

INDUSTRY SEGMENT
PROFILE

SIC 3519

***Internal Combustion
Engines, nec***

EPRI Center for Materials Fabrication

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Thumbnail Sketch of Typical Establishment
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SIC 3519 Internal Combustion Engines , nec

Average No. of Employees*	198.0
Median No. of Employees	17
Annual Shipments	\$60.1 Million
Annual Electricity Consumption	7.98 Million kWh
Electricity Opportunities	Induction hardening and vacuum thermal treatment for high strength engine components.
Technology Trend	Increased use of electronics to monitor and enhance engine performance.
Industry Issues	Lower emission designs to accommodate tougher EPA standards.

** Companies such as Cummins, Caterpillar, Detroit Diesel and Navistar employ significant numbers at large plants, somewhat distorting the average numbers for a "typical" establishment.*

Industry Characteristics

The production of Internal Combustion Engines, nec is dominated by 4 large companies – Cummins Engine Company Inc., Caterpillar Inc Engines Div., Detroit Diesel Corp, and Navistar.

Overall, the industry segment is made up of companies manufacturing the following products:

- ◆ Diesel and semi-diesel engines: for stationary, marine, traction, etc.
- ◆ Diesel engine parts
- ◆ Internal combustion engines, except aircraft and non-diesel automotive
- ◆ Tank engines and engine parts, internal combustion: military
- ◆ Outboard motors, except electric, etc

The segment does not cover companies that are primarily engaged in,

- ◆ Manufacturing aircraft engines.
- ◆ Manufacturing non-diesel automotive engines.

The major industries supplied products by the diesel engine equipment and parts segment are listed below (in order of importance):

- ◆ Highway trucks, buses and automotive diesel powered vehicles.
- ◆ Lawn & garden equipment.
- ◆ Marine industry.
- ◆ Construction machinery, farm machinery, railroad and mining equipment.

Within the SIC 3519 segment, the breakdown of the different product classifications is shown in Figure 1.

- ◆ Parts and accessories comprise 33% of total industry shipments. Fuel injection systems account for 12% of this total.
- ◆ Diesel, semi-diesel and dual fuel engines for automobiles, highway trucks and buses comprise 27% of total industry shipments. Retail sales of medium and heavy duty trucks are shown in Table 1.
- ◆ Diesel, semi-diesel and dual fuel engines (except automobile, highway truck, bus and tank) represents 12.8% of the total industry shipments.
- ◆ Gasoline engines, including lawn and garden engines, represent 13.3% of total industry shipments.
- ◆ Other internal combustion engines not elsewhere classified, make up 13.9% of total industry shipments.

Table 1. Retail Sales of Medium and Heavy Duty Trucks by Weight Class and Body Type

Gross Vehicle Weight	1995		1996		1997		1998	
	Units	% of Total						
Medium Duty Trucks	186,974	48.2	188,921	52.6	197,588	52.5	214,768	50.6
14,001-16,000 lbs (Class 4)	52,623	13.6	58,723	16.4	56,526	15.0	43,358	10.2
Domestic	46,261	11.9	53,286	14.8	49,607	13.2	33,603	7.9
Imports	6,362	1.6	5,437	1.5	6,919	1.8	9,755	2.3
16,001-19,000 lbs (Class 5)	4,291	1.1	7,264	2.0	9,262	2.5	28,189	5.9
Domestic	1,241	0.3	4,150	1.2	6,019	1.6	20,597	4.9
Imports	3,050	0.8	3,114	0.9	3,243	0.9	4,592	1.1
19,001-26,000 lbs (Class 6)	23,336	6.0	19,406	5.4	18,111	4.8	31,556	7.4
Domestic	19,771	5.1	16,325	4.5	14,728	3.9	27,782	6.5
Imports	3,565	0.9	3,081	0.9	3,383	0.9	3,774	0.9
26,001-33,000 lbs (Class 7)	106,724	27.5	103,528	28.8	113,689	30.2	114,665	27.0
Domestic	104,675	27.0	102,197	28.5	112,364	29.9	223,598	26.5
Imports	2,049	0.5	1,331	0.4	1,325	0.4	2,067	0.5
Heavy Duty Trucks								
Over 33,000 lbs (Class 8)	201,303	51.8	170,009	47.4	178,551	47.5	209,483	9.4
Total U.S. Sales								
	388,277	100.0	358,930	100.0	376,139	100.0	424,251	100.0

Source: American Automobile Manufacturers Association

In 1997, total internal combustion engines (except outboard, nondiesel automotive, aircraft and military tank) increased 2% from 1996 to just under 24 million engines.

- ♦ The number of non-automotive diesel, semi-diesel, and dual-fuel engines produced in 1997 amounted to 314,000, a 14% increase from the 270,000 reported in 1996.
- ♦ There were 763,000 automotive diesel, semi-diesel, and dual-fuel engines produced in 1997, 10% more than the 685,000 produced in 1996.
- ♦ The lawn and garden segment, including chainsaws, total nearly 19 million engines in 1997, but represented less than 10% of total shipment value for SIC 3519.

Exports exceeded imports by 29% in 1997 in terms of value at port for all of SIC 3519. In 1996, exports had exceeded imports by only 0.5%.

In 1997, exports increased about 22% compared to 1996 and imports dropped about 5%.

There were significant variances within certain sectors of SIC 3519; exports were more than 5 times higher than imports for automotive diesel engines and nearly 60% higher than imports for non-automotive diesel engines.

- ◆ According to 1997 Census data, the U.S. exported 81,000 automotive diesel engines valued at \$815 million, and imported 19,000 automotive diesel engines valued at \$144 million.
- ◆ According to Census data, the U.S. exported 103,000 non-automotive diesel engines valued \$1.4 billion in 1997, and imported 340,000 non-automotive diesel engines valued at \$885.5 million.
- ◆ The historical trend has been for imports to be less of a percentage of total sales for higher weight trucks.
 - Imports have been slowly increasing for medium weight trucks.

Imports have not yet become a factor in class 8 heavy-duty trucks.

In total, the segment represents a \$17.3 billion industry with the manufacturing operations concentrated in the Midwest.

- ◆ The leading states in terms of shipments are Indiana, Illinois, Wisconsin, Michigan and Ohio.
- ◆ Four states (Indiana, Illinois, Wisconsin and Michigan) account for nearly 68% of US shipment value.

