Substitution of galvanising by aluminising of steels

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ALUMINISING has been accepted by the Government of India as a substitute for galvanising because of the existing scarcity of zinc. Zinc resources of our country are limited whereas minerals for extraction of aluminium are available in plenty. The Hindustan Steel (P) Ltd., has decided to have provision for strip aluminising plant at Rourkela and Tata Iron and Steel Co. Ltd., may also be going for strip aluminising adopting the Sendzimir Process. Bokaro Steel Plant has also made provision for aluminising of steel strip.

National Metallurgical Loboratory has done extensive work on aluminising and has developed suitable techniques covered by various patents.[1,2,3] This process is of great importance in the context of present national emergency and foreign exchange difficulty. Many galvanising works face virtual closer for our inability to import zinc. It is, therefore, imperative to switch over to aluminising as aluminium is indigenous and we can hope to be self-sufficient in due course because of our bauxite reserves whereas zinc may have to be imported as we do not have sufficient zinc ores.

India has been importing progressively increasing quantities of zinc[4] as shown below, 50 to 70% of which are used in galvanising.

Year	Tonnage (in thousand metric tonnes of improted zinc)
1959	47·5
1960	60·0
1961	70-0
1962	84·6
1963	90·0

By now India has crossed the hundred thousand mark in its import of zinc involving foreign exchange equivalent to nearly rupees thirty crores.

Our zinc deposits at Zawar are very meagre. In 1964 only 10 744 tonnes of zinc concentrates[5] were produced at Zawar. The zinc smelters have to be commissioned. In any case we simply do not have ores to meet the current zinc demand and its subsitution is vital if we are to become self-sufficient.

Our aluminium position is on the other hand most fortunate. Our country is blessed with extensive deposits of bauxite, 5 91 000 tonnes of which were mined[5] in 1964.

Production of aluminium remains pegged at the level of approximately 53 000 tonnes a year and it is estimated to go up to about 93 000 tonnes per year at the end of the Third Five-Year Plan against the revised target of 120 000 tonnes.[6] Bharat Aluminium (P) Ltd., a new Public Sector company, is being set up to execute Korba and Koyna Projects.

All the galvanising pants in India for coating sheet, wire and tubes are potential concerns likely to be interested in switching over to aluminising for national and economic reasons. The aluminising of small fabricated articles and hardware can be taken up on cottage industry scale where cheap electric power or gaseous fuels are available besides the other raw materials.

Of the various methods of coating steel with aluminium, the hot-dip process is the most versatile in its scope and application. It consists in degreasing the steel base with either alkaline or solvent degreasers, pickling in sulphuric or hydrochloric acid, washing, drying and suitably fluxing prior to immersion in a bath of molten aluminium.

Scope of applications and advantages over galvanising

Atmospheric corrosion resistance applications

Aluminised steel can replace galvanised steel in sheet, strip, wire, tube and hardware coating plants. By virtue of atmospheric corrosion resistance aluminised steel sheet finds use in commercial and farm buildings, rolling shutters and silo covers because aluminium coatings are substantially superior in many ways to equivalent thickness of zinc coatings when exposed to industrial and highly humid atmospheres. Resistance to fire damage

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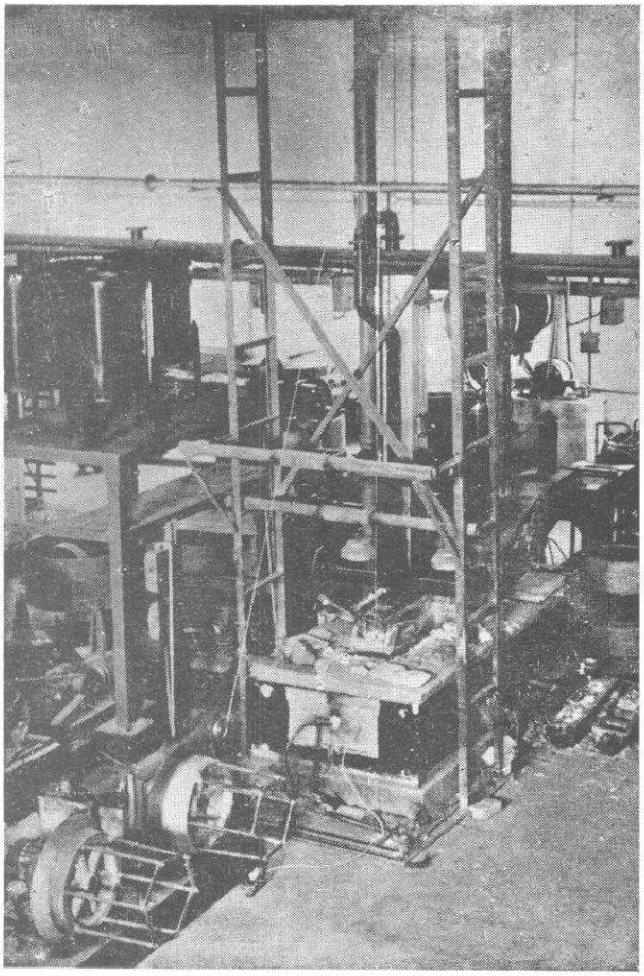


1 *General view of pilot plant*

is decidedly better in aluminised steel compared to galvanised steel.

