GUIDE DEFENCE · 12 MIN READ

High-temperature processes in the defence/ armaments industry

Why refractory technology is indispensable in the defence/armaments industry: metallurgy, thermal protection and energy systems in a defence context.

Metallurgy in a defence context

The manufacture of defence goods places the highest demands on metallurgical processes. Armour steel alloys, high-performance materials for engines and ballistically optimised materials are produced in melting, casting and heat treatment processes that require temperatures in excess of 1,600 °C. Refractory linings in electric arc furnaces, induction furnaces and vacuum furnaces must therefore be highly resistant not only thermally but also chemically — aggressive slags and special alloys attack conventional refractory materials considerably more severely than in civil steel production.

- Armour steel and ballistic protection steel: melting and casting at over 1,650 °C in electric arc furnaces with a basic refractory lining
- Engine alloys (nickel-based): vacuum induction melting (VIM) with alumina or magnesia crucibles
- Heat treatment: continuous furnaces and chamber furnaces for quenching and tempering, hardening and stress-relief annealing of safety-critical components
- Additive manufacturing: the atomisation of metal powders for 3D printing requires high-purity melting processes with special crucible linings
- Ammunition production: casting processes for projectile casings and penetrators with defined microstructures

Note: Quality requirements in comparison — Whereas reject rates of 1–2 % are acceptable in civil steel production, zero-defect tolerances apply in defence metallurgy. Any deviation in the refractory lining — for example an inclusion caused by eroding refractory material — can lead to material failure under operational conditions. Traceability and batch documentation are therefore mandatory for refractory materials as well.

Thermal protection and heat shield systems

Thermal protection is a technology field in its own right within the defence industry. From heat shields in missiles and exhaust systems in armoured vehicles through to thermal insulation in marine propulsion systems — refractory materials are used wherever temperatures exceed the capability of conventional materials. The requirements go far beyond static furnace linings: thermal shock resistance, low weight and resistance to vibration and acceleration are decisive selection criteria.

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Missiles and re-entry vehicles: ablative heat protection materials based on carbon fibre and ceramic composites

- Exhaust systems of armoured vehicles: refractory linings must withstand temperatures of over 900 °C while simultaneously being subject to vibration loads
- Ship propulsion: gas turbine combustion chambers and exhaust paths in frigates and corvettes require high-temperature-resistant insulating materials
- Rocket motors: nozzle throat linings made of graphite, tungsten or ceramic matrix composites (CMC)

Note: Dual-use aspects of thermal protection materials — Many high-temperature materials for thermal protection are subject to the EU Dual-Use Regulation (EU) 2021/821. Ceramic fibre composites, certain graphite grades and high-performance ceramics are listed in Annex I. Suppliers must therefore be aware of their export control obligations and establish internal compliance processes.

Energy systems and propulsion technology

Modern weapon systems and platforms depend on high-performance energy systems. Gas turbines in main battle tanks, ship propulsion systems and auxiliary power units in aircraft generate extreme temperatures that call for refractory linings, combustion chamber materials and thermal barriers. The move towards directed energy weapons (DEW) and hypersonic technologies is intensifying the demands on thermal management still further.

- Gas turbines (MTU, Rolls-Royce): thermal barrier coatings (TBC) based on yttria-stabilised zirconia protect turbine blades at over 1,300 °C
- Directed energy weapons: cooling systems and thermal shielding for high-energy lasers require materials with extremely low thermal conductivity
- Hypersonic technology: nose caps and leading-edge materials must withstand temperatures of over 2,000 °C while simultaneously subject to aerodynamic loads
- Field camp power supply: mobile combustion systems and waste heat recovery with refractory lining

Note: Technological advantage through materials research — Mastering high-temperature processes is a strategic technological advantage. Countries with their own capability to manufacture ultra-high-temperature ceramics (UHTC) such as hafnium carbide and zirconium diboride hold a decisive advantage in developing hypersonic weapons and re-entry vehicles.

Testing and quality assurance

Refractory materials in a defence context are subject to stricter testing and documentation requirements than in civil industry. Quality assurance covers not only materials testing (compressive strength, porosity, thermal conductivity) but also complete traceability of the raw materials, batch release by the client and compliance with military specifications.

- First Article Inspection (FAI): initial sample inspection to AS9102 for every new refractory product in a defence context
- Batch tracking: complete documentation from the raw material through to the installed refractory material — compliant with AQAP 2110
- Non-destructive testing (NDT): ultrasound, radiography and thermography to assess lining integrity in the installed condition
- Environmental simulation: thermal cycling, vibration testing and corrosion resistance under simulated operational conditions

Note: AQAP requirements for suppliers — The NATO Allied Quality Assurance Publications (AQAP) define the quality requirements for suppliers to the defence industry. AQAP 2110 (based on ISO 9001) is the minimum requirement. Suppliers that carry out their own testing are additionally subject to AQAP 2120. Compliance is

monitored by the Bundeswehr quality assurance offices (Güteprüfstellen, GüPrSt).

Future technologies and trends

The defence industry is investing heavily in future technologies, all of which require high-temperature processes. From the Future Combat Air System (FCAS) and hypersonic missiles through to new armour concepts — the demands on refractory technology and thermal management will continue to rise. This opens up long-term business opportunities for specialised suppliers.

- FCAS/NGWS: the next generation of engine materials for stealth requirements and higher operating temperatures
- Additive manufacturing: 3D printing of refractory components for prototypes and very small batches — shortening development cycles from years to months
- Ceramic matrix composites (CMC): lighter than metal, more temperature-resistant — a paradigm shift in engine technology
- Rare earth recycling: high-temperature processes for recovering strategic raw materials from decommissioned weapon systems

Frequently asked questions

Which refractory materials are most commonly used in the defence/armaments industry?

The most common refractory materials are high-alumina bricks and monolithics (Al2O3 > 70 %) for melting furnaces, magnesia-based products for basic furnace linings, silicon carbide for wear protection and zirconia-based materials for thermal barrier coatings. Graphite, tungsten and ultra-high-temperature ceramics (UHTC) are also used for extreme applications.

Which certifications does a refractory supplier need for the defence/armaments industry?

The minimum requirement is ISO 9001 as a basic QMS. For supplying defence groups or the Bundeswehr directly, AQAP 2110 (the NATO quality standard) is additionally required. Depending on the level of information access, a security clearance procedure (Ü1 or Ü2) may be necessary. For exports, knowledge of the Dual-Use Regulation and the KrWaffKontrG (German War Weapons Control Act) is essential.

Do the requirements for refractory materials in defence differ from those in civil industry?

Yes, considerably. In defence, tighter tolerances, complete traceability, batch release by the client and documentation to AQAP standards apply. The materials themselves are often identical, but the quality assurance, depth of testing and evidence obligations are far more extensive.