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(71) Applicant: **CRS Holdings, Inc.**
Wilmington DE 19801 (US)

(72) Inventors:
- **Thompson, Peter**
  Sinking Sprint, PA Pennsylvania 19608 (US)
- **Pilliod, Christopher**
  Sinking Spring, PA Pennsylvania 19608 (US)

(74) Representative: **Gill, Stephen Charles et al**
Mewburn Ellis LLP
33 Gutter Lane
London
EC2V 8AS (GB)

(54) **Blast resistant, non-magnetic stainless steel armor**

(57) An article of manufacture formed of an alloy having the following weight percent composition is described.

Carbon	0.25 max.
Manganese	14-20
Silicon	up to 2.0
Phosphorus	0.05 max.
Sulfur	0.5 max.
Chromium	12-22
Nickel	3.5 max.
Molybdenum	0.5-4
Copper	2.0 max.
Nitrogen	0.2-0.8
Boron	0.06 max.

The balance of the alloy is iron and the usual, inevitable impurities found in commercial grades of stainless steel alloys. Optionally, the alloy may contain niobium, titanium, vanadium, zirconium, hafnium, and tungsten in a combined amount of up to about 0.5%. An intermediate form of the article is armor plate made from the alloy. In accordance with another aspect of the present invention, the plate is shaped to form an armor part that is attached to a larger structure to provide resistance to an explosion fragments or a ballistic projectile.

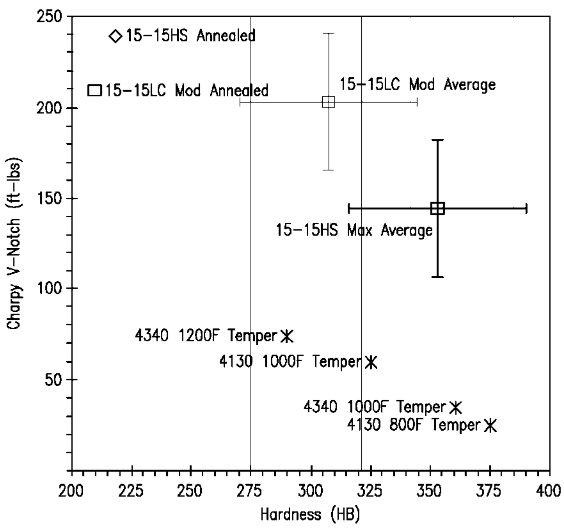

FIG. 1

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Description

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] This invention relates to blast resistant articles of manufacture and in particular to such an armor article made from a corrosion resistant, non-magnetic, high strength, high toughness steel alloy and to a process for making the armor article.

DESCRIPTION OF THE RELATED ART

[0002] The use of improvised explosive devices (IED's) and land mines by military insurgents causes significant destruction of military equipment and substantial injury and loss of life of military personnel. Because of such threats, a need has arisen among armored vehicle manufacturers for new blast-resistant materials which provide a better combination of strength with energy absorption capability than the materials currently in use. Energy absorption capability is related to the toughness of a material. The toughness of a material has been defined as the ability to absorb energy and deform plastically before fracturing. Two known families of materials used for blast resistant armor are martensitic steels and aluminum alloys. Martensitic steels provide high strength, but less than desirable energy absorption compared to aluminum alloys. On the other hand, aluminum alloys provide good energy absorption, but lower strength than martensitic steels. It is also desirable for the blast resistant material to be non-magnetic so that it would provide some protection from mines that are magnetically triggered.

[0003] Austenitic stainless steel alloys sold under the registered trademarks "15-15LC" and "15-15HS" are designed for and have been used exclusively for making components for the oil-drilling industry, primarily drill collars. The alloys sold under the marks "15-15LC" and "15-15HS" are described and claimed in U.S. Patent No. 3,904,401, U.S. Patent No. 5,094,812, and U.S. Patent No. 5,308,877.

SUMMARY OF THE INVENTION

[0004] In accordance with a first aspect of this invention there is provided a blast resistant armor article that is formed of an alloy having any of the following broad and preferred compositions in weight percent.

	Broad	Preferred 1	Preferred 2	Preferred 3
Carbon	0.25 max.	0.08 max.	0.05 max.	0.035 max.
Manganese	14-20	14-19	15-18	16-18
Silicon	up to 2.0	1 max.	1 max.	0.75 max.
Phosphorus	0.05 max.	0.05 max.	0.05 max.	0.05 max.
Sulfur	0.5 max.	0.03 max.	0.03 max.	0.03 max.
Chromium	12-22	12-21	14-19.5	16-18
Nickel	3.5 max.	3.5 max.	2.5 max.	1.5 max.
Molybdenum	0.5-4	0.5-4	0.75-2.5	1.0-2.0
Copper	2.0 max.	2.0 max.	1.5 max.	1.0 max.
Nitrogen	0.2-0.8	0.2-0.8	0.3-0.7	0.4-0.6
Boron	0.06 max.	0.06 max.	0.005 max.	0.005 max.

[0005] The balance of the alloy is iron and the usual, inevitable impurities found in commercial grades of stainless steel alloys. Optionally, the alloy may contain niobium, titanium, vanadium, zirconium, hafnium, and tungsten in a combined amount of up to about 0.5%. An intermediate form of the article is plate made from the alloy. In accordance with another aspect of the present invention, the plate is shaped to form an armor part that is attached to a larger structure to provide resistance to an explosion or a ballistic projectile.

