

THE HISTORY OF COMPONENTS

This section of the journal will deal with one of the metal components used in the automotive industry, recording the changes in its design. At the same time, the many ways in which the techniques and materials employed in its manufacture have developed will be described.

This approach will also serve to emphasize the vital role played by metal component manufacturers in developing the basic materials and working out production processes.

The article in this issue deals with aluminium cylinder block.

Aluminium Cylinder Block

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Abstract

Although aluminium has been used in the manufacture of cylinder blocks since the 1930s, the choice of this solution, and the problems involved in mass-production, are still studied and discussed.

The most significant applications of aluminium in cylinder blocks and factors determining the choice of aluminium or cast iron are surveyed. Design of casting, technological aspects and choice of casting process are considered.

Riassunto

Il blocco cilindri in alluminio

Anche se le prime realizzazioni di vetture con blocco cilindri in alluminio risalgono agli anni '30, oggi più che mai si sta studiando e dibattendo l'adozione di questa soluzione e le implicazioni connesse alla produzione per grandi serie.

L'articolo, a partire dalle esperienze più significative, esamina, oltre ai fattori che determinano la scelta tra alluminio e ghisa, le caratteristiche progettative e tecnologiche e i processi di colata di questo componente.

Most car manufacturers have included in their programmes, for various reasons, a "Research car" or an "Auto 2000" (Fig. 1).

These prototypes represent, above all, a reference for the development of projects to be completed in the short term, with solutions containing advanced innovative elements and which have every probability of being adopted in practice.

As for cylinder blocks (Fig. 2) very few car makers refuse to consider the use of aluminium, demonstrating their confidence in

finding a definitive solution to the various kinds of problems still outstanding.

Along this route, work has been going on for half a century, and today the pressures are intensifying more than ever.

But a distinction must be made, right at the outset. There are the different cases of the mass-

production of popular cars, the medium/short-run production of sporting and de-luxe types, and special production for fierce competition. For each of these cases, the production cost must be seen in relation to the different price that the customer is willing to pay. We are now considering certain points referring to the choice of aluminium as material for the

