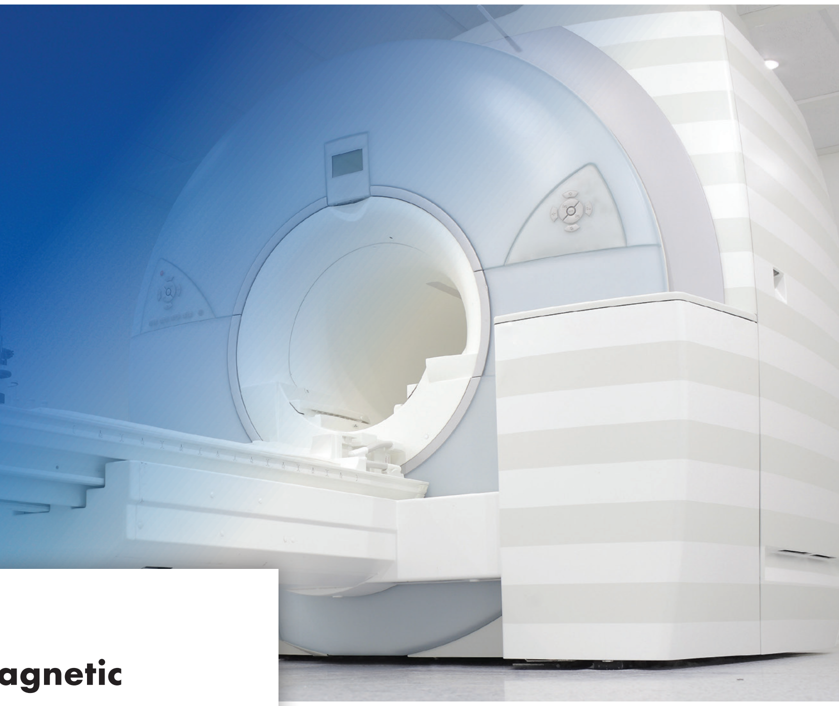
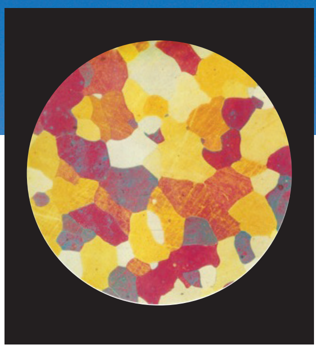
AK Steel International

ARMCO® PURE IRON

HIGH PURITY IRON

Product Data Bulletin



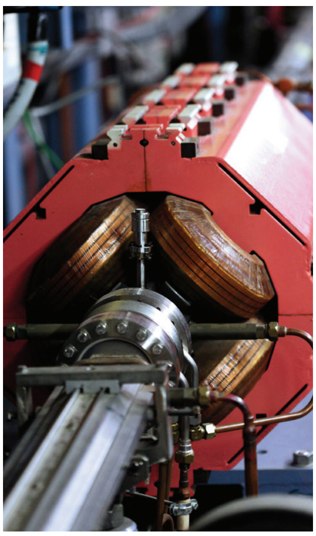


Electromagnetic Components

Galvanizing Tanks

Iron Base for Remelting

ARMCO® PURE IRON is used in several industrial processes and products. Uses for ARMCO Pure Iron include melt feedstock material to produce a variety of ferrous-bearing products such as low-carbon steels, stainless steels, acid-resistant steels, heat resistant steel, high nickel-iron alloys, magnetic alloys and casting alloys for stainless and heat resistant steels.



ARMCO Pure Iron is also used directly in applications for transportation (aerospace, railway and automotive), energy (chemical/petrochemical equipment, conventional power stations and various nuclear applications), highly corrosive environments (anodes, galvanizing tanks and like uses), magnetic devices (core, pole, yoke and armature magnets and magnetic shielding), and welding (rods and fuse wire).

ARMCO *Representing ARMCO® products since 1924*

AK Steel International

ARMCO® PURE IRON

HIGH PURITY IRON

TABLE OF CONTENTS

AK Steel International

ARMCO® PURE IRON HIGH PURITY IRON

Product Description

ARMCO® Pure Iron is a steelworks product unique in its purity, with a minimum iron content of 99.85%. All natural impurities have been largely removed.

Consequently, ARMCO Pure Iron has only marginal mechanical properties when compared to low carbon steel. This means that applications for ARMCO Pure Iron are mainly based on its purity and not on its mechanical properties.

Developed in 1909 in the USA, ARMCO Pure Iron was first produced in Germany in 1927. Even after a century of technical progress, ARMCO Pure Iron, now more highly refined, is still an important product because of its flexible application possibilities. Today as before, ARMCO Pure Iron is produced to meet the highest quality requirements.

ARMCO Pure Iron undergoes purification during melting using special steelmaking and refining techniques. Following solidification, it therefore has a homogenous composition with regard to the distribution of the accompanying elements, a very low oxygen content and very good slag purity. Due to the low carbon content, the microstructure consists of 100% ferrite.

GRADE 2

Composition		Max. Analysis %
Carbon	(C)	0.010
Manganese	(Mn)	0.100
Phosphorus	(P)	0.010
Sulfur	(S)	0.008
Nitrogen	(N)	0.006
Copper	(Cu)	0.030
Cobalt	(Co)	0.005
Tin	(Sn)	0.010

GRADE 4

Composition		Max. Analysis %
Carbon	(C)	0.010
Manganese	(Mn)	0.060
Phosphorus	(P)	0.005
Sulfur	(S)	0.003
Nitrogen	(N)	0.005
Copper	(Cu)	0.030
Cobalt	(Co)	0.005
Tin	(Sn)	0.005

The high purity of ARMCO Pure Iron is the primary reason for the following special properties:

- Excellent magnetic properties
- Improved resistance against corrosion and oxidation in comparison to normal steels
- Good cold forming capability
- Ideally suitable for welding

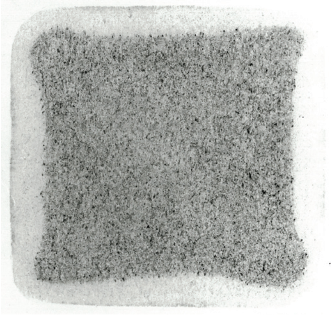
Product Description

SULFUR PRINTS (BAUMANN METHOD, ISO 4968)

FIGURE 1 – ARMCO® PURE IRON

homogenous structure
with very low S-content

FIGURE 2 – UNKILLED STEEL (S 235 JRG 1)



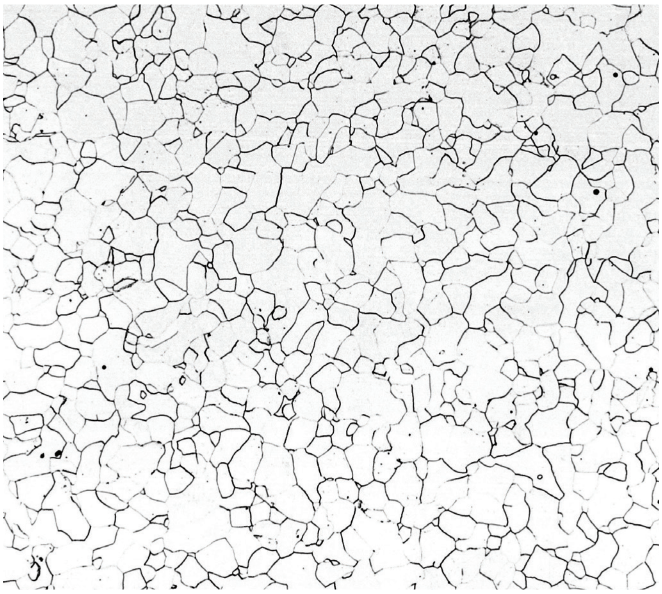
with separation-free edge zone
and separation zone