Steel sheet and strip aluminising

We are currently designing a continuous strip aluminising plant. The process was developed in the first instance on steel sheet panels.

Preliminary experiments on continuous hot-dip aluminising of mild steel were conducted using 7·5, 15 and 22·5 cm wide strip varying in thickness from 0·6–3 mm procured from the Indian Tube Company, Jamshedpur. Strips both in the as-annealed and cold-rolled finish were used as the basis material for aluminising.

In a typical run the strip coil is first loosened and batch degreased in I.C.I. degreaser No. 1, washed thoroughly and put on the reel. In the continuous line it passes though 1 : 1 hydrochloric acid, swill tank, spray wash, flux bath, drier and molten aluminium. Annealed strip has first to be batch descaled in 8% sulphuric acid. After hot-dipping the strip comes out either through a system of rolls or asbestos wipes to control the thickness and finish of coating.

Encouraging results have been obtained and demonstrations have been made to several interested parties who have evinced keen interest in the development of hot-dip aluminised strip which is expected to find a wide market.

Coatings obtained are lustrous, uniform and sound as ascertained by metallographic examination, preece test and nitric acid soundness test. Stripping test indicates 0·7–1·5 gm/sq.dm. wt. of coating.

Our process is very simple in operation and needs no foreign collaboration. The controlled atmosphere processes being used in U.S.A. and U.K. based on reducing atmosphere no doubt avoid use of fluxing technique but their adoption in the country will necessitate import of their plant and machinery also. If this is being done as a short cut to aluminise steel by whatever method is available from advanced countries we are at least happy that aluminising for which we have been advocating is at least coming to India.

Firms which however, have no resources to import foreign technology wholesale can adopt our simple fluxing technique which is also cent per cent indigenous in raw materials and equipments.

Wire applications

Aluminised steel wire equivalent to IS 279–1951 for G.I. wire can find applications for telephone and telegraph lines. Galvanised steel wire for signalling purpose to IRS SI-51 can be replaced with aluminised wire of equivalent properties. Steel core-wire of ACSR conductors can also be aluminised. Hardware applications like wire ropes and barbed wire can also be made.

The pilot plant

Pilot plant trials of the patented processes have been in progress since February, 1960. Initially work on hot-dip aluminising of wire has been undertaken. Fig. 1 shows a general view of the pilot plant established at National Metallurgical Laboratory.

Our set up is almost 1/6 the size of an industrial wire galvanising unit working at Jamshedpur. This unit is capable of running 5 strands of wires at a time with varying speeds up to 50 ft per minute, although we generally run only one wire for experimental runs. The plant is a continuous unit comprising feed reel, acid pickling, washing with water at different stages, fluxing in either of the three types of fluxes and finally applying hot-dip aluminium coating from molten bath of aluminium with or without alloying elements. The aluminised wire is suitably wiped and then coiled on take-up reels.

Selection of a suitable pot for holding molten aluminium presented difficulties. Refractory lined pots heated electrically by induction or resistance heating have been suggested. We had, due to import restrictions, to go for a cast iron pot. The casting of this pot was done in our laboratory.

The sinker design for continuous aluminising for wire was another serious problem because steel or iron gradually dissolves in the molten aluminium. One suitable material suggested is a refractory containing silicon carbide and silicon nitride. This material is not attacked by aluminium and has good wearing properties. In our present set up, we have once again simplified our work by taking cast iron sinker which is not easily attacked by molten aluminium. The sinker is removable from the bath when the aluminising operation is not taking place.

