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Commercialization of NASA's High Strength Cast Aluminum Alloy for High Temperature Applications

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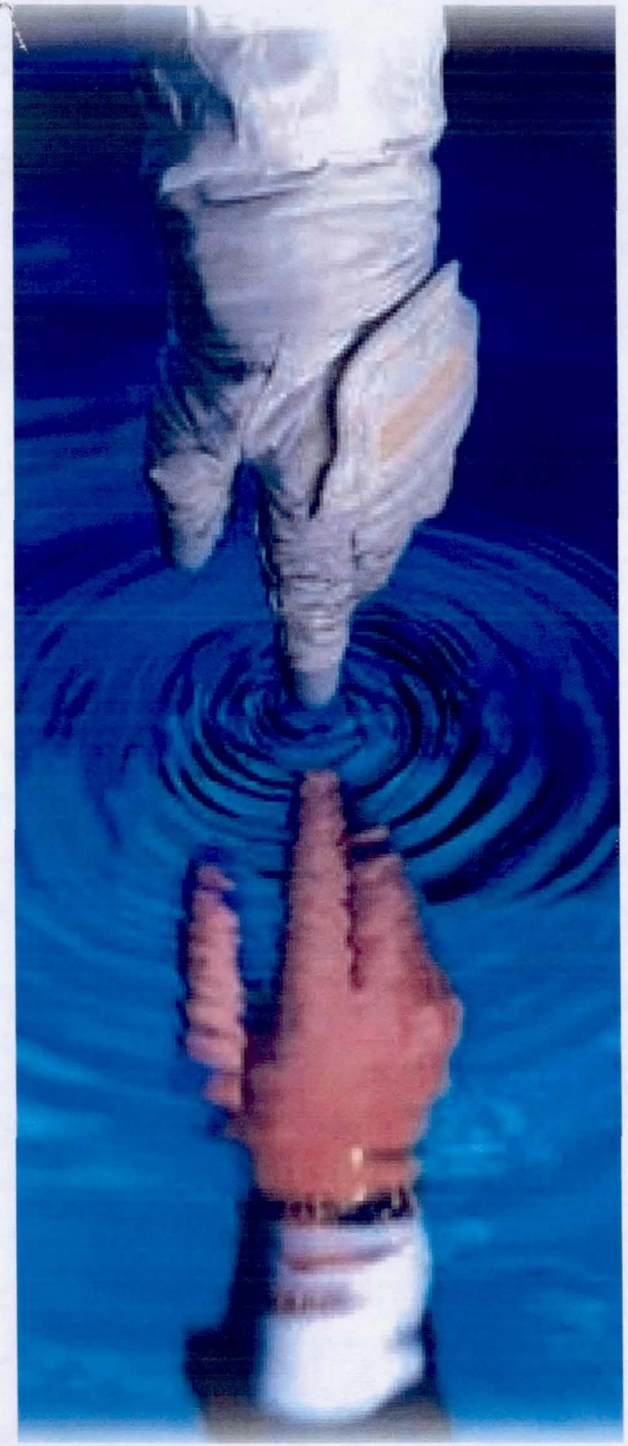
ABSTRACT

In this paper, the commercialization of a new high strength cast aluminum alloy, invented by NASA-Marshall Space Flight Center, for high temperature applications will be presented. Originally developed to meet U.S. automotive legislation requiring low-exhaust emission, the novel NASA aluminum alloy offers dramatic improvement in tensile and fatigue strengths at elevated temperatures (450°F-750°F), which can lead to reducing part weight and cost as well as improving performance for automotive engine applications. It is an ideal low cost material for cast components such as pistons, cylinder heads, cylinder liners, connecting rods, turbo chargers, impellers, actuators, brake calipers and rotors. NASA alloy also offers greater wear resistance, dimensional stability, and lower thermal expansion compared to conventional aluminum alloys, and the new alloy can be produced economically from sand, permanent mold and investment casting. Since 2001, this technology was licensed to several companies for automotive and marine internal combustion engines applications.



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Introduction

Marshall Space Flight Center

BACKGROUND

Originally developed by NASA as new piston alloys to meet U.S. legislation requiring low hydrocarbon emission for automotive engines, the novel NASA alloys also exhibit great improvement in strength at elevated temperatures for many other applications.

