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O T T A W A May 6th, 1942.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1213.

Possibilities Offered by the Malleable Irons
in the Present War Effort.

(Copy No. 38.)

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

O T T A W A May 6th, 1942.

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Introductory.

The present emergency is placing the supply of numerous materials, essential in many applications, in either a critical or a strategic condition. This situation requires that possible alternatives or substitutes for replacement of such materials be investigated.

In metal making, various materials enter into the metal as an essential constituent. For example, in practically all ferrous materials manganese in some amount is necessary.

The possibility of replacing a material in many instances with another of similar properties, suitable for the specific application but containing lesser amounts of strategic or critical elements, should be given consideration.

Two materials which for certain applications may be alternatively used or satisfactorily substituted are "blackheart" malleable cast iron and pearlitic malleable cast iron. "Blackheart" malleable can be described as an iron which as originally cast and of the proper composition was extremely hard, brittle, and with a white fracture, then by subjection to a heat treatment known as annealing or malleabilizing has been subsequently rendered soft, ductile, and with a black fracture. Pearlitic malleable cast iron is a comparatively recent development in the malleable iron industry and already has replaced steel forgings in certain applications. Information concerning pearlitic malleable has not been as readily available as it should be. Blackheart and pearlitic malleable cast irons, although commencing as the same basic material, possess properties in the ultimate product that are considerably different; hence they will be considered separately.

"Blackheart" Malleable Cast Iron.

"Blackheart" malleable cast iron has been developed and used for over one hundred years on this continent, to the complete exclusion, for the past eighty years, of another variety of malleable cast iron which, from its fracture, is named "whiteheart". This latter type, which is made and has considerable use in Europe, will not be considered in this article.

Manufacture.

The making of satisfactory blackheart malleable iron castings requires the same care and attention to details

(Manufacture, cont'd) -

that are necessary for the efficient founding of any metal.

The molten metal required is obtained from various types of furnaces: approximately 60 per cent of the tonnage is produced in a type of reverberatory furnace, commonly known as the air furnace; about 10 per cent is melted in cupolas; and the remainder is obtained by melting in cupolas, then superheating and refining in either air or electric furnaces. Installations of the last-mentioned process, known as "duplexing," are increasing, as it can supply hot metal continuously throughout the working day, an essential requirement for mechanicalized foundries.

The remaining foundry operations require the same attention and involve the same skill and good judgment necessary for the successful and efficient founding of all metals.

The annealing operation, in which the metal "as cast" is heat treated to yield the soft ductile product, is accomplished by two methods. The original method entails packing the 'hard iron' castings into metal boxes or "pots" (omitting the active material that is added in the manufacture of "whiteheart"). The boxes, covered and hermetically sealed, are placed in ovens, or kilns, which are then closed up tightly. The oven is next heated up to a temperature of 1650 - 1750° F. This temperature is maintained, depending upon the size of the oven and the total weight of the charge, for a period of from forty to sixty hours, then allowed to cool slowly to approximately 1250° F., after which the oven can be opened gradually and allowed to cool faster. This method of annealing is known as the "periodic." Although the quality of the metal annealed by this process is very satisfactory when proper precautions and control are employed, the annealing process is rather lengthy and time-consuming.

(Manufacture, cont'd) -

The second method was evolved from considerable study of the malleabilizing process, resulting in improvements in the heat-treating equipment, especially in the development of continuous type, controlled-atmosphere furnaces, either gas or electrically heated, with various zones of closely controlled temperatures. The time required for the complete cycle by this method varies from eighteen to thirty-six hours. The continuous, controlled-atmosphere method of annealing is very useful in the larger, mass-production-type foundries.

Composition.

The compositions of "blackheart" malleable cast iron, whether made by the air furnace, the cupola, or one of the duplexing methods, are very similar, with only minor modifications.

Chemical compositions of blackheart malleable cast iron, as noted, are for the "as cast" condition, since difficulty exists in obtaining satisfactory representative samples for chemical analysis from the annealed iron.

