PERSONALIZED ENGINEERING SERVICE

If you are now using forgings, stampings, welded assemblies or you machine parts from bar stock in volume, it will pay you to consider replacing those parts with a casting of ArmaSteel or Malleable Iron.

The experienced staff of metal forming engineers at our modern Product Engineering Center will gladly assist you in evaluating any design for potential performance improvements and cost savings.

CONTACT...Sales Department, Central Foundry Division, General Motors Corporation, Saginaw, Michigan for immediate technical assistance or for a prompt, accurate quotation on your requirements.

ArmaSteel® and Malleable Iron Castings

Central Foundry
DIVISION OF GENERAL MOTORS
SAGINAW, MICHIGAN

Quality Castings in ARMASTEEL—MALLEABLE IRON—GREY IRON—REGULAR IRON—ALUMINUM AND HEAT RESISTANT ALLOYS

Printed in U.S.A.
Hundreds of thousands of ArmaSteel® and Malleable Iron castings are produced every day by Central Foundry Division—for cars, trucks, marine engines, farm implements, refrigerators, compressors, and many other products where component parts must have high quality at low total cost.

This brochure tells why these castings are so widely used, and shows production parts of many types and sizes. From these pages you will quickly see how you can gain through use of Central Foundry products and services.

Color Key to Illustrations
- ArmaSteel
- Malleable Iron

CONTENTS

Advantages of Casting Process 4, 5
Introduction to ArmaSteel and Malleable Iron 4, 5
Advantages of ArmaSteel and Malleable Iron 6, 7
Draft Allowance, Size Tolerances 8
Selecting the Material 9, 11
Illustrations of Typical Production Parts
- Engine 12, 13
- Transmission 14, 15
- Drive and Differential 16, 17
- Diesel 18, 19
- Miscellaneous 20, 21

Small Engine Crankshafts 22
Compressor Crankshafts, C Clamps 23
Connectors Rods, Steering Gear housings 24
Doors, Beadlets 25
Yokes 26
Machining 27
Production Data 32-34
Foundry Data 35, 36
Metallurgical Data 38-40
Photographs 42
Hardening 42
Conversion Table 43
Foundry Terms 43
Advantages of Castings

Using high-strength, ductile and machinable Armasteel and Malleable Iron, the casting process offers important advantages compared to forgings, stampings and weldments. High on the list are these cost advantages:

1. The casting process can more readily provide metal where needed than any other process. This usually means less metal to be removed, with pronounced savings in machining time, man-hours and metal. (Example: Up to 50% in machining time is being saved where Armasteel castings have replaced steel forgings.)

2. Important savings in tool life are obtained because cast metals are machinable more easily than forgings or stampings—and there's less metal to remove.

3. Patterns generally cost much less than dies. This cuts tool-up costs and makes prototypes relatively inexpensive. For example, the cost of an experimental crankshaft pattern is only a small fraction of the cost of forging dies for the same crankshaft.

In addition, castings permit designs that are simply not feasible with other production methods. Patterns are quickly made and readily modified to suit minor changes in design. And, part for part, in most cases the finished castings are of lighter weight than finished forgings or weldments.

Castings of Armasteel and Malleable Iron offer further advantages in quality and performance characteristics, as explained on the following pages.

WHAT IS ARMASTEEL?

Armasteel is a pearlitic malleable iron with steel-like properties that combines the advantages of castings with maximum strength and reliability. It begins its existence as white cast iron; then it is annealed, quenched and tempered to obtain the desired percentage of combined carbon in the matrix—hence, the desired hardness, strength and other mechanical properties.

This metal is produced in five hardness ranges, giving a wide choice of properties similar to those of quenched and tempered medium carbon steel. Close metallurgical control at all stages of production assures uniform quality of cast parts—from part to part, day after day—month after month.

TYPICAL USES of Armasteel Castings

Because of its excellent
- strength,
- resistance to wear and shock,
- machinability,
- adaptability to selective hardening, and
- economics obtained through casting,

Armasteel has proven highly successful in the
automotive, 
marine, and 
farm implement fields
for such highly stressed parts as
- gears
- Diesel pistons
- rocker arms
- crankshafts
- universal joint yokes
- and many other parts, where top quality and economy are essential.

WHAT IS MALLEABLE IRON?

Malleable Iron is a ferrous alloy whose matrix contains no appreciable amounts of combined carbon. It is produced by controlled annealing of white iron castings of controlled composition. This material is very soft and ductile, is the most machinable of these metals, and has good magnetic permeability.

Malleable iron is a metal with many applications in automobile, appliance, and appliance fields. This makes it exceptionally easy-machining, for the nodules interrupt the continuity of the metallic matrix, permitting the chips to break off readily. This also results in small chip size, which facilitates chip-handling.

