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POTENTIEL DE RECHAUFFEMENT DU GLOBE REDUIT
(54) Title: BLANKETING METALS AND ALLOYS AT ELEVATED TEMPERATURES WITH GASES HAVING REDUCED
GLOBAL WARMING POTENTIAL

(57) **Abrégé/Abstract:**

An improved method of processing a nonferrous metal and alloys of said metal using a blanketing gas having a global warming potential is provided. The improvement involves reducing the global warming potential of the blanketing gas by blanketing the nonferrous metal and alloys with a gaseous mixture including at least one compound selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 .



ABSTRACT OF THE DISCLOSURE

5 An improved method of processing a nonferrous metal and alloys of said metal
using a blanketing gas having a global warming potential is provided. The improvement
involves reducing the global warming potential of the blanketing gas by blanketing the
nonferrous metal and alloys with a gaseous mixture including at least one compound
selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$,
10 SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 .

TITLE OF THE INVENTION:

BLANKETING METALS AND ALLOYS AT ELEVATED TEMPERATURES
WITH GASES HAVING REDUCED GLOBAL WARMING POTENTIAL

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BACKGROUND OF THE INVENTION

The present invention pertains to the blanketing of metals and alloys with gaseous mixtures, and in particular to a method of blanketing metals and alloys at elevated temperatures using gases having reduced global warming potentials relative to the prior art.

Open top vessels such as crucible and induction furnaces used to melt nonferrous metals are operated so that the surface of metal during melting and the surface of the molten bath are exposed to ambient atmosphere. Air in the atmosphere tends to oxidize the melt, thereby: causing loss of metal, loss of alloying additions and formation of slag that causes difficulty in metal processing; shortening refractory life; and promoting nonmetallic inclusions in final castings, pickup of unwanted gases in the metals, porosity, and poor metal recovery. One solution is to enclose the melt furnace in a vacuum or atmosphere chamber for melting and/or processing of the metals. However, completely enclosed systems are very expensive and limit physical and visual access to the metals being melted.

As alternatives, liquid fluxing salts, synthetic slag, charcoal covers, and similar methods and compounds have been used in the high-volume, cost-sensitive field of metal reprocessing for minimizing metal oxidation, gas pickup, and loss of alloying additions. For example, the prior art teaches that rapid oxidation or fire can be avoided
5 by the use of fluxes that melt or react to form a protective layer on the surface of the molten metal. However, this protective layer of thick slag traps good metal, resulting in a loss of up to 2% of the melt. It also can break up and be incorporated into the melt, creating damaging inclusions. In addition, metal in the slag is leachable and creates a hazardous waste product.

10 These prior art techniques also necessitate additional handling and processing, and cause disposal problems. These techniques often reduce furnace life or ladle refractory life, increase frequency of shutdowns for relining or patching of refractories, and produce non-metallic inclusions that have to be separated from the metal bath prior to pouring of the metal into a cast shape.

15 In searching for solutions to the above-described problems, metallurgical industries turned to inert gas atmosphere blanketing. One type of gas blanketing system is based on gravitational dispersion of cryogenically-liquified inert gas over the surface of a hot metal to be blanketed. For example, such cryogenic blanketing systems are disclosed and claimed in U.S. Pat. No. 4,990,183.

20 U.S. Pat. No. 5,518,221 discloses a method and apparatus for inerting the interior space of a vessel containing hot liquids or solids in induction furnaces, crucible furnaces or ladles during charging, melting, alloying, treating, superheating, and pouring or tapping of metals and metal alloys. The method and apparatus employ a swirl of inert gas to blanket or cover the surface of the metal from the time of charging of the furnace
25 until the furnace is poured or tapped or inerting of the molten metal contained in a furnace or ladle or other vessel. The gas swirl is confined by a unique apparatus

mounted on top of the furnace or vessel containing the material to be protected. Any inert gas that is heavier than air can be used to practice the invention. In addition to argon and nitrogen, depending upon the material being blanketed, gases such as carbon dioxide and hydrocarbons may be used.

5 While some cryogenic blanketing systems are quite effective, use of such systems is limited to metallurgical facilities and vessels that can be supplied by well-insulated cryogenic pipelines or equipped with cryogenic storage tanks in close proximity to the point of use of the liquid cryogen. This is not always practical, and some cryogenic blanketing systems have been plagued by poor efficiency due to premature boil-off of the
10 cryogenic liquid and oversimplified design of dispersing nozzles that wasted the boiled-off gas.