Overall, there are approximately 294 manufacturing facilities in the U.S.

- ◆ 45.9% of these facilities employ 20 or more employees. 26.5% of the establishments have 100 or more employees.

The average wage rate for production workers manufacturing internal combustion engines is \$16.89 per hour, 33.2% higher than the average wage rate for all U.S. hourly manufacturing plant workers (\$12.68 per hour).

The energy intensity involved in internal combustion engines production is comparable in energy intensity to the motor vehicle parts and accessories industry. In 1996 the segment,

- ◆ Purchased 2,292 million kWh of electricity at cost of \$93.4 million. In the same year, the cost of purchased fuels was \$28.8 million.
- ◆ Averaged 0.31kWh per dollar of value added. This is about the same as that calculated for the fabricated metal industry (0.33kWh/\$VA).

The industry growth is tied very closely to the performance of the general economy. The major manufacturers are projecting growth rates of 5 to 10 percent annually through 2002.

National Statistics

Figure 1. National Data of End-Product Classifications, 1996

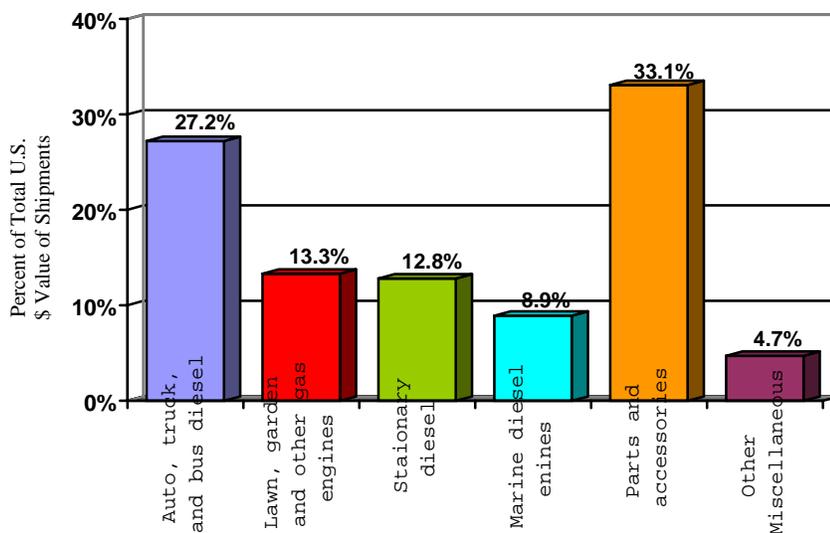


Table 2. Trends for SIC 3519 Internal Combustion Engines, nec

	1992	1993	1994	1995	1996
Industry Shipments (\$Millions)	11,826.9	12,600.3	15,307.9	16,641.9	17,286.1
Employment (1000s)	56.6	49.5	54.7	57.5	56.9
New Capital Expenditures (\$Millions)	461.1	370.7	406.1	499.4	527.5
Electricity Purchased (Millions kWh)	1,980.3	2,081.6	2,164.8	2,229.3	2,292.0
Full Production Capacity Utilization Rate (5)	79	75	86	77	75

Source: Census Data

Table 3. Top Ten U.S. Companies Ranked by Revenues

Firm	Location	1997 Sales (Millions)
Cummins Engine Division	Columbus, IN	5,257
Caterpillar Engine Division*	Mossville, IL	3,950
Detroit Diesel Corp	Detroit, MI	2,251
Navistar Engine Division	Chicago, IL	1,609
Briggs and Stratton Corp	Milwaukee, WI	1,327
Mercury Marine	Fond du Lac, WI	1,140
Outboard Marine Corp	Waukegan, IL	980
Cooper Energy Services	Mount Vernon, OH	736
Consolidated Diesel Co**	Whitakers, NC	520
Tecumseh Products Co	Grafton, WI	440

Source: Ward's Business Directory

* Caterpillar acquired Perkins Engines in 1998.

** Consolidated Diesel Co is 50% owned by Cummins Engine Company Inc. and 50% owned by Case Corporation.

Industry Data by State (1997)

Table 4. Industry Data by State

State	Establishments	Value of Shipments (\$Millions)	% of U.S. Shipments
Indiana	9	6,625	27.7
Illinois	23	4,950	20.7
Wisconsin	23	3,300	13.8
Michigan	19	2,320	9.7
Ohio	19	736	3.1
North Carolina	10	520	2.2
Tennessee	9	320	1.3
Maryland	2	280	1.2
California	31	267	1.1
Missouri	11	240	1.0
Subtotal	156	18,558	77.6
% U.S.Total	53.1	77.6	77.6

Source: 2000 Wards Directory

Competitive Threats

A high percentage of industry revenues come from foreign markets. Therefore, companies are exposed to financial risk resulting from volatility in foreign exchange rates, interest rates and commodity prices.

- ◆ International markets accounted for 43% of Cummins revenues

Over the past few years Congress has passed stricter clean-air laws, as well as incentives to encourage the use of alternative fuels. Natural gas is a viable alternative to gasoline and diesel-powered transportation, but this fuel still requires an internal combustion engine. Other alternative fuel approaches are more of a threat.

- ◆ In January 2000, the US Department of Energy signed a \$7.2 million research and development initiative with Eletricore Inc., Indianapolis, and Delphi Automotive Systems Corp., for the development of advanced motor-generator systems for producing hybrid and fuel cell vehicles. Though long range, hybrid and fuel cell vehicles may eventually compete against automotive diesels.
- ◆ Increases in the price of diesel fuel have accelerated more rapidly than gasoline prices over the past 5 years. This should encourage the continued development of alternate fuel sources. The truckers' strike in the first quarter of the year 2000 focused national attention on the increasing cost of diesel fuel.

The high industry demand for diesel engines in the economic boom years of the late 1990's strained manufacturing capacity, opening the door for competitors to gain market share.

Investment Issues

This \$17.3 billion a year industry is not considered capital intensive compared to other industries in the manufacturing sector.

- ◆ Machinery and equipment assets represent \$4,308.4 million or 25% of annual shipments. Machinery and equipment assets for most manufacturing industries average between 25% and 50% of annual shipments.
- ◆ Buildings and structures assets represent \$1,257.7 million.
- ◆ Thus, there is \$1 invested for every \$3.11 in shipments.

