



(86) Date de dépôt PCT/PCT Filing Date: 1998/05/15
 (87) Date publication PCT/PCT Publication Date: 1998/11/26
 (45) Date de délivrance/Issue Date: 2007/03/13
 (85) Entrée phase nationale/National Entry: 1999/10/29
 (86) N° demande PCT/PCT Application No.: US 1998/010034
 (87) N° publication PCT/PCT Publication No.: 1998/053110
 (30) Priorités/Priorities: 1997/05/19 (US60/046,941);
 1997/06/06 (US60/048,694); 1997/06/20 (US08/879,331)

(51) Cl.Int./Int.Cl. *C22C 38/14* (2006.01),
C22C 38/00 (2006.01), *C22C 38/04* (2006.01),
C22C 38/12 (2006.01)
 (72) Inventeur/Inventor:
 GRAY, JOHN MALCOLM, US
 (73) Propriétaire/Owner:
 MICROALLOYING INTERNATIONAL LP, US
 (74) Agent: PARKS, WILLIAM D.

(54) Titre : TUBE DE CANALISATION ET ACIER DE CONSTRUCTION PRODUITS PAR COULEE CONTINUE A
 GRANDE VITESSE
 (54) Title: LINEPIPE AND STRUCTURAL STEEL PRODUCED BY HIGH SPEED CONTINUOUS CASTING

(57) **Abrégé/Abstract:**

A high strength, high toughness, low carbon/low manganese steel is provided that is further resistant to stepwise cracking and sulfide stress cracking. The steel can be produced by conventional or thin slab casting techniques using normal speeds, with low manganese segregation levels. The steels are excellent candidates for linepipe applications in severe sour gas service.

PCTWORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : C22C 38/00, 38/12, 38/14	A1	(11) International Publication Number: WO 98/53110 (43) International Publication Date: 26 November 1998 (26.11.98)
(21) International Application Number: PCT/US98/10034 (22) International Filing Date: 15 May 1998 (15.05.98) (30) Priority Data: 60/046,941 19 May 1997 (19.05.97) US 60/048,694 6 June 1997 (06.06.97) US 08/879,331 20 June 1997 (20.06.97) US (71) Applicant: AMERICAN CAST IRON PIPE COMPANY [US/US]; P.O. Box 2727, Birmingham, AL 35202 (US). (72) Inventor: GRAY, John, Malcolm; 9025 Briar Forest Drive, Houston, TX 77024 (US). (74) Agent: KERINS, John, C.; Kerkam, Stowell, Kondracki & Clarke, P.C., Suite 600, 5203 Leesburg Pike, Two Skyline Place, Falls Church, VA 22041 (US).	(81) Designated States: BR, CA, JP, KR, MX, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i>	
(54) Title: LINEPIPE AND STRUCTURAL STEEL PRODUCED BY HIGH SPEED CONTINUOUS CASTING		
(57) Abstract <p>A high strength, high toughness, low carbon/low manganese steel is provided that is further resistant to stepwise cracking and sulfide stress cracking. The steel can be produced by conventional or thin slab casting techniques using normal speeds, with low manganese segregation levels. The steels are excellent candidates for linepipe applications in severe sour gas service.</p>		

**LINEPIPE AND STRUCTURAL STEEL
PRODUCED BY HIGH SPEED CONTINUOUS CASTING**

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 The present invention is directed to a high-strength
linepipe and structural steel that is resistant to
hydrogen-induced cracking (HIC) in sour service.

2. Description of Related Art

10 A continuing need exists to develop steels having
high strength which can provide extended service life as
linepipe in sour gas (H₂S) service. High strength
linepipe for this sour service has heretofore been
produced from low carbon-manganese steel, and
strengthened by the addition of niobium and/or vanadium.
15 Manganese levels for such steels have typically been in
the range of 0.90 to 1.20 weight percent, when it is
expected that the linepipe will be used in the most
severe service conditions. For the purposes of this
disclosure, manganese levels in the aforesaid range of
20 0.90-1.20 weight percent will be referred to as being
"relatively high" manganese contents for low carbon-
manganese steels.