FIGURE 3 – KILLED STEEL (C 15 E)

homogenous structure
with normal S-content

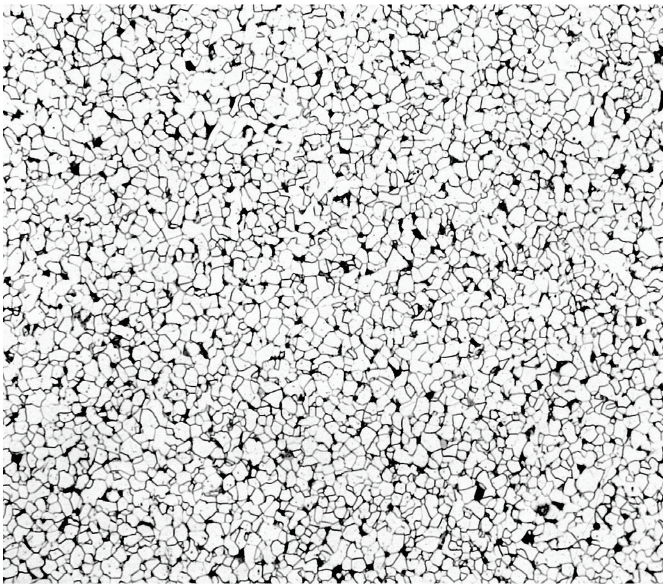
MICROSTRUCTURE

FIGURE 4 – ARMCO PURE IRON



Microstructure: 100% Ferrite

FIGURE 5 – C15 E/S 235 JRG 1



Microstructure: Ferrite + Pearlite Mixture

Physical Properties

TABLE 1 – TYPICAL PHYSICAL PROPERTIES

Density, g/cm^3 (lbs/in^3)	7.86 (0.284)
Melting Point, °C (°F)	1532 (2790)
Specific Heat, J/kg/°C (BTU/lbs/°F)	450 (0.107)
Thermal Conductivity, W/m°C BTU/(hr°F•ft^2/in.) 20 °C (68 °F)	73.2 (508)
Coefficient of Thermal Expansion, µm/m/°C (µin/in.°F) 20 – 399 °C (68 – 750 °F)	13.7 (7.6)

Mechanical Properties

ARMCO® Pure Iron is by definition an unalloyed product and as such is not designed to achieve specific mechanical properties. In particular, the very low carbon content lowers the mechanical properties compared to steels. Moreover, mechanical properties vary according to form, thickness and processing treatments. However, average values are given below for information only and, as such, shall not be used for design without testing. These values are given for a material when it has been annealed at moderate temperatures such as by stress-relief anneal (SRA) or recrystallization anneal (see the section titled "Background Principles for Heat Treatment and Annealing", page 12). A stress relieving heat treatment helps to prevent mechanical aging and stabilizes hardness.

Table 2 gives the average mechanical properties of ARMCO Pure Iron when it has been annealed at moderate temperatures such as by SRA/recrystallization anneal, Figure 9. These are values near the center of the range obtained in regular production and are a target toward which the processing of the heat is aimed. Consequently, the final results may be slightly higher or lower than the average.

TABLE 2 – TYPICAL MECHANICAL PROPERTIES AFTER ANNEALING – SRA/RECRYSTALLIZATION ANNEAL

Average room temperature mechanical properties – hot rolled ARMCO Pure Iron after annealing at a moderate temperature cycle.

UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Reduction of Area %	Brinell Hardness HB	Rockwell Hardness HRB	Modulus of Elasticity GPa (ksi)
290 (42)	186 (27)	38	73	74 – 83	40 – 50	207 (30 000)

When ARMCO Pure Iron is specially annealed, as by normalization anneal, Figure 9, to give high permeability at low and moderate inductions and low hysteresis loss, the typical mechanical properties will be as shown in Table 3.

TABLE 3 – TYPICAL MECHANICAL PROPERTIES AFTER HIGH TEMPERATURE ANNEALING

UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Rockwell Hardness, HRB
276 (40)	138 (20)	40	30 – 40

Electrical Conductivity

Table 4 shows resistivity values of ARMCO® Pure Iron at elevated temperatures. This resistivity will change if the iron is not protected from harmful atmospheres. Table 5 is a comparison of electrical conductivity and resistivity of ARMCO Pure Iron and other metals.

TABLE 4 – RESISTIVITY OF ARMCO® PURE IRON AT ELEVATED TEMPERATURES

Temperature, °C (°F)	Resistivity, µΩ•cm
0 (32)	9.6
100 (212)	15.0
200 (392)	22.6
300 (572)	31.4
400 (752)	43.1
500 (932)	55.3
600 (1112)	69.8
700 (1292)	87.0
800 (1472)	105.5

TABLE 5 – ELECTRICAL CONDUCTIVITY AND RESISTIVITY OF SOME COMMON METALS

Room Temperature	Density/Cubed, g/cm³	Electrical Resistivity, µΩ•cm	Resistivity x Density, Ω•g/m²	Electrical Conductivity Relative to Copper, %	
Metal				Volume	Mass
Copper (standard)	8.89	1.724	0.1533	100	100
ARMCO Pure Iron	7.86	10.7	0.84	16	18
Wrought Iron	7.70	11.0	0.85	15.6	18
Steel	7.84	14.0	1.10	12.3	14
Cu-bearing Steel	7.84	14.5	1.14	11.9	13
Type 302 stainless steel	7.93	72.0	5.7	2.4	2.7
Type 430 stainless steel	7.90	60.0	4.7	2.9	3.3

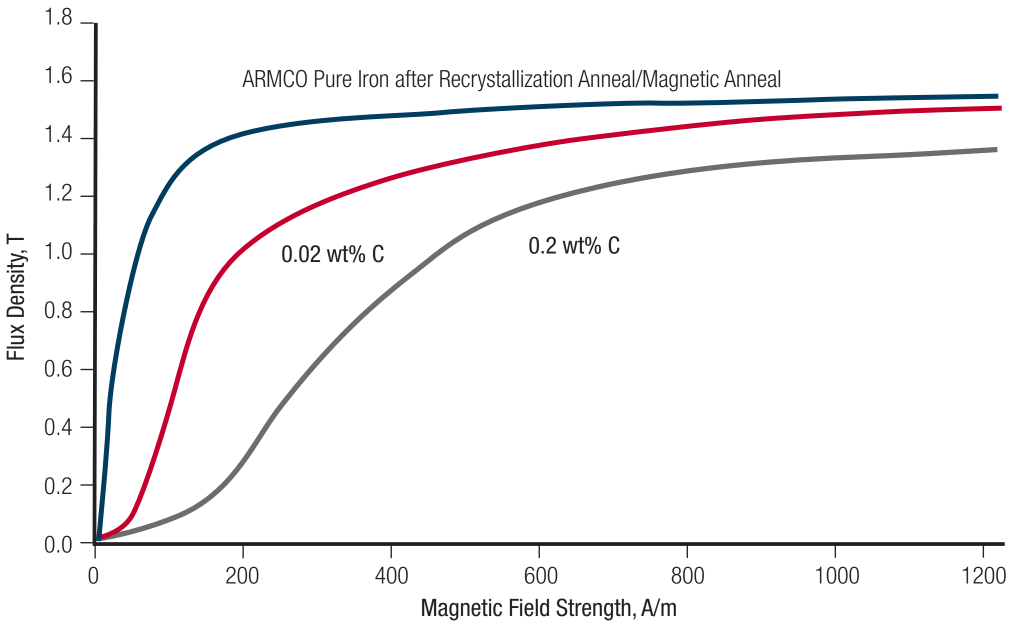
Magnetic Properties

ARMCO® Pure Iron vs. Low Carbon Steel

Effect of carbon content on magnetic properties

To ensure good magnetic properties, such as low coercivity and high permeability, the most important parameter is the carbon content which must be kept very low. Sulfur (S), Nitrogen (N), and Oxygen (O) are also detrimental to ferromagnetic properties. These elements affect the microstructure and, even in small amounts (ppm), they greatly interfere with the movement of the magnetic domains. ARMCO Pure Iron, thanks to its very low carbon content and very low residuals, has better magnetic properties than low carbon steel.