 Moreover, cryogenic dispensers often fail to uniformly disperse the cryogenic liquid over the blanketed surface, leading to a transient accumulation or entrapment of the liquid in pockets under the slag or dross, which may result in explosions in a
15 subsequent rapid boil-off.

 Other approaches have been taken for different molten metals and alloys in further attempts to solve the above-described problems. For example, U.S. Pat. No. 4,770,697 discloses a process for protecting an aluminum-lithium alloy during melting, casting and fabrication of wrought shapes by enveloping the exposed surfaces with an
20 atmosphere containing an effective amount of a halogen compound (e.g., dichlorodifluoromethane) having at least one fluorine atom and one other halogen atom; the other halogen atom is selected from the group consisting of chlorine, bromine, and iodine, and the ratio of fluorine to the other halogen atom in the halogen compound is less than or equal to one. A passivating and self-healing viscous liquid layer is formed
25 which protects the alloy from lithium loss due to vaporization, oxidation of the alloy, and hydrogen pick-up by the alloy.

Another approach for some molten metals, such as magnesium, is to use inhibitors in the air. The early practice was to burn coke or sulfur to produce a gaseous agent, CO₂ or SO₂. An atmosphere of CO₂ was found to be superior to the commonly used commercial atmospheres of N₂, Ar, or He because of the absence of vaporization
5 of the magnesium, the absence of excessive reaction products, and the reduced necessity for the enclosure above the molten metal to be extremely air tight.

However, the use of these inhibitors has several drawbacks. For example, both CO₂ and SO₂ pose environmental and health problems, such as breathing discomfort for personnel, residual sludge disposal, and a corrosive atmosphere detrimental to both
10 plant and equipment. Furthermore, SO₂ is toxic, corrosive, and can cause explosions.

While BF₃ has been mentioned as being a very effective inhibitor, it is not suitable for commercial processes because it is extremely toxic and corrosive. Sulfur hexafluoride (SF₆) also has been mentioned as one of many fluorine-containing compounds that can be used in air as an oxidation inhibitor for molten metals, such as
15 magnesium. A summary of industry practices for using SF₆ as a protective atmosphere, ideas for reducing consumption and emissions, and comments on safety issues related to reactivity and health are provided in *"Recommended Practices for the Conservation of Sulfur Hexafluoride in Magnesium Melting Operations,"* published by the International Magnesium Association (1998) as a "Technical Committee Report" (hereinafter "IMA
20 Technical Committee Report").

The use of pure SF₆ was generally discarded because of its severe corrosive attack on ferrous equipment. In addition, the use of pure SF₆ for protecting molten metals such as magnesium has been reported to have caused explosions. Although sulfur hexafluoride (SF₆) is considered physiologically inert, it is a simple asphyxiant which acts
25 by displacing oxygen from the breathing atmosphere.

Later, it was found that at low concentrations of SF_6 in air (<1%), a protective thin film comprising MgO and MgF_2 is formed on the magnesium melt surface. Advantageously, even at high temperatures in air, SF_6 showed negligible or no reactions.

However, the use of SF_6 and air has some drawbacks. The primary drawback is
5 the release to the atmosphere of material having a high global warming potential (GWP).

It also was found that CO_2 could be used together with SF_6 and/or air. A gas atmosphere of air, SF_6 , and CO_2 has several advantages. First, this atmosphere is non-toxic and non-corrosive. Second, it eliminates the need to use salt fluxes and the need to dispose of the resulting sludge. Third, using such an atmosphere results in lower
10 metal loss, elimination of corrosion effects, and clean castings. Fourth, a casting process using such an atmosphere provides a clean operation and improved working conditions. Fifth, the addition of CO_2 to the blanketing atmosphere reduces the concentration of SF_6 at which an effective inerting film is formed on the metal. In sum, the addition of CO_2 to an air/ SF_6 atmosphere provides much improved protection compared to the protection
15 obtained with an air/ SF_6 atmosphere.