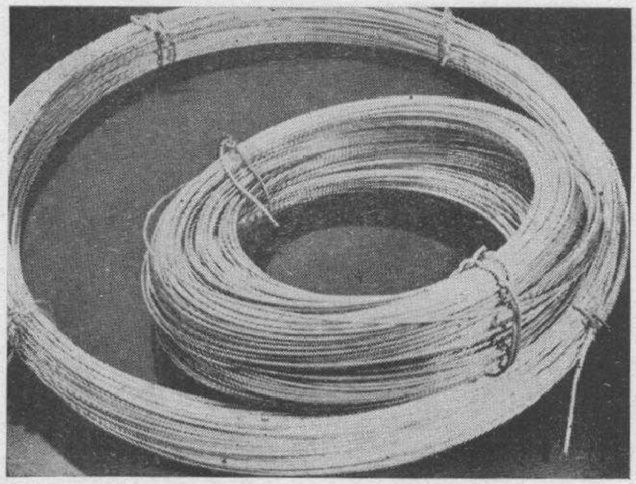
The furnace design is based on the optimum temperature requirements for hot-dip aluminising. The temperature for aluminising on the other hand depends on the flux used and also to some extent on the composition of the molten metal bath whereas time of contact of the basis metal with the bath determines and controls the intermetallic hard and brittle phase of iron and aluminium and also the outer aluminium layer.

Aluminised wire[7]

The pilot plant has taken up aluminising of M.S. wire suitable for general hardware applications, telephone and telegraph lines and core-wire of ACSR conductors.

A 1 cwt coil is first degreased in I.C.I. degreaser No. 1, washed in running water and placed on feed reel. Wire from the feed reel enters an alkathene line pickling tank. The flux employed is an aqueous solution of potassium flouride containing 20–30 gm KF/100 ml solution. The fluxed wire is passed through a drier and preheater heated by means of the flue gases from the gas fired aluminium melting furnace. The dry wire enters the molten aluminium bath maintained at a desired temperature and it is withdrawn vertically. The emerging wire is wiped with asbestos pads to avoid flux markings. The same can also be accomplished by a sizing die. The vertically withdrawn wire travels 10 to 15 ft. in air before touching any pulley. After air cooling the wire is coiled over take-up reels.

Fig. 2 shows coils of aluminised wire thus obtained.



2 *Coils of aluminised wire*

Visual examination

The aluminised wire as it emerges from the exit end of bath tends to carry the floating oxides and fluxing by-products whereby coating tends to be nodulous. Use of asbestos wiping pads and a split sizing die result in a continuous streak marking which may be a flux marking if it passes loosely through these devices or dark if due to excessive abrasion of coating the alloy layer being exposed.

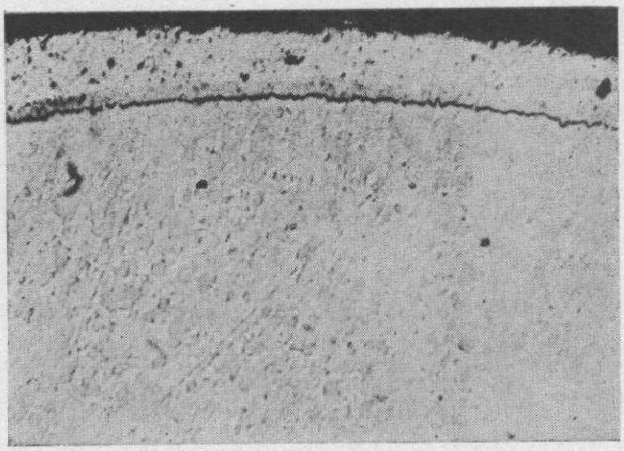
Metallographic examination

Metallographic examination on transverse sections of wiped wire at the Coatings Research Laboratory of the British Iron and Steel Research Association, U.K., was reported as follows:

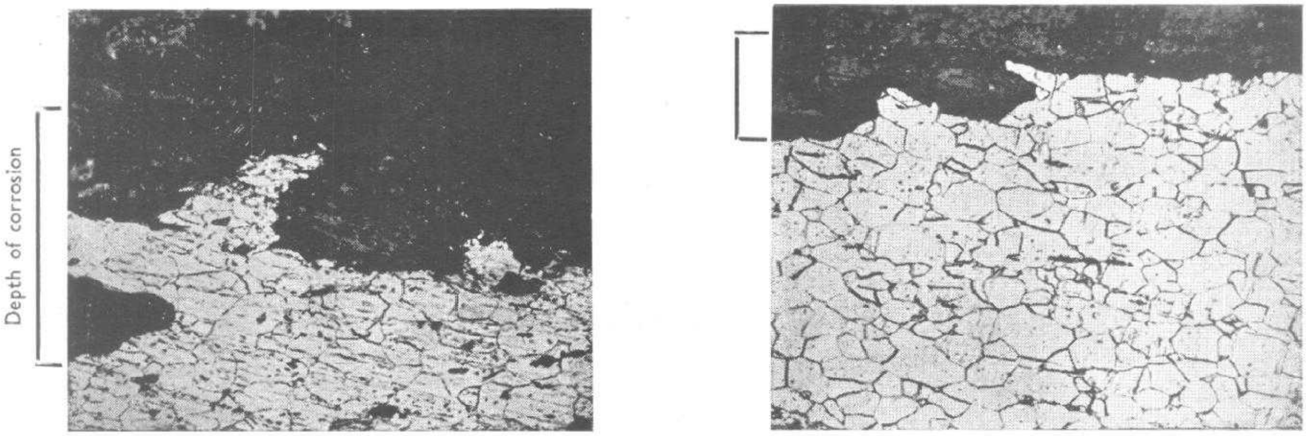
> Effective preparation and prefluxing as there is no sign of failure in alloy layer.
>
> Coating thickness varied from 0·6–1·5 mil in wiped condition.
>
> The problem of wiping off most of the aluminium without losing too much lustre has been solved.
>
> Coatings obtained by use of sizing die are thick (2–3 mils), uniform and concentric.

