Applications – Power train – Heat shields

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6 Heat shields

6.1 Introduction

Heat shields are designed to shield a component from absorbing excessive heat either by dissipating, reflecting or simply absorbing the heat. In an automobile powered by an internal combustion engine, the exhaust system from the engine exhaust manifold to the tailpipe is the biggest producer of heat after the engine itself. The surfaces of the parts that actually carry the exhaust gases can reach temperatures up to about 900°C. Since exhausts often pass near important (and thermally sensitive) components, it is especially important to protect the sensitive parts and modules from heat soak, but also to prevent local overheating of the car body.

The installation of a heat shield is one of the most widely used heat management option due to its cost-effectiveness and ease to fit. In the past, heat shields have usually been made out of aluminized steel. However, nowadays aluminium sheets and foils are generally used, often combined with ceramic thermal barrier coatings or mats of insulating materials. Aluminum heat shields in single-sheet or multi-layer construction are able to protect against quite high temperatures. Aluminized steel sheets are only required for heat shielding in the highest temperature range.
6.1.1 Aluminium – the material of choice

The physical properties of aluminium - reflectivity and emissivity, thermal conductivity and specific heat capacity - make it to the ideal material for the fabrication of heat shields.

- The high reflectivity and low emissivity of the aluminium surface (even when covered with the natural aluminium oxide film) ensure that aluminium both absorbs and re-emits little infrared radiation.
- The high thermal conductivity of aluminium ensures that heat is quickly conducted away from potential hot spots in the heat shield.
- Aluminium has also a high specific heat capacity. This means that the temperature increase after absorbing a given amount of heat energy is lower than for many other materials.

The favourable physical properties mean that as a rule of thumb, 70 % of the heat management tasks in the car can be handled by the aluminium surface alone. The remaining 30 % have to be dealt with by an appropriate design of the heat shield and, if necessary, additional measures.

Aluminium sheets and foils are well suited to satisfy the various manufacturing and service requirements of automotive heat shields. A most important requirement is a good formability in order to meet the extreme package restrictions. Heat shields have to cover the hot component as far as possible and as close as possible. Space is limited, in particular in the engine compartment and the underbody area, thus heat shields have normally fairly complex shapes to fit tightly between the different components. Typically, heat shields are positioned 15 - 25mm from the car underbody, 10 - 15mm from the fuel tank and 25 - 50mm from the exhaust pipe.

![Heat shield design asks for an extremely formable material](image)

**Source: Novelis (former Alusuisse)**

Another important requirement is an excellent corrosion resistance. Humidity and elevated temperatures, relevant environmental factors for heat shields, strongly promote corrosion effects. In addition, the majority of the heat shields are directly exposed to contamination from the road. Contaminants such as salt water, liquid asphalt, street dirt and mud must not, during the car's lifetime, lead to unacceptable corrosion of the heat shield. A different, but most important issue is the avoidance of galvanic corrosion. Aluminium heat sheets are often
attached to steel components, i.e. proper assembly methods (see below) must be used to ensure that heat shields do not suffer from unacceptable corrosion attack in service.

In addition, the heat shield material must offer sufficient resistance to fracture. Stone chipping and slight ground contacts may result in severe local deformations of underbody heat shields which should not lead to the formation of cracks. Moreover, in case of a rear crash, the heat shield must protect the plastic fuel tank against rupture and other damages from hot exhaust parts.
6.1.2 Aluminium alloy selection

Today, the standard heat shield material is the aluminium alloy EN AW-1050A in the soft temper. Its properties - among others excellent corrosion resistance, good cold formability, adequate tensile strength, excellent energy absorption before rupture (stone impact, car crash) - make it the preferred material regarding both ease of fabrication and performance in service.

Apart from EN AW-1050A, higher strength alloys such as EN AW-3003, EN AW-5052 and EN AW-5182 are also used. Heat shields made from higher strength alloys may be more damage-tolerant (in particular in underbody applications) or they can be made from thinner gauge sheets. However, the lower cold formability of these alloys limits their application due to complex geometry of many types of heat shields.

Embosed heat shield (BMW 7 series), produced by SEVEX AG
Source: Hydro Aluminium

Embosed heat shield
Source: Hydro Aluminium
6.2 Design of heat shields

With regular driving conditions, heat shields need to protect parts from nearby heat sources with surface temperatures up to 650°C. But also significantly higher temperature may occur, e.g. spark plug failures (misfire conditions) may cause overheating of catalytic converter and, consequently, downstream parts of the exhaust system will also reach abnormally high temperatures. The higher the temperature and the closer the distance between the heat source and the car component, the more complicated design is required of the heat shield.

There are basically three types of heat shields:

- **Single shell heat shields** (not insulated)
  Single shell heat shields are used for protection against heat sources of relatively low temperature, specifically when there is sufficient available space.

- **Double shell heat shields** (not insulated)
  These heat shields made of two aluminium sheets are used for moderate temperatures and limited package restrictions.

For single and double shell heat shields, aluminium sheets of 0.3 - 1.0 mm thickness are used. The sheets may be also embossed for increased stiffness.

