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Aronson et al.

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[54] **WELDED PIPE STRUCTURE OF HIGH STRENGTH LOW ALLOY STEELS**

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[51] **Int. Cl.** **B21d 39/02**

[58] **Field of Search** .....75/123 R, 123 E, 123 H, 123 G, 75/123 J; 148/12.1; 29/191, 196.1

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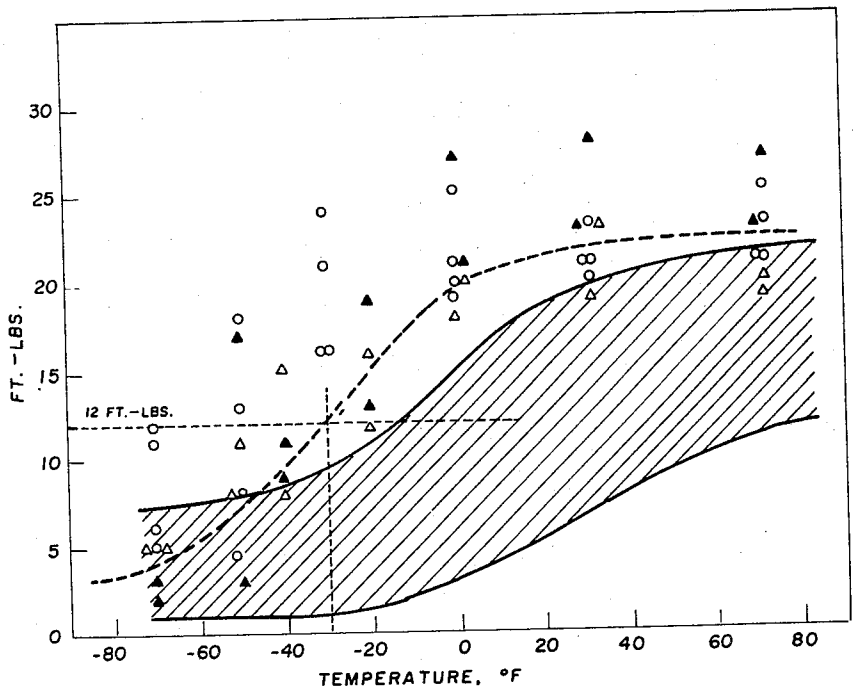
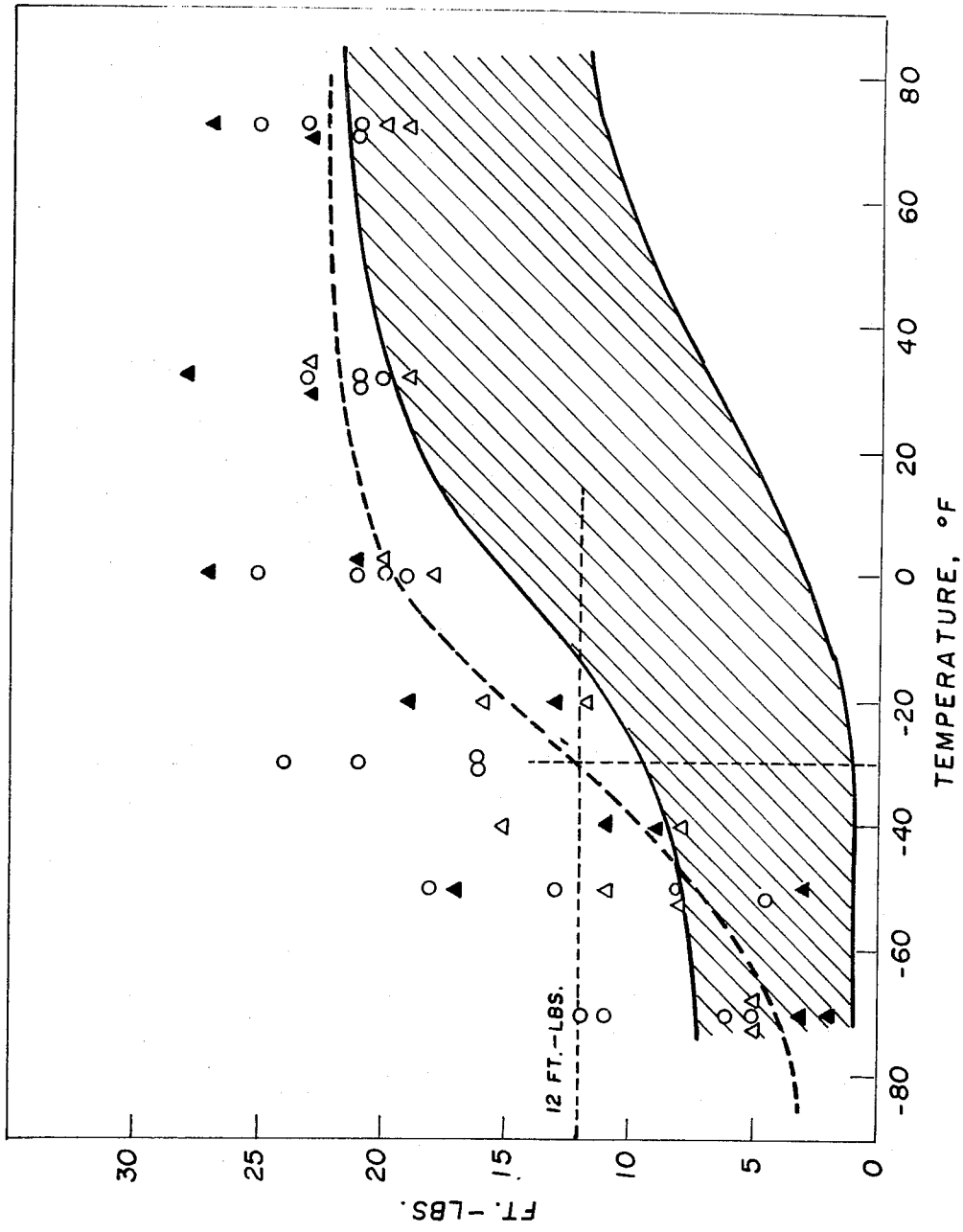
[57] **ABSTRACT**

