# Possible Use of Light Alloys on Indian Railways

## K. C. Choudhuri

THE resources of the raw materials from which aluminium and magnesium are produced, are so abundant and widespread in India that one can hardly visualise conditions in which the users will at any time have difficulty in obtaining their full requirements, if these are fully exploited. This free availability in a world of shortages has, in itself, led numbers of manufacturers to abandon traditional materials like steel, copper, lead, zinc, etc. in favour of light alloys; and many who were thus first attracted will never wish to forego the advantages they have found in their use. Nevertheless our main interest should be to further the development of light alloys in their natural and proper field—the field in which these materials stand supreme by reason of their unique characteristics and availability in India.

The combination of unequalled lightness and strength has given the aluminium and magnesium alloys their outstanding position amongst constructional materials. Aluminium alloys are approximately one-third, and magnesium alloys one-quarter the weight of steel; to be precise their specific gravities are:

| | |
|---|---|
| Steel ... ... ... | 7·624–7·813 |
| Aluminium alloys ... | 2·55 –2·95 |
| Magnesium alloys ... | 1·79 –1·83 |

But the significance of these ratios, which affects fundamentally the economic basis of many a business, must be considered in relation to the specific application; increased machine speeds, lower floor loads, less vibration, reduced wear, lower power cost, less physical effort and more output can all follow the introduction of light alloys, properly applied.

Certain other general characteristics of these alloys are as follows:

- (*i*) Their non-rusting and corrosion resisting qualities;
- (*ii*) their attractive appearance and possibility of many easily applied surface finishes;
- (*iii*) the remarkably high cutting speed at which these alloys can be machined;
- (*iv*) their fine casting qualities permitting the production of extremely clean castings to dimensional limits;
- (*v*) the small amount of scrap from defects revealed during machining; and
- (*vi*) the small risk of fracture from rough handling in use or in transit.

Since the discovery of aluminium in 1805 by Davy, and its isolation in 1825 by Wohler its production has steadily increased until today world output is approximately 3,810,000 tons per annum. In India, though

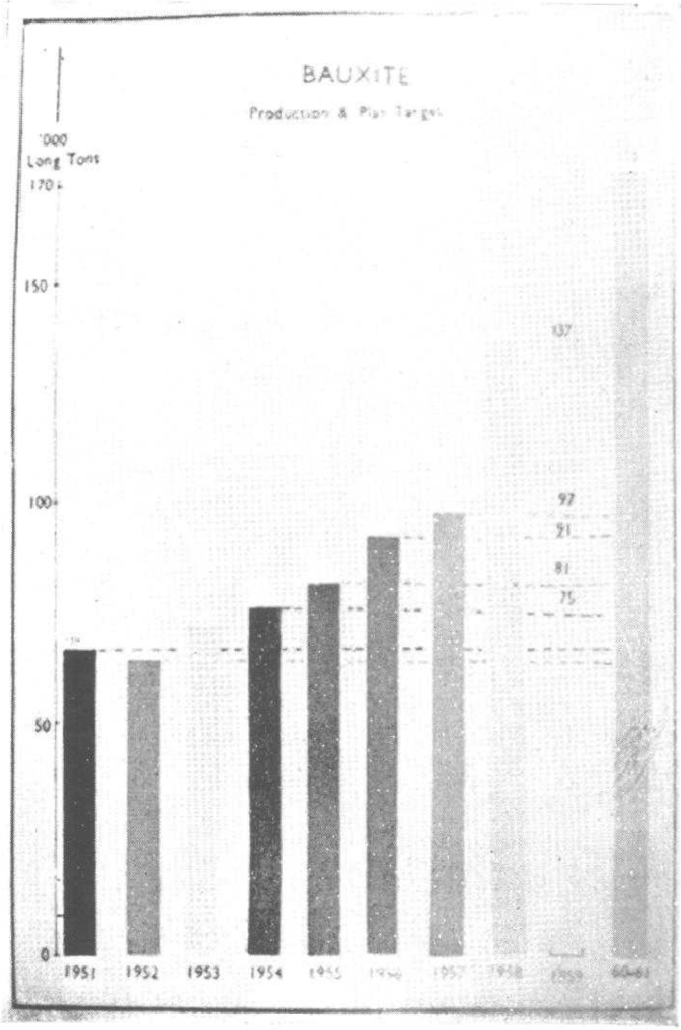

Fig. 1.
The production and Plan target of bauxite.

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insignificant, the industry expanded from a capacity of 4,000 tons per annum on the eve of the First Five Year Plan to 18,100 tons at present. Still this is hardly sufficient to meet even the 40% of our requirement. It is envisaged that the annual capacity will reach 82,500 tons and that an annual production of 75,000 tons will be achieved by the end of the Third Plan.

There is therefore no doubt that aluminium has an excellent future in India, considering that India's present per capita consumption is only 0·18 lb compared with 20·7 in U.S.A., 16·0 in U.K., 11·5 in Canada, 9·5 in France, 7·6 in Austria, 3·7 in Italy, and 2·5 in Japan.

## Resources of aluminium and magnesium

Aluminium is a product of endowment and energy of nature, the two essential requisites being bauxite and electrical energy. Bauxite is an ore formed by the normal decomposition of rock by weathering. Favourable geographical and climatic conditions have endowed India with extensive deposits of bauxite, capable of sustaining a sizeable aluminium industry for several generations to come. India's reserves are estimated to be of the order of 250 million tons out of which 50 million tons have been proved to be of high grade. The production and Plan target of bauxite is shown in Fig. 1. As regards electrical energy, which governs the cost of aluminium produced, with the installation of new power projects, it is expected to supply electrical energy to the existing as well as projected plants at a reasonable rate which would make the production of aluminium economical.

Workable deposits of bauxite are located in the Ranchi district of Bihar; Katni, Jubbulpore and Bhopal of Madhya Pradesh; Belgaum in Mysore State; Kolhapur and Ratnagiri in Bombay State; Salem and Vizag of Madras and in Kashmir as shown in Fig. 2.

Next to aluminium in importance in the light metal class is magnesium. It is the third most abundant of the engineering metals, surpassed in volume by aluminium and iron. Major recovery of magnesium has been from sea water, brines and salt deposits. The chief commercial minerals of magnesium are magnesite, dolomite and brucite. India possesses considerable deposits of magnesite and dolomite and no workable deposits of brucite.