Coating weight

Representative 12″ samples were tested for coating weights as per ASTM A428–58T stripping test wherein a substantial weight of coating is dissolved in 20% sodium hydroxide solution at 90°C and finally in conc. hydrochloric acid in one to three cycles. Wiped coatings had 220–350 mgm/ft. of aluminium on 10 SWG



3 *Microstructure of aluminised steel wire showing concentric coating*
Etched in nital ×*100*



Galvanised steel wire *Aluminised steel wire*

4 *Microstructure of exposed galvanised and aluminised wires showing comparative penetration of corrosion pits after 2½ years Etched in nital* ×100

wire. Coatings obtained by use of sizing dies had a coating weight of 300–400 mgm/ft.

Salt spray corrosion test

Accelerated corrosion test as per ASTM B117–54T shows that an increase in coating weight from 320 mgm/ft to 350 mgm/ft in wiped coatings decreases corrosion rate from 65 mgm/ft/120 hours to 15 mgm/ft/120 hours. Corrosion rate of coatings obtained by use of sizing die is only around 10 mgm/ft/120 hours.

Soundness tests

Coatings behaved well in preece test withstanding five dips and in 15% HNO_3 test wherein very little gas was evolved in 5–8 hours.

Electrical resistance

Good aluminised 10 SWG steelwire has an electrical resistance around 24 ohms/mile and will be suitable for telephone lines. In comparison galvanised wire of some gauge has a resistance of 26 ohms/mile.

Sample	Dia. in.	Max. stress T. S. I.	Elongation %
Uncoated annealed M. S. wire	0·125	33·93	18·75
Hot-dip aluminised wire	0·123	33·82	12·5
Cold-drawn aluminised wire	0·116	44·46	6·25

Mechanical properties

Tensile test results on M.S. wire in the uncoated, coated and drawn condition are given below:

Field trials of aluminised wire[8]

'One 0·70 mile loop (225 lb) aluminised iron wire

Resistance of galvanised iron and aluminised iron wires in Ohms/mile

	30-12-61	30-7-62	31-12-62	10-2-63	24-8-63	1-1-64
G. I. 300 lb/mile	22	27	79	55	*650/20	*450/140
Aluminised wire 150 lb/mile	44	58	60	60	73	*105/84

*With old and new loops.

150 lb/mile (10 SWG) was erected at Visakhapatnam on 30th December 1961. Alongside, a pair of galvanised iron wire 300 lb/mile of equal length was also erected. Six twist and Brittania joints were introduced.

Additional trials with aluminised wire are likely to be taken up at four different places viz. Jabalpur, Simla, Jaipur and Trivandrum Sub-Divisions.

The results of the exposure Field test at Visakhapatnam as given in the Table p. 298, show a resistance of 650 ohms/mile on 24th August 1963 for galvanised wire against 70 ohms/mile for aluminised wire indicating, thereby, the complete failure of the galvanised wire line. The resistance of aluminised wire indicates its its highly satisfactory serviceable condition even after 2½ years of trial run.

Further tests were carried out on 1½ ft. length of the two exposed wires received from the Posts and Telegraphs Department, Visakhapatnam, at the National Metallurgical Laboratory by boiling in distilled water to estimate soluble corrosion products, stripping in 20% caustic soda solution to determine weight of coating metal and the amphoteric oxide and finally treating with concentrated hydro-chloric acid inhibited with antimony tri-chloride to evaluate the weight of the alloy layer. Results are tabulated below :

Wire quality	150 lb/mile aluminised iron wire	300 lb/mile galvanised iron wire
1. Wt. of soluble corrosion products	51 mg/ft.	130 mg/ft.
2. Wt. of Al or Zn and their soluble oxides	75 mg/ft.	78 mg/ft.
3. Wt. of intermediate alloy layer	468 mg/ft.	1 004 mg/ft.

