Ductile Iron News

Ductile Iron Society

To Promote the production and application of ductile iron castings

Issue 2 1999

Keith D. Millis has been
Elected to the Rensselaer Polytechnic Institute
"Alumni Hall of Fame"

...Only 32 persons have received this high honor from the tens of thousands of men and women who have attended, graduated or been associated with this engineering school since it was founded in 1824 - the oldest engineering college in the English speaking world...

(See article Millis Elected to Hall of Fame)

FEATURES

DEPARTMENTS

COVER STORY

Keith D. Millis Has Been Elected to the Rensselaer Polytechnic Institute "Alumni Hall of Fame"

To: All the persons who supported Keith D. Millis in his election to the Rensselaer Alumni Hall of Fame

Your help and willingness to write and tell what Keith had accomplished as a co-inventor of Ductile Iron contributed greatly to his election. Thank you one and all!

Only 32 persons have received this high honor from the tens of thousands of men and women who have attended, graduated or been associated with this engineering school since it was founded in 1824 - the oldest engineering college in the English speaking world. Keith obtained both his Bachelor of Metallurgical Degree in 1938 and also his Master of Mechanical Engineering Degree in 1939 from RPI.

The first class of 16 persons was selected in 1996. Keith was elected in the second class of 16 persons and this induction ceremony will take place tentatively at RPI in Troy, New York on Friday, October 15, 1999 at about 4 P.M. according to Peter Pedone who is in RPI's Alumni Relations office. Of the 16 new inductees, 10 are deceased and 6 are living. I wish Keith were still alive to receive this great honor: however, I know that future generations of students at RPI will be inspired by his accomplishments as recorded by his election to this Hall of Fame.

Briefly, over 13 million metric tons of Ductile iron were produced in 1996 in 38 Countries throughout the world. My estimate of the value of the product is about $29 billion annually. Perhaps 200 thousand persons are employed today as a result of this invention. Quite an invention! Quite an accomplishment!

Keith's honor is reflected not only by (1) Rensselaer, but also by (2) Inco Limited - the successor company to International Nickel Company for whom Keith was employed when the discovery was made and the patents granted in 1949 (3) the entire metals industry represented by ASM International (4) the foundry industry represented by the American Foundrymen's Society (5) the Ductile Iron industry represented by the Ductile Iron Society which was founded by Keith and (6) all the companies as well as the men and women who are employed today and owe their livlihood to Keith's invention.

My thanks to you for your help and cooperation. I thought you would want to know that your efforts have been successful for Keith.

I am sending a copy of this letter to Keith's son, Stephen, as well as some RPI personnel and others interested in the Alumni Hall of Fame.

Best personal regards,

Robert E. Savage, Sc.D., Class of 1944 (RPI)

DIS MEETING - South Bend, IN

by Robert O'Rourke 

The 50th anniversary of the invention of Ductile Iron has been widely celebrated by metallurgists and foundries that appreciate the impact this engineered metal has had on the cast iron industry. When ductile iron was invented the door opened for enormous growth possibilities for any foundry that focused on converting targeted applications to ductile iron castings.

Steel parts became the natural conversion metal. Ductile iron is similar to steel in that both are ferrous metals. Strengths in ductile iron approach those of plain carbon steels. and offered free machining characteristics. Ductile iron has excellent castability, is free machining and has better damping properties and wear resistance as compared to carbon steel. Producers of ductile iron continue to have enormous growth potential considering the conversion opportunities that exist in steel castings, forgings and fabrications.

Over the past several years there has been an increase in the demand for more technical field sales people. Design Engineers are looking at material selection as a way to improve part performance and lower cost of manufacturing. This opens up new opportunities for ductile iron foundries looking to expand their business by focusing on conversions; from steel to ductile iron. The challenge for ductile iron producers is having intimate knowledge of mechanical properties, machinability ratings and a pretty good idea about which grade should work for the targeted application.

The most common objection by design engineers is that iron is too weak. The objection stems from the basic misunderstanding that cast iron is not one material but is a family of metals with each member having its own unique characteristics. Selecting the material with the best combination of strength, wear resistance and ability to process is the key to lowering cost.

In the broadest sense, parts fail in one of two modes – either they break or they wear out. So, for all applications, why isn't the strongest, most wear resistant material always used? The answer is because there are a lot of other factors to consider. Price of the raw material, ease of machinability are obvious ones. Other factors include noise-damping characteristics, which is important in gears and machine tool components. Another way to lower cost is to eliminate the need to heat treat by using a fully pearlitic cast iron instead of carbon steel.

Comparison of tensile strengths between carbon steel bars and ductile iron can lead to most of the objections for conversion opportunities. Those comparisons can be misleading. (Rarely a component is subjected to uniaxial loading at room temperature at a slow strain rate, as is the case when the tensile test is performed.) Usually, dynamic properties, the applied loads and the most likely mode of failure are the important considerations for design engineers.

Carbon steel is designated by chemical composition, not mechanical properties, as is the case with ductile iron. Ductile iron is characterized by tensile properties. Published carbon bar strengths are not always typical or even averages and the actual values may vary considerably depending on residual alloys, section size and the internal microstructures. (*source: ASM Metals Reference Handbook, 2nd Edition, 1983, American Society for Metals).*

Ductile iron by definition must conform to specified minimum mechanical properties, not average or even typical values. The minimum tensile and yield strengths can be used for design purposes. Ductile iron is isotropic and the mechanical properties are the same regardless of test bar orientation. Steel forgings have directional properties, which can be an important consideration for applications such as gears.

The tensile strength of a carbon steel bar will usually be higher than a ductile iron bar having a similar matrix, but in some cases, the yield strength may be lower. 1040 steel for example, in the normalized condition has 85,500 psi tensile strength, 54,300 psi yield strength and 28% elongation. (*source: ASM Metals Reference Handbook, 2nd Edition, 1983, American Society for Metals).* 80-55-06 ductile iron with a similar matrix has 80,000 psi tensile strength, 55,000 psi yield strength and 6% elongation. The graphite nodules reduce tensile strength and elongation but most parts are designed to the yield strength, not tensile.

Cast irons can be produced to a fully pearlitic matrix, which is an advantage over carbon steel. Approximately 1% carbon is required to produce an essentially pearlitic matrix. Most carbon steels commercially produced have between 0.10% to 0.80% so there is a limit to the amount of pearlite that can be obtained in the matrix. In order to achieve maximum wear resistance steel has to be heat-treated. Carbon steel grades having less than 0.35% carbon are usually carburized before they can be heat-treated. A fully pearlitic matrix or even a highly pearlitic one offers suitable wear resistance in the as cast state and can sometimes replace carburized and heat-treated steel, depending on the application.

