MEEHANITE

MEEHANITE

HANDBOOK

GENERAL ENGINEERING
ABRASION RESISTING
HEAT RESISTING
CORROSION RESISTING

www.meehanitemetal.com

MEEHANITE METAL HANDBOOK
Revised 2005

For information, write to:
Meehanite Metal Corporation
10936 N. Port Washington Rd. #141
Mequon, WI 53092 Phone 800-423-0992
E-mail info@meehanitemetal.com

The trade marks [MEEHANITE METAL] [M METAL] [DUCTLIRON] [ALMANITE] and [MEEHANITE] are registered with the U.S. Patent Office and designate products made under the direction and in accordance with the prescribed standards of Meehanite Worldwide.

ACKNOWLEDGEMENTS
Meehanite Metal Corp. gratefully extends sincerest thanks to all Meehanite foundries for permission to reproduce their photographs in this Handbook of Meehanite Metal.

The Meehanite Metal Corporation has been in business for over seventy years, developing a family of high performance cast ductile and flake irons described in the following sections. This handbook of Meehanite Metals has been prepared for designers, engineers and purchasing executives who strive to improve product performance and reduce manufacturing costs. It presents the mechanical & physical properties of each type of Meehanite Metal in a clear and concise manner in order to aid in the selection of the particular type of Meehanite® which will most completely meet the buyer's requirements.

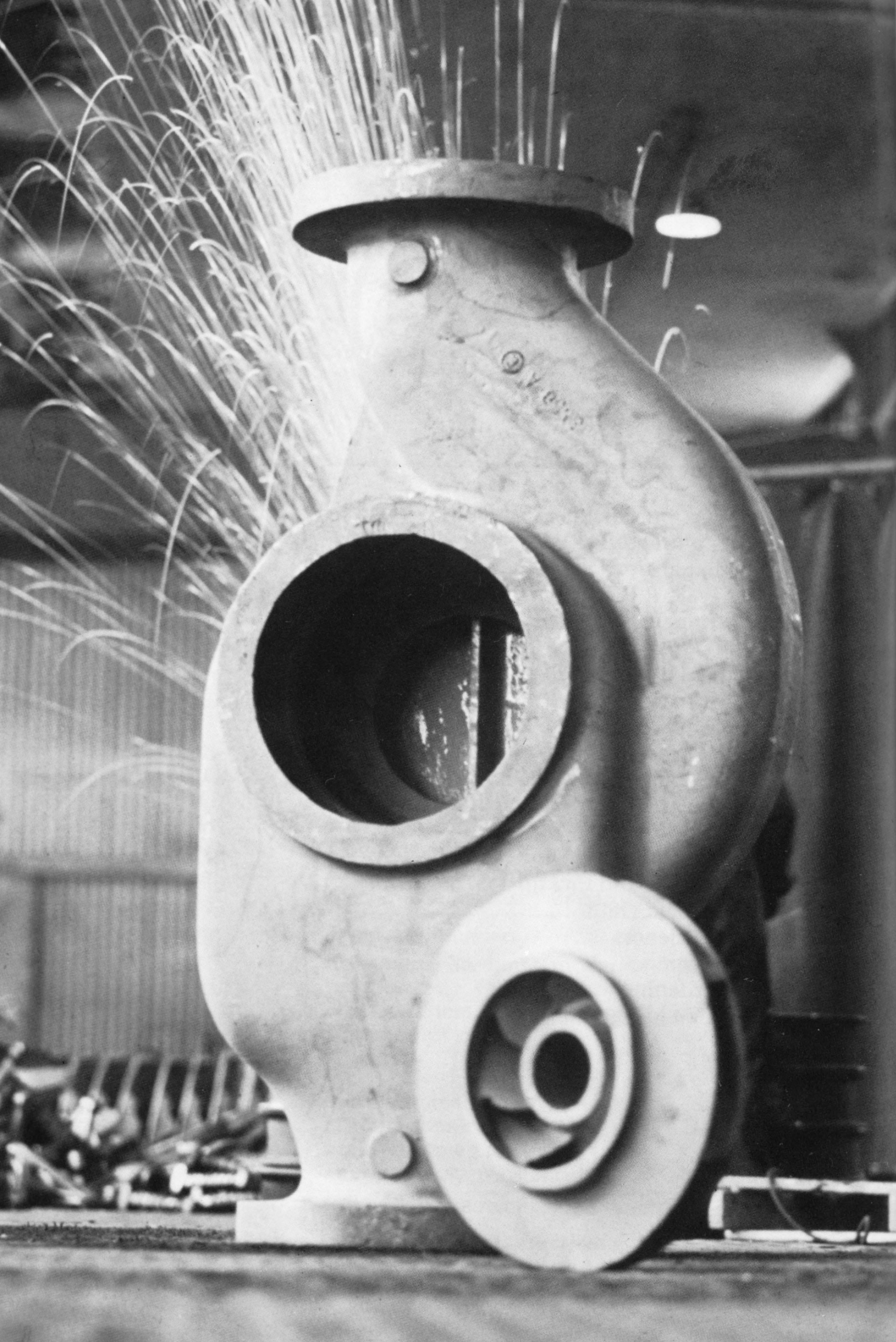
Meehanite Metals furnish industry with engineering materials of known and consistent properties on which casting design can be safely based. They have proved their value the world over from not only the viewpoint of dependable service, but economy as well.

The following pages outline some of the advantages to be gained by the use of Meehanite® and explain why this versatile material is so widely recognized and used throughout industry.

To compliment the development of these materials, Meehanite licenses only qualified foundries to produce these products. Every licensee is required to undergo a strict training regimen before they are permitted to produce any grade of Meehanite. Further to this, an ongoing program of auditing is followed, to ensure that the standards required for production are maintained.

If you are interested in obtaining a Meehanite license, you can find out what is involved and the services we provide by going to page 88 - The Meehanite Connection.

CONTENTS



Meehanite® pump impeller and casing.

The Meehanite Process

Meehanite Metal castings cover any casting within the overall cast iron composition range that have been produced by the Meehanite process.

This process involves a number of patented procedures seeking to control and produce the desired graphite distribution and the desired matrix structure in the casting. It depends primarily on the establishment of a melt of desired degree of undercooling often referred to as constitution and the controlled nucleation of this melt, usually by means of alkaline earth silicide additions. It requires very careful selection of raw materials, meticulous process controls and a very thorough knowledge of the foundry behavior of cast iron.

The Meehanite process involves the use of standard procedures in all phases of casting manufacture including gating and risering techniques, sand control testing methods and many specialized molding procedures. It seeks to eliminate guesswork, thereby resulting in an engineering product of high integrity and reliability.

Meehanite Metal Types

While the Meehanite process is a closely integrated procedure and will produce a truly quality casting, it is necessary for the engineer to have at his disposal exact figures on the physical and mechanical properties of Meehanite Metal so that he may design with confidence.

For this reason, Meehanite Metal has conveniently been divided into a number of broad type classifications each with its typical properties which enables the engineer to select that type of metal most suited to his particular application.

On the basis of use, the following broad categories apply:

1. General Engineering	Prefix G
2. Wear Resisting	Prefix W
3. Heat Resisting	Prefix H
4. Corrosion Resisting	Prefix C

These categories relate to the end use of the casting and are further sub-divided on the basis of metallurgical structure and property values.

Meehanite Units

This revised issue of the "Handbook of Meehanite Metal" has adopted the metric system along with the English system. The adoption of the metric system (International System of Units, or abbreviated as SI in all language) is due to the fact that the metric system will sooner or later be universal and we already have had many requests for metric data.

It would appear necessary to present the relations between metric measures of length, area, mass and derived units, and English units.

BASE UNIT

QUANTITY	UNITS & SYMBOLS SI	ENGLISH	FORMULA SI	ENGLISH
LENGTH	meter, m centimeter, cm milimeter, mm	foot, ft inch, in		
MASS	kilogram, kg gram, gm	pound, lb		
TIME	hour, hr minute, min second, sec	same as metric		
TEMPERATURE	Centigrade, °C	Fahrenheit, °F		

CONVERSION FACTORS FOR PHYSICAL QUANTITIES

QUANTITY	ENGLISH UNIT TO SI UNIT		SI UNIT TO ENGLISH UNIT	
LENGTH	1 in 1 ft	25.4 mm 304.8 mm	1 mm 1 mm	39.37 x 10^{-3} in 3.28 x 10^{-3} ft
MASS	1 lb 1 lb	0.454 kg 453.6 gm	1 kg 1 gm	2.20 lb 2.20 x 10^{-3} lb
TEMPERATURE	°F △°F	5/9 (°F-32) 5/9△°C	°C △°C	9/5°C + 32 9/5△°F
AREA	1 in^2	645.2 mm^2	1 mm^2	1.55 x 10^{-3} in^2
ENERGY	1 BTU	252 cal	1 cal	3.97 x 10^{-3} BTU
FORCE	1 lbf	4.45 newton	1 newton, N	0.225 lbf
MACHINING Feed Speed	 1 in/rev 1 s.f.m.	 2.54 cm/rev 0.31 m/min	 1 cm/rev 1 m/min	 0.394 in/rev 3.3 s.f.m.
PRESSURE	1 psi	6.895 x 10^{-3} N/mm^2	1 N/mm^2	145 psi
IMPACT STRENGTH	1 ft lbf	1.36 N.m	1 N.m	0.737 ft lbf
WORK	1 ft lbf	1.36 N.m	1 N.m	0.737 ft lbf
SPECIFIC HEAT	1 BTU/lb/°F	0.309 cal/gm/°C	1 cal/gm/°C	3.24 BTU/lb/°F
THERMAL CONDUCTIVITY	1 BTU/hr/ft^2/(°F/in)	0.34 x 10^{-3} cal/sec/cm^2/(°C/cm)	1 cal/sec/cm^2/(°C/cm)	2.94 x 10^3 BTU/hr/ft^2/(°F/in)

DERIVED UNIT

QUANTITY	UNITS & SYMBOLS SI	ENGLISH	FORMULA SI	ENGLISH
AREA	sq. centimeter sq. millimeter	sq. inch	cm^2 mm^2	in^2
ENDURANCE LIMIT	newton per sq. millimeter	pound-force per sq. inch (psi)	N/mm^2	lbf/in^2 (psi)
ENERGY	Joule	British thermal unit, BTU	N.m	ft lbf
FORCE	newton, N	pound-force, lbf	kg. cm/sec^2	lb ft/sec^2
IMPACT STRENGTH	newton-meter	foot-pound-force	N.m	ft lbf
MACHINING				
Feed	centimeter per revolution	inch per revolution	cm/rev	in/rev
Speed	surface meter per minute s.m. min	surface foot per minute, s.f.m.	m/min	ft/min
MODULES OF ELASTICITY				
tension	newton per sq. millimeter, E	pound-force per sq. inch, E	N/mm^2	psi
torsion	N*	N*	N/mm^2	psi
PRESSURE	newton per sq. millimeter	pound-force per sq. inch, psi	N/mm^2	psi
STRESS	newton per sq. millimeter	pound-force per sq. inch, psi	N/mm^2	psi
SPECIFIC HEAT	calorie per gram–Celsius	BTU per pound Fahrenheit	cal/gm/°C	BTU/lb/°F
THERMAL CONDUCTIVITY	thermal flux (calorie per second) per sq. centimeter–(Celsius per centimeter), K value	thermal flux (BTU per hour) per sq. foot–(Fahrenheit per inch), K value	$cal/sec/cm^2$/ (°C/cm)	$BTU/hr/ft^2$/ (°F/n)
WORK	newton-meter	foot-pound-force	N.m	ft lbf

*The possible confusion with this meaning of the symbol N and the newton N if not clear from the context must be avoided by the use of “torsion modulus of elasticity” instead of N.

Each type of Meehanite Metal is made to a predetermined structure thereby assuring uniform and dependable properties to precise engineering specifications. Four typical examples are shown below.

MEEHANITE TYPE GM 60 (GM 400)

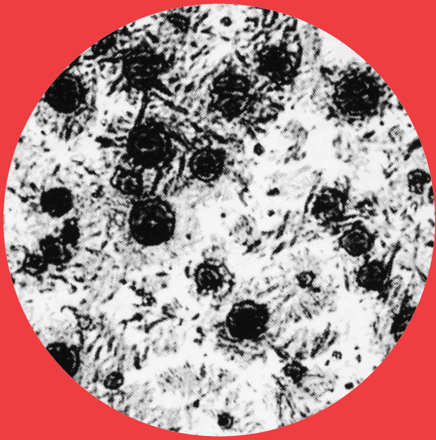
Tensile Strength	60,000 psi (400N/mm^2)
BHN (normal)	230

MEEHANITE TYPE AQ

Tensile Strength Heat Treated	65,000 psi (448N/mm^2)
BHN	Up to 550

MEEHANITE TYPE SH 100 (SH 700)

Tensile Strength	90/170,000 psi (620/1172N/mm^2)
BHN	263/600



MEEHANITE TYPE WS

Tensile Strength	60/80,000 psi (414/552N/mm^2)
BHN	400/525

General Engineering Types

This Meehanite Metal series is classified into flake graphite metals designated by the prefix G and nodular graphite metals designated by the prefix S.

The G, or flake graphite, metals are subdivided according to the tensile strength because this is the most convenient method. This method of division is used even though the engineer may be more interested in specific properties other than tensile strength.

Tensile strength is given in minimum values, but it should be realized that Meehanite Metal G may be produced to any specific minimum value either exactly corresponding to any specific type or to values that may fall exactly in between designated types.

In short, all properties show a gradual transition from the highest tensile value to the lowest tensile value and are separated into various types only for the purpose of specification.

Since we use the metric system along with the English system in this edition of the Handbook, the Meehanite Metal series has accordingly adopted numerical symbols for the metric designation. This designation includes only the Meehanite Flake Graphite G Types and Nodular Graphite S Types.

The Meehanite Wear Resisting Types, Heat Resisting Types and Corrosion Resisting Types remain the same as the previous designations because they do not involve the numerical symbols.

Sub-divisions are:

Flake Graphite "G" Types

Type GM 60 (GM 400)
–flake graphite, sorbo pearlitic matrix or tempered martensite if heat treated.

Type GA 50 (GA 350)
–flake graphite, pearlitic matrix.

Type GC 40 (GC 275)
–flake graphite, pearlitic matrix.

Type GE 30 (GE 200)
–flake graphite, pearlitic matrix.

Type GF 20 (GF 150)
–flake graphite, ferritic/pearlitic matrix.

Type AQ
–flake graphite, pearlitic/bainitic matrix.

The relationship between tensile strength (forming the basis of classification) and other pertinent properties are given in the appropriate section of this Handbook.

The sub-numerals 60, 50, 40, etc., indicate the PSI units on equivalent standard test bars for each type and 400, 350, 300, etc., indicate the minimum tensile strength in N/mm^2 units.

For example:

GM 60 (GM 400) means type GM metal has approximate tensile strength 60,000 psi or 400 N/mm^2.

Nodular Graphite "S" Types (Ductliron®).

Sub-division in this series again is for specification convenience. Specific property values of any value within the ranges given may also be provided.

Relationship between tensile strength and other properties may be found in the engineering data section of the Handbook.

Type SF 60 (SF 400)
–nodular graphite, ferritic matrix.

Type SP 80 (SP 600)
–nodular graphite, pearlitic/ferritic matrix.

Type SH 100 (SH 700)
–nodular graphite, pearlitic matrix, or tempered martensite if heat treated.

Type AQS
–nodular graphite, pearlitic/bainitic, martensite matrix.

Wear Resisting Types (Almanite®).

This series produced primarily for wear resistance while having specific mechanical properties is broadly classified according to metallurgical structures which, in turn, determines the wear resistance.

These metals may contain free carbon as graphite or as carbides or both. Those containing carbides as the major properties of free carbon are white irons.

Subdivisions are:

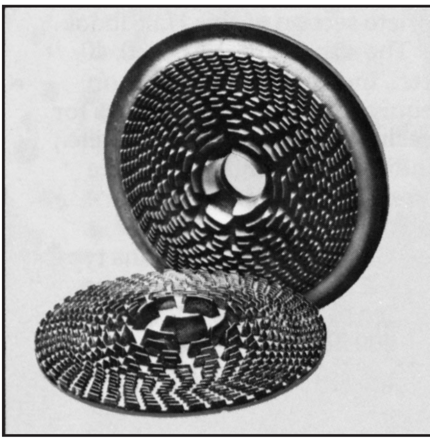
Type W 1
–carbidic, pearlitic matrix.

Type W 2
–carbidic, martensitic matrix.

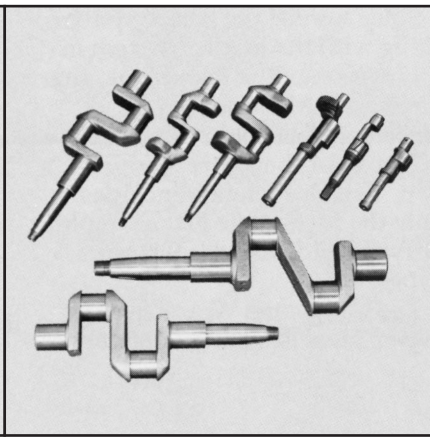
Type W 4
–carbidic, austenitic matrix.

Type WS
–nodular graphite, martensitic matrix.

Type WSH
–nodular graphite, austenitic matrix.



Rubber cutting discs cast in Meehanite nodular iron.



Meehanite crankshafts.

Heat Resisting Types

While even the General Engineering irons do have some good heat resisting properties, the heat resisting types of Meehanite are specifically produced to meet a wide range of high temperature service conditions.

Sub-division is on the basis of type of application, but is characterized by structure, thus:

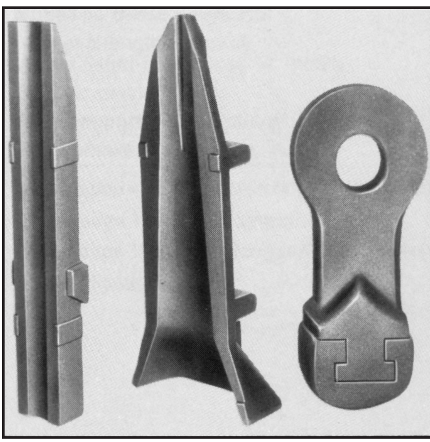
Type HR
–carbidic/pearlitic (heat with wear).
Type HS
–nodular graphite, ferritic. (temperature up to 1800°F (981°C).
Type HSV
–nodular graphite, ferritic/pearlitic.
Type HE
–flake graphite, pearlitic (heat shock).

Corrosion Resisting Types

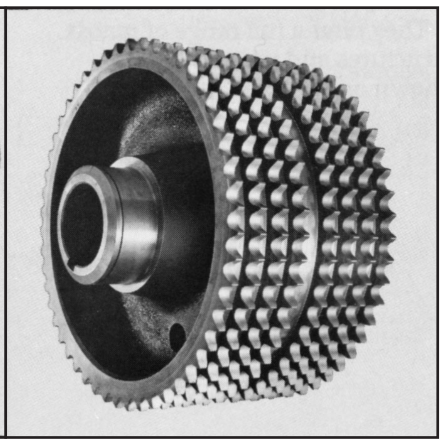
This series is sub-divided very broadly according to structure, but composition may be varied considerably to suit exact conditions of service. This should be done on the basis of consultation with your casting supplier.

The austenitic nickel types CR and CRS may be modified to meet all standard engineering society specifications for this type of material.

Type CC
–flake graphite, pearlitic.
Type CR
–flake graphite, nickel/austenitic.
Type CRS
–nodular graphite, nickel austenitic.
Type CHS
–nodular graphite, ferritic.



Almanite WSH rod mill guides



Ductliron sprocket for ship engine

Meehanite Nodular Graphite "S" Types (Ductliron®)

Ductliron®, a registered Meehanite trade-name for a group of high carbon ferrous materials containing graphite in the form of nodules or spheroids is also known as ductile iron and nodular iron.

This versatile engineering metal possesses high strength, ductility, castability and other properties that make it outstanding for many of industry's toughest applications.

Four types of Meehanite Ductliron for General Engineering purposes are available: SP 80 (SP 600), SH 100 (SH 700), SF 60 (SF 400) and AQS.

They offer a full range of matrix structures and properties, as shown on the following pages.

Meehanite Type SF 60 (SF 400)

This type possesses high ductility, exceptional resistance to shock and provides maximum toughness and machinability. Its structure is essentially ferritic and it is not readily flame hardened.

This material meets the requirements outlined in the following specifications:

ASTM A536 (60-40-18, 65-45-12)
ASTM: A395 (60-40-18)
ASME: SA395
ASM: 5315*2

Typical Applications:

For components subjected to both thermal and mechanical shock and for pressure castings, valves, cylinders, parts for automotive, machine tool, marine and where soft-steel castings, steel weldments or malleable iron has been used.

MEEHANITE TYPE SF60 (SF400)

Properties (As Cast)	English	SI Unit
Tensile strength–psi (N/mm²)	60,000	(>400)
Yield strength (tension)–psi (N/mm²)	40,000	(>310)
Yield strength (compression)–psi (N/mm²)	54,000	(>370)
Modulus of elasticity (tension), 10^6 psi (E x 10^6)	23	(0.17)
Modulus of elasticity (torsion), 10^6 psi (N x 10^6)	9.5	(0.07)
Elongation in 2″ or 50 mm bar, min %	15-20	15-20
Endurance limit (unnotched) psi (N/mm²)	0.50	0.50
(45° notch)	0.35	0.35
Poisson's ratio	0.32	0.32
Brinell hardness range, BHN	140/190	140/190
Impact strength–Charpy, ft lbf (N/m) 10 mm² bar "V" notch	7-15	(9.81-20.60)
Specific gravity	7.18	7.18
Solid contraction in/ft (mm/n)	1/32-3/32	(13)
Patternmaker's shrinkage, %	0.20-0.80%	

Meehanite Type SP 80 (SP 600)

This type possesses in the as-cast condition more than twice the strength of conventional gray cast iron in combination with exceptional toughness.

It has a predominantly pearlitic structure and is readily machinable. It responds easily to surface hardening by nitriding or by flame or electric induction heat treatment.