There are mainly two basic processes for production of magnesium—viz. (*i*) electrolytic reaction and (*ii*) chemical reduction. Cheap and abundant electric power is essential for the extraction of magnesium. Workable deposits of dolomite are widely distributed throughout India and innumerable deposits occur in Madras, Andhra, Bihar, Madhya Pradesh, Rajasthan and Orissa.

Magnesite deposits have been located in the Salem district of Madras, in Southern Mysore and in the Almora district of Uttar Pradesh. The former two are now under active exploitation.

## Aluminium and magnesium industry in India

The present annual smelting capacity for aluminium is 18,000 tons from three smelters—viz. the Aluminium Corporation of India at Jaykaynagar, Asansol, Indian Aluminium Co. at Alwaye and Hirakud. In the Third Plan, additional capacity has been proposed to be installed. The overall picture of annual primary aluminium capacity at present and by the end of the Third Plan has been given in Table I.

TABLE I

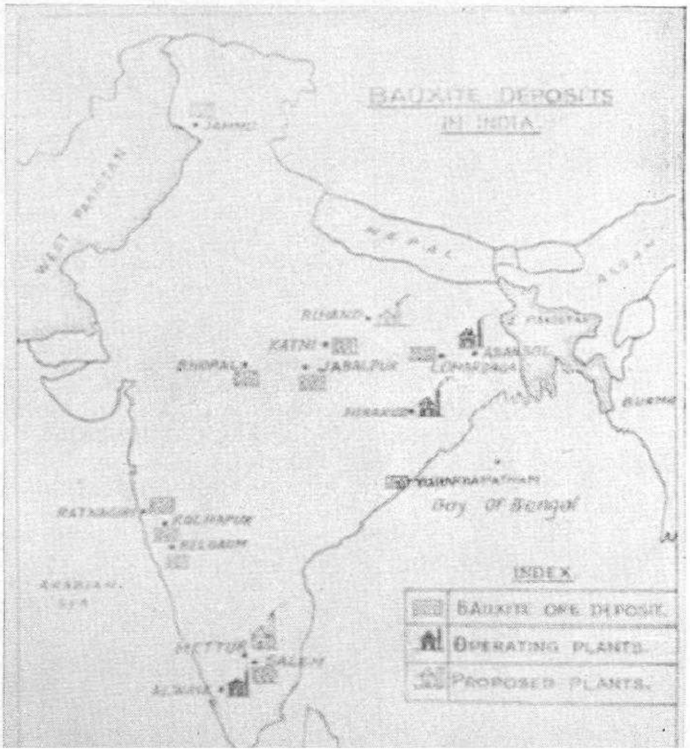
*Annual primary aluminium capacity.*

| | Present (long tons) | Third Plan additional capacity proposed to be installed (long tons) | Total by end of Third Plan (long tons) |
|---|---|---|---|
| Aluminium Corporation of India, Asansol ... | 2,500 | 5,000 | 7,500 |
| Indian Aluminium Co., Alwaye ... | 5,600 | — | 5,600 |
| Indian Aluminium Co., Hirakud ... | 10,000 | 10,000 | 20,000 |
| Hindustan Aluminium Corp., Rihand ... | — | 20,000 | 20,000 |
| Bombay State, Koyna | — | 20,000 | 20,000 |
| Madras State, Salem ... | — | 10,000 | 10,000 |
| | 18,100 | 65,000 | 83,100* |

* The draft Third Plan puts this total at 82,500 tons only.

Fig. 2.

Map of India showing bauxite deposit.



The annual fabricated aluminium capacity, as at present as well as by the end of the Third Plan, has been detailed in Table II. Out of the annual capacity of 15,900 tons at present, 12,700 tons are in the form of sheet, strip, coils, wire and other rolled products, 1,200 tons extrusions and 2,000 tons foils and linings.

TABLE II

*Annual fabricated aluminium capacity.*

| | Present (long tons) | Third Plan additional capacity proposed to be installed (long tons) | Total by end of Third Plan (long tons) |
|---|---|---|---|
| Aluminium Corporation, Asansol ... | 2,500 | 2,860 | 5,360 |
| Indian Aluminium Co., Belur, Calcutta ... | 9,000 | 7,500 | 16,500 |
| Indian Aluminium Co., Alwaye, Kerala ... | 1,200 | 2,500 | 3,700 |
| Venesta Ltd., Kamarhati (West Bengal) ... | 3,200 | — | 3,200 |
| | 15,900 | 12,860 | 28,760 |
| Hindustan Aluminium Corp., Rihand (U.P.) ... | — | 15,000 (Metric tons) | 15,000 (Metric tons) |

When primary capacity expands to about twice the current demand for aluminium (in all forms) and the fabricating capacity also keeps pace with the primary expansion, will the demand for aluminium have also doubled from its present volume ?—this is a logical question. The present demand for aluminium is around 44,000 tons as shown in Table III.

TABLE III

*Demand for aluminium.*

(in long tons)

| Industry | Tonnage |
|---|---|
| Building and construction | 2,000 |
| Household and commercial supplies | 10,500 |
| Transportation ... ... | 6,000 |
| Electrical industry ... ... | 18,600 |
| Food and farming ... ... | 900 |
| Canning and packaging ... | 3,500 |
| Miscellaneous ... ... | 2,500 |
| | 44,000 |

Depending on the power development targets ultimately finalised, analysts in the industry place the demand for aluminium by the end of the Third Plan at 64,000 or 81,500 tons. According to Government, the demand would touch the figure 100,000 tons. These estimates are shown in Table IV.

TABLE IV

*Estimates of aluminium demand at the end of the Third Plan i.e. 1965-66.*

(in long tons)

| Industry | Tonnage (1) | (2) | (3) |
|---|---|---|---|
| Building and construction | 3,000 | 3,000 | 6,000 |
| Transportation | 12,500 | 12,500 | 15,000 |
| Household and commercial supplies ... ... | 13,000 | 13,000 | 25,000 |
| Electrical industry ... | 22,500 | 40,000 | 40,000 |
| Food and farming ... | 1,500 | 1,500 | 2,500 |
| Canning and packaging ... | 7,500 | 7,500 | 7,500 |
| Miscellaneous ... | 4,000 | 4,000 | 4,000 |
| | 64,000 | 81,500 | 100,000 |

There is no reason to doubt that the lowest of these estimates at least will be achieved. In fact it is quite likely that the actual demand might exceed that figure because of the systematic development work which the main producer has been doing for the last seven years. The introduction of aluminium to industry has been a significant contribution to India's economic development because it has paved the way for scientific substitution of aluminium for other non-ferrous metals and for steel and other traditional materials in a growing variety of industrial applications.

