AMPCO®

Material Selection Guide for High Pressure Die Casting Components

Abstract

High-pressure die casting (HPDC) pushes the piston tooling and die-integrated hardware through rapid thermal cycling, high mechanical loading, and high-speed filling. In this environment, material selection is not a generic exercise. It is a practical decision about where heat must be removed quickly, where geometry must stay stable under load, and where system performance depends on a variety of other parameters. This guide provides an engineering selection framework for two component families that repeatedly define HPDC quality of cast: piston components (piston heads and piston-adapter assemblies) and die-integrated air management components (natural and vacuum venting concepts). It ties selection to verifiable inputs such as cooling flow capability, component size ranges, vent cross-section, connecting channel geometry, and serviceability. The goal is to help engineers shortlist AMPCOLOY® copper alloy options based on the dominant limiter in production and to define selection inputs that can be checked during design review and validated during operation.

Introduction

HPDC is often discussed as a process of speed and pressure, but in daily production it behaves like a repeatability problem. Small changes in heat balance, contact conditions, or die evacuation can gradually narrow the operating window and increase interruptions during production or maintenance frequency. That is why component and alloy choice matters. The right selection makes thermal behavior and service intervals predictable. The wrong selection forces the process to depend on constant adjustment and frequent maintenance.

This document is written for die casting engineers, process managers, die designers, toolmakers, and maintenance managers who need a clear selection logic. It is not a guide to tool design or a machine setup guide, and it does not attempt to cover gating theory, casting alloy metallurgy, or machine parameter tuning. It focuses on component functions within die casting pistons and die venting, measurable constraints, and the design inputs that determine whether a material choice will translate into stable production.

1. Objective

This guide is intended to help the reader:

- Identify the dominant parameter of a component (thermal, mechanical, wear, air evacuation, or maintenance).
- Translate that parameter into checkable selection inputs and property priorities.

- Use system constraints such as cooling capability, venting capacity, or geometric requirements to help select the most suitable component and alloy.

2. Selection Fundamentals for Die Casting Components

2.1 Starting with the dominant parameters

In HPDC, most component issues trace back to one or more of the following:

1. **Thermal constraint**
   Heat must be removed fast enough to prepare the system for the next shot. If heat accumulates, the component drifts toward higher temperature, which can lead, for example, to piston jamming and, as a result, to production interruptions and increased maintenance costs.
2. **Mechanical constraint**
   High injection forces and repeated cycling demand stable geometry and controlled load transfer. Components that see concentrated contact pressure are especially sensitive to deformation at elevated temperature.
3. **Wear and surface constraint**
   Sliding exposure, adhesion, and repeated cycling change surface condition over time. Premature wear can, for example, lead to an excessive gap between the piston and the shot-sleeve and, as a result, to shot-through.
4. **Air evacuation constraint**
   With the need for an excellent quality of the cast, gas must be evacuated effectively enough through an evacuation path that the system remains functional over long runs. The gap dimension in the venting block or venting channel has a potential influence on the venting performance. Venting-performance is often material dependent.
5. **Maintenance constraint**
   If a component is difficult to clean, inspect, or replace, its effective performance in production will degrade regardless of its nominal singular function.

2.2 Translating process parameters into selection priorities

Once the parameter is defined, selection should be based on property priorities and system constraints:

- Thermal constraints demand **high heat extraction capability**, but only if the design provides an efficient path into a cooling circuit.

- The mechanical design should focus on **strength and shape stability during repeated loading**. This is often achieved with a defined load path that keeps high-conductivity parts from carrying structural loads.
- Wear and surface constraint favors **stable contact behavior** and a configuration that is serviceable without long downtime.
- Air evacuation constraint favors **vent cross-section, connecting channel geometry, and protected entry conditions**, with maintenance access treated as a requirement.

3. AMPCOLOY® in HPDC: What the Material Is Being Asked to Do

In HPDC, the value of AMPCOLOY® is not an abstract claim about conductivity. It is the ability to use a high-conductivity copper alloy where heat extraction governs performance, while still meeting the mechanical and service requirements of the components in use.

In the third phase of the casting cycle, components like the piston repeatedly absorb heat from the biscuit and injection-gate region. If this heat is not effectively dissipated, local temperatures rise and components tend to wear prematurely due to softening, or piston sticking. High filling speeds, which can reach up to 120 m/s in typical HPDC descriptions of process conditions, in conjunction with the aluminum alloy used, lead to wear in the die casting die. Under these conditions, heat management and repeatability are closely linked.