However, using an atmosphere of SF_6 and CO_2 also has disadvantages. Both SF_6 and CO_2 are greenhouse gases, *i.e.*, each has a global warming potential over 100 years (GWP_{100}). Thus, there is a need to reduce the amounts of SF_6 and CO_2 released into the atmosphere. SF_6 has a 100-year global warming potential (GWP_{100}) of 23,900
20 relative to CO_2 . International concern over global warming has focused attention on the long atmospheric life of SF_6 (about 3,200 years, compared to 50-200 years for CO_2) together with its high potency as a greenhouse gas (23,900 times the GWP_{100} of CO_2 on a mole basis) and has resulted in a call for voluntary reductions in emissions. Because of this, the use of SF_6 is being restricted and it is expected to be banned in the near
25 future. In addition, SF_6 is a relatively expensive gas.

Some of the best alternatives to SF_6 for blanketing gases would be perfluorocarbons, such as CF_4 , C_2F_6 , and C_3F_8 , but these materials also have high GWP's. Other alternatives would be chlorofluorocarbons (CFC's) or partially fluorinated hydrocarbons (HCFC's). However, the use of CFC's and HCFC's also is restricted; most
5 of these materials are banned as ozone depleters under the Montreal Protocol.

Another alternative to SF_6 for a blanketing gas is SO_2 . When SO_2 is used as a blanketing gas, the effective concentration over a melt is typically in the range of about 30% to 70% SO_2 , with about 50% being normal. However, as discussed earlier, SO_2 poses environmental and health problems, is toxic, and can cause explosions. In
10 addition, the use of SO_2 in such relatively high concentrations can cause corrosion problems on furnace walls.

Even when metals and alloys containing high levels of nonferrous metals, such as alloy AZ61 (5.5-6.5% Al, 0.2-1.0% Zn, 0.1-0.4% Mn, (balance Mg), are exposed to high temperatures for purposes of solution heat treating, annealing, or in preparation for
15 rolling, forging, or other processing, it has been found advantageous to protect the metal or the shape with an atmosphere that will inhibit undesirable surface oxidation or ignition, as is taught in U.S. Pat. No. 6,079, 477.

It also has been found desirable to protect such metals and alloys when they are in a highly divided form, such as powders or chips, and are being fed into metals
20 processing systems prior to melting, as is taught in International Publication No. WO 00/00311.

It is desired to have a process for preventing oxidation of molten metals and alloys which overcomes the difficulties and disadvantages of the prior art to provide better and more advantageous results.

It is further desired to have an improved method of processing metals and alloys at elevated temperatures using blanketing gases having lower global warming potentials than the gases used in prior art methods.

It also is desired to have an improved method of processing metals and alloys at
5 elevated temperatures using blanketing gases which overcomes the difficulties and disadvantages of the prior art to provide better and more advantageous results.

BRIEF SUMMARY OF THE INVENTION

A first embodiment of the present invention is an improvement in a method of
10 processing a nonferrous metal and alloys of the metal using a blanketing gas having a global warming potential. The improvement comprises reducing the global warming potential of the blanketing gas by blanketing the nonferrous metal and alloys with a gaseous mixture including at least one compound selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF ,
15 F_2 and SF_4 .

There are several variations of the first embodiment of the improvement in the method. In one variation, the at least one compound is provided at a first concentration of less than about 10% on a mole basis of the gaseous mixture. In addition, there may be several variants of that variation. In one variant, the first concentration is less than
20 about 6%. In another variant, the first concentration is less than about 3%. In yet another variant, the first concentration is greater than about 0.1% and less than about 1%.

In another variation, the gaseous mixture further comprises at least one member selected from the group consisting of N_2 , Ar, CO_2 , SO_2 and air. In a variant of that
25 variation, the at least one member is CO_2 provided at a second concentration of about 30% to about 60% on a mole basis. In a variant of that variant, the at least one

compound is provided at the first concentration of less than about 3% on a mole basis and is selected from the group consisting of SO_2F_2 and COF_2 .

In yet another variation, the gaseous mixture used in the method also includes an odorant. And in another variation, at least a portion of the gaseous mixture is recovered
5 for reuse.