MILESTONES

- **1995-1996: NASA-Ford collaborative agreement to develop an alloy for dual-use technology under Partnership for Next Generation of Vehicles (PNGV) program.**
- **1996-1999: NASA-MSFC independently funded this alloy development.**
- **2002: First 2 U.S. patents were issued to NASA with several more U.S. patents under pending. Foreign patent filing is in progress.**
- **Present: Three (3) patent licenses have been granted to private companies for commercial products. On-going licensing negotiations with several companies.**

How NASA High Strength Alloy Can Help To Reduce Hydrocarbon Emission

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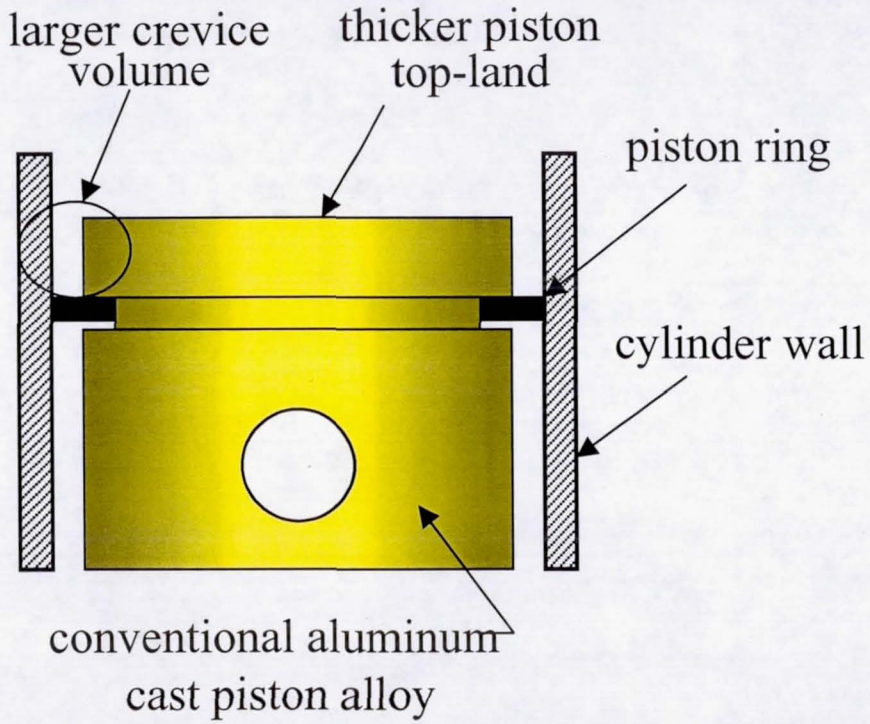

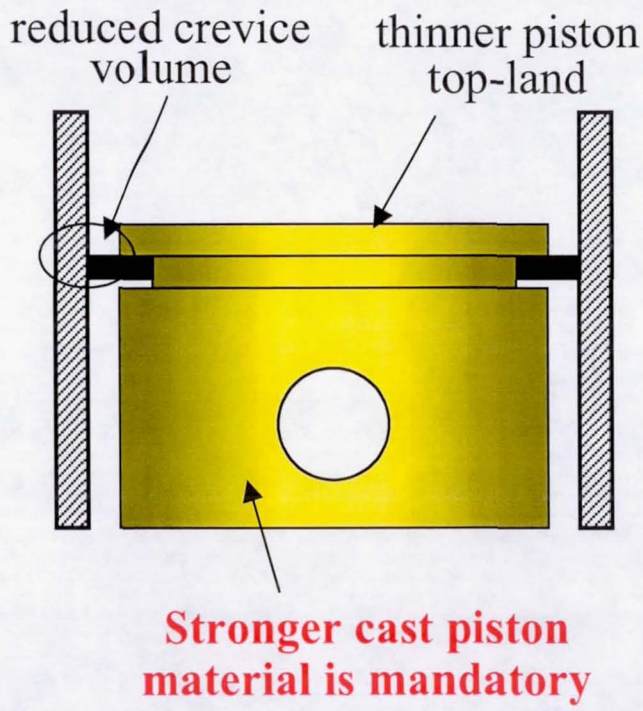

CONVENTIONAL PISTON DESIGN
LARGE CREVICE VOLUME
(Origin of Substantial Hydrocarbon Emission)

MODIFIED PISTON DESIGN
REDUCED CREVICE VOLUME
(Reduction of Hydrocarbon Emission)