After a decrease of 20% in new capital expenditures from 1992 to 1993, investment has since then been increasing along with the economy, including a 23% increase in 1995.

- ◆ A total of \$527.5 million was reinvested in new capital expenditures in 1996.
- ◆ This reinvestment amounted to 3.1% of shipments

National Trends

Shipments of internal combustion engines are very cyclical, due to the cyclical nature of customer revenues in the trucking, construction, farming, and automotive sectors.

- ◆ The industry had 4.9% decrease in shipments from 1988 to 1992 while employment dropped 11.1%.
- ◆ From 1992 to 1996, the shipments increased 46.1% and employment increased only 0.5%.

Productivity increases from 1992 to 1996 averaged 10% annually.

- ◆ Computer-based diagnostics and greatly improved materials have been incorporated into the design and manufacturing systems of the major manufacturers.
- ◆ Front office management and work force employment have not increased with increases in revenues.

From 1987 to 1992 the number of establishments increased from 278 to 294, an increase of 5.8%.

- ◆ Over the same period, the number of establishments with 1 to 20 employees increased from 128 to 159, an increase of 24.2%.
- ◆ The number of establishments has not changed significantly since 1992.

Market Structure

This industry manufactures engines that are used by customers in a wide variety of automotive, industrial, and power generation markets.

Four companies supply 70% of the total industry shipments: Cummins (29%), Caterpillar (20%), Detroit Diesel Corp (12%) and Navistar (9%) resulting in a concentrated oligopoly.

This industry is comprised 294 establishments and 250 companies according to the 1996 Census.

- ◆ 54% of manufacturers employ less than 20 people.
- ◆ 26.5% of the total employ 100 or more employees.
 - Average employment is 198 people per establishment.
 - Median employment is 17 people per establishment.
- ◆ Market power is very concentrated within the top level of this oligopoly, despite the large numbers of small companies.

Table 5. Number of Establishments by Employment, 1996

Number of Employees	1-19	20-99	100+	Totals
SIC 3519 Establishments	159	57	78	294
Percentage of Total	54%	19.5%	26.5%	100%

Source: Census Data

In 1999, industry leader Cummins reported the following market segmentation:

- ◆ The Automotive segment represented 54% of the total market, divided as follows:
 - 52% heavy-duty trucks
 - 22% medium-duty trucks
 - 26% bus & light commercial vehicles
- ◆ The Power Generation segment represented 25% of the total market, divided as follows:
 - 73% power systems
 - 13% alternators
 - 14% mobile
- ◆ The Industrial segment represented 21% of the total market, divided as follows:
 - 55% construction
 - 16% mining
 - 13% marine
 - 13% agriculture
 - 3% government
- ◆ 20% of Cummins Automotive sales came from International markets.
- ◆ 65% of Cummins Power Generation sales came from International markets.

The lawn and garden sector comprised less than 15% of shipment value in SIC 3519, with Briggs and Stratton controlling more than 40% of this market. Tecumseh, Kohler, Honda, and Onan also supply this market, consisting primarily of gasoline engines less than 25HP.

Summary of Industry Issues

Government regulations, particularly those mandated by the EPA, continue to drive the manufacturers to produce more energy efficient designs with lower emissions.

The EPA and California Air Research board sued the diesel engine manufacturers (including Cummins, Caterpillar, Detroit Diesel, Volvo, Navistar, and Mack) and reached a settlement in October 1998.

- ◆ The timetable for phasing in stricter emissions regulations (particularly to reduce NOx levels), originally set for January 2004 was moved forward to October 2002.
- ◆ Significant fines were levied against the major manufacturers in a disagreement over reported emissions test results. Cummins paid a \$25 million dollar fine in 1999 as a result of this lawsuit.

Congress has continued to offer incentives to encourage the use of alternative fuels.

Significant business opportunities for diesel engines manufacturers will come from the foreign market:

- ◆ Customers are found around the world in the truck, coach and bus, automobile, construction, mining, marine, industrial, power generation and military markets.
- ◆ Manufacturing presence outside the U.S. provides better access to key markets.
- ◆ U.S. companies use an international distribution and support network of authorized distributors and dealers through the world. Leading U.S. companies are established in overseas markets and have maintained their technological edge through industry downturns.
- ◆ Because of their efficiency and durability, diesel engines have the virtue of being useful in both developed and developing countries.
- ◆ During the next 10 years, Latin America countries are expected to spend \$50 billion in their infrastructure. Latin America also has become the second largest worldwide market for mining equipment due to its vast resources of copper, silver and coal.
- ◆ In the fast-growing regions of Central and Eastern Europe, investments in infrastructure development – and the aggregate and quarry business that supports it presents a potential opportunity as well.
- ◆ China has 21% of the world's population and its economy is expected to grow at about 8% a year, considerably higher than that of most other countries. China should evolve into one of the world's largest economies in the next 15 years.

Future factors that may impact this industry include:

- ◆ The cyclical nature of the business is not expected to change. The recent economic upswing is leading to investment in infrastructure, industrial expansion and spending on goods and services, all of which present the industry with opportunities for continued growth in sales and profitability.
- ◆ New entrants by foreign and domestic competitors will lead to increased price competition and rapid technological developments.
- ◆ Domestic and foreign governmental public policy changes might impact the business, including environmental regulations
 - Lower carbon dioxide emissions may give diesel engines an important advantage over gasoline engines in the global warming debate.
- ◆ The Occupational Safety and Health Administration (OSHA) and the American National Standard's Institute (ANSI) are both working on new standards to prevent injuries related to ergonomics, usually defined as musculoskeletal or cumulative trauma disorders.
 - Manufacturers of internal combustion engines have about the same total OSHA cases and lost work day incidents (LWDI) from injuries and illnesses as the major group it belongs – SIC 35 Ind. Machinery Equipment. However, they have about 25% more LWDI's compared to relatively light manufacturers such as those making electronic equipment as shown in Table 6.
- ◆ ANSI Committee Z-365 issued a document entitled, *Control of Cumulative Trauma Disorders* (CTD) - Working Draft, in June 1997, for public review and comment.
 - Review of this document shows that a program-based approach with an emphasis on the following core elements will be recommended: Management Responsibility, Training, Employee Involvement, Surveillance (identifying problem jobs), Evaluation and Management of CTD Cases, Job Analysis and Job Design and Intervention.