Detailed chemical analyses of the rusted coatings are tabulated below :

Wire quality	150 lb/mile aluminised iron wire	300 lb/mile galvanised iron wire
Fe_2O_3	419 mg/ft.	561 mg/ft.
Al	2·8 mg/ft.	—
Al_2O_3	47·4 mg/ft.	—
Zn	—	11·51 mg/ft.
ZnO	—	125·5 mg/ft.

The Fig. 4 indicate the heavy formation of iron oxide rust on galvanised iron wire. More so, the zinc oxide rust on galvanised iron wire has no protective value as its adhesion is poor and is easily removed, whereas aluminium-oxide coating on aluminised iron wire possesses high protective value because of its good tenacious adhesion to the surface.

Metallographic examination of the transverse sections indicated that galvanised wire had deteriorated 3 times faster than the aluminised wire in terms of penetration of corrosion pits.

These results have further confirmed the superior properties of the aluminised wire in comparison with the galvanised wire.

Hot-dip aluminising of ACSR core wire

ASTM B341-63T lays down the following chemical composition for ACSR core wire :

Carbon	...	0·50–0·95%
Mn	...	0·50–1·30
P max	...	0·040
S max	...	0·050
Si	...	0·10–0·30

It also specifies the following mechanical properties for the aluminised wire for this application.

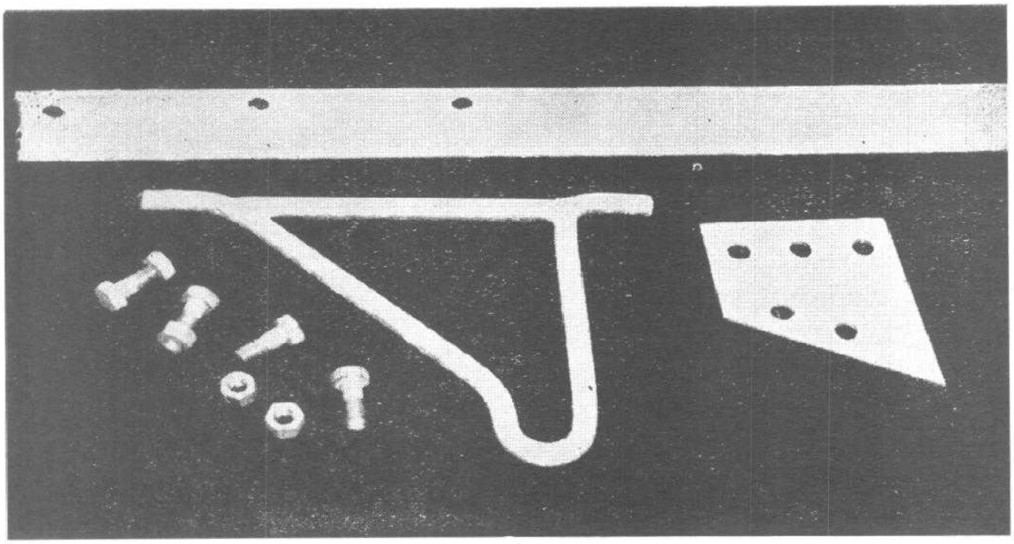
Nominal dia.	Stress at 1% extension min.	UTS min.	Elongation % on 10 in G. L. min.
0·05–0·19″	17 0000–135000 psi	185 000–165 000 psi	3·5–5·0

The minimum weight of coating is in the range of 0·23–0·38 oz/sq.ft. for these wire which should also pass the warp test.

We have at NML carried out extensive trials to aluminise steel wires to meet the above specifications. Effect of variation of diffusion parameters i.e. temperature, time of dipping and composition of both were studied and the optimum conditions to achieve desired results worked out.

High tension transmission tower members

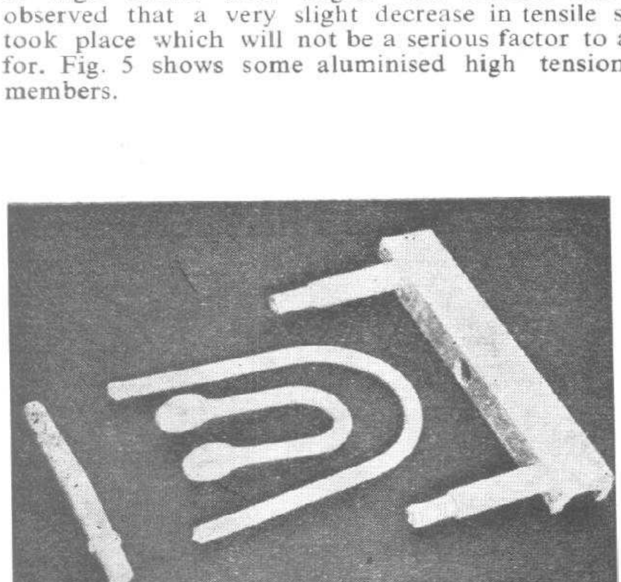
An investigation was undertaken at NML to find the feasibility of hot dip aluminising of structural members of H. T. transmission line towers, substation structures, nuts and bolts and line hardware. It was observed that aluminising could be done by our patented processes and that the products thus obtained compared favourably with similar galvanised materials. A comparative microstructural study showed that though the coating was continuous, an excess of aluminium was deposited in the threads, whereas in the case of galvanised coating,