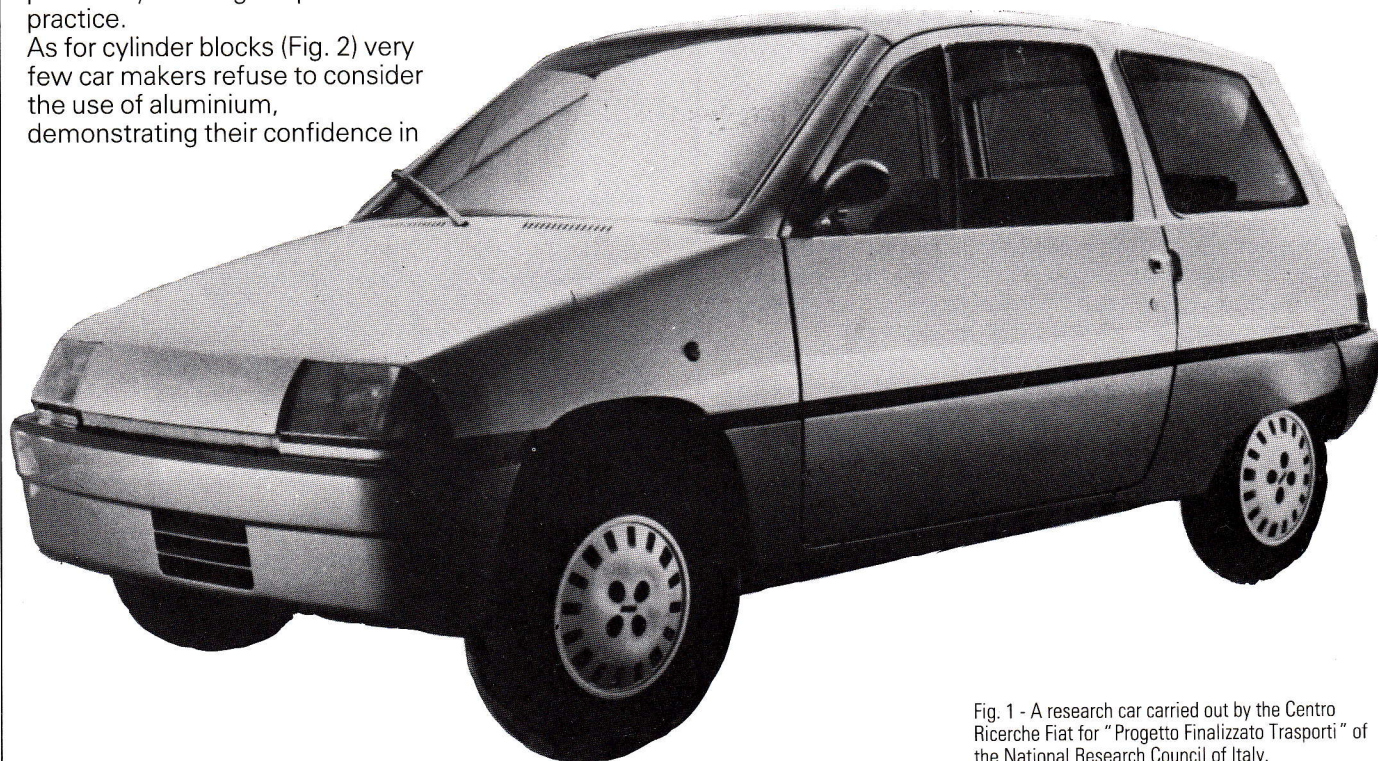
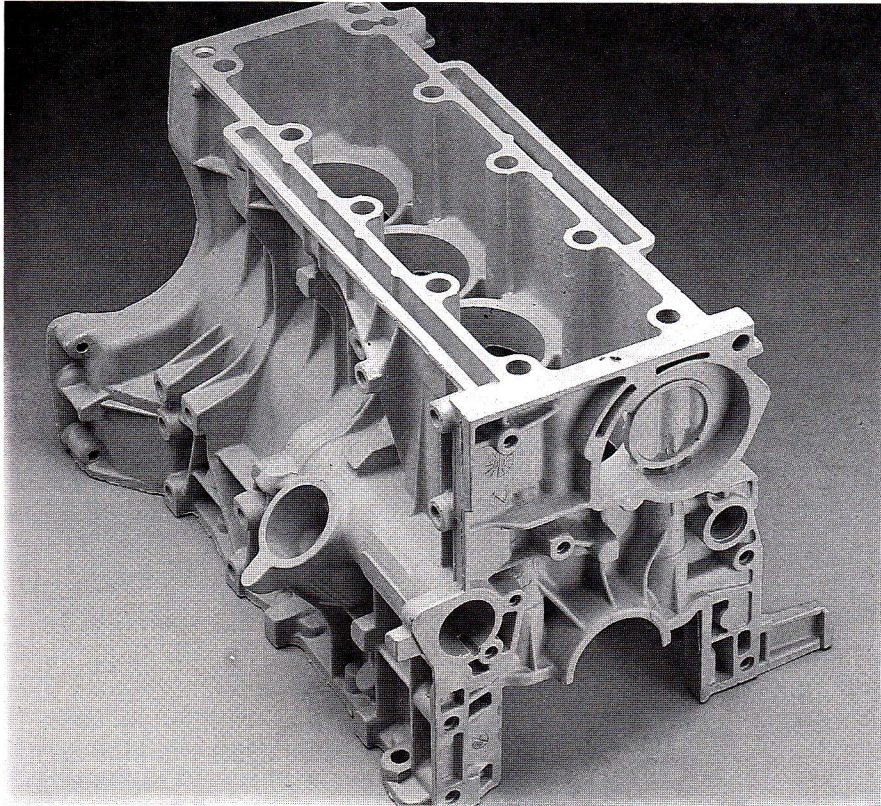


Fig. 1 - A research car carried out by the Centro Ricerche Fiat for "Progetto Finalizzato Trasporti" of the National Research Council of Italy.

Fig. 2 - A four-cylinder die cast aluminium block.
Teksid, Aluminium Foundry Division.