Method of Anneal.	Periodic.	Periodic.	Short Cycle, Continuous.
Melting Unit.	Air Furnace.	Cupola.	Usually Duplex.
Carbon, per cent	2.00 - 2.90	2.80-3.10	2.40 - 2.80
Silicon, "	0.80 - 1.10	0.70-1.10	1.00 - 1.60
Manganese, "	0.40 max.	0.40-0.60	0.40 max.
Sulphur, "	0.12 max.	0.15-0.25	0.12 max.
Phosphorus, "	0.20 max.	0.20 max.	0.12 max.

The manganese and sulphur contents should be maintained in a definite ratio for satisfactory annealable metal. Generally the sulphur content in most blackheart malleable

(Composition, cont'd) -

cast irons is 0.08 - 0.10 per cent, requiring a manganese content of 0.30 - 0.35 per cent to maintain the proper ratio.

The chemical composition is not given in specifications, since the mechanical properties required may be met by a number of compositions, depending upon foundry practice and conditions. Castings made from any of the compositions given, with adjustments made for the cross-sectional size, should be, in the "as cast" condition, hard, brittle, and with a white fracture. This white fracture is due to the fact that during the solidification of the casting the composition of the metal does not permit the carbon present to be precipitated as graphite and the carbon is retained entirely in chemical combination with the iron. Should any precipitation occur, the castings when malleabilized will be of inferior quality, although some authorities believe that a slight amount of primary graphite is to be preferred to the possibility of internal shrinkage in the heavier sections of a casting.

During the annealing treatment, the iron-carbon compound is broken down into iron and carbon of the form known as "temper" carbon, which is responsible for the characteristic appearance of the fractures surface, hence the name "blackheart." Coincident with the changes that take place during the annealing, a certain amount of carbon gradually is eliminated from the immediate surface of the casting, resulting in a decarburized surface or "skin".

The structure of blackheart malleable castings, of the proper composition and correctly annealed, consists of iron and of "temper" carbon (which is graphite in round nodules instead of in flakes as in grey iron). This type of structure yields some very desirable physical properties.

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Physical Properties.

Possibly the outstanding property of blackheart malleable cast iron is its ability to resist shock, in addition to good ductility, tensile strength, and ease of machineability. These properties, along with its durability, have led to wide usage in the automotive, agricultural implement, railroad fittings, and electrical industries.

A property of this material which should merit consideration is the fair resistance (for a ferrous metal) offered to corrosion, especially atmospheric. When protected by a hot-dip galvanized coating, it possesses decidedly superior corrosion-resistant qualities under a variety of conditions. The addition of copper in amounts up to 2.0 per cent has been found beneficial in increasing the resistance to certain kinds of corrosion, without affecting the other properties to any extent.

Blackheart malleable cast iron has been in use for so many years that its mechanical properties are well known. These are covered by specifications issued by the American Society for Testing Materials, A 47-33, Grades 32510 and 35018, for malleable iron castings for railroad, motor vehicle, agricultural implements, and general machinery purposes. These specifications apply to iron made by air-furnace, open-hearth, or electric furnace processes. Specification A 197-39 covers cupola malleable iron, an iron used especially for pipe fittings. Physical properties outlined in these specifications are given below. For comparison purposes, similar values listed in the British Standard Specification are also tabled.

(Continued on next page)

(Physical Properties, cont'd) -

	A.S.T.M. A 47-33 Grade No. 32510	A.S.T.M. A 47-33 Grade No. 35018	A 197-39	B.S. 310-1927 (amended Feb. 1942)
Tensile strength, minimum p.s.i. -	50,000	53,000	40,000	44,800
Yield point, minimum p.s.i. -	32,500	35,000	30,000	-
Elongation in 2 in., minimum per cent -	10	18	5	7.5
Bend test -	-	-	-	90°

The A.S.T.M. Specification A 47-33 has been adopted as a standard specification for malleable iron castings by the Society of Automotive Engineers (S.A.E.) and is endorsed by the American Foundrymen's Association.

Blackheart malleable cast iron made to meet A.S.T.M. Specification A 47-33 will very probably have the following physical and mechanical properties:

Specific Gravity - 7.15-7.45.

Coefficient of Thermal Expansion -
Per degree Centigrade, 0.000012.
Per degree Fahrenheit, 0.0000066.