TYPICAL USES of Malleable Iron Castings

Because of its
- excellent machinability,
- toughness,
- ductility,
- suitability for furnace hardening,
- adequate strength, and
- economy

Malleable iron has been highly successful for such parts as
- Differential carriers
- mounting brackets
- hingers
- Light-duty gears
- steering gear housings
- and similar parts in many industries.

Typical parts of both materials are shown on pages 12 thru 26.
Advantages of ArmaSteel and Malleable Iron Castings

**Performance Advantages**

**High Strength**
ArmaSteel has a yield strength comparable to that of steel forgings in the ASTM 1035 to 1050 range. Specific values are given on pages 10 and 11. Close control of heat treatment assures that ArmaSteel meets specific needs consistently and accurately.

**Excellent Bearing Properties**
ArmaSteel provides a smooth bearing surface. It is non-squealing in metal-to-metal contact because of the graphite particles that it contains. Thus, it often permits the elimination of costly bushings.

**Good Wear Resistance**
ArmaSteel parts withstand wear and give long, useful service under heavy loads at high speeds. Parts can be locally hardened for extreme conditions.

**High Rigidity**
ArmaSteel has excellent rigidity — maintains accurate alignment under stress.

**Long Fatigue Life**
ArmaSteel has excellent fatigue strength because of its strong, fine-grained microstructure. Thus, it assure maximum endurance and long service life for highly-stressed and repeatedly- stressed parts.

**Good Damping Capacity**
ArmaSteel absorbs vibratory energy approximately twice as well as steel — provides extra quiet operation for such applications as reciprocating engines and compressors.

**Adequate Strength**
Malleable Iron has a yield strength comparable to that of annealed low-carbon steel.

**Wear Resistance**
Malleable Iron can be given good wear resistance by furnace hardening.

**High Rigidity**
Malleable Iron has excellent rigidity — maintains accurate alignment under stress.

**Long Fatigue Life**
Malleable Iron has good fatigue strength — assures high endurance and long service life for repeatedly-stressed parts.

**Good Damping Capacity**
Malleable Iron absorbs vibratory energy approximately twice as well as steel — provides extra quiet operation for such applications as reciprocating engines and compressors.

**Processing Advantages**

**Exceptional Machinability**
ArmaSteel castings are machined more easily than steel forgings of comparable hardness because of (1) the small nodules of carbon in the ArmaSteel matrix and (2) the lower plasticity of ArmaSteel. These ArmaSteel properties result in smaller chips and lower tool forces. Because of the lower tool forces, feed and speed can usually be increased with the same machine and fixtures, with a corresponding increase in productivity. Also, tool life is increased.

Malleable Iron is even more machinable than ArmaSteel because it is softer.

Production data for machining and finishing is given on pages 31 thru 34.

**Hardenedullity**
ArmaSteel responds readily to localized hardening procedures: flame hardening, induction hardening and immersion methods. These can be performed on the production line, and eliminate the costly carbonizing treatment required for forgings. The result is a surface hardness of 50 Rockwell C or greater, giving wear resistance comparable to that of carbonized carbon steel. Malleable Iron can be furnace-hardened to 50 Rockwell C or greater.

**Weldability**
ArmaSteel and Malleable Iron castings can be joined to each other and to steel parts, on a production basis, by manual, semi-automatic or automatic electric welding. Joints of such assemblies have often shown that the weld is stronger than the component parts.

**Excellent Finishing Qualities**
ArmaSteel and Malleable Iron castings all made with extreme care to obtain uniform distribution of small carbon nodules. This permits a very smooth surface which finish-machined — a 10-microinch mirror finish when polished.

**Cost Advantages**
ArmaSteel and Malleable Iron parts usually cost appreciably less than equivalent parts produced by other methods — for the following reasons:

- **Savings in metal** because castings permit a distribution of metal that commonly results in lighter, weight parts than forgings or stampings, both before and after machining.

- **Savings in machining time resulting from greater machinability.**

- **Savings in tools, and in tool-sharpening cost because of longer tool life due to (3) easier machining, (2) less metal-removal required.**

- **Savings in chip-handling cost because chips produced in machining these metals break up as soon as they are formed.**

- **Savings in cost of tooling-up because patterns for castings usually cost much less than dies for forgings or stampings and there is less maintenance of patterns than with forging or stamping dies.**

- **Savings in hardening cost with ArmaSteel because, unlike low-carbon steel, ArmaSteel castings can be given localized hardening on the production line.**

In addition, many times one ArmaSteel or Malleable Iron casting replaces several forged, stamped or welded parts — with big economies in forming, machining, assembling and inventory.