[0006] In accordance with a further aspect of the present invention, there is provided a process for making armor plate for vehicles and other structures. The process includes the step of melting an alloy having any of the following broad and preferred weight percent compositions.

	Broad	Preferred 1	Preferred 2	Preferred 3
Carbon	0.25 max.	0.08 max.	0.05 max.	0.035 max.
Manganese	14-20	14-19	15-18	16-18
Silicon	up to 2.0	1 max.	1 max.	0.75 max.
Phosphorus	0.05 max.	0.05 max.	0.05 max.	0.05 max.
Sulfur	0.5 max.	0.03 max.	0.03 max.	0.03 max.
Chromium	12-22	12-21	14-19.5	16-18
Nickel	3.5 max.	3.5 max.	2.5 max.	1.5 max.
Molybdenum	0.5-4	0.5-4	0.75-2.5	1.0-2.0
Copper	2.0 max.	2.0 max.	1.5 max.	1.0 max.
Nitrogen	0.2-0.8	0.2-0.8	0.3-0.7	0.4-0.6
Boron	0.06 max.	0.06 max.	0.005 max.	0.005 max.
Iron	Balance	Balance	Balance	Balance

[0007] The "Balance" includes inevitable impurities found in commercial grades of stainless steel alloys. Optionally, the alloy may contain niobium, titanium, vanadium, zirconium, hafnium, and tungsten in a combined amount of up to about 0.5%. The alloy is hot worked to plate having a final thickness that provides a preselected level of strength and impact toughness. Alternatively, the alloy is hot worked to plate having an intermediate thickness. The intermediate thickness plate material is then preferably warm-worked to a final thickness that provides a preselected level of strength and impact toughness. The process further includes the step of shaping the warm-worked plate to form an armor part for a vehicle or other structure without annealing after the warm working step.

[0008] The foregoing tabulations are provided as convenient summaries and are not intended thereby to restrict the lower and upper values of the ranges of the individual elements of the alloy used in this invention for use solely in combination with each other or to restrict the various broad and preferred ranges of the elements for use solely in combination with each other. Thus, one or more of the broad and preferred ranges can be used with one or more of the other ranges for the remaining elements. In addition, a broad or preferred minimum or maximum for an element can be used with the maximum or minimum for that element from one of the remaining ranges. Throughout this application, the symbol "%" or "w/o" or the term "percent" means weight percent or mass percent unless otherwise indicated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The foregoing summary of the invention and the following detailed description will be better understood when read in conjunction with the drawings, wherein:

Figure 1 is a graph of Charpy V-notch toughness as a function of hardness for alloys used in the present invention compared to the known alloys.
Figure 2 is a schematic diagram of a passenger vehicle equipped with a blast protective armor article in accordance with the present invention.
Figure 3 is a schematic diagram of a .30 Cal armor piercing projectile.
Figure 4 is a schematic diagram of a .50 Cal fragment simulating projectile.
Figure 5 is a graph of .30 Cal APM2 V50 velocity as a function of the .50 Cal FSP V50 velocity for examples of armor plate made in accordance with the present invention.

DETAILED DESCRIPTION

[0010] An armor article according to this invention includes a shaped piece of steel plate. The steel plate is made from a high strength, corrosion resistant alloy have a weight percent composition that is within any of the broad or preferred weight percent ranges described above. The alloy used in the article according to the present invention provides substantial resistance to damage from explosions because it provides a unique combination of very high strength and high toughness. The toughness property is one measure of damage tolerance for armor material. The toughness of a material is typically evaluated based on the Charpy V-notch impact strength (CVN). CVN is determined in accordance with ASTM Standard Test Specification E 23. The hardness of a material is a measure of its strength. The harder a material is, the higher its strength is expected to be. Set forth in Figure 1 is a graph showing the CVN of certain alloys as a function of the hardness of the material.

[0011] The 15-15 LC Alloy and the 15-15 HS Alloy are alloys whose weight percent compositions are within the scope of the alloys used in the present invention as described in the Broad and Preferred ranges set forth above. Referring to

Figure 1, it is clear that the alloys used in the present invention provide significantly greater impact toughness than very high strength steels such as AISI 4340 and AISI 4130 which have variants that are currently used for armor applications. It is also seen from Figure 1, that the 15-15 LC alloy and the 15-15 HS alloy provide high strength in the unannealed condition that is at least as good as the very high strength alloys AISI 4340 and AISI 4130. The combinations of hardness and toughness illustrated in Figure 1 for the 15-15 LC alloy and for the 15-15 HS alloy are clearly superior to the combinations of those properties demonstrated for the AISI 4340 and AISI 4130 alloys. Moreover, the 15-15 LC alloy is nonmagnetic and so cannot set off a magnetically activated land mine or IED.