5 *High tension transmission tower members*

wetting of threads appeared poor and some portions remained uncoated. The aluminium coating showed a passive behaviour towards neutral salts owing to a film of alumina whereas zinc does not possess this property. Salt spray corrosion test also indicated superior corrosion resistance behaviour of aluminium coating compared to that of galvanised articles.

The effect of aluminising on the mechanical property of high tensile steel angles was studied and it was observed that a very slight decrease in tensile strength took place which will not be a serious factor to account for. Fig. 5 shows some aluminised high tension tower members.



6 *Pole line hardware*

Other hardwares

Aluminised hardware samples have also been supplied to Railway Electrification Project for trial on Traction Masts. Threaded Fasteners have been coated for Messrs Guest Keen Williams.

Bucket aluminising too has good prospects and in this form our work would reach even the house-wife.

Plumbing hardware small lengths of pipe, bends, tees, joints and unions have been aluminised for one of our licensee firms.

152 pipes of 4 ft. length were also aluminised and supplied to Messrs John Miles and Partner (London), C/o Indian Copper Corporation, Ghatsila, for fabrication of a heat exchanger unit.

Aluminising of Stalks and U-Backs for Indian Posts and Telegraphs Department giving consumption of materials for 2 800 pieces on pilot plant scale was carried out. The General Manager, Post and Telegraphs, has since taken license from N. R. D. C. to undertake aluminising of pole line hardware in Post and Telegraphs Workshops at Alipore, Calcutta, and Jubbalpore (Madhya Pradesh). Fig. 6 shows some aluminised pole line hardwares.

Heat resistance applications

Aluminised components find applications as auto-mufflers, furnace hardware, combustion chamber and jet aircraft parts, diesel exhaust pipes and petroleum refinery equipments on account of oxidation and sulphurisation resistance up to 800°C.

Cost of aluminising in comparison to galvanising

Both aluminising and galvanising are very similar in the technique of coating. The steps of degreasing, pick-

The prices of aluminised and galvanised wires as calculated are compared below (ACSR core wire) 9

	PRICES			Difference in galvanising and aluminising	
Wire dia	Rs per 100 lb galvanised steel wire based on international zinc price	Rs per 100 lb galvanised steel wire based on Indian zinc price	Rs per 100 lb aluminised steel wire	International price	Indian market price
				Extra	Less
0·062″	100·00	140·00	110·00	10% Ext.	21·5%
0·083″	90·00	126·00	100·00	11·2%	20·1%
0·102″	87·00	122·00	97·00	11·6%	20·5%
0·118″	87·00	122·00	97·00	11·6%	20·5%
0·161″	87·00	122·00	97·00	11·6%	20·5%

ling, fluxing and drying are common to both. Chief difference is in the hot-dipping. In view of the higher cost of aluminium as compared to the control price of zinc and higher working temperature of aluminising as compared to galvanising, the cost difference comes to about 10 to 20%.

This is more than offset by the longer service life expected from aluminised steel as proved by field trials. If we consider the prevailing actual market price of zinc which the small industries have to pay in view of their meagre quotas, aluminising may in fact be cheaper because it needs only ⅓ the amount of aluminium as compared to zinc to coat a unit surface area for the same thickness in view of their respective densities.

It may, however, be noted that the evaluation has not taken into consideration the market price of dross, which in the case of galvanising has a good sale value in India while in the case of aluminising it has still to find its market.

Conclusions

Adoption of aluminising in the country as a substitute for galvanising in the steel wire, sheet and hardware applications will save several crores worth of foreign exchange now spent on importing zinc. Aluminium is an indigenous metal and because of our bauxite reserves we can one day hope to be self-sufficient.

Extensive work on the aluminising of wire has been carried out at our pilot plant in NML. Field trials of aluminised telephone wire at Visakhapatnam in the highly corrosive marine atmosphere have shown that aluminised wire has three times the life of galvanised wire.