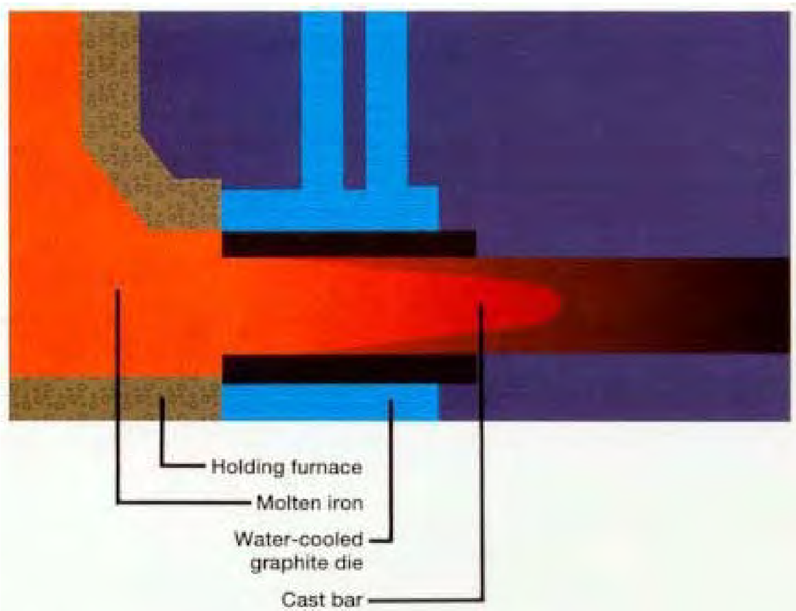
Hydrostatic cylinder blocks made with a fully pearlitic ductile iron were shown to have sufficient wear in the as cast condition. Eliminating heat treat significantly reduced the cost of the part compared to steel because of the additional processing required on the steel. Ductile iron is a natural replacement for carbon steels whenever wear resistance is the primary concern.

When Wells Manufacturing Company introduced the process of continuous casting into North America in 1960, the main focus was on casting conversions. As ductile iron production became more refined, the production of ductile iron continuous cast iron bar stock opened up opportunities for steel bar conversions. Ductile iron bar stock is free machining, has similar mechanical properties to carbon steels, is less dense and available in rounds, squares and simple shapes. By concentrating selling efforts toward steel conversions, the possibilities for new business were limitless.

Most ductile iron casting conversions from steel are directed at reducing costs by reducing manufacturing time. A complex weldment or forging can be cast to a closer net shape and eliminate the time to fabricate the same part from steel. Ductile iron castings as an alternate to steel castings will usually be an economical alternative because of the reduced cost to melt ductile iron. Lower melting temperatures usually equate to less dross and slag defects as well.

Dura-Bar reduces machining time. Ductile iron is a free machining grade and parts that are heavily machined are conversion candidates. Bar stock costs may be higher than rolled carbon steel but it is more machinable and easier to debur. A good application candidate starts with a round or rectangle carbon bar and the finished part cost is about 25% material, 75% machining.

In the process of continuous casting of ductile iron bar, molten iron is held in a refractory lined steel shell. A water-cooled graphite die is mounted on the bottom of the vessel. Molten iron enters the die and a solid skin begins to form that takes the shape of the bar. As the bar is pulled out of the die in a series of strokes, the skin becomes thicker until it can sufficiently support the head pressure of the molten iron inside the bar machine. When the bar exits the die, it consists of a thin outer shell with a molten iron core.



The heat from the molten iron core reheats the outer skin that was rapidly chilled inside the die. The matrix in the rim is transformed to austenite and cools in still air as the bar moves horizontally along a series of rollers. The center of the bar is allowed to solidify and cool in still air. The resulting microstructure in the continuous cast bar is a homogenized matrix of pearlite, ferrite, or a ratio of the two, depending on the grade being produced.

Solidification and cooling rates are consistent for each bar size and the different grades of ductile iron produced are controlled with the addition of pearlite stabilizing alloys added to the transfer ladles. This practice produces microstructures that are stable to temperatures up to 1000F.

Molten iron is continuously added to the bar machine crucible during the production run to maintain head pressure and a sufficient distance between the die opening and the top of the molten metal bath. Impurities float to the top of the bath, well away from the die opening which eliminates slag, dross and other tool wearing inclusions.

Consistency in the matrix structure and elimination of impurities is an essential part of reducing machining cost. A wide range of microstructures within a particular grade of ductile iron will cause variations in machinability. Consistency in chemistry matrix structures is the key to consistent machinability. Inclusions can cause catastrophic failure of the tool insert and must be eliminated.

Understanding material properties and knowing the property requirements for an application is very important in selecting the best grade of ductile iron for an application. Carbon steels are designated by chemical composition. Ductile iron is designated by the minimum tensile strength, yield strength and elongation. Besides tension properties, torsion strength, shear strength, modulus of elasticity, impact properties and heat treat response are just a few material characteristics that may also need to be considered.

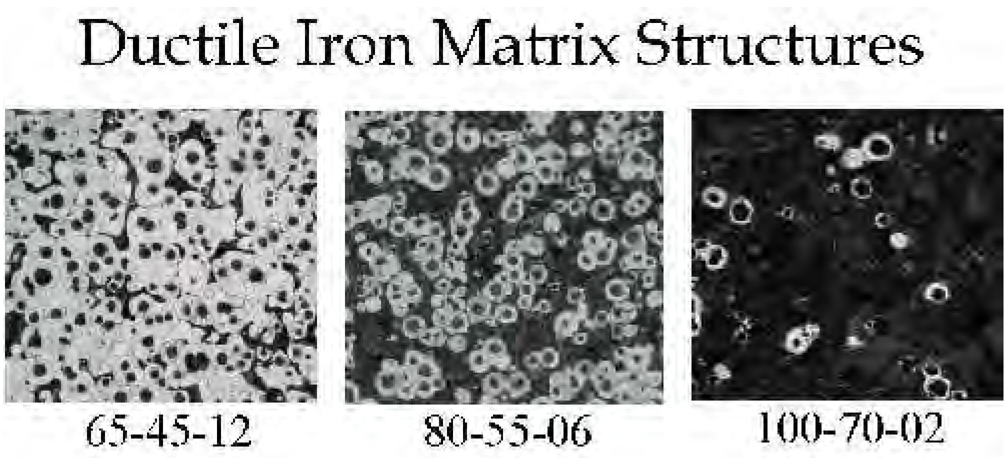
The chemical composition of carbon steel affects mechanical properties. High carbon steels will have higher tensile strengths, lower elongation, decreased machinability and better response to heat-treat than low carbon steels. Additions of sulfur, manganese, phosphorus and lead are commonly used to improve machinability, usually at the expense, to some degree, of strength.

The amount of carbon dissolved in iron determines the amount of pearlite in the matrix which influences most of the mechanical properties, heat-treat response and machinability. Elements such as sulfur and phosphorus form sulfides and phosphides that do not dissolve in iron and make carbon steel "free machining" which means the chip formed during cutting is discontinuous. Holes drilled in free machining steels will usually require less deburing time.

Ductile iron has carbon levels that exceed the solubility limit in iron. At 2800F, approximately 6% carbon is soluble in iron. At the eutectic point, only 2% can remain in solution and the excess carbon is precipitated into a graphite nodule. The precipitated graphite is a solid phase, which promotes the same benefits as the inclusions deliberately put in carbon steels. Ductile iron bars are free machining and drilled holes require less deburing.

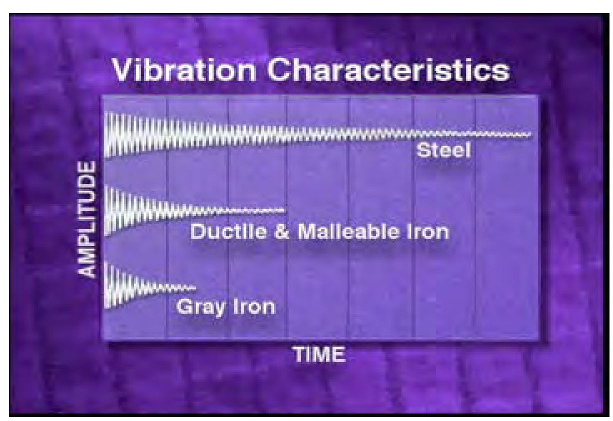
If there was no way to control the amount of carbon that remains in solution, there would not be any way to control mechanical properties, but fortunately that is not the case. In fact, the amount of carbon dissolved in the matrix is very controllable and so are the mechanical properties and the machinability of the ductile iron grade being produced.