This material meets the requirements outlined in the following specifications:

ASTM: A536 (80-50-06)
MIL: 1-11466B
ASM: 5316

Typical Applications:

Recommended for use where severe stresses, shock or high internal pressures are encountered, such as heavy duty gears, sprockets, crankshafts, connecting rods, cams, car journal boxes, differential housings, compressor cylinders and components for heavy machinery, diesel, automotive and related industries.

MEEHANITE TYPE SP80 (SP600)

Properties (As Cast)	English	SI Unit
Tensile strength, min., psi (N/mm^2)	80	550
Yield strength (tension), min., psi (N/mm^2)	60	410
Yield strength (compression), min., psi (N/mm^2)	72,000	500
Modulus of elasticity (tension), min., x 10^6 psi (E x 10^6)	25	0.18
Modulus of elasticity (torsion), min., x 10^6 psi (N x 10^6)	9.6	0.07
Elongation in 2 in. or 50 mm bar, min., %	3-10	3-10
Endurance limit, unnotched, psi (N/mm^2)	39,000	(269)
Endurance ratio, unnotched	0.49	0.49
Endurance ratio, 45° notch	0.35	0.35
Poisson's ratio	0.37	0.37
Brinell hardness range, BHN	170/230	170/230
Impact strength–Charpy, ft lbf (N.m) (10 mm^2 bar "V" notch)	1-5	(1.37-6.87)
Specific gravity	7.20	7.20
Solid contraction, in/ft (mm/m)	1/16-1/8	6-13
Patternmaker's shrinkage allowance, %	0.50%-1.00%	

Meehanite Type SH 100 (SH 700)

Characterized by its exceptional hardenability. Type SH 100 (SH 700) is particularly suited where high strengths are desired in relatively heavy section castings.

In the as-cast condition, SH 100 (SH 700) has a fully pearlitic structure. Any hardness value may be obtained ranging from that of a free machinable iron to that of the fully hardened tool steel.

This material meets the requirements outlined in the following specifications:

ASTM: A536 (100-70-03)
MIL: 1-11466

Typical Applications:

Specify for hard wearing castings requiring increased strength and hardness over that in the as-cast condition: heavy duty gears, spinning mandrels, pump liners, rolls, dies, clutch drums, pistons, brake drums, agricultural implement parts.

MEEHANITE TYPE SH100 (SH700)

Properties (As Cast)	English	SI Unit
Tensile strength–psi (N/mm^2)	100,000	>700
Yield strength (tension)–psi (N/mm^2)	70,000	>450
Yield strength (compression)–psi (N/mm^2)	85,000	>593
Modulus of elasticity (tension), 10^6 psi (E x 10^6)	25	(0.18)
Modulus of elasticity (torsion), 10^6 psi (N x 10^6)	4.8	(0.04)
Elongation min., % in 2 in or 50 mm bar	3 min	3 min
Endurance limit (unnotched) psi (N/mm^2) psi	43,000	(297)
Endurance ratio, (unnotched) (45° notch)	0.33 0.25	0.33 0.25
Poisson's ratio	0.37	0.37
Brinell hardness range, BHN	240-300	240-300
Impact strength–Charpy, ft lbf (10 mm^2 bar "V" notch)	1-3	(1.37-4.12)
Specific gravity	7.22	7.22
Solid contraction, in/ft (mm/m)	1/8 -3/16	13/19
Patternmaker's shrinkage, %	1.0 -1.5%	1.0 -1.5%

A good combination of hardness, strength and toughness can be had by an oil quench from 1650°F (898°C) and drawing at 750°F (399°C).

The drawing temperature will range from 400°F (204°C), to 1100°F (593°C), the lower temperature sufficing to relieve hardening strains without reducing the maximum hardness value, while the 1100°F (593°C) draw will result in hardnesses of approximately 300 Brinell.

MEEHANITE TYPE SH100 (SH800)

Properties (Heat Treated)	English	SI Unit
Tensile strength–psi (N/mm²)	100/170,000	(700/1190)
Elongation, %	1-5	1-5
Yield strength–psi (N/mm²)	70/130,000	(483/900)
Brinell hardness range, BHN	260/340	260/340
Impact strength–Charpy, ft lbf (Joules/cm²) (10 mm² bar "V" notch)	1-3	(1.36-4.07)
Pattern Makers Shrink	1.0 -1.5%	1.0 -1.5%

Figure 1

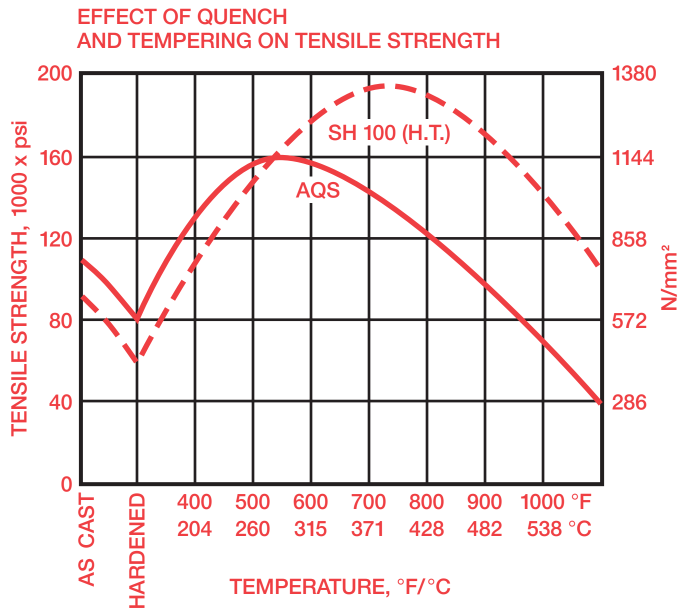
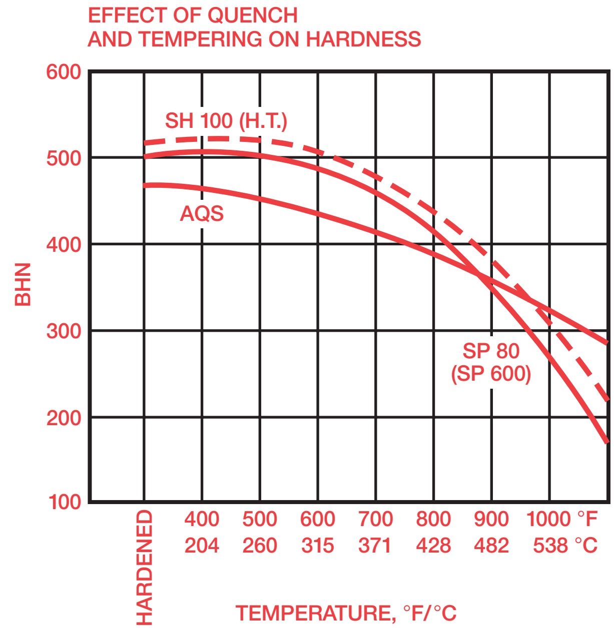
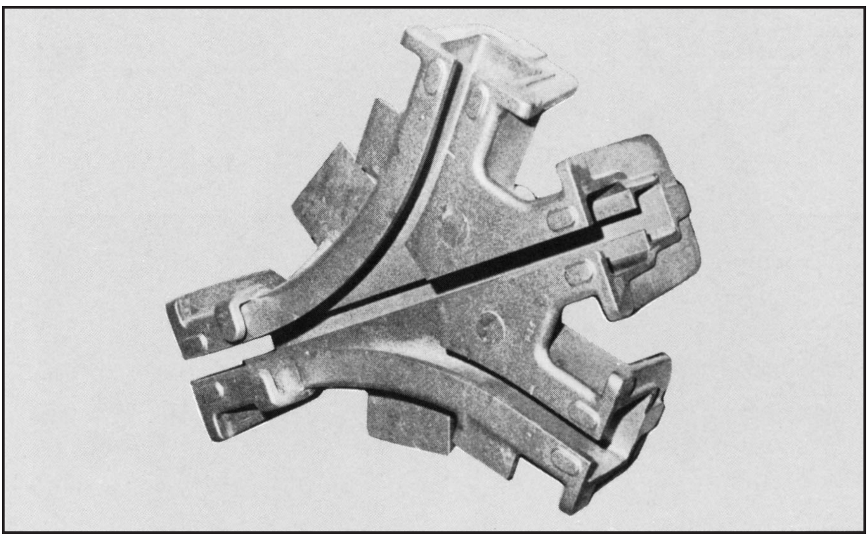


Figure 2





Type SH100 (SH800) Meehanite three-way switch casting for overhead conveyor system requiring superior strength and wear resistance.

Meehanite Type AQS

This is an air hardening metal possessing high strength, toughness and hardness.

It may be fully air quenched throughout casting section after machining to a wide range of strength and hardness values that are uniform with little or no risk of cracking or distortion.

Its endurance strength is higher than most types of ductile iron and AQS also provides an excellent degree of abrasion resistance due in part to its work hardening characteristics.

Typical Applications:

For components subject to cyclic stresses of a high order and requiring good wearing surfaces, such as crankshafts, cams, gears, and spinning mandrels or where resistance to abrasion by non-metallics is mandatory, the high hardness and fatigue strength of AQS is especially valuable. (Figure 3)

MEEHANITE TYPE AQS

Properties (As Cast)	English	SI Unit
Tensile strength–psi (N/mm^2)	80/180,000	(550/1240)
Yield strength–psi (N/mm^2)	70/140,000	(480/960)
Elongation in 2˝ or 50 mm bar, min., %	1-3	1-3
Brinell hardness range, BHN	225/500	225/500
Impact strength–Charpy, ft lbf (10 m^2 bar "V" notch) (Joules/cm^2)	1-3	(1.37-4.12)
Pattern Makers Shrink	1.0 -1.5%	1.0 -1.5%

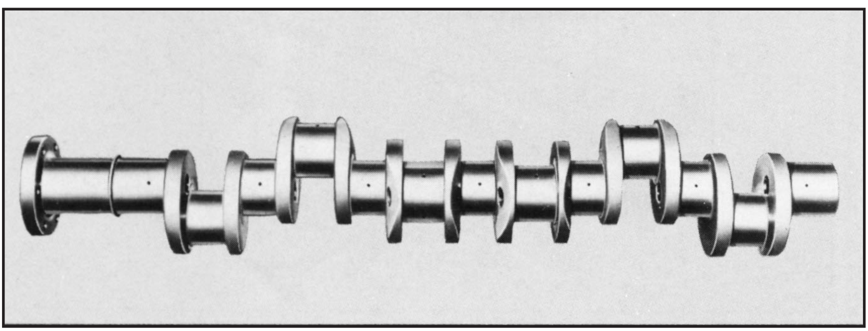
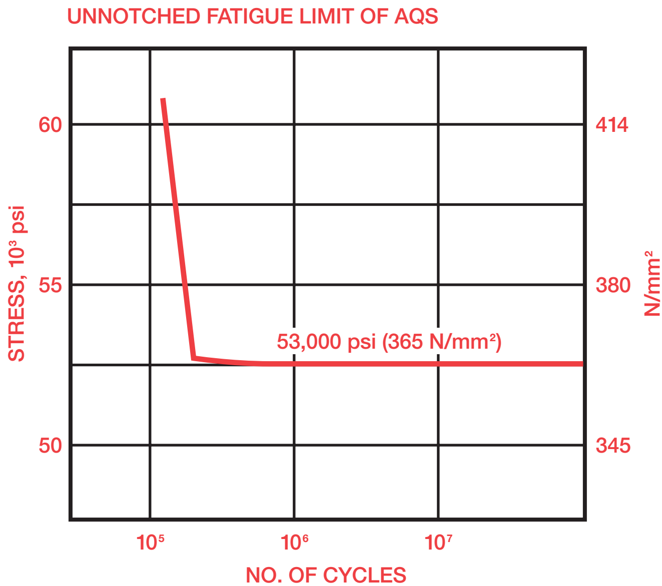


Figure 3



This 6680 lb. Meehanite mandrel was cast in type SH 100. Machined "as cast."
Hardened to 430-500 Brinell and then ground to size.

Meehanite Flake Graphite Types

There are six types available. Their properties are presented in the following pages.

Types GM 60 (GM 400), GA 50 (GA 350), GC 40 (GC 275), GE 30 (GE 200), GF 20 (GF 150), and AQ have been developed so as to provide specific materials to meet the broad requirements of industry.

They are unique in their combination of physical properties in so far as they bridge the gap between steel and cast iron, combining the most desirable properties of each in varying degrees.

Meehanite Type GM 60 (GM 400)

This is the most versatile of the general engineering types. It may be cast uniformly solid to any section thickness from 5/8˝ (16 mm) up to any reasonable cross-sectional dimension.

Having a dense, fine grain structure, this material possesses exceptionally high physical properties including good impact strength and shock resistance.

Machining to a very fine finish is recommended for heavy castings where pressure tightness is required. Type GM 60 responds to heat treatment and may be surface hardened by chilling, flame or induction heat treatment.

This material meets the requirements outlined in the following specifications:

ASTM: A48 (Class 60)
ANSI: G25.1
FEDERAL: QQ-1-652c

Typical Applications:

Type GM 60 has replaced both steel castings and forgings, high tensile bronzes and other non-ferrous materials where its particular combination of properties is advantageous.

It is used extensively for heavy service gears, sheaves, cable drums and crane wheels, kiln tires and rollers, stamping, drawing, pressing, blanking and heading dies; lathe spindles, chucks, ball mill heads and gudgeons, hydraulic cylinders and rams; crankshafts, high pressure chambers and valves; straightening, bending and shaping rollers, etc.

MEEHANITE TYPE GM60 (GM400)

Properties (As Cast)	English	SI Unit
Tensile strength–psi (N/mm^2)	55,000	(400)
Proportional limit–psi (N/mm^2) 0.01% permanent set	25,000	(179)
Modulus of elasticity, 10^6 psi (E x 10^6)	21.5	(0.15)
Modulus of rigidity, 10^6 psi (N x 10^6)	9.5	(0.07)
Poisson’s ratio	0.33	0.33
Modulus of rupture–10^6 psi (N x 10^6)	93,000	(640
Compression strength–10^6 psi (N x 10^6)	200,000	(1379)
Fatigue strength–10^6 psi (N x 10^6)	25,000	(172)
Shear strength–10^6 psi (N x 10^6)	53,000	(366)
Impact strength–Charpy, ft lbf (N.m)	8.0	(10.8)
Single impact–Izod 0.79˝ (20 mm) Dia. Unnotched Bar	30-40	(41.2-55.2)
Brinell hardness range, BHN	210/280	210/280
Machinability rating	50	50
Torsional strength–0.75˝ Dia. x 14.5˝ Long (19 mm x 368 mm)		
Ultimate Torsional Fiber Stress	65,000	(448)
Degrees Twist	99.3	99.3
Specific gravity	7.34	7.34
Solid contraction, in/ft (mm/m)	5/32-6/32	(13-16)
Patternmaker’s shrinkage, %	1.1-1.5	1.1-1.5
Thermal properties	see page 54	
Electrical properties	see page 67	

Meehanite Type GA 50 (GA 350)

This is a general utility iron combining high strength, toughness, wear resistance and machinability. Solid and dependable castings can be made to any thickness over 1/2˝ (12.7 mm).

If designed with good judgment, it can be used to replace certain steel forgings, steel castings and weldments to good advantage. Because of its structural homogeneity, GA 50 retains high dimensional accuracy in service. It responds to heat treatment and may be hardened locally or on the surface by either flame or the induction process.

This material meets the requirements outlined in the following specifications:

ASTM: A48 (Class 50)
ANSI: G25.1
FEDERAL: QQ-1-652c

Typical Applications:

Outstanding examples of its use occur in machine tool tables, saddles, racks and chucks, etc., press and drawing dies (cast to form), compressor and diesel engine cylinders and liners; camshafts and crankshafts; also high pressure castings at temperatures up to 700° (371°C).

MEEHANITE TYPE GA50 (GA350)

Properties (As Cast)	English	SI Unit
Tensile strength–psi (N/mm²)	50,000	(350)
Proportional limit–psi (N/mm²) 0.01% permanent set	20,000	(138)
Modulus of elasticity–10^6 psi (E x 10^6)	20	(0.14)
Modulus of rigidity–10^6 psi (N x 10^6)	8.75	(0.06)
Poisson's ratio	0.32	0.32
Modulus of rupture–10^6 psi (N x 10^6)	90,000	(621)
Compression strength–10^6 psi (N x 10^6)	180,000	(1242)
Fatigue strength–10^6 psi (N x 10^6)	22,000	(152)
Shear strength–10^6 psi (N x 10^6)	50,000	(350)
Impact strength–Charpy, ft lbf (N.m)	7.2	(9.8)
Single impact–Izod 0.78˝ (20.3 mm) Dia. Unnotched Bar	25/35	(34/48)
Brinell hardness range, BHN	190/250	190/250
Machinability rating	48	48
Torsional strength–0.75˝ Dia. x 14.5˝ Long (19 mm x 368 mm)		
Ultimate Torsional Fiber Stress	58,000	(400)
Degrees Twist	98.7	98.7
Specific gravity	7.31	7.31
Solid contraction in/ft (mm/m)	1/8-5/32	13/16
Patternmaker's shrinkage, %	1.0 -1.4	1.0 -1.14
Thermal properties	see page 54	
Electrical properties	see page 67	

Meehanite Type GC 40 (GC 275)

This is an all-around versatile iron for small and medium size castings.

It may be cast uniformly solid in castings varying from 3/8″ to 2½″ (9.5 to 51 mm) thick. Combining good strength with low coefficient of friction and self-lubricating properties, Type CG 40 finds wide application in engineering components where metal-to-metal friction develops thermal shock, such as heavy brake drums, clutch plates, pistons and cylinder liners, etc.

Because of its relatively high density and solidity, it is particularly suited to small types of pressure castings where sectional dimensions do not exceed 2½″ (64 mm).

This material meets the requirements outlined in the following specifications:

ASTM: A48 (Class 40)
ANSI: G25.1
FEDERAL: QQ-1-652c

Typical Applications:

Excellent for use in machine tool beds, head stocks, tables, press frames, bed plates, crankcases, flywheels, engine cylinders and small cylinder liners, brake drums, clutch plates, cams, pistons, pulleys, hydraulic valves.

This type finds general use due to its useful combination of good all-round properties with adaptability to large or small quantity productions.

MEEHANITE TYPE GC40 (GC275)

Properties (As Cast)	English	SI Unit
Tensile strength–psi (N/mm²)	40,000	(275)
Proportional limit–psi (N/mm²) 0.01% permanent set	14,500	(100)
Modulus of elasticity–10⁶ psi (E x 10⁶)	16.5	(0.11)
Modulus of rigidity–10⁶ psi (N x 10⁶)	7.25	(0.05)
Poisson's ratio	0.30	0.30
Modulus of rupture–10⁶ psi (N x 10⁶)	80,000	(600)
Compression strength–psi (N/mm²)	150,000	(1,035)
Fatigue strength–psi (N/mm²)	17,500	(117)
Shear strength–psi (N/mm²)	40,000	(300)
Impact strength–Charpy, ft lbf (N.m)	4.5	(6.2)
Single impact–Izod 0.78″ (20 mm) Dia. Unnotched Bar	12/20	(17/28)
Brinell hardness, BHN	170/230	170/230
Machinability rating	47	47
Torsional strength–0.75″ Dia. x 14.5″ Long (19 mm x 368 mm)		
Ultimate Torsional Fiber Stress	47,000	(324)
Degrees Twist	64.3	64.3
Specific gravity	7.25	7.25
Solid contraction in/ft (mm/m)	7/64 -5/32	11/16
Patternmaker's shrinkage, %	0.9-1.3	0.9-1.3
Thermal properties	see page 54	
Electrical properties	see page 67	

Meehanite Type GE 30 (GE 200)

This material is available as an alternative and superior material for all applications replacing ordinary gray cast iron.

Type GE 30 is manufactured under the same strict control as the other Meehanite types and therefore offers the benefits of structural uniformity and soundness. It permits higher feeds and speeds because of the uniformity and complete absence of hard spots, corners and edges.

Type GE 30 (GE 200) combines improved strength and density and assures uniform dependable performance.

This material meets the requirements outlined in the following specifications:

ASTM: A48 (Class 30)
ANSI: G25.1
FEDERAL: QQ-1-652c

Typical Applications:

Suitable for any size casting from the lightest repetitive to the large heavy individual casting.

MEEHANITE TYPE GE30 (GE200)

Properties (As Cast)	English	SI Unit
Tensile strength–psi (N/mm^2)	30,000	(2000)
Proportional limit–psi (N/mm^2) 0.01% permanent set	11,500	(79)
Modulus of elasticity–10^6 psi (E x 10^6)	13	(0.097)
Modulus of rigidity–10^6 psi (N x 10^6)	5.5	(0.038)
Poisson's ratio	0.27	0.27
Modulus of rupture–psi (N/mm^2)	61,000	(421)
Compression strength–psi (N/mm^2)	120,000	(840)
Fatigue strength–psi (N/mm^2)	13,500	(93)
Shear strength–psi (N/mm^2)	30,000	(210)
Impact strength–Charpy, ft lbf (N.m)	2.1	(2.9)
Single impact–Izod 0.79˝ (20 mm) Dia. Unnotched Bar	6/12	(7.9/15.7)
Brinell hardness, BHN	160/210	160/210
Machinability rating	38	38
Torsional strength–0.75˝ Dia. x 14.5˝ Long (19 mm x 368 mm)		
Ultimate Torsional Fiber Stress	38,000	(262)
Degree Twist	49.2	49.2
Specific gravity	7.06	7.06
Solid contraction in/ft (mm/m)	1/10-1/8	(10/13)
Patternmaker's shrinkage, %	0.8-1.2	0.8-1.2
Thermal properties	see page 56	
Electrical properties	see page 58	

Meehanite Type GF 20 (GF 150)

This material is designed principally for high machinability and is used where ultimate strength is not an important factor. For maximum machinability, an annealing treatment may also be specified although this metal because of its excellent foundry characteristics is free from hard spots and edges even in comparatively light sectioned castings.

It also possesses a high damping capacity and is therefore useful where vibration and noise of operation may be under consideration.

Typical Applications:
Recommended for components requiring high machinability.