These cost advantages, plus their processing and performance advantages, make ArmaSteel and Malleable Iron castings the logical choice for production parts of a vast range of types and sizes.
# Draft Allowance

Draft is the taper required on the vertical faces of a pattern to allow the pattern to be removed from the sand mold without tearing the walls of the mold. Recommended draft allowances are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Green Sand</th>
<th>Shell Mold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>2 Degrees</td>
<td>1 Degree</td>
</tr>
<tr>
<td>Minimum</td>
<td>1 Degree</td>
<td>1/2 Degree</td>
</tr>
<tr>
<td>In Pockets</td>
<td>3 to 10 Degrees</td>
<td>1 to 2 Degrees</td>
</tr>
</tbody>
</table>

## Size Tolerances for Castings

The chart below shows, in a general way, the tolerances that can be held on ferrous castings. The dimensional accuracy of any casting depends on many variables. At Central Foundry, careful maintenance of equipment and adherence to sound foundry practices holds the effects of such variables to a minimum.

### Tolerances Chart

<table>
<thead>
<tr>
<th>Dimension of Casting</th>
<th>Tolerances—Green Sand Casting</th>
<th>Tolerances—Shell Mold Casting</th>
</tr>
</thead>
<tbody>
<tr>
<td>0'-1'</td>
<td>±0.030'</td>
<td>±0.014'</td>
</tr>
<tr>
<td>1'-2'</td>
<td>±0.030'</td>
<td>±0.018'</td>
</tr>
<tr>
<td>2'-3'</td>
<td>±0.030'</td>
<td>±0.026'</td>
</tr>
<tr>
<td>3'-4'</td>
<td>±0.045'</td>
<td>±0.036'</td>
</tr>
<tr>
<td>8'-12'</td>
<td>±0.060'</td>
<td>±0.041'</td>
</tr>
</tbody>
</table>

*Add ±0.005" for dimensions across parting line.

---

# Material Selection Chart

<table>
<thead>
<tr>
<th>Material</th>
<th>Typical Applications</th>
<th>Has Replaced the Following Steels in Many Cases:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ArmcoSteel—</td>
<td>Where high strength and/or wear resistance is required;</td>
<td>Hardened medium carbon steels:</td>
</tr>
<tr>
<td>Grade</td>
<td>e.g., gears.</td>
<td>SAE 840—850</td>
</tr>
<tr>
<td>GM 88M</td>
<td>Where high strength is required;</td>
<td>Heat-treated SAE 1040—1050</td>
</tr>
<tr>
<td>GM 84M</td>
<td>e.g., connecting rods.</td>
<td></td>
</tr>
<tr>
<td>GM 65 M</td>
<td>Automotive crankshafts</td>
<td>SAE 40—60</td>
</tr>
<tr>
<td>MODIFIED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GM 65M</td>
<td>Where moderate strength and selective hardening are</td>
<td>SAE 35—50</td>
</tr>
<tr>
<td></td>
<td>required; e.g.,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>planet carriers.</td>
<td></td>
</tr>
<tr>
<td>GM 66M</td>
<td>Less highly stressed parts; e.g., certain compressor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>crankshafts.</td>
<td></td>
</tr>
<tr>
<td>Malleable Iron—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GM 11 M</td>
<td>For less highly stressed parts; e.g., steering gear</td>
<td>SAE 1005—1020</td>
</tr>
<tr>
<td></td>
<td>housings.</td>
<td></td>
</tr>
</tbody>
</table>

*Any two SAE prefix numbers can be applied.
## TYPICAL PROPERTIES and Comparison with Similar Cast Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Tension Strength, psi</th>
<th>Yield Strength, psi</th>
<th>Elongation %</th>
<th>Mean Fatigue Strength, psi</th>
<th>Compressive Yield Strength, psi</th>
<th>Compressive Ultimate Strength, psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>ArmaSteel GM 88M ASTM Grade 80CG2</td>
<td>105,000</td>
<td>85,000</td>
<td>2.0</td>
<td>43,000</td>
<td>85,000</td>
<td>250,000</td>
</tr>
<tr>
<td>ArmaSteel GM 84M SAE Grade 70002 ASTM Grade 80CG2</td>
<td>100,000</td>
<td>80,000</td>
<td>2.0</td>
<td>42,000</td>
<td>80,000</td>
<td>235,000</td>
</tr>
<tr>
<td>ArmaSteel GM 85M Modified SAE &amp; ASTM Grade 60CG3</td>
<td>90,000</td>
<td>60,000</td>
<td>3.0</td>
<td>40,000</td>
<td>60,000</td>
<td>220,000</td>
</tr>
<tr>
<td>ArmaSteel GM 85M SAE &amp; ASTM Grade 60CG3</td>
<td>80,000</td>
<td>60,000</td>
<td>3.0</td>
<td>39,000</td>
<td>60,000</td>
<td>210,000</td>
</tr>
<tr>
<td>ArmaSteel GM 85M SAE Grade 480GG ASTM Grade 48064</td>
<td>70,000</td>
<td>48,000</td>
<td>5.0</td>
<td>34,000</td>
<td>48,000</td>
<td>190,000</td>
</tr>
<tr>
<td>Malleable Iron GM 11M SAE &amp; ASTM Grade 32210</td>
<td>50,000</td>
<td>32,500</td>
<td>10.0</td>
<td>25,000</td>
<td>32,500</td>
<td>170,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Strength, Ft. Lbs.</th>
<th>Charpy Unnotched Bar</th>
<th>Charpy Notched Bar</th>
<th>Brinell</th>
<th>Rockwell</th>
<th>Modulus of Elasticity, Million psi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bhn</td>
<td>Diam.**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>26-27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.96-3.30</td>
<td>23.50-43.00</td>
<td>269-320</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.50-4.50</td>
<td>40.50-51.00</td>
<td>241-265</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.50-3.20</td>
<td>28.00-45.50</td>
<td>217-269</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.90-7.90</td>
<td>43.50-63.50</td>
<td>163-207</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.20-8.00</td>
<td>54.50-65.00</td>
<td>155 max</td>
</tr>
</tbody>
</table>

