Critical raw materials and substitutes in the light of India's self-sufficiency

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THE Secretaries Committee of the Ministries has been asked in October, 1965, by the Government of India to consider the situation that may arise as a result of any withdrawal of aid or any application of economic sanctions by the big powers, and to consider steps necessary to meet such extreme situation in view of the present emergency conditions in the country.

A preliminary assessment by the Committee is that the economy of the country can bear the strain easily for six months but special attention needs to be given in non-ferrous imports.

Non-ferrous imports

At present the main sources of supply of non-ferrous items that are insufficiently produced in India are copper, zinc and lead from Canada, U.S.A. and Australia. The total import value of these non-ferrous metals amounts to nearly Rs 70 crores annually, out of which Rs 50 crores is accounted for by copper alone.

Under Colombo Plan zinc and lead are mainly supplied by Australia and copper by Canada. It is assessed that in case of withdrawal of aid by the major western powers, the non-ferrous metals can easily be procured from the world market provided adequate foreign exchange is made available.

Indigenous capacity

To save scarce foreign exchange, it is necessary that as much as possible of these non-ferrous metals, and other 'aid covered' imports should be produced within the country. To ascertain such requirements the Secretaries Committee has requested the Directorate General of Technical Development as well as the department of defence production and important public sector units to work up and assess such requirements of production potential that can easily be switched over to manufacture of these urgently needed imports items.

Although any possibility of economic sanction by U.N.O. or making of aid by the major western powers conditional on maintenance of peace in the Indian subcontinent, is for the present a distant possibility only, yet the assessment is that India is in a better position to bear the strain. Nevertheless the possibility should not be ruled out in planning India's defence and defence oriented industries production.

Traditional market

In order thus to have sufficient liquidity in foreign exchange, to enable India to buy her non-ferrous metals and other defence oriented import requirements from the world markets, in the event of stoppage of aids, the present policy of exporting traditional items like tea, jute, cotton textile, woollens, leather and hides, and raw materials to the traditional markets needs to be reviewed. There is a vast scope for increase in trade with the East European countries, and in place of present system of export of only surpluses to the East European countries, as a matter of policy a substantial portion of the traditional items needs to be diverted to the East European countries, on a permanent basis, not only to secure some of the urgently needed import items, but also to insure the country against any sudden strain on the economy and on defence production, in case of sudden cutting out of aid by the U.N.O. or the major western powers.

Critical raw materials

Under a proposed three-year programme of bulk imports of 'critical raw materials' on top priority basis, for the engineering and chemical industries, can be listed about 22 items as scarce materials. These include non-ferrous metals, special steels, rock phosphates and potash. The Government of India has accordingly set up a special high-powered Committee including secretaries of the Commerce, Industry and Finance Ministries, and representatives of the Minerals and Metals Trading Corporation to go into the problem of detail, item by item, with a view to importing materials by barter deals or through outright payment.

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Import quota and import policy

The metal trade represented by the Indian Metal Merchants' Association is anxious that the Government of India should without delay declare the import policy regarding non-ferrous metals while the Import Trade Control Policy Book for licensing period, April 1965–March 1966, has been issued, the Import Book of non-ferrous metals by established importers is awaited publication presumably till a proper assessment of substitutes production is completed.

There is no quota for established importers for copper wrought and policy for copper unwrought is awaited. As for lead ingot, pig and scrap, the policy remains unchanged. The Import Policy for brass, bronze and similar alloys unwrought is yet to be channellised.

The import of tin blocks and tin scrap has to be channellised through an agency approved by the Government and proper assessment of substitutes has therefore to be completed early.

Import substitution

There is need for greater utilisation of aluminium in place of copper, aluminising in place of galvanising, discontinuation of use of copper and zinc for the manufacture of utensils and development of plastic containers to substitute non-ferrous metals containers.

Non-ferrous mineral output in India

The production of bauxite totalled 67 000 tonnes in March 1965. The output of copper ore during the same period was 41 000 tonnes.

The recovery of lead and zinc concentrates during March 1965 totalled 560 and 869 tonnes, and the figures for the first quarter of 1965 are respectively 1518 tonnes of lead concentrate and 2601 tonnes of zinc.

Metal position in India

India is deficient in copper, zinc, lead. India however is potentially rich in iron, aluminium, titanium, magnesium, manganese, beryllium, zirconium. Nickel, tin, and tungsten are practically non-existent. The need and policy for metal substitution have to be based accordingly.