As regards magnesium, there is no industry producing magnesium at present in India. There are proposals to start two units, one in the South which will take electrical power from Krishna Project and the other in the North which will utilise the Almora magnesite deposits and electrical power from the Rihand Project. The demand of magnesium in India will increase considerably with the increased demand of aluminium.

## Aluminium and magnesium—their alloys and properties

### (*a*) *Aluminium and its alloys*

Pure aluminium is available today in four groups, varying from 99·99 per cent minimum purity to so-called commercial purity of 99·0 per cent, the principal impurities being iron and silicon. It is not used in the cast condition, and in its wrought forms its mechanical strength is low, but it possesses high ductility and resistance to corrosion. The aluminium alloys, on the other hand, cover a range of tensile strength up to almost 63 kg/sq mm (40 tons per sq in) and also include materials with specific properties such as high resistance to marine corrosion or good strength at elevated temperatures.

Aluminium alloys are divided into two main groups—casting alloys and the wrought alloys.

### *Casting alloys*

The most commonly used casting alloys contain copper, silicon and magnesium as their important alloying elements.

(*i*) *Aluminium-copper alloys:* Several aluminium-copper alloys found general favour in the past and today there are several types containing, in addition to copper, quantities of silicon, zinc and other elements. One of the best known types contains 6-8 per cent copper and 2 to 4 per cent silicon, with 2 to 4 per cent zinc, whilst a rather better alloy contains 2 to 4 per cent copper and 3 to 6 per cent silicon. Their tensile strength ranges from 12·6 to 15·7 kg/sq mm (8 to 10 tons/sq in) with an elongation of 1 to 3% on 2 in. Many automobile parts, as for example, crank cases, oil pans, transmission housings, step plates, handles, brackets, etc. are manufactured from these alloys.

(*ii*) *Aluminium-silicon alloys:* The aluminium-silicon series of alloys contain silicon 5 to 13 per cent. The alloy containing 10 to 13 per cent silicon, having good fluidity is the easiest of the aluminium alloys to cast in complicated form and it has good resistance to corrosion. A variation of this alloy contains, in addition to the silicon, a small quantity of sodium, which renders it amenable to heat-treatment, resulting in an useful increase in mechanical properties, for example, ultimate tensile strength increasing from 18·9 to 29·9 kg/sq mm (12 to 19 tons/sq in).

(*iii*) *Aluminium-magnesium alloys:* The binary alloys with 4–10% magnesium have important uses. The alloy with about 10% magnesium requires heat-treatment to bring its optimum property. The alloys with 3–6% magnesium have a minimum tensile strength of 14·2 kg/sq mm (9 tons/sq in) with 3% elongation on 2 in as sand cast and 17·3 kg/sq mm (11·0 tons/sq in) with 5% elongation on 2 in as chill cast. These alloys are suitable for use, where corrosion is of paramount importance, and where high strength with good ductility and resistance to shock is required. They are less easy to handle in the foundry, however, than the other casting alloys and rather special technique is required.

(*iv*) *Piston alloys:* The first, and perhaps the best known, alloy to be developed specifically to withstand stresses at raised temperature is "Y" alloy (Al 92·5%, copper 4·0%, nickel 2·0%, magnesium 1·5%). Particular attention should be drawn to the aluminium-silicon alloy containing addition of about 1 per cent copper and 1 per cent magnesium, with at least 1 per cent nickel, as this alloy has a lower coefficient of expansion than other alloys ($19 \times 10^{-6}$ against an average value of $22\text{–}24 \times 10^{-6}$ at the expense of thermal conductivity however).

(*v*) *Bearing alloys:* A great deal of interest is apparent in the bearing properties of aluminium alloys and tests have shown that for certain applications suitably designed bearings of standard aluminium alloys may safely be used whilst for high duty bearings special alloys have been developed. The high heat conductivity of aluminium bearings (three times that of bronze or four times that of white metal) is a particular advantage.

For example, three types of bearing alloys have been developed in Switzerland. The first alloy contains small quantities of magnesium and zinc, and is relatively low in price. It resists corrosion very well and retains an oil film satisfactorily. The second alloy is based on the eutectic aluminium-silicon alloy with additions of copper, nickel, magnesium and manganese. Its thermal expansion is similar to that of bronze and it can run with minimum lubrication. In the third alloy there are additions of copper, nickel and magnesium, with about 8 per cent tin. This alloy is readily machined and has little tendency to seize even with a minimum lubrication.

### *Wrought alloys*

(*i*) *Pure aluminium and low alloys:* Aluminium sheet of high purity (99·6%–99·8%) is used chiefly for chemical plant, food processing equipment, and electrical conductors. Metal of commercial purity (99·0%) finds chief use in utensils and to some extent in motor vehicle body panelling, extruded mouldings, etc. It has a strength of 7·8–14·2 kg/sq mm (5–9 tons per sq in) depending upon the cold work carried on it.

Aluminium-manganese alloy, containing 1¼% manganese, has a higher tensile strength of 9·5–17·3 kg/sq mm (6–11 tons per sq in) and can be readily formed, welded and anodised. It is used extensively for vehicle panelling.

(*ii*) *Aluminium-magnesium alloys:* Four wrought alloys, having 2%, 3·5%, 5% and 7% magnesium with small additions of manganese (less than 1%) and possibly chromium up to 0·5% but free from copper and other heavy metals, are generally accepted ones. They resist corrosion extremely well and are particularly suitable for conditions involving exposure to sea water or marine atmosphere. The tensile strength ranges between 14·2 kg/sq mm and 36·2 kg/sq mm (9 and 23 tons/sq in) depending upon the magnesium content, These alloys are available in the form of sheet, strip and tubes in a variety of tempers, depending upon the amount of cold work. These work harden fairly rapidly. The alloys with lower magnesium are particularly amenable to cold forming. All these alloys anodise well.

(*iii*) *Magnesium silicide alloys:* The alloys with suitable proportions of magnesium and silicon and free of copper can be strengthened by heat treatment. They have a high resistance to corrosion and their strength ranges up to 31·4 kg/sq mm (20 tons/sq in). They can be welded and worked with ease. They can be anodised.

(*iv*) *Duralumin-type alloy*: It is a well-known heat treatable alloy and has been developed prior to the First World War. It contains 4% copper, 0·5% magnesium, with small amounts of manganese, silicon and iron. The naturally aged alloy has a tensile strength of 39·3 to 44 kg/sq mm (25 to 28 tons/sq in) whereas the fully heat treated one has a tensile strength of 50·3 kg/sq mm (32 tons/sq in) with a 0·2% proof stress of 44 kg/sq mm (28 tons/sq in) and an elongation of 17—19% on 2 in.