Ductile irons with relatively low levels of combined carbon will have a matrix consisting primarily of ferrite. They have the lowest tensile strength and wear resistance, highest elongation and usually will be the easiest to machine. The level of combined carbon can be increased to produce a matrix that is fully pearlitic which results in higher tensile strengths and wear resistance, lowest elongation and will be more difficult to machine. The ratio of pearlite to ferrite in the matrix will produce ductile iron grades that have properties somewhere between those with a fully pearlitic or fully ferritic matrix.



The most common question for any design engineer or field salesperson that is looking to replace a carbon steel part with ductile iron is "which grade matches the one being replaced?". That question is difficult to answer without knowledge of the application and knowing which properties are important to its function.

Since parts usually fail because they break or they wear out the best alternate grade is the one that more closely matches the mechanical properties and matrix of the one being replaced. With an equivalent matrix, ductile iron will usually exhibit better wear resistance because of the graphite nodules. The surface of a ductile iron part will retain lubricant better than a steel part with the same matrix, which can also improve wear resistance.



Vibration damping is important in gears and in applications where harmonic vibrations cause failure. In an automotive balance shaft, gear noise reduction resulted directly from the conversion of 1144 steel to 80-55-06 ductile iron without any change in how the part was being manufactured. The 4140 pistons in an impact hammer were cracking prematurely because of harmonic vibrations. The failures stopped when the part was converted to austempered ductile iron. Although the ductile iron had lower tensile strengths, the vibration damping characteristics reduced harmonic vibrations and the conversion was a success.

The best way to select a ductile iron grade to be used in place of carbon steel is to pick one that has a similar matrix and hardness. The best way to do that is to match the matrix structure as close as possible. Usually a ferritic ductile will be the best candidate to replace carbon steels having up to .35% carbon. Partially pearlitic ductile irons such as an 80-55-06 are the best candidates for the medium carbon steels. Fully pearlitic ductile irons are best for replacing carbon steels that require heat treat to improve wear resistance. The machinability of a fully pearlitic ductile may be less than the carbon steel but the savings from eliminating all the steps associated with heat treat can offset the additional cost of machining.

It would be naïve to assume that all carbon bar applications can be directly replaced by ductile iron and that is certainly not the case. However, there is an enormous opportunity for ductile iron in applications that can benefit from lower machining and processing costs, the possible elimination in heat treat, improved vibration damping properties and the domestic availability of ductile iron bars and castings.

The challenge for the ductile iron producer is to generate solid engineering data on properties other than tensile, yield and elongation. Machinability ratings and current recommendations for speeds, feeds, depth of cut and type of inserts need to be established for modern machine tools. Engineering data including fatigue properties and other strength characteristics must be readily available for the design engineer. Most importantly, the field sales person must have the technical knowledge required to answer the questions and concerns a designer may have regarding a ductile iron candidate.

What is the future for ductile iron? Definitely it is more steel conversions. Looking for and developing conversion opportunities makes the market potential for this engineered metal limitless.

Factors Affecting the Mechanical Properties of GGG 40.3

by George Goodrich

Proper machining of test specimen is crucial for reliable results. GGG 40.3 specification requires a "U" notch in the machined bar. Proper machining of the "U" notch specimen is very critical before testing the impact specimen. The way the "U" notch is machined can affect the result. The way the "U" notch is machined can affect the result. For example, if the "U" notch is ground instead of broaching (even if one uses a new broach tool) the impact values are two to three foot pounds higher.

In general, the impact value increases as the "U" notch is broached vs. milled vs. ground.

Broaching / Milling / Grinding

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Impact Value Increases

There was no difference found in the impact value of a "U" notch specimen vs. a "V" notch specimen, under the following conditions:

"V" notch	2mm deep	45^{o} angle	0.25mm radius at the root of the notch
"U" notch	3mm deep		1mm radius "U" notch

The fracture appearance of the impact specimen can give some indication of the impace value. Higher amount of crystalline (clevage) white shiny appearance in the fracture will indicate less impact.

Investigation was conducted from samples received from a foundry which experienced wide fluctuations in impact values. Above .011% molybdenum, impact was poor.

Conclusions:

1. The type of machining the "U" notch is very critical for reliable accurate impact values.
2. Grinding the notch gave the highest impact values.
3. Presence of intercellular carbides are detrimental for impact values.
4. Carbon, silicon, nickel and molybdenum have the most influential effect on impact value.
5. Regression formula of chemistry vs. impact is available in the literature.

The chemistry of the sample had the following range:

Carbon	3.45 - 3.84
Silicon	1.74 - 2.61
Manganese	0.13 - 0.23
Chromium	0.034 - 0.042
Aluminum	0.006 - 0.042
Magnesium	0.041 - 0.080

There was good correlation between silicon and aluminum on the impact values. Higher silicon had higher aluminum and lower impact.

The foundry was using nickel magnesium alloy for treatment and in-mold inoculation.

As inoculation increased, silicon and aluminum nicreasd and impact decreased.

Other conclusions on this investigation were:

1. There was good correlation between carbon/silicon/nickel vs. field strength.
2. There was good correlation between aluminum/silicon vs. tensile strength.
3. There was NO good correlation between aluminum/silicon vs. % elongation.
4. There was good correlation of carbon/nickel with impact strength.

Note: Analysis of nickel on the sample was not provided.

5. When molybdenum was present in the sample, when it was less than .007%, 100% of the bars passed 8 ftl lb. value. 68% of the bars passed 10 ft. lb. value.

Reviewer's Comment (*P.H. Mani*)

Foundries currently producing or planning to produce in future, castings to meet the specification GGG 40.3 will benefit from this paper on the advantages of grinding the "U" notch to get two or three foot pounds increased impact values. As opposed to broaching the "U" notch.

The use of looking at fracture appearance is beneficial. But because the impact sample is very small, especially at the fractured face, it is difficult to get reliable indications of impact value by looking at the fracture alone.

Members are advised to refer to DIS Project 19, which correlates fracture appearance with impact value on a larger specimen - dynamic tear specimen.

One should use caution in interpreting the correlation between impact properties and the chemistry of the iron. It is the metallurgy of the iron which influences the impact properties, more than the chemistry.

Two Practical Suggestions for Saving Money and Improving Metal Quality

by George D. Haley

Number One:

Controlling the pickup of oxygen during melting and casting can result in substantial savings. The two primary sources of oxygen introduced during melting and pouring are: a) Rust in the scrap b) Oxidation of solid and liquid iron.

There is some reoxidations of the iron as it enters the mold. Minimizing the oxygen pickup can lead to less casting defects, less furnace slag, increased refractory life, increased and consistent magnesium recovery and consistent recovery of carbon and silicon additions.

Loose rust in the charge should be screened out prior to charging. The vibratory connectors with screens should be inspected daily to avoid plugging of the screen with rust.

Heavy coatings on steel scrap (another potential source of oxygen) should be removed prior to use or the scrap should be rejected. Badly oxidized pig iron should be avoided.

Shot blasting badly oxidized charge should be looked into, if it is cost effective.

The oxides (rust) that accumulate in the bottom of the scrap bins should be disposed of as a waste. It should never be charged into the melting furnace.