How High Temperature Strength Alloy Can Improve Piston's Functional Requirements

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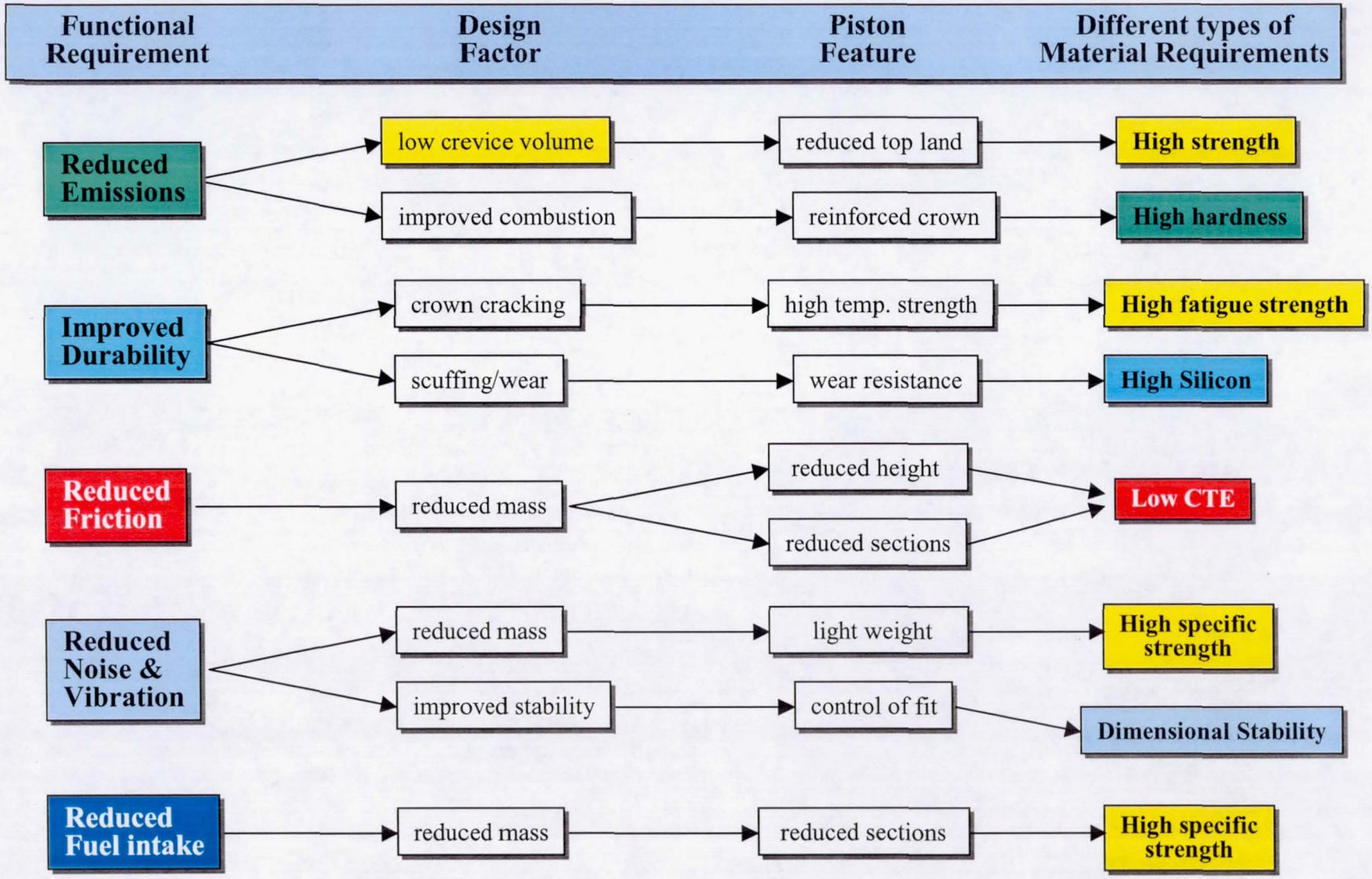

NASA's Novel Material Development Principles for New High Strength Cast Al Alloys

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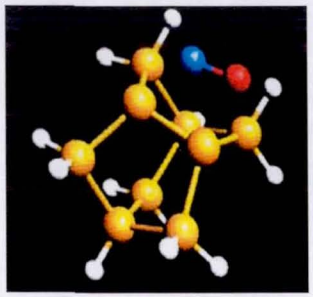
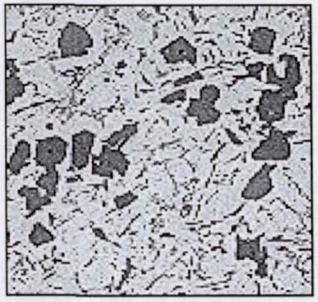


Develop New Strengthening Mechanisms

- Precipitates are coherent to the Al matrix.
- $L1_2$ crystal structure and low lattice mismatch.
- Low cost chemistry formulations for alloy (<$0.75/lb).