The copper containing wrought alloys have a lower resistance to corrosion than the other aluminium alloys, and welding reduces their high strength. They are often used as forgings and, of course, structural sections, either extruded or formed from strip.

(*v*) *Aluminium-zinc-magnesium-copper alloys* : These alloys contain essentially of 6% zinc, with up to 3% copper and 4% magnesium and other small additions. It is normally supplied in the heat-treated condition and has a tensile strength of about 62·9 kg/sq mm (40 tons/sq in). It is a special purpose alloy.

### (*b*) *Magnesium and its alloys*

Magnesium is relatively soft and malleable to some extent in the cold state but when heated to temperatures between 350 and 450°C, it becomes extremely malleable and ductile. It can be cast into moulds and afterwards worked into various forms. It has a low elastic or proportional limit. It is the lightest metal employed for construction work. It does not oxidise in dry air.

Magnesium, only when alloyed with aluminium, zinc, cadmium, manganese and other metals, acquires sufficient mechanical strength and corrosion resistance to be used as constructional material. As it is only about two thirds the weight of aluminium, it combines, when alloyed, high strength together with extreme lightness. Though certain alloys are obtained and used in the wrought condition, great numbers are used and supplied in the form of castings.

### *Casting alloys*

The alloys containing 90% magnesium have the following advantages :

(1) a weight reduction of 40% when compared with aluminium alloy,
(2) useful resistance to failure by fatigue,
(3) absence of embrittlement when in use, and
(4) freedom from "pin holing".

These alloys enable the designer to eliminate cored holes and pockets resulting in simple design of castings, lesser cost and less casting defects. These alloy castings, because of their lightness, are easy to set up in machine tools and to transport. They can be easily machined at higher speeds, with the result that their machining operations require minimum time. These alloys can be both gravity and pressure die cast.

### *Wrought alloys*

Magnesium alloys are available in the form of extruded rods, bars, angles, sections and tubes as well as in the form of sheets, forgings and pressings. Welding of magnesium alloys requires high skill.

In general, wrought magnesium alloys closely correspond to the aluminium alloys in their mechanical properties. Their yield and proof stress values are slightly lower.

The most economically important and best known magnesium-aluminium alloy is termed as "Elektron metal" named after the manufacturer Messrs Magnesium Elektron Ltd. This incorporates in its composition small percentages of zinc, as well as minor quantities of manganese, silicon and cadmium.

In general cast alloys having a magnesium base contain less aluminium than the wrought alloys. Zinc is introduced into those alloys from which it is desired to manufacture forgings. D.T.D. 59A, which is a casting alloy, contains 3·5–8·5% aluminium, 2·5–3·5% zinc, 0·50% (max) manganese, the balance being magnesium. It has a tensile strength of about 19 kg/sq mm (12 tons/sq in) with an elongation more than 2% on 2 inches. This alloy is designed for cast parts of automobiles e.g. crank cases. D.T.D. 88B, which is a wrought alloy, contains 11% aluminium, 1·5% (max.) zinc, 10% (max.) manganese. It has a tensile strength not less than 23·6 kg/sq mm (15 tons per sq in) with an elongation over 5% on 2 inches. Forgings and pressings of various types may be manufactured from this alloy.

## Economic and technical considerations which favour the application of light alloys in the construction of coaches and wagons

(*a*) *Economic considerations :* Timber was used for decades in the rail coach construction. The need to reduce the dead weight and increase strength led to the construction of steel coaches. The current increasing desire to provide the passenger with more amenities and comfort, which means additional equipment or dead load, has resulted in new designs which make use of light metals.

Even though aluminium is higher in its initial cost, the economies, that result by its use, make its utilisation an attractive commercial proposition. A weight saving of up to 50% is possible by replacing steel by aluminium. Aluminium carriages are much lighter than those of timber or steel and so more can be hauled by the same locomotive, thereby increasing the pay load and revenue. In places where use of longer trains is limited, speed can be increased without additional strain on the locomotive or rail tracks and faster schedules can be maintained.

The following statistics of the rail transport in India will give an idea about the importance of weight saving by the use of aluminium alloys. The Railways have to haul 15 tons for every ton of III class passenger traffic (16 passengers) and 40 tons for each ton of 1st class passenger. At present for each ton of 3rd class traffic Indian Railways are spending about Rs. 2,700 for fuel. If 5,080 kg (5 tons) were reduced from the tare weight of each coach by replacement of steel with aluminium, this weight reduction would result in a fuel economy of about Rs. 1½ crores per year or alternatively an extra lakh tons of additional passenger trains could be hauled without any extra cost. In the case of electrically driven trains the cost of power is more closely related to the weight being pulled. Experience has proved that with all aluminium trains an economy of 15% in maintenance costs and 16% in fuel (electricity) is achieved.

By the use of aluminium, considerable economy in maintenance can be achieved as the metal has high resistance to corrosion. Aluminium metal is expected to last the full coach life with normal inspection and care and still retains high scrap value, which is about 50% of the initial cost. On the other hand, steel coaches have to undergo repairs many times during the carriage life. The aluminium panels require repainting at much less frequent intervals, as the paintwork remains longer in good conditions provided suitable etch primer is used. One main advantage of this metal is that it can be left unpainted.

Especially in these days, when the country is growing industrially day by day, it has resulted in increased wagon traffic to transport the raw materials to the industries, which has brought about a situation in which haulage capacity is absorbed as fast as it is increased. In these circumstances increased pay load alone will result in increased profit. In addition, elimination of repairs results in less idle hours spent in railway workshops with consequent increased utilisation of rolling stock.

(*b*) *Technical considerations*: When aluminium is used for coach work, the centre of gravity of the vehicle is lowered; this has a direct effect on the stability of the vehicle and improves the riding properties by minimising the sway. This is of importance particularly on the metre and narrow gauge railways where safety and maximum speed are to a great extent controlled by this factor. It also reduces the self stresses set up in the construction and favourably influences collision behaviour.

Properly designed aluminium structure can have the same strength and stiffness as steel structure and still be much lighter. Aluminium's lower elastic modulus and correspondingly higher resilience give a cushioning effect in case of accidents. Unlike timber, it is non-splintering.