Table 6. Nonfatal Occupational Injury And Illness Incidence Rates Per 100 Full-Time Workers, By Industry, 1996

Industry	Injuries & Illness			Injuries	
	SIC	Total Cases	LWDI*	Total Cases	LWDI*
Internal Combustion Engines, nec	3519	9.4	3.6	7.5	3.0
Ind. Machinery & Equip.	3500	9.5	4.0	8.7	3.6
Electronic And Other Electric Equipment	3600	5.9	2.8	4.8	2.3
Transportation Equip.	3700	14.6	6.6	11.2	5.3

Source: OSHA

*LWDI = Lost Work Day Incident

Table 7 shows some recent OSHA data on inspections and fines.

- From October 1997 to September 1998, there were only 12 OSHA inspections of Internal Combustion Engines manufacture facilities.
- About 80% of total fines are received by only three OSHA standards (out of over 32 total).
- The standard Permit-Required Confined Spaces accounts for 72% of the total fines for SIC 3519 just by itself Other standards that received important penalty include Electrical Systems Design (General Requirements), Eye & Face Protection and Electrical Training.

Table 7. Standards Cited by Federal OSHA from October 1997 to September 1998 for SIC 3519, Internal Combustion Engines, nec

Standards	Description	Cited	# Insp	\$Fine
1910.0146	Permit-Req.Confined Space	21	2	12,985
1910.0134	Respiratory Protection	2	1	0.00
1910.0333	Elec.,Select&Use Work Practices	2	1	0.00
1910.1200	Hazard Communication	2	2	1,350
1910.0023	Guarding Floor&Wall open.	1	1	414
Subtotals		28	7	\$14,749
Total <u>All</u> Standards Violations		33	12	\$17,996

Source: OSHA

National Energy Consumption Patterns

This industry spends roughly \$95 million annually on energy.

Total energy consumption increased a total of about 10% from 1993 to 1996 for SIC 35 (Industrial Machinery and Equipment). As shown in Table 8, natural gas and electricity energy consumption is approximately equal.

Table 8. SIC 35 Total Energy Consumption 245 Trillion BTU (1994)

Natural Gas	45%
Electricity	44.5%
Other (Fuel Oil etc.)	10.5%

Source: DOE Energy Information Administration

Table 9. Fuel Switching Potential

Electricity	2.5% to Natural Gas, Oil, Coal or other
Natural Gas	17.5% to Electricity ,Oil, Coal, LPG or other
LPG	20% to Natural Gas, Electricity, or Distillate Fuel Oil
Residual Oil	48% to Natural Gas or Distillate Fuel Oil
Coal	40% to Natural Gas, Oil or LPG

Typical Electricity Requirements

In 1996, the \$17.3 billion internal combustion engine industry purchased 2.3 billion kWh of electricity at a cost of \$93.4 million.

- ◆ This represents only 6% of the total electricity consumed by the industrial and machinery industry (SIC 35).
- ◆ Electricity accounts for about 76% of total purchased energy costs in SIC 3519.
- ◆ Total energy costs are less than 1% of shipment revenues.

As shown in Table 10, the internal combustion engine industry is more energy intensive than an assembly operation or establishments involved in sheet metal work. It is comparable to the motor vehicle parts and accessories industry.

- ◆ The ratio of kWh electricity consumption per dollar of value added for SIC 3519 is higher than that for automotive assembly operations (SIC 3711) and sheet metal work manufacturers (SIC 3444), and slightly lower than that for the manufacturer of automotive parts (SIC 3714).
- ◆ SIC 3519 is twice as capital intensive as the sheet metal work industry and about the same compared to the motor vehicle parts and accessories industry.

Table 10. Intensity of Electricity Consumption and Capital Investment

Industry SIC Code	1996 Value Added (\$, Million)	Electricity Purchased (kWh, Million)	kWh/VA	Mach./Equip. Assets (\$, Million)	Mach. & Eq. Assets/ \$ VA
3519	\$7,344.9	2,292.0	0.31	4,440.5	0.93
3444	7,512.7	1,471.6	0.20	2,424.9	0.42
3711	\$55,369.1	9,737.4	0.18	\$21,095.9	0.47
3714	\$44,209.9	15,559.4	0.35	\$26,709.4	0.86

Source: Census Data

Table 11 shows that nearly 44% of electricity end-use in SIC 35 is by Machine Drive manufacturing.