No Industry Infrastructure Modifications

- Baseline casting process for pistons: Permanent Mold.
- Can be used for sand and investment castings.
- Raw material can be recycled and mass produced.
- Technology can be adopted easily by any casting vendors.



Maintain Similar 300 Al-Series Properties

- High hardness, wear resistance, low CTE, machining, etc.
- NASA398 (Hyper-eutectic) comparable to 390 & Z16.
- NASA388 (Eutectic) comparable to 384 & Mahle 124.
- NASA358 (Hypo-eutectic) comparable to 356, 357.

Strength Comparison For Piston Alloys After 100 hrs. Soaking at 600 °F & Test at 600 °F

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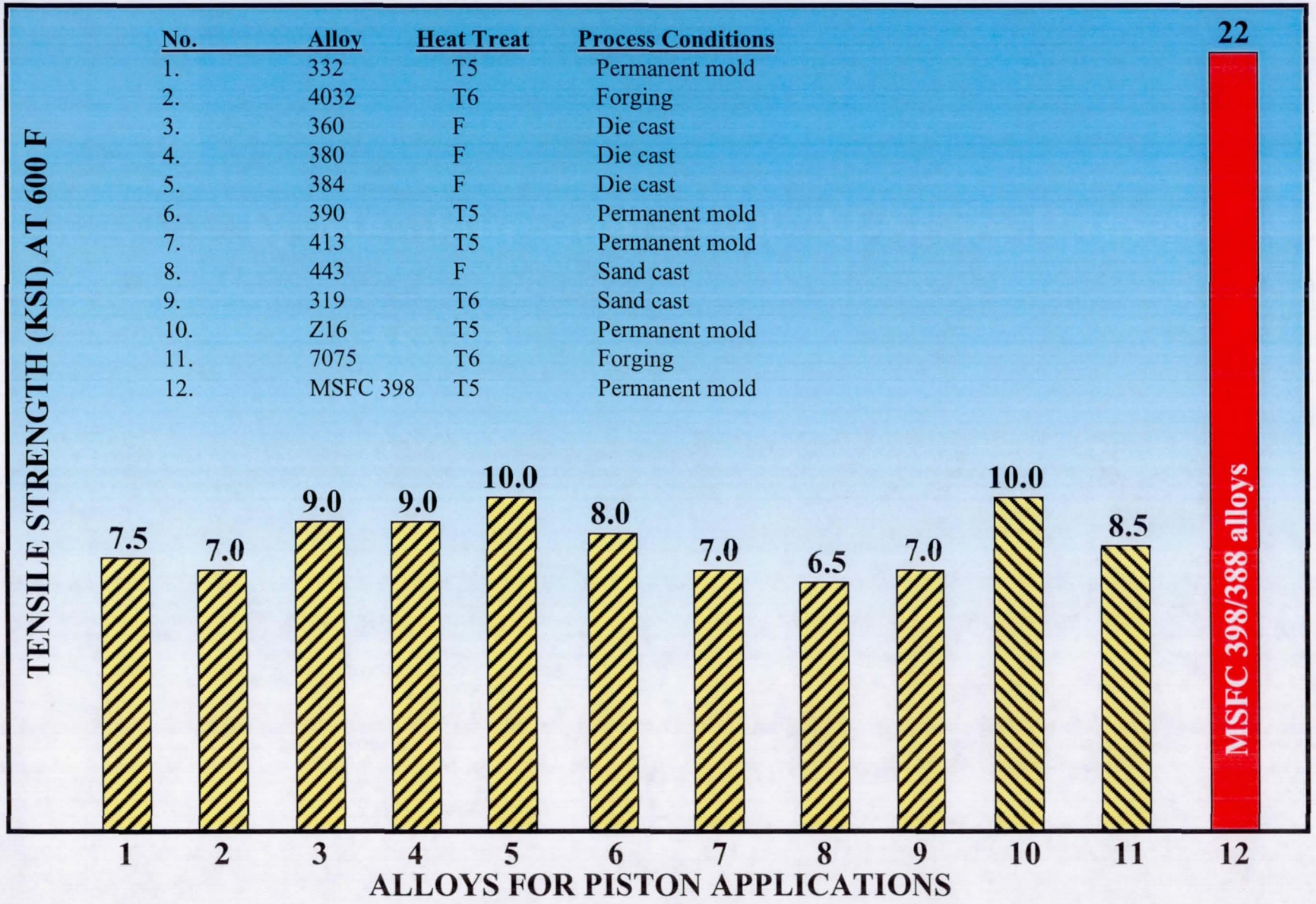
No.	Alloy	Heat Treat	Process Conditions
1.	332	T5	Permanent mold
2.	4032	T6	Forging
3.	360	F	Die cast
4.	380	F	Die cast
5.	384	F	Die cast
6.	390	T5	Permanent mold
7.	413	T5	Permanent mold
8.	443	F	Sand cast
9.	319	T6	Sand cast
10.	Z16	T5	Permanent mold
11.	7075	T6	Forging
12.	MSFC 398	T5	Permanent mold