25 While providing resistance to cracking due to
exposure to sour gas, these steels are prone to manganese
sulfide stringer formation, due to the relatively high
level of manganese employed in the steel. This is the
case even where the steel has very low sulfur levels
(<0.003 wt. percent), because the Mn:S ratio is very high

($>40,000:1$). In order to combat this tendency to form manganese sulfide stringers, the inclusion of calcium, which causes preferential formation of globular or angular calcium oxysulfide inclusions, has become the standard practice. Rare earth metals have also shown the ability to reduce the tendency of the steel to form manganese sulfide stringers. However, both calcium and rare earth additions are expensive and can give rise to processing difficulties such as generation of excessive fumes, nozzle blocking or poor cleanliness ratings.

In casting linepipe steel, from a processing standpoint, steels having manganese contents above 1.0 weight percent are also prone to centerline segregation when casting speeds are high. Further, centerline segregation can occur when proper superheats are not maintained and/or when machine maintenance and water cooling practices are poor.

It is therefore a principal object of the present invention to provide a high strength steel which is suitable for extended use in wet, sour gas service.

It is a further principal object of the present invention to provide a high strength steel having a very low manganese content, yet which is resistant to sour gas (H_2S) degradation.

It is an additional important object of the present invention to provide a high strength steel composition, suitable for sour gas service, which can be continuously

cast at the high, normally desired, speeds employed in casting non-linepipe steel compositions.

It is a further important object of the present invention to provide a high strength steel composition that avoids the need to treat the alloy with calcium or rare earth metals in order to reduce the formation of manganese sulfide stringers.

It is an additional object of the present invention to provide a high strength, high toughness steel that is remarkably resistant to stepwise cracking and to sulfide stress cracking.

It is a further object of the present invention to provide a high-strength steel that has a very low carbon and manganese content as compared to high strength steels currently used in sour gas service.

SUMMARY OF THE INVENTION

The above and other important objects of the present invention are accomplished by providing a steel composition that produces a high strength, high toughness steel that is resistant to attack in even the most severe sour gas or wet sour gas service. Notably, it has been found that a steel that does not rely on a high manganese content to provide the high strength levels, but rather relies on niobium and, optionally, vanadium and/or other alloying elements to provide the necessary mechanisms to achieve high strength in the steel, will avoid many of the aforementioned problems in sour-gas service experienced with

the previously used high strength steels having higher manganese contents.

According to one aspect of the present invention, there is provided a high strength steel comprising elements of the below Table I in the ranges indicated with a balance of iron and impurities:

TABLE I

<u>Element</u>	<u>Range (wt. %)</u>
C	0.015-0.080
Mn	0.10-0.55
Nb	0.005-0.15
Ti	0.005-0.030
N	0.001-0.01
and optionally	
Cr	≤ 0.50
Ni	≤ 0.95
Mo	≤ 0.60
B	≤ 0.0025
S	≤ 0.008
Ca	≤ 0.005
Si	≤ 0.210
P	≤ 0.025
Cu	≤ 0.25
Al	≤ 0.063
V	≤ 0.007

The steel so formed has a microstructure substantially free of coarse grained ferrite, a yield strength in the range 36 to 80 ksi and being resistant to H₂S degradation.

In a specific form of the invention, the high strength steel comprises the elements of Table I but with the elements of below Table Ia in the ranges indicated.

TABLE Ia

<u>Element</u>	<u>Range (wt. %)</u>
C	0.015-0.050
Mn	0.10-0.55
Nb	0.03-0.09
Ti	0.015-0.025
N	0.001-0.005
Mo	≤0.10
B	≤0.0025
S	≤0.003
Ca	≤0.0025
P	≤0.008

10 According to another aspect of the present invention there is provided a linepipe formed from a high strength steel of elements of Table I above, with balance of iron and impurities.

 In a preferred form of another aspect of the invention there is provided a linepipe of the elements of Table I above, with a balance of iron and impurities but with the ranges of
15 Table Ia.

 More specifically, in the linepipe of the present invention, the steel has a yield strength of 36 to 80 ksi and the linepipe meets the criteria of API specification 5LX.

 The present invention also resides in the method of forming high strength steel for use in linepipe, or other uses having the composition of above elements in the ranges of above
20 Table I, or preferably, but not necessarily, in the ranges indicated in Table Ia above, and at a casting rate between 0.8 and 3.0 m/min, whereby the steel exhibits low manganese segregation intensity and resistance to stepwise cracking in an H₂S environment.