Clean scrap can be oxidized in preheaters, if the burners are not properly adjusted.

It is not advisable to put steel scrap at the bottom of the induction furnace. It will cause oxidation of the scrap prior to melting.

Keep the furnace covered as much as possible. Always cover ladles when transporting iron.

Silicon carbide addition to the melt can deoxidize the iron.

The rate of oxidation depends upon temperature, time and area exposed. Overheating (super heating) increases oxide (oxygen) content.

Exposure of metal through aspiration of air causes oxidation.

Fans positioned to cool operators can inadvertantly blow on metal surfaces and cause oxidation.

Cold metal left in the ladle should be pigged.

Gating systems that create turbulance increase oxidation of the iron.

Do not use cover steel that is oxidized.

Number Two:

Use of fluorospar in the treatment ladle (about four to eight ounces of acid grade fluorospar (97% CaF_2, 100 mesh and down) per 1000# base metal) with MgFeSi can provide consistent, improved magnesium recovery. The life of the treatment ladle is increased. Slag does not build up on the lining, dams, etc.

Conclusions:

1. Reduce oxygen (oxidation) of the iron and reduce casting defects.
2. Controlled addition of fluorospar to the treatment improves magnesium recovery and increases treatment ladle life.

Reviewer's Comments: (*P.H. Mani*)

1. Foundries can greatly benefit from following the number one suggestion of the author.

Leonardite & Its Effects on Green Sand Molding

Part 1. What is Leonardite

By Karen Dailey, Ph.D., American Colloid Company

What is Leonardite?
Leonardite is a low rank coal derived from terrestrial plant matter. Leonard Dave of the University of North Dakota discovered it in 1919. Leonardite is found in North Dakota, Utah and New Mexico. It is found as outcropping of lignite deposits, usually very close to the surface.

There are two theories on the origin of Leonardite. The first one is that it is an oxidized lignite. Compared to Lignite it has about 30-35% of oxygen whereas Lignite has about 25-30%. The second theory is that it is predominately Humic acid leached from topsoil by alkaline waters and subsequently precipitated into subsurface soil strata. (Humic acid is a form of organic plant matter).

Leonardite Characterization:
Humic Matter: Humic matter is complex organic molecules formed by the breakdown of organic matter. Humic matter is a class of compounds with variable structure, functionalities and reactivities. Leonardite typically contains greater than 85% Humic acid.

Humic Matter Characterization:
Three types of organics are identified in Leonardite. They are

1. Fulvic Acid
2. Humin
3. Humic Acid

It is important to note that Leonardite has less than 7% of Fulvic acid and greater than 85% Humic Acid.

Leonardite has many industrial uses.

Agriculture	soil amendments and fertilizers
Waste Water	organics and metal filtration
Oil Drilling	drilling muds
Foundry	green sand additives

Leonardite, after mining, has a pH of about 3.5. However, foundry sands have a pH of greater than 7.0. So to make the Leonardite compatible to the foundry sand, it is made into "Causticized Leonardite." You raise the pH of the Leonardite with the addition of a base such as NaOH. But this changes the reactivity of the Leonardite! It makes the material soluble.

Humic Acid Interactions with Bentonite:
There is flocculation of the clay. Humic acid blocks electrostatic interactions, and makes the clay unwettable.

The conclusions:

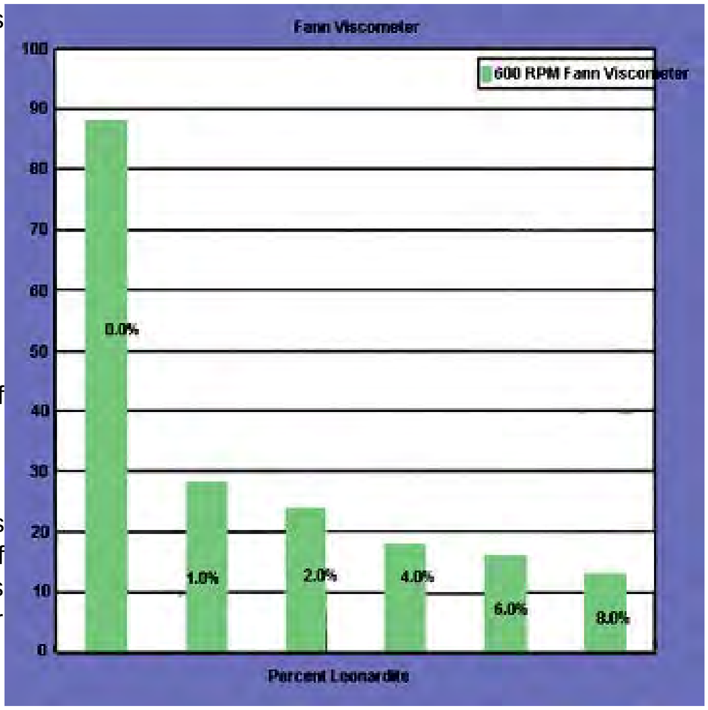
1. Leonardite is likely derived from Lignite (Oxidized Lignite).
2. Leonardite is composed of Humic Substances (<85% is Humic Acid).
3. Leonardite ore is acidic. Hence it is causticized to increase it pH.
4. Humic Acid in Leonardite disrupts bentonite and its electrostatic interactions and modifies its ability to swell.
5. Causticized Leonardite is a reactive material.

Leonardite & Its Effects on Green Sand Molding
Part 2. Applications in Green Sand Systems

by Mike Van Leirsburg, American Colloid Company

The use of Leonardite in Green Sand Systems is well established. Its effects on the Green Sand are:

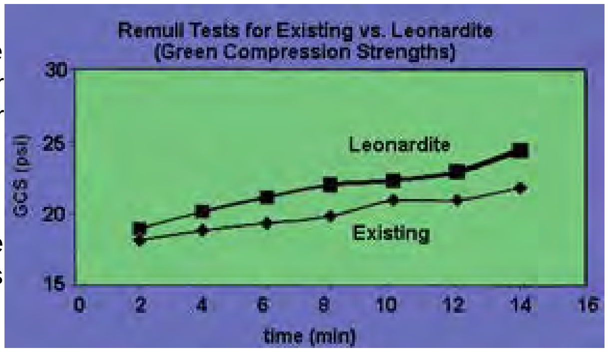
1. Reduces clay viscosity
2. Improves Muller efficiency
3. Increases mold permeability
4. Absorbs and retains water
5. Improves shakeout
6. Improves foundry environment



Leonardite reduces clay viscosity.
(See Fann Viscometer graph) Leonardite retards the free swelling of clay. It improves flowability and clay efficiency.

Leonardite improves Muller efficiency.
(See Remull Tests for Existing vs Leonardite graph) Leonardite works well in foundries where the mulling cycles are short due to demand of mulled sand. By using Leonardite, for the same compactability, there is an increase of green strength. Foundrymen can use less clay in their sand system. This can be a big cost saving in the long run.