Scope of non-ferrous substitution[2]

Aluminium is a multiple end user, its low weight reduces transportation cost also. Substitution of copper by aluminium during Third Five-Year Plan covers a replacement of bare copper conductors by aluminium conductors at 5 000 tons for 1965–66, and estimated 15 000 tons in 1970 ; substitution of 1 000 miles of paper-insulated cable based copper wire by aluminium wire in 1965, and estimated 2 500 miles in 1970, substitution of copper by aluminium in heavier VIR and PVC wires to an extent of 200 million yards by 1965 and estimated 600 million yards in 1970 ; replacement of copper and copper based alloys by aluminium and other alloys in manufacture of electrical switch gears by 10 per cent in 1965 and estimated 20 per cent in 1970. Aluminium can also substitute copper, zinc or lead in manufacture of motors, generators, transformers, condensors, conduit pipes, lithographic plates, paints, hardware brass and bronze fittings, and in foil industry.

Zinc consumption in India during 1960–61 was around 70 000 tonnes representing a 100 per cent increase over the previous five years. The estimated annual requirement of zinc by end of 1965 is 185 000 tonnes. The big gap in indigenous capacity and requirement of zinc thus warrants immediate switch over to or replacing galvanising by aluminising, since the galvanising industry in India consumes the bulk or imported zinc. Even the setting up of zinc smelter plants at Udaipur, Alwaye and Vishakhapatnam will not be able to meet the total requirement of zinc in future.

Lead is a vital defence metal. It is however used extensively through imports in the form of lead sheets. The lead sheets are used for roofing and as impervious floor sheet in basement and foundations, and also in container like toothpaste container and others. Such sheets can largely be replaced by plastic sheets of varying thickness and plasticity. Lead foils can also be replaced by aluminium foils and plastic foils. There is also need for recovery of waste metal from consumer goods waste or scrap, and for reprocessing.

Tin is another defence metal. Commercial substitution of tin can be effected by using aluminium sheet containers and plastic or plastic lined metal containers in place of tin plate containers.

Ferrous metals and alloy substitutes

These criteria also apply equally to alloy steel, tool steel, special steel and stainless steel. Hence there is need to formulate and develop families of indigenous substitute alloys compositions which can elminate drastically or minimise the use of such scarce alloying elements as nickel, molybdenum, tungsten, cobalt, etc. by the introduction of substitute alloys.

India should henceforth restrict the export of ilmenite available in Kerala and Madras plentifully, in as much as it can be produced from 'Titanium' the metal of the future[4] and which is used increasingly in the aircraft, shipbuilding and automobile industries because the metal combines to an unusual degree the properties of lightness, strength and resistance to corrosion.

The National Metallurgical Laboratory at Jamshedpur has already given the lead in this direction over the past several years by carrying out major research and development work on such substitute alloys and alloy steels such as nickel-free austenitic stainless steel, low alloy high tensile structural steel indigenous tool and die steel, iron-aluminium alloys, nickel and cobalt free electrical resistance alloys, manganese bearing substitute brass, aluminising of steel and other aluminium based substitute alloys for various ranges of end products.

Defence production and substitutes

There are 24 ordnance factories in India whose production was valued at Rs 111·34 crores in 1963–64 against Rs 41·88 crores in 1961–62. Four more new factories are to be set up. The ordnance factories have turned out more than 5 900 Shaktiman trucks, 11 200 Nissan one-tonne trucks and 4 500 Nissan patrol jeeps. The indigenous component of Shaktiman is more than 70 per cent, of Nissan trucks about 38 per cent, and of Nissan patrol jeeps more than 31 per cent. About 1000 tractors of 4 different types with varying percentages of indigenous parts have also been produced. Order placed with civil industries is worth Rs 15 crores; besides, research organisations like Hindustan Aeronautics and Bharat Electronics have made remarkable progress in self-sufficiency. According to the members, Industry, Planning Commission, the Fourth Plan programmes are expected to make the country virtually self-sufficient in power equipment, between 70 and 80 per cent self-sufficient in transport equipment, and to a similar extent in machine tools and automobile industries, all requring varying uses of high tensile steel, special steel and alloy steel.

