



Casting Emission Reduction Program

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**The Contribution of Metal Castings to Military Rolling  
Stock: High Mobility Multipurpose Wheeled Vehicle  
(HMMWV) Case Study**

**Technikon # 1410-500**

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*(Revised for public distribution)*



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## **The Contribution of Metal Castings to Military Rolling Stock: High Mobility Multipurpose Wheeled Vehicle (HMMWV) Case Study**

### **Technikon # 1410-500**

This report has been reviewed for completeness and accuracy and approved for release by the following:

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## Overview

“[Metalcasting] is considered the backbone of American industry. The metalcasting industry plays a critical role in every major manufacturing sector in the United States - whether it is energy, transportation, agriculture, aerospace or national defense. Metalcasting is unique among metal-forming processes. It allows us to produce complex components in any metal, ranging in weight from several tons to less than an ounce,” according to Foundry Industry Recycling Starts Today (FIRST)<sup>1</sup>.

The Metal Casting Industry is comprised of mostly small businesses located throughout the United States. About 80% of these small businesses employ less than 100 people.

“The Metal Casting Industry is one of the largest recyclers in North America and perhaps the world, saving about 15-20 million tons of scrap metal from disposal into landfills and junkyards each year, and using this waste as a source of raw material to produce useful products,” according to the Cast Metals Coalition<sup>2</sup>.

The automotive and light truck industries are the largest end users of casting products. Castings can be found in engine blocks, cylinder heads, suspension systems, differentials, intake manifolds, wheels, and transmission cases.

“Automotive and other transportation equipment use nearly 35% of all castings produced. Engine blocks, braking components and pistons are just a few of the cast parts used in motor vehicles. Approximately 10% of all castings produced are solely for military applications. Tanks, planes, ships, weapons and a myriad of other military hardware contain thousands of cast parts. The figures do not begin to include the dual-use applications that support the military,” reports the metal recycling organization FIRST. Examples include infrastructure components at the Department of Defense (DoD) installations, i.e. pumps, pipes, fittings, structural castings, rebar, storm drain parts and manhole covers<sup>1</sup>.

Simply stated, you cannot have a “rolling vehicle” without the engine, and you cannot have an engine without castings.

The remaining percentage of all castings produced in the United States are used in other applications such as the construction industry, consumer use, railroads, mining machinery, and a long list of other everyday items as seen in Table 1.

The focus of this report is on the critical role castings play in the Department of Defense. The DoD does not buy castings directly. It purchases equipment or components that contain castings. It relies on outside suppliers and foundries to supply them with products, including weapon systems and vehicles that meet their military needs. Foundries are vital to these suppliers completing these products.

**Table 1 Current Market Uses Of Castings**

Gray Iron	Cars, light trucks, and engines	5.02 million tons
Ductile Iron	Cars, light trucks, pipes and valves	3.92 million tons
Malleable Iron	Cars, light trucks, and fittings	149,000 tons
Graphite Iron	Internal combustion engines and motor vehicles	66,00 tons
Steel	Railroads, construction machinery and equipment, motor vehicles, and mining	1.17 million tons
Aluminum	Motor vehicles and internal combustion engines	1.87 million tons
Copper-base Alloys	Valves and fittings	302,000 tons
Magnesium	Motor vehicles, power tools, and sporting goods	78,000 tons
Zinc	Motor vehicles and parts	298,000 tons
Investment Castings	Corrosion-resistant stainless steel pumps and valves for use in chemical plants, petrochemical applications, food products and other corrosive environments.	145,000 tons

The above table is a summary of information contained in the annual report entitled “U.S. Metal Casting Demand & Supply Trends-2002,” is written by Kenneth H. Kirgin, Stratecasts, Inc. and Michael J. Lessiter, Editor/Publisher and published by the American Foundry Society.



## Off-Shore Foundry Production Concern

U.S. foundries are capable of applying the latest in technologies and offering the highest quality products available anywhere in the world. Yet, sadly, the majority of the castings made today come from foreign countries.

Many of the U.S. foundries have closed their doors because they cannot afford to upgrade their systems and processes; they lack the ability to afford research and development, or cannot keep up with tough environmental constraints in the United States. Overseas competition, especially from China, has forced the price of castings per pound delivered to the U.S. to be less than what foundries in the States can produce.

The American Foundry Society states:

“With about one-third of all castings shipped from American foundries going into the automotive and light truck market, global competition has also had a dramatic impact on U.S. casting shipments. Imports of other cast parts have also grown during the past two decades. Most significantly we have seen growing imports in gray iron municipal castings and diesel engine components, malleable iron fittings, steel construction parts and aluminum die cast automotive parts<sup>3</sup>.”