MEEHANITE TYPE GF20 (GF150)

Properties (As Cast)	English	SI Unit
Tensile strength–psi (N/mm^2)	20,000	(150)
Proportional limit–psi (N/mm^2) 0.01% permanent set	9,500	(66)
Modulus of elasticity–10^6 psi (E x 10^6)	9	(0.062)
Modulus of rigidity–10^6 psi (N x 10^6)	4	(0.028)
Poisson's ratio	0.24	0.24
Modulus of rupture–psi (N/mm^2)	41,000	(283)
Compression strength–psi (N/mm^2)	90,000	(621)
Fatigue strength–psi (N/mm^2)	11,000	(76)
Shear strength–psi (N/mm^2)	21,550	(149)
Impact strength–Charpy, ft lbf (N.m)	1.5	(1.96)
Single impact–Izod 0.79˝ (20 mm) Dia. Unnotched Bar	4/9	(5.9/12.8)
Brinell hardness, BHN	150/200	150/200
Machinability rating	30	30
Torsional strength–0.75˝ Dia. x 14.5˝ Long (19 mm x 368 mm)		
Ultimate Torsional Fiber Stress	31,000	(207)
Degree Twist	35	35
Specific gravity	6.80	6.80
Solid contraction, in/ft (mm/m)	5/64-1/8	(8/13)
Patternmaker's shrinkage, %	0.60/1.00	0.6/1.00
Thermal properties	see page 56	
Electrical properties	see page 58	

Meehanite Type AQ

This is a wear and abrasion resisting iron that is readily machinable "as-cast," but may be "air hardened" after machining with little or no risk of cracking or dimensional change.

Heat treatment is simple consisting of cooling by air blast from a temperature of 1650°F (898°C).

Castings may also be locally hardened for improved service of working faces or edges of such parts as dies, punches, cams and rollers, etc.

Retaining a good hardness "hot", as shown by the chart (Figure 4), this material especially recommends itself where abrasion resistance is required at elevated temperatures up to 1000°F (538°C).

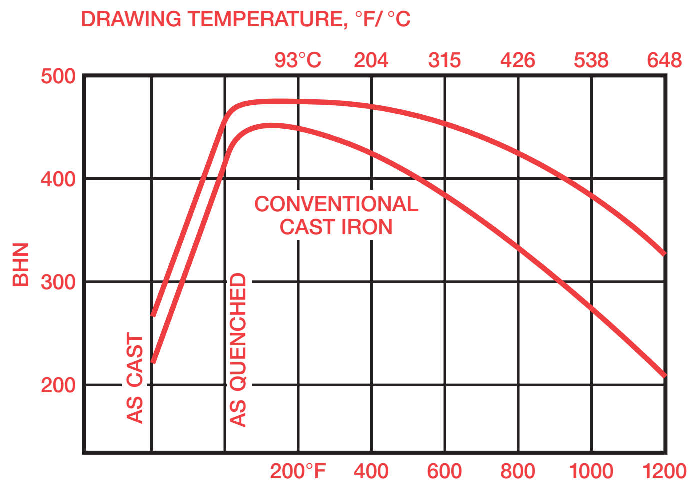
Typical Applications:

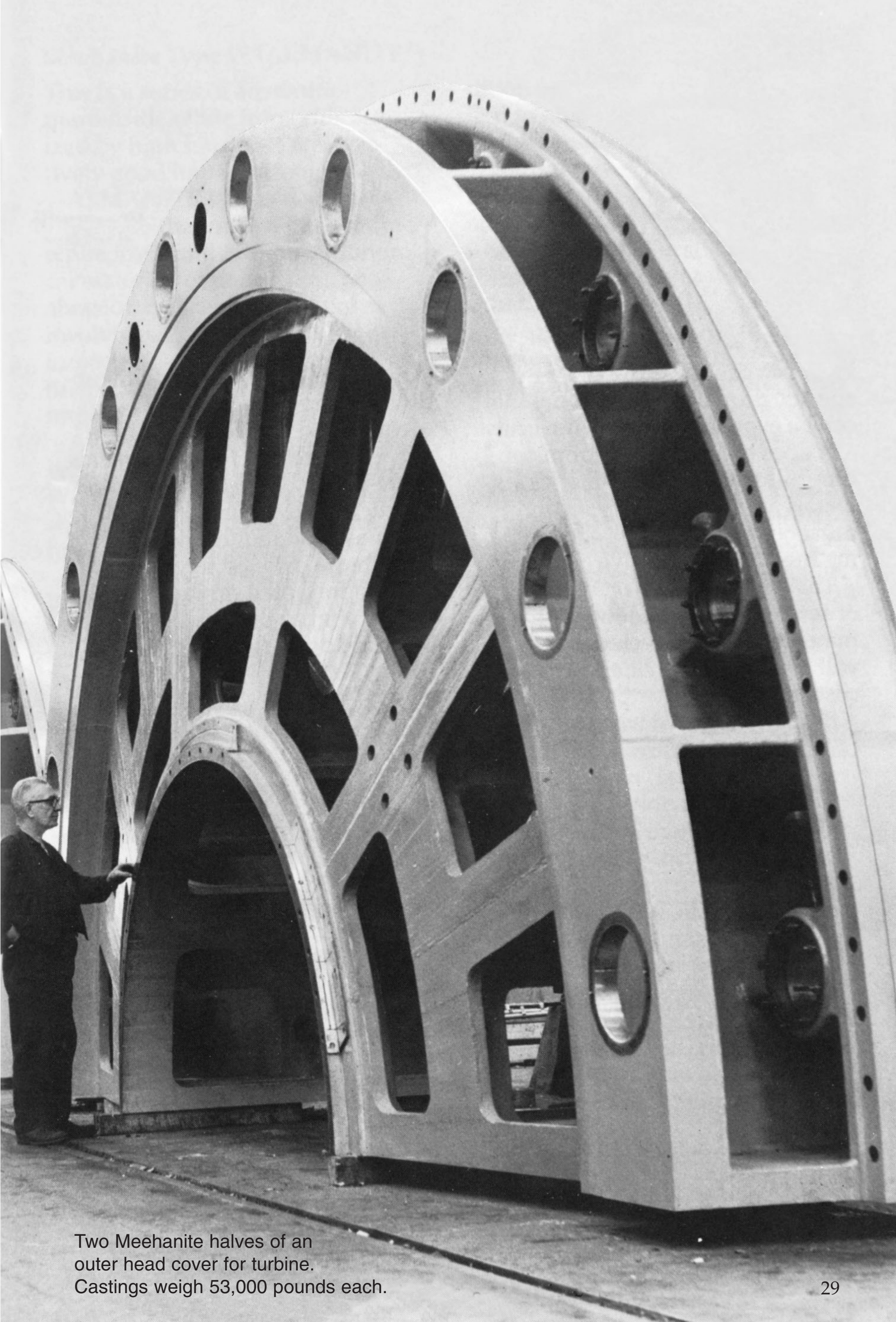
Components requiring good strength and abrasion resistance, such as are used in conveyor and road making and agricultural equipment, etc. Type AQ is highly recommended for parts that must be machined and subsequently hardened without distortion such as cams, spinning mandrels, sheaves, wheels, dies, punches, rollers, engine liners and for equipment in service at elevated temperatures up to a dull red heat.

MEEHANITE TYPE AQ

Properties	As-Cast	Heat Treated
Tensile strength–psi (N/mm^2)	50,000 (345)	65,000 (448)
Fatigue strength–psi (N/mm^2) Unnotched		30,000 (207)
Brinell hardness, BHN	Up to 280	Up to 500
Thermal properties		See page 54
Magnetic Properties		See page 67

Figure 4





Two Meehanite halves of an
outer head cover for turbine.
Castings weigh 53,000 pounds each.

Meehanite Metal Abrasion or Wear Resisting Types (Almanite®)

Wear is a general term, not a specific property of a material that can be expressed in absolute units.

It does not exist apart from conditions in service and so far as metals are concerned, selection must be determined by the limiting mechanical abrasive condition.

This means that exact conditions of service must be known if that material is to be selected which will give maximum life at lowest cost.

Broadly, abrasive wear conditions can be placed in three groups . . .

a. metal to metal, where lubrication is not involved;
b. erosion, where suspended solids are carried in a liquid or gas;
c. dry abrasion, such as involved in the crushing of materials, etc.

It must be recognized, however, that there is no clear line of demarcation between these groups and that experience or good judgement is necessary when one overlaps the other.

There are three types of Meehanite Metal recommended for abrasive applications: Types W, WS, WSH. Type W is further subdivided into W1, W2, and W4 according to the microstructure.

These abrasion-resistant metals trade-named "ALMANITE", offer practically any combination of hardness and toughness.

For more detailed information than is presented on the following pages, refer to Bulletin 60. Copies available upon request.

Meehanite Type W (ALMANITE®)

This is a series of austenitic-martensitic white irons characterized by high hardness and relatively good impact strength.

ALMANITE W has better wear resistance than nickel-chromium white irons and is a most economical material for general purpose abrasion resistant applications involving scratching with slight impact, as encountered in end liners, wear shoes, sand-pump impellers and similar parts.

ALMANITE W is conveniently separated into Types W1, W2 and W4. All of these are white irons with excess carbon in the form of hard wearing carbides.

Type W1 has a pearlitic matrix; W2 has a martensitic matrix, and W4 is highly alloyed to provide an austenitic matrix in the as-cast condition which may be further modified to give a martensitic matrix by heat treatment or by freezing.

Hardness values above 650 Brinell result from this treatment and, in the as-cast condition, machining . . . while still difficult . . . is considerably easier than in any other white iron.

The carbides in W4 are of the trigonal and orthorhombic type giving it a toughness higher than that usually associated with white iron.

Typical Applications:

Recommended for severe abrasive wear, dry or wet, with moderate impact: liners, muller wheels, pan bottoms, pug-mill knife blades, wear shoes, and sand-pump impellers, etc.

MEEHANITE TYPE W (ALMANITE)

Properties (As Cast)	English	SI Unit
Type W1		
Tensile strength, min, psi (N/mm²)	50/60,000	(345/414)
Impact strength, 1.2 in. Izod, ft lbf (30 mm Izod, N.m)	30-50	(39-69)
Brinell hardness range, BHN	500-600	500-600
Microstructure	Pearlitic	
Type W2		
Tensile strength, min, psi (N/mm²)	50/60,000	(345/414)
Impact strength, 1.2 in. Izod, ft lbf (30 mm Izod, N.m)	40-60	(59-79)
Brinell hardness range, BHN	500-600	500-600
Microstructure	Martensitic	
Type W4		
Tensile strength, min, psi (N/mm²)	60/80,000	(345/550)
Impact strength, 1.2 in. Izod, ft lbf (30 mm, Izod, N.m)	40-70	(59-156)
Brinell hardness range, BHN	400-700	400-700
Microstructure	High alloy austenitic (as-cast) Martensitic (heat treated)	

Meehanite Type WS (ALMANITE®)

ALMANITE WS is a martensitic iron with free carbon in the nodular form.

The hardness value of WS is lower than that of Type W, but this is accompanied by a very high impact strength three to four times that shown by competitive materials, with improved resistance to metal flow and wear.

ALMANITE WS is an ideal metal to use for service conditions involving high impact and abrasion.

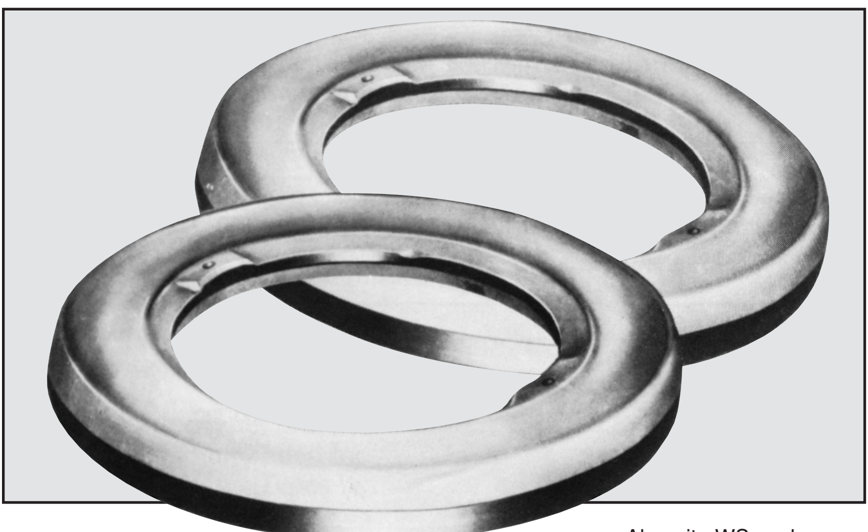
ALMANITE WS can be machined by conventional means, but with difficulty. It may be rendered more machinable by an anneal at 1600°F (871°C) followed by a slow cool in the furnace. After machining, it is necessary to normalize or air harden to produce high hardness values.

Typical Applications:

Crusher jaws, crusher rings and rolls, liners of all types, hammers in impact, pulverizers, slusher-scraper parts, etc.

MEEHANITE TYPE WS (ALMANITE)

Properties	English	SI Unit
Tensile strength–psi (N/mm^2)	60/80,000	(414/552)
Yield strength–psi (N/mm^2)	50/65,000	(345/448)
Modulus of elasticity–10^6 psi (E x 10^6)	24	(0.17)
Elongation, %	2-4	2-4
Brinell hardness, BHN	400/525	400/525
Impact strength–1.2″ Izod, ft lbf (30 mm Izod, N.m)	180	(up to 245)
Impact strength–Charpy unnotched ft lbf	20	



Almanite WS coal pulverizer rings

Meehanite Type WSH (ALMANITE®)

ALMANITE WSH is an austenitic nodular iron possessing superior tensile strength, toughness and ability to work harden under conditions of severe pounding impact.

It has the same basic characteristics as austenitic manganese steel, but it has a much superior yield point and a lower elongation.

It may be regarded as an extension of Type WS for use where shock and stresses in service are unusually severe.

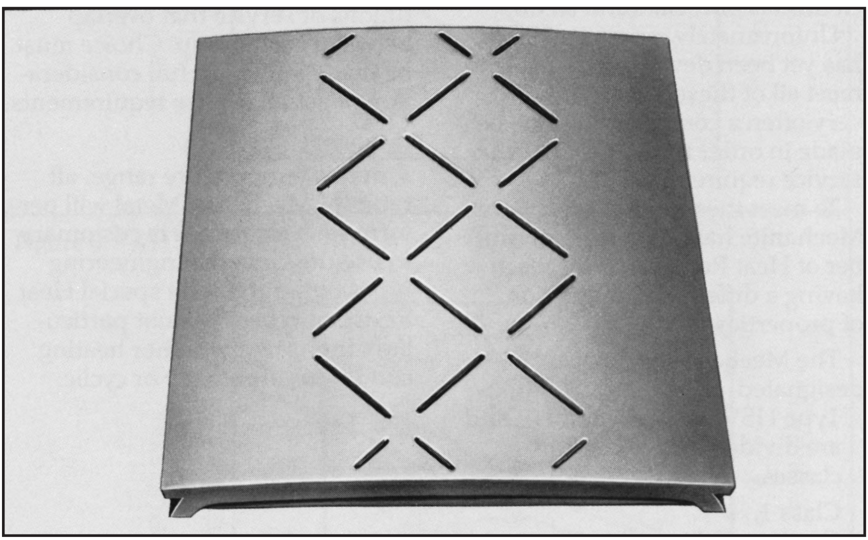
Type WSH is extremely difficult to machine. Procedures used for austenitic manganese steels should be followed. It is conventional to finish grind wherever possible.

Typical Applications:

Crusher liners, hammers, wearing blades, dredge buckets, dipper teeth, etc.

MEEHANITE TYPE WS (ALMANITE)

Properties	English	SI Unit
Tensile strength–psi (N/mm^2)	100,000	(690)
Yield strength–psi (N/mm^2)	75,000	(517)
Elongation, %	4-10	4-10
Brinell hardness, BHN	350-500	350-500
Impact strength–1.2˝ Izod, ft lbf (30 mm Izod, N.m)	120	(up to 167)



In service in a crusher installation 1100 lbs (500 kg), ALMANITE WSH jaw crusher castings of the type shown above are used to crush 8˝ (203 mm) rock to 1½˝ (38 mm) size in a single pass. They have worked for 57 days, crushing for 8 to 10 hours per day at 100 tons per hour without substantial wear.

Meehanite Heat Resisting Types

Selection of the most suitable material to withstand the various conditions of heat influence in service presents unusual problems because of the varied temperature and corrosive gases encountered.

These conditions may include thermal shock (rapid heating and cooling)–continuous heating (scaling and growth)–low or high temperature effect, local flame impingement under high or low pressures–contact with gases, chemicals or metals and so on.

Unfortunately, no one material has yet been developed suitable to meet all of these conditions and very often a compromise must be made in order to meet a particular service requirement.

To meet these varied conditions, Meehanite has developed a number of Heat Resisting irons, each having a different combination of properties.

The Meehanite metals are designated:

Type HSV, HS, HR, and HE and are divided into two main classes.

Class 1.
Castings Subjected to Thermal Shock (Rapid heating and cooling). Type recommended for this service is HE. The individual characteristics and industrial uses of each of these will be dealt with separately.

Class 2.
Castings Subjected to Continuous Heating (Scale and growth resistance). Types recommended for such service are HS, HR and HSV.

There are, of course, certain conditions of service that overlap between each group. Choice must be made only with full consideration of actual service requirements.

Up to 750°F (400°C)

In this temperature range, all types of Meehanite Metal will perform satisfactorily. It is customary to use the General Engineering types rather than the special Heat Resistant types. It is not particularly important whether heating conditions are steady or cyclic.

750°F to 1250° (400°C to 675°C)

At temperatures above 750°F (400°C), the loss of hardness and strength in all metals is quite rapid. As creep strength is considerably more important in this range, very little emphasis is given to short-time mechanical strength values.

Values given are typical for various types of Meehanite Metal suitable for use in this range. (Figure 5)

TABLE 1 TYPICAL HARDNESS VALUES FOR MEEHANITE

Temperature °F (°C)	Brinell Hardness GA 50	GC 40	HR
750 (399)	225	212	288
900 (482)	205	197	260
1000 (538)	182	180	230
1100 (593)	139	134	176
1250 (675)	—	—	133

Figure 5

TENSILE STRENGTH FROM 750°F to 1250°F (399°C to 675°C)

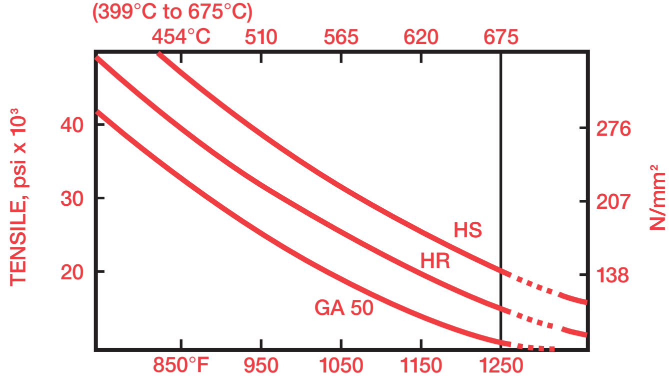
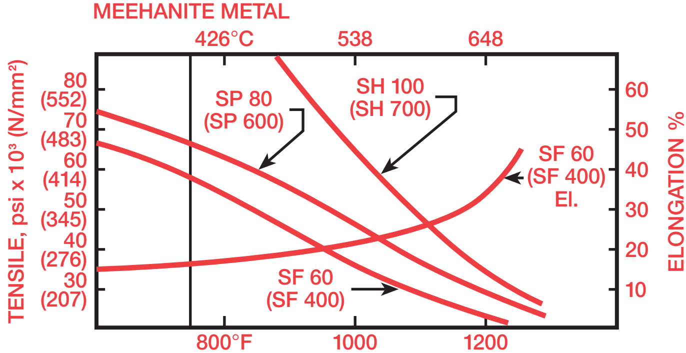


Figure 6

ELONGATION & TENSILE STRENGTH OF MEEHANITE METAL



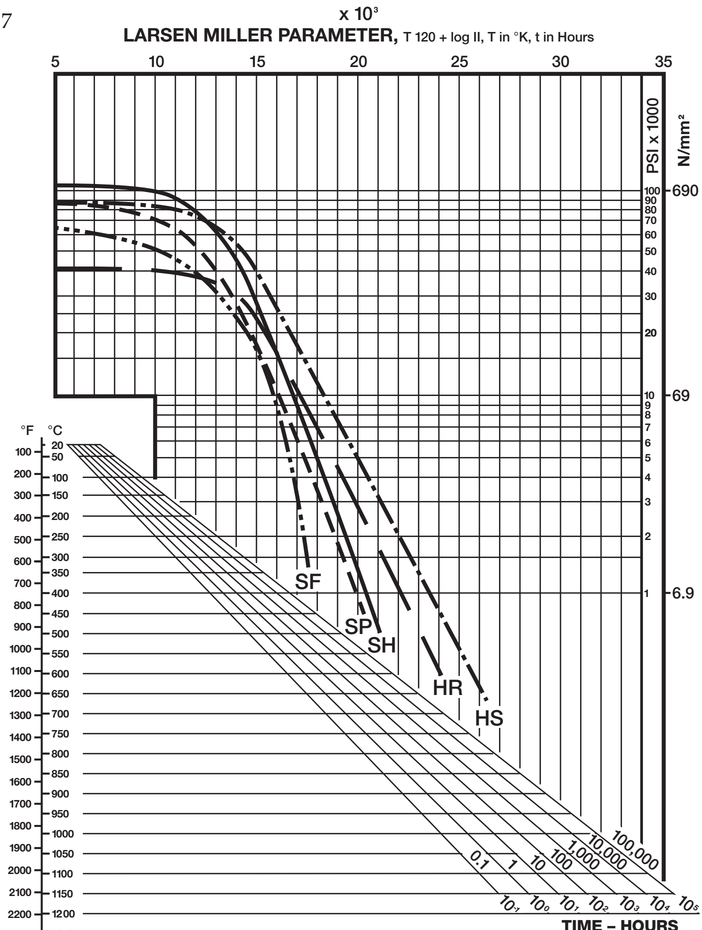
Resistance to plastic flow or creep is a major design consideration in the 750°F to 1250°F (399°C to 677°C) range.