## Some application on railways in foreign countries

Considerable quantities of aluminium and its alloys are now being used in railways in U.S.A., U.K., Canada, Australia and the Continental countries. These are briefly mentioned below:

*Great Britain*: As early as 1905, the Lancashire and Yorkshire Railway Company panelled their electrified motor coach units with aluminium with success. Motor coaches panelled in 1915–16 have been in service for 40 years and so far as is known no change has been made during that time. Gradual development since then has culminated in the biggest application of the metal—the new aluminium stock for the London Transport Executives. Ninety coaches are in service, while eighty more are under construction and an order for 500 additional ones is being placed.

British Railways have now constructed over one hundred two-car aluminium units.

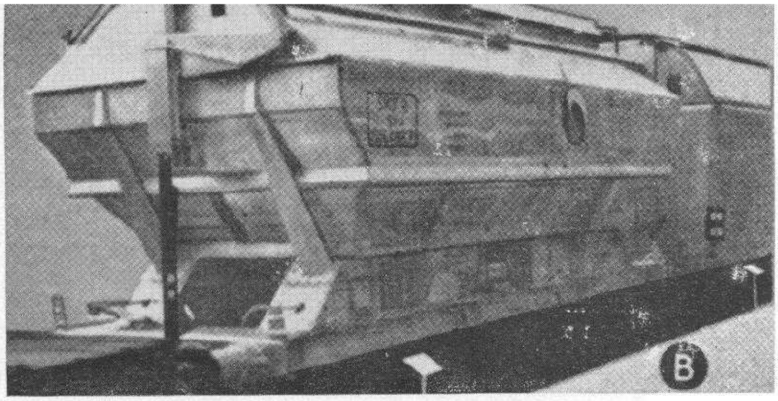


Fig. 3.
Sulphur wagon with Al-Mg 5 body and underframe (France).

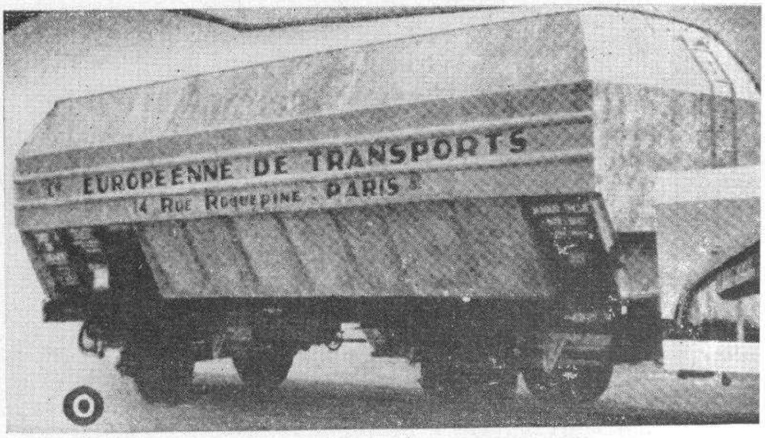


Fig. 4.
Cement wagon with an Al-Mg 5 body on a steel underframe (France).

As a result of successful trails over the last 10 years, about 100 mineral wagons plated with aluminium have recently been put into service and orders for more are expected to be placed in the near future.

*United States of America*: Development in the use of light metal in this country has been faster since 1930. The famous aluminium trains "New Haven Comet" and the "Missouri Pacific Eagles", have been produced. This country has also made the famous superspeed "Talgo" now in use in Spain.

A considerable number of tank wagons and mineral hopper wagons have also been constructed in aluminium.

*France*: Sixty double decker coaches have been produced in aluminium between 1933 and 1936 and were put in service by SNCF. No deformation or failure has been reported during their continuous service under most severe conditions. A welded aluminium three-coach unit put in service in 1935 has been running satisfactorily. The outstanding achievement in this country is the construction of electric suburban aluminium carriages on integral design principle. Many closed hopper wagons built entirely in aluminium were put into service in 1951 (see Figs. 3 and 4).

*Switzerland* : On the Steep Brunigg Branch of the Swiss Federal Railways, 32 all aluminium passenger coaches are in service. Aluminium alloy sheets have been used as roof coverings in about 7,000 goods wagons.

*Italy* : The "crack" Milan Naples electric train carries 160 passengers at a speed of 100 m. p. h. It utilises aluminium in its construction. The Italian Railways have ordered for aluminium hopper wagons for transport of coal, which are 44% lighter than the present steel ones.

*Australia* : The "Silvery City Comet", a five-car diesel train in use since 1937, has been built in aluminium.

*Canada* : The Toronto Transit Commission has put an aluminium train consisting of six cars in service in the new subway. Hopper cars have been used on the CNR and CPR Railways.

## Application on Indian Railways

Though aluminium has established itself as a proven material for rolling stock construction during the last 50 years in the U.S.A., U.K., and other European countries, its very limited adoption in this country is only of recent origin. There is a great scope of its wider application on Indian Railways without any major changes in design or fabrication practice.

### *Coaches*

The modern tendency in railway coach construction is to reduce dead weight without sacrificing comfort and safety and the necessity for economical coach building has led to the adoption of integral stressed skin construction. So far the metal used for this purpose is steel. The necessity to further reduce dead weight and maintain faster schedules is making Railway Engineers turn to aluminium. The substitution of aluminium for steel or timber in standard coaches also results in substantial savings.

An aluminium body structure will reduce the weight of a carriage by nearly 4,064 or 5,080 kg (4 or 5 tons) at a slightly increased initial extra expenditure. Besides maintaining faster schedules with such light trains there will be considerable economies due to the advantage viz., freedom from corrosion leading to reduced maintenance and repair, longer life, less wear and tear of the moving gear, brake equipment and the rail track.

### *Panelling*

Direct substitution of aluminium panels in the same thickness as used for steel will reduce the weight of a coach by 1,016 to 1,524 kg (1 to 1½ tons).

Narrow gauge coaches panelled in aluminium at the North Western Railway Workshops, Lahore in 1928 have been in continuous service on the Simla-Kalka line for 32 years and a recent examination revealed no deterioration (see Fig. 5).

200 coaches panelled with aluminium sheet to NS 3 and NS 4 grade to IS : 737 by H.A.L. are on service on Indian Railways, since 1954 without showing any corrosion so far. Railways are now using more and more aluminium sheets for panelling new coaches as well as steel coaches, which come for repair (see Fig. 6).