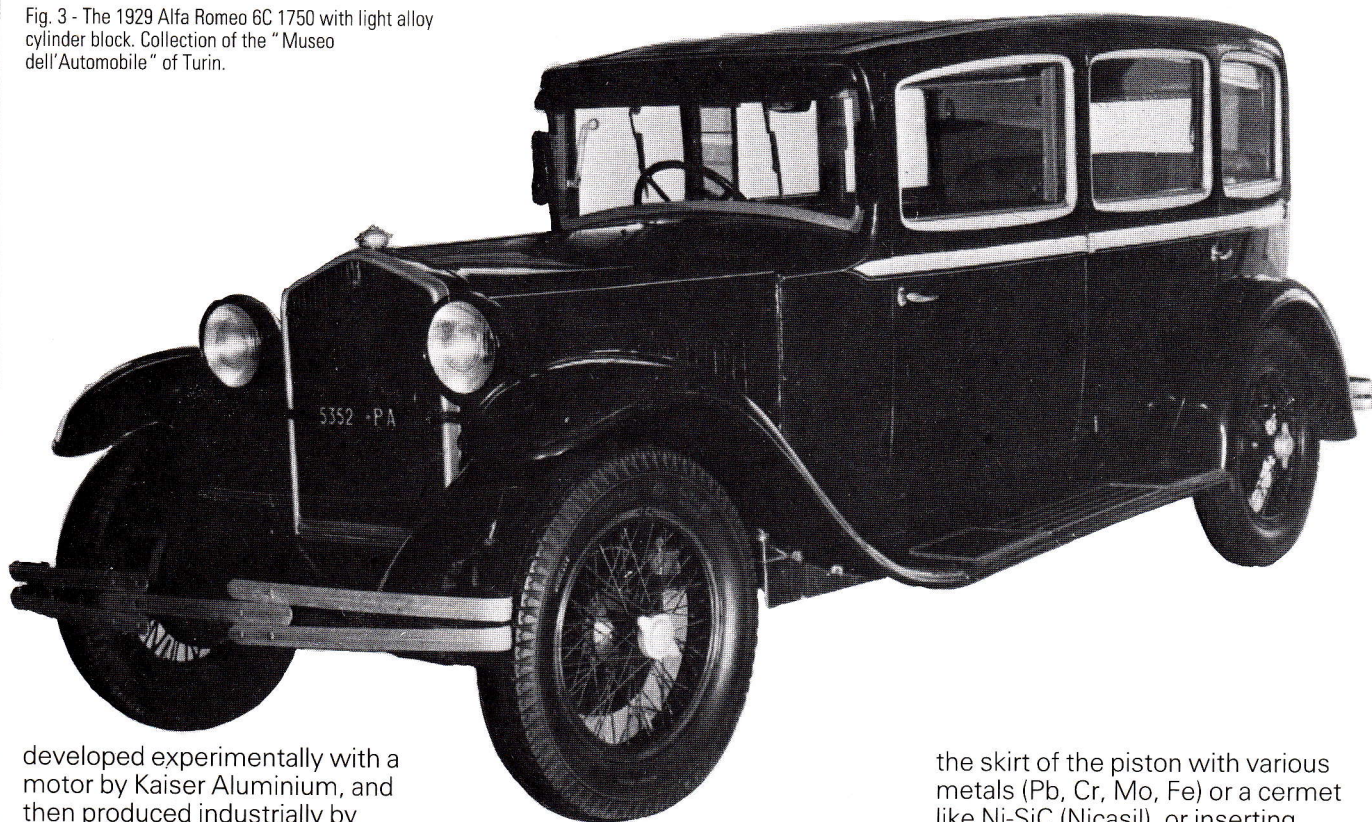


production of cylinder blocks. In the first place, account must be taken of the unit cost of aluminium in comparison with that of cast iron, of the plant involved in the cast iron solution, of the supply of the raw material and the pricing policy practised by the big aluminium suppliers. Then there are the considerations of the foundry process, essentially permanent mould casting and high — and low-pressure die casting. Design too is to be considered, for example, the configuration of the main bearings. The open deck offers indisputable advantages for foundry casting, not involving the necessity of water jacket cores. The closed deck presents better overall rigidity, but greater tolerances must be envisaged on the thicknesses of walls made with sand cores. At the design stage, allowance must be made for the better

thermal conductivity of aluminium relative to that of cast iron, in the sense that the lengths of the water jacket can be differently arranged. A feature of the design is that solid zones result more sensitive to shrinkage phenomena. We must bear in mind that the cylinder-head valves are of steel and that their coefficient of thermal expansion is markedly different from that of the possible aluminium head and of the cylinder block. This difference is responsible for the different forces exerted between these components, and this in turn creates different demands on the gaskets compared with those of the conventional cast iron solution. The gasket will be different from that used for cylinder blocks in cast iron, and on this point there is the experience gained with engines built, for example, by Chevrolet, Lancia, Peugeot, Renault, Alfa-Romeo, Porsche and Daimler-Benz.