[0012] The alloys used in an article according to this invention are readily prepared by means of conventional, well-known techniques including powder metallurgy. Cast and wrought forms of the alloys are initially melted by electric arc melting (ARC) preferably followed by argon-oxygen decarburization (AOD) and cast as an electrode or as an ingot. In addition, the electrodes of this alloy may be further refined by electroslag remelting (ESR). After final melting is complete, the ingot is preferably homogenized and then formed into plate of a desired thickness. In this regard, the ARC or ESR ingot is initially hot worked to form an elongated slab. The slab is then further processed in either of two ways. In a first process, the slab is hot worked, preferably by rolling, pressing, or forging the slab until a plate having a desired thickness is obtained. The final thickness is selected such that the alloy receives a reduction in thickness (RIT) that is sufficient to provide a desired combination of strength, hardness, and toughness in the alloy plate. In the first process, the slab is preferably hot rolled to plate from a temperature of about 1500°F-2000°F (about 816°C-1093°C) down to a finish temperature of about 1100°F-1400°F (about 593°C-760°C). Preferably, the plate is rapidly cooled from the finish temperature such as by quenching with water or oil. The cooling should be conducted quickly after completion of the hot rolling to avoid further sensitization of the alloy. However, the inventors have determined that some sensitization of the alloy may be beneficial to the ballistic properties of the armor applications. The hot rolling step can be conducted in one or more passes with reheating as necessary if the finish temperature is reached before the desired thickness is obtained.

[0013] In the second process, the slab is hot worked, again preferably by rolling, pressing, or forging the slab to an elongated plate having an intermediate thickness. The hot working step is preferably conducted from a start temperature of about 1700°F-2200°F (about 927°C-1204°C) down to a finish temperature of about 1600°F-1900°F (about 871°C-1038°C). Preferably, the intermediate thickness plate is rapidly cooled as above, preferably within minutes after completion of the hot rolling step in order to avoid sensitization of the alloy. The intermediate thickness plate material is preferably annealed at about 1600°F-2350°F (about 871°C-1288°C) for about 30 minutes per inch of thickness and then water cooled to room temperature. The annealed intermediate plate is then warm-worked, again preferably by rolling, pressing, or forging, at a temperature of about 800°F-1200°F (about 427°C-649°C) to an RIT that is sufficient to provide the desired combination of strength and toughness in the as-worked material. The warm-worked plate is quenched, as in water, but is not subsequently annealed. The amount of warm working applied to the alloy, i.e., the percent RIT, is selected based on the level of hardness and strength to be provided by the armor article. The greater the RIT is the greater will be the strength and toughness of the alloy plate. It is anticipated that the plate material produced in accordance with this invention will provide a Brinell hardness (BHN) of about 275-400.

[0014] After the plate material is formed, it is cut into parts which are shaped by bending operations, for example. The shaped parts are then machined as necessary and attached to a vehicle or other object by any known technique such as by welding or with fasteners such as bolts, screws, or rivets. Armor articles made in accordance the present invention, exhibit an outstanding combination of properties including very high strength and toughness, good corrosion resistance, and good non-magnetic behavior. It is contemplated that armor articles made in accordance with this invention can be used in or on a wide variety of vehicles and other objects for which blast resistance/tolerance is needed. Military vehicles such as tanks, trucks, personnel carriers, aircraft, ships, and submarines are all suitable candidates for receiving armor articles made according to the invention. In addition, civilian security vehicles would also benefit from the use of armor articles according to the invention. Shown in Figure 2 is an arrangement for an armored vehicle made in accordance with the present invention. The vehicle includes a passenger compartment that is supported on a floor. An armor substructure made in accordance with the present invention is mounted beneath the vehicle floor. The armor substructure provides a blast resistant barrier to protect the passenger compartment from the effects of an exploding IED or mine. Buildings and architectural features such as doors can also be fitted with armor articles in accordance with this invention. It is also contemplated that the armor articles of this invention can be used in luggage, storage containers and containment trashcans for nuclear waste and other types of hazardous waste that may be transported on public roads or rail lines.

<u>Working Examples</u>

[0015] In order to demonstrate the process and product of the present invention, two heats were melted and processed into plate. The plate material was then tested to determine the relevant mechanical properties, ballistic tolerance, and blast resistance of the as-processed material. The weight percent compositions of the two heats are set forth in Table 1 below.

TABLE 1

Element	Heat 1	Heat 2
C	0.035	0.027
Mn	17.99	18.41
Si	0.36	0.37
P	0.022	0.028
S	0.001	<0.001
Cr	17.66	18.56
Ni	0.94	1.97
Mo	0.77	0.74
Cu	0.06	0.06
N	0.52	0.57
B	0.0019	0.0024

[0016] The balance of each heat is iron and usual impurities. Heat 1 was ARC-AOD melted whereas Heat 2 was ARC-ESR melted.

Example 1

[0017] The objective of this example was to produce plate material in accordance with the first process described above. Material from the ingot of Heat 1 and from the ingot of Heat 2 was hot worked to provide slabs 2.58 inches (6.55 cm) thick. The slab formed from Heat 1 was heated to a temperature of 1650°F (899°C) and hot rolled to 0.55 inch (13.97 mm) thick plate. The slab formed from Heat 2 was heated to a temperature of 1650°F (899°C) and hot rolled to 0.53 inch (13.5 mm) thick plate. For both heats, the plate material was quenched with water within about 10 minutes of the last rolling pass. Longitudinal and transverse samples for hardness, tensile, and toughness testing were cut from the plates and machined to form standard size test specimens. The results of room temperature hardness, tensile, and Charpy V-notch toughness testing are shown in Tables 2A and 2B below including the Brinell hardness number (BHN), the 0.2% offset yield strength (YS) and ultimate tensile strength (UTS) in ksi, the percent elongation (%El.), the percent reduction in area (%R.A.), and the Charpy V-notch impact strength in foot-pounds (ft-lbs). The value for BHN is the average of five (5) different readings. The CVN values are presented as the average of four (4) tests.