The following information is a summary of the Top Ten nation’s metric tonnage production/shipments (of all types of metals) in 2001 according to a report published by the American Foundry Society<sup>4</sup>.

China.....	14.8 million tons
U.S. ....	11.8 million tons
Japan .....	5.8 million tons
Germany.....	4.6 million tons
India .....	3.1 million tons
France.....	2.5 million tons
Italy .....	2.3 million tons
Mexico .....	1.8 million tons
Brazil.....	1.7 million tons
Korea.....	1.6 million tons

At the 2004 CERP (Casting Emission Reduction Program) Metal Casting Technology Forum, Dr. Sheila Ronis Stated,

“The US metal casting industrial base is eroding daily and this situation has enormous national security implications. The nation is facing a time when we are becoming so dependent on foreign countries for critical components and systems, we may have lost our ability to engineer, manufacture or manage the engineering

and manufacturing processes. As OEMs around the country, both for the military and U.S. industrial corporations outsource more and more of their engineering and manufacturing, our ability to control supply chains is disappearing.

It is not difficult to think about potential scenarios where a country, such as China, India, Russia, France or Germany, is controlling our ability to make and use the necessary tools for war. It is already happening. There is even the possibility of any one of these countries telling its local company that they may not sell a critical component to the United States, deliberately holding us hostage, because they do not agree with our foreign policy decisions. This is a national security issue. It would be a shame for the United States to be dependent on a country like China for its Howitzers! But, that is not as far fetched as it sounds.”

The reason the casting industry is essential to our national defense is; “Castings are the most cost-effective and direct way to obtain a complex metal shape – saving 50-80% compared to other manufacturing processes”, according to Dan Gearing, Program Manager for the Defense Logistics Agency’s metalcasting program in Fort Belvoir, Virginia.<sup>5</sup>

## HMMWV Case Study

The High Mobility Multi-purpose Wheeled Vehicle (HMMWV) is the replacement vehicle for the M151 series jeeps. The HMMWV's mission is to provide a light tactical vehicle for command and control, special purpose shelter carriers, and special purpose weapons platforms throughout all areas of the modern battlefield. The HMMWV is equipped with a high performance diesel engine, automatic transmission, and a four-wheel drive that is air transportable and droppable from a variety of aircraft. The HMMWV can be equipped with a self-recovery winch capable of up to 6000 pound 1:1 ratio line pull capacity and can support payloads from 2,500 - 4,400 pounds depending on the model. The HMMWV is produced in several configurations to support weapons systems; command and control systems; field ambulances; and ammunition, troop and general cargo transport. Based on the M998 chassis, using common components and kits, the HMMWV can be configured to become a troop carrier, armament carrier, S250 shelter carrier, ambulance, TOW missile carrier, and a Scout vehicle.

LTV HMMWV M998-series multipurpose wheeled vehicle variants include:

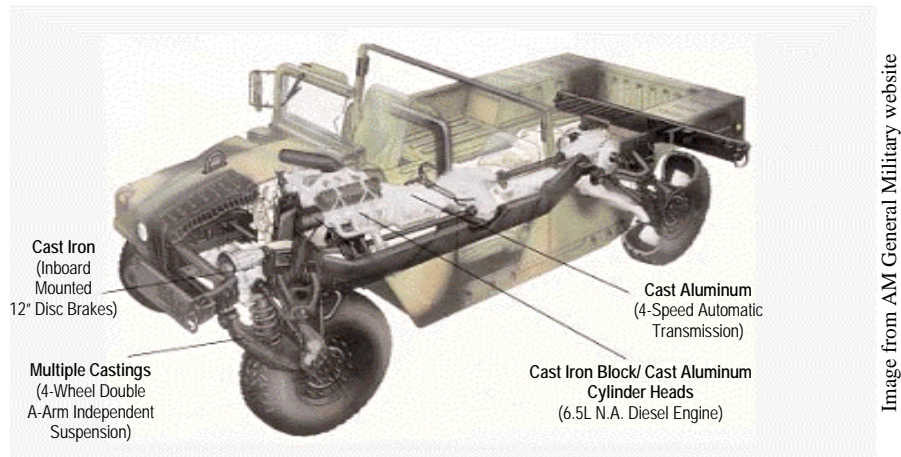
- M998 cargo/troop carrier without winch
- M1038 cargo/troop carrier with winch
- M966 TOW missile carrier, basic armor, without winch
- M1036 TOW missile carrier, basic armor, with winch
- M1045 TOW missile carrier, supplemental armor, without winch
- M1046 TOW missile carrier, supplemental armor, with winch
- M1025 armament carrier, basic armor, without winch
- M1026 armament carrier, basic armor, with winch
- M1043 armament carrier, supplemental armor, without winch
- M1044 armament carrier, supplemental armor, with winch
- M996 mini-ambulance, 2-litter, basic armor
- M997 maxi-ambulance, 4-litter, basic armor
- M1035 soft-top ambulance, 2-litter
- M1037 S-250 shelter carrier, without winch
- M1042 S-250 shelter carrier, with winch
- M1069 tractor for M119 105-mm light gun