In still yet another variation, the nonferrous metal and alloys have a temperature of at least about $0.5 \times T_{\text{melt}}$ (in degrees Kelvin). In addition, there are several variants of this variation. In one variant, the temperature is at least about $0.7 \times T_{\text{melt}}$ (in degrees Kelvin). In another variant, the temperature is a solidus temperature of the metal and
10 alloys. In yet another variant, the temperature is greater than a solidus temperature of the metal and alloys but less than a liquidus temperature of the metal and alloys. In still yet another variant, the temperature is greater than a liquidus temperature of the metal and alloys but less than about $2.0 \times T_{\text{boiling}}$ (in degrees Kelvin).

Another aspect of the present invention is a method as in the first embodiment of
15 the improvement in the method, wherein at least one operation is performed on the nonferrous metal and alloys, the at least one operation being selected from the group consisting of melting, holding, alloying, ladling, stirring, pouring, casting, transferring and annealing of the nonferrous metal and alloys.

The present invention also includes an improvement in a method of processing a
20 melt comprising at least one nonferrous metal using a blanketing gas having a global warming potential. The improvement comprises reducing the global warming potential of the blanketing gas by blanketing said melt with a gaseous mixture including at least one compound selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 .

25 The present invention also includes a process for preventing oxidation of a nonferrous metal and alloys of the metal. A first embodiment of the process includes

blanketing the nonferrous metal and alloys with an atmosphere containing an effective amount of at least one compound selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{COF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 .

There are several variations of the first embodiment of the process. In one variation, the at least one compound is provided at a first concentration of less than about 10% on a mole basis of the atmosphere. In addition, there may be several variants of that variation. In one variant, the first concentration is less than about 6%. In another variant, the first concentration is less than about 3%. In yet another variant, the first concentration is greater than about 0.1% and less than about 1%.

In another variation, the atmosphere further comprises at least one member selected from the group consisting of N_2 , Ar, CO_2 , SO_2 and air. In a variant of that variation, the at least one member is CO_2 provided at a second concentration of about 30% to about 60% on a mole basis. In a variant of that variant, the at least one compound is provided at the first concentration of less than about 3% on a mole basis and is selected from the group consisting of SO_2F_2 and COF_2 .

In yet another variation, the atmosphere used in the process also includes an odorant. And in another variation, at least a portion of the atmosphere is recovered for reuse.

In still yet another variation, the nonferrous metal and alloys have a temperature of at least about $0.5 \times T_{\text{melt}}$ (in degrees Kelvin). In addition, there are several variants of this variation. In one variant, the temperature is at least about $0.7 \times T_{\text{melt}}$ (in degrees Kelvin). In another variant, the temperature is a solidus temperature of the metal and alloys. In yet another variant, the temperature is greater than a solidus temperature of the metal and alloys but less than a liquidus temperature of the metal and alloys. In still yet another variant, the temperature is greater than a liquidus temperature of the metal and alloys but less than about $2.0 \times T_{\text{boiling}}$ (in degrees Kelvin).

Another aspect of the present invention is a process as in the first embodiment of the process, wherein at least one operation is performed on the nonferrous metal and alloys, the at least one operation being selected from the group consisting of melting, holding, alloying, ladling, stirring, pouring, casting, transferring and annealing of the nonferrous metals and alloys.

The present invention also includes a process for preventing oxidation of a melt including at least one nonferrous metal, the process comprising blanketing the melt with an atmosphere containing an effective amount of at least one compound selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 .

DETAILED DESCRIPTION OF THE INVENTION

The invention provides a process for preventing oxidation of nonferrous metals or alloys thereof by blanketing the metals or alloys with an atmosphere containing an effective amount of at least one compound having a reduced GWP, preferably selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , SOF_2 , SOF_4 , NF_3 , SO_2ClF , NOF , F_2 and SF_4 . The invention also provides an improved method of processing nonferrous metals and alloys thereof using a blanketing gas having a reduced GWP (relative to the prior art) by blanketing the nonferrous metals or alloys with a gaseous mixture including at least one compound having a reduced GWP, preferably selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , SOF_2 , SOF_4 , NF_3 , SO_2ClF , NOF , F_2 and SF_4 .

The invention may be applied in many types of operations, including but not limited to the melting, holding, alloying, ladling, stirring, pouring, casting, transferring and annealing of nonferrous metals and alloys thereof. Additional applications include such operations as cladding, plating, rolling, protecting scrap when compacting, preparing

powder for improved alloying, protecting reactive metals during electric arc spray coating or any other thermal spray coating, fusing, brazing, and joining/welding operations, and improving the corrosion and wear resistance of articles of magnesium or magnesium based alloys. Persons skilled in the art will recognize other operations where the
5 invention also may be applied.