TABLE 2A

	Longitudinal					
	BHN	Y.S.	U.T.S.	%El.	%R.A.	CVN
Heat 1	339	142.3	157.6	34	60	38.3
Heat 2	353	149.9	165.2	34	63	62.7

TABLE 2B

	Transverse					
	BHN	Y.S.	U.T.S.	%El.	%R.A.	CVN
Heat 1	339	130.7	151.3	34	63	43.5
Heat 2	353	143	160.4	31	60	40.7

Example 2

[0018] The objective of this example was to produce plate material using the two-step process described above. Additional material from the ingot of Heat 2 was hot worked to provide slabs nominally 5 inches (12.7 cm) thick. The slabs were then hot rolled to intermediate thicknesses. A first slab was hot rolled from a start temperature of about 2100°F (1149°C) to an intermediate thickness of about 0.72 inches (18.3 mm). A second slab was rolled from a start temperature of about 2100°F (1149°C) to an intermediate thickness of about 0.905 inches (23 mm). A third slab was rolled from a start temperature of about 2100°F (1149°C) to an intermediate thickness of about 1.25 inches (31.75 mm). A fourth slab was rolled from a start temperature of about 2100°F (1149°C) to an intermediate thickness of about 2.55 inches (6.48 cm). The intermediate forms were rapidly cooled with water within about 5 minutes of completion of the last rolling pass on each intermediate slab. After the intermediate hot rolling, the slabs were annealed at a temperature of about 1832°F (1000°C) for about 30 minutes per inch of thickness and then water cooled.

[0019] The annealed intermediate forms were then warm worked from a start temperature of about 800°F to about 1200°F (426.7°C to 649°C) to impart RIT's ranging from about 15% to about 85%. More specifically, the 0.72-inch (18.3 mm) thick slab was warm worked from a temperature of about 1100 °F (593°C) to a thickness of about 0.55 inches (13.97 mm) representing an RIT of about 24%. The 0.905-inch (23 mm) thick slab was warm worked from a temperature of about 1100 °F (593°C) to a thickness of about 0.55 inches (13.97 mm) representing an RIT of about 41 %. The 1.25-inch (31.75 mm) thick slab was warm worked from a temperature of about 1100 °F (593°C) to a thickness of about 0.55 inches (13.97 mm) representing an RIT of about 56%. The 2.55-inch (6.48 cm) thick slab was warm worked from a temperature of about 1100 °F (593°C) to a thickness of about 0.55 inches (13.97 mm) representing an RIT of about 78%. The hot rolled plates were cooled in air.

[0020] Longitudinal and transverse samples for hardness, tensile, and toughness testing were cut from the plates and machined to form standard size test specimens. The results of room temperature hardness, tensile, and Charpy V-notch toughness testing are shown in Tables 3A and 3B below including the Brinell hardness number (BHN), the 0.2% offset yield strength (YS) and the ultimate tensile strength (UTS) in ksi, the percent elongation (%El.), and the Charpy V-notch impact strength in foot-pounds (ft-lbs). The value for BHN is the average of five (5) different readings. The CVN values are presented as the average of three (3) tests.

TABLE 3A

Longitudinal						
RIT	**BHN**	**Y.S.**	**U.T.S.**	**%El.**		**CVN**
24%	351	125.7	160.1	38		131
41%	373	146.7	176.2	33		120.3
56%	406	167.9	188.4	28		48.7
78%	419	165	198.1	27		18

TABLE 3B

Transverse						
RIT	**BHN**	**Y.S.**	**U.T.S.**	**%El.**		**CVN**
24%	351	149.4	164.3	39		42.3
41%	373	143.8	175.6	33		33.0
56%	406	152.3	185.3	29		27.3
78%	419	163	195.9	27		16.7

[0021] The combination of hardness, strength, and toughness provided by an armor article made in accordance with the present invention makes the armor highly resistant to both armor piercing projectiles and blast fragments such as from IED's. Specimens of the armor plate produced in the examples were tested to determine the V50 velocity for both armor piercing rounds (.30 cal APM2) and fragment simulating projectiles (FSP) fired normal to the plane of the armor tested in accordance with MIL-STD-662F. The V50 velocity is defined as the projectile velocity at which 50% of projectiles impacting the armor will defeat the armor such as by penetration. A typical APM2 round used for the ballistic testing is shown in Figure 3. A typical FSP projectile used for the blast resistance testing is shown in Figure 4. The combination of .50 Cal FSP V50 and .30 Cal APM2 V50 provided by 0.55-inch thick armor plate samples prepared in accordance with the present invention is shown in Figure 5. The data points are for samples having different combinations of melting technique, annealing temperature, and percent RIT as described above. Data points near the upper right hand corner of the graph represent the best combination of APM2 and FSP V50 velocities.

[0022] It will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiments without departing from the broad inventive concepts of the invention. It is understood, therefore, that the invention is not limited to the particular embodiments that are described.

Claims

1. A blast resistant armor article formed of a high strength, high toughness, stainless steel alloy having the following composition in weight percent, about

Carbon	0.25 max.
Manganese	14-20
Silicon	up to 2.0
Phosphorus	0.05 max.
Sulfur	0.5 max.
Chromium	12-22
Nickel	3.5 max.
Molybdenum	0.5-4
Copper	2.0 max.
Nitrogen	0.2-0.8
Boron	0.06 max.

said alloy optionally containing niobium, titanium, vanadium, zirconium, hafnium, and tungsten in a combined amount of up to about 0.5%; and the balance of the alloy is iron and usual impurities.