Every engine requires its own individual gasket which allows for different structural details. Now attention must be paid to some problems concerning the compatibility of the light-alloy cylinder with a piston also in light-alloy, equipped with sliding rings with various functions. Aluminium in friction with aluminium can easily weld together. This fact hinders the sliding of the piston in the bore of the block, where both are made of aluminium. And furthermore, the phenomenon of seizure must be considered, as well as that of wear. These kinds of considerations make it worthwhile to sketch a hindsight view of pertinent experiences. The project of achieving an "all-aluminium" engine first arose during the First World War. In 1917 the Aluminium Company of America built an experimental V-8 engine in aluminium, and then produced a short series of 6-cylinder cars, of which some were able to cover more than 150,000 km (over 92,000 miles) without much trouble. Around 1930, in the USA and in Europe, "all-aluminium" air-cooled engines were appearing, but with cylinder liners in cast iron, steel or hard chromed aluminium. In 1929, Vittorio Jano's legendary Alfa Romeo 6C 1750 came out with light alloy cylinder block (Fig. 3). Its Gran Sport version had experimental engines with pressed-in steel cylinder liners and was racing and winning in all major road competitions, starting with the 3rd Mille Miglia in 1929. From 1929 to 1933 about two thousand Alfa Romeo 1750 were produced. However, the first popular production car with aluminium alloy block and head was probably the 1937 Lancia Aprilia, which used set-in cast-iron cylinder liners in the V-4 block. The water-cooled engine with cylinder block and cylinder head in aluminium appeared during the Second World War, in a Pontiac straight 6-cylinder model, and was

Fig. 3 - The 1929 Alfa Romeo 6C 1750 with light alloy cylinder block. Collection of the "Museo dell'Automobile" of Turin.



developed experimentally with a motor by Kaiser Aluminium, and then produced industrially by various European and American manufacturers starting in the '50s and '60s.

These engines, because of the poor tribological compatibility between piston and cylinder, and because of difficulties with the level of heat transmission and expansion, retained the cast-iron cylinder liner. The idea of employing an Al-Si hyper-eutectic alloy to achieve a cylinder integral with the block finally appeared at the end of the 1950s.

Tests showed that an alloy with 20% of silicon behaved excellently from the point of view of dimensional wear, but remained sensitive to seizure. Other attempts have been made with 24% Al alloys and also with 30% Si. But notwithstanding the good wear resistance of these materials, difficulties in mechanical working and casting have held back their application in industry.

Ultimately, the researchers of the Reynolds Metals Company brought

about, in 1969, the construction by General Motors of the Vega 2300 car, in which the four-cylinder water-cooled block was high-pressure die cast according to the Acurad process in an alloy designated 390 and containing 16-18% Si and 4.0-4.5% Cu.

This Si content represented a good compromise between wear resistance (attributable to adequate distribution of the free silicon grains in the eutectic matrix) and ease of mechanical working and foundry casting. Other examples are the Porsche 928 and 944 engines.

The problems of friction between pistons, generally in type A-S12 UN eutectic alloy, and the cylinder, in Al-Si hyper-eutectic alloy, were solved by the device of treating the piston with an electrolytic deposit of Fe on a Zn-Cu base and the cylinder with a polisher in two stages, and a chemical etchant intended to bring the primary silicon grains into relief. Other solutions provide for coating