Steel compositions falling within the ranges set forth above have been demonstrated to provide high strength and toughness characteristics, and have demonstrated an ability to withstand stepwise cracking and sulfide stress cracking, such that they will be highly suitable for use in severe sour gas service, and particularly as linepipe used in sour gas service.

5 With such steel compositions, high yield strengths in the range of 36 - 80 ksi and high ultimate tensile strengths in the range of 45 - 90 ksi can be achieved. In addition, steels within the above ranges demonstrate excellent impact strengths (high energy impact values) and Charpy V-notch transition temperatures.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

 These and other features of the present invention and the attendant advantages will be readily apparent to those having ordinary skill in the art and the invention

15

20

will be more easily understood from the following detailed description of the preferred embodiments taken in conjunction with the accompanying drawings.

FIG. 1 is a graph depicting the results of a NACE
5 TM0284-96 stepwise cracking test, plotting the weight percent of manganese against the yield strengths of the samples.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In a preferred embodiment of the present invention, a
10 composition that yields a high-strength, high toughness steel, without relying on the use of a relatively high manganese content to provide the relatively high strength characteristics, is provided. The manganese content in the steels according to the present invention can be very
15 low, such as 0.15 weight percent or less, thereby virtually eliminating manganese segregation and the tendency of the steel to form manganese sulfide. Further, the low manganese-to-sulfur ratio present in the steels, which is preferably approximately 3,000:1 to
20 5,000:1, minimizes the tendency of any MnS that may be formed, to form into stringers.

The steel of the present invention relies on the addition of niobium to provide the high strength characteristics, and, optionally, any one or more of
25 vanadium, molybdenum, chromium, boron, copper and nickel, used in combination with the niobium. These elements combine to lower the austenite-to-ferrite ($\gamma \rightarrow \alpha$)

transformation temperature and to prevent the formation of coarse ferrite grains at the very low manganese and carbon levels employed in the steel. The benefits derived from these strengthening mechanisms are enhanced or maximized by water cooling the steel after the strip or plate rolling.

The steel can be more consistently produced due to the reliance on niobium, and optionally also vanadium, precipitation hardening, and on control of the austenite to ferrite transformation temperature. The normally-experienced variations in mechanical properties in coiled product resulting from coiling temperature variations and head-to-tail (leading end to trailing end) temperature variations are minimized or eliminated by the strengthening elements (principally niobium) and mechanisms used in producing this steel.

The steel of the present invention can be treated with calcium or rare earth metals for sulfide inclusion shape control, as in conventional practice. However, the use of titanium reduces manganese sulfide plasticity, especially at low manganese and nitrogen contents, and when the manganese-to-sulfur ratio is very low, which are both features of the steel of the present invention.

The very-low carbon and manganese contents in the steel maximize delta (δ) ferrite formation during solidification and facilitate solute redistribution. Tolerance for phosphorous impurity is increased and there is a virtual absence of pearlite banding. The steels can

be rolled on plate mills or strip mills using either direct hot charging or conventional reheating practices.

Steels having the above characteristics can be obtained within the following preferred compositional ranges:

TABLE II

	<u>Element</u>	<u>Range (wt. %)</u>
	C	0.015-0.080
	Mn	0.10-1.0
10	Nb (Cb)	0.005-0.15
	Ti	0.005-0.030
	Cr	≤0.50
	Ni	≤0.95
	Mo	≤0.60
15	B	≤0.0025
	S	≤0.008
	N	0.001-0.010
	Ca	≤0.0050
	P	≤0.025

Within this overall range, an especially preferred compositional range is as follows:

TABLE III

	<u>Element</u>	<u>Range (wt. %)</u>
	C	0.015-0.050
25	Mn	0.10-0.55
	Nb (Cb)	0.03-0.09
	Ti	0.015-0.025
	Cr	--
	Ni	--
30	Mo	≤0.10
	B	≤0.009
	S	≤0.003
	N	0.001-0.005
	Ca	≤0.0025
35	P	≤0.008

Steels having compositions within the ranges set forth above can be cast at high casting speeds, in the range of 0.8 to 3.0 m/min, that are desired for production efficiency, by conventional (200 to 300 mm

thick) or thin (50-90 mm thick) slab caster. The steels cast at such high speeds exhibit low segregation intensity, and, as noted previously, high strength, high toughness, and resistance to degradation or failure in sour service applications.