2. An armor article as claimed in Claim 1 wherein the article comprises plate made from the alloy.

3. An armor article as claimed in Claim 1 wherein the article comprises plate made from the alloy and said plate is shaped to form an armor part for attachment to a larger structure to provide resistance to damage from an explosion blast, an explosion fragment, or a ballistic projectile.

4. An armor article as claimed in any of Claims 1 to 3 wherein the alloy comprises the following elements in weight percent,

Carbon	0.08 max.
Manganese	14-19
Silicon	1 max.
Phosphorus	0.05 max.
Sulfur	0.03 max.
Chromium	12-21
Nickel	3.5 max.
Molybdenum	0.5-4
Copper	2.0 max.
Nitrogen	0.2-0.8
Boron	0.06 max.

5. An armor article as claimed in any of Claims 1 to 3 wherein the alloy comprises the following elements in weight percent,

Carbon	0.05 max.
Manganese	15-18
Silicon	1 max.
Phosphorus	0.05 max.
Sulfur	0.03 max.
Chromium	14-19.5
Nickel	2.5 max.
Molybdenum	0.75-2.5
Copper	1.5 max.
Nitrogen	0.3-0.7
Boron	0.005 max.

6. An armor article as claimed in any of Claims 1 to 3 wherein the alloy comprises the following elements in weight percent,

Carbon	0.035 max.
Manganese	16-18
Silicon	0.75 max.
Phosphorus	0.05 max.
Sulfur	0.03 max.
Chromium	16-18
Nickel	1.5 max.
Molybdenum	1.0-2.0
Copper	1.0 max.
Nitrogen	0.4-0.6
Boron	0.005 max.

7. A process for making an armor component comprising the steps of:

melting an alloy having the following weight percent composition, about

Carbon	0.25 max.
Manganese	14-20
Silicon	up to 2.0
Phosphorus	0.05 max.
Sulfur	0.5 max.
Chromium	12-22
Nickel	3.5 max.
Molybdenum	0.5-4
Copper	2.0 max.
Nitrogen	0.2-0.8
Boron	0.06 max.

said alloy optionally containing niobium, titanium, vanadium, zirconium, hafnium, and tungsten in a combined amount of up to about 0.5%, and the balance of the alloy is iron and usual impurities;
casting the alloy into a mold to form an ingot; and then
mechanically working said alloy ingot to form plate.

8. The process claimed in Claim 7 wherein the step of mechanically working the alloy ingot comprises the steps of:

hot working the ingot to form a slab;
hot working the slab to form the plate; and then
cooling the as-formed plate at a cooling rate that is fast enough to avoid substantial sensitization of the alloy; and
wherein the step of hot working the slab is performed such that the alloy receives a reduction in thickness selected to provide a combination of strength, hardness, and toughness in said plate after said cooling step sufficient to resist damage from an explosion blast, an explosion fragment, or a ballistic projectile, when tested in accordance with MIL-STD-662F.

9. The process claimed in Claim 8 wherein the step of hot working the slab comprises the steps of:

heating the slab to a starting temperature of about 816°C-1093°C (1500-2000°F); and then
reducing the thickness of the slab from the starting temperature down to a finish temperature of about 593°C-760°C (1100-1400°F).

10. The process claimed in Claim 7 wherein the step of mechanically working the alloy ingot comprises the steps of:

hot working the ingot to form a slab;
hot working the slab to form an intermediate thickness plate;
warm working the intermediate thickness plate to provide a final thickness plate; and then cooling the warm-worked plate;
wherein the step of warm working the intermediate thickness plate is performed such that the alloy receives a reduction in thickness selected to provide a combination of strength, hardness, and toughness in said final thickness plate after said cooling step sufficient to resist damage from an explosion blast, explosion fragment, or a ballistic projectile, when tested in accordance with MIL-STD-662F.

11. The process claimed in Claim 10 wherein the step of hot working the slab to intermediate thickness plate comprises the steps of
heating the slab to a start temperature of about 927°C-1204°C (1700-2200°F);
reducing the thickness of the slab from the starting temperature down to a finish temperature of about 871°C-1038°C (1600-1900°F); and then
cooling the intermediate thickness plate at a cooling rate that is fast enough to avoid sensitization of the alloy.

12. The process claimed in Claim 11 wherein after said step of cooling the intermediate thickness plate, the alloy is annealed at about 871°C-1288°C (1600-2350°F).

13. The process claimed in any one of claims 10 to 12 wherein the warm working step is carried out at a temperature of about 427°C-649°C (800-1200°F).

14. The process claimed in any one of claims 10 to 13 wherein after said warm working step, the final thickness plate is cooled at a cooling rate that is fast enough to avoid substantial sensitization of the alloy.

15. The process claimed in any of Claims 7 to 14 comprising the steps of forming the plate into an armor part; and then attaching the armor part to a vehicle, a building structure, or a containment vessel.