Reduction of Area (not usually determined, since the specimens are tested in the unmachined condition and measurement of reduction of area is hard to make in this state. Furthermore, malleable iron stretches throughout the whole gauge length of the tensile bar with but little local "necking"):

On carefully prepared cylindrical specimens, reductions of area of from 18 to 23 per cent have been recorded.

Modulus of elasticity in tension, in pounds per square inch (p.s.i.)	-	25,000,000
Ultimate shearing strength, p.s.i.	-	48,000
Yield point in shear, p.s.i.	-	23,000
Modulus of elasticity in shear, p.s.i.	-	12,500,000
Modulus of rupture in torsion, p.s.i.	-	58,000

(Continued on next page)

(Physical Properties, cont'd) -

(Probable physical and mechanical properties)
(possessed by blackheart malleable cast iron)
(made to meet A.S.T.M. Spec. A 47-33, cont'd)

Brinell hardness - 110-145.

Impact values for malleable iron are seldom determined, but the following results have been reported:

Charpy, foot pounds	-	7.75
Izod, foot pounds	-	9.5

Fatigue endurance limit, p.s.i.	-	25,000-26,500
Endurance ratio (endurance limit/ultimate strength)	-	0.43-0.54

-

Effect of Temperature on Properties.

If malleable iron is heated above 1400° F. (760° C.) the carbon redissolves and the character of the material changes. Hence, the use of malleable iron for temperatures over 1200 to 1300° F. should be avoided.

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Welding of Malleable Castings.

Since the physical properties of malleable iron are dependent on heat treatment (annealing), the heat of fusion welding will change the structure and physical properties permanently unless the temperature is kept low (under 1400° F.). If the casting may be annealed after welding, both arc and gas welding may be used, and various methods may be employed. Where annealing after welding is not feasible, such as in repairing broken parts, bronze-welding may be done provided the temperature is controlled. It is reported that the tensile strength and elongation of good arc, gas and resistance welds in malleable iron, which have been annealed after welding, are approximately 90 per cent of those of the original malleable iron.

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Industrial Uses of Malleable Castings.

Where strength, ductility, machinability, and resistance to shock are important considerations, malleable iron castings find a wide field of industrial application. Some of the industrial uses of blackheart malleable iron castings are as follows:

Agricultural Implements -

Plows, tractors, harrows, reapers, mowers, binders, cultivators, rakes, spreaders, pumps, feed grinders and cutters, hand implements, wagon parts, vegetable washer and binder, hay mowers, hemp harvesters, cotton gin machinery, beet diggers, potato diggers, pea binders, ensilage cutters and loaders, corn huskers, corn pickers, combines, threshers, grain drills, hay presses, hay loaders, hay tedders, manure spreaders, fence post parts and fittings, poultry equipment, dairy equipment, barn equipment, ferrules, clevises.

Automotive -

Parts for frame, wheels, spring assembly, brakes, motor transmission, axles, steering gear assembly, body, accessories, etc., including: Passenger cars--Differential carriers, differential cases, bearing caps, spring hangers, spring seats, spring seat caps, shock absorber brackets, shock absorber housings, shock absorber liners, brake and clutch pedals, pedal brackets, pedal and master cylinder brackets, transmission brake supports, bearing retainers, steering gear cases, steering gear brackets, steering post brackets, steering post lock bodies, spare tire lock bodies, adjusting nuts, hubs, combination hub and brake drums, motor supports, generator and fan supports, vibration dampener plates, bumper brackets, radiator inlets and outlets, exhaust pipe flanges, body brackets, shifter forks and spare wheel brackets. Trucks--The parts listed under passenger cars are similarly used in truck construction. In addition, many rear axle housings and dual wheel hubs are of malleable iron.

Automotive and Garage Equipment -

Jacks for passenger cars, heavy duty garage hydraulic jacks, trailer supports and tire inspection devices.

Boilers, Tanks and Engines -

Boilers, tanks, fittings, engine parts, outboard motors, diesel engines.

Building Equipment -

Hardware for windows, doors, garage equipment, awning hardware.

