluoride leaching of ore extraction. This process did not go through to full scale operation mainly because the increasing blast furnace efficiency made it just not sufficiently economic, but I was wondering, while listening to Mr Misra, if it might not be very appropriate to some of your ores over here.

Mr **R. N. Misra** (Author) : Extraction of iron by leaching is not our objective. We want to utilise our low grade chrome ore with Cr/Fe ratio less than 3 : 1 for metallurgical purposes and have attempted to remove and discard iron from such chrome ores to improve their Cr/Fe ratios. Iron from chromite cannot be leached as easily as it can be from iron ores. Our attempts, therefore, consisted of preferential reduction of iron in the mineral and its subsequent separation by leaching. We can recover ferrous sulphate as a bye-product which can be calcined to red oxide pigment releasing sulphur dioxide to be converted to sulphuric acid and recycled.

Dr **R V. Thamankar** (D. M. R. L., Hyderabad) : Dr Vaidyanath has presented an interesting review of the world's situation as regards copper. It appears that the communist countries produce only one-tenth of the total world copper and yet they are able to balance their requirements. I want to point out that we, in India, are the worst abusers of copper. We use it for household vessels and appliances, in ammunition, etc. where we can easily substitute. We hardly produce 9 000 tons of copper a year while our requirements are estimated at 237 000 tons for the next year. I think it is high time we sat together in right earnest to devise ways and means for closing this gap.

Dr **G. P. Chatterjee** (Hindustan Steel Ltd., Durgapur) : The last three papers gave us a very good idea of the various substitutions taking place and the results obtained in the respective fields.

Regarding low carbon ferro-chromium the situation does not seem to be very encouraging. We will be needing about 44 000 tons of low carbon ferro-chromium and manufacture of this material has not even been established in India today, particularly the raw material. The Sukinda ores in Orissa have the highest Cr : Fe ratio in the world but the reserves being limited to about a million tons, the parties concerned are somewhat reluctant to set up a plant for the production of ferro-chromium. The Government of Orissa has undertaken this task and they may produce about 10 000 tons of ferro-chromium by 1972 when our requirements would be of the order of 52 000 tons. Obviously this would not meet the demands of the industry.

On the other hand, we have huge deposits of other low grades of chromium ore in South India. It is very appropriate that the NML is most actively working in this direction and I would like to see that effective steps are taken to fully develop the technology for large scale production of low carbon ferro-chromium. If this is achieved within a year's time, I am sure the industry will be forthcoming to exploit the process. The importance of research in this case cannot be overemphasized, because unless we take up these low grade ores for beneficiation and production of high grade low-C-Fe-Cr, there is no point in producing stainless steel as we cannot remain dependent on imports from abroad for all the years to come.

My second point concerns copper. Indian copper contains about $\frac{1}{2}\%$ Ni which is being wasted from the fire refined copper. I need not stress the importance of Ni, especially for alloying purposes, and I feel that its recovery from the fire refined copper is not receiving due attention. Here again I would urge upon the NML and the Indian Copper Corporation to earnestly take up the matter for study.

Dr **B. R. Nijhawan,** (Author) : I will first touch upon Dr Chatterjee's comments on the production of low carbon ferro-chrome and the necessity of doing so. For the last 10 years or so we have been very actively working on the thermal beneficiation of low grade chrome ore to upgrade the Fe : Cr ratio in a metallurgically feasible and economically acceptable manner but nothing in India is economically acceptable until and unless you put up a plan and with the present increase in prices the entire economic structure completely changes. However, when the process is technically sound I see no reason why it should not be worked out on an industrial scale because if one does bring out a product the Government is there to see that some profit is made therefrom and the price structure is suitably adjusted accordingly. I would like to state that it is now for the industry to come forward to try out these processes on a certain scale which will convince not the consumer but also themselves. In other countries I am quite sure such processes would have been tried, the snags thrashed out and the economics improved upon to establish the complete cycle from laboratory to pilot plant on ultimately to industrial scale operations. Such a transition or cycle in India is not easy because the industry wants abnormally high returns and that too right from the start. I think production of low Ce-Fe-Cr is feasible even from low grade ore by our thermal beneficiation method. Conditions in India are very different especially from the marketability and the producer's point of view when he looks upon anything new as risk and anything risky as not workable but uses it as a good excuse to criticise the NML. I am very conscious about Dr Chatterjee's remarks ; he has said the right thing and has set the ball moving in the right direction, and I earnestly hope that his comments will be taken by the persons concerned in all seriousness. Import of ferrochrome will no doubt adversely affect the economics of production of stainless steel and then prices will have to be raised overall and this will promote again a vicious circle.