A steel composition having particular applicability to the manufacture of high-strength, low-alloy line pipe comprises 0.10 to 0.20 percent carbon, 0.85 to 1.25 percent manganese, 0.10 percent maximum phosphorus, 0.05 percent maximum sulfur, silicon in an amount not adversely affecting steel properties, 0.02 to 0.05 percent columbium, 0.10 percent maximum vanadium, an inclusion shape-control agent selected from the group consisting of zirconium, a rare earth or mischmetal, the balance iron.

4 Claims, 1 Drawing Figure





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WELDED PIPE STRUCTURE OF HIGH STRENGTH LOW ALLOY STEELS

The present invention relates to high-strength low-alloy steels having improved properties. The steels are particularly useful in the manufacture of electric-resistance welded line pipe.

Non-metallic inclusions in a high-strength low-alloy steel reduce the steel's resistance to ductile fracture and impair its forming properties. Deterioration of these properties increases with increasing numbers of inclusions and increasing inclusion elongation. We have developed high-strength low-alloy steels having an inclusion type and morphology far less deleterious to toughness and formability. The steels of the invention have particular applicability to the manufacture of welded line pipe and result in pipe of improved flattenabilty and toughness.

The desired inclusion characteristics are achieved by controlling overall steel chemistry and deoxidation practice and, most importantly, by the use of an inclusion shape-control agent comprising zirconium, a rare earth, e.g., cerium, lanthanum, praseodymium, neodymium, yttrium, and scandium, or mischmetal which, of course, is a mixture of rare earths. The use of an inclusion shape-control agent results in the formation of spherically shaped inclusions, particularly sulfide inclusions, which are not plastic at hot-rolling temperatures and consequently do not become elongated but retain their spherical shape in the finished steel.

An object of the present invention is to provide steels of improved toughness and ductility. Another object of the invention is to provide welded line pipe characterized by improved flattenability and weld toughness.

These and other objects and advantages of the present invention will become apparent from the following detailed disclosure with reference to the FIGURE of the drawing which is a graphical representation of the improved impact properties possessed by the steels of the present invention.