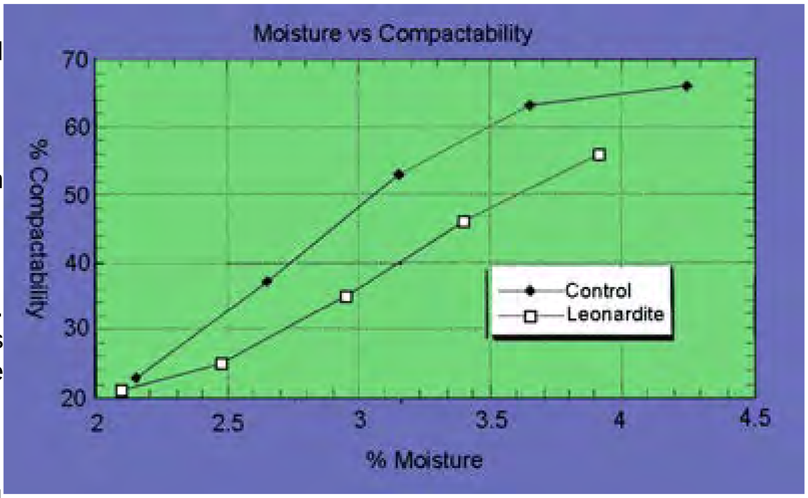
Use of Leonardite increases the permeability of the green sand.
This increase in permeability could result in the reduction of Gas defects. Cold iron defects such as misrun, cold shut is also reduced. Use of Leonardite does not replace the good practice of venting of the molds.



Leonardite helps the absorption and retention of water in the sand system.
(See Moisture vs Compactability graph) Use of Leonardite helps improve the sand system performance especially in the hot sand conditions. Free water defects in the castings are reduced. The use of Leonardite requires more water in the sand system to obtain the same compactability.

Leonardite improves shakeout.
(See Remull Tests for Existing vs Leonardite graph) The use of Leonardite allows the use of more Western Bentonite in Foundries with less than vigorous shake out systems. It reduces dry strength, resulting in less sand carry out.

Leonardite does not affect clay durability.
Despite lowering dry strength, sodium clays (Western) retain their natural, high durability when blended with Leonardite. The durability of the clay is obviously a function of clay chemistry.



Leonardite improves foundry environment.
The use of Leonardite reduces smoke on the cooling lines and at shakeout.

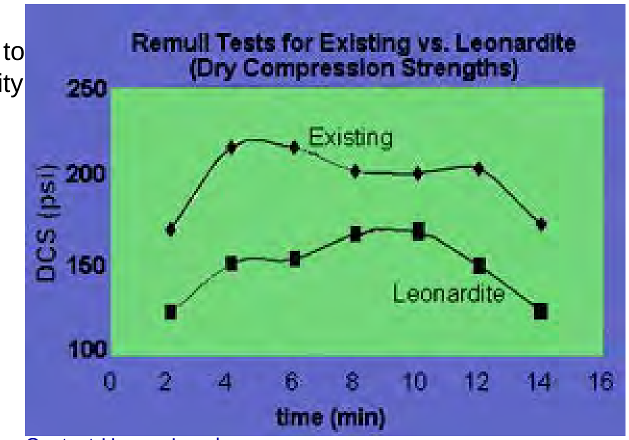
Leonardite may reduce foundry emissions.
Initial testing at the CERP foundry in California has been completed recently. Preliminary results look very encouraging.

Leonardite affects the methylene blue testing.
Methylene blue tests measure the cation exchange of the clay. Since Leonardite has its own cation exchange capacity of its own, Bentonite/Leonardite systems will have higher methylene blue readings than Bentonite systems without Leonardite.

Exercise caution when reducing clay.
It is important that one should be very familiar with the sand system. Sand testing should be done frequently when reducing the clay. Reducing the clay based on green strength or methylene blue alone may result in too great of a loss in dry strength.

Conclusion.

The use of Leonardite to the green foundry sand systems can be beneficial to the foundryman seeking to improve clay efficiency, increase sand permeability and improve the foundry environment.



Albert P. Gagnebin, Obituary

Albert P. Gagnebin,
Former Chairman of the International Nickel Co. of Canada, Ltd.

Albert P. Gagnebin died on February 14, 1999 in Jupiter, Florida at the age of 90. Born in Torrington, Connecticut, he was a graduate of Yale University where he received a degree in mechanical engineering in 1930 and a Master's degree in Metallurgy in 1932. He spent his entire career with INCO, starting as a research metallurgist in 1932. He became President 1967 and retired as Chairman of the Board in 1974, but continued as a Director until 1980.

After leaving Yale, he worked in the Bayonne, N.J. laboratory for seventeen years. During the course of this work, he directed all the research on ferrous castings which led to a number of patented inventions, the most notable being Ductile Iron, acclaimed as one of the major metallurgical inventions of the twentieth century, and now manufactured in millions of tons worldwide. The invention was based on the introduction of a small quantity of magnesium into cast iron, which transforms it from a weak, brittle material into a strong, tough material with properties resembling those of steel. In 1949, when the patent was issued, he was put in charge of its commercial development. Several hundred foundries were licensed for its manufacture. Ductile Iron became the second largest casting material with an endless variety of applications, including automotive crankshafts and centrifugally cast pipe.

In 1956, he became Manager of nickel sales and subsequently, as Vice President and Executive Vice President, he was responsible for the research, development, sales and marketing of all the company's metals and products. With a completely restructured marketing system, in combination with a favorable industrial climate, sales expanded steadily, nickel production increased sharply with the opening of new mines in Manitoba, and the company entered one of the most prosperous eras in its history.

After extensive study of the complexities involved, he pioneered International Nickel's entry into post-war Japan and established a position that has developed into one of the company's major markets. In a parallel objective, he established an INCO joint venture in Indonesia with Japanese and Indonesian participation for a nickel operation which has become a major supplier of nickel to Japan. He also negotiated an agreement with the French government that resulted in the acquisition of extensive nickel deposits in New Caledonia.

In recognition of the invention of Ductile Iron, he was awarded gold medals by the American Foundrymen's Society and the American Institute of Mining & Metallurgical Engineers, as well as the Grande Medaille d'Honneur and the Ordre National du Merite (Officier) by France. He was a member of the National Academy of Engineers and received a citation from the American Society of Mechanical Engineers.

He was also a Director of Abex Corp., Atlantic Mutual Insurance Co., Bank of New York, Ingersoll Rand Co., Illinois Central Industries, Schering Plough Co., the Toronto Dominion Bank, a member of the North American Advisory Board of Swissair and a Board Member of the Institute of International Education. He was a founder of the National Mining Hall of Fame and a past President of the international Copper Research Association.

He was a member of the Yale Club and the University Club of New York, the Rumson Country Club, the Seabright Beach Club in New Jersey and the Tequesta Country Club in Tequesta, Florida.

He is survived by his wife, Genevieve Hope, whom he married in 1935, two daughters, Mrs. John D. Coffin and Mrs. David O. Wicks, Jr., both of New York City and four grandchildren.

A memorial service was held on February 20, 1999 at St. George's-by-the-River, Rumson, New Jersey.

Contributions may be made to the Albert P. Gagnebin Fellowship Fund, Yale Development Office, c/o John M. Sargent, P.O. Box 2038, New Haven, CT 06521-2038.

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NEWS BRIEFS

Meetings

The next meeting of the Ductile Iron Society will be held November 10-12, 1999 at the Radisson Plaza Hotel in Fort Worth, Texas. There will be visits to EBAA Iron Eastland, TX and Albany, TX.

People

Milwaukee, Wisconsin – **Grede Foundries, Inc.**, announces changes in plant management.

E.J. Kubick has been appointed Plant Manager of Duport Harper foundry in Tipton, West Midlands, England. **Mike Gray**, Vice President of Operations, has been appointed Plant Manager for Wichita foundry, Wichita, Kansas, and **Tom Jacobs**, has been named Vice President of Operations at Pryor foundry, Pryor, Oklahoma.