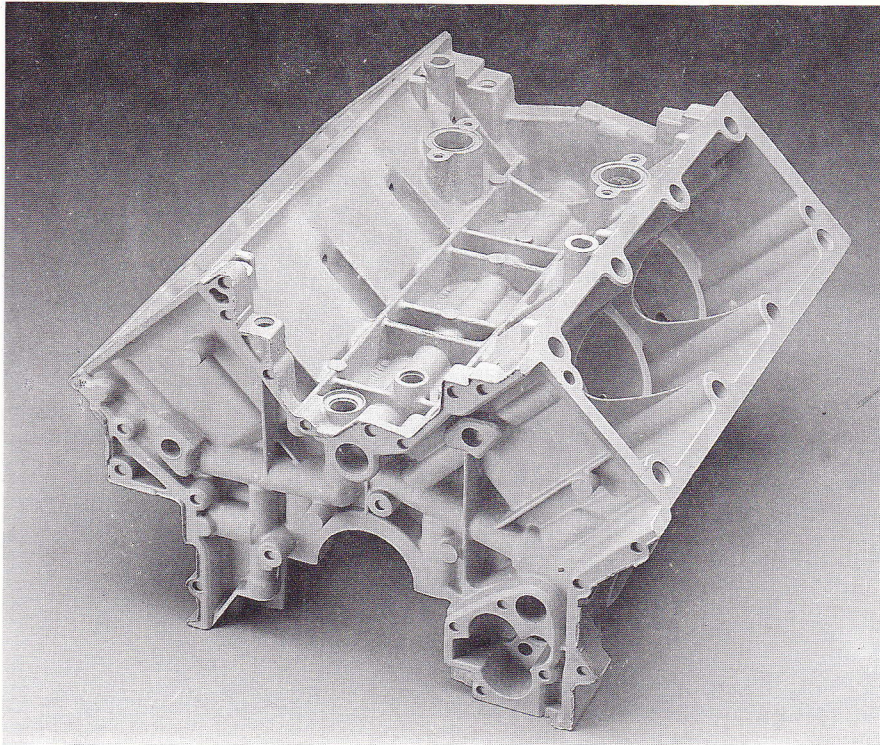
the skirt of the piston with various metals (Pb, Cr, Mo, Fe) or a cermet like Ni-SiC (Nicasil), or inserting piston rings in steel, or hard-chromium plating the bore, with or without final current reversal.

In the choice of this treatment, we must not forget the problem of instant lubrication of the piston-cylinder system.

Another way of attacking the problem is to make the liner by the powder metallurgy system. This solution will bring two advantages: 1) The possibility of forming the compacts (blanks) by mixing other elements of high lubricating power with the Al, and thus render surface treatment of the piston unnecessary. 2) The possibility of making the dispersion of Si in the Al matrix even finer.

A comparison made at a French car manufacturer's takes, as the cost basis 100, the cylinder block and liner in light alloy, permanent mould cast with hard-chromium plating in the bore. The liner obtained with the monobloc in Al-Si hyper-eutectic alloy equals 105; the monobloc in Al alloy with liner of cast iron equals

Fig. 4 - Die cast aluminium cylinder block. Teksid, Aluminium Foundry Division.



blocks, as well as the capacity to solve the related sealing problems (Fig. 4).

The cylinder block must be so designed as to avoid too massive sections.

Reinforcement of the structure is then possible simply with the aid of ribs.

The preferred material for this performance is an alloy of AlSi8Cu3 type, otherwise, for the solution with integral cylinders, an alloy of AlSi17Cu4Mg type. Cylinder blocks are very big castings, and call for pressure die casting machines with a closing force of at least 2500 t (Fig. 5). The moulds are also very big, with weights of the order of several tens of tons.