In addition to the aforementioned advantages in processing, the steels of the present invention have the notable advantage of providing excellent resistance to stepwise cracking and sulfide stress cracking even when calcium and/or copper are not employed in the steel. Further, the high strength properties can be obtained in the absence of molybdenum. When molybdenum is present within the stated range, the high strength and excellent resistance to stepwise cracking and sulfide stress corrosion cracking can be obtained in the absence of calcium.

In order to demonstrate the suitability of the steels of the present invention for use as linepipe in sour service, as well as to demonstrate the high strength and high toughness characteristics of the steels, several steels falling within the compositional ranges set forth in Table I above were subjected to tensile tests, impact tests, stepwise cracking (hydrogen-induced cracking or HIC) tests, and sulfide stress cracking tests. In particular, samples from four heats, denoted in Table IV below as A-D, were subjected to tensile testing, Charpy V-notch impact tests, drop weight tear tests and stepwise cracking tests. Samples from other heats, designated in

Table IV below as E-G, were tested for resistance to sulfide stress cracking in accordance with the National Association of Corrosion Engineers (NACE) Standard TM0177. Samples from all of these heats, plus dozens of others having compositions falling within the compositional ranges of Tables II and III, were tested for resistance to hydrogen-induced cracking, or stepwise cracking, in accordance with NACE Standard TM0284-96. The results of those tests are discussed below, and with respect to FIG. 1.

TABLE IV

Steel	C	Mn	P	S	Cr(Nb)	Si	Ti	Cu	Ni	Mo	Cr	V	Al	B	Ca	N
A	.046	.230	.005	.004	.054	.210	.013	.250	.130	.000	.020	.007	.063	.000	.002	.004
B	.032	.220	.006	.004	.052	.200	.021	.250	.130	.011	.020	.007	.039	.000	.000	.004
C	.045	.190	.005	.004	.048	.160	.017	.000	.010	.240	.020	.007	.047	.000	.001	.005
D	.052	.220	.007	.004	.051	.200	.020	.250	.130	.230	.020	.007	.044	.000	.000	.004
E	.043	.741	.015	.003	.022		.001	.009	.020	.000		.000	.028		.002	
F	.046	.734	.013	.003	.024		.002	.009	.019	.001		.000	.043		.004	
G	.048	.727	.015	.003	.024		.003	.008	.019	.000		.000	.032		.004	

Table V presents the results of the Charpy V-notch impact tests conducted on triplicate samples prepared from steel heats A-D, with the Charpy test samples being 2/3 of the standard specimen size. As can be seen in the table, the fracture energies are very high, even at sub-zero (°F.) temperatures, with Steel Heat B demonstrating remarkable impact resistance down to -80°F.

TABLE V

	CHARPY V-notch Energy						Size: $\frac{2}{3}$							
	Energy Average (ft-lbs)						Shear Area Average (%)							
	72°F	32°F	0°F	-20°F	-40°F	-60°F	-80°F	72°F	32°F	0°F	-20°F	-40°F	-60°F	-80°F
Steel A		158	128	142	101	108	76		100	100	100	84	86	67
Steel B		182	181	184	184	181	177		100	100	100	100	100	100
Steel C		161	144	130	118	92	9		100	100	100	100	76	8
Steel D		151	133	129	130	69	67		100	100	100	92	46	40

Table VI below presents data from drop weight tear testing, as well as the 50% and 85% values for brittle/ductile fracture transition temperatures as demonstrated in the Charpy V-notch impact tests and in the drop weight tear tests (DWTT). Again, the steels demonstrate excellent notch toughness characteristics with the pipe made from Heat B demonstrating truly outstanding results.

TABLE VI

	DROP WEIGHT TEAR TEST							TRANSITION TEMPERATURE			
	Shear Area Average (%)							Charpy		DWTT	
	72°F	32°F	0°F	-20°F	-40°F	-60°F	-80°F	50%	85%	50%	85%
Steel A		100	100	31	21			< -80	-56	-14	-4
Steel B		100	100	100	100	100	28	< -80	< -80	-75	-65
Steel C		100	100	27	18			-68	-56	-14	-4
Steel D		100	58	27	18			-58	-43	-5	19

The yield strengths and ultimate tensile strengths of tensile specimens from heats A-D, as well as from heats E-G, are reported in Table VII below. In general, for the linepipe applications to which this steel is directed, the desired range for yield strength is about 36-80 ksi, and the desired range of ultimate tensile strengths is 45-90 ksi. These would be considered as high-strength steels, as the term "high strength" is used herein. Since the higher strength steels can be more susceptible to hydrogen-induced cracking, a more preferred range of yield strengths is about 36-70 ksi, and a more preferred range of ultimate tensile strengths is 45-75 ksi. As can be seen, most of steels A-G fall within the preferred range.