FIGURE 6 – EFFECT OF CARBON CONTENT ON THE BH CURVE OF IRON AT LOW INDUCTIONS

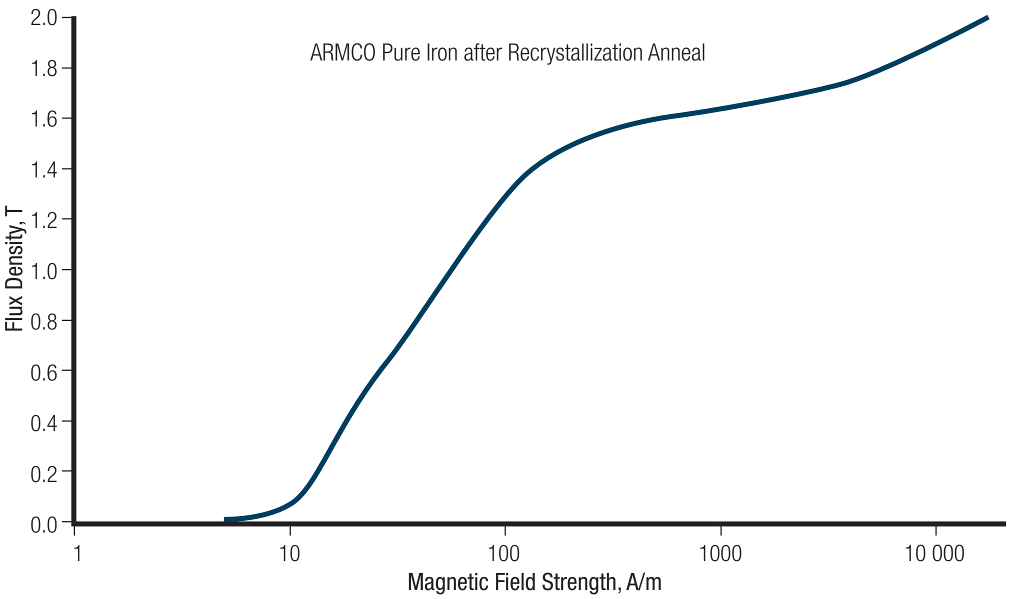


Magnetic Properties

LOW AND MODERATE INDUCTIONS

Some D-C applications operate at medium or low inductions where the metal must magnetize and demagnetize with ease. At these inductions, the chemical composition of the metal determines the level of magnetic quality which is possible. The grain size and the stress in the finished part determine the degree of quality which is actually attained. When properly annealed, ARMCO Pure Iron meets requirements at these inductions. Annealing temperatures for ARMCO Pure Iron are chosen based off prior processing and required final properties and vary from 649 °C (1200 °F) to more than 927 °C (1700 °F). At 910 °C (1670 °F), a phase transformation takes place which results in substantial grain growth and a marked increase in permeability.

FIGURE 7 – REPRESENTATIVE LOW AND MEDIUM INDUCTION VALUES FOR ANNEALED ARMCO® PURE IRON

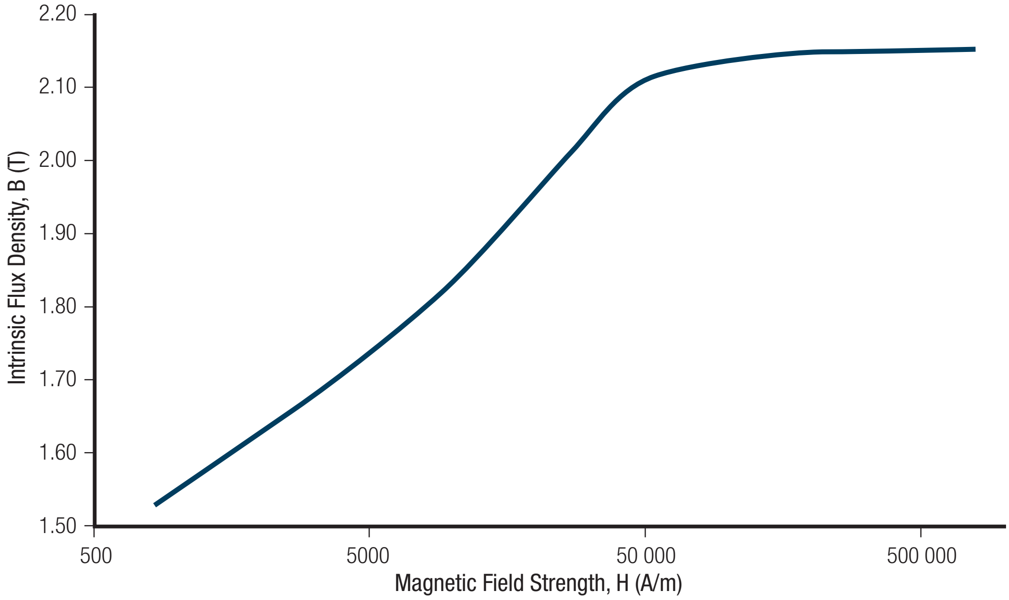


Magnetic Properties

HIGH INDUCTIONS

For many applications it is desirable to produce the highest possible flux density with a minimum of ampere-turns. ARMCO Pure Iron is especially suited for these uses because of its high degree of purity. Many investigations have shown that maximum magnetic saturation values, and the greatest permeability at high inductions, are always associated with highly refined irons containing the largest possible amount of pure ferrite. The only exceptions are very expensive cobalt-iron alloys. High induction values obtained with ARMCO Pure Iron, over the range of high magnetic field strength where magnetic saturation is being approached, are shown in Figure 8. Over this range, the permeability (or B/H ratio) is high when compared with the permeability of nearly all magnetic materials. ARMCO Pure Iron has a maximum intrinsic induction ($B-\mu_0 H$), or a saturation induction value of 2.15 T (21.5 kG).

FIGURE 8 – HIGH INDUCTION MAGNETIZATION CURVE FOR ARMCO® PURE IRON

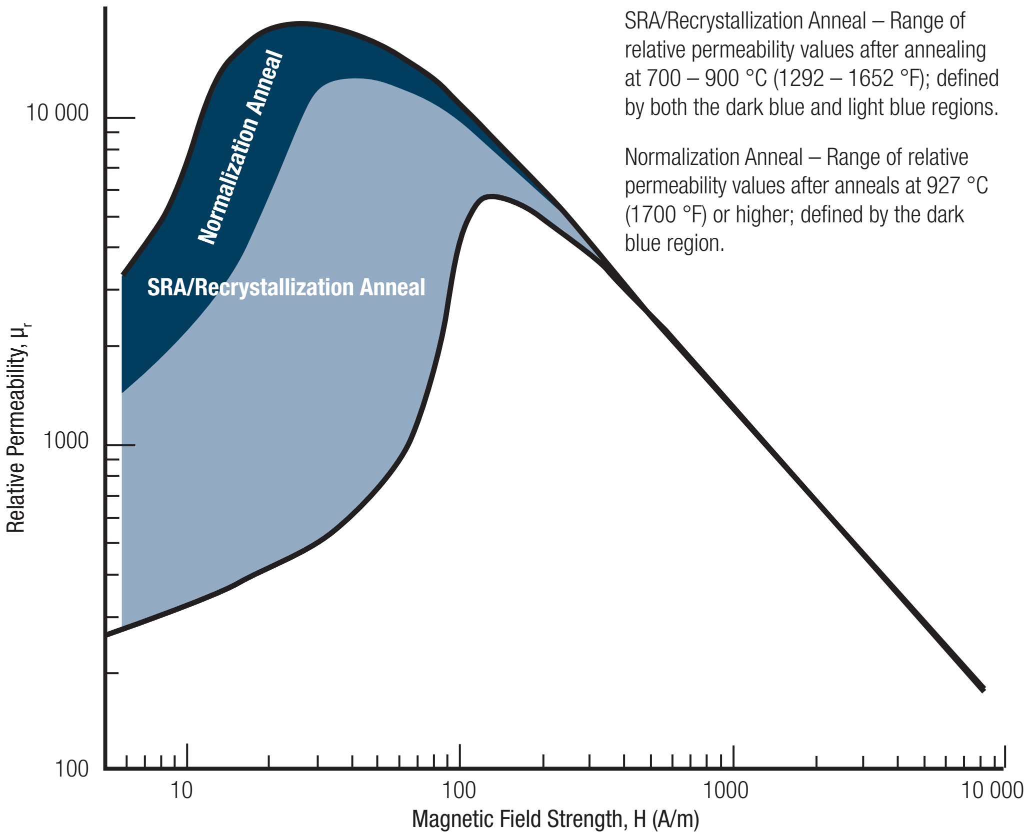


Magnetic Properties

PERMEABILITY

Figure 9 shows a plot of the relative permeability, or the $B/(\mu_0 H)$ ratio, over a wide range of magnetic field strengths. The two portions of the curve at low and medium inductions are representative of results after annealing 700 – 900 °C (1292 – 1652 °F) and at or above 927 °C (1700 °F).

FIGURE 9 – RELATIVE PERMEABILITY OF ARMCO® PURE IRON OVER A RANGE OF MAGNETIZING FIELD STRENGTH



Laboratory tests on magnetic materials are usually made with a closed magnetic circuit in which there is no air gap, or one in which the air gap is either compensated for or held to a minimum. As a rule, however, magnetic core circuits include an air gap. This results in apparent properties that are somewhat different from those of the magnetic material. For this reason, it is recommended that the performance of ARMCO Pure Iron be judged from tests made under the actual conditions in which it will be used.