Density: all ArmaSteels and Malleable Iron: 0.265 lb. per cu. in.
Coefficient of Expansion, In./ln.°F x 10^-4: All ArmaSteels and Malleable Iron: 5.7 at 100° F; 7.7 at 500° F; 9.4 at 1000° F.
Typical Composition, %: all ArmaSteels and Malleable Iron: carbon, 2.55; silicon, 1.40; manganese, 0.45; sulphur, 0.12; phosphorus, 0.05.
**Diameter of indentation in mm., with 10-mm. ball, 3000-kg, load.
*Polished specimen.
10 million cycles.
Reversed loading.
Typical Automotive Engine Parts

Crankshaft

Connecting Rod

Rocker Arm

Crankshaft Balancer Hub

Harmonic Balancer Hub

Crankshaft Balancer Hub

Crankshaft Pulley Hub
Typical Automotive Transmission Parts

- Rear Planet Carrier and Shaft
- Planet Carrier
- Front Internal Gear
- Multiplier Hub
- Rear Internal Gear
- Reaction Drum
- Planet Carrier
- Converter Damper Hub
- Input Shaft
- Reverse Ring Gear
- Converter Turbine Hub
Typical Automotive Drive and Differential Parts

- Differential Bearing Cap
- Companion Flange
- Ball Stud Yoke
- Limited Slip Differential Half Case
- Slip Yoke-Propeller Shaft
- Differential Case
- Link Yoke
- Differential Carrier
Typical Diesel Engine Parts

- Piston
- Timing Gear
- Torsional Vibration Damper Housing
- Piston Pin Carrier
- Crankshaft Bearing Cap
- Rocker Arm Support and Cap
- Camshaft Front Bearing
Whenever you have a forged steel part, a welded assembly, a part machined from bar stock, a stamping or a part cast in another metal, it will pay you to evaluate the many advantages of replacing that part with a casting of ArmaSteel or Malleable Iron.
Machining Advantages of ArmaSteel and Malleable Iron Castings

SHORTER MACHINING TIME and LONGER TOOL LIFE

When ArmaSteel and Malleable Iron are machined, their uniform distribution of small graphite nodules results in short chips, lubricates the cutting tool, and provides free cutting action. Furthermore, with castings, the distribution of metal is determined by the needs of the finished part, and not by the forging process; so in most cases, there’s less metal to remove—hence less machining, and less tool wear.

FOR EXAMPLE:

1. Two output shafts are shown in Fig. 1 (previous page) before machining. The piece in the foreground is an ArmaSteel casting with cored pinion pockets. The other piece—a steel forging—does not have these pockets. A plunge milling operation is required on both parts; but, due to the cored pockets, the casting costs less to machine.

Fig. 2 shows the parts after machining. The casting is milled with inserted-tooth cutters at high speed; but the forging requires brazed-tipped cutters to avoid excessive breakage. Here ArmaSteel (1) saves tooth-changing time (inserted saws are changed more quickly than brazed tips); (2) gives more pieces per tool grind; (3) produces fewer and more easily-trimmed burrs; and (4) leaves no chips that must be picked out.

2. In machining internal gears, to prevent loading and tearing of the teeth, the broach is run at 17:1 rpm with forged gear blanks, with a .0007"-.0015" chip per tooth. With ArmaSteel gear blanks, broaching speed is doubled (32 to 35 spm) with .002"-.003" chip per tooth—giving far shorter machining cycle time.