Strength Comparison For Piston Alloys After 100 hrs. Soaking at 700 °F & Test at 700 °F

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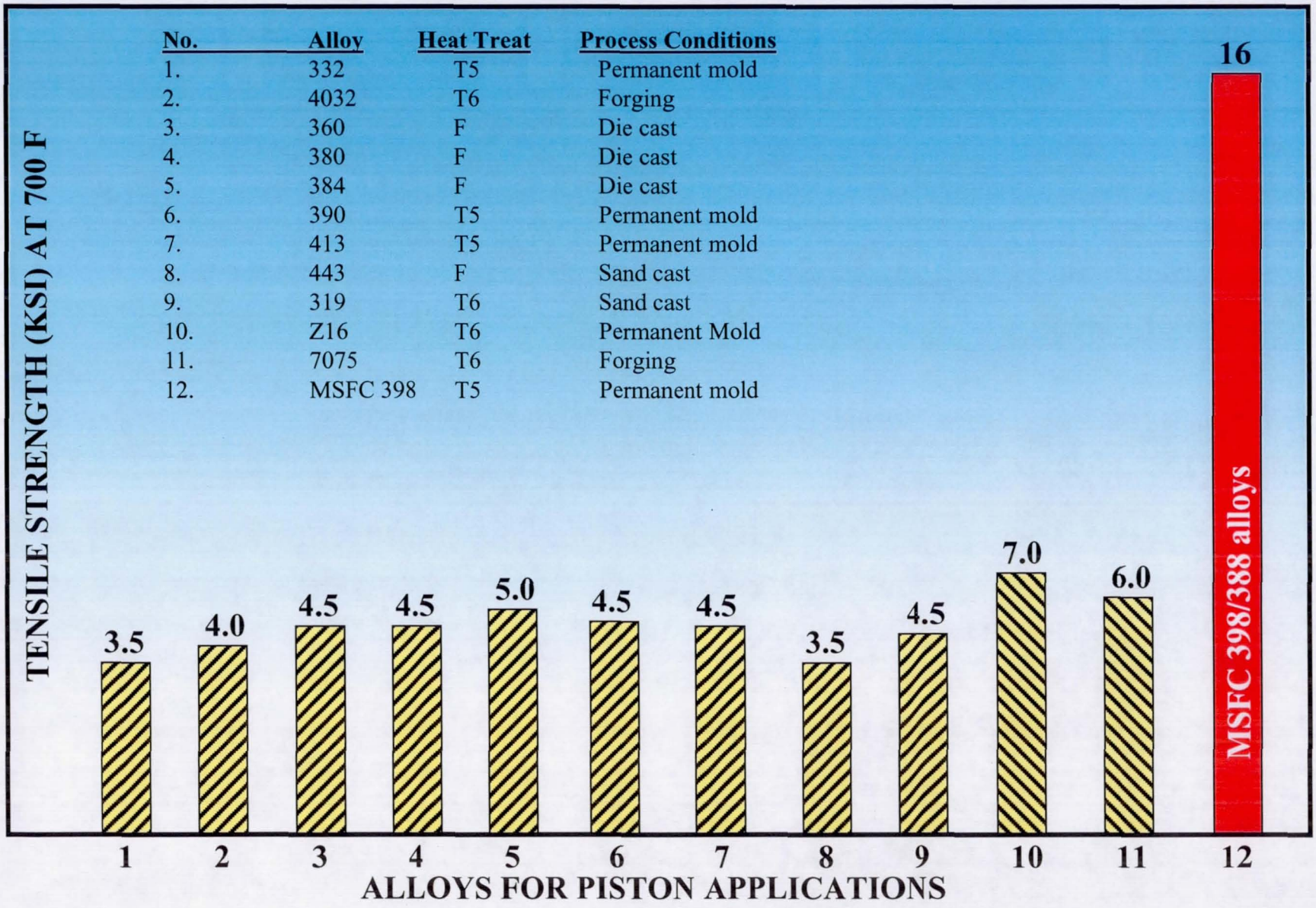
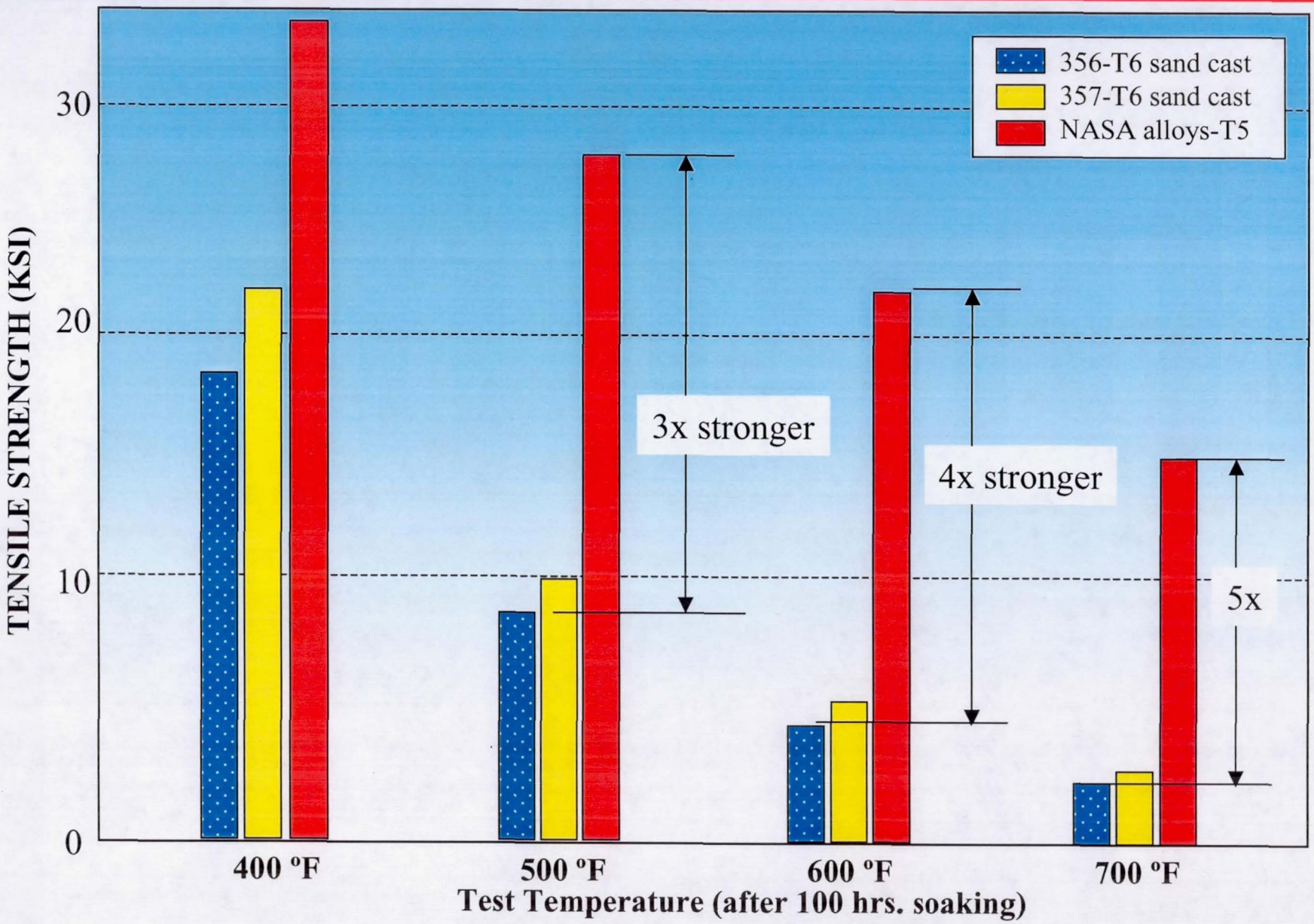
No.	Alloy	Heat Treat	Process Conditions
1.	332	T5	Permanent mold
2.	4032	T6	Forging
3.	360	F	Die cast
4.	380	F	Die cast
5.	384	F	Die cast
6.	390	T5	Permanent mold
7.	413	T5	Permanent mold
8.	443	F	Sand cast
9.	319	T6	Sand cast
10.	Z16	T6	Permanent Mold
11.	7075	T6	Forging
12.	MSFC 398	T5	Permanent mold