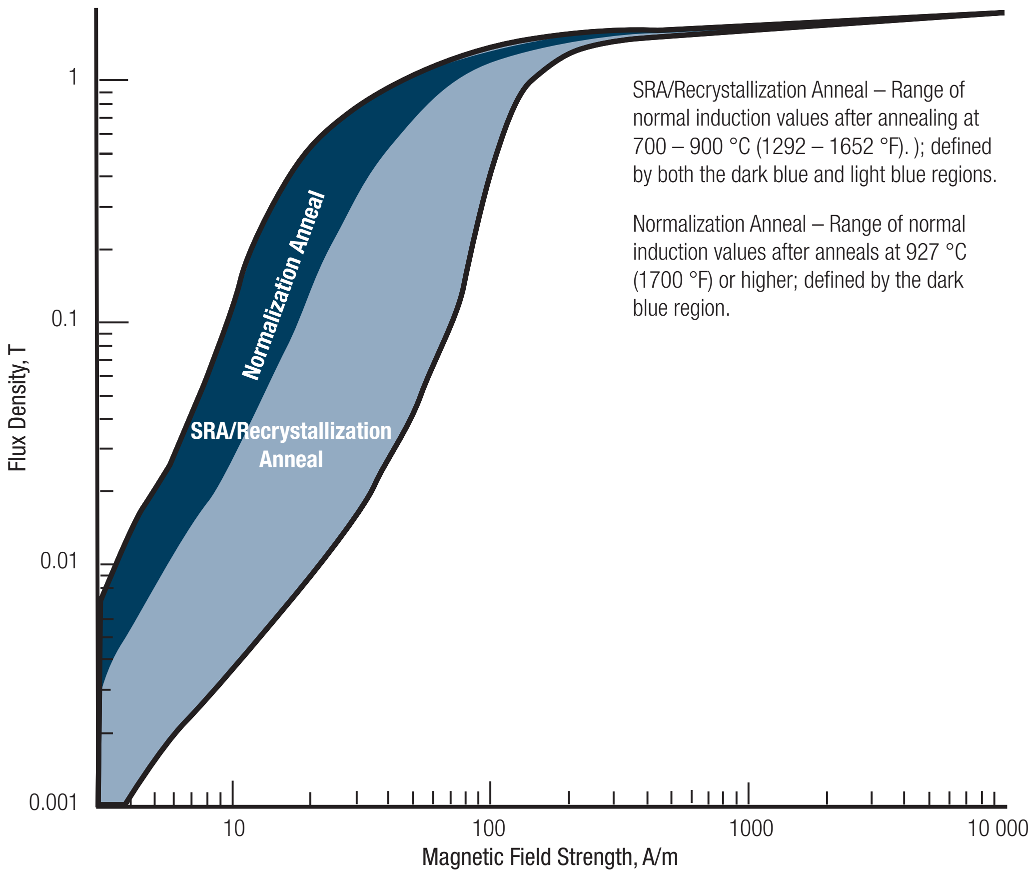
Magnetic Properties

RANGE OF VALUES

The variety of gauges, shapes, and sizes in which ARMCO® Pure Iron is available results in corresponding differences in processing. For these reasons the permeability to be expected can best be represented by a range of values, rather than a single curve. The magnetization curves obtained on representative samples of ARMCO Pure Iron given an anneal at 700 – 900 °C (1292 – 1652 °F), such as SRA/recrystallization anneal of Figure 13, would lie mostly within both dark and light blue regions of Figure 10.

Using an annealing program similar to normalization anneal, Figure 13, at a temperature of 927 °C (1700 °F) or higher, the magnetization curve would be included in only the dark blue shaded region of Figure 10. The location of a curve within a band or zone would be determined by such factors as annealing temperature, time of soaking period, type and condition of the annealing atmosphere, and previous processing history. For optimum magnetic properties and simplicity of annealing, a temperature of 816 – 843 °C (1500 – 1550 °F) is generally recommended.

FIGURE 10 – MEDIUM AND LOW INDUCTION VALUES – ANNEALED ARMCO® PURE IRON

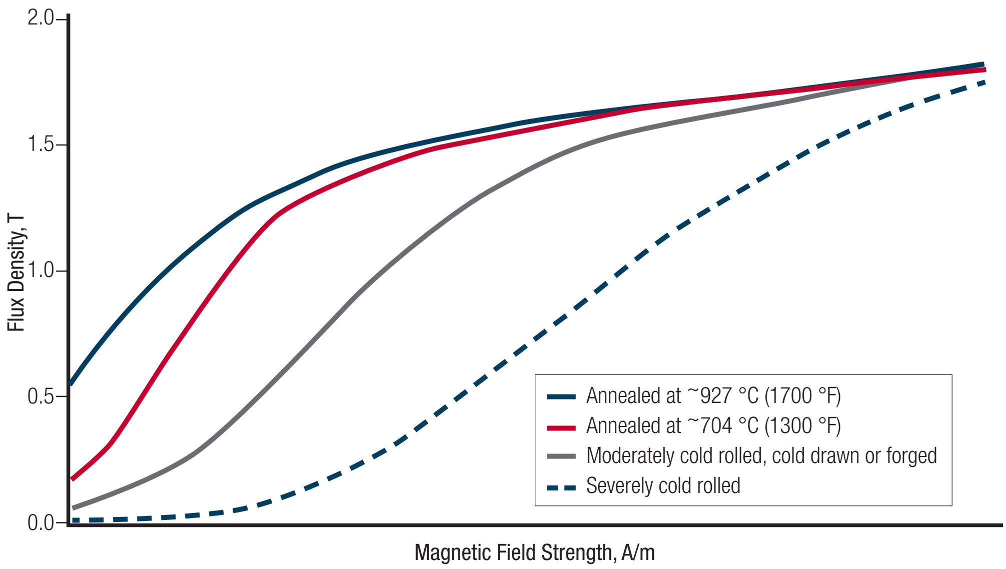


Magnetic Properties

EFFECT OF STRESSES ON MAGNETIC PROPERTIES

All mechanical operations on iron and steel – such as rolling, drawing, forging, bending, forming and machining – create internal stresses. This is especially true of cold-working operations. It applies to a lesser degree as the working temperature is raised. Stresses which result from mechanical work are harmful to the magnetic properties. Figures 11 and 12 illustrate the effect of cold work on the shape of the magnetization curve and the hysteresis loop. At low and moderate inductions, permeability is lowered sharply by moderate cold rolling, drawing or forging. More severe working causes a further decrease in permeability.

FIGURE 11 – EFFECT OF STRESS ON THE MAGNETIZATION CURVE OF ARMCO® PURE IRON



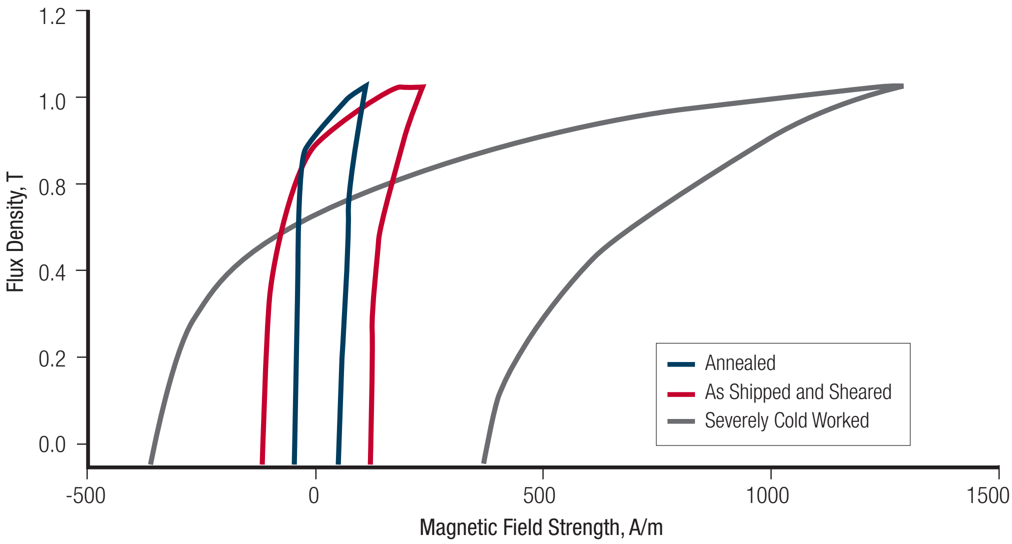
Magnetic Properties

AFFECTED BY SEVERE WORKING

High-induction permeability is not adversely affected by cold working normally encountered in the fabrication of finished parts. But severe working has its effect even at 1.8 T. The general effect of mechanical and machining stresses on the hysteresis loop, as shown in Figure 12, is to increase the coercive force and to pull the tip to the right, thereby increasing the hysteresis loss. To fully restore these qualities, the iron must be annealed after mechanical working.