The military, particularly the Army, places its “rolling stock” into three classifications: military light trucks, medium-duty trucks, and heavy-duty vehicles commonly called semis. Using the HMMWV as an example, the HMMWV body is comprised mostly of sheet metal aluminum, but the main Powertrain consists of a Diesel engine, transmission, brakes and steering components that contain castings, see Table 2 (Derived from Army Technical Manual TM 9-2320-280-10). The majority of the components listed in Table 2 are assemblies containing one or more castings such as a transfer case, transmission, brake caliper, steering gear, or oil pump. Each component

has been assigned a National Stock Number (NSN) and unique part number by the government to allow ready identification and ordering by our war fighters in the field. It is because of military deployment conditions that most parts are identified as assemblies rather than discrete castings in the maintenance manual. Only a few of the parts listed in Table 2 are individual castings intended for bolt on use; such as an exhaust or intake manifold.

Castings are found mainly in the Powertrain, which consists of the engine, transmission, transfer case and geared hubs. The materials used in the Powertrain assembly consist of iron, aluminum and steel. It is difficult to obtain precise weights on cast components of the HMMWV, but it is estimated that 10% of the base HMMWV weight is made up of castings.



**Figure 1 Major Casting Components in Typical HMMWV**



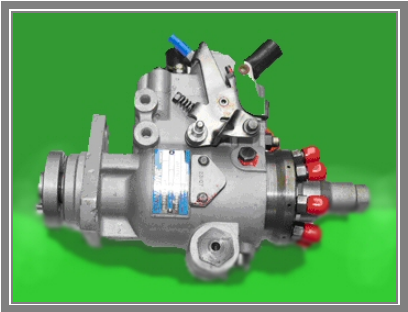
**Figure 2 HMMWV Models**

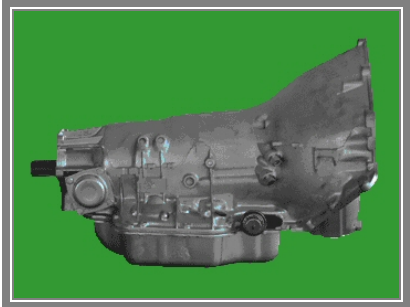



**Table 2 HMMWV Components Containing Metal Castings**


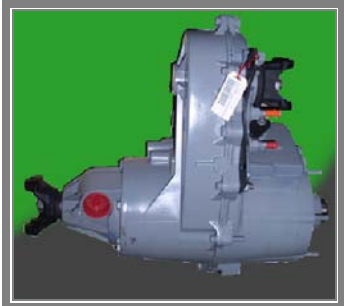
	DESCRIPTION	NATIONAL STOCK NUMBER	PART NUMBER	QUANTITY
<b>ENGINE</b>				
 <p><i>6.2 Liter Diesel Engine</i></p>	Engine	2815012313672	5705684	1
	 <p><i>6.2 Liter Diesel Engine</i></p>	Block		23500104
Cylinder head			SC300079	2
Oil pump assembly		2815014750825	12556342	1
Oil filter mount bracket		4730011687872	12338780	1
Intake manifold		2815011687909	23500035	1


	DESCRIPTION	NATIONAL STOCK NUMBER	PART NUMBER	QUANTITY
 <p><i>Generator to Engine Bracket</i></p>	Generator to engine bracket	5342012577706	5597344	1
 <p><i>Belt Tensioner</i></p>	Tensioner	2920014207894	12460353	1
	Alternator belt adjusting arm	2920014731763	12460442	1
	Alternator bracket	2590014444365	12338786-1	1
	Exhaust manifold - Left side	2815011687918	12338787	1
	Exhaust manifold - Right side	2815011687917	12338788	1
	Fuel metering pump	2910011992355	DB2829-4523	1