Kubick graduated from the University of Wisconsin with BS and MS degrees in Metallurgical Engineering. He joined Grede in 1991 at its Liberty foundry in Milwaukee, Wisconsin. He served in the capacity of Technical Director before becoming Factory Manager in 1994. In 1998, he was promoted to Works Manager at the Wichita foundry.

Gray earned a BS degree in Physics from Eastern Illinois University and joined the Pryor foundry in August, 1976, as a Maintenance General Foreman. In 1979, he was promoted to Maintenance Superintendent; in 1983, Facilities Manager; in 1986, Manufacturing Manager in 1991, Manager of Manufacturing, Materials, Production Control, and Maintenance; and in 1992, General Plant Manager. In February, 1994, with the acquisition of Pryor by Grede, Mike was named Works Manager. He was promoted to Vice President of Operations in November, 1997.

Jacobs graduated from the University of Wisconsin with a BS in Electrical Engineering and from the University of Louisville with a BS in Management. He held general management positions at a former American Motors Corporation, the Mueller Company, Stanley G Flagg and Company, and others. Jacobs joined Grede as Vice President of Operations at Pryor on June 14, 1999.

Grede Foundries operates 12 foundries in the U.S. and the U.K. and is a recognized leader in the production of high quality castings in gray iron, ductile iron, and steel.

Gary F. Ruff Joins Intermet as Vice President -- Technical Services

Troy, Michigan - John Doddridge, chairman and chief executive officer of Intermet Corporation, announced today that effective June 1, **Gary F. Ruff** has been named vice president - technical services of Intermet. Ruff will be responsible for research and development, materials and product engineering and development, product quality, and education and training.

Ruff spent 12 years at CMI International and its successor company, Hayes Lemmerz International, where he was president, responsible for manufacturing, engineering, sales and financial activities of the North American Aluminum Wheels Group. At CMI, Ruff was chief technical officer, executive vice president and director, responsible for engineering, research and development, quality assurance, and marketing and sales. Previously, as executive vice president, he was responsible for CMI's 13 manufacturing plants. He also has 18 years of experience with General Motors, where he was chief process engineer of the Central Foundry Division.

Ruff is active in the American Foundrymen's Society, where he has held the chairmanship of various boards, councils and committees, and is the recipient of the AFS Award of Scientific Merit. He is the author of more than 20 technical papers and the holder of five metal casting patents. He also is a member of the American Society for Metals and the Society of Automotive Engineers. He serves as a member of the Visiting Committee of the Case School of Engineering, Case Western University.

He received a B.S. in mechanical engineering from General Motors Institute, an M.S. in metallurgical engineering and Ph.D. in metallurgy and material science, both from Case Western Reserve University.

With headquarters in Troy, Michigan, Intermet Corporation and its subsidiaries design and manufacture precision iron and aluminum cast components for automotive and industrial equipment manufacturers cranes and specialty service vehicles. Intermet also produces precision-machined components and manufacturers worldwide. Intermet also produces precision-machined components and manufactures cranes and specialty service vehicles. The company has 7,000 employees at 19 operating locations in North America and Europe. Intermet's internet address is www.intermet.com.

Business

Ashland Distribution Company and Ashland Specialty Chemical Company Material Safety Data Sheets (MSDS) Available on Company Web Site

Dublin, Ohio (USA) – **Ashland Distribution Company** and **Ashland Specialty Chemical Company** today announced that Material Safety Data Sheets (MSDS) for approximately 15,000 Ashland-manufactured or-blended products are now available to customers on the companies' web site, at http://www.ashchem.com.

Once logged onto the web site, customers can link directly to the "MSDS" section from the left-hand side of the home and from there conduct a search by product name or Ashland Product Code. Individual MSDSs can be viewed, printed on-line, or downloaded to a text file.

Users will also be able to develop and maintain a personalized or customized list of product MSDSs by registering through the site. This personalized list feature will allow a user quick access to frequently used MSDSs. In addition, the list feature will automatically note which MSDS Ashland has updated since the user's last visit to the site so the most current MSDS is viewed.

Together Ashland Distribution Company and Ashland Specialty Chemical Company carry approximately 20,000 different products and blends. Initially the companies have added to the web site only some of the products manufactured by Ashland Specialty Chemical Company and Ashland- branded blends from Ashland Distribution Company.

"As part of our ongoing commitment to the Chemical Manufacturers Association's Responsible Care* initiative and our Product Stewardship responsibility, we felt it was imperative that we provide our customers with an accurate, up-to-date resource for as many of the products we handle as possible," stated Glenn Hammer, vice president, Ashland's Environmental, Health & Safety Department.

"While several independent databases are accessible to the public, some of these external or public resources are not updated on a regular basis. As a result, some of the critical emergency response or product handling information could be out of date. Our MSDSs will be updated real-time on the web as revisions are made to them so that the most current MSDS information will be available. By doing so, we are providing our customers with an easy, accessible way to obtain MSDSs 24 hours a day," Hammer added.

The companies anticipate adding more product MSDSs in the future, in addition to translations and Canadian compliant (WHMIS) versions.

Customers requiring an MSDS sheet that is not currently available on the company's web site may contact Ashland's Environmental, Health & Safety Department during normal business hours of 8:00 a.m. to 4:30 p.m. U.S. EST, Monday through Friday (excluding U.S. holidays). For emergency situations after-hours, customers can also contact the Ashland Emergency Response Line at 1-800-ASHLAND (1-800-274-5263) or Chemtrec at 1-800-424-9300.

Ashland Distribution Company and Ashland Specialty Chemical Company are divisions of Ashland Inc. Ashland Distribution Company is the largest distributor of chemicals, plastics and fiber reinforcements in North America, a leading distributor of fine ingredients in North America, and a leading Pan-European distributor of plastics. Ashland Distribution has 100 distribution centers serving North America and Europe. Ashland Specialty Chemical Company is a leading, worldwide supplier of specialty chemicals serving industries including adhesives, automotive, composites, foundry, merchant marine, paint, paper, plastics, and semiconductor. Visit our Internet web site at http://www.ashchem.com to learn more about these operations.

*Responsible Care and Responsible Care Logo are Registered Service Marks of the Chemical Manufacturers Association in the United States and of the Canadian Chemical Producers' Association in Canada and may be registered to other entities in other countries.

New Furnace in Sweden Provides Additional ThermoPURE, Desulco Capacity

Chicago, IL – A newly completed expansion at **Superior Graphite's Sundsvall, Sweden**, plant will allow the company to increase its global Desulco output and expand capacity for its ThermoPURE line of products half a world away.

A third furnace was added to the Swedish plant to boost production of its main product, Desulco – the purest form of carbon additive available – by 650 metric tons a month, or 8,000 tons a year. The expansion will allow Superior's Hopkinsville, Ky., plant to produce more ThermoPURE materials by shifting much of its export Desulco sales to Sweden. The Kentucky plant is Superior's only site for the manufacture of ThermoPURE – thermally purified natural and synthetic graphite products – which are used in battery, friction materials, graphite foil and other industries.

"It's an expansion that serves a global purpose," said Stephen Bolger, president of Superior Graphite Europe. "It provides for increases in capacity for ThermoPURE products at our Hopkinsville, Ky., facility and also allows us to capture new market opportunities for Desulco from Sweden."

Superior chose to boost Desulco production in Sweden to better serve its export markets outside of the United States. Logistically, the company will realize cost savings by supplying a number of countries in South America, Asia and the Pacific Rim from Sweden rather than Hopkinsville, Bolger said.