Industry's aim

According to a recent assessment of the Ministry of Industry, our industry's aim should be to effect a saving of at least Rs 200 crores a year in import substitution both in raw materials and components and spares in view of the fast developing steel alloy industry and non-ferrous substitutes.

On the basis of 100 per cent increase in industrial production during the Fourth Five-Year Plan the foreign exchange requirements for industries are approximately Rs 1320 crores in public sector, and Rs 900 crores in private sector[5], aggregating to Rs 2 220 crores. At 10% of value in import substitution, Rs 222 crores worth of import substitution is required, out of which metals ferrous and non-ferrous will probably account for the largest share.

High alloy Indian steels as substitutes

The role that carbon plays in raising the strength of iron is well known. Examination in both single and polycrystalline specimens between 0·001 and 0·03 C (10–300 ppm) shows particularly at low temperatures the large effect on the yield stress of this interstitial solute. It is also known that chromium is the least effective solid-solution strengthener while prosphorus is the best.

Solid-solution strengthening is also effected at elevated temperature by substitutional solutes. At 500°C chromium and molybdenum are more effective hardeners than nickel and silicon which are better at room temperature.

Martensitic steel

There is no convincing evidence that alloying elements in steel other than the interstitial elements carbon and nitrogen, have any appreciable effect on the mechanical properties of martensite in the as-quenched state. Indirectly however, they may influence the mechanical properties of steel by altering the hardenability, lowering the Ms temperature or by encouraging the retention of austenite.

The effectiveness of the various alloy carbide forming elements in the development of secondary hardening varies greatly. In plain chromium steel no rise in hardness occurs in the range of 500–600°C until the chromium content is raised to 10–12%.

However 10–12% Cr steels[6] do not show as marked a secondary hardening phenomenon as do steels with as little as 2% Mo or V. Molybdenum steel containing 3–4% molybdenum and vanadium steel with 1–2% vanadium show pronounced strengthening on tempering in the range of 500–600°C.

Recently works have been carried out by Irani[7] and Raynor[8] in the University of Sheffield on several high purity ternary iron alloys including Fe-4%M-0·2%C, Fe-1%V-0·2%C, Fe-5% Cr-0·2%C. The molybdenum and vanadium alloys exhibited secondary hardening in a similar way to the steels based on them, while the chromium containing alloys showed no hardening. The same carbide sequences were observed and could be studied in detail by thin film electron metallography.

Austenitic steel

Austenitic steels based on 18%CR-10%Ni with about 0·1%C are relatively weak. They can however be strengthened by work hardening to high levels.

The results for separate 1% addition to the Ni-Cr base with 0·1% shows that the precipitation hardening occurs if the solution treated and quenched alloys are tempered in the range of 600°C–700°C.

Classifications

High alloy containing about 10% or more total alloy content martensitic steels are classified into 4 general groups.[9]

Group I

Steel depending principally on the production of 'hard' martensitic structure for their mechanical properties, i.e. the hot work die steels and high carbon 12% Cr steels. In this category are high alloyed tool steel, such as 18/4/1 type, having a tempered martensitic matrix.

5% Cr. Steel: A tensile strength greater than 100 tons/in^2 is obtainable from low alloys steels such as :

(i) Nickel-chromium-molybdenum-vanadium steels.

(ii) Silicon-manganese-nickel-molybdenum steels.

(iii) the 3% Cr base steels (recently developed alloy containing 3% Co).

(iv) 5% Cr base steel.

The 5% Cr base steel is also considered high alloy steel, and has been applied to structural applications especially for aircraft components and provides the most favourable strength/density ratio. In fully hardened and tempered condition the hot hardness and strength increases with increasing addition of tungsten, molybdenum and vanadium to the 0·3–0·4% C—5% Cr base alloy, being effective over 550°C.

5–9% Si Steel : The effect of silicon retards the tempering and increases the oxidation resistance of chromium steels at high temperature, and the alloy is suitable for use for exhaust valves in internal combustion engines. Formerly 0·3% C—12% Cr stainless alloys, and now more economic 0·5% C—1% Si—6%Cr valve steel are used rising to 0·5% C—3% Si—8% Cr for optimum properties.

12% Cr Steels : 12% Cr Steel has corrosion resistant properties and suitability for use in gun barrels.

The carbon content of the steel determines the strength of the martensitic structure produced on hardening and the applications accordingly vary from lightly stressed engineering fittings to turbine blading and cutlery as the carbon content increases to eutectoid composition (0·3% C) and beyond.