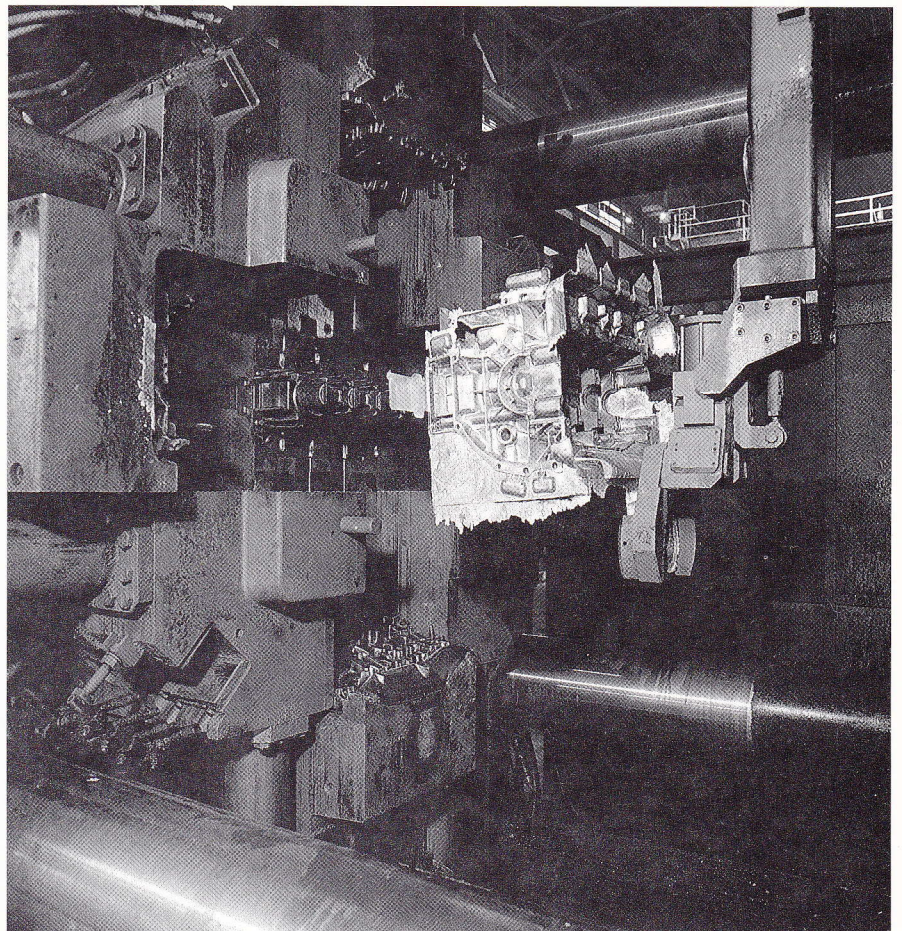
111, and the monobloc of Al high-pressure die cast, with liner in hyper-eutectic alloy obtained by powder extrusion, again equals 100. But this is not to say that there are no other routes, and the economic balances can result differently under different conditions.

In choosing one of the different routes the following criteria must be considered: the times necessary to start production, the times of testing the product, comparison with the existing production method, the technical results, the ease of foundry operations and machinability, besides considerations of the engine power, the possibility of repairs and the risk of the operation.

An important decision concerns the casting process from which spring important consequences about the other factors cited above.

High-pressure die casting has applications in the production of cylinder blocks with "wet" liners made of cast iron. Adopted mainly in France and Italy, this requires the prospect of large quantities, and absolute mastery of the design techniques of these open cylinder

Fig. 5 - A 2500 t die casting machine.



Low-pressure die casting is recommended when, for technical reasons, it is necessary to make the cylinder blocks with closed deck and liners obtained with sand cores. An example of this system of casting is the cylinder block of the Mercedes Benz M 117/51 in AlSi17Cu4Mg alloy. Low-pressure die casting is convenient when the number of castings to be produced does not justify the investment in a high-pressure die casting plant, or when walls of increased thickness are otherwise unobtainable. It permits the production of cylinder blocks with closed or open deck and the use of cast-in or pressed-in liners.

No less important than the two systems just mentioned is the *permanent mould casting* process. With the mould mounted on a carousel and mechanisation of most of the operations, there are less restrictions with this method on the possibility of producing long runs of castings (Fig. 6).

Rather, taking into account the requirements of the cylinder block in the matter of strength, the permanent mould casting process becomes extremely attractive by its capacity to give castings that are very sound and free from porosity (Fig. 7).

In permanent mould casting the number of parameters to check is much lower, compared with the aforementioned processes. These parameters are essentially the pouring temperature, the fluidity of the metal, the rate of cooling and of solidification of the metal in the mould, the air and the entrapped impurities.

At the same time, the dimensional and weight limitations of the mould which are significant in the case of high-pressure die casting, are not so important in permanent mould casting.