AMPCOLOY® selection should therefore be framed as a family decision: Select the AMPCOLOY® alloy that best meets the dominant requirements of the application.

Table 1. AMPCOLOY® grade snapshot for HPDC shortlisting

Typical/nominal values shown for relative comparison and shortlisting. Not a material specification.

AMPCOLOY® grade	Product form (HPDC piston)	Hardness (HBW)	Thermal conductivity at 20°C (W/mK)	Thermal conductivity at 100°C (W/mK)	Thermal conductivity at 200°C (W/mK)	Practical use intent in HPDC selection
AMPCOLOY® 940	Forged or pressed	210	208	226	243	Use when geometry stability and resistance to deformation are the

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						dominant constraints, and you still need strong heat extraction capability.
AMPCOLOY® 88	Forged or pressed	270	230	251	272	Use when heat extraction from the hot zone is critical, and you also need higher hardness compared with softer high-conductivity options.
AMPCOLOY® 95	Forged or pressed	240	217	235	254	Use when heat extraction is critical, and you want a balanced option with strong thermal conductivity and moderate hardness.

4. Shot-End Components: Piston Heads and Piston-Adapter Systems

4.1 Piston head selection

Piston heads operate where thermal and mechanical loads overlap. Selection should begin by identifying the parameter that has to be fulfilled and then using Table 1 to shortlist:

- **If heat extraction dominates and beryllium can't be used:** start with AMPCOLOY® 940 which offers a very good compromise between thermal conductivity, strength, and overall price/performance ratio.
- **If heat extraction along with highest shot-number dominate:** then evaluate AMPCOLOY® 88 as a strength-dominant option, with excellent thermal conductivity, high strength and durability.
- **For a more balanced approach between strength and conductivity** AMPCOLOY® 95 serves as very good middle ground solution.

This is based on the practical meaning of "material selection" in HPDC: not choosing a single alloy, but choosing the correct balance for the dominant parameters.

4.2 Piston-adapter architecture: separating load path and heat path

A piston-adapter assembly can be designed, so the structural load path is handled by a steel adapter interface while the copper-alloy head is selected for hot-zone thermal and functional behavior. This separation is important because it prevents the high-conductivity element from being unintentionally treated as a structural member in the same way as the adapter interface.

From a selection standpoint, this architecture implies:

- The adapter is the structural baseline that defines load transfer and protects geometry.
- The piston head is the hot-zone element where heat extraction and contact stability matter most.
- Service behavior can be made more predictable when the head is treated as a functional replaceable element and the load-bearing interface remains consistent.

4.3 Configuration inputs that must be defined up front

A selection guide should state what engineering must define before a piston-adapter assembly can be finalized. The required inputs are straightforward:

1. Total system length (piston head + adapter + piston rod)
2. Cooling drill-hole diameters for forward and return flow
3. Connecting thread to the piston rod (internal or external)

If these construction parameters are not defined early, it is impossible to create the design of the piston adapter.

4.4 Cooling is a hard constraint

High conductivity only helps if heat can be carried away through a cooling circuit with adequate flow and stable routing. Cooling capability should be treated as a selection constraint, not as a late-stage commissioning detail.

Table 2. Recommended water flow by piston diameter

Piston diameter (mm)	Recommended water flow (L/min)
50–80	12–16
80–110	16–20
110–130	20–25
130–150	25–35
150–170	35–45
170–210	45–55

The information in the tables is to be understood as a guideline. Deviations from this are perfectly permissible. If the water flow is too low, the piston may overheat, which could result in the piston jamming up.

4.5 Size coverage to support early selection and layout planning

The piston-adapter concept spans a broad piston-diameter range. These tables support early selection and layout planning by linking diameter windows to typical lengths.

Table 3A. Family A (baseline configuration): piston diameter coverage and typical L1 length by type

Type	Diameter A (mm)	Length L1 (mm)
10	50–80	75
15	70–100	75
20	80–110	90
25	100–130	120
30	110–140	120
40	140–170	129
50	160–210	134

Table 3B. Family B (wear-ring / split-ring configuration): piston diameter coverage and typical L1 length by type

Type	Diameter A (mm)	Length L1 (mm)
10	70–80	80
15	80–100	80
20	95–110	95
25	115–130	120
30	130–155	120
40	160–170	129
50	180–210	134

4.5.1 What “Family A” and “Family B” mean

The two families represent two piston-adapter configurations with different functional intent and operating envelopes.