While the General Engineering types are not normally considered for use in the upper end of this range, the "S" types of Meehanite, in particular, have good tensile strengths and data on these of short-term tensile is given in Figures 5 and 6.

The heat resistant types "HR", "HS" are recommended for use in the upper region of this temperature range because of their overall heat resisting ability.

Creep is usually expressed as the stress to rupture at various temperatures for various times. This is shown in Figure 7.

Figure 7



CREEP VALUES FOR MEEHANITE METAL

(Stress to Rupture)

Surface Crazing

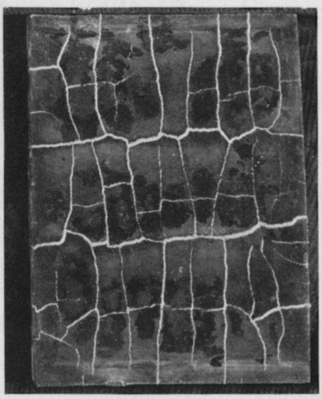
Some surface crazing may occur at the upper end of this temperature range, particularly if the rate of temperature change is severe.

In general, the denser, higher strength engineering metals–GM 60 (GM 400), GA 50 (GA 350), SP 80 (SP 600), and SH 100 (SH 700) are most resistant to surface crazing at temperatures up to 1250°F (675°C).

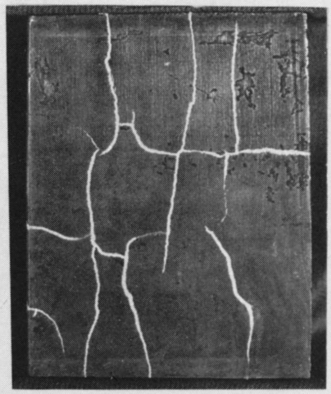
Examples of GA 50 (GA 350) Meehanite compared to soft and chilled cast irons in a special test from 1200°F (649°C) are shown.

Surface oxidation in temperatures up to 1250°F (675°C) is not normally a serious consideration. The "S" types of Meehanite are more resistant than the "G" types because the rounded graphite retards oxide penetration from the surface.

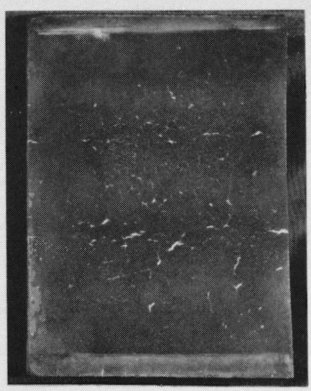
TEST RESULTS SHOW RESISTANCE OF TYPE GA MEEHANITE TO SURFACE CRAZING.



SOFT CAST IRON



CHILLED IRON



TYPE GA50

1250°F to 1600°F (675°C to 870°C)

Loss of strength and hardness above 1250°F (675°C) is quite severe in all metals. In design involving load at these temperatures, allowance must be made for low bearing capacities.

Despite low strength values, Meehanite Metal types “HR”, “HS” and “HSV” are giving good service as dies in hot forming of titanium and other metals in this temperature range and higher.

Short-time tensile strength of “HS” and “HSV” Meehanite varies according to the curves shown below. (Figure 8)

Figure 8

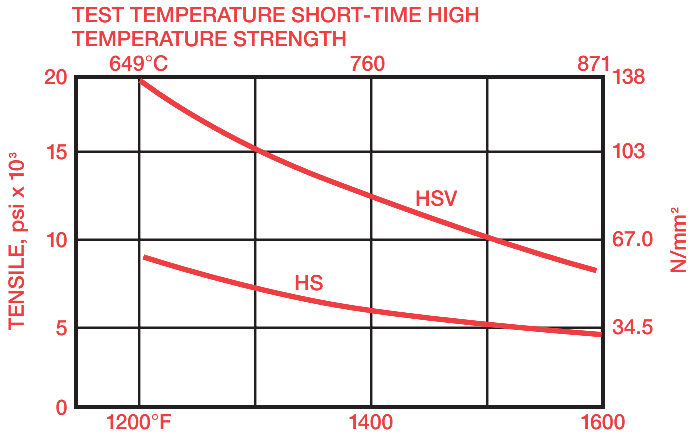
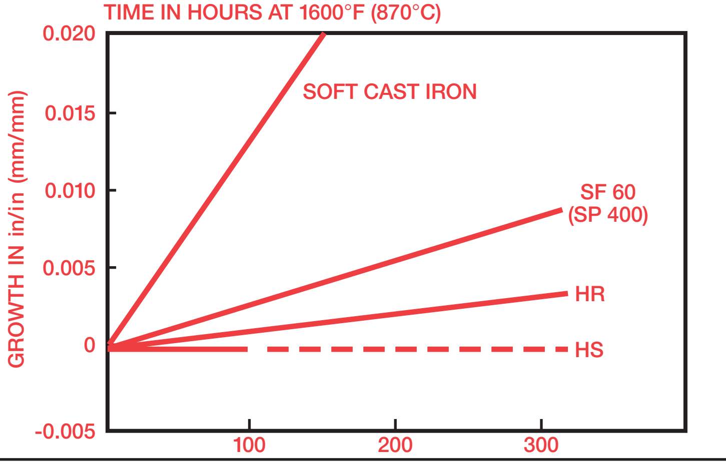


Figure 9



As 1600°F (871°C) temperature is within the plastic range, flow under load becomes quite rapid. Creep data on types "HR" and "HS", the only types recommended for service involving mechanical loads, is given. (Figure 9)

Surface crazing can occur in this range to a more marked degree and where cyclic temperatures influence occurs, a full anneal is always recommended before the casting is put into service. Of particular interest is the excellent behavior of Meehanite Metal for glass molds and plungers.

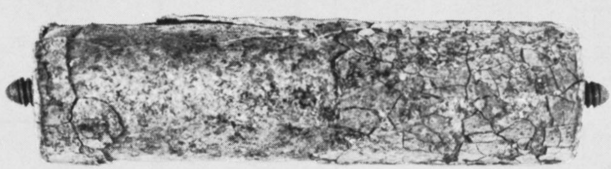
Oxidation and scaling can become severe in the 1600°F (871°C) temperature range. The scale resistant ability of Types "HS", "HSV" and "HR" is excellent under most conditions.

The behavior of Type "HS" Meehanite is well illustrated in a special test conducted where a sample is repeatedly heated to and cooled from 1600°F (871°C) in an oxidizing atmosphere. (Figure 10)

Type "HS" forms a tight adhering oxide scale that effectively prevents further deterioration due to oxide penetration towards the center of the sample.

Figure 10

Type HS Meehanite casting heated to and cooled from 1600°F (871°C) for a period of 300 hours shows no growth or scaling.



Alloy iron casting given same test shows considerable growth and scaling.

1600°F to 1800°F (871°C to 981°C)

For temperatures in the range above 1600°F (871°C), mechanical properties fall off so rapidly that they become of questionable use in design.

Selection of the right material for a given application becomes a matter of judgment based on proven experience in similar applications.

For service in this range, only two types of Meehanite are recommended.

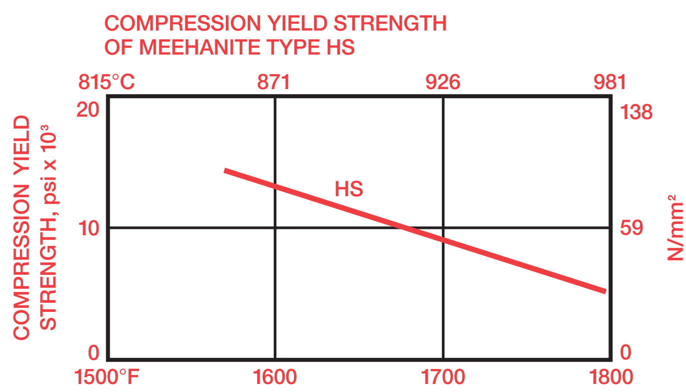
Type HS Meehanite, which compares very favorably from a strength standpoint with any heat resisting metal, is recommended for applications at temperatures above 1650°F (898°C) and under conditions of furnace gases and when intermittent heating and cooling and continuous heating may be encountered without thermal shock.

Type HE Meehanite is recommended for cyclic heating applications involving severe shock. Large, continuous graphite flakes contained in the metal structure dissipate heat stresses. Because of this, it has relatively moderate mechanical strength-tensile–30,000 psi (207 N/mm²), compression–130,000 psi (897 N/mm²).

Manufacturing procedures used give Type HE the optimum type of structure. It is particularly suited for applications such as ingot molds, slag pots, bottle molds, etc.

In bottle molds, it is customary to densify the working or machined surface of the mold by the use of chills. Type HE, when chilled, will give the desired combination of density and ability to absorb heat stresses.

Figure 11



Meehanite Type HS, (Ductliron®)
Type HS compares very favorably from a strength standpoint (Figure 8) with any heat resisting metal and is recommended for applications at temperatures up to 1800°F (981°C) under both conditions of cyclic and continuous heating without thermal shock.

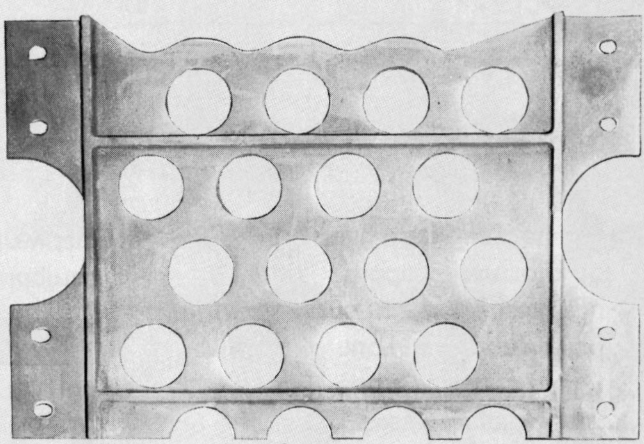
Compositional adjustments are made to suit the exact service conditions. It machines easily and provides maximum resistance to scaling and growth. (Figure 9)

Typical Applications:

For blast furnace parts, boxes, trays, dampers, doors and frames, hot gas valves, rails and skids, reduction pots, glass molds, annealing pots, drums, sagger bottoms, retorts, floor castings, etc.

MEEHANITE TYPE HS

Properties	English	SI Unit
Tensile strength–psi (N/mm²)	60/100,000	(414/690)
Yield strength–psi (N/mm²)	45/75,000	(310/517)
Modulus of elasticity–10^6 psi (E x 10^6)	23	(0.16)
Elongation, %	2-10	2-10
Brinell hardness range, BHN	200/280	200/280
Impact strength–Charpy, ft lbf (N.m) 10 mm² bar “V” notch	1-7	(1.4-9.8)



Tube support made in Type HS Meehanite. Weight 500 pounds.

Meehanite Type HSV

This is an iron developed essentially for engineering parts that are subjected to long, continuous heating at temperatures up to 1600°F (871°C). It has been designed to have the maximum load bearing ability.

Castings may be produced in any shape. They are readily machinable, and possess an excellent combination of properties at room temperature as well as good strength and hardness at elevated temperatures.

Typical Applications:

Hot forming dies, turbo and supercharger castings, furnace parts.

MEEHANITE TYPE HSV

Properties	English	SI Unit
Tensile strength–psi (N/mm^2)	100/120,000	(670/828)
Yield strength–psi (N/mm^2)	50/80,000	(345/512)
Elongation, %	2-10	2-10
Brinell hardness range, BHN	200/280	200/280
Thermal conductivity, 50°F-450°F (10°C-232°C) °C/cm, btu/hr/ft, °F/in ($cal/cm^2/sec$)	278	(0.095)
Co-efficient of thermal expansion per °F from 100°F to 1000°F (°C from 38°C to 538°C), $x 10^6$	6.7	(12.1)

Grate bars removed from service at temperature above 1200°F (648°C). Bar #1 is alloy steel (25% chrome – 12% nickel), Bar #5 is cast in HSV. Note freedom from growth and distortion.

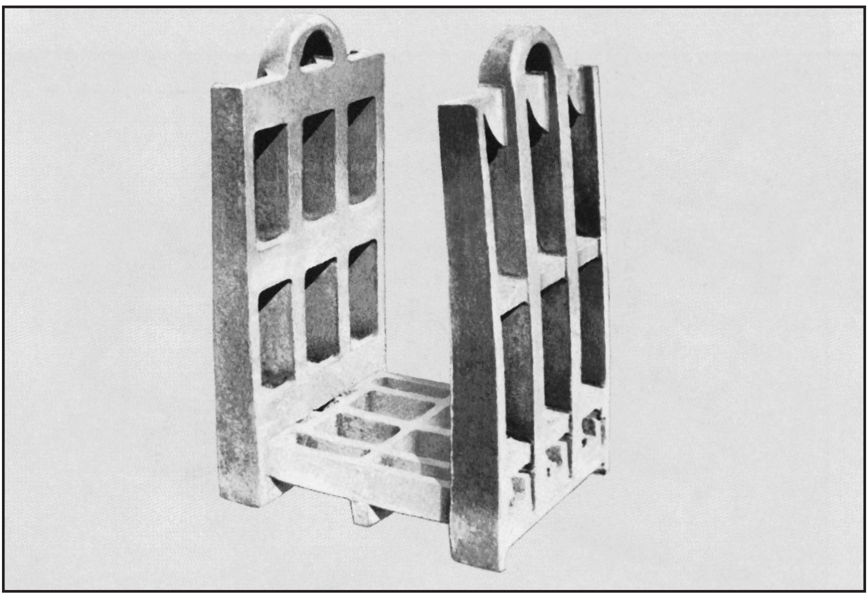
Meehanite Type HR

Type HR is a strong, dense iron of high rigidity and excellent resistance to scaling under most conditions. Type HR is non-growing for temperatures up to 1350°F (734°C). It possesses good load carrying ability.

Typical Applications:
Recommended for service conditions where intermittent heating and cooling and continuous heating may be encountered without thermal shock–furnace skid bars, stoker dead plates, stocker tuyeres and extension plates, retorts, tube supports, furnace parts, etc.

MEEHANITE TYPE HR

Properties	English	SI Unit
Tensile strength–psi (N/mm^2)	40,000	(300)
Compression strength–psi (N/mm^2)		(1,138)
Modulus of elasticity, 10^6 psi (E x 10^6)	21	(0.15)
Brinell hardness range, BHN	300/370	300/370
Thermal conductivity	235 BTU/hr.ft.^{2}	0.08 cal/cm.sec.°C



Meehanite type HS annealing basket used to support over 2000 lbs. of bar stock during heat treat cycles at 1450°F.

Meehanite Type HE

This material withstands rapid heating and cooling without premature failure. HE is an all-around material for general use. It is also advantageous where dimensional stability or a fine machine surface is required.

The constitution of this iron is so designed that the structure of the iron readily accommodates itself to sudden changes of thermal stress which cause rapid expansion and contraction of the casting.

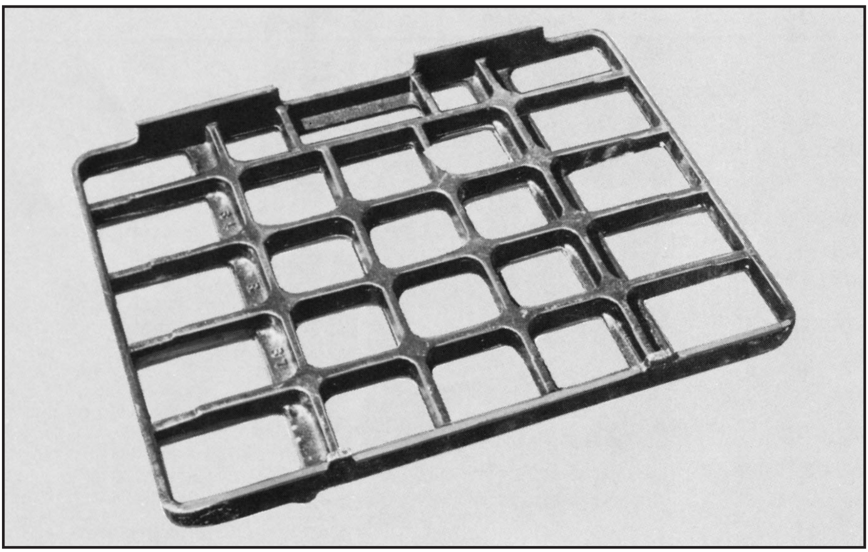
Type HE possesses a high degree of refractoriness and a useful range of strength properties at various temperatures. It is freely machinable in the "as-cast" condition.

Typical Applications:

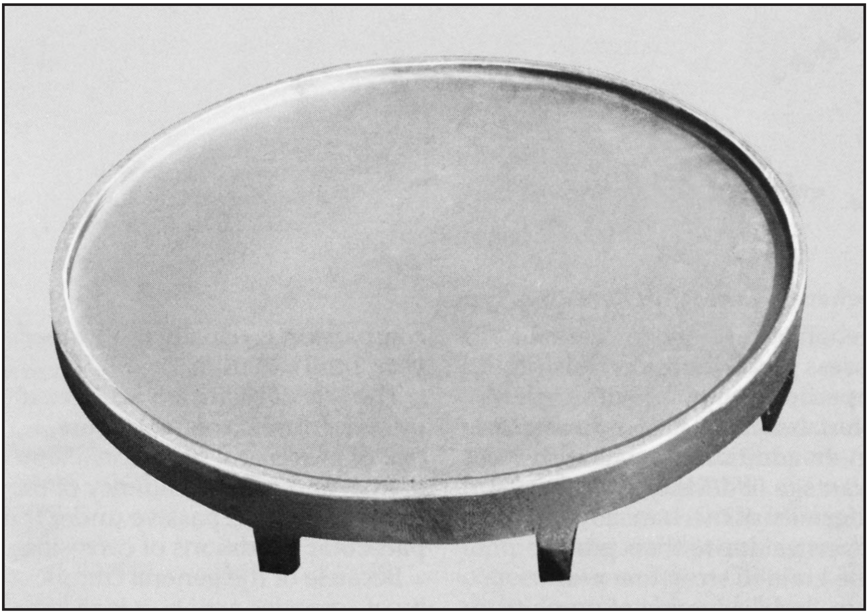
Ingot molds, slag pots, hot plates, parts heated rapidly by a naked flame as in certain salt baths, lead or zinc pots, sintering grates, pig casting machine parts, coke oven doors and liners, etc.

MEEHANITE TYPE HE

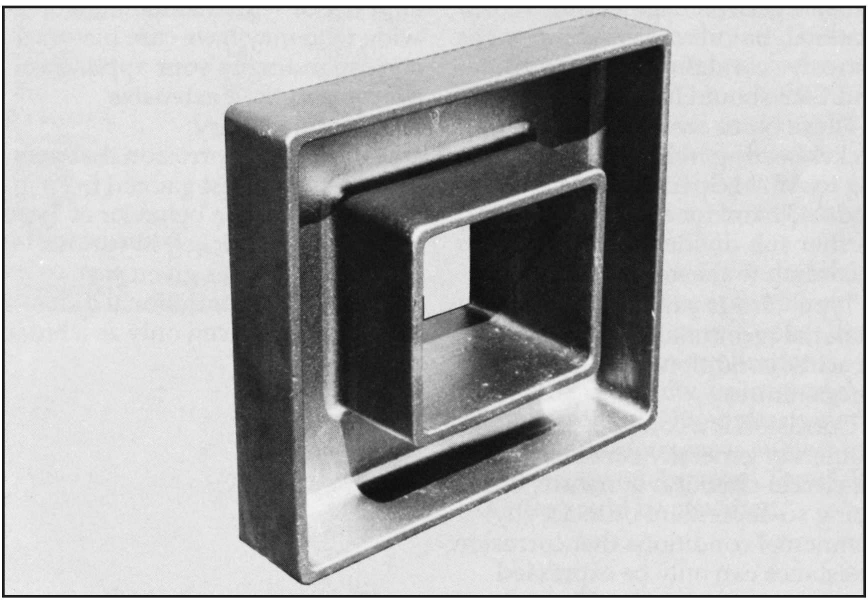
Properties (Room Temperature)	English	SI Unit
Tensile strength–psi (N/mm²)	25,000	(172)
Modulus of elasticity, 10^6 psi (E x 10^6)	14	(0.10)
Brinell hardness, BHN (as-cast)	170/210	170/210



Meehanite Type HS bracket provides good heat resistance and resists warping.



Sagger bottoms cast in Type HS resist scaling and warping at 1600°F.



Waste gas disposal headwall casting made in Type HS Meehanite
provides excellent service at 1450F and higher.

Meehanite Corrosion Resisting Types

Meehanite castings, in general, possess good corrosion resisting properties compared with such materials as steel and ordinary cast iron. In addition, they have the advantage of density, solidity and uniformity of mechanical properties due to their purity, close-gained structure and controlled dispersion of graphite.

For mildly corrosive conditions, Type CC is an all-round inexpensive general engineering material, but for more severe corrosive conditions, Types CR and CRS should be used.

These types are austenitic nickel-bearing irons corresponding to ASTM Specifications A436 and A439 and for convenience are further sub-divided into types according to these specifications.

Type CHS is a higher strength material recommended for use in acidic conditions at high temperatures.

Corrosion is a complex phenomenon generally considered to be electro-chemical in nature, but being so dependent on exact environmental conditions that corrosion resistance can only be expressed on a comparative basis. The unit of comparison is usually in mils per year, 1 mil = 0.001 in.

The rate of corrosion is affected by concentration, temperature, rate of movement of the corrosion media, and by the tendency of the metal to become passive under the particular conditions of corrosion.

Because of the general complexity of corrosive action, it is recommended that specific cases be discussed directly with your casting supplier or with Meehanite Worldwide who may have case histories corresponding to your application available in their extensive engineering library.

The extent of corrosion that may be expected is best gauged from test results on the behavior of Type CR (austenitic-nickel) in various chemicals. Ranges given vary because of concentrational differences and are given only as a broad guide.