And ArmaSteel provides another big saving here. It permits 1600 pieces per tool sharpening, vs. 1000 for the forging—a saving of 60% in tool life and tool-sharpening cost.

3. As part of a study at University of Illinois, rough-turning cuts were made on forged steel and on ArmaSteel, with all conditions the same except work speed. Here are the data:

<table>
<thead>
<tr>
<th>Machining Operation</th>
<th>Tool Life Increase</th>
<th>Production Rate Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill Oil Holes</td>
<td>300 to 500%</td>
<td>37%</td>
</tr>
<tr>
<td>Tap Holes</td>
<td>112%</td>
<td></td>
</tr>
<tr>
<td>Balance Drill</td>
<td>286%</td>
<td></td>
</tr>
</tbody>
</table>

Note the tool life increases, ranging from 33% to 112%—and production rate increases up to 57%.

In addition, this manufacturer now uses only six types of standard carbide tools, instead of 25 types of specialty-ground HSS tools formerly used in turning the main journals.

5. Another crankshaft customer reports the following as typical of the gains obtained by using ArmaSteel castings instead of steel forgings:

- Turning main journals: 17 castings per hour, vs. 12 forgings per hour—6 instead of 26 types of carbide tool bits.
- Rough grinding the journals: 40 castings per hour vs. 35 forgings—with 50% longer wheel life.
- Drilling oil holes: 48 castings per hour, vs. 35 forgings—with more than 5 times the tool life with 360° drill, more than 3 times with 240° drill.
- Finish grinding crankpins: 9.5 castings per hour, vs. 8 forgings—with 4 times the wheel life.

These figures (and many more like them) speak for themselves—and for the savings in production time and tool life provided by ArmaSteel and Malleable Iron castings.
LOWER CHIP-HANDLING COST

Short chips are produced when machining Armasteel and Malleable Iron castings. As a result, there is no need for chip-breakers; chip removal is greatly simplified; and there is less need for chip storage facilities.

FOR EXAMPLE:

In machining steel on a vertical lathe (Fig. 3), prolonged downtime is necessary for removing the long, entangling turnings. Frequently, the steel turnings wind around the chuck, actually causing the tool to break.

After the operator clears the turnings from the machine, downtime is an item of constant expense.

With Armasteel and Malleable Iron, you avoid these delays and expenses, because these metals form short chips instead of long turnings. The chips are so small that the coolant blows them directly into the storage bin, where they can be collected on a belt conveyor and delivered directly into a transfer cart (See Fig. 5.) Downtime is greatly reduced, and there is no need for manual chip removal.

In addition, these chips pack better than steel turnings, so two transfer carts can do the work of three.

PRODUCTION DATA

The following tables give pertinent data for roughing, sizing, and finishing operations of many kinds. These figures give good results under average shop conditions with castings that are rigidly held in machines of adequate power. However—

For any given production setup, the "best" values of feed, speed, etc., depend on many factors. These include . . .

- the shape and rigidity of the workpiece;
- the rigidity of the work holder;
- rigidity of the machine and tool— including freedom from vibration as well as freedom from deflection;
- size and shape of the cut;
- required dimensional accuracy;
- required surface finish; and
- desired life of tools . . .

and also, of course, on the feeds, speeds and power provided by the machine.

For this reason, we present the following data only as a general guide and starting point. A little experimentation will often result in even higher production rates than these figures provide, and in maximum over-all economy—letting you take full advantage of the exceptional machinability of these materials.

### TURNING

With tungsten carbide tools, on continuous cut, with coolant

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ROUGHING CUT</th>
<th>FINISHING CUT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DRY</td>
<td>SLO</td>
</tr>
<tr>
<td>Armasteel—GM-84M, GM-85M, GM-85N Modified, GM-86M and GM-86M</td>
<td>150</td>
<td>0.04</td>
</tr>
<tr>
<td>Malleable iron—GM-11</td>
<td>150</td>
<td>0.04</td>
</tr>
<tr>
<td>Armasteel—GM-84M</td>
<td>150</td>
<td>0.04</td>
</tr>
<tr>
<td>Malleable iron—GM-11</td>
<td>150</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Tool Geometry

<table>
<thead>
<tr>
<th>ROUGHING</th>
<th>FINISHING</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACK Rake</td>
<td>-5°</td>
</tr>
<tr>
<td>SIDE Rake</td>
<td>-5°</td>
</tr>
<tr>
<td>SIDE SETTING EDGE ANGLE</td>
<td>15°</td>
</tr>
<tr>
<td>END CUTTING EDGE ANGLE</td>
<td>15°</td>
</tr>
<tr>
<td>SIDE WIPER</td>
<td>5°</td>
</tr>
<tr>
<td>END RELIEF</td>
<td>5°</td>
</tr>
<tr>
<td>NEAT RADIUS</td>
<td>1/4&quot;</td>
</tr>
</tbody>
</table>

* For GM-85N Modified, see note 1.