TABLE VII

<u>STEEL</u>	<u>Yield Strength</u> <u>(ksi)</u>	<u>Ultimate Tensile Strength</u> <u>(ksi)</u>
A	66	73.0
B	66	71.5
C	68	72.5
D	79	85.5
E	65.5	71.0
F	66.5	72.5
G	64.5	71.5

Resistance to sulfide stress cracking is normally assessed, in accordance with the level of skill in the art, by the test methods set forth in NACE Standard TM0177. In the development of the present invention, tests were conducted on heats E-G in accordance with this NACE standard, modified to include a test period of 96 hours at 80% percent of the specified minimum yield

strength (SMYS). No cracking was evidenced in these tests, indicating an acceptable level of resistance to sulfide stress cracking. It is notable that these heats tested for resistance to sulfide stress cracking had manganese contents toward the upper end of the range of manganese content desired for the present invention. It is expected that steels having lower manganese contents, in the more preferred range set forth in Table III above, will exhibit the same or even an improved level of resistance to sulfide stress cracking.

Samples from the above heats, as well as numerous other samples both within and outside of the compositional ranges set forth in Table I above were tested for resistance to hydrogen-induced cracking, or stepwise cracking, in accordance with NACE Standard TM0284-96, "Standard Test Method--Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking". Figure 1 presents, in graphical form, a summary of the results of those tests, plotting the manganese content of the steels against their yield strength (in ksi). It can be seen from that graph that steels having higher manganese contents and steels having yield strengths approaching and exceeding 70 ksi are susceptible to stepwise cracking. This figure substantiates that the increased strength resulting from the use of higher levels of manganese comes at a price, namely, the increased susceptibility to stepwise cracking.

Nearly all of the steel compositions tested under the NACE TM0284-96 standard had a sulfur content of <0.006 wt.%. Accordingly, it was possible to delineate a crack/no crack boundary 100 based on the test results, and specifically based upon the three failed samples having lower manganese contents and higher yield strengths and those having higher manganese contents with lower yield strengths.

The examples of the invention are those having a manganese content in the range of about 0.10-0.60 wt.% and having a yield strength in the range of about 379-483 MPa (55-70 ksi). Steels meeting those criteria fall within the shaded region of FIG. 1. Because steels having both 0.60 wt.% manganese and a yield strength of 483 MPa (70 ksi) would fall close to the crack/no crack boundary 100, a more conservative set of criteria would include a decreasing maximum yield strength from 483 MPa (70 ksi) to 469 MPa (68 ksi) maximum as the manganese content increases from 0.50 wt.% to 0.60 wt.%.

It is to be noted that the results presented in FIG. 1 are based on tests conducted using the Solution A (pH 5.2) standard test solution defined in NACE TM 0284-96. Additional tests were conducted in accordance with the standard, but using the lower pH, more severely corrosive, Solution B defined in the standard. Samples

from heats A-D, as well as four other samples falling within the steel composition of the present invention, were tested using Solution B in the NACE test, and all samples passed the test, demonstrating a complete absence of stepwise cracking, even under these more severely corrosive conditions.

The American Petroleum Institute (API) has promulgated specifications for tubular products, such as line pipe, that are to be used for oil and gas transmission, and that are to be used in other oil and gas service. In particular, API Specification 5LX is directed to high-strength welded or seamless steel line pipe for oil or gas transmission, a use for which the steel of the present invention is especially well suited.

Included in API 5LX are several material grades, such as X46, X52, X56, X60, X65 and X70. The numbers following the "X" in these designations are the minimum yield strengths (in ksi) for materials of the respective grades. Each material grade further has certain compositional requirements and tensile strength requirements.