CHEMICAL	mil/year	mm/year
MINERAL ACIDS		
Hydrochloric	10-370	0.25-9.40
Sulphuric	5-50	0.13-1.30
Nitric	70-2300	1.78-58.42
Phosphoric	20-100	0.51-2.50
ORGANIC ACIDS	1-120	0.03-3.05
WATER		
Fresh	0.06	0.001
Salt	8-10	0.20-0.25
Mine & Industrial	5-40	0.13-1.02
ALKALIES		
Sodium Hydroxide	0.1-90	0.003-2.29
Ammonia	0.05-90	0.001-2.29
Calcium Hydroxide	0.2	0.006
CHLORIDES		
Ammonium	3-10	0.08-0.25
Barium	40	1.02
Calcium	1-4	0.03-0.10
Sodium	0.04-4	0.01-0.10
Zinc	20-80	0.51-2.00
SULPHATES		
Aluminum	2-16	0.05-0.41
Ammonium	0.07-6	0.002-0.15
Copper	35-490	0.89-12.45
Manganese	550	13.97
Zinc	560	14.22
PAPER CHEMICALS	0.8-40	0.02-1.02
PETROLEUM CHEMICALS	0.1-400	0.003-10.16

Choice of Meehanite Types To Suit Corrosive Conditions

Mineral Acids: Type CC has excellent corrosion resistance to 100% sulphuric acid at temperatures up to 250°F (121°C). Corrosion increases with increasing temperature and decreasing acid concentration. Types CR and CRS resist corrosion by cold dilute sulphuric acid.

Organic Acids: Types CR and CRS resist corrosion by acids such as formic, acetic, oxalic, etc., better than low alloy gray irons.

Alkalies: Type CC is not corroded by dilute alkali solutions at any temperature. Hot solutions [above 150°F (65°C)] exceeding 30% concentration are mildly corrosive.

Industrial Waters: For industrial waters of low acid concentration, Type CC is satisfactory. Types CR or CRS are used in applications where the pH is low, or in strongly acidic conditions. In applications where the component is subject to high velocity or abrasion, Type CR or CRS should be specified.

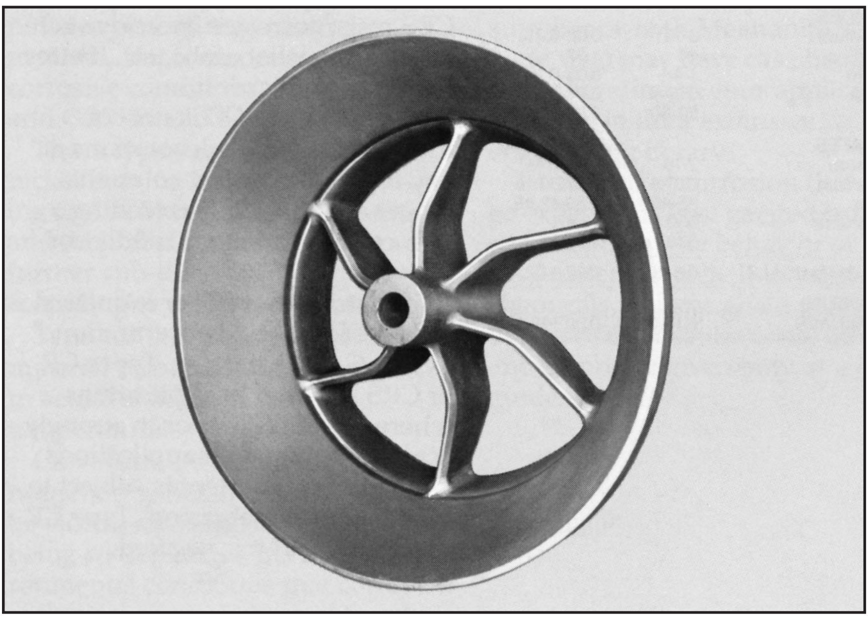
Meehanite Type CC

While not considered corrosive resisting in the normal sense, this is a general utility material with a minimum of alloying elements to give an improvement in corrosion resistance over that which would normally be expected from the General Engineering types of Meehanite Metal. It can be used for slightly acid solutions, alkali solutions at temperatures up to 150°F (65°C) and concentrated sulphuric acid at temperatures up to 250°F (121°C).

Typical Applications:
Acid pans, kettles, pumps, valves, fittings, evaporators, condensers, retorts, filter presses, stills, reaction vessels, etc., for handling chemicals, mine and sea water, carbonators, causticizers, and generally for solutions of less than 2 pH.

MEEHANITE TYPE CC

Properties	English	SI Unit
Tensile strength–psi (N/mm^2)	40,000	(276)
Brinell hardness, BHN	190/230	190/230



Meehanite Type CR

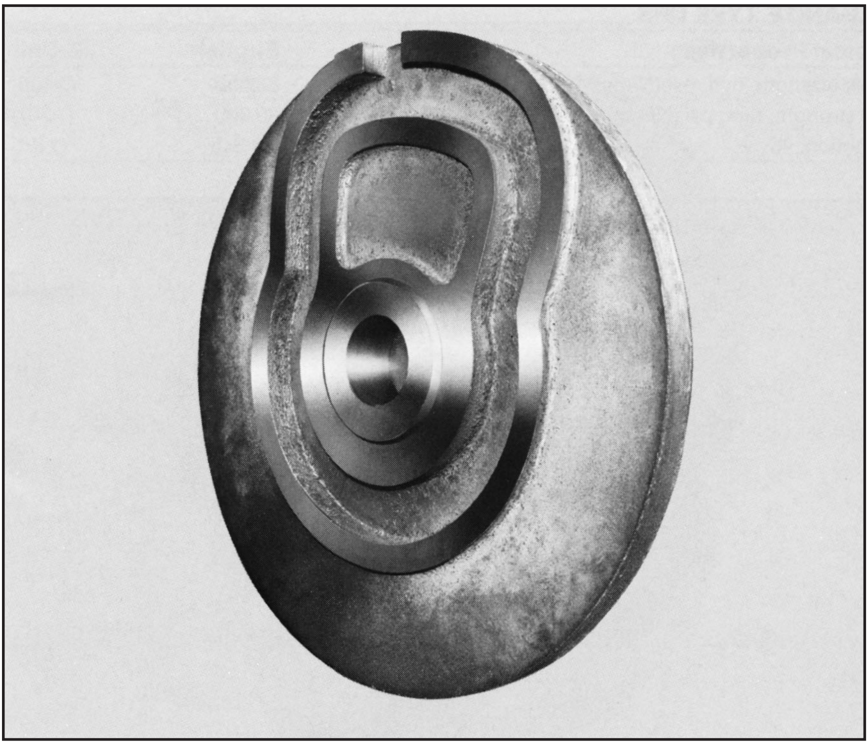
Type CR is an austenitic material especially designed to meet a wide variety of corrosion, wear and heat applications. It has flake graphite and chemical analysis conforming to ASTM Specification A436-78.

Where ranges are broad and high at one end of the scale; e.g., copper sulphate, or ammonia, a close look at the exact corrosion conditions is called for.

In general, Type CR is used for all applications, with modification of CR types being used for occasional special conditions of service.

MEEHANITE TYPE CR

Properties	English	SI Unit
Tensile strength–psi (N/mm^2)	25,000	(>172)
Brinell hardness, BHN	130/180	130/180



Meehanite Type CRS

This is an austenitic material with graphite in the nodular form. It conforms to ASTM designation A439-80 and provides much higher strength than Type CR with excellent resistance to corrosion, wear and heat.

The CRS types are approximately the same as the CR types when it comes to corrosion resistance, but they show excellent heat resistance and also have superior physical and mechanical properties.

Other properties, electrical characteristics and thermal properties are available on request from Meehanite Worldwide.

Typical Applications:

Types CR and CRS are recommended for components which involve handling acid and alkali solutions at temperatures up to 1300°F (704°C) for abrasive slurries, salt water and other heat and wear applications with or without corrosive media.

MEEHANITE TYPE CRS

Properties	English	SI Unit
Tensile strength, min, psi (N/mm²)	58,000	(>400)
Yield strength, min, psi (N/mm²)	30,000	(>207)
Elongation, %	>8.0	(>8.0)

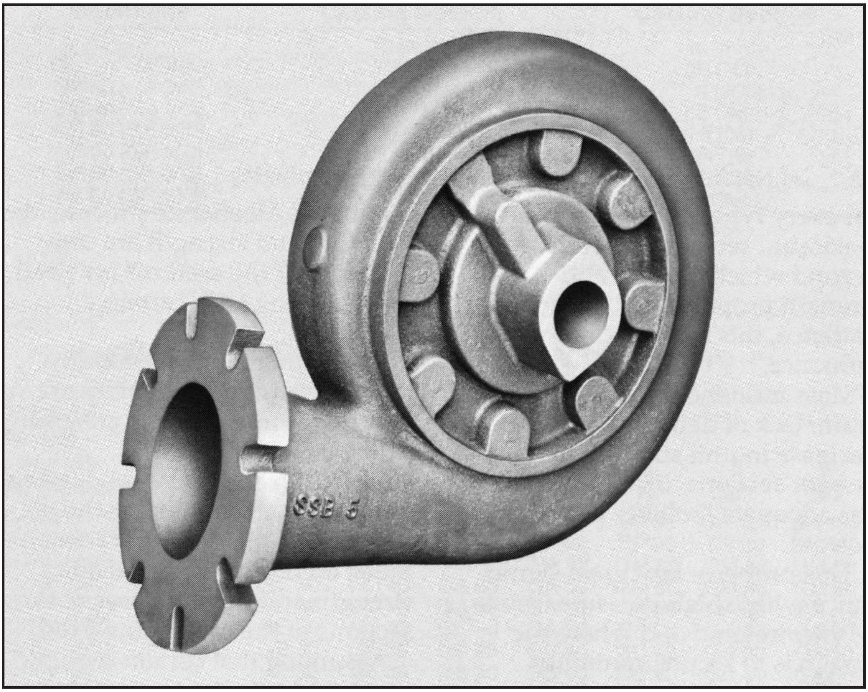
Meehanite Type CHS

This corrosion resistant type is a higher strength material with good shock resistance. Compositional adjustments are made to suit exact service conditions.

Typical Applications:
Types CHS is recommended for use for components subjected to concentrated sulphuric acid or oleum.

MEEHANITE TYPE CHS

Properties	English	SI Unit
Tensile strength, min, psi (N/mm^2)	60/100,000	(414/690)
Yield strength, min, psi (N/mm^2)	45/75,000	(310/517)
Modulus of elasticity, min, x 10^6 psi (E x 10^6)	23	(0.16)
Elongation, %	2-10	2-10
Brinell hardness range, BHN	200/270	200/270
Impact strength, Charpy, ft lbf (N.m) (10 mm^2 bar “V” notch)	1-7	(1.4-9.8)



Meehanite metal possesses good corrosion resisting properties and is used throughout the world for pumps, impellers, volutes and casings.

Austempered Ductile Iron

Austempered ductile iron is a ductile iron which is processed by alloying and special heat treatment. The heat treatment requires an interrupted quench usually into a salt bath. The resulting material has a combination of exceptional strength and toughness, meeting and often exceeding those of alloy steels.

Austempered ductile can be made in sections up to about seven inches, but to achieve fully Austempered microstructures in sections over three and a half inches, requires a specialized and proprietary Meehanite heat treatment process along with carefully controlled alloying.

For applications where wear resistance is the major issue, it is a simple matter to adjust the heat treatment to obtain higher hardness and strength values, but this is achieved with some sacrifice to toughness. It should also be remembered that this material will work harden on the surface, and so the material will, under the right circumstances, wear better than the quoted hardnesses would suggest, and so A.D.I. will often out wear other materials of the same hardness.

Typical applications for A.D.I. are where high strength is needed, and where excellent wear resistance and fatigue strength are required. Such an application is gears, and A.D.I. has been used with great success. This tough work hardening material has proved to be an excellent replacement for hardened steels. The use of A.D.I. can result in less weight, reduced number of components, and quieter running, because A.D.I. has a lower modulus than steel, better face to face contact can be achieved which reduces Hertzien or contact stress on the teeth surfaces. Also A.D.I. will work harden which adds to the contact fatigue strength. As a result, gear face widths and diameters can be reduced which will make the gear run better axially and reduces weight, and at the same time provide better protection under overload conditions. The superior tribological properties of A.D.I. have resulted in the elimination of bronze bearing bushings, and will allow the gears to run temporarily without lubrication. Due to the type of matrix structure, the softer grades of A.D.I. can be shot-peened to double the root fatigue strength. One caveat to be aware of is that A.D.I. is not suitable for heat applications where the service temperature will reach 350° C.

Another common application of A.D.I. has been crankshafts and axles. The majority of sealed-for-life refrigeration units are made with austempered crankshafts. Axle applications benefit from the materials lack of notch sensitivity, good fatigue strength, and reasonable machinability.

The railroad industry has an immense application both in retarders and rolling stock. A.D.I. is very popular for retarder brake shoes, where its superior quietness and wear resistance is well received in urban semi residential communities. A.D.I. brake beams have also been shown to outlast steel beams, and withstand the cold weather, at more than 20% less cost.

Another type of major use of A.D.I. is for shells and projectiles. Also steel forged track shoes are being replaced with A.D.I. Track shoes in A.D.I. have also been very successful both in military, construction, and earth moving equipment.

Other typical applications are:

Abrasive Protection Liners
Bearing Sleeves
Brake Shoes
Bushing Sleeves
Cable Drums
Camshafts
Chain Sprockets
Connecting Rods
Crankshafts
Cultivating Tools
Differential Spiders
Drive Shafts
Engine Mounting Brackets
Friction Blocks
Ground Engaging Tools
Guide Rollers
Hydraulic Pump Bodies
Piston Sleeves
Pulleys
Pump Impellers
Rack and Pinion Gearing
Railroad Car Wheels
Rollers and Sprockets
Shredder Knives
Steering Knuckles
Trolley Wheels
Wear Plates and Guides
Wire Guides

Machining of A.D.I.

Machining of A.D.I. is generally speaking, possible, using normal machining techniques. Only the tapping of small diameter holes (especially dead end) and scraping of the softest type is very difficult due to work hardening. It is however common practice to machine to near final size and then heat treat. This is possible because the heat treatment is considered "soft", and the consequent volume changes are small, and predictable with volume expansion of between only 0.2% - 0.4%.

There are three specifications of Meehanite austempered ductile iron and these are defined most conveniently by their average hardness values.

K300
This is the softest of the three grades, with the highest elongation and exceptional impact values. Though the tensile strength is no higher than can be achieved with normal quenched heat treated ductile. The much higher impact and elongations make this an attractive material for extreme applications. As the softest of the three grades with the highest content of austenite (30%-40%) it is the grade most readily able to surface work harden and thus wear better than its hardness would suggest. Though all ductile irons benefit from shot peening to improve fatigue strength this material especially benefits from this practice.
Bending fatigue strength is almost doubled by shot peening and in fact raised to the same level achieved by the K500 Grade.
This is an ideal material for gears of all types, crankshafts, couplings or any application where high impact and fatigue strengths are required.

K400
This is the middle grade specified for high strength combined with moderate elongation and impact values. Often specified for applications such as differential spyders, bearing rolls, annular type gears, structural suspension parts, disc brake rotors, retarder shoes, axe heads.
The ability to cast this material into complex shapes makes it a perfect replacement for many steels reducing casting volume and weights.

K500
This is the hardest and strongest grade specified at a minimum of 230,000 psi but capable of reaching

Austempered Ductile Iron Properities

Type	K300	K400	K500
UTS (x 1000)	130 (900)	175 (1200)	230 (1600)
Yield (x 1000)	98 (675)	140 (960)	185 (1275)
% Elongation	8 - 14	4 -10	0 - 4
BHN	260 - 310	360 - 430	450 - 550
Endurance Limit Un Notched Notched	 63 (440) 39 (270)	 74 (510) 51 (360)	 85 (580) 62 (430)
Endurance ratio	0.49	0.48	0.46
Charpy Unnotched ft. lbs.	75 - 90	45 - 70	0 - 40
Charpy Notched	5 - 7	4 - 6	1 - 5

in excess f 250,000 psi, while maintaining impact values typical of a regular pearlitic type ductile iron.

This is a material designed for severe wear applications, such as crushing and grinding. It should be understood that this material at its highest hardness will probably contain some martensite which is ideal for crushing and grinding applications, but not for impact. To maximize impact resistance the material should be specified at the lower hardness ranges (i.e., 450 Hb - 500 Hb). In this form the material is even used for gears. Other applications include snowplough runners, coal mill hammers, and muller wheels.

Meehanite Engineering Data

Effect of Section Thickness On Strength and Solidity

For every type of metal there is a maximum section thickness beyond which solidity and strength properties fall. In foundry parlance, this is called "mass influence."

Mass influence results in open grain, lack of density and drastic decrease in unit strength in heavier sections, unless the metal has adequate "solidity penetration power".

This property is of great significance where high pressures are to be encountered and where the design is to secure minimum weight with assured safety.

With the Meehanite process, the structure and strength are controlled to fit the sections involved in the casting with certain limitations.

Where uniformity of solidity (density) and machinability are required, these sections are given below in Table II.

Table III (see next page) displays a simple chart permitting the selection of the type of Meehanite Metal according to the tensile strength and the thickness of the sections of the casting involved.

Assuming that certain requirements indicate the section of the casting will vary considerably; *for example, from ½″ (12.7 mm) to 3″ (76.2 mm) section can readily be cast in Type GC and uniformity will be obtained in the 3″ (76.2 mm) section, but the allowable stress value will be based on a 35,000 psi (241 N/mm²) ultimate tensile value. However, if the 3″ (76.2 mm) section could be reduced to 2″ (50.4 mm) and Type GA 50 (GA 350) used, the allowable stress would be based on a 40,000 psi (276 N/mm²) ultimate.* Thus, by proper adjustment of the minimum section and/or consideration of the ultimate tensile value available in the heaviest section, a decision can be made as to type of metal which is most economical and best to do the job.

From these data, one can select the type of Meehanite Metal for a particular casting which will result in efficient use of both weight and the available characteristics.

Further data on mass effect is available in B-58 Meehanite Castings Quality Guide.

TABLE II
RECOMMENDED MINIMUM AND MAXIMUM CASTING SECTION

Type of Meehanite	Minimum Casting Section		Maximum Casting Section
	in (mm)		in (mm)
GM 60 (GM 400)	3/4 (19)	to	30 (762)
GA 50 (GA 350)	1/2 (13)	to	8 (203)
GC 40 (GC 275)	1/4 (7)	to	3 (76)
GE 30 (GE 200)	1/8 (3)	to	1.5 (38)
GF 20 (GF 150)	3/32 (2)	to	3/4 (19)
SP 80 (SP 600)	3/8 (10)	to	12 (305)
SF 60 (SF 400)	1/4 (6)	to	12 (305)

TABLE III
SELECTION OF TYPE OF MEEHANITE ACCORDING TO CASTING THICKNESS

Ultimate Tensile Strength psi(N/mm²)	in mm	¼ 6	½ 13	1 25	2 51	3 76	4 102	6 152
75,000 (517)		SF 60	SP 80	SP 80	SP 80	SP 80	SH 100	SH 100
65,000 (448)		SF 60	SF 60	SP 80	SP 80	SP 80	SP 80	SH 100
55,000 (380)		SF 60	GA 50	GM 60	GM 60	GM 60	GM 60	GM 60
50,000 (345)		GC 40	GC 40	GA 50	GA 50	GM 60	GM 60	GM 60
45,000 (310)		GC 40	GC 40	GA 50	GA 50	GA 50	GA 50	GA 50
40,000 (276)		GE 30	GC 40	GC 40	GA 50	GA 50	GA 50	GA 50
35,000 (241)		GE 30	GE 30	GC 40	GC 40	GC 40	GA 50	GA 50
30,000 (207)		GE 30	GE 30	GE 30	GC 40	GC 40	GC 40	GA 50
20,000 (138)		GF 20	GF 20	GE 30	GE 30	GE 30	GE 30	GC 40

Thermal Conductivity

Thermal conductivity may be defined as the heat-conducting power of a uniform, or homogeneous, substance per unit of cross-sectional area.

Values arrived at for thermal conductivity under controlled laboratory testing methods may be used as a comparison between different materials, but they give little indication of how much heat conductivity power the metal will have in a particular application. This is because the heat-conductivity in service depends on many factors such as:

1. The rate of heat input.
2. The temperature gradient between the two walls of the casting and the actual temperature of the metal.
3. The shape of the casting.
4. The condition of the surfaces of the casting.
5. The type of gas, liquid or solid, that is supplying the heat units to the casting.
6. The thermal conductivity of the metal.

We see that in any heat conductivity consideration, the thermal conductivity of the metal is only a relatively small factor.

In steam chests, for example, the importance of design, steam temperature and flow rate, and the condition of the casting surface are considered more important than the thermal conductivity of the metal comprising the chest.

In air-cooled engines, the design of the cooling fin is considered to be the most important single factor.

The previous points have been made not to de-emphasize the importance of the thermal conductivity of the metal, but to illustrate that normally other factors are more important to heat transfer than thermal conductivity.

With Meehanite Metal, both the chemistry and the microstructure affect the thermal conductivity with graphite content, silicon content, and matrix structure the most important factors.

Graphite has the highest conductivity of any constituent in Meehanite and increasing the amount of graphite increases the thermal conductivity.

Increases in carbon content will raise the thermal conductivity only if these increases enlarge the number or size of the graphite flakes. If the carbon change results in an increase in the pearlite in the matrix, then thermal conductivity is decreased because the cementite composing the pearlite has a much lower thermal conductivity than ferrite.

Flake graphite irons have greater thermal conductivity than nodular irons, and a random graphite orientation conducts better than undercooled, or rosette graphite.

The addition of almost all other alloying elements lowers the thermal conductivity. These include silicon, manganese, phosphorus, aluminum, copper, nickel and chromium. Molybdenum and tungsten seem to give slight increases.

When both the silicon content and the graphite are increased such as when going from Type GA 50 (GA 350) to Type GE 30 (GE 200), the effect of silicon on lowering thermal conductivity over-balances an increase due to more graphite as long as the matrix remains pearlitic. Ferritization of the matrix increases the thermal conductivity.