Tensile Strength Compare With Popular 356 & 357 Alloys for NON-Piston Applications



Fatigue Strength Compare With 224 Series Alloy for NON-Piston Applications

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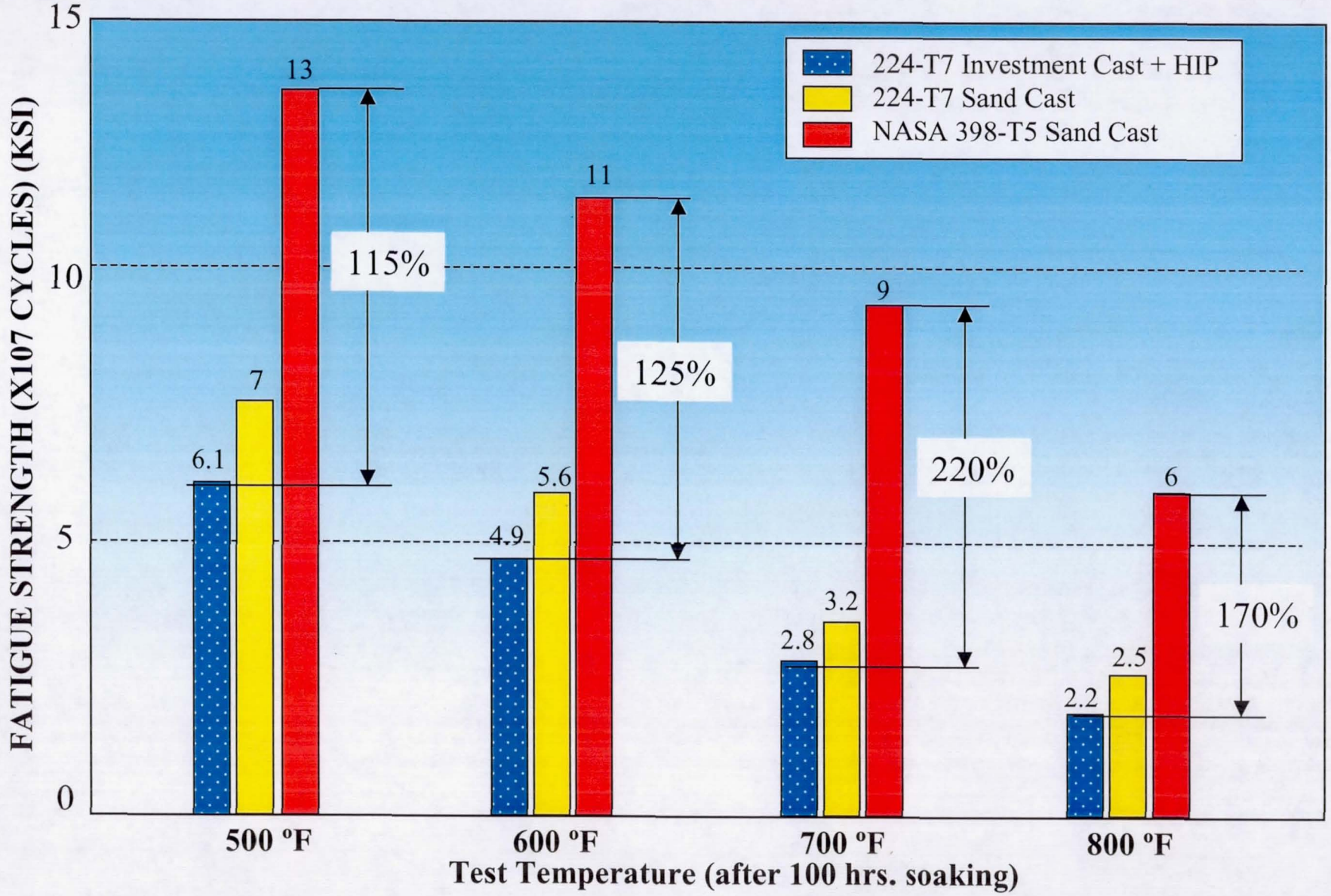

