FUEL ADDITIVE FOR REMOVING AND INHIBITING FRESIDE DEPOSITS

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This invention relates to a fuel additive for removing and inhibiting the formation of fireside deposits, more particularly fireside deposits in oil and coal fired furnaces. The invention also relates to a method of burning carbonaceous fuels.

It is well recognized that the burning of many fuels causes troublesome fireside deposits, such as slag, which are difficult to remove. This is particularly true if the case of fuel oils and the formation of such deposits is also prevalent with other carbonaceous fuels, such as coal.

The exact cause of the formation of fireside deposits is not clearly understood and their removal presents a difficult problem. Most of the troublesome deposits are mainly inorganic compositions such as slag and their formation is undoubtedly due to inorganic contaminants in the fuel. These contaminants are present in such small amounts and in such chemical combinations that methods for their removal from the fuel are difficult to apply economically on a commercial scale.

One of the objects of the present invention is to provide new and improved fuel additives for diminution of fireside deposits which can be added readily to the fuel or directly to the furnace.

A further object of the invention is to provide a method of preventing or minimizing fireside deposits of mainly inorganic compositions, such as slag, in the radiant, superheater, economizer, or air preheater section of a boiler furnace or in similar locations in other types of furnaces, by feeding with the fuel or into the combustion chamber a chemical additive.

Another object of the invention is to provide a method of the type described in which the quantity of the chemical composition required is relatively small. An additional object of the invention is to provide a method described which is effective in removing old slag deposits or in reducing them to a form in which they are readily removed by blowing them with air.

Another object of the invention is to provide a new and improved method of reducing corrosion in economizer and air preheater sections of a boiler furnace.

A more specific object of the invention is to provide a chemical composition which can be suitably blended with pulverized coal and when so blended is effective in preventing or minimizing the formation of fireside deposits without interfering with the combustion of the coal.

A further specific object is to provide a chemical composition which can be dispersed in fuel oil and when so dispersed is effective in preventing or diminishing the formation of fireside deposits without interfering with the combustion of the fuel oil. Other objects will appear hereinafter.

In accordance with the invention it has been found that the occurrence of fireside deposits of mainly inorganic compositions, such as slag, in the radiant superheater, economizer or air preheater of a boiler furnace or in similar locations in other types of furnaces are prevented or greatly reduced by feeding with the fuel or into the combustion chamber a compound from the group consisting of magnesia and compounds decomposing to magnesium oxide and compounds decomposing to magnesium oxides under the combustion conditions, together with a compound of a metal which is effective in lowering the ignition temperature of carbon, preferably a compound of copper or a compound of cobalt.

The essential components are preferably prepared in the form of a chemical composition in which the components are intimately mixed or blended together. The preferred components of the composition are magnesium oxide in the form of a very finely divided, high melting point powder and copper oxychloride. These two components when blended together form an excellent additive for pulverized coal.

Where the composition is to be added to a fuel oil, it is desirable to include a dispersing agent and for this purpose in the practice of the invention it is preferred to use magnesium stearate which is not only effective as a dispersing agent but also decomposes during combustion to magnesium oxide. The compositions which are to be added to fuel oil are preferably prepared initially as a blend of finely divided solid components, for example, magnesium oxide, copper oxychloride and magnesium stearate.

Example I

To evaluate a typical composition of this invention a test was conducted using a boiler located in a large manufacturing concern. The particular boiler was chosen for several reasons, the most important one being the troublesome nature of the slag deposits formed in the furnace and superheater areas. This boiler was rated at a capacity of 150,000 pounds of steam per hour at a pressure of 740 pounds per square inch and a superheater temperature of 750° F. Under normal conditions it operates at rated temperature and pressures with a load of 130,000 pounds of steam per hour. The fuel may be either pulverized coal or gas with the former being capable of utilizing either coal or natural gas.