The gases used in the present invention have lower GWP's than the gases used in the prior art and/or provide greater protection to operators under operating conditions that utilize lower concentrations of the gases. Since the gases used in the present invention are more reactive than SF_6 , these gases can be used at concentrations
10 supplying an equivalent or lower fluorine level. In other words, if SF_6 can be beneficially used at a concentration in the range of about 0.3% to about 1%, then SO_2F_2 will have a similar utility at concentrations from about 0.2% to about 3%.

In a preferred embodiment, the selected compound is provided at a concentration of less than about 10% (on a mole basis) of said gaseous mixture. It is more preferable
15 that the concentration be less than about 6%, and it is even more preferable that it be less than about 3%.

However, since F_2 , ClF , and ClF_3 are much more reactive than the other gases used in the present invention, these gases (F_2 , ClF and ClF_3) should only be used at lower concentrations, *i.e.*, at a concentration less than 5% and preferably less than 1%.
20 In particular, if used at higher concentrations (*e.g.*, 10%) in connection with a molten or hot metal, these gases (F_2 , ClF and ClF_3) may ignite and cause a metal/fluorine fire. Also, as shown in Table 1 below, F_2 , ClF and ClF_3 are very toxic. These gases will react relatively indiscriminately with any surfaces exposed to any of these gases, such as iron/steel structures used in melt processes (*e.g.*, melt pots, furnaces, etc.). This could
25 result in relatively thick metal fluoride layers that may increase the risk of "thermite" type

reactions, generation of HF upon exposure to atmospheric moisture, and HF burns to operators due to accidental contact with metal fluoride layers.

In a preferred embodiment, the gaseous mixture further comprises at least one member selected from the group consisting of N_2 , Ar, CO_2 and air as a diluent. SO_2 also
5 could be used as the diluent, but is less desirable because of potential corrosion problems associated with SO_2 . In addition, F_2 is violently reactive with SO_2 , which would make it extremely dangerous to use SO_2 as a diluent if F_2 is present above trace levels.

The most efficacious mixtures for blanketing nonferrous metals contain significant concentrations of CO_2 , preferably in the range of about 30% to about 60%. Some
10 nonferrous metals also could benefit from the addition of chlorine or chlorine-containing species (such as SO_2-ClF) to the blanketing gas mixture.

For example, in one embodiment, CO_2 is the diluent in the blanketing atmosphere at a concentration of about 30% to about 60% on a mole basis, and SO_2F_2 is provided at a concentration of less than about 3% on a mole basis. In another embodiment, CO_2 is
15 the diluent in the blanketing atmosphere at a concentration of about 30% to about 60% on a mole basis, and COF_2 , either alone or in combination with SO_2F_2 , is provided in a concentration of less than about 3% on a mole basis (referring to COF_2).

In a preferred embodiment, an odorant is added for safety purposes to the mixture used for the blanketing atmosphere. This is especially preferred for odorless gases, such
20 as SO_2F_2 . In contrast, since F_2 , SOF_2 and SF_4 have distinctive odors, the addition of an odorant is less important when these gases are used. The same is true when SO_2 is used as a diluent because of the odor of SO_2 .

Table 1 compares the preferred gases used in the present invention to various gases used in the prior art with regard to GWP and other characteristics. Several gases
25 which technically could be used in the present invention, but are likely to be too

expensive or too reactive to use, include ClF , ClF_3 , CF_3COCl , $(\text{CF}_3)_2\text{NH}$, and $\text{CF}_2(\text{O})\text{CFCF}_3$.