For best thermal conductivity, specify a high carbon, fully ferritic flake iron such as GF 20 (GF 150) with low silicon and no other alloy content.

However, since the thermal conductivity of the metal is usually a minor point in the overall heat transfer of a component, the type of Meehanite is more frequently chosen for its other physical properties in preference to its thermal conductivity.

Ingot molds are an exception to this; however, and a high carbon iron is chosen because of its high thermal conductivity.

Thermal conductivity is normally expressed as either BTU's per hour per square foot per degree Fahrenheit for one inch of thickness, or calories per second per square centimeter per degree Centigrade for one centimeter of the thickness.

Conversion factors that may be helpful are as follows:

BTU/(hr) (ft^2) (°F per in)
x 0.00034 = gm-cal/(sec) (cm^2) (°C per cm)
x 0.124 =kg-cal/(hr) (M^2) (°C per M)
x 0.0833 =BTU/(hr) (ft^2) (°F per ft)

Cal/(sec) (cm^2) (°C per cm)
x 2941 =BTU/(hr) (ft^2) (°F per ft)

Typical values for thermal conductivity at 100°C for Meehanite Metal are listed in Table IV.

Annealing to produce a fully ferritic matrix from a fully pearlitic one increases the thermal conductivity by approximately 0.01 cal/(sec) (cm^2) (°C per cm) or 30 BTU/(hr) (ft^2) (°F per in).

Raising the mean temperature of the metal from 100°C to 400°C lowers the thermal conductivity by approximately 0.01 cal/(sec) (cm^2) (°C per cm).

TABLE IV

Type	BTU/(hr) (ft^2) (°F per in)	Cal/cm.sec.°C
GM 60	323	0.108
GA 50	290	0.112
GC 40	325	0.120
GE 30	365	0.127
GF 20	365	0.131
HR	210	0.080
HE AS-CAST	298	0.100
HE ANNEALED	332	0.130
SF 60	249	0.090
SP 80	221	0.085
SH100		0.080

Thermal Expansion

When a solid material is subjected to a change in temperature, it undergoes a change in volume, which corresponds to the magnitude of the temperature variation.

This expansion is usually expressed as inches per inch of linear elongation.

The expansion of cast iron is quite complex. Irons may contain ferrite, carbides (either uncombined or in pearlite), free graphite, and varying amounts of inclusions, such as MnS. In addition, these irons may be heat treated or alloyed to produce ferritic, pearlitic, bainitic, martinsitic, or even austenitic structures.

The behavior of cast iron is further complicated by a magnetic change in cementite, which occurs at 210°C and the changes of crystal structure, which occur as heating progresses.

Several factors also contribute to volume changes which, unlike the reversible expansion, result in a permanent growth. Among them are structural changes such as decomposition of pearlite and internal oxidation.

As can be seen in the summary graph, all Meehanite Metals (except austenitic CR), regardless of structure or composition, initially expand at about the same rate. This rate will fall in the area designated as 1 on the graph (Figure 12) above 800°F (426°C); however, the expansion is not so regular.

The expansion curves for the flake-type General Engineering irons, GA 50 (GA 350), GC 40 (GC 275), and GE 30 (GE 200) will fall in area 2. These materials undergo abrupt rate changes at the critical temperature above which they expand, as indicated in area 3.

Above 800°F (426°C) increased alloy content decreases the rate of expansion, as does nodularity. Expansion curves for the following types of Meehanite lie in area 4, AQ, GM 60 (GM 400), HS, SP 80 (SP 600), and SH 100 (SH 700).

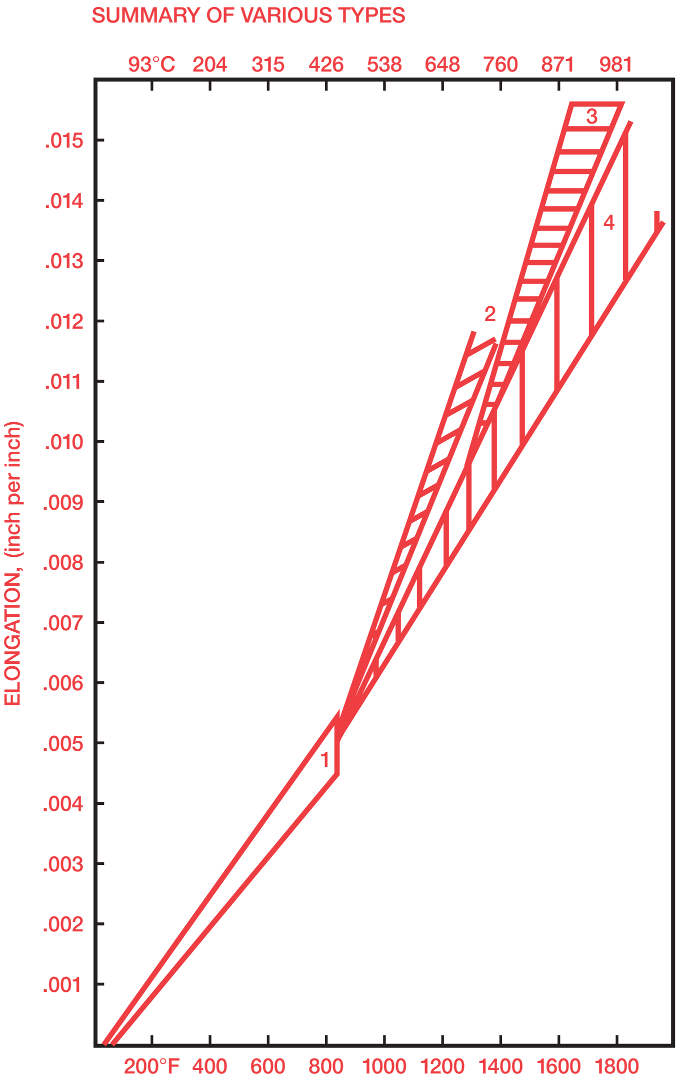
It is interesting to note that quenching influences the rate of expansion only until the time at which the hardened structure has completely tempered, after which expansion is the same as in the as-cast condition. These rates are also applicable upon recycling; the only change will be a vertical displacement of the curves after each cycle due to the permanent growth.

Table V lists the approximate rates of expansion for some typical Meehanite Metals.

The following are some general observations which are applicable to Meehanite Metal:

1. Increased carbon equivalents result in lower expansion in nodular irons.
2. Nodularity results in a higher rate of expansion at low temperatures and a lower rate

Figure 12


SUMMARY OF VARIOUS TYPES
93°C
204
315
426
538
648
760
871
981
.015
.014
.013
.012
.011
.010
.009
.008
.007
.006
.005
.004
.003
.002
.001
ELONGATION, (inch per inch)
200°F
400
600
800
1000
1200
1400
1600
1800
1
2
3
4

at high temperatures than that of a flake iron of similar composition.

3. Alloys increase the rate of expansion to about 800°F (426°C), above which they decrease the rate.
4. Manganese contents in excess of 0.8 percent have more effect on expansion than do copper and chromium. Likewise, the influence of copper is greater than that of chromium.

TABLE V
APPROXIMATE RATES OF THERMAL EXPANSION
ROOM TEMPERATURE TO °F/°C

Type	200°F 93°C	400°F 204°C	600°F 315°C	800°F 426°C	1000°F 538°C	1200°F 648°C	1400°F 760°C	1600°F 871°C
	in./in per °F x 10^{-6} (µm.n.k)							
GE 30	5.85 (10.53)	5.95 (10.71)	6.35 (11.43)	6.80 (12.24)	7.90 (14.22)	9.05 (16.29)		
GC 40	5.45 (9.81)	5.75 (10.35)	6.25 (11.25)	6.70 (12.06)	7.60 (13.68)	9.0 (16.20)		
GA 50	5.05 (9.09)	5.35 (9.63)	6.10 (10.98)	6.50 (11.70)	7.20 (12.96)	7.80 (14.04)		
GM 60	5.00 (9.00)	5.30 (9.54)	6.00 (10.80)	6.40 (11.52)	7.05 (12.69)	7.50 (13.50)	7.80 (14.04)	8.30 (14.94)
AQ	5.00 (9.00)	5.65 (10.17)	6.35 (11.43)	6.50 (11.70)	6.75 (12.15)	7.20 (12.96)	7.70 (13.86)	8.30 (14.94)
AQ (1)	6.65 (11.97)	9.40 (16.92)	10.95 (19.71)	9.75 (17.55)	8.15 (14.67)	8.20 (14.76)	8.40 (15.12)	9.10 (16.38)
AQ (2)	5.85 (10.53)	5.95 (10.71)	7.70 (13.86)	7.75 (13.95)	7.05 (12.69)	7.20 (12.96)	7.55 (13.59)	8.20 (14.76)
CR	10.00 (18.00)	10.20 (18.36)	10.40 (18.72)	10.20 (18.36)	10.10 (18.18)	10.30 (18.54)	10.60 (19.08)	
HR	5.85 (10.53)	5.95 (10.71)	6.15 (11.07)	6.35 (11.43)	7.15 (12.87)	7.75 (13.95)	8.25 (14.85)	9.30 (16.74)
HS	5.85 (10.53)	6.25 (11.25)	6.35 (11.43)	6.50 (11.70)	7.00 (12.60)	7.20 (12.96)	7.40 (13.32)	7.50 (13.50)
SP 80	5.85 (10.53)	5.95 (10.71)	6.15 (11.07)	6.40 (11.52)	6.85 (12.33)	7.05 (12.69)	7.25 (13.05)	7.35 (13.23)
SH 100	6.55 (11.79)	6.65 (11.97)	6.75 (12.15)	6.80 (12.24)	7.40 (13.32)	7.80 (14.04)	8.25 (14.85)	8.50 (15.30)
SF 60	5.85 (10.53)	6.10 (10.98)	6.25 (11.25)	6.50 (11.70)	6.95 (12.51)	7.10 (12.78)	7.35 (13.23)	7.40 (13.32)

AQ(1) WATER QUENCHED
AQ(2) AIR QUENCHED

Specific Heat

The amount of heat required to raise a unit mass of material one degree in temperature is called the heat capacity of that material.

The ratio of this amount of heat to that required to raise a unit mass of water one degree at some specified temperature is the specific heat of the material.

For most engineering purposes, heat capacities may be assumed numerically equal to specific heats. In general, specific heat varies with temperature but for moderate ranges, a mean value may be taken.

While specific heat may not be regarded as important engineering wise as thermal conductivity, or thermal expansion, it nevertheless is a factor that must be given some consideration in certain engineering applications involving heat.

Any material with a high specific heat is capable of absorbing more heat units before its temperature rises and, consequently, its properties would not be likely to change as severely or as soon as materials having lower specific heat.

The differences involved may be appreciated by comparing widely different materials, for instance:

BRASS	0.0883	cals/gm/°C
CORK	0.485	cals/gm/°C
MARBLE	0.210	cals/gm/°C
GLASS	0.199	cals/gm/°C
NICKEL STEEL	0.109	cals/gm/°C
MACHINE OIL	0.400	cals/gm/°C
PINEWOOD	0.670	cals/gm/°C

The various constituents that go to make up the structure of cast iron have quite different specific heat values, for example:

	150°C	850°C	
PURE IRON (FERRITE)	.121	.194	cals/gm/°C
AUSTENITE	.130	.159	cals/gm/°C
CEMENTITE	.149	.220	cals/gm/°C
GRAPHITE	.254	.454	cals/gm/°C

Actually, the specific heat of these materials will vary more as the temperature changes than these figures would indicate.

For example, pure iron will show a gradual increase to 750°C and will then increase extremely rapidly to a peak in the range of 750 to 775°C, dropping down again beyond 800°C.

Similarly, the specific heat of graphite changes quite rapidly as the temperature rises, thus:

at 20°C	0.170	cals/gm/°C
at 138°C	0.254	cals/gm/°C
at 642°C	0.455	cals/gm/°C
at 896°C	0.454	cals/gm/°C

Values given for specific heats of materials are usually the mean or average values over a given temperature range.

As graphite has a different value for specific heat than ferrite (iron) or cementite, it follows that the amount of graphite in the matrix and also its distribution could have an effect on the overall specific heat value. One would expect a high carbon cast iron to have a higher specific heat than a low carbon cast iron. Actually, this is not so and, in fact, a higher carbon cast iron usually has a lower specific heat than a low carbon cast iron. Some investigators claim that below 500°C, this position is reversed.

Various types of Meehanite show the specific heat temperature relationship. (Figure 13)

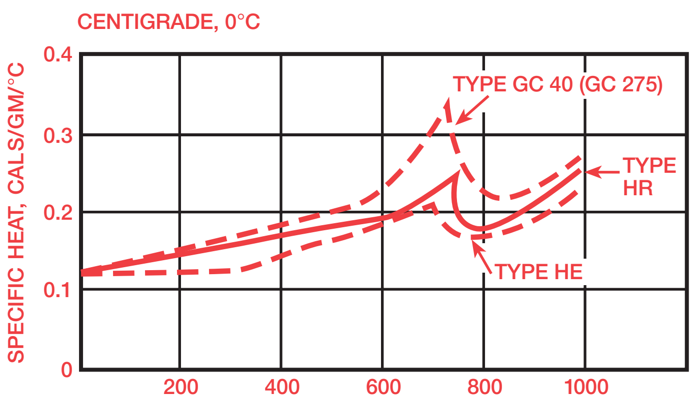
It is also a fact that the amount of phosphorus has an influence on the specific heat of a cast iron, for example:

.15% Phosphorus cast iron 0.118 cals/gm/°C

.55% Phosphorus cast iron 0.104 cals/gm/°C

Phosphorus, therefore, lowers the specific heat of cast iron.

Figure 13



Sub-Zero Impact Properties

It is generally known that temperatures below freezing tend to lower the strength and impact resistance of most metals.

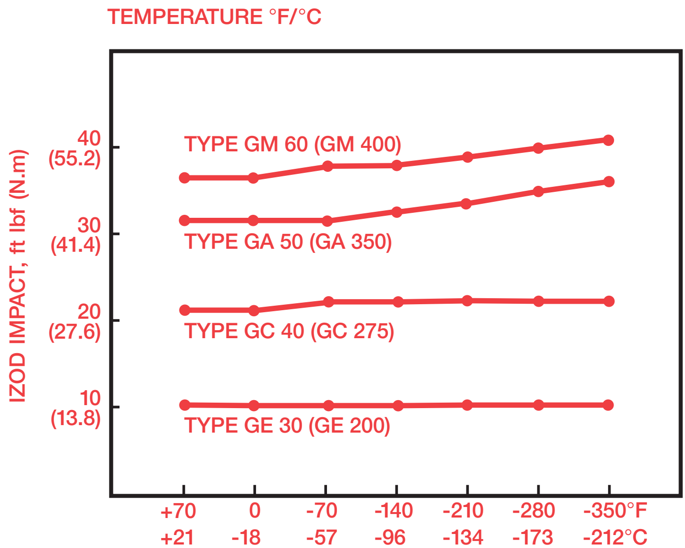
Impact test results per sé can be vague and misleading because of the many variables in the test itself. Factors such as the type of test bar, the temperature of testing and the method of applying the load are sometimes varied quite indiscriminately. This has introduced an element of uncertainty in assessing test results.

Izod impact tests on a 0.798˝ (20 mm) diameter unnotched bar on the flake graphite types of Meehanite over a range of temperatures from room temperature to -320°F (-196°C) are shown. (Figure 14)

The toughness of Types GM 60 (GM 400) and GA 50 (GA 350) actually increased as the temperature decreased to -320°F (-196°C) as at normal room temperature. In design, normal room temperature impact values may be used for these metals.

When designing with Meehanite nodular irons which are ductile for operation at subzero temperatures, it is necessary to consider factors affecting the "transition temperature" of the iron. The transition temperature is temperature below which the material behaves in a brittle way and exhibits a different appearing fracture. Above this temperature, the material behaves in a ductile manner.

Figure 14



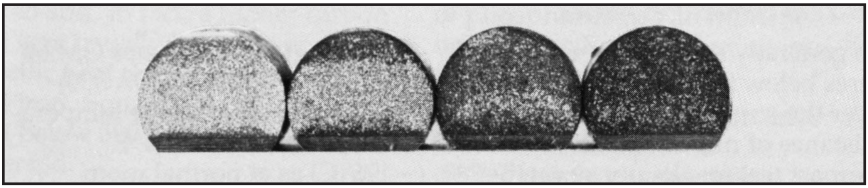


Figure 15

In illustration Figure 15, the dark fractures are typically ductile whereas the lighter fractures which have been tested at a lower temperature exhibit the typical appearance of a brittle fracture.

In dealing with the more ductile materials, the chemistry as well as the metallurgical structure becomes important in determining the impact strength and the transition temperature. Therefore, in applications where toughness is a factor, a material is chosen whose transition temperature occurs below its normal operating temperature.

In the Meehanite nodular irons, Type SF 60 (SF 400) is designed to maintain its toughness even down to sub-zero temperatures.

Types SP 80 (SP 600) and SH 100 (SH 700) are primarily designed for high strength, and their toughness characteristics do not suit them for sub-zero applications with high shock loadings; however, they can be used in sub-zero applications where high strength is required but there is no shock loading.

Figure 16 shows transition temperature tests for SF 60 (SF 400). Tests are conducted on a notched bar. With the normal composition for average use as in Curve 3, the transition temperature occurs at about 40°F (4.4°C). Where chemistry is suitably altered, as in the curve marked No. 2, the transition temperature may be lowered about -30°F (-34°C).

Special heat treatments can also be used to further lower the transition temperature of SF 60 (SF 400) to about -80°F (-62°C), as in Curve 1.

The heat treatment in this case consisted of heating to 1300°F (704°C), holding for ½ hour and water quenching, then reheating to 400°F (204°C) and holding at temperature for 24 hours. This heat treatment not only lowers the transition temperature, but also raises the impact strength.

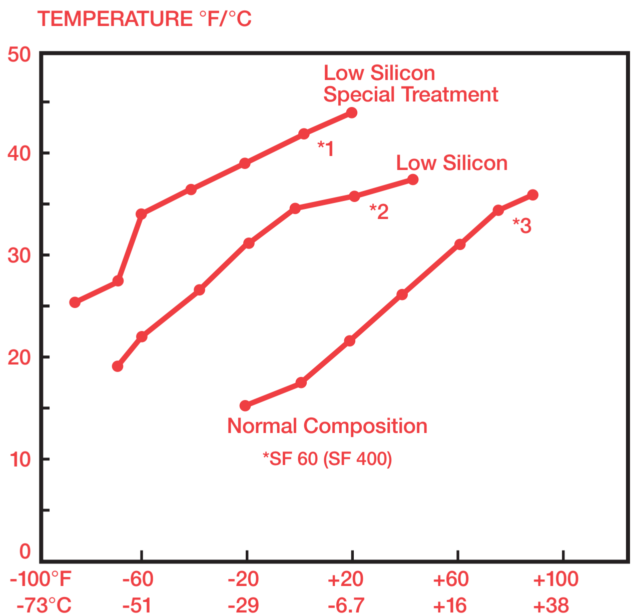
The lesson to be learned from these comparisons is that materials, such as nodular iron, which are supposed to have good toughness, may exhibit severe brittleness if there composition is not related to service temperature.

Nodular iron castings having the silicon a little too high have been known to fracture with a light blow on a cold day, although tests taken from the same metal were well above specification and exhibited normal ductility values.

When a design engineer designs for impact or shock resistance and he does not get it, the result may be catastrophic. On the other hand, the flake graphite General Engineering irons which are not ductile to start with behave in a very rational and predictable manner in low temperature service.

While due allowance in design must be made for the fact that they do not offer a high degree of shock resistance, they can be expected to conform to design conditions even at abnormally low temperatures.

Figure 16



Damping Capacity

Damping capacity is that property which permits a material to absorb vibrational stresses.

With Meehanite Metal, its combination of high damping capacity and strength puts it in a unique position and supplies the Meehanite foundry with a very valuable sales tool.

In order to understand the principle of damping vibration, consider what would happen to a tuning fork made of Type GE 30 (GE 200) Meehanite: When struck, it would vibrate for a few seconds only. A similar fork made of Type GA 50 (GA 350) Meehanite would probably vibrate for a second longer–one of a nodular type perhaps another second longer.

A fork made of steel would vibrate five to eight times longer and one of aluminum about twelve times longer.

The high damping capacity of Meehanite Metal is a result of its controlled metallurgical structure; i.e., random graphite distribution in a uniform matrix.

Although it is possible to express the damping capacity in fairly precise terms of energy of amplitude absorption, as determined in a laboratory investigation, it is difficult to make use of this information in a quantitative manner.

Along with ductility and impact resistance, damping capacity helps to prevent stresses from getting out of control. Of course, strength is also necessary to control stresses and this is where the basic principles of the Meehanite Process are important because the uniform distribution or graphite in Meehanite Metal enables it to maintain the high damping characteristics of gray iron together with high tensile strength.

To better understand the value of damping capacity, consider the application of a crankshaft in a combustion motor.

If the crankshaft is made of Meehanite Metal with high damping capacity, then the amplitude of the vibrations caused by operation are more readily kept within the fatigue limit of the material.

If the same crankshaft were made from a material of similar strength, but with lower damping properties, then the stresses might build up to exceed the fatigue limit and ultimately cause failure.

Materials having high damping values are able to be deformed to a higher degree than Hooke's law predicts without being damaged.

While there are several methods of measuring damping, all methods involve applying a known stress and then measuring the reduction in stress accompanying one or more cycles of vibrations.