During the winter months this boiler primarily uses pulverized coal as its main source of fuel but on Saturdays there is a limited supply of natural gas available and on Sundays natural gas is generally the only fuel used. Natural gas is almost exclusively burned during the summer months. Slag formations present in the boiler prior to the test were caused by the combustion of pulverized coal. Accordingly, it was decided to conduct a test of three months' duration that would be concluded in the spring, at which time the boiler would be shut down for its annual inspection and cleaning operations.

The condition of the boiler before the test was most unsatisfactory with large accumulations of slag having been deposited on the various surfaces of the furnace and the superheater. In particular, there was a large slag deposit that nearly covered the entire rear furnace wall. This deposit was thick, hard and brittle in nature. Similarly, there were heavy incrustations on the superheater tubes and slag screen tubes. These deposits for the most part were difficult to remove during prior shutdowns. The deposit on the rear furnace walls was so thick and bulky it fell onto the floor tubes necessitating a costly shutdown and repairs.
The treatment used in this test was a formulation that consisted of 96% by weight of commercial magnesium oxide and 4% by weight of commercial copper oxychloride (CuCl₂·3Cu(OH)₂) or 3CuO·CuCl₃·3H₂O. This material was fed directly into the furnace by blowing it through a piece of pipe located directly adjacent to one of the burners, thus allowing a uniform mixing of the treatment with the pulverized coal. Dosage was on the basis of the amount of pulverized coal burned during a given period of time and was computed to be 1/3 pound of treatment per ton of coal consumed. It was found that it was not necessary to constantly fed the composition to the coal but three 20 to 30 minute dosings per day gave adequate results.

At the end of the three month test period a thorough inspection of the furnace and superheater sections of the boiler was made and the observed results were excellent. The large deposit on the rear furnace wall was substantially reduced in size with but a small residuum of slag remaining. Some of the previously slagged areas were completely freed of the troublesome deposits with only a gray powdery coating remaining. The roof tubes previously covered with deposits were freed of slag. The most satisfactory results were found in the superheater tubes. Nearly all the slag had been dissipated and the small amounts remaining were negligible. The usual cleaning operations that were required in the past, to rid the superheater of the deposits, were not necessary and the superheater tubes were ready to resume their normal operations.

**Example II**

This example illustrates the application of the invention to a fuel oil. In this case the boiler had a capacity of 250,000 pounds of steam per hour with an operational pressure of 900 pounds per square inch and a rated superheater temperature of 900° F. The furnace was lit and put on a load of 200,000 pounds of steam per hour.

The fuel used was mostly asphalt containing some No. 6 fuel oil. Analyses of the asphalt used as fuel showed an ash content of 0.059% by weight and of the No. 6 fuel oil an ash content of 0.076% by weight.

The quantity of fuel used at a load of 200,000 pounds of steam per hour was approximately 12,250 pounds of fuel per hour or 294,000 pounds of fuel per day.

Before the operation began deposits were noted in both the furnace and super-heater areas of the boiler. These deposits were particularly heavy on the rear furnace wall tubes despite the four burners. A section approximately 400 square feet in area was covered with black friable material that extended 1/4 to 3/4 inch from the surface of the tubes. Similar type deposits were attached to the side wall tubes at the elevation of the lower burners. The remainder of the furnace wall tubes were covered with a light powdery coating which was easily removed. There were also dense non-porous deposits which covered the lower half of the slag screen tubes. The trailing edges of the first bank of superheater tubes were covered with a 1/4 to 1/2 inch thick deposit, which was similar in nature to the slag adhering to the rear furnace wall tubes opposite the burners.

The existing deposits were removed from the furnace and superheater tubes so that the bare metal surfaces were again exposed. The boiler was fired at a low rate and was brought up to load within about a 36 hour period. During this relatively short time small deposits had begun to form on the slag screen tubes. As the boiler reached normal conditions of the treatment, hereinafter described, was begun and within four hours a fine protective dust had formed on nearly all of the tubes.