(Continued on next page)

(Industrial Uses of Malleable Castings, cont'd) -

Conveyor and Elevator Equipment -

Chains, buckets, pulleys, rollers, cranes, hoists, fittings.

Electrical and Industrial Power Equipment -

Motor and generator parts, pumps, stokers, electric locomotives and tractors, steam specialties, outlet and switch boxes.

Hardware and Small Tools -

Pneumatic and portable tools, miscellaneous tools, saddlery, hardware, table and kitchen utensils.

Household Appliances -

Stoves, sewing machines, refrigerators, washing and ironing machines, vacuum cleaners, dishwashing machines, oil burners, electric fans and toasters, radios.

Machine Tools -

Lathes, planers, shapers, grinders, screw machines, gear cutters, drills.

Machinery for Special Uses -

Textile, cement, rubber, shoe, mining and quarrying, grinding, forging, foundry, bakery, woodworking, bottling, ice, laundry industries.

Marine Equipment -

Anchors, chains, capstans, fastenings, towing bits, hardware.

Metal Furniture and Fixtures -

Stoves, beds, desks, filing cabinets, shelving, hotel supply equipment.

Municipal, State and Public Service -

Bridge and Street--Guard railings, drain scuppers, catch basin and manhole covers, street lamp standards, curb armor and traffic markers. Highway Construction--Guard rail parts, including brackets, turnbuckles, anchors; road building parts, including joint supports, drainage inlets and traffic markers. Transmission Line Equipment--High voltage insulator caps, guy line anchors, electric railway fittings.

Pipe Fittings and Plumbing Supplies -

Elbows, unions, reducers, flanges, valves, bolts, nuts.

(Continued on next page)

(Industrial Uses of Malleable Castings, cont'd) -

Railroads -

Wide variety of parts for construction of locomotives, freight and passenger cars, guard rails, track accessories, etc., including: Locomotive Parts--Oil cups, cab ventilator castings, cab storm window parts, cylinder cocks, smoke box lug and hinge, hand rail column, grease cup bushing, grease plug, reverse lever handle, signal, air, steam and tank hose clamps, valve handles, flexible steam connectors. Passenger Car Parts--Signal lamp and flag brackets, uncoupling lever guide, draft sill filler block, buffer plate, lid for journal box, buffer stem brackets, foot plate for vestibule, threshold plate for side door, queen post, flexible steam heat connectors, air and signal hose clamps, side bearings, window hardware. Freight Car Parts--Uncoupling lever brackets, journal bearing wedges, journal box lid, draft lugs, push pole pockets, door fixture castings, centre plates, striking plates, door post pockets, brake shaft bearings, coupler carriers, card holders, ownership and brake diagram badge plates, drop bottom gondola operating mechanism parts, hinge butts, brake beam parts, brake beam support parts, draft gear parts, side bearing braces, hopper car door operating mechanism castings, brake wheels, power brake castings. Tank Car Parts--Dome covers and rings, outlet valves, safety valve flanges, safety valve housings, tank band anchors, body side bearings, slabbing castings, card holders, valve hand wheels, pipe brackets. Refrigerator Car Parts--Ice rack supports, door hinges, hatch door hinges, drain castings. Track and Switch Castings--Rail braces, adjustable rail braces, guard rail braces, combined rail brace and tie plate, special tie plates, filler blocks, rail anchors, gauge rod ends, track gauge ends, switch stands, bell cranks, turnbuckles, clevises, pipe connectors, pipe supports.

Road and Contractor's Machinery -

Rollers, excavators, cranes, hoists, tractors, graders, mixers, pavers.

Toys and Specialties -

Sleds, wagons, automobiles, bicycles, carriages, gun parts.

In view of its good combination of strength, ductility, and corrosion resistance, blackheart malleable cast iron should be a satisfactory substitute material in many applications. In considering it as a substitute, attention should be given to the properties of the iron and the properties of the metal to be replaced. In any substitution, however, it should not be overlooked that malleable iron is magnetic and, consequently, cannot be used in applications where non-magnetic properties are required.

Pearlitic Malleable Cast Iron.