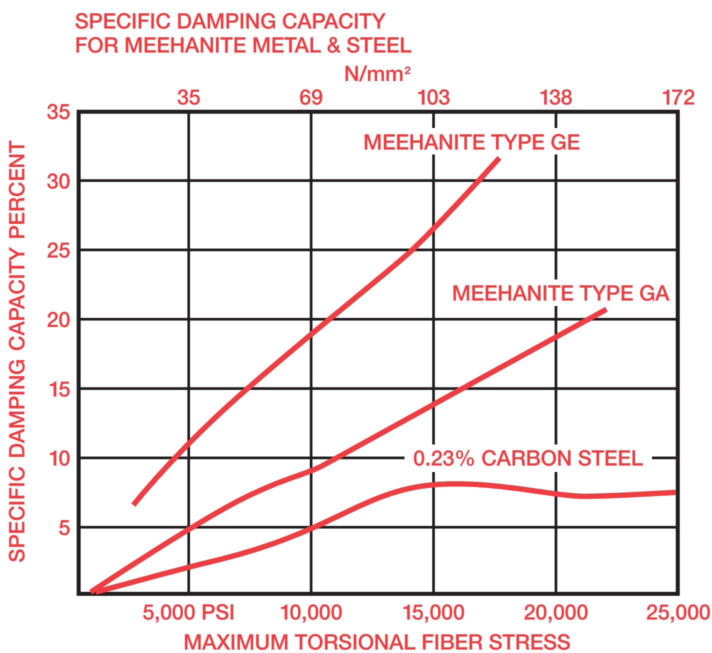
A curve, such as that shown in Figure 17, is obtained from such a test.

It can be seen that as the applied stress is increased, then the specific damping capacity increases. The amount of applied stress is just one factor that can change the damping capacity of a type of Meehanite once it has solidified with a defined graphite size and distribution.

For example, heat treatment can be used to alter the matrix and hence the damping capacity of a particular type. Stress relief treatments produce about a 20% reduction in damping capacity. On the other hand, annealing to produce a fully ferritic structure increases the damping capacity. The same is true of quenching to produce martensite; however, as the structure is tempered and quenching stresses reduced, the ability to absorb vibration also decreases.

The damping capacity for various materials expressed as the percent of energy dissipated on

Figure 17



the first cycle is given in the following Table VI.

Common gray iron also shows the high damping characteristics of Meehanite Metal; but unless it also shows the high strength of Meehanite Metal, it cannot maintain its damping efficiency at high stresses.

Take the example of a power hammer frame which failed when made from common gray iron: Engineers would immediately recommend increasing sections of the replacement casting, but a Meehanite foundryman should know that unless a metal with a pearlitic matrix is used, little, if any, advantage is gained because the heavier section and slower cooling rate would produce a weaker casting.

Meehanite Metal with its various types makes it possible for the design engineer to select for a given strength an iron of high damping capacity, and provides a much wider range of choice in this respect than all other engineering materials.

TABLE VI
DAMPING CAPACITY
(Percent of Energy Dissipated on the First Cycle)

Torsional Stress	TORSION 20,000 psi (138 N/mm²) Load	TORSION 10,000 psi (69 N/mm²) Load
Soft Gray Iron	40.0	28.2
1020 Carbon Steel	8.0	5.5
Aluminum	42.0	29.4
GF 20 (GF 150)	32.0	19.2
GE 30 (GE 200)	28.0	16.3
GC 40 (GC 275)	24.0	12.0
GA 50 (GA 350)	21.0	
GM 60 (GM 400)	14.0	
SF 60 (SF 400)	12.0	
SP 80 (SP 600)	11.0	
SH 100 (SH 700)	11.0	
GE 30 (GE 200) Stress Relieved	26.0	
GA 50 (GA 350) Quenched	32.0	
GA 50 (GA 350) Q & T (370°C/700°F)	28.0	

Dimensional Stability

Maintenance of accuracy of dimension in service is of first importance in most modern engineering components.

In measurements made at the National Physical Laboratory, the movement of Meehanite Type 50 (GA 350) samples was found to be as follows:

CONDITION	TIME	MOVEMENT
AS-CAST	28 Months	4 x 10^{-5}″/ft (3.33 x 10^{-3}mm/m)
STRESS RELIEVED	20 Months	2 x 10^{-5}″/ft (1.66 x 10^{-3}mm/m)

Magnetic Properties

While it is well realized that Meehanite Metal is not produced primarily for its magnetic properties, and does not compare as such to materials made specifically for this purpose, cases arise when it forms part of a magnetic circuit and it is still important to be familiar with its magnetic properties.

It is frequently necessary for the engineer to consider other factors such as (1) cost (2) machinability (3) ease of manufacturer and (4) damping capacity, and it may well be that he will choose Meehanite for certain components carrying magnetic flux in spite of its lesser magnetic properties.

An advantage of Meehanite over ordinary cast iron lies in the fact that each type of Meehanite Metal is made to definite chemical and metallurgical properties and, therefore, each type has well defined magnetic properties, while cast iron covers a broad range of chemistry and metallurgy giving the engineer only vague magnetic properties limits unless he specifies the material's chemistry himself.

It is somewhat easier to compare magnetic terms to electrical terms that are more familiar. In magnetism, flux (Maxwells) is analogous to current, permeability (Gauss) analogous to conductivity, and magnetic field or force (Oersteds) analogous to voltage.

The most commonly used magnetic properties are illustrated by means of the conventional magnetization curve and hysteresis loop. (Figure 18)

1. Field strength or magnetizing force (Symbol H) is expressed as oersteds, gilberts/cm, ampere turns/cm or ampere turns/inch.
2. Saturation intensity (gauss) is the value of flux density (B) when saturation is reached (point A).

3. Permeability (μ) (gauss) is the ratio of B to H at any point on the magnetization curve OA. It is quite common to quote values of B for particular values of H (magnetizing force). Its value is unity for air or other nonmagnetic media.
4. Remanence (gauss) is the flux density remaining after saturation and removal of the applied field (value = line OC).
5. Coercive force (oersteds) is the field strength required to demagnetize after saturation (value = line OD).
6. Hysteresis loss (ergs/cc/cycle) is the energy lost and dissipated as heat through one cycle, and is proportional to the area of the loop = area in gauss x oersteds/ 8π. It is more commonly expressed as watts/lb at 50 or 60 cycles for a given flux density, usually 10,000 gauss.
7. Flux (maxwell or line) is the total quantity of magnetism in a circuit.
8. Flux density (gauss or maxwell/sq. in) (Symbol B) is the induction of magnetic intensity.

Conversion and interrelation of magnetic units is as follows:

$$1 \text{ oersted} = \frac{1}{0.4\pi} \text{ a.t/cm} = \frac{2.54}{0.4\pi} \text{ a.t/inch}$$

$$\text{field in oersteds} = 0.4\pi \text{ field in a.t./cm} = \frac{0.4\pi \text{ field in a.t./in}}{2.54}$$

1 gauss = 6.45 lines/sq. in

$$\text{flux density in gauss} = \frac{\text{flux density in lines/sq. in}}{6.45}$$

1 gauss = 1 maxwell/sq. in = 1 maxwell/sq. cm

1 oersted = 1 gilbert/centimeter

Figure 18

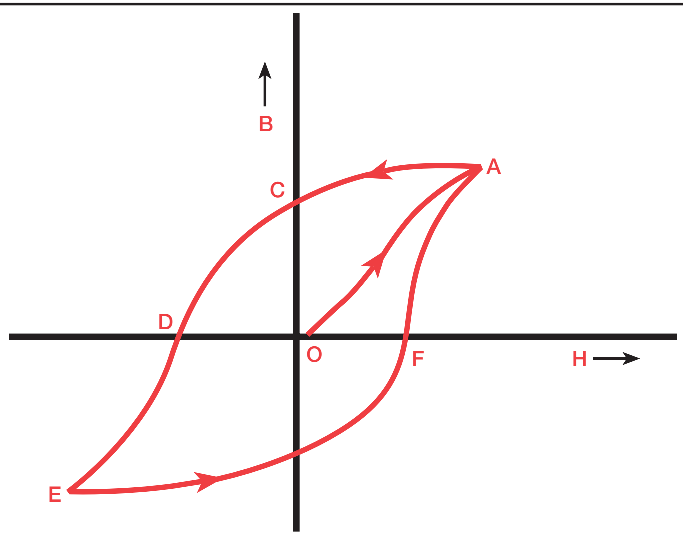


TABLE VII

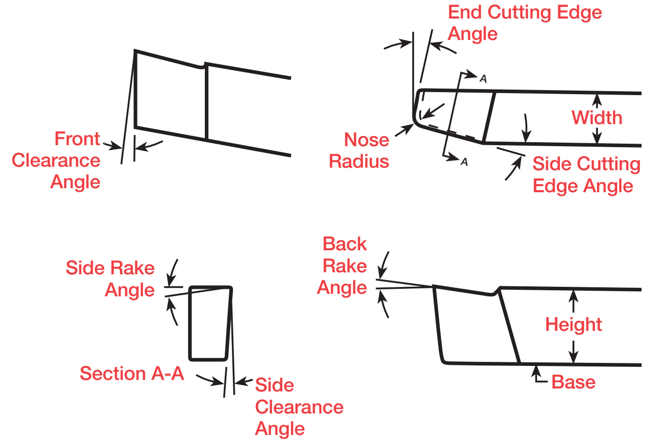
	MAX. PERM	Flux Density at Varying Magnetizing Force H-oersteds 10	20	50	100	200	B (lines/sq. in) at 40 at/in	100 at/in	Remanence (gauss)	Coercive Force (oersted)	Hysteresis ergs/cc/watts/lb Cycle at 60	
GA 50 as-cast	300	2200	4800	8000	10000	12000	31000	51000	5400	15	26000	9
GA 50 annealed	550	5250	7100	9000	10500	12500	45500	58000	6500	4-7	12000	4
GA 50 quenched	80	400	1000	7000	9000	9500	6500	44500	5900	50	6000	20
GA 50 quenched & tempered	275	1200	5000	8200	10250	12200	32000	53000	7000	18	30000	10
GC 40 as-cast	220	1600	4300	7500	9500	10000	27700	48500	5100	12.5	24000	8
GC 40 annealed	500	5000	7000	9000	10500	11000	45000	58000	5000	4-7	9000	3
GE 30 as-cast	200	1600	4000	6900	9000	9600	25800	44500	4700	12	22000	7
GE 30 annealed	400	4000	5600	7500	9200	9900	36000	48500	5000	4-6	9000	3
SP 80	1450	7500	9100	11500	13500	15000	58500	74000	3600	2.0	7000	
SF 60	425	4200	7000	10200	12700	14000	45000	66000	6000	7.5	28000	

Machinability and Machining

The machinability of Meehanite Metal castings is one of their most valuable properties and the Meehanite organization is actively engaged in devising ways to helping machine shops to obtain the utmost benefit from this property.

It is recognized that machinability ratings are of little value without information on the practical details of the machining operation. Emphasis, therefore, is being laid on the provision of the best combination of speed, feed, depth of cut, etc., for the different types of Meehanite.

Figure 19



Machining Practice and Tool Design

Tool shapes for roughing cuts, based on the use of High Speed Steel and on Cemented Carbide Tools, are given above. (Figure 19)

TABLE VIII

Tool Angle	HIGH SPEED STEEL TOOLS Lathe	Planer	Boring Mill	TUNGSTEN CARBIDE TOOLS Lathe	Planer	Boring Mill
Side cutting edge angle	6°-10°	8°-10°	6°-10°	8°-10°	5°-10°	6°-10°
End cutting edge angle	8°-12°	8°-12°	5°-8°	8°-10°	8°-10°	10°-12°
Front clearance angle	2°-4°	2°-4°	4°-6°	4°-6°	4°-6°	2°-6°
Side clearance angle	2°-5°	2°-5°	2°-8°	4°-6°	4°-6°	4°-6°
Back rake angle	4°-8°	3°-5°	0°-4°	0°-4°	0°-8°	0°-2°
Side rake angle	6°-10°	6°-10°	6°-8°	2°-6°	2°-6°	2°-10°
Nose radius	3.2-6.4mm 1/8-1/4″	6.4mm 1/4″	3.2-4.8 mm 1/8-3/16″	3.2 mm 1/8″	3.2 mm 1/8″	0.8-6.4mm 1/32-1/4″

The recommended machining practice (turning, boring and milling) using carbide tools is given below:

TABLE IX

TURNING	ROUGHING CUT		FINISHING CUT	
Type Meehanite Metal	Speed s.f.m. (m/min)	Feed in/rev (mm/rev)	Speed s.f.m. (m/min)	Feed in/rev (mm/rev)
GM-GA-SP	150-200 (46-61)	0.020-0.030 (0.508-0.762)	200-300 (61-91)	0.008-0.020 (0.203-0.508)
GC	200-250 (61-76)	0.020-0.030 (0.506-0.762)	250-350 (76-107)	0.008-0.020 (0.203-0.508)
GE-HE-SF	200-360 (61-110)	0.020-0.030 (0.506-0.762)	250-450 (76-137)	0.008-0.020 (0.203-0.508)
BORING	**ROUGHING CUT**		**FINISHING CUT**	
Type Meehanite Metal	**Speed s.f.m. (m/min)**	**Feed in/rev (mm/rev)**	**Speed s.f.m. (m/min)**	**Feed in/rev (mm/rev)**
GM-GA-SP	120-400 (37-122)	0.010-0.020 (0.254-0.508)	160-200 (49-61)	0.010-0.020 (0.254-0.508)
GC	180-240 (55-73)	0.010-0.022 (0.254-0.559)	200-250 (61-76)	0.010-0.020 (0.254-0.508)
GE-HE-SF	200-250 (61-76)	0.015-0.025 (0.381-0.635	250-300 (76-91)	0.010-0.020 (0.254-0.508)
MILLING	**ROUGHING CUT**		**FINISHING CUT**	
Type Meehanite Metal	**Speed s.f.m. (m/min)**	**Feed in/rev (mm/rev)**	**Speed s.f.m. (m/min)**	**Feed in/rev (mm/rev)**
GM-GA-SP	150-200 (46-61)	0.008-020 (0.203-0.508)	150-250 (46-76)	0.008-0.025 (0.203-0.635)
GC	180-200 (55-61)	0.008-0.022 (0.203-0.559)	180-275 (55-84)	0.008-0.030 (0.203-0.762)
GE-HE-SF	200-300 (61-91)	0.008-0.025 (0.203-0.635)	250-400 (76-122)	(0.008-0.030) (0.203-0.762)

Coolants: Many castings may be machined dry except for tapping and threading. Increased production is obtained by using established water soluble cutting compounds that have a high wetting and dispersing quality.

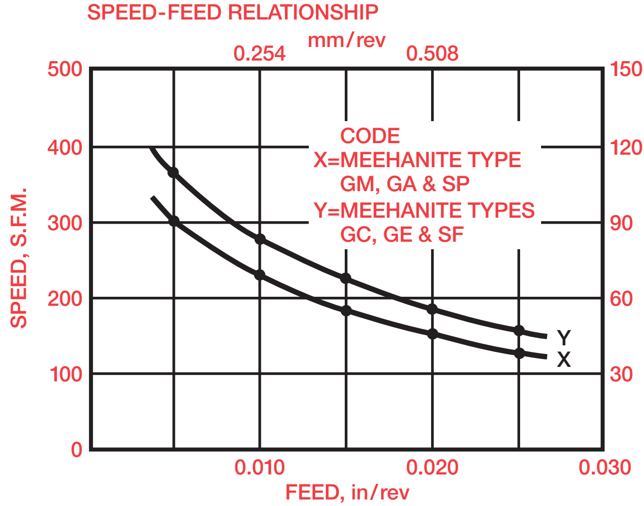
Meehanite castings may also be machined with high speed steel, or cast form cutters.

Speed Feed Relationship

The best cutting efficiency is obtained by using high feed and adjusting speed to the maximum tool life desired.

The speed-feed relationship for the engineering types of Meehanite Metal GA 50 (GA 350), GM 60 (GM 400), SP 80 (SP 600) as well as for the softer types GC 40 (GC 275), GE 30 (GE 200) and SF 60 (SF 400) are charted in Figure 20, based on actual turning tests.

Figure 20



Preparation and Sharpening of Tools

Dull tools cost money and waste time. Correct angles, rakes and clearance are vital to efficient metal removal. Grinding of tools must be exact. This requires use of fixtures and competent tool grinders. Hand grinding is undesirable.

Avoid water quenching of cutters after grinding. This causes minute edge cracking and premature failure in operation.

Use grinding-cutters entirely dry or under a wheel with ample water directed on the cutter.

Avoid forcing cutters against a grinding wheel. This overheats and burns the cutting edge of the tool causing flaking during machining operations.

Check all cutter angles with a cutter grinding gauge.

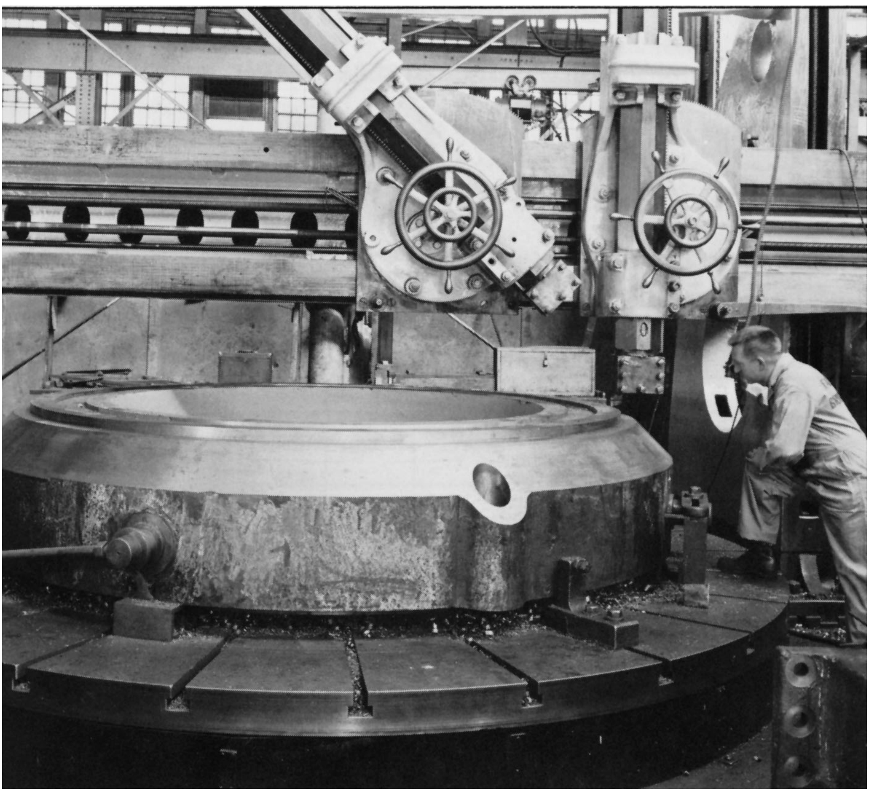
Machining Allowances

Do not skimp in finish limits. The quality of the surface of a casting is usually better on the bottom face of the casting. Therefore, design the pattern so that the important surface may be in the most favorable casting position.

Complicated and large castings require wide tolerance limits. Castings having large flat areas require extra finish ⅜″-½″ (9.5 mm-12.7 mm) on top face, while ⅛″ (3.1 mm) may be enough on bottom face. If only one face must be perfect, top limits may be reduced.

Before commencing machining, lay out machine surface at small end or side of casting with draft to assure "clean-up" on all surfaces.

Castings may not clean up on all surfaces if the casting draft is not taken into account. Machining allowances involve many variables. Consult foundry.



Meehanite adapter ring for atomic reactor.

Properties Not Measured by P.S.I. Values

Rolling Friction Type of Wear

Such components as gears, sprockets, clutch plates, sheaves, trunnions, wheels, worm screws, ball races, cable drums, tires and rollers, etc., all involve wear resistance in terms of surface behavior as a result of friction with or without shock, heat or attrition.

The basic surface stress values provide an index of resistance to surface disintegration or surface fatigue.

The basic bending strength factors provide an index of strength in terms of tool shape.

These tests provide comparative data showing the high resistance of Meehanite castings to failure from bending stresses in both the cast and heat treated conditions and to resist surface wear and disintegration.

BY THE DAVID BROWN TEST
TABLE X

BASIC SURFACE STRESS FACTOR	
Meehanite Type GM 60 “as-cast”	1,600 (11.0)
Meehanite Type GM 60 Heat Treated 400-500 BHN	2,400 (16.6)
Meehanite Type GA 50 “as-cast”	1,450 (10.0)
Meehanite Type GC 40 “as-cast”	1,400 (9.7)
Meehanite Type SP 80 “as-cast”	1,800 (12.4)
Meehanite Type SP 80 Heat Treated 340 BHN	2,500 (17.2)
Meehanite Type SH 100 “as-cast”	2,500 (17.2)
Meehanite Type SH 100 Heat Treated 350 BHN	2,700 (18.5)
Ord. Cast Iron “as-cast”	1,000 (6.9)
Phosphor Bronze, Sand Cast	700 (4.8)
Cast Steel (C 0.35)	1,400 (9.6)

BASIC BENDING STRESS FACTOR	
Meehanite Type GM 60 “as-cast”	15,500 (106.9)
Meehanite Type GM 60 Heat Treated 500 BHN	16,000 (110.3)
Meehanite Type GM 60 heat Treated 400 BHN	17,500 (120.7)
Meehanite Type GA 50 “as-cast”	15,000 (103.4)
Meehanite Type GC 40 “as-cast”	14,000 (96.6)
Meehanite Type SP 80 “as-cast”	19,000 (131.0)
Meehanite Type SP 80 Heat Treated 340 BHN	30,000 (206.9)
Meehanite Type SH 100 “as-cast”	22,000 (151.7)
Ord. Cast Iron	5,800 (40.0)
Phosphor Bronze	7,000 (48.3)
Cast Steel (C 0.35)	14,000 (96.6)

Galling, Seizing and Pickup

In the design of industrial machinery, it is impossible to avoid the mating of two or more metallic surfaces under conditions that involve movement and some degree of friction.

Under many conditions, this friction may exceed a critical value causing adherence. The tearing action that results damages one or both surfaces and is usually referred to as galling.

Where it is severe enough to cause a welding, this is known as seizing. Pickup, scuffing and scoring represent various ramifications of the same problem.

Metal surfaces are actually attracted to one another by the natural tendency of atoms and molecules to combine. As surface molecules are only bounded on three sides, they exert a strong attraction towards similar surface molecules.

By conditioning the metal so that an amorphous non-crystalline layer known as the Beilby layer occurs, it is possible to considerably reduce this molecular attraction and decrease the surface friction between moving parts.