TABLE 1

Name	Formula	CAS Number ⁽¹⁾	OSHA PEL/ Ceiling/ Max Peak ⁽²⁾	ACGIH TWA/STEL ⁽³⁾	GWP ₁₀₀ ⁽⁴⁾	Atmospheric Lifetime years	Odor (detection limit in ppm)
Sulfur Hexafluoride	SF ₆	2551-62-4	1,000/x/x	1,000/1,250	24,900	3,200	Odorless
Sulfur Dioxide	SO ₂	7446-09-5	2/5/x	10/15	~1 ⁽⁵⁾	NK ⁽⁶⁾	Irritating Acid (3-5)
Carbon Dioxide	CO ₂	124-38-9	5,000/30,000	asphyxiant	1	50-200	Odorless
Perfluoromethane	CF ₄	75-73-0	X	asphyxiant	6,500	50,000	Odorless
Perfluoroethane	C ₂ F ₆	76-16-4	X	asphyxiant	9,200 to 12,500	10,000	Odorless
Perfluoropropane	C ₃ F ₈	76-19-7	X	asphyxiant	6,950	7,000	Odorless
Sulfuryl Fluoride	SO ₂ F ₂	2699-79-8	5/10/x	toxic	~1	NK	Odorless
Thionyl Fluoride Sulfinyl Fluoride	SOF ₂	7783-84-8	X	toxic	~1	NK	Suffocating
Sulfur Oxidifluoride	SOF ₄	13709-54-1	X	toxic	~1	NK	NK
Sulfur Tetrafluoride	SF ₄	7783-60-0	x/0.1/x	0.1/0.3	~1	NK	Like SO ₂
Nitrogen Trifluoride	NF ₃	7783-54-2	10/x/x	10/15	8,000 to 9,720	180 to 740	Moldy
Nitrosyl Fluoride	NOF	7789-25-5	X	toxic	~1	NK	NK
Sulfuryl Chloride Fluoride	SO ₂ ClF	13637-84-8	X	toxic	~1	NK	NK

Name	Formula	CAS Number ⁽¹⁾	OSHA PEL/ Ceiling/ Max Peak ⁽²⁾	ACGIH TWA/STEL ⁽³⁾	GWP ₁₀₀ ⁽⁴⁾	Atmospheric Lifetime years	Odor (detection limit in ppm)
Carbonyl Fluoride	COF ₂	353-50-4	2/5	2/5	~1	50-200	Sharp HF Irritating
Trifluoro acetyl Fluoride	CF ₃ COF	354-34-7	X	toxic	NK	NK hydrolyzes	NK
Trifluoro acetyl chloride	CF ₃ COCl	354-32-5	X	toxic	NK	NK hydrolyzes	NK
Hexafluoro-acetone	(CF ₃) ₂ CO	684-16-2	X	toxic 0.1PPM skin	NK	NK	NA ⁽⁷⁾
Hexafluoro-acetone	(CF ₃) ₂ NH	1645-75-6	X	toxic	NK	NK	NA
Fluoroxy- trifluoromethane	F ₃ COF	373-91-1	X	toxic	~1	50-200 hydrolyzes to CO ₂	Sharp HF Irritating
Bisfluoroxy- difluoromethane	F ₂ C(OF) ₂	16282-67-0	X	toxic	~1	50-200 hydrolyzes to CO ₂	Sharp HF Irritating
Hexafluoro-propene oxide	CF ₂ (O)CFCF ₃	428-59-1	X	toxic	NK	NK	NA
Fluorine	F ₂	7782-41-4	0.1	1/2	~0	<1 hydrolyzes	Sharp Pungent Irritating
Chlorine	Cl ₂	7782-50-5	0.5/1.0	1/3	~0	<1 hydrolyzes	Disagreeable Suffocating
Chlorine Fluoride	ClF	7790-89-8	Not established toxic	toxic	~0	<1 hydrolyzes	Acid Halogen odor VERY sharp pungent
Chlorine Trifluoride	ClF ₃	7790-91-2	/0.1	/0.1	~0	<1 hydrolyzes	Sweet Suffocating

Table 1 Notes:

- (1) "CAS" is Chemical Abstract Services.
- (2) "OSHA" is Occupational Safety and Health Administration; and
"PEL" is Permissible Exposure Limit in parts per million (ppm), 29 CFR 1910.1000.
- (3) "ACGIH" is American Conference of Governmental Industrial Hygienists;
"TWA" is Time Weighted Average in parts per million (ppm); and
"STEL" is Short Term Exposure Limit in parts per million (ppm).
- (4) "GWP₁₀₀" is Global Warming Potential relative to that of CO₂ estimated over 100 years; for example, the GWP₁₀₀ of SF₆ is 24,900 times the GWP₁₀₀ of CO₂. Applicants are not aware of any published data regarding the GWP's for the compounds for which the GWP₁₀₀ is indicated to be ~1.
- (5) Atmospheric reactions of SO₂ produce sulfate aerosols. These aerosols result in negative radiative forcing, *i.e.* tend to cool the earth's surface, but also are a major source of acid rain.
- (6) "not known (NK)"; the atmospheric lifetime of these species are not known to the applicants, but are believed to be comparable to that of CO₂.
- (7) "not available (NA)"