Several tonnes of hardware have been aluminised and supplied to Post and Telegraphs Department, Railway Electrification Project and our licensee firms interested in bucket aluminising and aluminising of high tension transmission tower members.

A strip aluminising pilot plant is being fabricated.

Besides replacing galvanised steel in atmospheric corrosion resistance applications, aluminised steel—owing to its oxidation resistance up to 800°C—will find heat resistance applications; thus also saving expensive alloy steels now being used.

A change over from galvanising practice to aluminising in the existing plants will necessitate only minor changes in the pretreatment line but may require modification of furnaces in view of the higher melting point of aluminium. Zinc kettles for galvanising can be coke-fired whereas aluminium melting would require gas or oil-fired or electric furnaces. The galvanising kettles constructed from fire-box quality steel plate will have to be replaced by cast iron pots or top-heated refractory lined holding furnaces fed by separate melting units.

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Discussions

Mr **L. J. Balasundaram** (NML): Referring to the paper on substitution of non-indigenous non-ferrous metals and alloys I would like to know the basis of estimating the future demands of metals and products which have been projected by the authors. Do they bear any relationship to the possibility of being fulfilled ?

Mr **C. Sharma** (Author): Most of the estimates are by the prospective Planning Division of the Planning Commission of India and also by the Engineering Association on the basis of statistics compiled from various sources. All references have been quoted in our paper.

Dr **B. R. Nijhawan** (Author): I might also indicate another modus operandi that we have followed in preparing some of the estimates. We have taken the consumption and production figures of ferrous metals in overseas countries and the corresponding non-ferrous metal consumption and production figures for the last 10 years. Now, assuming that in years to come we shall industrialise to the same extent and in the same pattern as some of these advanced countries have done, our production of steel at the end of 4th Plan and 5th Plan will correspondingly amount to certain consumption and production figures for non-ferrous metals.

Dr **Dharmendra Kumar** (Hindustan Aluminium Corpn., Renukoot): The prospects of using aluminium and its alloys to substitute other scarce metals have to be fully explored and encouraged. Nature has been kind to us in providing comparatively abundant resources of bauxite, the total estimated reserves being 250 million tonnes. A substantial part of these however, are of low grade and early steps should be taken to judiciously upgrade these bauxites by suitable mineral dressing methods. We have faced problems about our iron ores with the marked increase in our steel production capacity. An effort on a national scale is called for to tackle this problem in case of bauxites to ensure a sustained and rapid growth of our aluminium production capacity.

Dr **B. R. Nijhawan** (Author): On Dr Kumar's concern over bauxite deposits, I might mention that sooner or later we will be exhausting our good grade of different ores. This is bound to happen in any country. Steel production in the U.S. today is approximately 125 million tons/year and they do not have reserves of ore comparable in any way to ours. The iron content of some of their taconite is hardly 30% and they have to beneficiate it, upgrade it, and also import the iron ore, use the scrap, have a mass scrap recovery drive and so on.

At the same time I do agree of course, that the low-grade bauxite deposits will have to be upgraded for use and may be after a couple of centuries red mud will replace bauxite for the production of aluminium. These are the problems on which metallurgists and industrialists have got to get together. There is however no need to be unduly pessimistic about it but at the same time we must by all means try to avoid wastes and while we are working with the good grades of our ores, we should concurrently take up work on the low grades to suitably beneficiate and upgrade them. We have been stressing this point at the top of our voice from every platform, in relation to Indian manganese ores for example. While the high grade of Indian Mn ore is shipped out, and used to a limited extent for the production of ferro-manganese in India, nothing or very little is being done about the low grade Mn-ore which is produced at the rate of 2 to 3 tons for every one ton of the high grade ore. Since the industry wants to make quick money they are not interested in upgrading or beneficiating the low grade Indian manganese ores not realising that the problem has got to be faced sooner or later and that there is no escape from it because mineral deposits are not agricultural crops which can grow every season and more so with the use of fertilisers etc. It takes a geological age to get an ore deposit ; whether we squander it or make an intelligent use of it is entirely our own outlook.