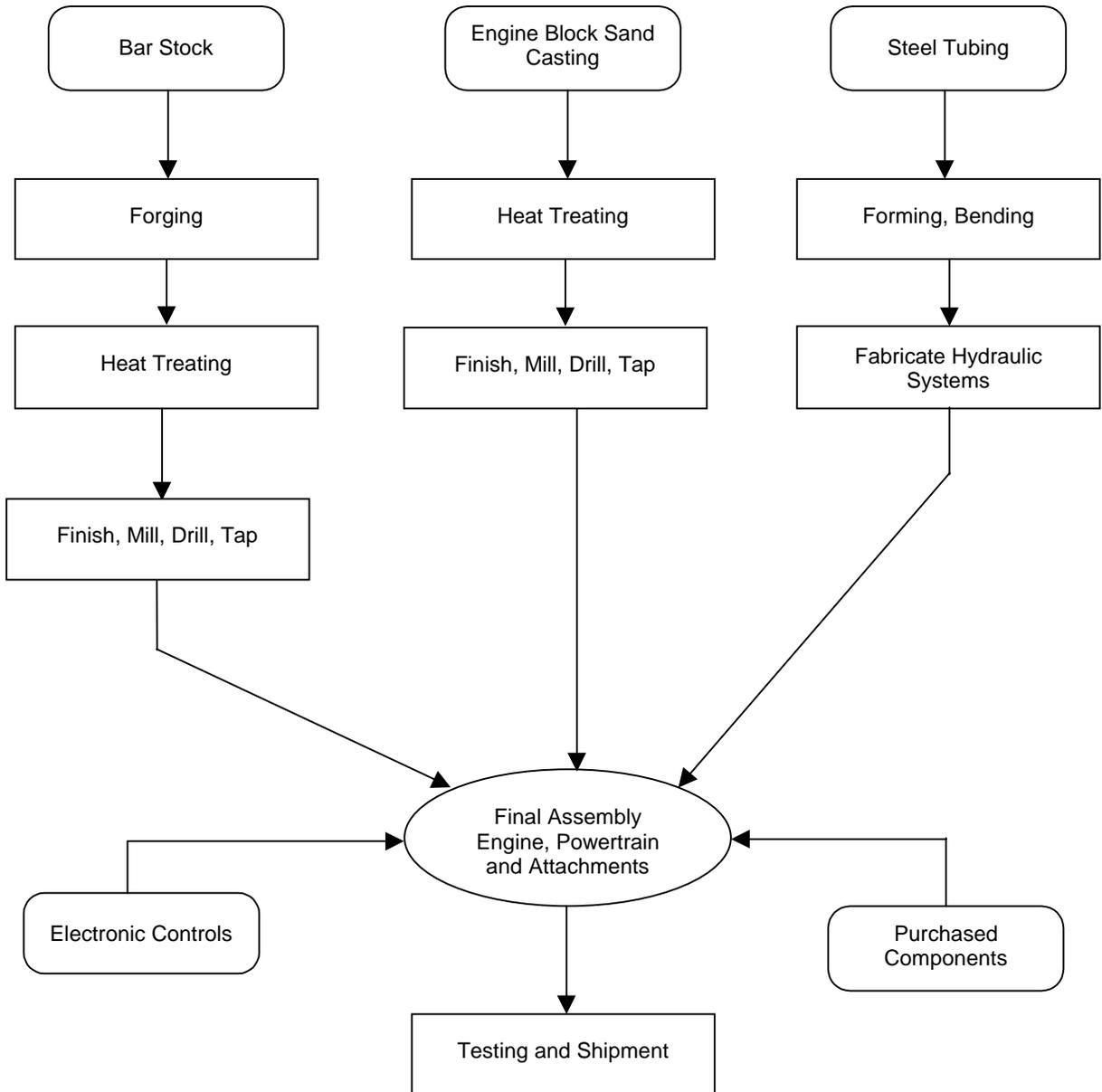
Table 11. SIC 35 Major Electricity End-Uses (1994)

End Use	Percent of Total
Machine Drive	43.8%
HVAC	17.4%
Facility Lighting	14.3%
Process Heating	9.7%
Facility Support, Other	14.8%

Source: DOE Energy Information Administration

Process Flow Chart for Engine Manufacture

Figure 2. Typical Process Flow Chart



Manufacturing Process Issues

The manufacture of diesel engines is similar to the manufacturer of gasoline powered engines with some notable exceptions:

- ◆ The compression ratio is typically in the range of 16:1 for a diesel engine, compared to 8:1 for a gasoline-powered engine. This allows the diesel to have the highest thermal efficiencies (40%).
- ◆ Higher pressures in diesel engines are necessary to create combustion without the use of spark plugs, which are characteristic of gasoline-powered engines.
- ◆ Replaceable cylinder liners are used in diesel engines to expedite engine refurbishment.
- ◆ High-pressure tubing is used in fuel lines, in some designs capable of handling up to 20,000 psi.
- ◆ Engine blocks are made of heavy cast iron, liberally webbed to withstand stress.
- ◆ Gear drives are used in lieu of less expensive chains or belts.
- ◆ Machine tolerances are very tight to accommodate the higher pressures and compression ratios found in diesel engines.

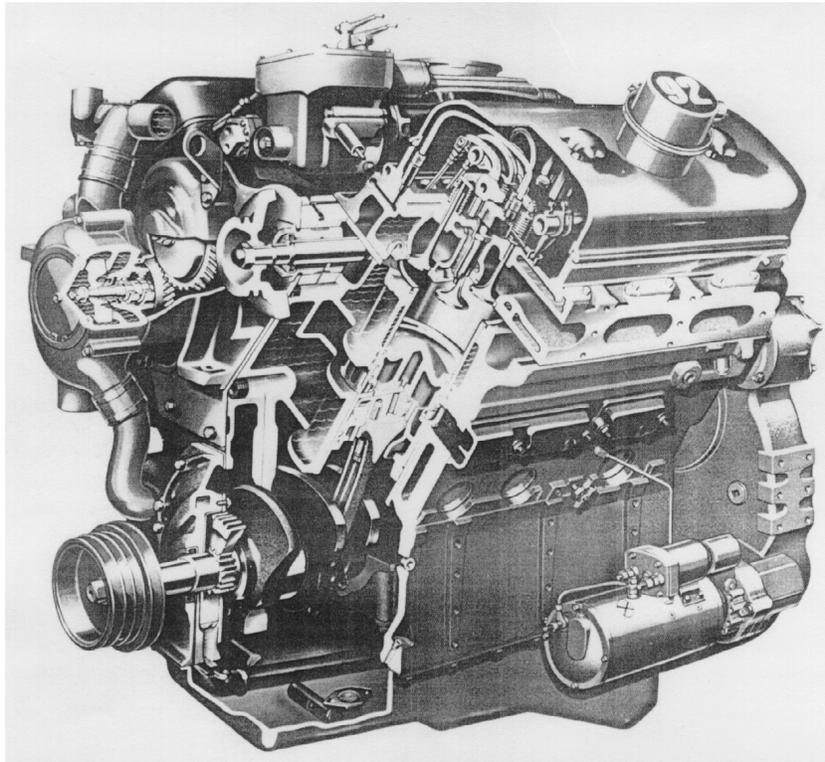
The critical parts of an engine are the engine casting, crankshaft, camshaft, pistons, connecting rods, fuel lines, pumps, inserts such as cylinder liners, and the associated electronics to control the engine's performance.

There are large numbers of shaping and non-shaping processes, the most energy intensive of which are casting/molding, metal deformation, and surface finishing.

- ◆ Sand casting processes are used for making engine blocks, crankshafts and heads.
 - The manufacture of the sand casting molds is complicated by the number of orifices and internal channels that are characteristic of engines.
 - An iron charge, generally containing a portion of recycled scrap iron, is combined with other alloying additives and fed into a furnace (usually an electric arc, an electric induction, or a gas fired cupola furnace).
 - The molten iron is fed into the sand casting and left to cool.
 - The advances in casting technology have been focused on the reduction of voids in the castings, minimizing temperature variations, and insuring that the design maximizes molten metal flow for a specified range of casting conditions.