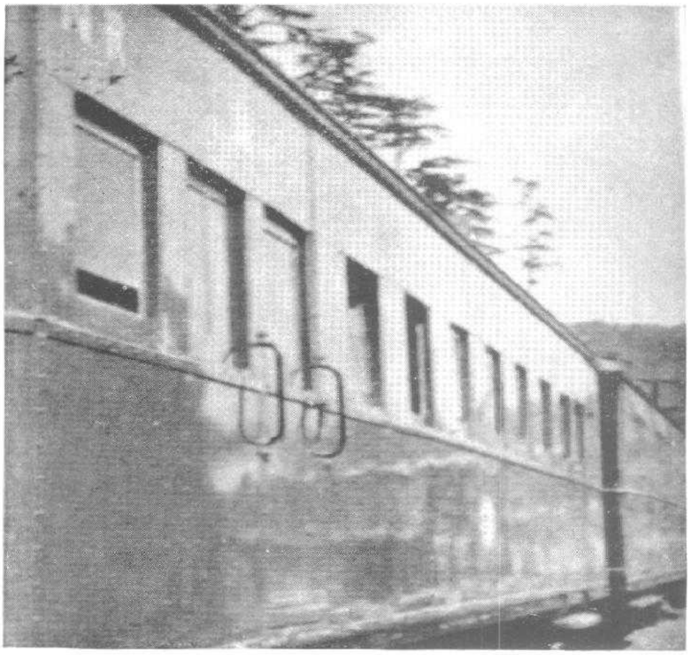


Fig. 5.
Narrow gauge aluminium panelled coach running on Simla-Kalka line since 1928.

### *Windows*

Normally windows are made of timber which easily absorbs moisture and tends to warp. Steel windows have also been tried but they are difficult to handle because of their heavy weight. Aluminium windows reduce the weight of a coach by 272·2 kg (600 lb). They require little maintenance, are easier to operate, last longer and retain their attractive appearance throughout their life. Aluminium windows are already standard items in the coaches built by I.C.F., H.A.L. and Jessops and will soon be for all coaches built in Railway Workshops.

### *Roofing*

Aluminium alloy sheets find use in the roof structure to replace steel sheets or timber decking. They reduce the weight of a coach by about 453·6 kg (1,000 lb). A steel roof requires frequent repair or replacement whereas timber decking has to be covered with Ruberiod which hardly lasts 4 or 5 years. Aluminium roof sheets have been extensively used by North Eastern Railway for MG coaches.

Aluminium alloy extruded flanged channel sections bent to the contour of the roof sticks can replace the heavy steel carlines used at present. This replacement may result in weight reduction by 690·4 kg (1,500 lb) per coach at an extra cost of about Rs. 250.

### *Flooring*

There is scope to replace the existing method of covering the timber decking with oxy-chloride flooring compound by a specially developed aluminium floor. Some carriages with aluminium flooring have been imported in India and used in suburban electrified systems. It is reported that they are giving good service.

### *Interior fittings*

Many interior fittings of a railway coach can be made in aluminium. The metal has proved effective for bath room walls, floors and toilet fittings. Aluminium alloys can be used for seat frames, luggage racks, ceilings and partitions, Aluminium seat frames used in Metro-cammel coaches are already well known in India. For seat frames, luggage racks and upper berths aluminium alloys are used in I.C.F. coaches. Also trims and mouldings of aluminium alloys are used in I.C.F., H.A.L. and Jessops coaches. Cast aluminium sliding doors are in service in EMU stock running on Madras suburban service as well as in that, built by Jessops running in Bombay and Calcutta (see Fig. 7).

### *Buffers*

Aluminium buffers are probably the most promising item for extensive use in underframe equipment, This will result in a weight saving of about 272·2 kg (600 lb) per coach (see Fig. 8).

### *Water tanks*

Roof water tanks, fitted in coaches are normally made from zinc sheet or galvanised (zinc coated) steel. Zinc sheets have to be imported and are more expensive than aluminium whilst the galvanised tanks which are only about 25% cheaper do not last more than 6 to 8 years. Aluminium tanks are now being used in coaches built by HAL and ICF and in Railway Workshops. Use of aluminium tanks will reduc deadweight of a coach by about 272·2 (600 lb).

### *Wagons*

*Goods wagons*: 100 wagons (50 covered and 50 open) were plated with aluminium in 1949-50 and were put in service to examine the suitability of the metal for this purpose. So far they have suffered pratically no corrosion.

In 1953 Calcutta Port Commissioners plated the bottom panels including flooring of six open type wagons with aluminium. These wagons were meant for transport of wet coal ash which has a very high corrosive effect on steel and limits its maximum life to 1½ to 2 years. Recent examination of these wagons

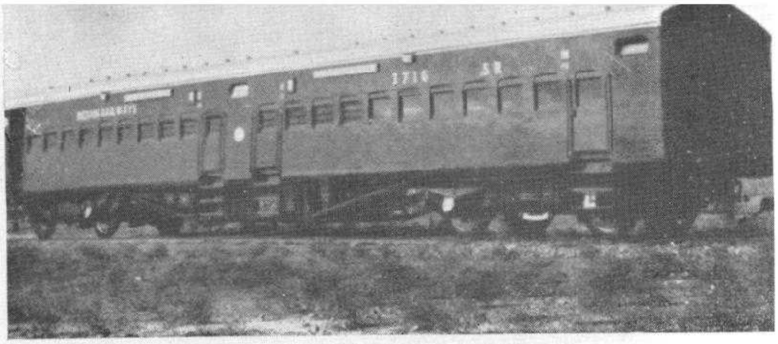


Fig. 6.
Aluminium panelled coach built by Hindustan Aircraft Ltd., Bangalore.

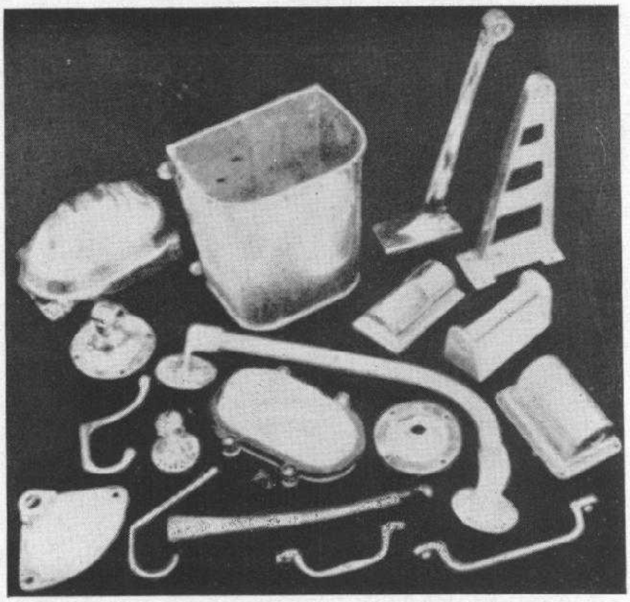


Fig. 7.
Some examples of interior fittings in aluminium.