* Example: 150 in/min at 1 rev/min, use 150 rpm, no coolant.
DRILLING

Tool Geometry

<table>
<thead>
<tr>
<th>Angle</th>
<th>For A-2 Steel</th>
<th>For GM-1M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point angle</td>
<td>125°</td>
<td>118°</td>
</tr>
<tr>
<td>Chamfer angle</td>
<td>7°</td>
<td>7°</td>
</tr>
</tbody>
</table>
* With thin wax at drill point

With double-loter HSS drill—with coolant

DRILLING THROUGH THE SKIN

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>GM-4BN</th>
<th>GM-6BN</th>
<th>GM-8BN</th>
<th>GM-10M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill Dia., Inches</td>
<td>Feed, In./Revs.</td>
<td>Speed, sfpm</td>
<td>Feed, In./Revs.</td>
<td>Speed, sfpm</td>
</tr>
<tr>
<td>1/4</td>
<td>.060-.081</td>
<td>120-140</td>
<td>.066-.095</td>
<td>90-120</td>
</tr>
<tr>
<td>1/8</td>
<td>.050-.071</td>
<td>120-140</td>
<td>.060-.085</td>
<td>90-120</td>
</tr>
<tr>
<td>1/4</td>
<td>.060-.081</td>
<td>120-140</td>
<td>.066-.095</td>
<td>90-120</td>
</tr>
<tr>
<td>1</td>
<td>.060-.081</td>
<td>120-140</td>
<td>.066-.095</td>
<td>90-120</td>
</tr>
</tbody>
</table>

* For GM-8BN Modified, use same data

BORING

Use same production data and tool geometry as for turning (page 31).

REAMING with HSS Reamer

Speeds should be 1/3 to 1/8 the speed listed for drills of similar size (above). 
Feeds should be 2 to 3 times the feed listed for drills of similar size.

TAPPING

A speed of 90 to 150 sfpm is recommended for tapping all grades of Armalight and GM-1M Malleable Iron. 
Recommended lubricant: Soluble oil, 1:20.

FACE MILLING—SIDE MILLING

With tungsten carbide inserted-tipped cutter

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>BRINELL HARDENED</th>
<th>ROUGHING SKIN CUT</th>
<th>FINISHING CUT, SKIN REMOVED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chip per Tooth, In.</td>
<td>Speed, sfpm</td>
<td>Depth of Cut</td>
</tr>
<tr>
<td>C44-4BN</td>
<td>100-200</td>
<td>.010</td>
<td>1700</td>
</tr>
<tr>
<td>C44-6BN</td>
<td>100-200</td>
<td>.006</td>
<td>1700</td>
</tr>
<tr>
<td>C44-8BN</td>
<td>90-160</td>
<td>.008</td>
<td>900</td>
</tr>
<tr>
<td>C44-10M</td>
<td>100-200</td>
<td>.006</td>
<td>1000</td>
</tr>
<tr>
<td>C44-15M</td>
<td>130 Max</td>
<td>.010</td>
<td>1700</td>
</tr>
</tbody>
</table>

* For GM-8BN Modified, use same data. | Per tooth, in. inches.

TOOL GEOMETRY

- 3° Axial rake
- 5° Radial rake
- 4° square x 5°
- 3° Corner radius

Recommended coolant: Soluble oil, 1:20.
### FACE MILLING - SIDE MILLING

With HSS inserted-tooth cutter, on continuous cut, with coolant

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>BRINELL HARDNESS</th>
<th>RESIDING SKIN CUT</th>
<th>TOOL GEOMETRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM-99H</td>
<td>103-201</td>
<td>.110 30 1/4 1/4</td>
<td>31° Face angle</td>
</tr>
<tr>
<td>CN-38H</td>
<td>107-211</td>
<td>.110 60 1/4 1/4</td>
<td>7° Radial rake</td>
</tr>
<tr>
<td>GM-94H</td>
<td>241-219</td>
<td>.108 50 1/4 1/4</td>
<td>11° Elliptic angle</td>
</tr>
<tr>
<td>GM-94M</td>
<td>263-302</td>
<td>.108 45 1/4 1/4</td>
<td>15° Corner rake</td>
</tr>
<tr>
<td>GN-11H</td>
<td>150 max.</td>
<td>.110 120 1/4 1/4</td>
<td></td>
</tr>
</tbody>
</table>

* For GARM Modified, use same data.  † For tooth, in inches.  Recommended coolant: Soluble oil, 1:20