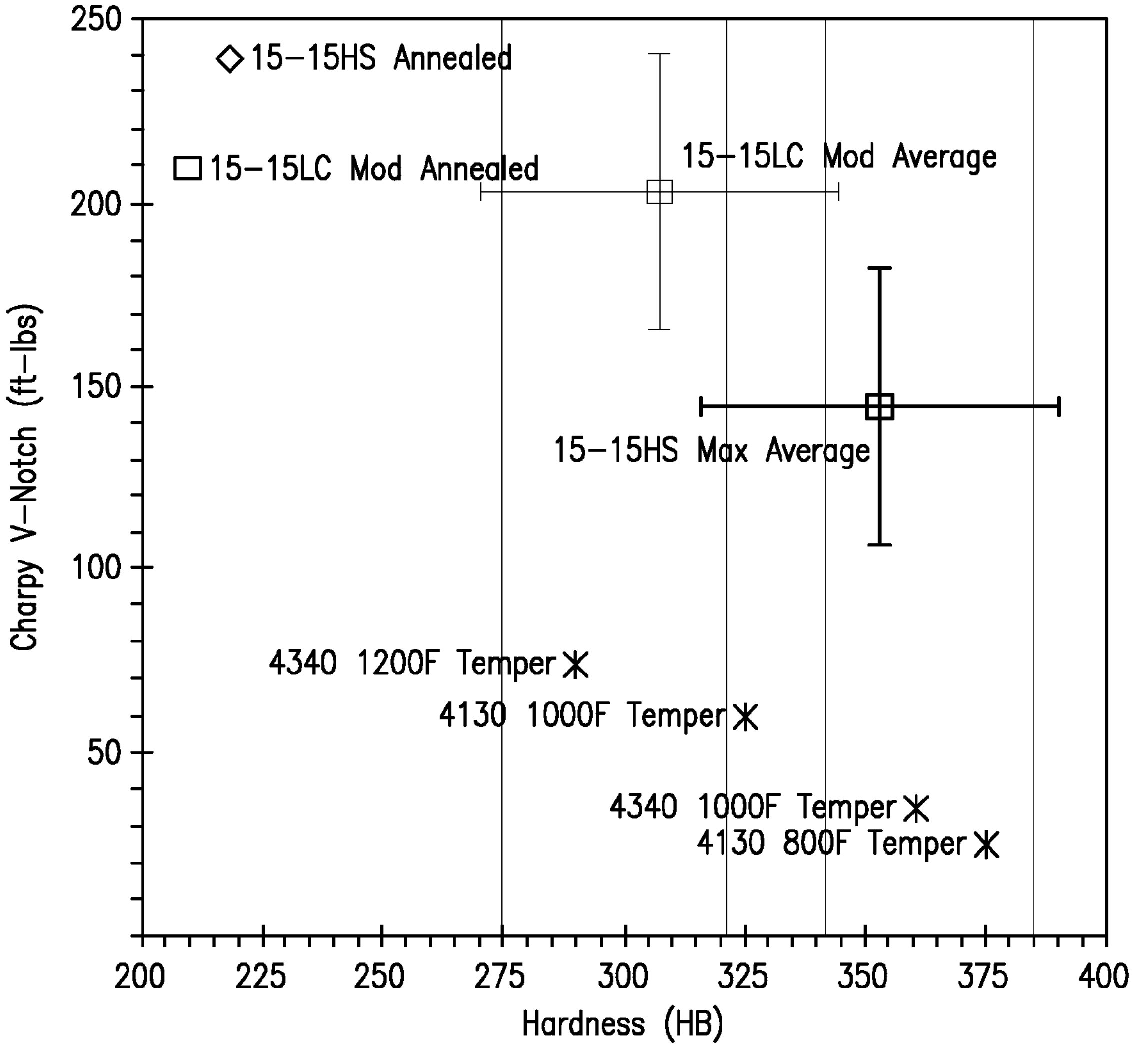
15-15HS Annealed
15-15LC Mod Annealed
15-15LC Mod Average
15-15HS Max Average
4340 1200F Temper
4130 1000F Temper
4340 1000F Temper
4130 800F Temper
Charpy V-Notch (ft-lbs)
250
200
150
100
50
200
225
250
275
300
325
350
375
400
Hardness (HB)

FIG. 1

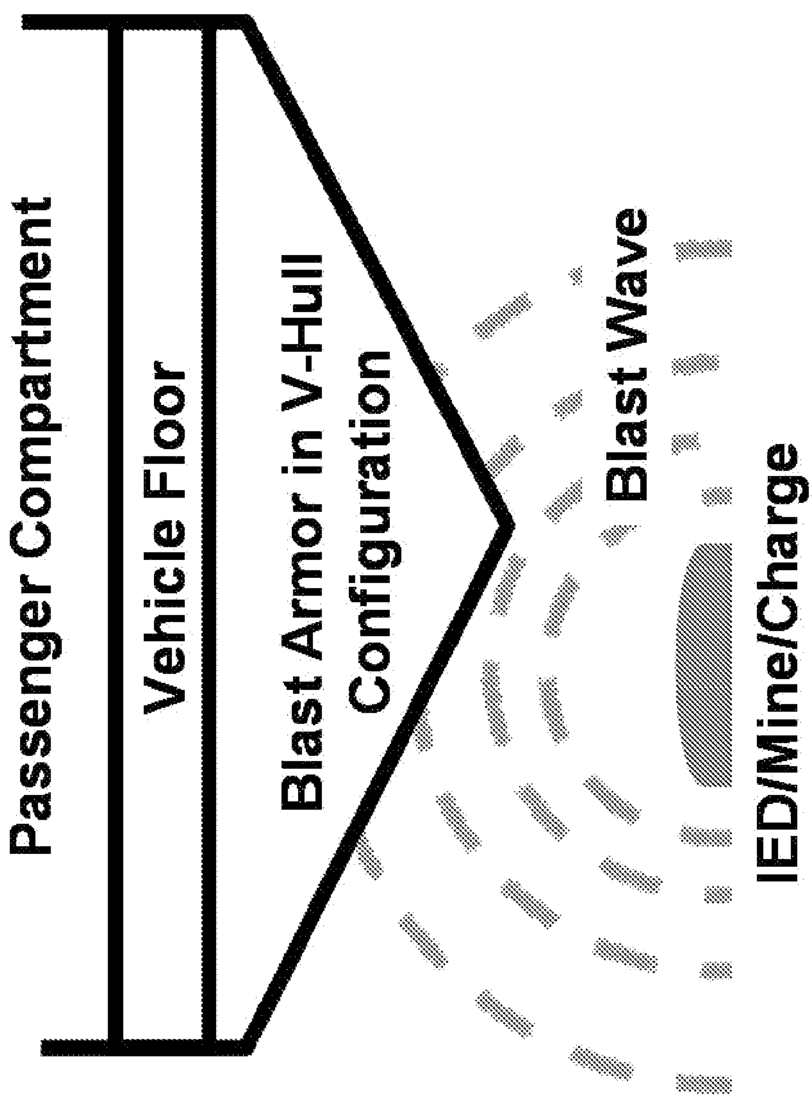
Passenger Compartment
Vehicle Floor
Blast Armor in V-Hull
Configuration
Blast Wave
IED/Mine/Charge