- ◆ Forging processes are used in the production of the heavy-duty crankshafts, camshafts, pistons, roller bearings, ring gears and other engine parts.
 - Typically a straight steel bar is upset (or forged) into the desired shape of the part.
 - Though forging processes are often single shot, there are several large parts that need to be run through progressive dies with multiple shots to form the part.
 - Forging is used instead of lower cost casting processes, where the strengths achieved in cast parts are not sufficient to meet the higher duty design loads.

Figure 3 Internal Combustion Engine (V-Body)



Gears and bearings can be cast or forged. Forging and post forming treatments produce the highest strength, most wear resistant components.

- ◆ Heat treating operations such as surface carburizing and induction hardening are used to selectively harden the gears at the areas of greatest stress. Uniform heat pattern through the gear root increases fatigue life.
- ◆ Vacuum thermal processing is used to through-harden key components such as gears or bearings requiring full heat treatment.
- ◆ Connecting rods, crankshafts fillets, propeller shafts for marine applications and other high strength shafts are shot peened to increase fatigue strength.

Near net shape processing minimizing distortion and subsequently, post- grinding operations.

Manufacturers in SIC 3519 are both OEM's (Cummins, Detroit Diesel, Briggs and Stratton), and vertically integrated producers (Caterpillar, Ford, Mack and Honda).

- ◆ Machining operations include an extensive array of special dies, tools, and machine tool accessories.
- ◆ Foundry operations can serve other manufacturing divisions.
- ◆ Research and development costs typically run 3 to 4% of sales and have enabled the large manufacturers to maintain a technological advantage over smaller competitors.

Technology Trends

In the late 1990's, demand increased for electronic engines to produce better torque and better fuel economy. The major driver was to meet EPA emissions regulations.

Advanced engine designs are equipped with datalinks that download engine operation information to optimize engine maintenance.

- ◆ Engine load and ambient conditions are monitored and adjustments to the fuel/air ratio are made for higher fuel economy and performance.
- ◆ Sophisticated diagnostic and preventive electronics signal the user when the engine exceeds operating parameters.
- ◆ Systems that seize an increased load and automatically deliver an extra 5%-10% more horsepower to the axle.

New types of internal combustion engines are continually proposed, though radical changes from conventional designs are rarely accepted.

- ◆ One recent design replaces the familiar crankshaft and connecting rods with a one piece connecting plate that converts the linear motion of the pistons into rotating force. Varying the point at which the driveshaft and connecting plate touch alters the engine's stroke and controls the power output.
 - Preliminary tests of the 120-hp-plus engine suggest the new design can increase power by as much as 100 percent over diesel engines.
- ◆ Oligopolies are resistant to changes, and can prevent new designs from entering the market.

Automotive fuel cell technology, which would generate electricity with few byproducts by combining hydrogen and oxygen, still has a long way to go before it can compete with the internal combustion engine. Competitive fuel cell based automobiles are many years from the commercial market.

- ◆ A Volvo study in 1998 found that fuel cells were not only extremely expensive at that point (\$15,000 and up), but actually less energy efficient than internal combustion engines.
- ◆ For the future, though, researchers believe that the technology and cost performance of fuel cells will improve and significant research efforts are being supported in this area.

In January 2000, the US Department of Energy signed a \$7.2 million research and development initiative with Eletricore Inc., Indianapolis, and Delphi Automotive Systems Corp., for the development of advanced motor-generator systems for producing hybrid and fuel cell vehicles. DOE will provide \$3.6 million over the next 3 years, which Delphi will match. The goal is to make hybrid propulsion affordable.

The University of California Riverside will evaluate a new internal combustion engine, which weighs just 120 pounds and contains three major moving parts. It produces the same torque as a 3.8-liter V6 engine and could provide a significant advancement in combustion engine technology.

- ◆ The engine uses porting rather than valves and has no camshaft, distributor, oil pump or water pump.
- ◆ The engine provides four times the output per revolution of a conventional four-stroke engine at the same displacement.

Advancements are being made in ceramics, which are expected to improve diesel engine performance.

Enhancements continue to be made in electronic fuel injection technology.

- ◆ Airless injection systems improve efficiency by removing the need for an auxiliary air compressor to feed the air blast injection system.

High-speed direct injection engines are being developed to improve performance, economy, emissions, cost effectiveness and noise control.

- ◆ Design changes are being made to the pre-combustion chamber.
- ◆ Swirl chamber configurations are used to induce air to swirl around the specially shaped chamber, thereby ensuring a good air/fuel mix and even burn.

Diagnostic systems are being developed to monitor engine performance and other parameters via remote satellite hookup, and are now being used on diesel engines in the farm machinery sector.

Recent highlights of new achievements by the industry include the following:

- ◆ An all-new electronic engine, rated 600 horse-power that had the first dual overhead camshafts in diesel engine history. It utilized a new high-pressure injection system.
- ◆ The introduction of the first midrange products incorporating advanced electronic technology and improvements in air handling to optimize engine performance.
 - The driver, service technician or dispatcher can interact directly with the engine to monitor and record critical functions within the engine; including lubrication, cooling, fuel and air handling in addition to crankcase pressure and individual cylinder performance.
 - Users can access real-time engine information on an ongoing basis.
- ◆ Development of the Constant Pressure Fuel System, which delivers high-injection pressures independent of engine speeds.

In the lawn and garden engine market (less than 25HP), liquid-cooled models are now being offered.

Design changes incorporate rapid prototype technology where possible to make component modification faster and cheaper.

The increased use of cryogenic thermal treatments to enhance material properties.

- ◆ Cryogenic processing increases wear resistance, dimensional stability and hardness particularly for steels.
 - Eliminates the possibility of spontaneous transformation of retained austenite to martensite in the steel part during fabrication or while the part is in service.
 - The formation of fine eta carbides within the metal microstructure has been correlated to significant improvements in material properties.
- ◆ The most successful, consistent applications of cryogenic processing are incorporated directly into the heat treating process, after austenitizing but before the first temper.
- ◆ Many of the published applications involve the improvement in performance of tool steels.