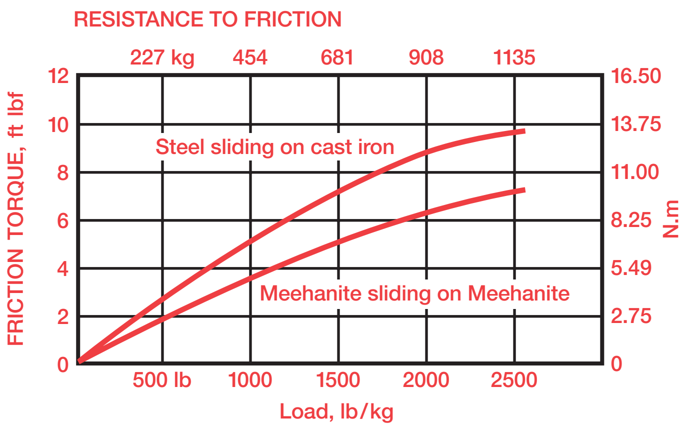
The ability of a material to be so conditioned and any built-in lubricative properties it may have play a vital part in avoiding galling action.

Meehanite Metal contains free graphite, which gives a certain "built-in" protective feature when metal parts operate together for a short time without lubrication.

This feature is well illustrated below by the friction torque that results when Meehanite slides against Meehanite, compared to when it slides against steel containing no free graphite. (Figure 21)

Comparative tests run using steel as a rotating member and

Figure 21



increasing the working load in 100 pounds (45.4 kg) increments until seizing occurs show the proportionate galling values of the materials listed below.

By far the most important factor that is operative in any galling problem is the surface condition of the mating surface. The effect of surface finish as measured in a special series of tests is tabulated below.

Material	Seizing Load, kg (lb)
Meehanite Type GA 50 (GA 350)	1300 (590)
Meehanite Type GE 30 (GE 200)	1200 (545)
Graphitic cast iron	1000 (454)
Navy bronze	800 (363)

Surface Condition	Finish, in x 10^{-6}(mm x 10^{-6})	Seizing Load, lb (kg)
Machined	65 (1651)	1000 (454)
Ground	12 (305)	Did not seize at 2500 (1135)
Lapped	8 (203)	Did not seize at 2500 (1135)

The finer the surface finish, the closer the surface is to having a Beilby layer. Consequently, the running-in period needed to develop such a layer becomes increasingly more critical as the original surface becomes rougher.

In general, a material having a finish of 12 micro-inches (305 micro-mm) or less will not require a careful "wearing-in" period.

"Wearing in" may be accomplished by running at light loads for short periods of time, allowing adequate time for rest or recovery between the running periods. The graphical illustration shows how the friction co-efficient varies with "running in". The final low co-efficient indicates the production of a Beilby layer on the surface. (Figures 22, 23)

On the other hand, a part that has been "superfinished" at a heavy load, as shown above, may be regarded as being in the "run-in" condition because it exhibits a low frictional co-efficient right from the start.

Heat treatment of Meehanite Metal followed by honing gives a surface that is virtually gall resistant. Additionally, the hardening treatment will result in excellent wear resistant characteristics.

Lubrication is obviously important in any metal to metal contact. Meehanite with its "built-in" lubricant in the form of graphite, is less critical in this regard. Be sure that lubrication is adequate and that only the best lubricants are used.

Metals of high density (specify gravity 7.15 to 7.4) and with a uniform distribution of graphite in an all pearlitic matrix, or in a sorbitic matrix, offer the ultimate in galling resistance.

Avoid the use of castings that exhibit excessive variation of Brinell hardness across a surface or from section to section. It is quite likely that such castings will not possess the best structure to resist galling where the conditions of service are such that galling is a problem.

Figure 22

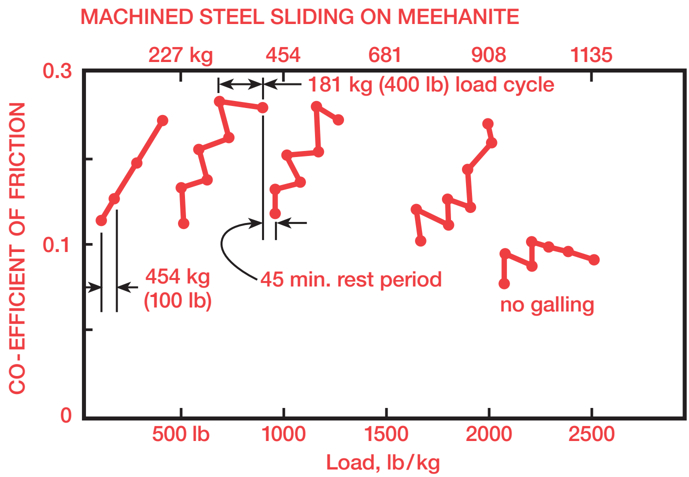
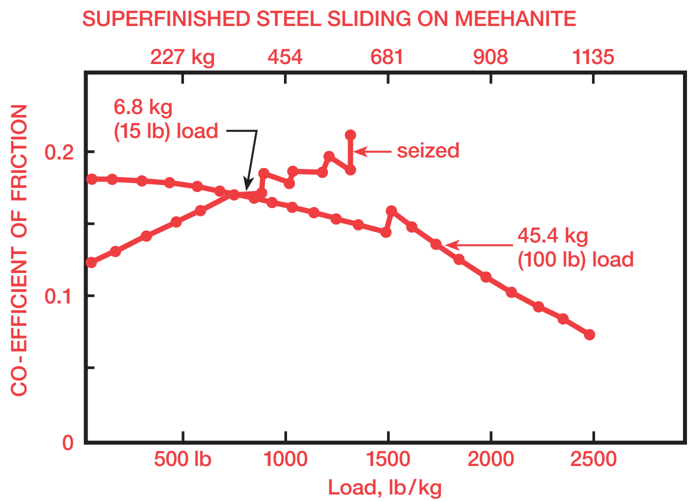


Figure 23



Heat Treatment Data

Meehanite Types SP 80 (SP 600), GM 60 (GM 400) and GA 50 (GA 350) respond to heat treatment in the same way as Carbon Steels. By proper treatment, improved toughness and/or hardness may readily be obtained.

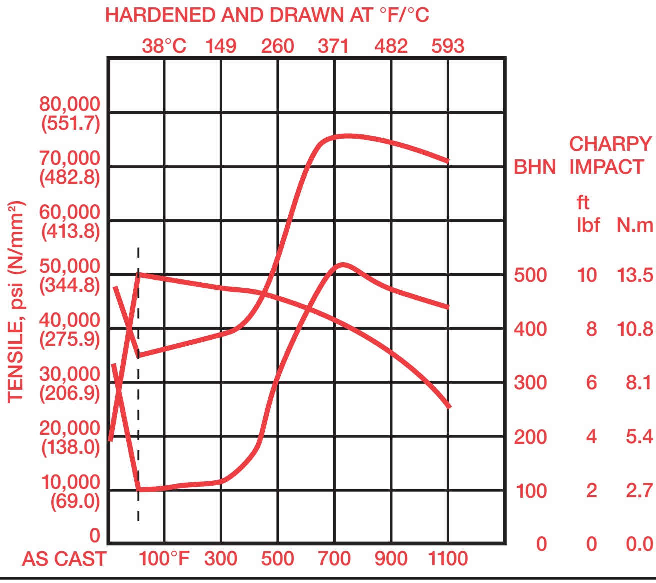
The effect of heat treatment on the tensile strength and hardness is illustrated in Figure 24 for Type GA 50 (GA 350) Meehanite.

It will be noted that hardness is not influenced by tempering at temperatures up to 400°F (204°C); therefore, when full hardness is required in a casting, tempering treatment at this temperature is recommended to remove hardening stresses. Maximum combined toughness and strength are obtained by tempering in the range 716°F (379°C) to 806°F (430°C).

Where improved wearing properties are required but machining is necessary, tempering in the range 1000°F (538°C) to 1100°F (593°C) will give Brinell hardness figures around 280 to 300.

Where hardness is required in combination with improved toughness, this may be obtained by quenching from above the critical temperature direct into a molten lead or salt bath at 500°F (260°C) to 720°F (382°C) where it should remain one or more hours, according to the degree of hardness or toughness desired.

Figure 24



The effect of quench and draw treatment on the impact strength and hardness of Type GA 50 (GA 350) Meehanite is portrayed above.

General Heat Treatment Instructions

Preheat the casting to 1100°F (593°C). Raise the temperature to 1575°F (858°C) to 1600°F (871°C) as quickly as possible. When the casting temperature blends with the furnace, quench in oil or water according to the degree of hardness required. Withdraw from the quenching bath while warm–above 300°F) 149°C)–and temper immediately.

The quenching medium used; i.e., oil, cold or warm water, should be modified according to the complexity of the casting to avoid overstress causing cracking.

To temper hardened castings to remove stresses without losing any hardness, reheat in oil at 400°F (204°C) for 1 to 2 hours per inch (0.4 to 0.8 hour per cm) of casting thickness.

Small castings in Meehanite Type GC 40 (GC 275) also respond to heat treatment, but all castings to be so treated should be specified on the castings order.

Annealing For Improved Machinability

There are two kinds of annealing for the purpose of improved machinability:

Low Temperature Anneal–
Improves machinability without markedly affecting the hardness, but may cause about ten percent loss in strength properties.

High Temperature Anneal–
May cause loss of both strength and hardness to a marked extent if annealing time is excessive. In the case of high temperature annealing, which involves heating through the critical range, it is recommended practice to heat slowly to 1200°F (648°C) and allow to soak at this temperature.

The casting may then be transferred to another furnace which has been previously heated to full annealing temperature or else the temperature of the preheating furnace may be raised as quickly as possible to the full annealing temperature.

This procedure is recommended to avoid excessive thermal shock with the possible development of cracks in the casting.

Table XI shows the recommended temperature for annealing for improved machinability.

Heating time should not exceed one hour per inch of casting section following by a slow cooling.

No Meehanite casting should require annealing for softening for machining purposes except in unusual cases, in which case the foundry supplying the castings should be advised.

TABLE VIII

Type	Low Temp. Anneal °F (°C)	High Temp Anneal °F (°C)
GE 30 (GE 200)	1230/1260 (664/681)	1550 (842)
GC 40 (GC 275)	1240/1280 (670/692)	1580 (860)
GA 50 (GA 350) and GM 60 (GM 400)	1250/1300 (675/704)	1600 (871)

Temper Brittleness

In the treatment of ferrous metals, it is possible to develop an unexpected degree of brittleness in an otherwise ductile material.

Basically, three types of brittleness may occur; viz., the ductile-brittle inversion which occurs at near zero or sub-zero temperatures, brittleness that results on tempering or drawing a previously hardened part, and brittleness in a ductile part resulting from slow cooling after the annealing treatment.

There is some similarity between these three types of brittleness; and up to now, no completely satisfactory answer has been found to this phenomenon. However, its existence has been recognized and means of avoiding it are being used.

In a flake graphite cast iron, the question of temper brittleness may be ignored because the graphite flakes themselves are so effective in lowering toughness or impact strength that the effect of secondary factors, such as temper embrittlement, is completely masked.

In steels and in nodular cast iron, however, care must be taken during heat treatment to avoid the development of this unexpected brittleness.

In steels which may be considered as closely parallel to nodular irons, temper embrittlement was first observed on drawing back steels, which had been hardened by an oil quench treatment.

Figure 25 shows the change in Izod impact value with increasing tempering temperature.

In curve "B", the sample is slowly cooled from each temperature; whereas, in curve "A", it is rapidly cooled.

It is evident, therefore, that rapid cooling from the drawing temperature produces higher toughness. It has been recognized that a steel may be susceptible to temper embrittlement and a measure of susceptibility has been proposed.

The susceptibility ratio is the comparison between the impact strength after water quenching from a tempering of 1200°F (650°C) and the impact strength after slow cooling from this temperature.

Alloys such as chromium, manganese, and phosphorus increase susceptibility to temper brittleness–carbon, nickel, silicon, and vanadium have little effect while molybdenum has a very marked effect in preventing this brittleness. It has, therefore, become a standard addition to steels where embrittlement must be avoided.

In nodular cast irons where the structure is ferritic, and where good elongaton and impact strengths are desired, this embrittlement also is an important factor. It may occur in hardened nodular irons which are drawn at temperatures ranging from 840°F to 930°F (450°C to 500°C) or in ductile nodular irons which are slowly cooled through this temperature range after an annealing treatment.

An iron quenched from 1200°F (650°C) is more ductile than one cooled slowly from this temperature. Maximum ductility and the lowest impact transition temperature will result when the sample is water quenched from 1200°F (648°C) and then aged for 24 hours at 400°F (204°C).

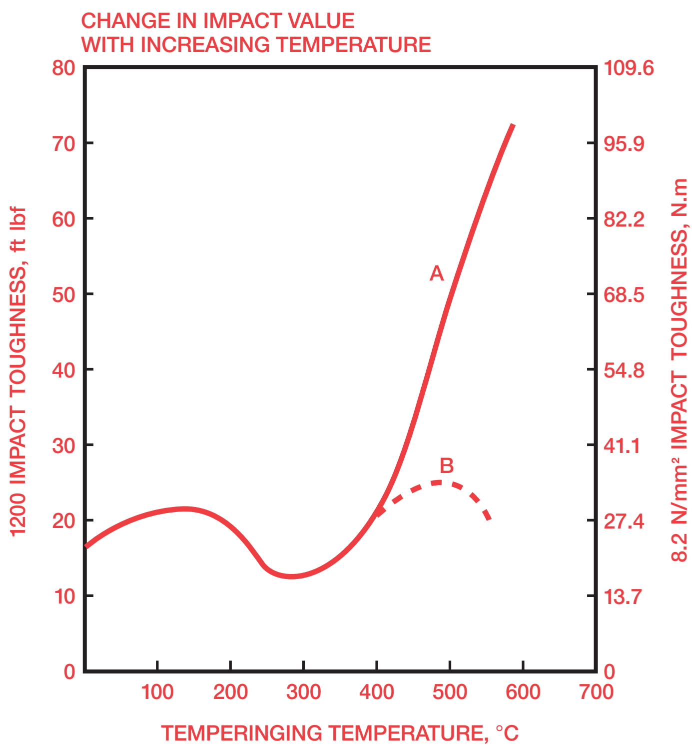
Embrittlement produced in an iron by tempering at 840°F (450°C) may be removed by quenching from 1200°F (650°C).

The susceptibility of nodular irons to temper embrittlement is increased by additions of phosphorous and silicon, but phosphorus is more harmful than silicon.

The addition of molybdenum inhibits embrittlement obtained in the 843°F to 932°F (450°C to 500°C) range, providing that other composition factors such as silicon and phosphorus are normal.

Glavanizing embrittlement occurs in irons which are galvanized primarily because treatment during galvanizing involves heating in the critical 843°F to 932°F

Figure 25



(450°C to 500°C) range during immersion in the galvanizing bath.

Galvanizing embrittlement may be reduced or eliminated by a pre-quenching treatment from 1200°F (650°C) before the galvanizing treatment. In addition to this, a minimum time in the galvanizing bath is desirable because embrittlement, in general, increases with the time of exposure of the part in the embrittlement range.

While embrittlement may not normally be a factor in producing commercial nodular irons, it is important to recognize that it can occur and, where impact strength requirements are important, it may not be advisable to avoid the temper embrittlement range by cooling rapidly from above this range and also to keep the composition where the iron will be less susceptible to such embrittlement.

Stress Relieving

Where a casting is complex in form involving abrupt section changes, internal stress may result from varying cooling rates during solidification in the mold.

Annealing at a specific temperature followed by slow cooling is the correct scientific method of removing casting stress. The older method of aging or weathering is relatively useless (See Table XII).

The temperature and time of annealing depend upon the type of Meehanite used, the size of the casting, and on the degree of stress relief required.

Heating time should be such that no casting will be held at the specified temperature longer than is necessary to penetrate all sections uniformly. Castings should then be slowly cooled.

Table XII RECOMMENDED TEMPERATURES

	°F (°C)
Type GE 30 (GE 200)	950/1000 (510/538)
Type GC 40 (GC 275)	1020/1070 (549/576)
Type GA 50 (GA 350) and GM 60 (GM 400)	1080/1150 (582/620)

Welding

Meehanite castings may be welded by means of the electric arc using a steel or alloy rod, or special cast iron rod, or by gas, using cast iron, Meehanite or bronze rods.

It is recommended that in gas welding, pre-heating of the casting (or at least of the parts to be welded) should be done to a dull red heat. Allow to cool slowly after welding.

For more information, refer to Bulletin No. 59–Welding Meehanite.

Surface Hardening

Meehanite castings may be hard surfaced by:

1. Chilling.
2. Induction or flame hardening.
3. Welding hard alloy such as stellite on the surface.

Flame hardening is fundamentally a simple process employing an oxy-acetylene flame direct against the surface to be hardened. Rapid cooling is affected by contact with a suitable quenching medium (usually water spray) immediately after heating.

The zone of maximum surface hardness obtained with flame or induction hardening is usually one-half to three-quarters of the total depth of the case and is file-hard.

Points to be remembered about castings for flame hardening are:

1. Extra metal is desirable on light castings to take care of warpage and ensure clean-up on machining.
2. Holes cause difficulty but, if necessary, should be countersunk and should not be too near the edge of a casting.
3. Designs which involve sudden changes of light and heavy sections should be avoided.
4. If full hardness is desired on the extreme ends of hardened surfaces, it must be specified.
5. Wall sections and ribs adjoining a hardened surface should not be less than half an inch thick.

Coatings

Meehanite Metal is suitable for coating by welding high chromium alloys to the surface or by tinning, chrome-plating, metal spraying, aluminizing or chromizing, etc., to increase its resistance to heat and chemical attack.

THE MEEHANITE CONNECTION

Meehanite metal is a superior engineering cast iron, including nodular cast iron, flake graphite cast iron and white cast iron. It is made to exact and well-defined engineering specifications and, in the minds of experienced casting buyers, represents quality and dependability. Each type of Meehanite metal has a definite identity, but what is perhaps more important is that any cast iron specification can be produced by the Meehanite process, and can probably be made better by this process than by any other procedure. Now, the Meehanite process is being applied very successfully to the manufacture of steel castings.

There is no question about the engineering acceptability of Meehanite castings and there can be very little question about the relative merit of the Meehanite process. Consider only the fact that there are now over two hundred Meehanite licensees throughout the world and that close to fifty of these licensees have been using the Meehanite process for over twenty-five years, while about one hundred have been using it for more than ten years. To them, at least, it must be a worthwhile proposition.

This is an association of progressive foundries that is very much alive and up-to-date. In over 75 years of doing business, the Meehanite Metal Corporation has been granted seventy three United States patents relating to foundry methods and foundry technology. Today, it has many new developments on file, and we continue to lead the way in progressive foundry techniques. Suppose now we consider exactly what happens when you take out a Meehanite license so that you can understand just how we operate, and you can then evaluate what our services might mean to you in the long run. It should be emphasized that this is no "get rich quick deal"! This is a carefully planned, gradual approach to the overall improvement of your operations – one that will survive the test of time, and one that will leave you with a better foundry, making better castings at a better profit!

Plan of Action

The first step is a careful analysis of your operations. This is followed by a plan of action for systematic correction of your practice at a pace that you can keep up with, and in such a way that you do not experience any costly delays or any major upset of your established routine. When the overall plan has been decided and agreed upon, we begin the procedure of implementing it and gradual conversion to the Meehanite process. We are not talking only about your metal or your sand control – we are talking about every single facet of your operation, including that oft neglected area of casting sales. This is a complete package leading to overall quality improvement.

Metal Control

We usually begin with the metal and melting; we show you where it could be improved, and we teach your people by on-the-spot demonstration, by lectures and by the use of training courses which will ensure a standard of competency in your key employees. We establish a quality control procedure that will give you day-to-day consistency of operation at a high level of quality. Remember that there is no single individual in your foundry who has our combined experience in the melting and processing of molten metal, and we have been able to successfully pass on this experience in foundries all over the world, operating under a great variety of conditions.

Gating and Risering

We then usually proceed to gating and risering practice, sand practice, molding practice and all of the technological phases of foundry operations. The exact sequence of installation will be governed by your needs, and by the extent of your problems. Having installed the process in hundreds of foundries, we know what to do and when to do it.

Standardization

All of the operations of the Meehanite process are standardized in that they follow definite principles. Our technical instruction books containing these standards are well-written and are clear and concise regarding the technical details of the process. We will provide you with standardized methods for all operations and will set up control limits and a testing program to maintain a very high standard of quality in your product.

Quality Management Traning (ISO 9000)

Not only can Meehanite provide the casting technology but we are also experienced at training to the new quality system standards including ISO 9000, Ford Q1, and so on.

We have our own quality program which we call the Meehanite Acceptance Criteria, which, when achieved, will meet all the requirements of ISO 9000, but contains much more emphasis on continuous improvement, which as we all realize, is the only road to survival. We provide complete guidance, and all the documentation necessary. We train in the use of statistics and other management techniques designed to improve quality and solve problems. Our trainingmeans implementation of the quality program, without additional staff.

We are probably the only group of experienced professional foundry engineers who are also experience not only in training to the ISO standards, but also experienced in operating under this and similar quality systems. We provide very practical down-to-earth guidance, which will lead you to, and through ISO 9000 certification.

Technology Training

A license will provide you with the advantages of training your people in better methods and procedures implemented with written instructions on all phases of your operation. It will provide lectures and discussion on any foundry subject, and a technological training program is available to be used at home by your key people, so that their knowledge may be increased, and so that the quality of their performance in their daily tasks will be enhanced. Standardization of normal operations will allow them more time to devote to a continuous improvement of your product both in quality and in reduced cost of manufacture. It is only a group effort, as typified by the Meehanite organization, that makes such a program available even to the relatively small foundry operations.

S.P.C. TRAINING

Meehanite has years of experience in the use of S.P.C. and we have definite programs for dealing with S.P.C. in the jobbing foundry environment. We will train your personnel.

The efficient use of S.P.C. when applied correctly can be the basis for developing effective continuous improvement programs. We will help you implement and integrate S.P.C. into your quality system, so that you receive the most benefit from this technology.