No attempt is made here to show the effect of light mechanical working, since this would be influenced by both the type and the degree of working. On small cross sections, even light mechanical stresses may affect the operation of the part. On heavy sections, the effect of a light machining operation is likely to be negligible.

FIGURE 12 – EFFECT OF STRESS ON THE HYSTERESIS LOOPS OF ARMCO® PURE IRON



Background Principles for Heat Treating and Annealing

ANNEALING

Since practically all applications for ARMCO® Pure Iron require mechanical work during fabrication, it is strongly recommended that finished parts are annealed for best magnetic performance. The only exceptions are where parts are large, or where operating inductions are unusually high. The function of the usual, commercial anneals of ARMCO Pure Iron is to restore the magnetic properties without the benefit of any further purification.

The following are general rules, precautions, and suggestions for the commercial annealing of magnetic parts. The cycle to be used depends on a number of factors:

1) The magnetic application (induction range).

2) Annealing equipment available (size and type of furnace).

3) Mass, weight, and thickness of charge.

The material may be heated at a relatively fast rate, but through the high temperature range it should be cooled slowly to avoid even slight distortion and the accompanying strains. The normal heating and cooling rates for batch furnaces are usually quite satisfactory, except that the cooling rate at high temperatures should not be much faster than the heating rate for this same range of temperatures. If the charge is fully protected by a box or cover, it may be removed from the furnace at approximately 316 – 371 °C (600 – 700 °F). The temperature at which the charge itself may be exposed to the air depends upon the amount of surface oxidation which can be tolerated. The material should be soaked at a maximum temperature just long enough to insure a uniform temperature throughout. This may vary from one to several hours. To obtain consistently good results, the fabricator is advised to arrive at the best annealing cycle by experimentation. Figure 13 is offered only as a guide.

THE SRA AND MAGNETIC ANNEAL

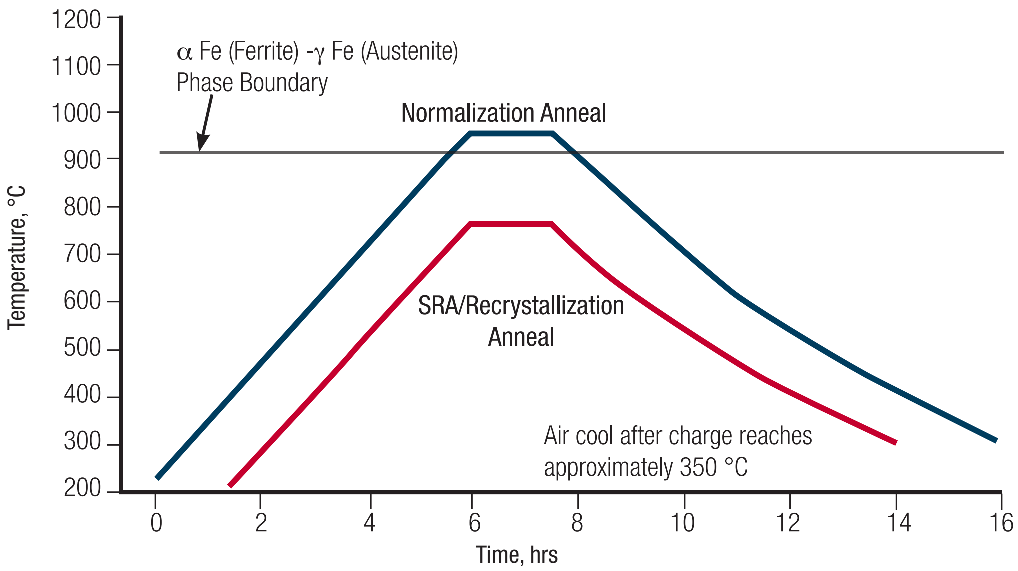
When the material is to be used at high inductions above 1.2 T, annealing at 649 – 704 °C (1200 – 1300 °F) is generally satisfactory. Two recommended anneal cycles, a stress relief anneal 700 °C (1292 °F) and a magnetization anneal 820 °C (1508 °F), are detailed on page 14, however specific applications may require alternative anneal cycles. For optimum magnetic properties at all inductions, annealing at 816 – 871 °C (1500 – 1600 °F) is recommended. Where parts are large or when only the permeability at very high inductions is of interest, annealing may be unnecessary. Representative magnetic properties are detailed in Table 6. In general, higher anneal temperatures yield better magnetic properties.

THE NORMALIZATION ANNEAL

To obtain good magnetic qualities at low and medium inductions, especially in heavily stressed and cold worked materials, it is best to anneal the material at temperatures above the Ferrite-Austenite Phase Boundary. An example curve is shown in Figure 13. In general, these anneals are performed at a temperature of 927 °C (1700 °F) or higher to ensure that the material reaches a high enough temperature to undergo a complete transformation to austenite before cooling and transforming back to ferrite. A word of caution though, the volume change that will occur during the subsequent phase transformation may cause some additional warping of parts. An example anneal cycle, the Normalization Anneal 950 °C (1742 °F), is detailed on page 14. Representative magnetic properties are detailed in Table 6.

NOTE: For both types of anneal and for the magnetic characteristics on the charts, it is assumed that a neutral atmosphere surrounds the parts.

FIGURE 13 – EXAMPLE ANNEALING CYCLES OF ARMCO® PURE IRON



Background Principles for Heat Treating and Annealing

SPECIAL ANNEALS

Purification annealing at temperatures above that needed for stress relieving can provide further improvement in the magnetic properties of ARMCO® Pure Iron. This purification is usually accomplished by special annealing for extended periods in a vacuum or in a carefully controlled atmosphere.

The approximate ranges of magnetic properties reported when using these special annealing treatments at temperatures up to 1204 °C (2200 °F) are shown in Table 6. It is important to remember that when annealing at these elevated temperatures, increased tendency to stick and decreased mechanical strength require consideration.

TABLE 6 – REPRESENTATIVE MAGNETIC PROPERTIES – AS RECEIVED, SRA/MAGNETIC ANNEAL, AND NORMALIZATION ANNEAL/SPECIAL ANNEAL

	As Received		SRA/Recrystallization Anneal		Normalization and Special Anneals	
	SI	U.S. Customary	SI	U.S. Customary	SI	U.S. Customary
Relative permeability at 8 A/m (0.1 Oe), μ_8	50 – 100		250 – 5000		1500 – 2500	
Maximum relative permeability, μ_{max}	1000 – 2500		5000 – 19 000		10 000 – 16 000	
Coercive force, H_c at H = 2.4 kA/m (30 Oe)	95 – 200 A/m	1.2 – 2.5 Oe	16 – 120 A/m	0.2 – 1.5 Oe	24 – 45 A/m	0.3 – 0.6 Oe
B at H = 40 A/m (0.5 Oe)	0.006 – 0.02 T	0.06 – 0.2 kG	0.03 – 0.85 T	0.3 – 8.5 kG	0.63 – 0.76 T	6.3 – 7.6 kG
B at H = 1.2 kA/m (15 Oe)	1.45 – 1.57 T	14.5 – 15.7 kG	1.60 – 1.68 T	16.0 – 16.8 kG	1.61 – 1.62 T	16.1 – 16.2 kG
B at H = 24 kA/m (300 Oe)	2.05 – 2.10 T	20.5 – 21.0 kG	2.05 – 2.10 T	20.5 – 21.0 kG	2.05 – 2.10 T	20.5 – 21.0 kG

ATMOSPHERE

It is important that ARMCO Pure Iron does not become contaminated by the annealing atmosphere. Even as little an increase as 0.01% in carbon content is harmful to the magnetic properties. Excessive oxidation is injurious to the magnetic qualities and sometimes produces brittleness. An ideal atmosphere is one which is neither oxidizing nor carburizing. Best atmospheres are reducing atmospheres such as moist hydrogen or dissociated ammonia. A common annealing atmosphere is 20% wet hydrogen mixed with 80% dry hydrogen by volume at a dew point of 13 – 18 °C (55 – 65 °F). If a reducing atmosphere cannot be achieved, an inert atmosphere should be used. Inert atmospheres include dry nitrogen, argon, or a vacuum.