Laser processing and Electrical Discharge Machining (EDM) increase both speed and quality of punches, drill holes and cuts.

Coordinate Measuring Machines (CMM) for part inspection are further reducing inspection cost.

- ◆ Temperature compensation systems for gauges eliminate the need for expensive thermally stabilized inspection rooms.
- ◆ New CMM's integrate affordable and fast multi-point laser scanning of part features with traditional single-point probing.

Environmental Regulations and Issues

Government regulations are increasingly becoming important to internal combustion engine manufacturers.

The EPA and California Air Research board sued the diesel engine manufacturers (including Cummins, Caterpillar, Detroit Diesel, Volvo, Navistar, and Mack) and reached a settlement in October 1998.

- ◆ The timetable for phasing in stricter emissions regulations (particularly to reduce NOx levels), originally set for January 2004 was moved forward to October 2002.
- ◆ Significant fines were levied against the major manufacturers in a disagreement over reported emissions test results.
 - The EPA sued the engine makers for using electronic fuel injection to outsmart emissions tests.
 - Cummins was forced to pay a \$25 million fine to the EPA to settle the dispute.
- ◆ A \$15 million research initiative funded by the major manufacturers was set up to examine the correlation between diesel emission exposure and disease.

The most significant CAA (Clean Air Act) regulations that affect the internal combustion engines address mobile source air emissions. New standards for on highway heavy-duty diesel engines include compliance with the following by October 2002.

- ◆ EPA has set limits on exhaust emissions from new heavy-duty engines. EPA considers heavy-duty engines to be those in vehicles weighing at least 8500 pounds.
- ◆ Off-highway heavy-duty diesel engines from 300 bhp to 750 bhp will meet January 1, 2006, standards by January 1, 2005.
- ◆ In 1994, the regulations required all heavy-duty engines to reduce the emission of nitrogen oxides (NOx) from 5.0 g/bhp-hr to 4.0 g/bhp-hr by 1998. Emissions standards are also set for hydrocarbons (HC), carbon monoxide (CO), and particulates (PM).
- ◆ The following table exhibits the heavy-duty engine emission standards in g/bhp-hr measured during EPA heavy-duty engine test:

Table 12. Emissions Standards for Heavy-Duty Engines

Model Year	NOx (g/bhp-hr)	HC (g/bhp-hr)	CO g/bhp-hr)	PM
1991	6	1.3	15.5	0.6
1994	5	1.3	15.5	0.25
1998	4	1.3	15.5	0.1

- ◆ Allowable NOx (nitrous oxide) emissions levels will decrease to 2.5 g/bhp-hr by October 2000.

Diesel engine manufacturers are working with the government to comply with the consent decree to reduce emissions.

- ◆ Over the past 20 years, the diesel engine manufacturers have reduced NOx emissions by almost 70% and lowered particulate emissions by 90%. During that same period, diesel fuel efficiency improved 25%. In addition, the industry and the EPA reached voluntary agreements in 1995 to reduce urban NOx emissions another 50% by 2004.
- ◆ Cummins became the first marine diesel engine manufacturer to receive International Maritime Organization (IMO) MARPOL 73/78 Annex VI emissions Statements of Compliance from the U.S. Environmental Protection Agency (EPA) for its marine engines.
- ◆ With the advent of electronic controls on engines, manufacturers developed products using electronic control strategies to be in compliance with the Clean Air Act and EPA emissions regulations.
- ◆ Engine manufacturers are incorporating exhaust gas recirculation. EGR redirects part of the exhaust flow, cools it and routes it to the intake.
 - It is an excellent way to reduce emissions, but it can increase acids and soot in the crankcase oil.
 - The American Petroleum Institute is working on a new lubricant standard to deal with EGR. Oils displaying the new certification should be available some time around the October 2002 emissions deadline.

Over the past few years, Congress has provided incentives to encourage the use of alternative fuels.

- ◆ Federal and State tax deductions for Alternative Fuel Vehicles (AFVs) are available. The maximum tax deductions range from \$2,000 to \$50,000 for each AFV. Deductions on vehicles apply to the incremental cost of an AFV over the cost of its gasoline or diesel counterpart.

- ◆ Almost any gasoline or diesel-powered vehicle can be converted to run on natural gas including buses, light-duty trucks and vans, medium-duty trucks, and even heavy-duty trucks such as semi-tractors.
- ◆ Diesel conversions are somewhat more complicated than converting gasoline-powered vehicles because they involve reducing compression and adding a sparked-ignition system.
- ◆ Other fuels include methanol, ethanol, and propane.

CAA regulations mandate the use of alternate fuels for fleets of vehicles in the 8500-26,000 pound class that operate in 22 of the country's most populated areas.

- ◆ Fleets will be required to purchase 50% of their new or replacement vehicles as clean fuel vehicles in any one of the covered areas.
- ◆ Alternative fuels are defined by their ability to reduce Nox and non-methane hydrocarbon emissions by a combined 50% from diesel baseline levels, although a 30% reduction is permitted if 50% is unattainable.

The EPA tracks emissions through a Toxic Release Inventory report according to whether pollutants are released in air, water, or in solid form.

- ◆ On-site and off-site total releases in pounds are reported by SIC codes.
 - Air emissions are further classified according to whether they are nonpoint (fugitive) or point (stack) emissions.
 - Water releases are either surface water or underground injection to wells.
 - Land releases are either on-site landfill or hauled away to other sites.
- ◆ The industrial machinery sector (SIC 35) is a minor TRI-offender (Toxic Release Inventory –offender) compared to other sectors. The chemical industry (SIC 28) reported 797.4 million pounds, or 30.9%, of on-site and off-site releases in 1997.
 - Primary metals (SIC 33) reported 694.6 million pounds, or 27%, and pulp and paper (SIC 26) reported 228.8 million pounds totaling 9.1%.
 - The industrial machinery sector (SIC 35) reported 22.4 million pounds, or less than 1% of total releases for the manufacturing SIC's 20-39.

Parts cleaning has been significantly impacted by government regulations such as

- ◆ EPA's National Emission Standards for Hazardous Pollutants (NESHAP),
- ◆ EPA's Significant New Alternatives Policy (SNAP), enacted in March of 1994,
- ◆ The 1987 Montreal Protocol, and more recently
- ◆ The Metal Products and Machinery (MP&M) standard, whose guidelines were published in April 1995, and sent out for comment regarding discharge of cleaning effluent to Publicly Owned Water Treatment (POWT).