FIGURE 2

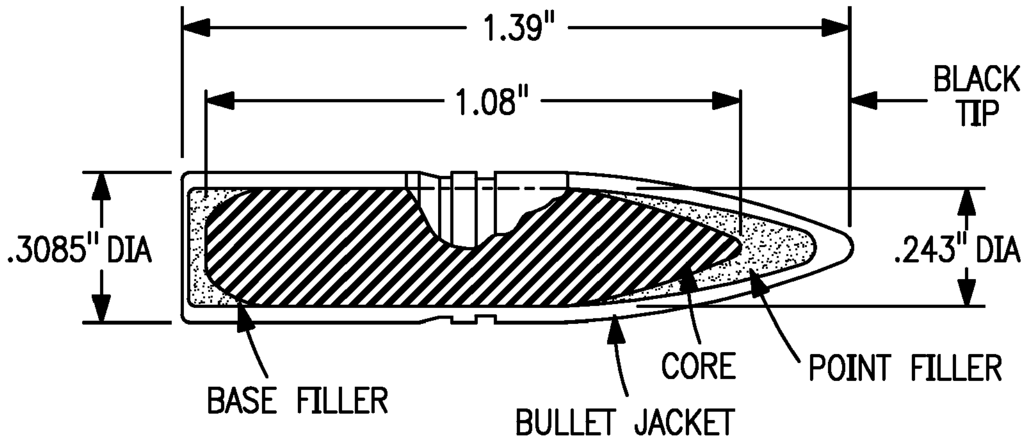
1.39"
1.08"
BLACK TIP
.3085" DIA
.243" DIA
BASE FILLER
CORE
POINT FILLER
BULLET JACKET

FIG. 3

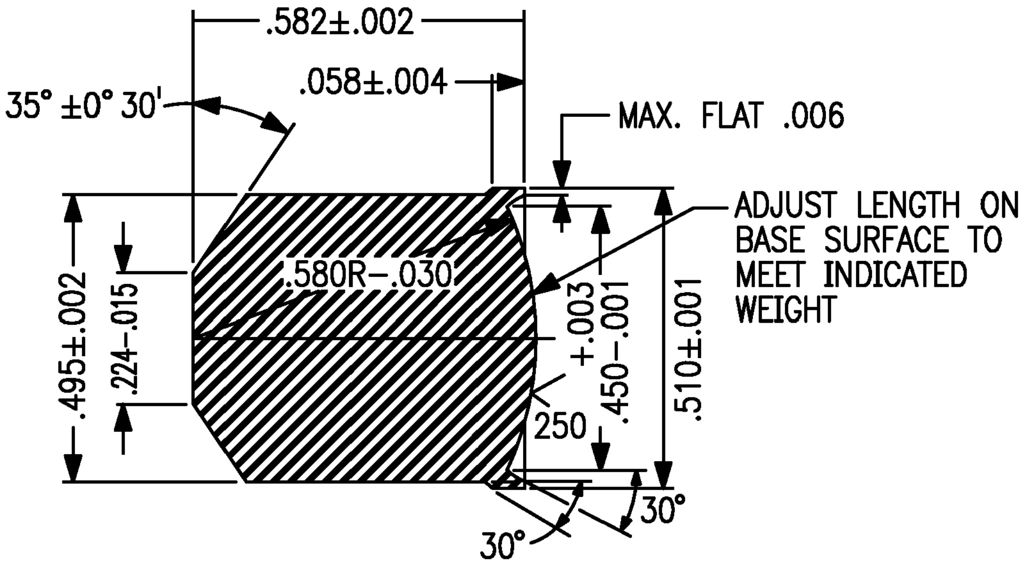
.582±.002
.058±.004
35° ±0° 30'
MAX. FLAT .006
ADJUST LENGTH ON BASE SURFACE TO MEET INDICATED WEIGHT
.580R-.030
.495±.002
.224-.015
+.003
.450-.001
.510±.001
250
30°
30°