Material Selection Guide & Potential Applications

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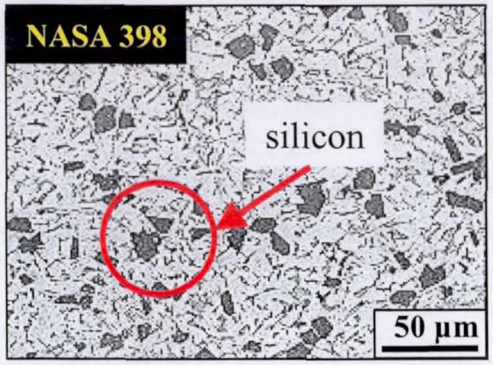
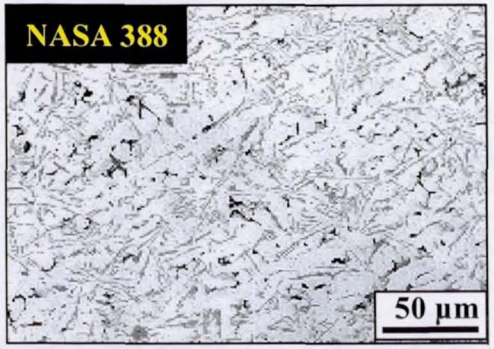
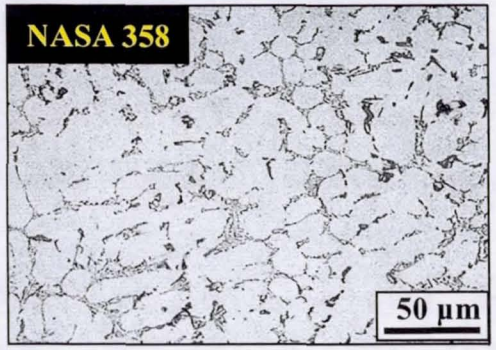






NASA alloys	Replacement	Potential Applications
NASA 398 (16% - 18% Si) Permanent Mold	390, Zollner Z-16 Mahle 126, AE 425 AC9B, KB alloys	Pistons Bearings A/C Compressors Cylinder liners Brake calipers
NASA 388 (10% - 13% Si) Sand Cast	336, 339, 383, 384 413, M124, 4032 2618, KS 1295	Pistons Cylinder blocks Cylinder heads Connecting rods Metal Composites
NASA 358 (6% - 9% Si) Sand Cast	319, 332, 355, 356, 357, 359, 360, 380 201, 206, 224, 242	Jet engine parts Turbochargers Metal composites Impellers Metal Composites

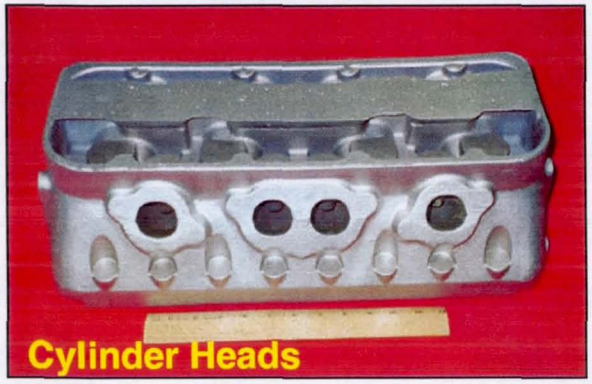
NASA New High Strength Cast Aluminum Alloys for High Temperature Applications

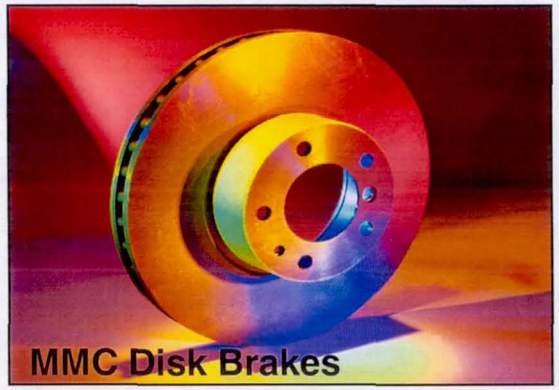

Turbo Charger


Cast Pistons

Jet Engine Parts

Originally developed by NASA as piston alloys to meet U.S. legislation requiring low hydrocarbon emission for internal combustion engines, the novel NASA alloys also exhibit dramatic increase in high temperature strengths for many aerospace and commercial applications.


Cylinder Heads


MMC Disk Brakes


Forged Pistons