Aqueous cleaning has been steadily replacing solvent-based systems.

- ◆ Aqueous systems have a mechanical focus on anything that breaks the bond between the soil and the part.
- ◆ Aqueous mechanical agitation methods include high-pressure spraying, part rotation and ultrasonic cavitation in a variety of techniques.

Aqueous cleaning systems require heated drying techniques such as evaporative hot air or non-evaporative high-velocity air blowoff to prevent rust, corrosion or spotting on workpieces.

- ◆ Neutral pH, aqueous-based degreasers are typically used for the removal of light soils, specifically light oils which include cutting, shearing, honing and machining oils.
 - There are certain applications involving heavy oils and greases, and/or heavy soil loads that require a much more aggressive chemical approach such as caustic cleaners.

The handling and disposal of metal removal fluids (MRFs) is increasingly becoming another environmental issue that machining operations such as those found in SIC 3519 have to confront.

- ◆ UV based systems are commercially available for the destruction of bacteria found in MRF's without the use of biocides such as chlorine.
- ◆ New NIOSH and OSHA regulations are being proposed which lower the allowable concentrations of bacteria in MRF's by a factor of 10.

Table 13. Metal Shaping & Preparation – Environmental Inputs and Outputs

	INPUTS	OUTPUTS		
Process	Material	Air Emission	Process Wastewater	Solid Waste
Metal Shaping				
Metal cutting and/or Forming	Oils, degreasing and cleaning solvents, acids, alkalis and heavy metals	1,1,1-trichloroethane, acetone, xylene, toluene, etc.	Ethylene glycol waste oil and hydrochloric, sulfuric, and nitric acid. Alkalines and solvent wastes	Metal chips, cutting fluid sludge, and solvent still-bottom wastes
Surface Preparation				
Degreasing and cleaning	Solvents, emulsifying agents, alkalis, and acids	Degreasing and emulsion cleaning solvents	Solvent, alkaline, and acid wastes	Ignitable wastes, solvent wastes, and still bottoms

Table 14. Surface Finishing – Environmental Inputs and Outputs

	INPUTS	OUTPUTS		
Process	Material	Air Emission	Process Wastewater	Solid Waste
Anodizing	Acids	Metal-ion-bearing mists and acid mists	Acid wastes	Spent solutions, wastewater treatment sludges, and base metals
Chemical Conversion Coating	Metals and acids	Metal-ion-bearing mists and acid mists	Metal salts, acid, and base wastes	Spent solutions, wastewater treatment sludges, and base metals
Electroplating	Acid/alkaline, heavy metal, and cyanide bearing solutions	Metal-ion-bearing mists and acid mists	Acid/alkaline, cyanide, and metal wastes	Metal and reactive wastes
Plating	Metal salts, complexing agents, and alkalis	Metal-ion-bearing mists	Cyanide and metal wastes	Cyanide and metal wastes
Painting	Solvents and paint	Solvents	Solvent wastes	Still bottoms, sludges, paint solvents

Opportunities for Increased Electricity Use

Induction heating for selective heat treating of components.

Vacuum processing for through-hardening near net shape parts.

Aqueous cleaning uses various heaters for drying parts after washing. Replaces solvent based cleaning and eliminates VOC emissions.

UV based systems for the destruction of bacteria in MRF's without the use of biocides.

Increased compressor load to produce liquid nitrogen for use in cryogenic processing.

Plasma arc cutting of metal is more economical than oxyfuel for thicknesses under 1".

Laser cutting, drilling and punching for automating production operations.

Electrical discharge machining (EDM) can cut shapes into thick or hardened steel more economically than sawing or milling.

- ◆ Electric spark erodes metal in front of spooled wire or shaped plunger.
- ◆ Electrochemical machining process variation adds conductive fluid between shaped plunger and the part.

Areas of Decreased Electricity Use

Energy efficient motors and drives.

Energy efficient shop lighting.

More efficient compressed air systems

Opportunities for Electric Utilities

Utilities should target mid size establishments and be sure that technology advances and business strategies fit with the industry leaders.

Though most of the energy used in this industry is used for motors, heating, and lighting, there are specific opportunities using electrotechnologies to improve manufacturing efficiencies.

- ◆ Capital investment should target replacing worn out equipment with new technology.

- Preheat equipment for forging presses.
- Combination punching and laser cutting machines.
- ◆ Opportunities to replace gas fired heat treating technology with induction, particularly for camshafts, crankshafts, connecting rods and other parts where selective heat treating is required.
- ◆ Opportunities to use vacuum thermal processing in near net shape technology to minimize distortion and thereby reduce post-grinding operations.
- ◆ UV based systems for treating bacteria contamination in metal removal fluids.

Industry Associations and Periodicals

The following trade associations are resources for industry information and possible collaborative efforts.

US Census Bureau

4700 Silver Hill Rd
Suitland, MD 20746
Phone: (202) 457-2000
www.census.gov

American Trucking Association

2200 Mill Rd
Alexandria, VA 22314
Phone: (703) 838-1978

Equipment Manufacturers Institute

10 S. Riverside Plaza
Chicago, IL 60606-3170
Phone: (312) 321-1470
Fax: (312) 321-1480
www.emi.org

National Marine Mfgs Association

200 E Randolph Dr.
Suite 5100
Chicago, IL 60601
Phone: (312) 946-6200
www.nmma.org

The following trade publications are resources for industry information.

Automotive Industries

Cahners Business Information
3011 W. Grand Blvd, Suite 2600
Detroit, MI 48202
Phone: (313) 875-2090
www.ai-online.com

Crain Communications

1400 Woodbridge Ave
Detroit, MI 48207-3187
Phone: (313) 446-2000
www.automotivenews.com

Ward's Automotive Reports

Ward's Communications
3000 Town Center, Suite 2750
Southfield, MI 48075
Phone: (248) 357-0800
www.wardsauto.com

Boat and Motor Dealer

Preston Publications
6600 W Touhy Ave
Niles, IL 60714
Phone: (847) 647-2900
www.prestonpub.com

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