	DESCRIPTION	NATIONAL STOCK NUMBER	PART NUMBER	QUANTITY
 <p><i>Fuel Pump</i></p>	Fuel pump	2910011687905	12342893	1
	Water crossover	6620011468006	14077122	1
	Water outlet	2930014607507	12554091	1
	Water pump assembly	2930011937802	15633485	1
	Engine mount, R.H.	2510011856115	12339133	1
	Engine mount, L.H.	2510011856112	12339132	1

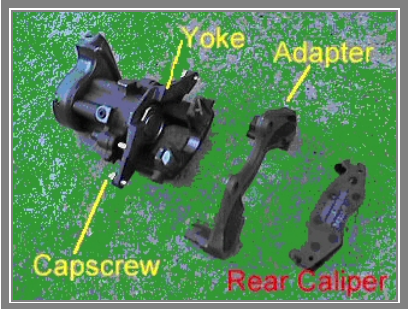
	DESCRIPTION	NATIONAL STOCK NUMBER	PART NUMBER	QUANTITY
<b>TRANSMISSION/TRANSFER CASE</b>				
 <p><i>Transmission</i></p>	Transmission	2520011612136	12339146	1
	Transmission housing	3040014489611	8629991	1
	Transmission valve assembly	2520011609570	8655027	1
	Transmission adapter assembly	2520011757220	12339134	1
	Transmission housing, rear	2520012063877	5740514	1
	Transmission housing	2520012063875	5740503	1
 <p><i>Transfer Case</i></p>	Transfer transmission	2520014527569	12342643-1	1


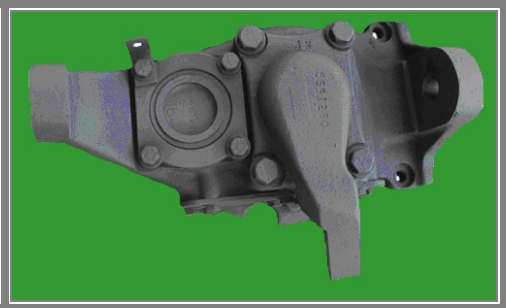



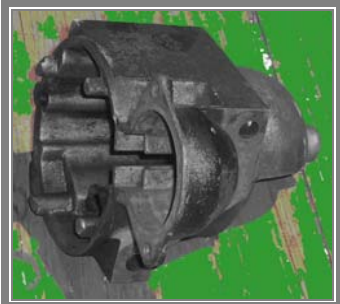
	DESCRIPTION	NATIONAL STOCK NUMBER	PART NUMBER	QUANTITY
 <p><i>Transfer Case Housing</i></p>	Transfer case housing	3040013591116	17292	1
 <p><i>Rebuilt Transfer Case</i></p>	Transfer case mechanical housing	3040013604448	16221	1
	Transmission oil pump body		24205778	1
	Transmission oil pump body cover		24202681	1

	DESCRIPTION	NATIONAL STOCK NUMBER	PART NUMBER	QUANTITY
 <p><i>Steering Gear Body</i></p>	<b>STEERING SYSTEM</b>			
	Steering idler arm	2530014203839	6004839	1
	Steering gear arm	2530014205180	6004838	1
	Steering gear	2530014231796	12460232	1
	Power steering pump assembly	2530011687876	12339495	1
	Steering drag link	2530011859651	12338622	1
	power steering pump bracket	2530012035661	5590725	1
	Power steering gear housing	26049931	26049931	1

	DESCRIPTION	NATIONAL STOCK NUMBER	PART NUMBER	QUANTITY
<b>BRAKES</b>				
 <p><i>Brake Caliper</i></p>	Parking brake caliper	2530011747441	D00-09102	1
	Parking inner side cam		5740910	1
	Parking brake outer side cam		5740911	1
 <p><i>Brake Caliper</i></p>	Parking brake caliper bracket		5590530	1
	Parking brake rotor	2530011849821	5577659	1
	Rear parking brake caliper assembly, L.H.	2530013336080	12173602	1
	Rear parking brake caliper assembly, R.H.	2530013338263	12173601-01	1

	DESCRIPTION	NATIONAL STOCK NUMBER	PART NUMBER	QUANTITY
 <p><i>Brake Caliper Parts</i></p>	Rear parking brake yoke, R.H. and L.H.	2530014628079	12821501	2
	Rear parking brake rotor	2530011856712	106980-02	2
	Rear service brake caliper assembly, R.H.	2530012076256	103700-02	1
	Rear service brake caliper assembly, L.H.	2530012042583	103700-01	1
	Front service brake caliper assembly, L.H.	2530012076256	103700-02	1
	Front service brake caliper assembly, R.H.	2530012042583	103700-01	1
	Front disk brake adapter, L.H.	2530011853879	5578809	1
	Front brake valve adapter, R.H.	2530013141129	10453002	1
	Disk brake yoke	2530011856713	104534-01	2
	Master cylinder	2530011797589	2232134	1
	Hydro-Booster	2530013579708	5399396	1