"The capacity increase allows Superior to further diversify its product line into value-added purified graphite for nonmetallurgical applications," he said. "Additionally, there's an increased global demand for Desulco in high-volume carbon steel production, where a low gas content is essential. This expansion will allow us to capture further market opportunities for these applications."

The third furnace, which Superior designed allows the company to reduce down time between runs, according to Swedish plant Manager Peter Wikingsson. The plant will operate two furnaces simultaneously, with a third furnace on standby at all times. As a result, two-furnace production will continue even when one is down for repairs.

Participants Invited

Chicago, IL – **Superior Graphite Co**., with the assistance of technical specialists from the Argonne National Laboratory, Northwestern University, Bio-Imaging Research Inc. and Biztek Consulting, is developing for industrial use a low-cost method of pressure assisted densification called Electroconsolidation®. Grant funding from the U.S. Department of Commerce Advanced Technology Program (ATP) has been provided to install a pilot facility to be used for detailed study of the factors affecting the process and for developing non-intrusive methods for process control.

The pilot facility, which is located at Argonne, comprises a 200MT computer controlled double acting hydraulic press, a 10,000 amp pulsed dc power supply and an x-ray imaging system for observing and recording the densification process. The pilot facility can process preforms of up to 4-inch size at temperatures to 2500C and with applied pressures of 10,000 psi (70Mpa).

Industrial firms interested in evaluating the use of Electroconsolidation are being invited to participate in this program. Participants will submit preforms and determine the properties of the densified parts. Companies interested in this program should contact Peter Booth, Asst. Vice President of Product Commercialization, Superior Graphite Co., 10 S. Riverside Plaza, Chicago IL 60606, (312) 559-2999; email Pbooth@GraphiteSGC.com.

Globe Metallurgical Names 1999 Challenge Scholarship Winners

Beverly, OH – Nine high school seniors who have overcome challenges or helped others do so have been selected to receive $1,250 tuition payments as part of Globe Metallurgical's 1999 High School Challenge Scholarship Program.

Now in its seventh year, the program honors students in the four communities in which Globe Metallurgical operates production facilities, including Beverly/Waterford, OH; Niagara Falls, NY; Selma, AL; and Springfield, OR. Scholarship recipients are:

Beverly, OH

- Lana Knoch, Fort Frye High School
- Tara Tuten, Marietta High School

Niagara Falls, NY

- Jennifer Drake, LaSalle Senior High School
- Jennifer Hinton, Niagara Falls Catholic High School
- Maria Panzarella, Niagara Falls High School

Selma, AL

- Kimbernice Marshall, Selma High School

Springfield, OR

- Anthony Case, Thurston High School
- Tiffany Wright, Thurston High School
- Ziming Huang, Springfield High School

Ashland's Foundry Products Division Introduces RESINS-PLUSsm Program, a Safe and Efficient Resin Handling and Storage Process

Dublin, Ohio – **Ashland Specialty Chemical Company's Foundry Products Division** has introduced the RESINS-PLUS Program to provide customers in North America with a safe and efficient handling and storage system for flammable/combustible products.

Unlike many containers on the market today, the RESINS-PLUS Program includes a stackable storage system made from carbon steel that meets all OSHA storage regulations and DOT transportation regulations for flammable/combustible products.

Storage of flammable/combustible products in polyethylene container systems is not allowed by OSHA regulations or, in some instances, by local fire codes, except under certain conditions. Further, such storage can potentially result in employee injury and exposure, as well as costly hazardous materials spills and fines. In addition, it can be expensive to bring a facility into compliance with the OSHA storage regulations in order to use these standard polyethylene containers legally.

The RESINS-PLUS stackable storage system is composed of two separate tanks, a 549-gallon bottom base tank and a smaller 345-gallon returnable tank on top. The larger base tank remains at the customer location and has a visible resin level on the outside of the tank. The closed resin delivery system results in less material handling, less waste, minimal cleaning costs, and no container disposal since the tanks are returned to Ashland empty and unopened. In addition, the closed system ensures complete container discharge and reduces the threat of air locks or moisture.

The benefits of using Ashland's RESINS-PLUS Program versus plastic containers which do not meet *fire codes* or OSHA regulations for *storage* of flammable/combustible products, include the following:

- No required, expensive upgrades to facilities to be in compliance with OSHA and fire code regulations for storage of flammable/combustible products.
- Carbon steel, closed delivery system containers mean less chance for product contamination from moisture.
- Closed delivery system means less waste and less employee contact and exposure.
- Stackable – lift truck or other properly rated material handling equipment can easily move and stack tanks. Total top and bottom tank dimension, including stacking clearance, are an estimated 149 inches or just under 12-1/2 feet. Both tanks are 48 inches x 42 inches wide.
- Elimination of drum disposal.
- Improved manufacturing efficiencies – less chance of running out of product at the mixer.
- Store more product in less space – bottom base tank stores up to 549 gallons.

With the RESINS-PLUS Program, customers purchase the base tank and sight tube for the visible resin level from Ashland's Foundry Products Division. Customers are also required to sign a proper care agreement with Ashland. This proper care agreement specifies that the returnable tank must be returned to Ashland with the seals unbroken to avoid contamination and that all tanks must be returned within a standard time frame and in good condition or be subject to late fees, parts and services fees or cleaning expenses.

The Foundry Products Division also represents MT Systems to provide state-of-the art bulk resin handling systems for large resin users. Both the MT Systems and RESIN-PLUS Program meet or exceed Ashland's ***Responsible Care**** Initiative.

Contact your local Ashland Foundry Products Division sales representative or call Ashland Specialty Chemical Company, Foundry Products Division at (614) 790-3514 to learn more about this safe, effective storage alternative for flammable/combustible products. To learn more about Ashland's Foundry Products Division, log onto the Ashland Specialty Chemical Company's web site at http://www.ashspec.com and click on the appropriate division link – or go directly to http://www.ashchem.com/fp.html for the Foundry Products Division page.

Ashland's Foundry Products Division manufactures and sells foundry chemicals worldwide, including sand-binding resin systems, refractory coatings, release agents, engineered sand additives and riser sleeves. The division serves the global metal casting industry from 23 locations (including licensees and joint ventures) in 21 countries.

Ashland Specialty Chemical Company, a division of Ashland Inc., is a leading, worldwide supplier of specialty chemicals serving industries including adhesives, automotive, composites, foundry, merchant marine, paint, paper, plastics, and semiconductor.

Ashland Inc.'s Internet address is http://www.ashland.com.

Foseco-Morval Opens New Plant in Alabama

Cleveland, OH - Foseco-Morval Inc., the leading supplier of expendable patterns to the lost foam foundry industry, held a grand opening of its new 70,000 sq. ft. facility in Bessemer, Alabama. Customer officials and local dignitaries performed the official ribbon cutting on April 9, 1999. Invited guests included community officials, customers and members of the North American management team.

The expansion represents the company's commitment to its rapidly expanding customer base in the southern U.S. and to the local community. Business growth will necessitate hiring up to 40 new employees in 1999.

Foseco is a leading provider of proprietary products and systems designed to enhance quality and efficiency in aluminum, iron and steel foundries. The company maintains more than 100 operations in 34 countries for local service and onsite expert technical assistance. Through its dedications to research, Foseco is credited for numerous advancements in metal casting since its founding in 1932. Foseco International is part of Burmah Castrol's worldwide Chemicals Group.