Increase in chromium content beyond 13–24% produces a steel which is ferritic at all temperatures up to liquidus and therefore unhardenable.

Group II

For use in jet aircraft engine, the demand is for corrosion-resistant steel with better creep strength. Such demand in the steel can be met by developing the secondary hardening characteristics produced by carbide precipitation from the matensitic matrix of a hardened 12% Cr steel. Studies on variations of mechanical properties of such steel has been made for types to which manganese, nickel, molybdenum vanadium and niobium additions have been made. Alloy additions such as Mo, Co, Cu, Al, Ti and Nb provide hardening effects on tempering thus increasing the strength.

Group III

In recent years a new means of obtaining strength level greater than 125 tons/in.^{2} without impairing ductility has been developed. As strength and ductility of quenched and tempered martensitic steel bear an inverse relationship to one another, strength levels of the above order are usually accompanied by inadequate ductility for most engineering applications. The limitation is overcome when martensite is formed from strain hardened austenite.

If austenite is plastically strained while in metastable condition, according to Brook and Russel, between Ac and Ms the decomposition of austenite to pearlite or bainite is accelerated. The presence of certain alloying elements, principally chromium, produces a range of temperature of high austenite stability between the pearlite and bainite transformations in which deformation can be performed without austenitic decomposition. The strain hardened structure is then allowed to transform to martensite and to be highly tempered. This results in increase of yield and ultimate tensile strengths by 0·3-0·5 tons/in.^{2} for each percentage of deformation.

Experience at ESC has shown the limitations of conventional hammer and press forging techniques when applied to certain alloys. Neither of these processes have been found to be possible on a commercial basis for the ausforming of 12% Cr alloys due to cracking of the work piece at about 60% deformation. These restrictions may be alleviated to some degree by the development of alloys specifically for fabrication by ausforming, with close control of working conditions.

The strengthening effect obtained by deforming tempered martensite is similarly related to carbon content, but a strengthening effect is observed, from Reports of Brook and Russels, on tempering after straining at all carbon levels. It is reported that AISI 4340 steel in the martensitic condition when tempered at 205°C and plastically strained 3% in tension, and is then retempered at 205°C, the yield strength is increased from 102 ton/in.^{2} to 145 ton/in.^{2} The strengthening effect attributed to the resolution and reprecipitation of the carbides is in a much more finely dispersed form than can be achieved by ordinary tempering.

Group IV

In recent years the demand has developed for material specially suited to cyrogenic applications such as transportation and storage of highly volatile liquids like methane at temperatures as low as —196°C. Use of ferritic steel for such purpose is restricted because of the poor low temperature impact strength of such materials. Low carbon 3–5% Ni steel provides charpy impact strength of 15 ft lb at temperature down to —150°C, providing the key to a major break through. Armstrong and Brophy[10] have shown that impact strength of this order can be obtained at —196°C in low carbon steels containing 8–13% Ni. A nickel content of 8·5% has been suggested as the most economic alloy commensurate with the desired impact properties.

Effect of silicon

Silicon addition of 1% and 2% made to 12% Cr–Mo–V base steel when compared with base steel containing low and high nitrogen contents, shows that strength level is reduced by ferrite in the microstructure produced by 2% Si, so 1% Si is probably as much as can be accommodated. The effect of 1% Si is to raise the tempering curve of a low nitrogen steel nearly to the level of a high nitrogen steel.

Effect of niobium

To increase secondary hardening, carbide forming elements are used. The increasing order of these elements is vanadium, molybdenum, tungsten, titanium and niobium. Addition of 0·33% to 0·37% niobium to 12% Cr–Mo–V base steel shows that after tempering for one hour at 650°C, it is possible to increase the strength of steel, and the effect is additive to that produced by a nitrogen increase.

High tungsten steel

Irvine and Pickering[11] report for Co-W additions that if tungsten content up to 8% is used and suitably balanced by cobalt, the high tungsten steel shows a high temperature reaction, but when the results of the steel containing molybdenum and tungsten are compared, the result shows that greater amount of tungsten is required to produce an equivalent effect to molybdenum. Mechanical properties of a typical Co-W steel after tempering for one hour at 650°C shows :

Co%	5	10	15
W%	4	6	8
Ts tons/in²	64·2	101·7	109·8
0·2% Ps, tons/in²	51·2	80·0	70·2
Elongation%	22·3	14·7	5·8
RA%	60·8	40·0	4·8
Charpy impact ft. lbs	48	6	9

At tensile strength below 80 tons/in², the Co-W steels have slightly better impact strength than Co-Mo steel.