The comparison of GWP₁₀₀ shows that ten of the thirteen preferred gases used in the present invention (COF₂, CF₃COF, (CF₃)₂CO, F₃COF, F₂C(OF)₂, SO₂F₂, NF₃, SO₂ClF, SF₄, SOF₂, NOF, F₂ and SOF₄) have significantly lower GWP₁₀₀'s than the gases used in the prior art. (Of the thirteen gases, only NF₃ has a GWP₁₀₀ greater than ~1; but
5 the GWP₁₀₀ of NF₃ is still several fold lower than the GWP₁₀₀ of SF₆, and the atmospheric life of NF₃ also is shorter than that of SF₆. For two of the other gases, CF₃ COF and (CF₃)₂CO, the GWP₁₀₀'s are not known.) Furthermore, the prior art did not teach or even appreciate the possible use of these gases for blanketing. For example, the IMA Technical Committee Report shows that SO₂F₂ and SF₄ are by-products of the SF₆
10 protective chemistry for magnesium, but that report fails to realize that both SO₂F₂ and SF₄ can be potent sources of fluorine for protection of the melt. The gases used in the present invention may be recovered and recycled for reuse. Recovery techniques that may be used include the use of membranes, absorption, condensing and other means to concentrate the desirable gases for reuse.

15 While the present invention has been described in detail with reference to certain specific embodiments, the invention is nevertheless not intended to be limited to the details described. Rather, it will be apparent to persons skilled in the art that various changes and modifications can be made in the details within the scope and range of the claims and without departing from the spirit of the invention and the scope of the claims.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. In a method of processing a nonferrous metal and alloys of said metal using a blanketing gas having a global warming potential, the improvement comprising reducing said global warming potential of said blanketing gas by blanketing said nonferrous metal and alloys with a gaseous mixture including at least one compound selected from the group consisting of COF_2 , CF_3 , COF , $(\text{OF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 , wherein said nonferrous metal and alloys have a temperature of at least about $0.5\text{XT}_{\text{melt}}$ in degrees Kelvin, wherein said temperature is greater than a solidus temperature of said metal and alloys but less than a liquidus temperature of said metal and alloys.

2. The method as in claim 1, wherein said at least one compound is provided at a first concentration of less than about 10% on a mole basis of said gaseous mixture.

3. The method as in claim 2, wherein said first concentration is less than about 6%.

4. The method as in claim 2, wherein said first concentration is less than about 3%.

5. The method as in claim 2, wherein said first concentration is greater than about 0.1% and less than about 1%.

6. The method as in claim 2, wherein said gaseous mixture further comprises at least one member selected from the group consisting of N_2 , Ar, CO_2 , SO_2 and air.

7. The method as in claim 6, wherein said at least one

member is CO₂ provided at a second concentration of about 30% to about 60% on a mole basis.

8. The method as in claim 7, wherein said at least one compound is provided at said first concentration of less than about 3% on a mole basis and is selected from the group consisting of SO₂F₂ and COF₂.

9. The method as in any one of claims 1 to 8, wherein said temperature is at least about 0.7XT_{melt} in degrees Kelvin.

10. The method as in any one of claims 1 to 9, wherein at least a portion of said gaseous mixture is recovered for reuse.

11. In a method of processing a nonferrous metal and alloys of said metal using a blanketing gas having a global warming potential, the improvement comprising reducing said global warming potential of said blanketing gas by blanketing said nonferrous metal and alloys with a gaseous mixture including at least one compound selected from the group consisting of COF₂, CF₃COF, (CF₃)₂CO, F₃COF, F₂(OF)₂, SO₂F₂, NF₃, SO₂ClF, SOF₂, SOF₄, NOF, F₂ and SF₄, wherein said nonferrous metal and alloys have a temperature of at least about 0.5XT_{melt} in degrees Kelvin, wherein said temperature is a solidus temperature of said metal and alloys.