During the past few years, modifications of the normal blackheart malleable irons have come into increasing prominence in industry. While these materials have characteristics essentially different from those of normal blackheart malleable iron, they are made by practically the same methods. Such irons are commercially known as "pearlitic malleables," a name which, while not rigidly justifiable metallographically, seems to be the commercially most useful generic name, as it avoids the cumbersome nomenclature required for strict scientific precision.

Pearlitic malleable cast iron is distinguished from the blackheart malleable cast iron by the character of the matrix. This distinction is due to the fact that pearlitic malleable iron contains some carbon in the combined form whereas blackheart malleable iron contains, generally, only a minute quantity of combined carbon. The pearlitic malleables differ in properties as their matrices differ. The significant amounts of combined carbon in pearlitic malleable make it stronger, harder, and less ductile than standard blackheart malleable iron.

The pearlitic malleables may be classified into two major divisions: (I) metal produced by interrupting graphitization before completion, and (II) metal produced by reheating completely graphitized alloys.

Division I can be subdivided into two classes: (A) metal having a composition similar to that of blackheart malleable iron, in which the retention of combined carbon is due to a shortening of the annealing cycle, and (B) metal to which various retarding elements have been added to secure a retention of combined carbon even with reasonably extensive

(Pearlitic Malleable Cast Iron, cont'd) -

heat treatment. Division II contains in practice alloys of Class A only. If one is to completely graphitize the metal there is no point in retarding the operation.

Pearlitic malleable cast irons can be classified as those having completely pearlitic backgrounds for the temper carbon and those in which the temper carbon background is a mixture of pearlite and ferrite. In each group, there would be subdivisions depending upon the condition of the pearlite (i.e., coarsely laminated, sorbitized, or spheroidized). A number of the commercial pearlitic malleables are of the spheroidized type.

By regulating the process, materials can be made with varying amounts of desired combined carbon, but the amounts contained usually are from 0.30 to 0.80 per cent. By variations in the heat-treating methods, the form and amount of carbides may be varied. It becomes possible, therefore, to produce different types of pearlitic malleables with physical properties that vary from those of standard (blackheart) malleable to those with a tensile strength of about 125,000 p.s.i. and an elongation of 2 to 3 per cent.

General Properties.

Pearlitic malleable cast iron is stronger and less ductile than normal blackheart malleable iron and has a higher elastic ratio. It machines somewhat less readily than normal blackheart malleable cast iron but as compared with steel forgings and steel castings it may be machined in substantially less time, with greater tool life. The indentation hardness is higher than that of straight malleable. The fatigue ratio is

(General Properties, cont'd) -

near the expected value of 50 per cent. Because of the possibility of variations in heat treatment, the possible range of physical properties is very broad (tensile, 45,000 to 125,000 p.s.i.). Generally the tensile strength and elongation vary inversely, although this is qualified by the fact that ductility is more dependent on the form of the combined carbon and its distribution in the matrix than is the tensile strength. There is a correlation between tensile strength, combined carbon content, and Brinell hardness. Because of the combined carbon content, pearlitic malleable cast iron can be successfully selective-hardened. Care must be taken, however, if an increase in combined carbon, brought about by solution of temper carbon, is to be avoided.

Most of the producers of pearlitic malleable cast iron claim superior wear characteristics for the material, and performance in commercial applications seems to bear out their claims. The high resistance to wear includes both frictional and abrasive or galling applications.

Specifications.

Committee A-7, on Malleable Iron Castings, of the American Society for Testing Materials has been considering pearlitic malleable iron castings and has issued a tentative specification A220-39T to cover such material. Information is given regarding the classification, description, size of test specimens, etc., but as yet no values for tensile and yield strengths, nor for elongation, are included.

References.

Due to the comparatively recent commercial development of pearlitic malleable iron castings, there are but few references thereto in the literature. Possibly the earliest

(References, cont'd) -

published information was given by E. Touceda at a meeting of the American Society of Mechanical Engineers in 1919. In 1923, E. K. Smith summarized much data in a paper, "Hardened and Tempered Malleable Castings," at the American Foundrymen's Association convention at Cleveland. Over the next few years, most of the information on pearlitic malleable irons is to be found in patent papers; until 1936, when the American Society for Testing Materials held a Symposium on this subject. The report of this meeting contributed some very valuable metallurgical information on this subject. In a paper given by Dr. C. H. Lorig at the 1940 annual meeting of this society, considerable data on various pearlitic malleable irons was given from information supplied by different manufacturers. A bulletin by D. L. Boyes, published in 1941, gives much information on the properties and uses of present-day commercial pearlitic malleable irons.