Now regarding copper, I fully agree with Dr Thamankar that at least half of the copper in India is misused, which is still worse than not using it at all ; it is going to wrong places, towards wrong end products where simple substitution measures could be most effective leaving aside highly technical aspects of substitution such as the replacement of cartridge brass by light alloys or by rimming steel etc. So, apart from such cases which I mentioned in my paper concerning the possibilities of developing light alloy armour on which considerable work has been done in U. S. A., I am reminded of one paper published in the U. S. in 1962 reporting their work on the development of light alloy armoured tanks, weighing less than half of the normal tank. Concerning commercial and economic aspects I might indicate that one ton of Cu imported at the international controlled price can sell here at a market price two to three times higher yielding abnormal profits without having to do any metallurgical research or development work. The Copper Development Wing established in India will have to break through such a barrier leaving aside any metallurgical and technical feautures of copper consumption or substitution in this country. Thus if you get 10 tons of zinc at the price of Rs 2 500 per ton controlled price, you can straightaway sell it at Rs 5 000 without anybody being able to do anything about it. And so, if any new process or substitution measure sidetracks this 'fair income' from Rs 2 500 to 5 000 per ton of copper without bothering about any technical know-how of production or equipment or substitution it is branded as uneconomic. How can you even think of aluminising steel in such conditions, and I agree that it is 'uneconomic' from such points of view and it cannot be otherwise. Thus to preserve their 'fair income' they go on criticising one thing or the other about corrosion resistance, practical difficulties and so on and finally they find fault with our pilot plant stating that it is only a 'baby' pilot plant and suggest the installation of a plant costing nothing less than 20 million rupees which will give them enough time to make sufficient money to last them a long time to come. Exactly the same thing applies for other methods and means of substitution ; we are up against problems which are not technical but are nevertheless so closely linked with the technical aspects that we cannot divorce them. For example, when we have no low Ce-Fe-Cr, we could use carbon-free Fe-Cr which can be obtained by alumino-thermic process ; price naturally would be higher because the aluminium producers want Rs 7 per lb for the Al powder but for which no foreign exchange would be involved and yet even at double the price paid in Indian rupees for the Al powder a good profit can be made. I know Dr Chatterjee is up against a tremendous job in this direction. My sympathies are fully with him and with Mr Nemethy also who is the Production Adviser to the Alloy Steel Plant ; Atlas Steel Co. of Canada with their world reputation and experience in the field, can only impart the technical know-how and it is really for us to get things moving. We have been talking about ferro-alloys production in India for the last ten years, but very little has really been done about it and as Dr Chatterjee stated, Hindustan Steel was to set up a ferro-alloy plant, which came up to the blue print stage and then nothing happened. This is the general context of conditions here which many from overseas may not be able to fully appreciate. We want them to know what we are up against.

Mr **W. E. Duckworth** : I thank Dr Nijhawan for very appropriately summing up and winding up the discussions this afternoon. I might say that the difficulties he finds are not peculiar to India as he might think. Similar speeches have often been made on behalf of BISRA. It has been found that there are three stages in presenting a new process to the industry. First of all they say it is impossible, secondly they say it is uneconomic, and finally they say 'we have been doing it all the time' !