Family A (baseline piston-adapter configuration)
Family A covers the standard piston-adapter concept without the additional wear-ring or split-ring features. It supports a wide piston diameter range. Within Family A, the “Type” numbers (10, 15, 20, 25, 30, 40, 50) are standardized size bands that link a piston diameter window (Diameter A) to a typical length **L1**. The total system length **L2** is flexible and is set based on the installation constraints (piston head plus adapter).

Family B (wear-ring / split-ring configuration)
Family B corresponds to the ring-based piston-adapter configuration intended for extended service life. Because of the ring-based front-end design, the recommended size range begins at a higher minimum diameter compared with Family A. As with Family A, Family B types represent standardized diameter windows linked to typical **L1** values, while **L2** remains flexible. The ring-based configuration is the preferred selection when service interval is the dominant constraint.

How to choose between the families as a rule

- Choose **Family A** when baseline service life is sufficient and diameter coverage down to the smallest range is required.
- Choose **Family B** when service life and maintenance interval are limiting output, and a wear-ring or split-ring configuration is required by the application.

4.6 Documented durability option

Where piston service life is the bottleneck, configuration choice can matter as much as material choice. A solid wear-ring concept (part of family B) is documented as increasing lifetime by a factor of 2 to 2,5 compared to a full-copper configuration. In a selection guide, this becomes a decision trigger: if service life is limiting output, evaluate the durability configuration as part of the selection, not as an afterthought.

5. Die-Integrated Air Management Components

5.1 Selection intent

Air management components must evacuate air/gas before metal arrival and remain functional over long runs. Performance is commonly limited by the evacuation path as well as by the vent element. The most important output of the calculation is the vent cross-section dominated by the height of the gap in the venting block and the connecting channel geometry as well as the gate of the overflow compared to the cast. This leads to the decision whether natural venting or vacuum venting is the solution. And which kind of vacuum venting offers the lowest maintenance.

5.2 Natural venting concept

For natural venting, vent cross-section is a practical factor that needs to be calculated. The dominant factor for the cross-section is not the width but the height (gap in the venting block). The height has potential influence. Doubling the height results in a fourfold increase in venting performance. Venting blocks are available as standardized options or could be designed according to the needs of the application.

The channel cross-sections can be defined based on the calculation of the necessary vent cross-section, and the correct vent insert (1 or more) can be selected. Also, the connection of the overflows must be checked and adjusted.

5.3 Vacuum venting concept

In conjunction with vacuum venting, however, the requirements for the die casting tool and the die casting pistons or piston systems used are particularly high. Any leakage should be avoided, as this reduces the performance of the vacuum venting system. It should be therefore treated as a system requirement, not as a single component.

The same applies here as we explained for natural venting. The calculation is only the first step. In close consultation with the responsible persons in the foundry, the necessary boundary conditions are agreed upon for the tool, namely the channel geometry and channel routing from the overflows to the venting insert, the connection of the overflows, and the placement of the venting insert(s) in the die frame.

5.4 Non-negotiable entry condition

The metal velocity should be reduced shortly before the venting block, before the metal flow reaches the venting inlet. Excessive metal velocity increases the risk of shot through and, in the case of natural venting, the risk to plant operators. It also increases maintenance requirements.

Key Takeaways

When talking about the piston:

- Consider whether the use of beryllium is allowed for the piston or not, then choose the best AMPCOLOY® for your piston
- Treat service life as a selection: copper alloy piston versus piston with solid or split-steel ring
- Treat cooling flow as a selection constraint. High conductivity cannot compensate for an insufficient heat removal path.

When talking about venting:

- In mold venting, performance is defined by the cross-section and geometry of the connecting channels. Performance depends primarily on the height of the gap in the vent block. The gap height has a potential influence, while the width has only a linear influence.
- Choose natural- or vacuum venting. But this can only be done in close consultation with the responsible people at the foundry and with knowledge of the problem to be solved.
- Protect vent entrances by reducing metal velocity upstream, regardless of venting mode.
- Validate selections with measurable production metrics, not assumptions.

Conclusion

The stability of HPDC depends on many different factors. The die-cast piston, the piston-chamber clearance, and reliable die venting are factors that can be influenced. AMPCOLOY® copper alloys support these goals when used in applications where heat dissipation determines performance and when the design provides the necessary cooling and load path architecture to translate material capability into production stability. A selection guide should therefore be practice-oriented: Define the requirements, select the appropriate AMPCOLOY® alloys, define the cooling and geometry constraints, and establish clear validation criteria. If these steps are followed, material selection becomes a controlled technical decision rather than a trial-and-error adjustment made after production has started.