The steels of the present invention are fully aluminum-killed and have the following chemistry in weight percents: carbon, 0.10 to 0.20 percent; manganese, 0.85 to 1.25 percent; phosphorus, 0.10 percent maximum; sulfur, 0.05 percent maximum; silicon, in amounts not adversely affecting steel properties; columbium, 0.02 to 0.05 percent; vanadium, 0.10 percent maximum; and an inclusion shape-control agent comprising 0.04 to 0.20 percent zirconium, a minimum of about 0.02 percent of a rare earth or mischmetal; and balance iron. To insure good recovery, the inclusion shape-control agent preferably is added to the steel in the ingot mold or in the ladle after the steel has been killed.

The requisite high strength is imparted to the steel by hot rolling it in a manner to achieve a finishing temperature within the range of **1,550°** to **1,650°** F, followed by in-line cooling at a rate of **20°** to **135°** F per second to a coiling or piling temperature within the range of **975°** to **1,125°** F. As indicated above, the spherically shaped inclusions formed through the use of the inclusion shape-control agent are not plastic at hot-rolling temperatures and retain their desired spherical form in the finished product. In its preferred application, the manufacture of welded line pipe, the steel is hot-rolled into skelp, formed, and electric-resistance welded.

The superior impact properties possessed by welded line pipe manufactured according to the present invention is shown in the FIGURE of the drawing. The data on which the FIGURE is based were obtained from transverse one-half size

Charpy V-notch specimens taken from 12¾ inch O.D. electric-resistance-welded line pipe. For line pipe manufactured from a semi-killed columbium-vanadium high-strength low-alloy steel not containing an inclusion control agent, all impact data fell within the cross-sectioned area of the figure. This type of steel has been used quite extensively in the manufacture of line pipe. All of the individual data points plotted on the figure were obtained from specimens having chemistries within the ranges of the steels of the present invention, as set out above, and employing zirconium as the inclusion shape-control agent. The dashed curve drawn through these points is a conservative estimate of the transition curve and illustrates that, typically, the steels of the present invention result in pipe with transverse 12 ft.-lb. transition temperatures of minus 30° F.

Improved flattening behavior of welded pipe manufactured from the steels of the present invention is shown in the following table:

Welded Pipe run	Pipe O.D. (in.)	Pipe Wall Thickness (in.)	Pieces Tested	Failures	% Failure
1	12¾	0.250	1527	14	0.9
2	12¾	0.250	157	0	0
3	12¾	0.312	93	0	0
4	12¾	0.203	1217	1	0.07

Welded pipe run **1** was a semi-killed columbium-vanadium high-strength low-alloy steel of the type referred to above. Welded pipe runs **2**, **3** and **4** comprised fully killed steels having compositions falling within the ranges of steels of the invention, as set out above, and containing zirconium as an inclusion shape-control agent. The tests reported in the table were carried out as described in paragraphs 4.14 through 4.16 of API Std. 5LX, 16th edition, April 1969.

Control of inclusion shape, which is primarily responsible for the improved properties possessed by the steels of the present invention, is also obtained through the use of 0.01 to 0.10 percent of a rare earth or mixture of rare earths such as mischmetal.

We claim:

1. A welded pipe structure formed of a fully killed steel having a composition consisting essentially of 0.10 to 0.20 percent carbon, 0.85 to 1.25 percent manganese, 0.10 percent maximum phosphorus, 0.05 percent maximum sulfur, silicon in an amount not adversely affecting steel properties, 0.02 to 0.05 percent columbium, 0.10 percent maximum vanadium, an inclusion shape-control agent selected from the group consisting of 0.04 to 0.20 percent zirconium, 0.01 to 0.10 percent of a rare earth and 0.01 to 0.10 percent mischmetal, balance iron.

2. A welded pipe structure as defined in claim **1** wherein the inclusion shape-control agent comprises **0.04** to **0.20** percent zirconium.

3. A welded pipe structure as defined in claim **1** wherein the inclusion shape-control agent comprises **0.01** to **0.10** percent of a rare earth.

4. A welded pipe structure as defined in claim **1** wherein the inclusion shape-control agent comprises **0.01** to **0.10** percent mischmetal.

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