With any of the annealing methods, care should be taken to avoid the inclusion of any carbonaceous materials, such as uncombusted natural gas, oil, or high-carbon alloys. This is especially important at the higher temperatures of normalization anneal or special anneal. Under certain annealing conditions, there may be some tendency toward brittleness of the iron. This can be prevented by annealing either in a sealed package, a box sealed by welding, or in a combusted gas atmosphere as described above. Either of these anneals can be used to remove brittleness caused by a previous anneal.

Recommendations for Heat Treating and Annealing

AK Steel Research provides the following heat treatment guidelines for ARMCO® Pure Iron. These recommendations are considered to be conservative and may be optimized as required to account for factors such as part geometry, the efficiency of the furnace, available annealing atmospheres, and time restraints. The temperatures listed in the procedures below are charge temperatures; the furnace set points should be selected to ensure the product reaches the desired heat treatment temperature. Additionally, when designing a furnace cycle, it is critical to ensure that the heating and cooling rates are sufficiently slow to provide uniform thermal gradients throughout the charge. The magnetic properties of iron are highly dependent on the final strain-state of the metal matrix and non-uniform thermal gradients may result in development of internal stresses.

STRESS-RELIEF ANNEAL (SRA)

A low temperature anneal used to minimize adverse effects of production and machining processes. Minimal change to the grain structure is observed.

Heating:	2 – 4 °C (4 – 7 °F) per min
Hold Temperature:	700 °C (± 20 °C) / 1292 °F (± 36 °F)
Hold Time:	A minimum of 60 minutes with an additional 15 minutes per each 5 mm (0.2 in.) thickness over 25 mm (1.0 in.)
Cooling:	2 – 4 °C (4 – 7 °F) per minute until the change temperature is below 550 – 600 °C (932 – 1112 °F).

The parts should remain in a protected atmosphere until the temperature of the parts is below 300 °C (572 °F).

RECRYSTALLIZATION ANNEAL OR MAGNETIC ANNEAL

This is a more severe treatment than the stress-relief anneal; the higher temperature initiates nucleation and growth of strain-free grains. This treatment typically follows the last mechanical processing stage.

Heating:	2 – 4 °C (4 – 7 °F) per min
Hold Temperature:	820 °C (± 20 °C) / 1508 °F (± 36 °F)
Hold Time:	A minimum of 60 minutes with an additional 15 minutes per each 5 mm (0.2 in.) thickness over 25 mm (1.0 in.)
Cooling:	2 – 4 °C (4 – 7 °F) per minute until the change temperature is below 550 – 600 °C (932 – 1112 °F).

The parts should remain in a protected atmosphere until the temperature of the parts is below 300 °C (572 °F).

NORMALIZATION ANNEAL

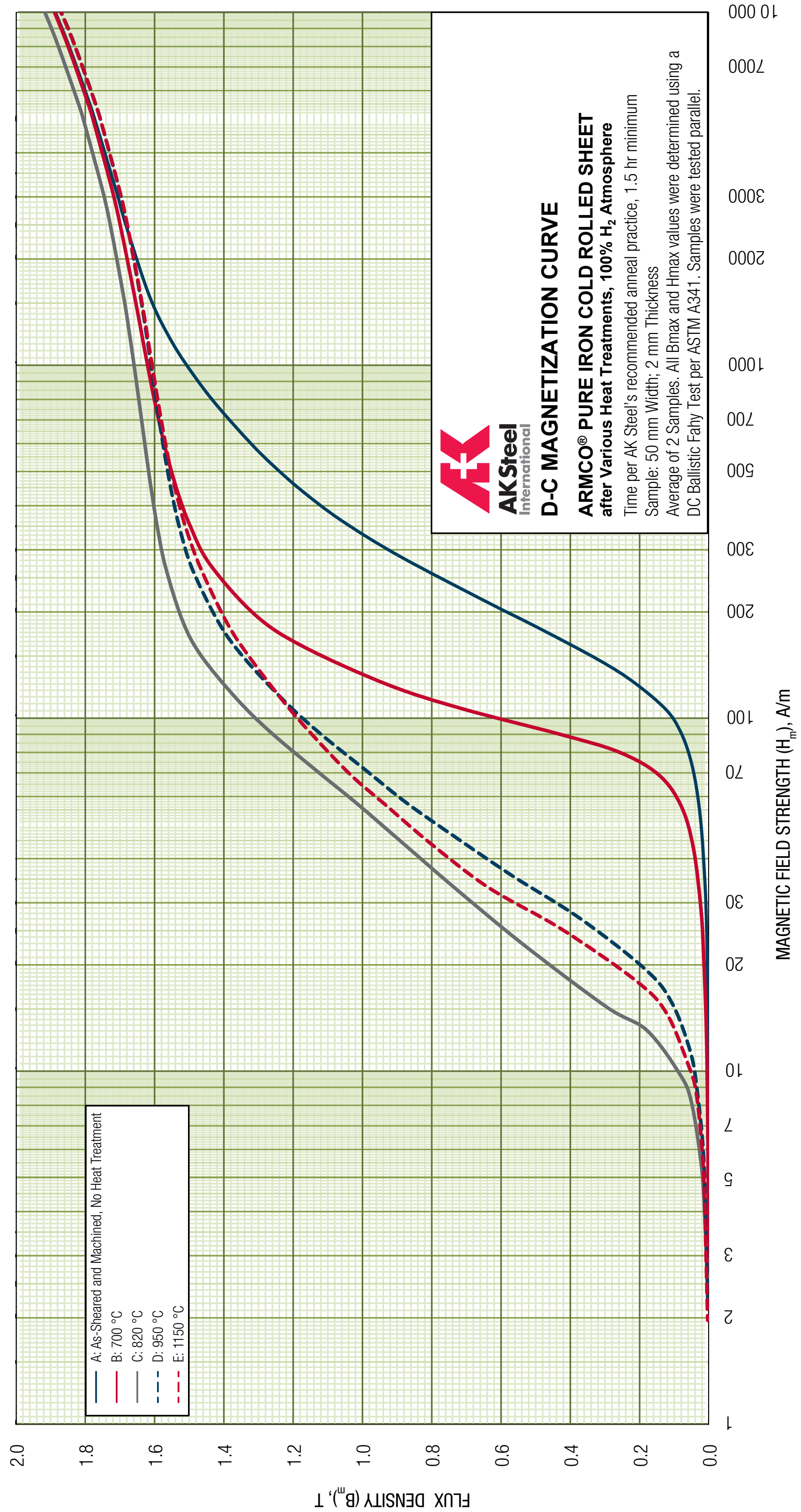
A high temperature anneal used to optimize magnetic properties. The iron undergoes a solid phase transformation which results in small, refined grains and uniform composition within the matrix. If carbon and nitrogen levels are not sufficiently low, magnetic aging may occur.

Heating:	2 – 4 °C (4 – 7 °F) per min
Hold Temperature:	950 °C (+ 20 °C / – 10 °C) / 1742 °F (+36 °F / -18 °F)
Hold Time:	A minimum of 90 minutes with an additional 15 minutes per each 5 mm (0.2 in.) thickness over 25 mm (1.0 in.)
Cooling:	2 – 4 °C (4 – 7 °F) per minute until the change temperature is below 550 – 600 °C (932 – 1112 °F).

The parts should remain in a protected atmosphere until the temperature of the parts is below 300 °C (572 °F).