Intermet Second Quarter Results Above Expectations

Troy, MI - Intermet Corporation announced today that its second quarter results would exceed analysts' earnings estimates despite diffuculties in production operations.

Intermet expects to realize a one-time tax benefit as a result of a tax law change in Germany during the second quarter. Based on meetings the company conducted with German taxing authorities and its accountants through the end of last week, this change will allow greater tax advantage for the company's December, 1998 purchase of a foundry in Ueckermunde, Germany. although total earnings are expected to be bgreater, operational earnings will be below original estimates due to several major production disruptions in the last two weeks of June.

With headquarters in Troy, Michigan, Intermet Corporation and its subsidiaries design and manufacture precision iron and aluminum cast components for automotive and industrial equipment manufacturers worldwide. Intermet also produces precision-machined components and manufactures cranes and specialty service vehicles. The company has 7,100 employees at 19 operating locations in North America and Europe. Intermet's internet address in www.intermet.com.

License and Technical Assistance Agreement Signed

Milwaukee, WI - **Grede Foundries, Inc. and Teknik, S.A. De C.V. of Monterrey, Mexico**, signed a License and Technical Assistance Agreement on July 1, 1999. The terms of this agreement allow Grede and Teknik, a subsidiary of Proeza, S.A. De C.V., to share technical and sales functions in the marketing and production of iron castings in Mexico.

Bruce Jacobs, President and CEO of Grede Foundries, and Enrique Zambrano, President and CEO of Proeza, view this agreement as a significant step in serving the casting needs of customers located in Mexico.

Grede Foundries operates 12 foundries in the U.S. and the U.K. and is a recognized leading producer of high quality castings in gray iron, ductile iron, and steel.

PLANT VISIT

Bremen Castings, Inc.

Bremen Castings, Inc., (BCI), a medium-sized gray and ductile iron foundry, was founded in 1939 as Bremen Gray Iron Foundry by Ellis Brown, Harold Heckamen and Charles W. King. Today, the Brown family has controlling interest in the foundry.

The foundry produces gray cast iron classes 20-40 and ductile iron grades 60-40-18, 65-45-12 and 80-55-06. The casting sizes range from 0.5 to 125 pounds with annual shipments of 13,000 tons serving the motor vehicles, valves and pipe fittings, farm machinery, engines, pumps, and lawn and garden equipment industries.

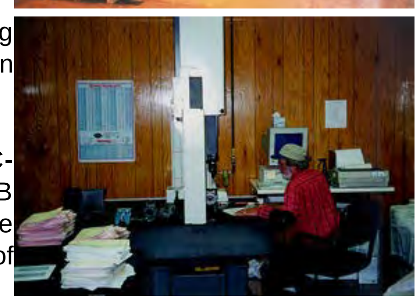
Beginning the casting process in the molding department, the foundry utilizes green sand molding equipment with five 14x19 Hunter Automatics, one 20x24 Hunter Automatic and one 20x26 Roberts Sinto Automatic.

Cores for the molds are produced on two Redford 22 Isocure Core Machines, one Redford 42 Shell Core Machine, four Redford 43 Shell Core Machines and two Dependable 200 Shell Core Machines.

Melting for ductile is done using two 4 ton Ajax Coreless Furnaces. The foundry takes advantage of off-peak melting and produces 25-30 tons per day of molten metal between the hours of 3:00 P.M. and 6:00 A.M. For gray iron production the foundry uses a 12-ton per hour, 60" diameter WRIB/Whiting with a wet scrubber. This metal at a rate of 100 to 140 tons per day is transferred to a 40 ton Inductotherm Duplex-Holder. The normal melt schedule for the cupola is four days a week and ten hours per day.

Pouring is done on conveyor lines with fume hoods to maintain a clean atmosphere in the foundry.

After sufficient cooling time the molds containing the castings are transferred to a Didion MD100 Rotary Media Drum. Hooded vibratory conveyers then deliver the castings to the cleaning room where they can be passed through one of three 14 cubic foot Super Tumblast Wheelabrators.



Quality control is accomplished using a variety of testing equipment including, spectrometer, micro examination, carbon analysis and ultrasound.

BCI offers machining service in house using one Mazak HTC-400 Horizontal Machining Center and one Mazak VTC-20B Vertical Machining Center. Also available is on Wesel Knee Mill LC-1850vs. This equipment provides a full range of capabilities.

For more information on quality castings from BCI call Lon Kipfer at 219-546-2411, ext. 219.

PLANT VISIT

Rochester Metal Products, Disa Plant

Rochester Metal Products, located in Rochester, Indiana, is a gray and ductile iron foundry which utilized Hunter and Disa green sand molding and electric melt. The company received its QS-9000 certification in November 1997. The plant described herein is the Disa Plant, which is strictly a ductile iron jobbing shop.

Core Production
The core room uses Isocure resins, at a level between 1 and 1.3 percent, and DMEA gas. Sand mixing is achieved using a Redford Carver Mark I high speed traveling batch mixer. The sand used is a 60 GFN round grain silica. The prepared sand is delivered to two Hottinger FC 16-core machines and one CMI CB26 Horizontal Core Machine.

Molding
The new sand used is a 60 GFN round grain silica. Sand cooling is employed using water sprays, aeration, and a fluidized bed cooler. The sand temperature drops are approximately 150-200^{o}F, producing an average sand temperature at the muller of 110^{o}F. The sand is prepared at a rate of 75 tons per hour in two B&P 100B speed mullers equipped with Hartley Compactability Controllers. This system feeds sand to two 2013B Mark V Disas which are equipped with core setters. The goal for mold production is 350 molds per hour at 85% uptime and the average casting weight is 5-7 pounds.

Melting
The iron grades produced are 60-40-18, 65-45-12, 80-55-06 and 100-70-03. The shop is approximately 60% ferritic and 40% pearlitic. Primary melting is done in two 30-ton line frequency BBC coreless induction furnaces and the tap temperature from these furnaces is 2630-2650^{o}F. The holding furnace is a 30-ton Ajax Vertiplex vertical channel furnace with 20 useable tons. The average base iron chemistry is carbon 3.75-3.90%, silicon 1.65-1.85%, sulfur 0.01-0.02% and the manganese is 0.32-0.38%.

Pouring and Treating
The two pouring furnaces are 10 ton Duca Pressure Pour vertical channel induction furnaces equipped with Selcom Laser Pour systems, which have a usable capacity of 7 tons. The stopper rods used in the system are alumina graphite and the nozzles are fused silica with a diameter of 1-1/8 inches. The average final chemistry is carbon 3.60-3.80%, silicon 2.45-2.65%, and magnesium 0.030-0.037%. Copper is used as the pearlite stabilizer for the grades 80-555-06 and 100-70-03 and the average pour temperature is 2525 to 2575^{o}F.

Ductile treatments are done in an open-top 4500-pound ladle with an alloy pocket using 5% MgFeSe and cover steel. Any required alloys are added at this time using a treatment temperature of 2650-2700^{o}F. Using this method Rochester treats and pours 250-275 tons per day and the average mold cooling time is 45 minutes.

Inoculation
All inoculation is done in-stream. The units used are Foseco MSI System 90 and the normal inoculation is 7 grams/second using Foseco I-90. Certain jobs may require a higher level of inoculation.

Laboratory Facilities
All ductile iron chemistry samples are run on a Spectro LAVMB08B spectrograph. Carbon and sulfur chemistries are run on a Leco CS-300 carbon determinator. Each tap is qualified by polishing an in-mold coupon and test bars are pulled in-house. A sand lab is available to run necessary tests.