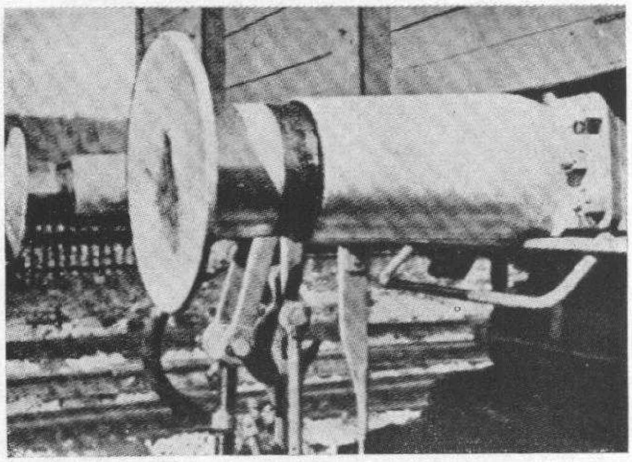


Fig 8.
Aluminium buffers have been in use in Switzerland.

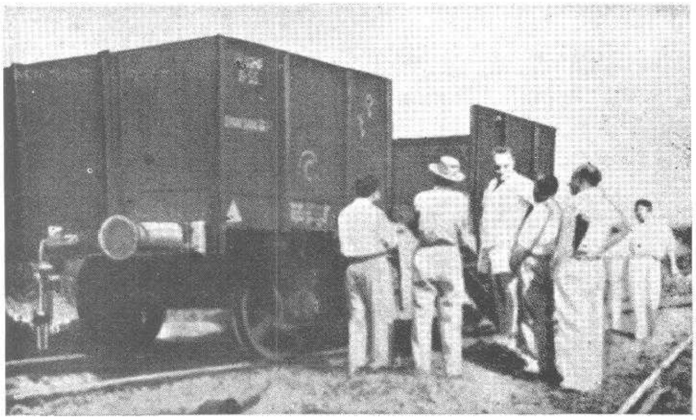


Fig. 9.
Wagon used for conveying wet ash, built by Calcutta Port Commissioners.

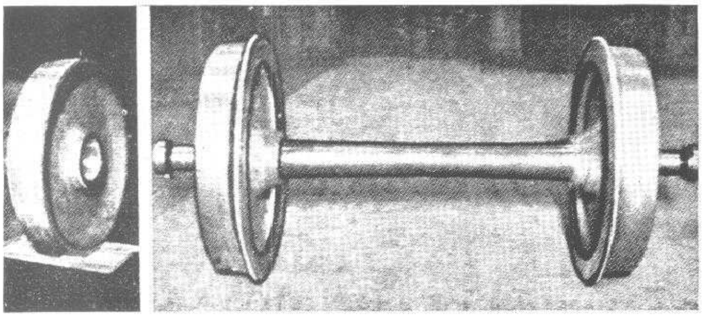


Fig. 10.
The light-alloy wheel disc.

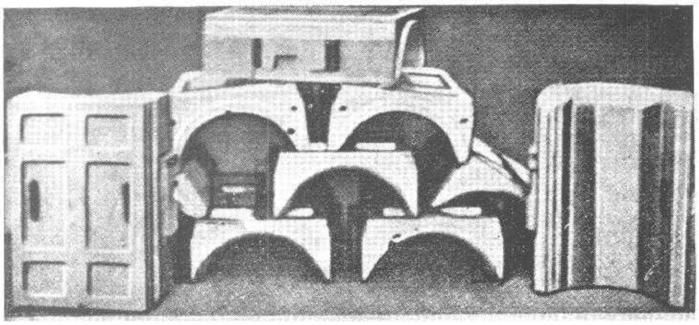


Fig. 11.
Light-metal axle box and bearings.

showed no signs of deterioration to the aluminium plates (see Fig. 9).

Complete plating of a wagon with aluminium costs initially about Rs. 1,000 to 1,200 more and reduces its tare weight by 1,016 kg (1 ton) thereby increasing the pay load capacity by the same margin, an important advantage in carrying mineral traffic to meet the need of the industry.

Substitution of steel panel by aluminium will not only obviate the necessity of frequent replacement which is unavoidable in case of steel due to its rapid corrosion, but will also permit an additional pay load with little extra cost.

*Cattle wagons* : Cattle trucks have to endure very arduous conditions in service not only due to the harsh treatment received from the hoofs and horns of animals but also, on account of severe corrosion caused by animal excreta and the need for frequent washing. Wood is often used although its absorbent nature reduces its durability and makes it rather difficult to clean. Aluminium is able to resist the corrosion effect of the animal excreta and, being non-absorbent, is hygienic, can be easily cleaned and durable.

According to the Railway Board's 1960–61 wagon programme 50 CMR aluminium body cattle wagons are to be manufactured. Refrigerated fish vans (6 nos.) have been built by Central Railway using a considerable quantity of aluminium. It is now under study by the Railway Board to manufacture all aluminium tank wagons and mineral hopper wagons.

In addition to the above, there are possibilities of using aluminium for cabs, reflectors of head lights, axle box and bearings, wheel disc, main frame, bogie frame etc. (see Figs. 10 and 11).

## Magnesium and its alloys

Because of lightness of magnesium alloys even over aluminium ones, there is a great scope to use these alloys in railways in future. Therefore the development of magnesium industry from the Indian raw materials should be encouraged.

## Conclusion

Amongst the diversified uses of aluminium greater attention is needed for its application on railways, for construction of coaches and wagons, considering the advantages of reducing dead weight with corresponding increase in pay-load and in reduction of maintenance cost due to its corrosion resistance properties, even though there is slight increase in initial cost.

When the Ministry of Railways is planning for increasing the present 1,500 tons goods trains to 5,000 tons in the Third Plan and thereafter to 7,000 tons, there is a greater scope for application of aluminium alloys in wagon construction from the point of view of increasing pay load. Therefore serious consideration should be given for construction of all aluminium wagons whereby tare weight of wagons, say, for 4 wheeler open and covered wagons, can be reduced by about 4,064 to 4,572 kg (4 tons and 4½ tons) respectively. This means a train of 67/68 wagon load can be increased to about 79/80 wagon load without any extra strain on locomotive and fuel cost. This will alone justify high initial cost.