12. In a method of processing a nonferrous metal and alloys of said metal using a blanketing gas having a global warming potential, the improvement comprising reducing said global warming potential of said blanketing gas by blanketing said nonferrous metal and alloys with a gaseous mixture including at least one compound selected from the

group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 , wherein said gaseous mixture further comprises an odorant.

13. The method as in claim 12, wherein said nonferrous metal and alloys have a temperature of at least about $0.5\text{XT}_{\text{melt}}$ and said temperature is greater than a liquidus temperature of said metal and alloys but less than about $2.0\text{XT}_{\text{boiling}}$.

14. The method as in claim 12, wherein at least one operation is performed on said nonferrous metal and alloys, said at least one operation being selected from the group consisting of melting, holding, alloying, ladling, stirring, pouring, casting, transferring and annealing of said nonferrous metal and alloys.

15. In a method of processing a melt comprising at least one nonferrous metal using a blanketing gas having a global warming potential, the improvement comprising reducing said global warming potential of said blanketing gas by blanketing said melt with a gaseous mixture including at least one compound selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 wherein said gaseous mixture further comprises an odorant.

16. A process for preventing oxidation of a nonferrous metal and alloys of said metal comprising blanketing said nonferrous metal and alloys with an atmosphere containing an effective amount of at least one compound selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 , wherein said nonferrous metal and alloys have a temperature of at least

about $0.5X T_{\text{melt}}$ in degrees Kelvin and wherein said temperature is a solidus temperature of said metal and alloys.

17. A process for preventing oxidation of a nonferrous metal and alloys of said metal comprising blanketing said nonferrous metal and alloys with an atmosphere containing an effective amount of at least one compound selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 , wherein said nonferrous metal and alloys have a temperature of at least about $0.5X T_{\text{melt}}$ in degrees Kelvin, wherein said temperature is greater than a solidus temperature of said metal and alloys but less than a liquidus temperature of said metal and alloys.

18. The process as in claim 17, wherein at least a portion of said atmosphere is recovered for reuse.

19. The process as in claim 17, wherein said at least one compound is provided at a first concentration of less than about 10% on a mole basis of said atmosphere.

20. The process as in claim 19, wherein said first concentration is less than about 6%.

21. The process as in claim 19, wherein said first concentration is less than about 3%.

22. The process as in claim 19, wherein said first concentration is greater than about 0.1% and less than about 1%.

23. The process as in claim 19, wherein said atmosphere further comprises at least one member selected from the group consisting of N_2 , Ar, CO_2 , SO_2 and air.

24. The process as in claim 23, wherein said at least one member is CO_2 provided at a second concentration of about 30% to about 60% on a mole basis.

25. The process as in claim 24, wherein said at least one compound is provided at said first concentration of less than about 3% on a mole basis and is selected from the group consisting of SO_2F_2 and COF_2 .

26. The process as in claim 1, wherein at least one operation is performed on said nonferrous metal and alloys, said at least one operation being selected from the group consisting of melting, holding, alloying, ladling, stirring, pouring, casting, transferring and annealing of said nonferrous metal and alloys.

27. A process for preventing oxidation of a nonferrous metal and alloys of said metal comprising blanketing said nonferrous metal and alloys with an atmosphere containing an effective amount of at least one compound selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 , wherein said atmosphere further comprises an odorant.

28. The process as in claim 27, wherein said nonferrous metal and alloys have a temperature of at least $0.7\text{XT}_{\text{melt}}$.

29. The process as in claim 27, wherein said nonferrous metal and alloys have a temperature of at least about $0.5\text{XT}_{\text{melt}}$ and said temperature is greater than a liquidus temperature of said metal and alloys but less than about $2.0\text{XT}_{\text{boiling}}$.

30. The process for preventing oxidation of a melt comprising at least one nonferrous metal, said process

comprising blanketing said melt with an atmosphere containing an effective amount of at least one compound selected from the group consisting of COF_2 , CF_3COF , $(\text{CF}_3)_2\text{CO}$, F_3COF , $\text{F}_2\text{C}(\text{OF})_2$, SO_2F_2 , NF_3 , SO_2ClF , SOF_2 , SOF_4 , NOF , F_2 and SF_4 wherein said atmosphere further comprises an odorant.