### SLOT AND SLAB MILLING

With HSS helical plain milling cutter, with coolant

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>BRINELL HARDNESS</th>
<th>SKIN CUT</th>
<th>TOOL GEOMETRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM-99H</td>
<td>103-201</td>
<td>.062-307 50 1/4 1/4</td>
<td>31° Face angle</td>
</tr>
<tr>
<td>CN-38H</td>
<td>107-141</td>
<td>.063-307 65 1/4 1/4</td>
<td>7° Radial rake</td>
</tr>
<tr>
<td>GM-94M</td>
<td>263-302</td>
<td>.002-307 45 1/4 1/4</td>
<td>15° Corner rake</td>
</tr>
<tr>
<td>GN-11H</td>
<td>150 max.</td>
<td>.062-307 90 1/4 1/4</td>
<td></td>
</tr>
</tbody>
</table>

* For GARM Modified, use same data.  † For tooth, in inches.  Recommended coolant: Soluble oil, 1:20

### BROACHING

With HSS broach and coolant

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>BRINELL HARDNESS</th>
<th>SKIN CUT</th>
<th>TOOL GEOMETRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM-99M</td>
<td>103-201</td>
<td>.002-005 40 15°</td>
<td>31° Face angle</td>
</tr>
<tr>
<td>GM-87H</td>
<td>107-211</td>
<td>.003-015 30 10°</td>
<td>7° Radial rake</td>
</tr>
<tr>
<td>GM-94H</td>
<td>241-239</td>
<td>.003-015 30 10°</td>
<td>11° Elliptic angle</td>
</tr>
<tr>
<td>GM-94M</td>
<td>263-302</td>
<td>.003-015 25 10°</td>
<td>15° Corner rake</td>
</tr>
<tr>
<td>GN-11H</td>
<td>150 max.</td>
<td>.003-015 45 10°</td>
<td></td>
</tr>
</tbody>
</table>

* For GARM Modified, use same data.  Recommended coolant: Soluble oil, 1:20

### TOOL LIFE VS. CUTTING SPEED FOR MATERIALS AND CONDITIONS STATED

NORTH: ARMASTEEL, MALLEABLE IRON OR STEEL, AS NOTED

TOOL: 0.125, 0.250, 0.50 CARBIDE INSERT SIZE: 1/8 X .625

FEED: 0.020 IN

DEPT: 0.030 IN

SKIN CUT - DRY

**BROACHING**

Use same production data and tool geometry as for turning (page 31).

**GRINDING**

Recommended wheel specifications:

- Material: V5
- Grade: 604 and 605
- Grain: 26-A
- Bond: N5 & 9-5
**DRILLING TORQUE AND THRUST FOR VARIOUS MATERIALS**

**DRILL THRUST TRENDS FOR 100 HOLES**

A MOTION PICTURE in color, with sound, shows a number of interesting machining and finishing operations being performed on ArmaSteel castings. Title: "A Real Blue Chip Operation."

Running time: 13 minutes. It's available without charge for showing to your factory group or technical society.

OUR ENGINEERING SERVICE stands ready at all times to advise you on machining and finishing ArmaSteel and malleable iron castings to your best advantage—and for consultation on application and design.

Simply get in touch with your Central Foundry representative, or with our headquarters in Saginaw.
METALLURGICAL DATA on ArmaSteel and Malleable Iron

The material below and on the next three pages gives details on the metallurgical characteristics of ArmaSteel and Malleable Iron. This information will supplement that on the preceding pages in enabling your engineers to determine how these materials can be used to best advantage in your products.

**HARDNESS VS DRAW TEMPERATURE**

- **ARMASTEEL**

This curve is for \( \frac{1}{4} \)-round, held 30 minutes at 1600°F, and oil-quenched—then drawn for 2 hours at heat in a recirculating-type draw furnace. Quenched hardness, 58 Rockwell C.

**HARDNESS VS ULTIMATE TENSILE STRENGTH**

- **ARMASTEEL**

Green sand-casting, \( \frac{1}{4} \)-round, held 30 minutes at 1600°F, oil-quenched, and tempered 2 hours at heat in a recirculating air-type furnace.

**HARDENABILITY CURVE**

- **SAE 50504H STEEL**

Bars Aустenitized at 1500°F, 1 Hr.

**HARDENABILITY CURVE**

- **SAE 1041H STEEL**

**STRESS VS RUPTURE TIME**

- **ARMASTEEL**

**STRESS VS RUPTURE TIME**

- **MALLEABLE IRON**
Hardening of ArmaSteel and Malleable Iron

Induction hardening, flame hardening, furnace hardening and nitriding may be used to harden ArmaSteel and furnace hardening and nitriding may be used to harden Malleable Iron. Proper selection of a process and hardening cycle readily produces hardnesses equal to those obtained by carburizing steel. The time required to harden these materials largely depends on the amount of combined carbon and the desired hardness. Quenching in oil is recommended for most castings, particularly those with sharp corners and abrupt changes in thickness in the heated area. In all castings, the quench medium should be thoroughly agitated.