Now, regarding aluminising I might make a passing reference to some of the overseas developments in this field based on processes other than the hot-dip method. BISRA has almost perfected a process for dry deposition under electrophoresis of aluminium powder of very fine subdivision of about -200 mesh ; this is deposited in one case wet with methanol and in another case they are trying total dry deposition and then compaction under a powerful rolling mill. When I visited the pilot plant at the Swansea Laboratory of BISRA last year, the dry process was said to be successful at pilot plant stage up to a width of 11″. Mr Patel did apply for a license for aluminising by the Elfal process years back. This was referred to me and knowing the BISRA so well as I do I strongly supported it. Meanwhile the U.S. Steel at their Monroewille Laboratory have almost perfected a process which has recently been announced on the vacuum deposition of Al-vapour on a continuous coil passing through their new pilot plant. A continuous coil of 3′ width is their objective but I believe at present 1′ to $1\frac{1}{2}$′ width is continuously deposited with Al-vapour which condenses on both sides of the sheet and subsequently this layer is given the desired surface finish. I think this process also has great potentiality because the total weight of Al deposited on the steel surface is much less than in the case of the hot dip process, and it does not lead to the problem of wastes and recovery of the Al-metal contaminated with the iron. However, a very heavy capital may be required for the installation of such a plant and its control particularly under continuous operations on a continuous coil. In Sweden also considerable work is being done on aluminising. Yawata Steel Works in Japan are also working on this process on an industrial unit. These are developments which we have to watch and the interest that these processes arouse will have undoubtedly many potential applications to us irrespective of the process that we actually finally adopt. There is no denying that aluminium coated steel surface has much better properties and metallurgical characteristics under tropical conditions such as in India and it has also potential applications for different engineering uses apart from roofing purposes. Hot dip aluminising appears to be the optimum process under our conditions but I think at the pace at which we are going for its industrial scale utilisation, we will soon be overtaken by plastic coating of sheets. There is a limit to which a research laboratory can go to prove a process; we can upscale it to a certain optimum extent and no more. I would in this connection make a reference to a welcome arrangement we have made with a British firm M/s Efco. With the help of Mr. Atherly we hope to adopt this process in India, on the basis of technical know-how developed at the NML and the plant being supplied by his firm mostly under rupee payment. The process will relate to hardware and steel wires, and not to steel sheets at present. We are conscious of the difficulties and we do not want NML know-how dirven down the throat or any one knowing that it may not be fully acceptable and that other processes such as Armco or Sendzimir may be just as well applicable. Our objective in taking up aluminising work was to focus attention on the use of aluminium as a substitute for Zn. I earnestly hope our collaboration will soon bear fruit and that the parties concerned will come forward to invest capital and exploit the process. This triangular collaboration will be a very major step in the break-through towards substitution in general and application of indigenous technical know-how in particular.

Mr **M. V. Mohan Rao** (Hindustan Steel Ltd., Ranchi) : Regarding strip aluminising, I would like to add a few points. We are now installing two continuous galvanising lines at Rourkela and two more are planned for Durgapur. Among the several advantages of the Armco Sendzimir process, the three factors that have influenced us in the section of this process are :

(i) The coating adherence of the product is extremely good.
(ii) Fluxing of the strip surface is not necessary.
(iii) The cold-rolled coils are directly fed to the coating line from the Tandem Reduction Mill without intermediate batch annealing.

Whereas in the NML Process, fluxing of the strip surface is vital to coating adherence and it is also necessary to batch-anneal the cold-rolled coils before they are processed in the aluminising line.

We are now considering the question of converting the galvanising lines at Rourkela to aluminising lines. Two factors appear to be unfavourable in the production of aluminised sheets on continuous coating lines.

(i) The line availability when producing aluminised sheets will be 15 to 20% less than when producing galvanised sheets.
(ii) The operating and maintenance costs for aluminising are considerably higher than for galvanising.

Despite these disadvantages, it is felt desirable to go in for the production of aluminised sheets as there is no other effective substitute for galvanised sheets.

Lot of research is being done in the U.S.A. to prolong the life of the aluminium pot by using special materials. It has been reported the pot life can be effectively increased by keeping the batch saturated with 2-3% iron.

About the strip aluminising plant to be built at NML, I would like to ask Mr Arora the following questions.

(i) What material is used in the construction of the pot and what is its expected life ?
(ii) If any coating rolls are used for controlling the coating thickness ; if so, what is the expected life of the coating rig ?

Dr **B. R. Nijhawan** : On the question of production capacity the problem seems to be purely hypothetical because you are not going to convert your existing galvanising line into an aluminising line. The existing line cannot be used because the bath itself has to be changed. What matters is the speed at which one is passing the strip or sheet or coil into the bath and this has to be adjusted depending on the thickness of the coating required. If you want to treat 3 000 or 40 000 tons of steel per month in the plant, there is no difficulty in designing the plant capacity accordingly. Regarding the aluminising bath I think eventually the British process of electrode dipping in a monolithic refractory lining will eliminate the question of containers because the bath will be contained in a refractory lined vessel ; there will be no direct contact between any container and the aluminium metal and the heat will be provided by the electrodes dipping just like in the case of electrode salt bath heating.