Commercial Pearlitic Malleable Cast Irons.

There are approximately fifteen distinct pearlitic malleables in common use, some of which differ in manner of production rather than in properties.

Among the better-known commercial trade names under which pearlitic malleable iron castings are sold are:

Promal - Link-Belt Co., Indianapolis, Indiana.
ArmaSteel - Saginaw Malleable Division, General Motors Corporation, Saginaw, Michigan.
Z-Metal - Ferrous Metals Corporation, New York, with seven licensees authorized to manufacture.
Belmalloy - Belle City Malleable Iron Company, Racine, Wisconsin.
Mallix - National Malleable and Steel Castings Company, Cleveland, Ohio.
Pearlitic Malleable Meehanite - licensed by Meehanite Metal Corporation, Pittsburgh, Pa.

(Continued on next page)

(Commercial Pearlitic Malleable Cast Irons, cont'd) -

Promal -

Promal, a product of the Link-Belt Company, Indianapolis, Indiana, was one of the first pearlitic malleables in the commercial field. Its general physical properties are given as follows:

Tensile strength	-	70,000 - 75,000 p.s.i.
Yield point	-	50,000 - 55,000 p.s.i.
Fatigue strength	-	35,000
Elongation	-	14 to 10 per cent
Modulus of elasticity	-	26,000,000
Brinell hardness	-	170 - 190
Specific gravity	-	7.35
Coefficient of thermal expansion	-	0.000019.

The amount of carbon recombined is between 0.30 and 0.40; by increasing the amount, the tensile strength can be increased to 85,000 to 90,000 p.s.i. but with reduced elongation. By suitable alloy additions, the tensile strength can be raised to over 100,000 p.s.i., with proportionately raised yield point and Brinell hardness and with an elongation of 10 to 14 per cent.

Probably the largest use of Promal is in cast elevating, conveying, and power transmitting chains, but it is also used in a great variety of parts where higher strength and good wearing characteristics are required, as in gears for chain hoists, stokers, lawn mowers, road graders, and other machines, and parts for power shovels, lawn mowers, and farm implements. Some of these parts were formerly made from either forgings or steel castings.

ArmaSteel -

ArmaSteel (arrested malleablized steel), a product of the Saginaw Malleable Iron Division of General Motors Corporation, is of standard duplexed blackheart malleable composition with retention of the desired amount of combined carbon

(ArmaSteel, cont'd) -

achieved by interrupting graphitization before completion. The combined carbon is present as a sorbitic structure and also in the form of minute spheroids of iron carbide imbedded in the matrix of the iron. When heat-treated, martensite, or some other form of decomposition product of austenite, will be produced.

ArmaSteel possesses excellent wear characteristics. It has been successfully adapted to selective hardening either by the Tocco process, the flame-hardening process, or by immersion in lead or salt bath.

The physical properties of ArmaSteel, as made for different applications, are given as follows:

Ultimate tensile strength	- 65,000 - 90,000 p.s.i.
Yield point	- 45,000 - 82,000 p.s.i.
Elongation	- 6 - 3 per cent.
Brinell hardness	- 143 - 241.

It has been used in the replacement of steel forgings, for camshafts and rocker arms in automotive and Diesel engines, and has given remarkable service when used for pistons for Diesel engines.

It is reported that development work is in progress on an alloyed ArmaSteel to be used for parts requiring higher strength and greater hardenability than possessed by regular ArmaSteel.

Z-Metal -

Z-Metal manufacture is covered by a series of patents, dealing with equipment, process and product, which are owned and licensed for use by the Ferrous Metal Corporation, of New York City. The principle involved in the production of pearlitic malleable is the use of retarding elements added to the molten metal either in the melting furnace or in

(Z-Metal, cont'd) -

the pouring ladle. In common with other types of pearlitic malleable, Z-Metal derives its physical properties from the retention of combined carbon and the physical condition of this combined carbon (spheroidized). By adjustment of the heat treatment and by variation of the alloy content, a wide variation of physical properties can be obtained.