The API 5LX material grades are specified when alloy steel pipe is to be used in gas or sour gas service. Steels of the present invention having compositions falling within the ranges set forth in Table I meet all compositional limitations set forth in API 5LX, and, as can be seen by the yield strength results set forth in

Table VII, steels can be produced to meet the requirements of all grades up through the X70 grade. Accordingly, the steels made in accordance with the present invention can be used as line pipe virtually
5 across the entire spectrum of the API 5LX linepipe specification. Further, with the demonstrated increased resistance to hydrogen-induced cracking over steels currently supplied under the 5LX specification, the steels of the present invention will be especially well
10 suited for use as 5LX linepipe (e.g. X52) in instances where, in addition to the material grade specification, requirements for resistance to hydrogen-induced cracking are specified or imposed.

It can thus be seen that the low carbon/low
15 manganese steels of the present invention possess the desirable properties for use in linepipe applications, especially in sour gas service. Because of its high strength and toughness, the steel is also well suited to being used as structural steel. However, the particular
20 embodiments and compositions discussed above are for illustrative purposes, and the invention is not intended to be limited to specific examples. Modifications may become readily apparent to those of ordinary skill in the art upon reviewing the foregoing specification, without
25 departing from the spirit and scope of the invention. Accordingly, reference should be made to the appended claims to determine the scope of the invention.

Claims

1. A high strength steel comprising:

<u>Element</u>	<u>Range (wt. %)</u>
C	0.015-0.080
Mn	0.10-0.55
Nb	0.005-0.15
Ti	0.005-0.030
N	0.001-0.01
and optionally	
Cr	≤ 0.50
Ni	≤ 0.95
Mo	≤ 0.60
B	≤ 0.0025
S	≤ 0.008
Ca	≤ 0.005
Si	≤ 0.210
P	≤ 0.025
Cu	≤ 0.25
Al	≤ 0.063
V	≤ 0.007

balance iron and impurities, the steel having a microstructure substantially free of coarse grained ferrite, a yield strength in the range 36 to 80 ksi and being resistant to H₂S degradation.

2. A high strength steel according to claim 1 and comprising:

<u>Element</u>	<u>Range (wt. %)</u>
C	0.015-0.050
Mn	0.10-0.55
Nb	0.03-0.09
Ti	0.015-0.025
N	0.001-0.005
Mo	≤ 0.10
B	≤ 0.0025
S	≤ 0.003
Ca	≤ 0.0025
P	≤ 0.008

balance iron and impurities, the steel having a microstructure substantially free of coarse grained ferrite, a yield strength in the range 36 to 80 ksi and being resistant to H₂S degradation.

3. A method for forming a steel, the method comprising continuously casting a steel having a composition according to claim 1 or 2 at a casting rate between 0.8 and 3.0 m/min, whereby the steel exhibits low manganese segregation intensity and resistance to stepwise cracking in an H₂S environment.

4. A linepipe formed from a high strength steel comprising:

<u>Element</u>	<u>Range (wt. %)</u>
C	0.015-0.080
Mn	0.10-1.0
Nb	0.005-0.15
Ti	0.005-0.030
N	0.001-0.01
and optionally	
Cr	≤ 0.50
Ni	≤ 0.95
Mo	≤ 0.60
B	≤ 0.0025
S	≤ 0.008
Ca	≤ 0.005
Si	≤ 0.210
P	≤ 0.025
Cu	≤ 0.25
Al	≤ 0.063
V	≤ 0.007

balance iron and impurities.

5. A linepipe according to claim 4, in which the steel comprises:

<u>Element</u>	<u>Range (wt. %)</u>
C	0.015-0.050
Mn	0.10-0.55
Nb	0.03-0.09
Ti	0.015-0.025
Mo	≤ 0.10
B	≤ 0.0009
S	≤ 0.003
N	0.001-0.005
Ca	≤ 0.0025
P	≤ 0.008

balance iron and impurities.

6. **A linepipe according to claim 4 or claim 5, in which the steel has a yield strength of 36 to 80 ksi and the linepipe meets the criteria of API specification 5LX.**

7. **A method for forming a steel for use in a linepipe, the method comprising continuously casting a steel having a composition as defined in claim 4, claim 5, or claim 6 at a casting rate between 0.8 and 3.0 m/min, whereby the steel exhibits low manganese segregation intensity and resistance to stepwise cracking in an H₂S environment.**