FIG. 4

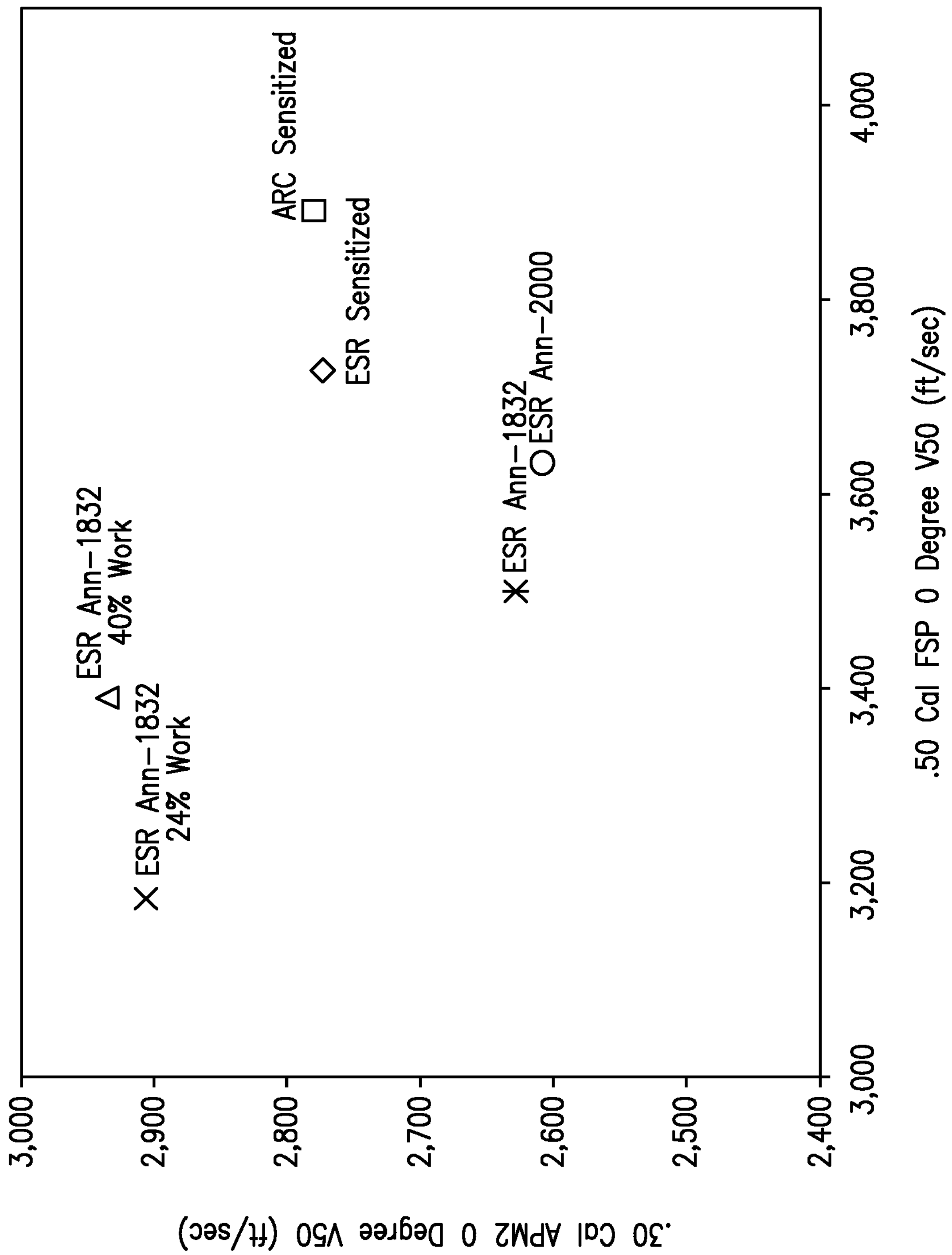
ARC Sensitized
ESR Sensitized
ESR Ann-1832
ESR Ann-2000
ESR Ann-1832
40% Work
ESR Ann-1832
24% Work
3,000
3,200
3,400
3,600
3,800
4,000
.50 Cal FSP 0 Degree V50 (ft/sec)
2,400
2,500
2,600
2,700
2,800
2,900
3,000
.30 Cal APM2 0 Degree V50 (ft/sec)

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 11 17 1129

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	DE 10 2008 005803 A1 (UNIV FREIBERG TECH BERGAKAD [DE]) 23 July 2009 (2009-07-23) * claim 1 * * paragraph [0001] * * paragraph [0036] *	1,7 1-15	INV. C21D6/00 C21D9/42 C22C38/38 C22C38/58 F41H5/00 C21D8/02
X Y	DE 196 07 828 A1 (VSG EN & SCHMIEDETECHNIK GMBH [DE] VSG EN UND SCHMIEDETECHNIK GMB [DE]) 17 October 1996 (1996-10-17) * page 2, lines 56-63 * * abstract; claim 1 *	1-5,7-15 1-15	
X Y	DE 728 159 C (BOEHLER & CO AG GEB) 21 November 1942 (1942-11-21) * claims 1,2 * * page 2, lines 84-91 *	1,7 1-15	
Y,D	US 3 904 401 A (MERTZ DAVID L ET AL) 9 September 1975 (1975-09-09) * column 4, lines 30-43 * * column 4, lines 44-54 * * the whole document *	1-15	TECHNICAL FIELDS SEARCHED (IPC) C21D C22C F41H

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	11 October 2011	Ugarte, Eva

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 17 1129

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The members are as contained in the European Patent Office EDP file on
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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