The physical properties of Z-Metal are reported as follows:

Tensile strength	-	70,000 - 90,000 p.s.i.
Yield point	-	48,000 - 60,000 p.s.i.
Fatigue limit (average)	-	37,500 p.s.i.
Elongation	-	18 - 8 per cent.
Brinell hardness	-	155 - 225
Modulus of elasticity	-	26,000,000 - 29,000,000.

As in the case of other pearlitic malleables, Z-Metal is susceptible to surface hardening. When selective hardening is to be performed, the material is made with an addition of molybdenum to the composition.

Z-Metal has been used to replace normal malleable, steel forgings, steel castings, and other types of ferrous materials. It is reported as being used in many applications in railway, automotive, fittings, machine parts and tool industries, and in ordnance material such as pistol and gun parts and shell castings.

Other Trade Names -

The other trade-named pearlitic malleables have physical and mechanical properties that conform closely to those previously mentioned and are used in similar applications. It is also reported that pearlitic malleable iron castings have been used in the replacement of some non-ferrous materials.

Summarization.

The advantages possessed by pearlitic malleable in strength, selective hardening, and wear and abrasion resistance have been shown. It also possesses reasonably good machineability (not as good as blackheart malleable but better than steel forgings or steel castings of the same Brinell hardness). It may also be machined to a fine finish and will take a high polish. It has proved superior to many competitive materials in damping capacity. Its resistance to many corrosive media is quite good, and may be further improved by the addition of small amounts of copper to its composition. With all of these properties are included the advantages inherent in casting rather than forging a part. Parts requiring cavities may have these cored out and cast practically to shape, with a resultant saving of material and also a reduction of the amount of machining necessary to obtain the necessary dimensions. Parts of intricate design also can usually be more successfully cast than forged.

Limitation of the uses of pearlitic malleable iron is due to the difficulty that is encountered in producing castings which have section-thickness exceeding one inch, and also because no satisfactory welding technique has been developed. However, there are many applications where these limitations do not interfere with its efficient use.

Pearlitic malleable iron would seem to have a large potential field, due to wide variation of physical properties possible by heat treatment. It can be produced in the air furnace as well as in the electric furnace. It is being sold under several trade names with some slight variation in method of manufacture, and also with some variation in the microstructure accomplished by the heat treatment.

It is felt that the possibilities shown in the

(Summarization, cont'd) -

properties of pearlitic malleable iron are not sufficiently known by those who might use it advantageously, either as a replacement for parts made from steel forgings or as a substitution in some applications for certain non-ferrous materials.

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(Part III, concluded) -

Distribution Characteristics.

PROPERTY	Unit	NO. OF RESULTS Period 1	Period 2	AVERAGE Period 1	Period 2	STANDARD DEVIATION Period 1	Period 2
Ballistic	Ft./sec.	50	55	1930	1880	61.0	43.5
Carbon	0.01%	46	44	29	28	2.2	2.83
Silicon	0.01%	45	43	27	27	7.67	6.5
Sulphur	0.001%	48	43	16	20	3.5	1.96
Phosphorus	0.001%	48	45	19.4	19.4	7.3	4.17
Manganese	0.01%	48	44	62	64	7.7	3.9
Nickel	0.01%	46	44	1.63	1.82	1.97	2.02
Chromium	0.01%	44	58	166	160	97.48	14.5
Molybdenum	0.01%	48	45	55	53	8.8	11.8
Tensile	1,000 p.s.i.	55	82	140	134	18.3	15.9
Yield	1,000 p.s.i.	49	79	119	116.4	19.6	19.4
Elongation	1%	55	73	19	20	4.38	3.05
Reduction of Area	1%	55	76	51	55	13.3	10.77
Izod	1 foot pound	60	79	41	48	19.57	20.3
Brinell	1 unit	63	83	285	284	33.6	33.2

(NOTE: Limits of normal variation are average ± 3 x standard deviation.)

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Ottawa, Canada.
May 1st, 1942.
HHF:PES.