- **Sandwich heat shields** (insulated)
  For protection against the highest temperatures and in cases of severe space limitations, heat shields in sandwich designs are being used. Sandwich heat shields usually consist of a single carrier sheet (0.3 - 1.0 mm thick aluminium), an insulating core and a cover (0.03 to 0.1 mm aluminium foil or 0.2 to 0.5 mm aluminium sheet). The core can be built up from several layers of embossed aluminium foils (0.03 - 0.05 mm thick), which are sandwiched together. It can also be an insulating mat (ceramic felt or glass fibre mat). Depending on the temperature range, other types of fibres (plastic, cotton, wood, etc.) can be used too.
In the design of heat shields, specific care must be taken with respect to the configuration of the edges. The geometry of the edges of aluminium heat shields has to be selected to minimise the injury risk during handling (manufacturing, assembly and maintenance/repair of the car).

Apart from thermal management, sandwich type heat shields are also useful for noise management in the car and to reduce noise emissions to the environment.

**Noise absorbing sandwich heat shields** consist of:
- Carrier sheet with partial perforation, backed up by a
- Membrane foil, aluminium 0.03 - 0.05 mm thick, followed by an
- Insulation core and cover sheet (see description above).
Another possible solution for a noise absorbing heat shield consists of two-layer sheet metal design with a viscoelastic core optimised for sound dampening.

Sound absorbing heat shield with viscoelastic layer
6.3 Heat shield applications

The most important functions of thermal management in motor vehicles are to protect sensitive vehicle components from the effect of heat and to provide optimal thermal comfort for the occupants. Heat shielding products are custom designed to effectively manage radiant, convective and conductive heat from the front to the back of a vehicle. The number of heat shields per car varies considerably. Small, low-power vehicles may need only as many as two heat shields, whereas high-powered luxury cars may have up to thirty.

For a long time, heat shields were mainly used for heat management in the engine compartment, specifically to protect against “hot spots” like exhaust manifolds. Their design was fairly straightforward, in general they consisted of double aluminium shells with an intermediate rock wool layer. More powerful engines, the introduction of catalytic converters and the trend towards closed engine compartments (for reduced noise emissions) has strongly contributed to the increased use of heat shields.

Major application areas are:
- Exhaust manifold heat shields
- Catalytic converter heat shields
- Turbocharger heat shields
- Starter motor heat shields

Heat shields are also useful to reduce the under-bonnet temperatures allowing for lower air intake temperatures and thus enabling increased power output. They can also keep more heat in the exhaust therefore reducing exhaust back-pressure. Heat shields for the dashboard often have an additional sound dampening function.
The centre and rear underbody have to be protected against heat from the front and rear silencers and the catalytic converter. Moreover, thermally sensitive parts such as the lambda probe, the fuel and hydraulic lines, the electric wiring and the fuel tank itself have to be protected. Lately, car designers tend to place the exhaust system closer to the underbody in order to reduce aero-dynamic drag. This development made heat management more difficult, the hot surfaces are not only closer to the underbody, also the slipstream also has less cooling effect.

Furthermore, off-road vehicles are equipped with “fire shields”, which are fixed under the exhaust system. These heat shields help avoid igniting dry grass and scrub when driving in grassland or open woodland.
6.4 Assembly techniques

The assembly technique has to be chosen to satisfy the requirements of
- stiffness and strength,
- feasibility for disassembly (maintenance, repair) and
- life time performance (corrosion resistance).

Apart from the use of rivets and screws (electrolytically galvanised for corrosion protection), aluminium heat shields are generally attached to the (steel) car body with nuts and sacrificial washers.

At the attaching points, a sacrificial washer (aluminium disk with a thickness of about 2 mm) is integrated into in the heat shield. The heat shield is then fastened with nuts on screw bolts which are stud-welded to the car body. The sacrificial washer is pressed by a spring to the (steel) body and corrodes over the car's service life, hence the term "sacrificial". This system avoids corrosion of the heat shield where the mounting points contact the car body (see following figure). Typically, the spring and nut have a galvanised surface.

Attachment of the heat shield with nut and washer to a welded stud bolt
6.5 Ongoing developments

Today, heat protection (or thermal management) is not seen anymore as an isolated issue. In a total system approach, the applied heat shields are increasingly integrated into multifunctional components. Aluminium heat shields will be more and more integrated into innovative solutions for:

- Engine encapsulations to reduce fuel consumption and polluting emissions while treating noise at its source
- Combined heat protection and sound management solutions for the engine and exhaust line
- Thermal comfort in light vehicle passenger compartments.

Acoustic heat shields combine effective thermal protection with a clear reduction in external noise. Underbody heat shields can also be considered as an integral component of the underbody system itself and even contribute to an improvement of the underbody aerodynamics.

An example is the newly developed aluminium foil technology of Autoneum which integrates the heat protection properties of the aluminium foil into plastic composite parts of the underbody, thus eliminating the need for separate heat shields, i.e. a cost and weight saving measure ideal for underbody panels exposed to low to medium heat levels. The aluminium foil is directly pressed onto the long-fibre (glass or natural fibres) thermoplastic composite carrier in the compounding and moulding process.