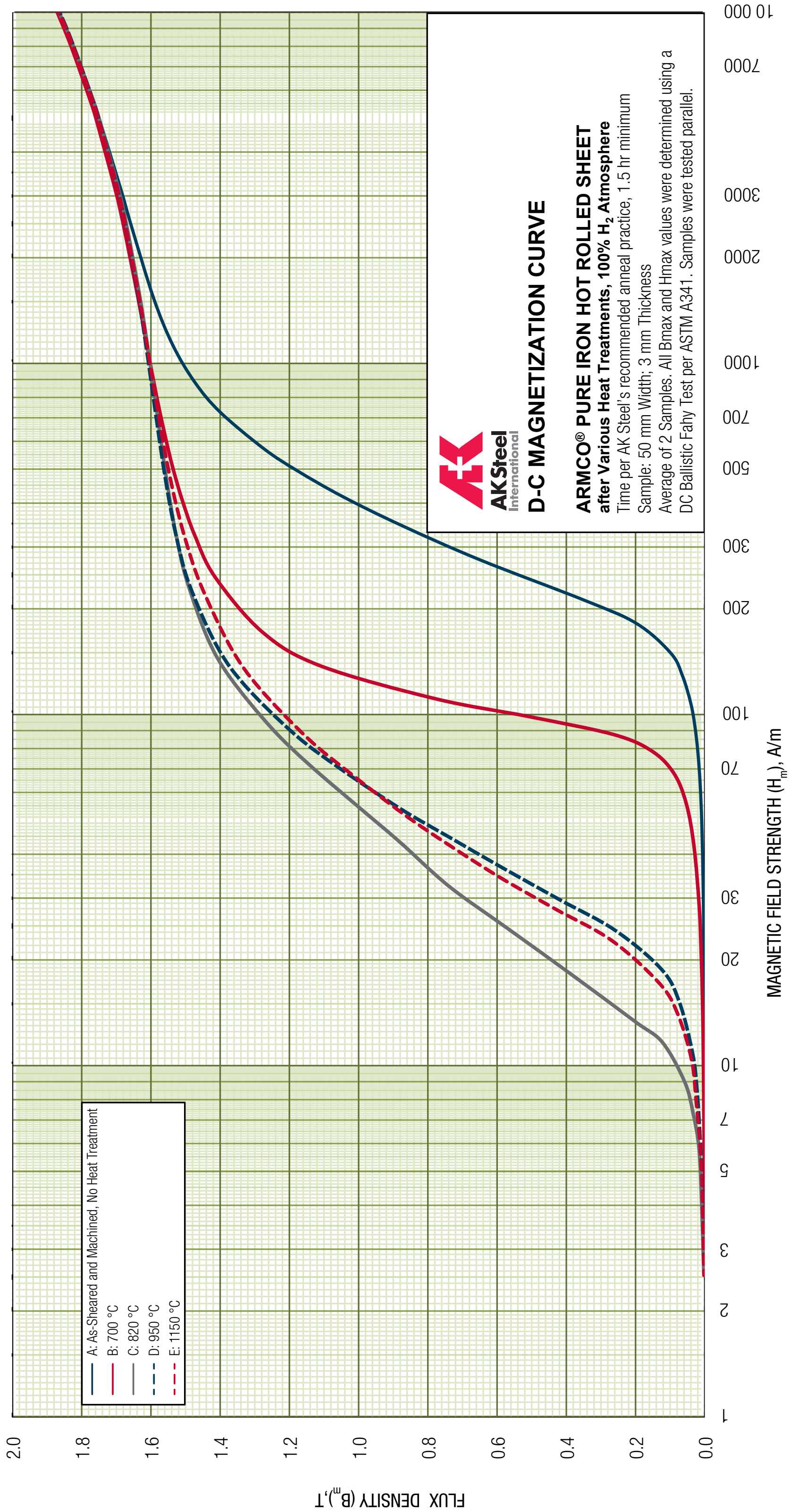
Curves

FIGURE 14 – 2 MM COLD ROLLED ARMCO® PURE IRON SHEET



Curves

FIGURE 15 – 3 MM HOT ROLLED ARMCO® PURE IRON SHEET



Magnetic Aging

While aging in higher purity grades of ARMCO® Pure Iron should be minimal, it is characteristic of commercial irons that a slow change may take place in the magnetic properties at low and medium inductions. This is especially true of material that has higher carbon content. This change in magnetic properties, commonly termed "magnetic aging", is caused by a gradual precipitation of carbon, oxygen, or nitrogen compounds from solid solution. As aging progresses the magnetic permeability decreases and the coercive force, residual induction and hysteresis loss increase. At room temperatures, it may take years for the change in magnetic properties to be significant and may not change at all. At higher temperatures, the rate of change increases. The maximum rate of change, as well as the maximum total change, occurs between 100 – 150 °C (212 – 302 °F). Above 177 °C (350 °F) these changes are less marked.

Aging can often be greatly reduced using a magnetic anneal (see the section titled "Recommendations for Heat Treating and Annealing", page 14) within a hydrogen-bearing atmosphere. Annealing under these conditions will reduce the change in magnetic properties from aging by lowering the carbon, oxygen, and nitrogen content of the iron. If stabilized magnetic properties are a primary requirement, it is recommended that a baking treatment at a lower temperature, usually between 177 – 260 °C (350 – 500 °F), is performed after magnetic annealing. This will result in stable magnetic properties at a somewhat lower level than freshly annealed.

Hot Working

ARMCO Pure Iron has a critical working range between 860 – 1050 °C (1580 – 1920 °F) as shown in Table 7. Within this temperature range IT MUST NOT BE worked. If the approximate temperature is determined by the naked eye, as is often done by individuals working the metal, no part of the material should be heated to a bright red or full cherry red. When the iron is worked within the limits of the critical range, it is likely to "check" or break.

TABLE 7 – TEMPERATURES FOR HOT WORKING ARMCO® PURE IRON

Temperature, °C (°F)	Hot Working	Welding
1371 (2500)	Above 1050 °C (1920 °F) Hot Working Range	1250 – 1371 °C (2280 – 2500 °F) Welding Range
1250 (2282)		
1000 (1832)	860 – 1050 °C (1580 – 1920 °F) Critical Range (Red Shortness) DO NOT Work ARMCO® Pure Iron in This Range	
750 (1382)	DO NOT Heat Rivets Above 800 °C (1470 °F) Working Range	
500 (932)		
250 (482)	232 – 427 °C (450 – 800 °F) Brittle Range DO NOT Work Any Iron or Steel in This Range	
0 (32)		

Grey, horizontally hatched areas indicate temperature ranges in which ARMCO Pure Iron must not be worked. The grey, diagonally hatched areas indicate satisfactory hot-working temperature ranges.

When ARMCO Pure Iron is to be forged or hammer welded, it is typically heated to white heat or above. It can then be worked until the temperature drops to 1050 °C (1920 °F), or a bright orange color. If more working is necessary, it should be reheated, although many forging operations are effective on ARMCO Pure Iron at dull red heat, below 816 °C (1500 °F). Aside from the critical range, you will find ARMCO Pure Iron is easily fabricated.

Properties

COLD WORKING

ARMCO Pure Iron has excellent cold-working qualities. Its density, ductility, and uniformity contribute to successful bending and drawing operations. It is especially well suited to forging, spinning, stamping, soldering, and brazing operations. Cold working, however, is more injurious to the magnetic qualities than hot working, and annealing is usually necessary to restore its magnetic properties.

CORROSION RESISTANCE

The behavior of iron and steel against corrosion largely depends on the purity of the material. The purer the iron, the greater is its resistivity against electrolytic self-destruction, which takes place at the border areas between the iron crystals and the other elements. With regard to rusting, ARMCO Pure Iron is superior to plain carbon steels, since it forms cohesive and adhesive rust layers, which protect the metal underneath from further attack.

Years of experience have confirmed that ARMCO Pure Iron resists destruction by rust and corrosion longer and better than plain carbon steels. ARMCO Pure Iron is resistant to acids, bases and salt solutions associated with chemical compounds related to the element Fe. Although ARMCO Pure Iron cannot replace a rust- and acid-resistant material, it nevertheless offers advantages wherever a certain level of chemical attack has to be accepted and the material needs to be similar to a plain carbon steels.

Thanks to its homogenous structure and high level of purity, ARMCO Pure Iron is attacked by many iron-decomposing chemicals more slowly than plain carbon steels.

ARMCO Pure Iron and construction steel S235JR (St 37) are compared in Table 8, below, with regard to the rate of metal loss on perforated plates for galvanizing baths and etching baskets. The results of this trial show that ARMCO Pure Iron had a slower corrosion rate, with overall metal loss being reduced by 41%, in comparison to S235JR (St 37). ARMCO Pure Iron was, with regards to corrosion rate, the superior material for this application.

OXIDATION RESISTANCE

In a similar way to corrosion, oxidation (scaling) also depends heavily on the purity of the material. The scaling caused by oxidation not only impairs the heat transmission, but also reduces the material thickness, thus having a destructive effect. As in the case of rust attack, ARMCO® Pure Iron demonstrates superior resistance by the formation of adhering, protective layers of scale. In contrast, more impure, normal steel forms relatively thick and loose layers of scale, which become easily detached and then form again.