Induction Hardening

Time, power and frequency are the factors controlling case depth and hardness. Good results are being obtained with both high- and lower-rated cycle units. One large user of ArmaSteel obtains a hardened depth of 0.08" to 0.065" with equipment rated at 450 cycles at 20 kva. Using a single-turn coil, with a 12-second heat cycle, a hardness of Rockwell C 50 is obtained.

A representative producer using two 15-kva units rated at 9600 cycles on a 27 second cycle obtains a complete section of Rockwell C 54-60.

Flame Hardening

Propane, acetylene, methylacetylene-propane (MAPP) and natural gas may be used as fuels for flame hardening. Flame velocity, fuel/oxygen ratio, coupling distance and time are important factors affecting the case depth and hardness.

In the case of refrigerator-compressor crankshafts the problem was to achieve an ideal hardness pattern — with the maximum hardness right up to the flange. The solution: ArmaSteel castings flame hardened and quenched. The method: 14-second heating cycle. Production rate: 1600 per 5-hour day. Distortion: negligible. The hardened parts are well within grinding limits, with no burning or cracking at the oil hole.

The ArmaSteel shifter yokes on one make of car are flame-hardened by applying an oxyacetylene flame to two surfaces for 10 and 25 seconds respectively, followed by a water quench. This is done on an automatic hardening machine, in the production line, which turns out over 6,000 each of two different yokes in 16 hours with a good, wear-resistant surface.

Furnace Hardening

A procedure generally recommended for ArmaSteel is to heat to 1550°-1600° F. and hold for 20 to 30 minutes, followed by an oil bath quench at 120°-150° F. A temperature as low as 1550° F for 30 minutes on some sections will produce satisfactory hardness. A 1" section of 3.9-4.3 mm. Brinnell, heated to 1560° F for 30 minutes and quenched, will give a minimum Rockwell C of approximately 50. The same section held at 1600° F for 30 minutes and quenched in oil will give a minimum Rockwell C of approximately 55.

Salt Bath Quenching

Salt Bath Quenching can be utilized in conjunction with ArmaSteel and Malleable Iron to achieve both martensitic and bainitic structures.

Nitriding

Nitriding has been successfully applied to ArmaSteel by treating for 3 hours at 1500° F in an atmosphere of carburizing gas and ammonia. A shallow case of approximately 0.004" is obtained. This has been particularly satisfactory on such parts as shifter yokes and small gears. Both ArmaSteel and Malleable Iron can be "Tuffried." Acceptable structures have been obtained at 1600° F.

---

### HARDNESS CONVERSION TABLE

<table>
<thead>
<tr>
<th>Brinnell Indentation Diameter, mm</th>
<th>Brinnell Hardness Number 3000 Kg.</th>
<th>Rockwell Hardness B-Scale 100 Kg Load 1//16 in. Ball</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.80</td>
<td>156</td>
<td>90</td>
</tr>
<tr>
<td>4.75</td>
<td>159</td>
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<td>3.60</td>
<td>285</td>
<td>103</td>
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<tr>
<td>3.55</td>
<td>293</td>
<td>104</td>
</tr>
<tr>
<td>3.50</td>
<td>302</td>
<td>105</td>
</tr>
</tbody>
</table>

---

### FOUNDARY TERMS

commonly used when referring to ferrous castings

- **FLASK**—Container in which a mold is made.
- **COPE**—The upper or topmost section of a flask, mold or pattern.
- **DRAIN**—The lower or bottom section of a flask, mold or pattern.
- **CORE**—A body of sand or other material placed in a mold to produce a cavity of desired shape in a casting.
- **CORE PRINT**—An extension of the pattern for locating the core or an extension of the mold cavity for locating the core.
- **SET CORE**—A core placed in the core print of a mold to produce a cavity of desired shape in a casting.
- **RAIN-UP CORE**—A core placed in the pattern before the flask is filled with sand, so that it rams up as an integral part of the mold.
- **FEEDER**—A reservoir of molten metal provided to compensate for contraction of metal as it solidifies, by feeding down liquid metal to prevent voids. Also called a riser.
- **SPRUE**—The vertical portion of the gating system through which the molten metal first enters the mold.
- **POURING BASIN**—Reservoir on top of the mold to receive molten metal.
- **GATE**—Specifically, the point where molten metal enters the casting cavity. Sometimes employed as a general term to indicate the entire assembly of connected columns and channels carrying the metal.
- **RUNNER**—The channel of a gating system through which molten metal flows from the sprue to the castings and risers.