Steel containing aluminium or titanium additions

Precipitation hardening resulting from Ni-Al or Ni-Ti addition are known to be effective in ferritic and austenitic stainless steels. Investigation by Irvine and Pickering in such 12% Cr transformable steel has shown that with precipitation hardening at 500-550°C, such a steel with 3% Ni, 1% Al has no advantage over the 12% Cr-Mo-V steel. Any higher aluminium addition has to be balanced by an increasing amount of austenite forming element. It is not possible to do this with nickel because of the marked effect the element has in lowering the Ac temperature. Addition of cobalt to replace the nickel is also reported to be not successful because the combination of cobalt and aluminium does not produce age hardening. Ni-Ti addition to introduce age hardening has the same effect as Ni-Al, and there is equal difficulty in balancing the composition adequately to allow sufficient titanium to be used to produce appreciable age hardening. Further, titanium combines with carbon to lower the initial strenght of martensite.

Due to this difficulty in producing a balanced composition with no δ-ferrite and an Ac temperature above 653°C addition of Ni-Al or Ni-Ti are considered not very suitable for producing high strength levels in 12% Cr steel.

Copper addition

Steel with 4% copper addition shows a marked increase in secondary hardening due to copper precipitation but over-ageing is relatively rapid. Hence the hardness level, even of the highest copper steel, at tempering temperatures of 650°C is not as great as can be obtained from the 12% Cr-No-V steel. In view of difficulties in hot working high-copper steels do not appear attractive.

Defence user experience

For missiles main design requirements are for strength and stiffness over the required range of temperatures. J. Fielding's[12] report on investigation is that 12% Cr martensitic steel used for years for engine components gives the best results. This type of steel (FV 488) however cannot be produced in sheet form to the required degree of flatness in necessary sizes, nor is this suitable for forming processes for airframe structures. Heat treatment of thin sheet structures with this steel at 1000°C also proves difficult.

PHSS steel more recently introduced in Britain and U.S.A. for air frames and missile frames shows greater promise. As manufacturers of supersonic airframes Hawker Siddeley Aviation Ltd. have accumulated considerable experience using precipitation hardening stainless steel (PHSS). This experience began with the design of the Avro 730 supersonic bomber in 1956. For supersonic rocket aeroplane, guided and controlled by autopilot and inertial navigation system of the British Blue Steel class, introduction of PHSS steel structures has been necessary with development of special tools suitable for production.

The greater promise of PHSS steel is for the following reasons.

1. Ease of manipulation

In the soft austenitic condition the steel can be shaped just as readily as soft 18/8 stainless steel.

2. Flexibility of heat treatment

The usual heat treatment with heating at 750°C followed by 550°C is more suitable for sheet components than the higher temperature required for other steels. Transformation by subzero heat treatment, cold working or combination of the three methods is possible.

3. Strip rolling

PHSS can be strip rolled to close thickness tolerance, to provide the long sheets with very consistent proportions and good surface finish required.

4. Strength and stiffness properties

Though not comparable to martensite steel, the properties are adequate.

5. *Availability*

The PHSS steel can be manufactured in strip, sheet, bar, forging and cast form.

Mechanical properties of PHSS steel are :

Type	Designation	0·1% proof stress tons/in.^{2}	Max. stress in. tons/in.^{2}	Ex106 lb/in.^{2}
TENSION				
Double aged 750 C 550 C	FV 520	64	70	28·6
Subzero transformed –75 C 550 C	SF 80T	64	72	28·4
COMPRESSION				
Double aged 750 C 550 C	FV 520	61·7	73	28·6
Subzero transformed –75 C 550 C	SF 80T	65	75	29·2

The advantage of PHSS is that it can be hardened from a soft or relatively soft condition to 75 tons/in.^{2} maximum stress, and can be transformed from austenite to martensite by a variety of treatment like conditioning treatment at about 700°C followed by precipitation at 550°C (known as double ageing).

Stretch forming—PHSS is supplied in soft condition and 0·1% proof stress is roughly between 15 and 25 tons/in^2.