Another possible large scale application of suitable aluminium alloys is for bearings and bushes to replace expensive tin bronze for which major portion of the raw materials is now being imported involving large expenditure in foreign exchange.

An exhibition on light alloys Railway rolling stock held in January 1960 in Strasbourg under the auspices of the Transport Committee of the Central International de Development de 18 Aluminium (C.I.D.A.) has clearly demonstrated the trend for applications of light alloys in the Railway industry in advanced countries.

Amongst the wide variety of components may be mentioned axle boxes, bogie parts, brake equipment parts, pantograph, windows, doors, etc. The extensive application of aluminium alloys on Indian Railways in near future will of course depend upon the price factor and faster increase of production in the country. Price has been and is one of the most important factors in determining the continued growth of the aluminium and competition with other metals and materials in the Western countries. Unfortunately in India aluminium costs 30 to 40 per cent more than in the developed countries. This can be brought down by achieving the advantages of large scale operation and cheap power production.

Although present aluminium production (18,100 tons) in India has more than doubled as compared to the previous years the present production falls far short of the consumption, which is in the region of about 45,000 tons and so a large quantity has to be imported from Canada, U.K., U.S.A., Germany, etc.

An estimate of projected consumption of aluminium by the various industries is given in Table V.

TABLE V

| Industry | 1960-61 | 1965-66 |
|---|---|---|
| Electrical conductors and applications | 19,000 | 30,000 |
| Cooking utensils | 11,000 | 20,000 |
| Transport (marine, land, air) | 6,000 | 13,000 |
| Packing and canning | 4,000 | 8,000 |
| Building and construction | 2,000 | 3,000 |
| Miscellaneous | 2,500 | 4,000 |
|  | 44,500 | 78,000 |

Despite the low production of aluminium in the country, aluminium alloys in rolled as well as extruded forms are available to the railways for their varied requirements, and the projected expansion of the industry in the primary as well as semi-fabricated sectors ensures adequate, if not plentiful, supplies for all railway applications.

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## DISCUSSIONS

*Mr. K. S. Ganapathi, Aluminium Mfg. Co. (P) Ltd., Calcutta:* The author has given a very fine account of the possible uses of aluminium and other components as well as the gist of developments in other countries like France, U.K., U.S.A., etc. The use of aluminium forgings which have the maximum mechanical properties in the direction needed and ability to withstand adverse conditions of loading such as frequent reversal of stresses for various railway and engineering components, should be developed in the country. In this connection, I would like to refer to the paper presented by Mr. Brockway at the Institution of Locomotive Engineers, U.K., wherein the successful use of aluminium forgings in Morocco Railways has been detailed. The actual load tests called for the above wagons was 36·41 tons without residual deformation and the wagon actually stood a load of 55·10 tons without residual deflection.

As regards welding of aluminium, the latest development is the Rowen-Arc process which is a continuation of M.I.G. inert gas process applicable to welding of 0·064″ thick and thinner aluminium. In the advance of aluminium technology, the possibility of making all welded aluminium coach now seems to be a practical proposition. This aspect should also be considered by the Indian Railways.

The author has made a reference to the use of aluminium roof water tanks in Indian Railways. In this connection, I would like to mention that there are actually 8 different varieties of tanks and rationalisation of the size of tanks required in railways will definitely contribute to the economy of uses of this valuable metal aluminium which is quite costly in India, and to higher productivity. I am aware of the work that is being carried out by the Research, Designs and Standards Organisation on the interchangeability of items used in railways and it is requested that this question of rationalisation of sizes of roof water tanks should be studied specifically.

*Mr. K. C. Choudhuri (Author)*: Thank you, Mr. Ganapathi. I will certainly bring the points mentioned by you to the notice of the Design Section of our organisation. As regards aluminium forgings, the British Railways have put in service aluminium forged connecting rods in 1960 and it is reported that they are still in service and are giving good service performance. There is a possibility of using forged alumiminium alloy components in Indian Railways.

*Mr. U. P. Mullick, Institute of Consulting Engineers, Calcutta*: I would like the Research, Design and Standards Organisation to consider the use of aluminium and aluminium alloys in Indian Railways in signalling and interlockIng systems, on signal bridges and wires, sleeper ties (steel ties in sleepers rust out quickly), bridge platforms and railings, in station overbridges, platform and passenger sheds in stations, in engine tenders and driver's cabs, which will reduce the weight of engine adding to the haulage capacity, etc.

*Mr. K. C. Choudhuri (Author)*: The suggestions are welcome. The driver's cab of the metre gauge engines manufactured in the Tata Engineering and Locomotive Co. Ltd. is made of aluminium. As regards the oher suggestions, I will bring them to the attention of our Design Office.

*Mr. R. W. Flint, Greaves Foundry Services Ltd., Bombay*: I would like to know the contribution of the railways in the development and production work and the contribution they would like to receive from the private sector.

*Mr. K. C. Choudhuri (Author)*: The estimates arise only when the service life trials now underway are completed. However, we can expect that light alloys will find much increased applications if it is decided to switch on to using aluminium in railways as detailed in the paper.

*Dr. V. A. Altekar, Department of Chemical Technology, University of Bombay, Bombay*: The author is to be complimented for the very interesting data presented in his paper. It may be of interest to note here that aluminium happens to be a very versatile material of construction for handling and transport of a very wide range of chemicals. To mention only a few of these as examples, the following may be cited: Acetic acid, acetic anhydride, ethyl acetate, ammonium nitrate, ammonium carbonate and ammonium hydrooxide; fatty acids, formaldehyde, freon, glycerin, hydrogen peroxide, distilled water, de-ionised water, milk, meat, fish, wines, and beer, edible oils, nitric acid, petroleum and its products, particularly sour, crude as also such organics as benzene, ethylene glycol, methenol, cyclohexane, toulene, water white rosin, sulphur and several sulphur compounds; almost all refrigants, etc., etc.

It would be apparent from such a long but partial list that aluminium and its alloys have a great scope as a material of construction in tanks and tank-cars on the Indian Railways in service of the fast developing chemical industry of India.

*Mr. K. C. Choudhuri (Author)*: This is already in the attention of our Design Office. It may be too early to use aluminium tank cars and wagons in our country as the production of aluminium is far below the required consumption. As production of virgin metal increases, the various alloys will find applications.