	DESCRIPTION	NATIONAL STOCK NUMBER	PART NUMBER	QUANTITY
<b>AXLES/PROPELLER SHAFT/SUSPENSION</b>				
 <p style="text-align: center;"><i>Differential</i></p>	Shock absorber lower control arm bracket	2510011877037	5590363	4
	Differential axle assembly – front	2520013583160	5597777	1
	Differential axle assembly – rear	2520012912975	12338415-3	1
	Wheel drive spindle – front	2530012035746	5598767	2
	Wheel drive spindle – rear	2530014133653	6009352	2
	Joint assembly	2520011891636	5740550	4
	Steering arm cover – left side	2530012035662	5591280	1
	Steering arm cover – right side	2530012035663	5591279	1
 <p style="text-align: center;"><i>Rebuilt Geared Hub</i></p>	Knuckle and gear hub assembly		5593993	4

	DESCRIPTION	NATIONAL STOCK NUMBER	PART NUMBER	QUANTITY
	U-Joint cross assembly		2-5-668X	3
	Shock mount bracket	2510011877037	12338315	4
	Stabilizer bar connecting link	3040011863718	12338323	2
 <p><i>Cast Alternator Case</i></p>				
	<b>ELECTRICAL</b>			
	Starter motor assembly	2920011687891	MFY-6701UT	1
 <p><i>Starter Motor Pinion Housing</i></p>				
	Starter motor star pinion housing	2920012909245	PS-1475SS	1
	Alternator assembly	2920014209968	12447109	1
	Generator	2920009092483	10929868	1

## **Conclusion**

Clearly the American foundry industry plays a critical role in supporting the military mission and our war fighters. The cast metal parts and assemblies identified for the HMMWV maintenance manual are typical across a broad range of military rolling stock. An important concern is the reliance of the foreign imports and the closing of many foundries.

This study identified 89 castings in a basic Humvee. Most of these castings are in the drive train, suspension and brakes of this vehicle. Without castings the Humvee would not meet its performance requirements.

Keeping the metalcasting business alive in the United States is vital. Diminishing manufacturing capability is affecting many core processes that are required to manufacture DoD weapon systems. The U.S. Foundry Industry is one of these core processes.

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## APPENDIX A GLOSSARY

<b>AFS</b>	American Foundry Society
<b>ARDEC</b>	US Army Armament Research, Development and Engineering Center
<b>CARB</b>	California Air Resources Board
<b>CERP</b>	Casting Emission Reduction Program
<b>CISA</b>	Casting Industry Suppliers Association
<b>CRADA</b>	Cooperative Research & Development Agreement
<b>DoD</b>	Department of Defense
<b>EPA</b>	Environmental Protection Agency
<b>FIRST</b>	Foundry Industry Recycling Starts Today
<b>HMMWV</b>	High Mobility Multi-purpose Wheeled Vehicle
<b>LTV</b>	Light Tactical Vehicle
<b>OEM</b>	Original Equipment Manufacturer
<b>TOW</b>	Tube launched, Optically tracked, Wire guided
<b>USCAR</b>	United States Council for Automotive Research

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## APPENDIX B REFERENCES AND RESOURCES

- <sup>1</sup> *Anonymous.* "Frequently Asked Questions," FIRST - Foundry Industry Recycling Starts Today, November 11, 2002. 1-2 [<http://www.foundryrecycling.org/faqs.html>]
- <sup>2</sup> *Anonymous.* "Metal Casting Industry Profile," The Cast Metals Coalition, January 22, 2003. 2 [<http://cmc.aticorp.org/industryprofile.html>]
- <sup>3</sup> *Anonymous.* "Facts & Figures About the U.S. Foundry Industry," American Foundry Society, February 24, 2003. 8 [<http://www.afsinc.org/Trends/FactsandFigures.htm>]
- <sup>4</sup> *Anonymous.* "2003 AFS Metalcasting Forecast & Trends", Stratecasts, Inc. Booklet October 2002. 26-28
- <sup>5</sup> *Lessiter, Michael J.* "Mission Accomplished: Advancement in Military Castings," Engineered Casting Solutions, Spring 2003, 21-23. [<http://www.castolutions.com>]