0·1% proof stress—It is a decided advantage to have proof stress between 15 and 30 tons/in^2, 45 tons/in^2 being limit of satisfactory forming.

Stress strain curve—PHSS shows much better stress strain curve than 18/3 Ti stabilised stainless steel, as in the latter in steel form only a small amount of elongation can be imparted before failure due to local 'necking'.

The American developments of PHSS are in series 17–7 PH, PH 15—7 Mo and PH 14—8 Mo. These steels are used by the North American Aviation Inc. in the manufacture of Valkerie B-70 aircraft with 70% of structure made from PHSS. The honeycomb sandwich construction is used, and brazed stainless steel honeycomb panels are used for most of the structure joined by machine seam welding, the remainder being panels stiffened by steel stringer or webs.

Manufacture requirements

Structures for missiles and large aircrafts are similar in type, though small structures require more from the steel than large ones. The curvatures of the skin are tighter and the radii of frames are smaller. For a complicated structure, mostly from thin gauge sheet which is finally heat-treated to over 70 tons/in^2, it is really a structure in 'spring steel' and is a difficult undertaking.

Short term measures for substitute raw materials

The above pages indicate to what extent it is possible to effect critical raw material substitutes in non-ferrous and ferrous groups. As a short-term measure, a considerable saving in wastage of materials can be effected by developing the scrap trade for conservation of metals. Scrap can be collected from the processing and fabrication plants, and from discarded articles that go to junk heap. In USA the amount of lead produced from scrap is twice that of the mineral product. As regards antimony, 57% of this is of secondary origin, derived from old automobile storage batteries.

Antimony can be replaced by titania, zirconia and plastics ; arsenic by organic compounds ; cobalt generally by manganese, lead by plastics ; aluminium, titanium, zinc, synthetic resins and manganesium nickel by chromium, aluminium and manganese ; phosphate rock by basic slag ; platinum by gold and other platinum group metals, tin by glass, paper, enamels, zinc, plastics and land, and zinc by ceramics, plastics, aluminium, lead and titanium, tungsten by titanium carbide (to limited scope and inferior performance).

The known reserves of tungsten though small are enough to meet the present requirements for making our own tungsten steel. But as in USSR, demand for nickel and tungsten can be kept low by replacement with the more readily available manganese, chrome and vanadium, particularly for stainless steels, tank armour and artillery barrel liners.

As to sulphuric acid, Amjore pyrites rich in sulphur can help replace imported sulphuric acid by indigenously manufactured sulphuric acid.

Flurospars of Gujarat and Rajasthan can meet the demand for use as flux in steel making and the raw materials for manufacturing hydrofluroic acid essential to the aluminium industry.

Production programme for alloy steel

The alloy steel plant at Durgapur will start producing finished product from December 1965 with the commissioning of the forge shop. This will enable the plant to meet the entire tool steel requirements for defence purposes, for which engineering steel will be supplied by Tatas.

The Durgapur alloy steel plant's basic production is scheduled to be expanded four-fold in 1966, and will further go up in 1967.

The present revised alloy steel production target is 550,000 tonnes out of which Durgapur alloy plant's share is the major portion.

The export committee appointed by the Government of India has stated in its report that the country will need 250,000 tonnes of construction steel, 160,000 tonnes of spring steel and special steel, and 140,000 tonnes of stainless, high speed tool and die steel. The Tatas also propose to set up special steel and alloy steel plants to meet the industry's requirement.

As aluminium is required for airplane production, defence and for substitutes, its production is to be raised from 68 000 tonnes per annum to 273 000 tonnes by 1970–71. Similarly production of copper is to be raised from 9 600 tonnes to 64 000 tonnes per annum. As for zinc, apart from zinc smelters in Rajasthan based on Zawar mines, zinc refining will be taken up at Vishakhapatnam with Polish collaboration. Efforts are being made to produce elements like antimony, cobalt and nickel, and particularly efforts require to be made for molybdenum and vanadium and the Indian Bureau of Mines has accordingly to be enlarged four-fold.

Standardisation

The programme of replacement of maintenance imports of spares and components is proposed to be based on standardisation and interchangeability, and intensive work is presently going on in the programme. USA has also gone a great way in this line of work. The Hindustan Machine Tools Ltd. is also understood to have evolved some interchangeable parts, resulting in import saving and saving of critical raw materials.

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