TABLE 8 – COMPARISON OF THE CORROSION RATE OF ARMCO® PURE IRON VS. S235JR (St 37)

	Sample Number	Weight of Sample		Rate of Metal Loss		
		Condition of Delivery (g)	After Pickling (g)	grams	%	average %
	1	702.8	689.9	12.9	1.84	
ARMCO® Pure Iron	2	732.5	717.6	14.5	1.98	2.15
	6	728.0	708.9	19.1	2.62	
	3	848.3	820.1	28.2	3.32	
S235JR	4	734.8	706.9	27.9	3.80	3.65
	5	702.0	675.2	26.8	3.82	

Trial: Verzinkerei Lenzburg, 9.6.1989

Processing

NON-CUTTING FORMING

The outstanding purity of ARMCO Pure Iron provides a high level of softness and cold forming capability (reduction in area of approximately 90%). Non-cutting cold forming processes (especially drawing, deep-drawing, pressing, and cold forging) therefore produce only minor compressive strain which enable high forming levels. Under controlled forming, the tensile strength can increase to double the initial value.

Hot forming by rolling, forging, bending, border crimping, and compressing should not be carried out in the critical area 860 – 1050 °C (1580 – 1920 °F) as shown in Table 7.

MACHINING

TURNING

Both high-speed steel and hard metal tools can be used for machining ARMCO Pure Iron. Sharply ground tools and carefully selected cutting data are particularly important, since in the case of incorrect selection, ARMCO Pure Iron tends to smearing. The most rational production for coarse turning is achieved with a slow feed and a deep cut. Where the best surface quality and dimensional accuracy are required in fine turning, the feed should not exceed 0.1 mm. With correctly selected cutting data, surfaces that have not been machined will be matte and the turned surfaces will have a smooth, glossy appearance. Adequate cooling and lubrication are also essential in order to preserve the tool and the workpiece. It is recommended to use a mineral oil containing 1 – 1.5 % sulfur and 5 % grease.

MILLING

In order to obtain a fine surface, a cylindrical milling cutter with a pitch angle of 45° – 52° is recommended. The radial cutting angle should be 30°. At cutting speeds of 25 – 45 m/min, a feed of 19 – 32 mm/min should be selected. The use of side milling cutters requires a radial cutting angle of 10°. A clean, swarf gap shape must be ensured on the tool. For cooling and lubrication, the same recommendations apply as for turning.

THREAD CUTTING

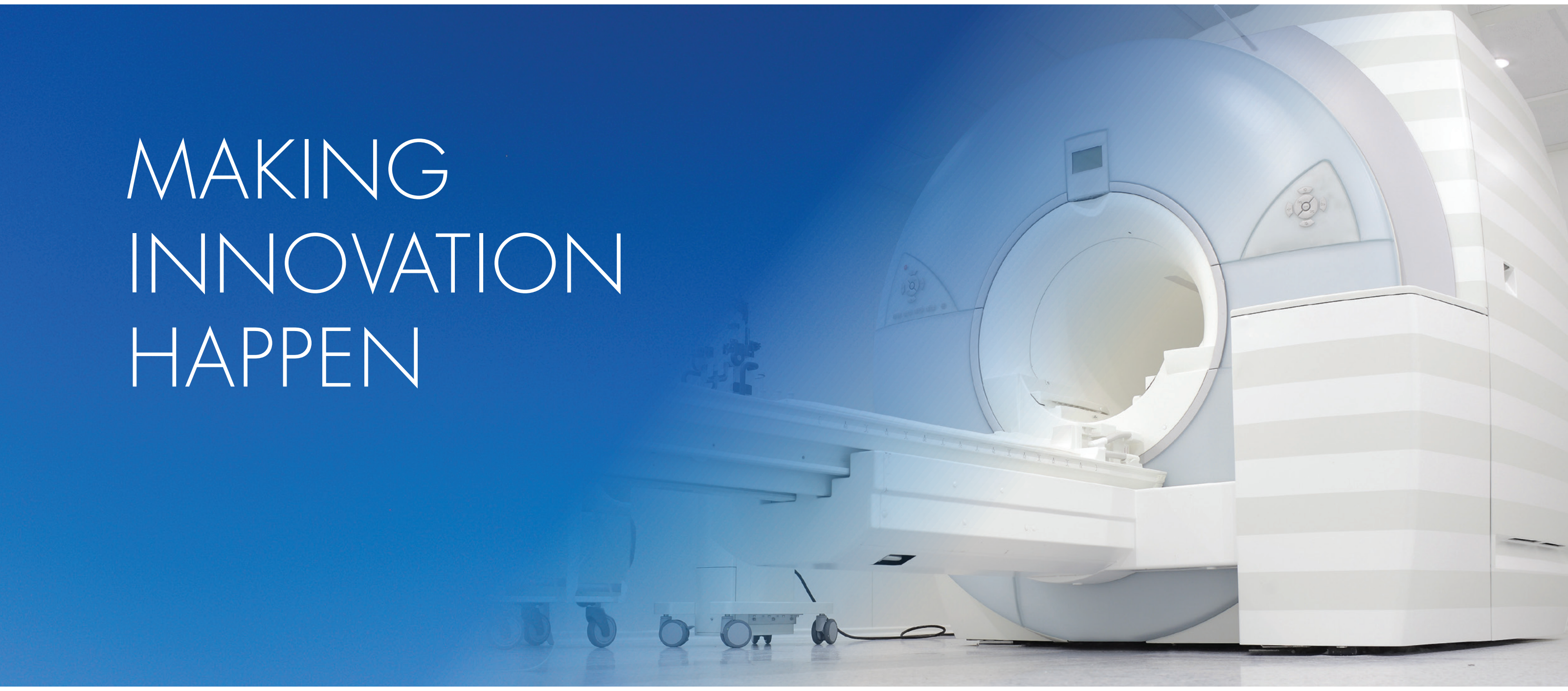
Normal cutting tools can be used for the production of individual threads. As soon as the required number of threads increases however, non-cutting thread production provides more economical results. This can be used for the production of both internal and external threads. This increases the strength values, reducing the danger of the thread being stripped.

DRILLING

A slightly lower free angle should be selected than for drilling normal steels. The cutting speed is approx. 24 m/min, the feed approximately 0.05 – 0.10 mm/rev.

WELDING

An iron which is as metallurgically pure as ARMCO Pure Iron also has excellent welding characteristics. This applies for arc, plasma, TIG, and MIG welding. The finished weld seam needs no subsequent treatment. It is also possible to take advantage of the benefits of welding rods made of ARMCO Pure Iron for the production of weld connections to normal construction steels. The characteristic features of ARMCO Pure Iron are also excellent in the form of welding wire for repair work on cast components.



SAFETY | QUALITY | PRODUCTIVITY | INNOVATION

AK Steel International B.V.
Rat Verleghstraat 2A
4815 NZ Breda
The Netherlands
+31.(0)76.523.73.00

AK Steel International B.V.
Germany Branch
Holzmarkt 1
50676 Cologne
Germany
+49.(0)221.97352.0

AK Steel Merchandising S.A.
Muntaner, 374 – 376
08006 Barcelona
Spain
+34.93.209.41.77

AK Steel SARL
2-6 rue des Bourets
92150 Suresnes
France
+33.(0)1.80.46.37.46

AK Steel s.r.l.
Piazza della Vittoria 15/31
16121 Genoa
Italy
+39.010.582746

AK Steel Ltd
The Business & Technology Centre
Room S04
Bessemer Drive
Stevenage
Hertfordshire
SG1 2DX
United Kingdom
+44.(0)1438.842910

www.aksteel.eu

AK Steel International is a wholly owned subsidiary of AK Steel.

AK Steel is a leading producer of flat-rolled carbon, stainless and electrical steel products, primarily for the automotive, infrastructure and manufacturing, including electrical power, and distributors and converters markets. Through its subsidiaries, the company also provides customer solutions with carbon and stainless steel tubing products, die design and tooling, and hot- and cold-stamped components. Headquartered in West Chester, Ohio (Greater Cincinnati), the company has approximately 9,200 employees at manufacturing operations in the United States, Canada and Mexico, and facilities in Western Europe. Additional information about AK Steel is available at www.aksteel.com.

The information and data in this document are accurate to the best of our knowledge and belief, but are intended for general information only. Applications suggested for the materials are described only to help readers make their own evaluations and decisions, and are neither guarantees nor to be construed as express or implied warranties of suitability for these or other applications.

Data referring to material properties are the result of tests performed on specimens obtained from specific locations of the products in accordance with prescribed sampling procedures; any warranty thereof is limited to the values obtained at such locations and by such procedures. There is no warranty with respect to values of the materials at other locations.

12.18