Furthermore, the mechanical characteristics of a piece solidified in a mould present appreciably higher values (double or triple). The molten metal flowing from the

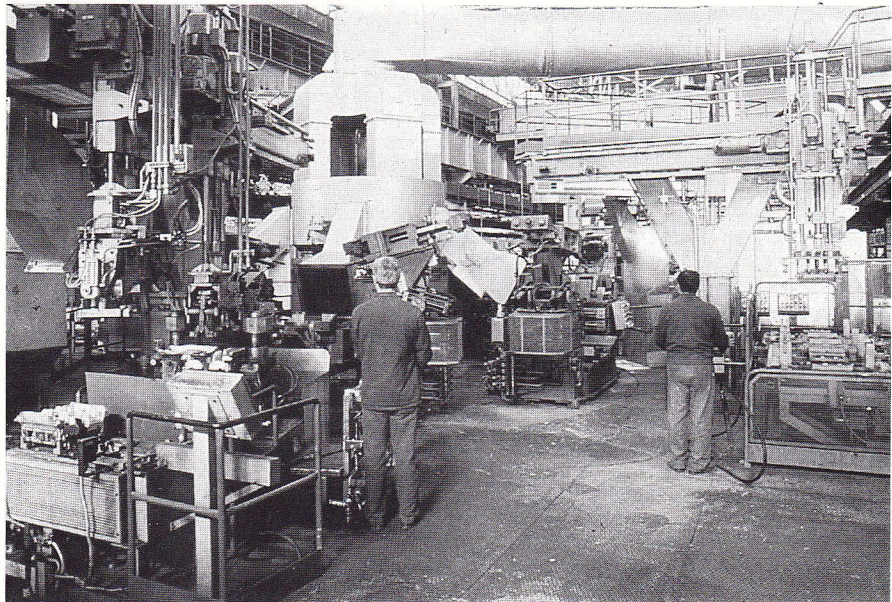
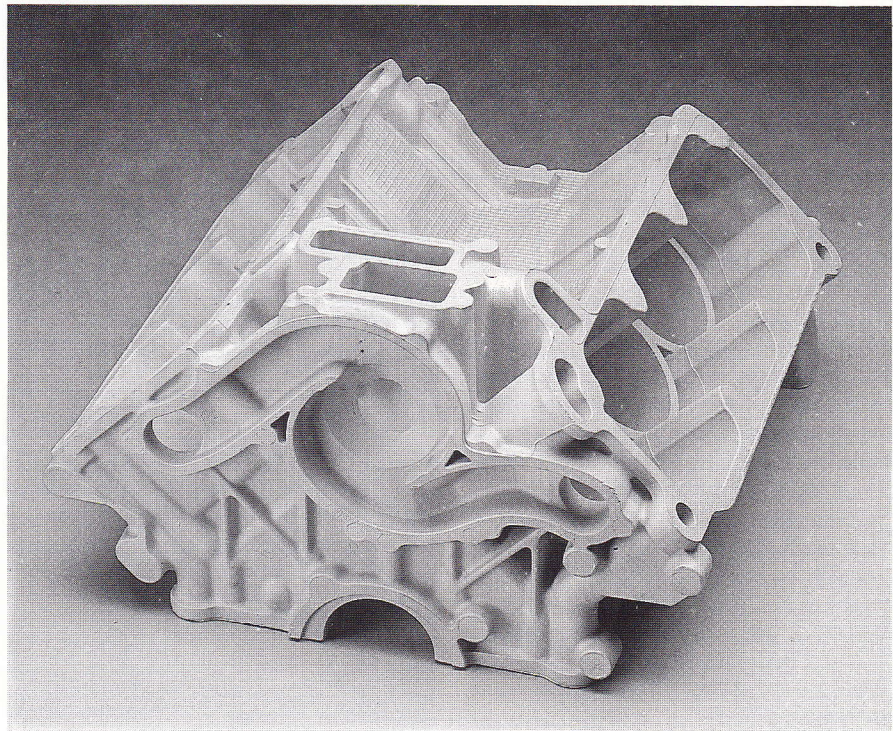


Fig. 6 - View of a carousel at Teksid, Aluminium Foundry Division.

Fig. 7 - Aluminium semi-permanent mould cylinder block used by Maserati. Produced by Teksid, Aluminium Foundry Division.



holding furnace passes into the mould cavity along a shorter route, meeting turbulence phenomena of lower intensity. Actually it does not allow the formation of gas-metal and impurity-metal emulsions, which are extremely undesirable. The choice of the casting process, however, is made in various ways, based on the foundry's experience and long-practised ability to control the variables and the unforeseen snags that inevitably arise in practice. The solution of aluminium cylinder block can successfully be adopted with experienced managers at the head of industries equipped with the most advanced means of production and inspection. Furthermore, success and product reliability depend on the degree of co-operation between the motor manufacturer and the foundry as from the design stage.

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Acknowledgements

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