The chemical composition employed for the purpose of the invention was prepared by intimately blending together 91% by weight of commercial magnesium oxide, 4% by weight of commercial copper oxychloride and 5% by weight of magnesium stearate.

The resultant powdered blend was made into a slurry by mixing it with the oil used for burning in the furnace to produce a composition containing about 5% by weight of the blend and 95% by weight of the fuel oil. The slurry was prepared in a separate tank and the slurry tank was insulated and provided with a steam coil for maintaining the temperature at approximately 180° F. The slurry was pumped from the slurry tank by a positive displacement pump into the oil going to the burners at a point beyond where the fuel oil was recirculated to the storage tank. The slurry tank was also equipped with a stirrer to keep the slurry liquid in continuous agitation.

The chemical composition prepared as above described was introduced into the fuel at a dosage rate of 100 pounds per day.

At the end of seven days the furnace walls, slag screen and superheater tubes were examined and found to have only a film of dust adhering thereto. No slag was found in any section.

The initial dosage of 100 pounds per day of the additive was continued for 15 days and then reduced to 50 pounds per day. After an additional operational period of 7 days the furnace walls were inspected and showed no sign of deposit other than a light colored dust film. The slag screen was clean except for a few pieces of slag on the tubes nearest the back wall. The superheater tubes were clean.

After an additional operational period of 6 days the dosage of the additive was reduced from 50 pounds per day to 25 pounds per day. After a further operational period of 8 days the fireside of the furnace and the superheater were inspected and it was observed that the tubes in both sections contained only a dust film.

The operation was continued at a dosage of 25 pounds per day of the additive for an additional period of 19 days. The fireside of the furnace and superheater were again observed. The furnace had some slag on the rear wall opposite the burners about the size of buttons. The superheater showed no fireside deposit. The slag screen had small amounts of fireside deposits on the top closest to the rear wall.

The operation was continued at a dosage of 25 pounds of the additive per day and 26 days later was observed again. The boiler had button-shaped deposits on the rear wall, thin and about 1/2 inch in diameter. The leading edge of the slag screen tubes showed a slight accumulation but generally the boiler was in clean condition. The slight deposits were powdery and had little bending strength. A section of the tubes.

In the foregoing examples the commercial magnesium oxide used had the following composition and physical characteristics:

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<tr>
<th>Component</th>
<th>Percent</th>
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<tr>
<td>SiO₂</td>
<td>0.9</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.3</td>
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<tr>
<td>Al₂O₃</td>
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<td>CaO</td>
<td>1.5</td>
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<td>MgO</td>
<td>93.9</td>
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<tr>
<td>Ignition loss</td>
<td>3.0</td>
</tr>
<tr>
<td>Through 325 mesh screen</td>
<td>98.0</td>
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The commercial copper oxychloride used in the foregoing examples had the following composition and physical characteristics:

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<tr>
<th>Component</th>
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<tr>
<td>Copper</td>
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<tr>
<td>Chlorine</td>
<td>16.0-17.5</td>
</tr>
<tr>
<td>Zinc</td>
<td>Under 0.05</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Under 0.000015</td>
</tr>
<tr>
<td>Lead</td>
<td>Under 0.003</td>
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<tr>
<td>Iron</td>
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</tr>
<tr>
<td>SO₂</td>
<td>Under 0.3</td>
</tr>
<tr>
<td>SO₃</td>
<td>Under 0.01</td>
</tr>
<tr>
<td>Caught on a 325 mesh screen</td>
<td>Under 0.5</td>
</tr>
</tbody>
</table>
It will be understood that the invention is subject to some variation and modification in the manner of its practical application. The quantities of the additive employed for slag diminution are subject to some variation, depending upon the type of fuel. For example, where pulverized coal is used as in Example I, excellent results have been obtained by employing about 100 parts by weight, expressed as Mg, of magnesium compound per million parts of coal, and about 4 parts by weight, expressed as Cu, of a copper compound per million parts of coal. In the treatment of a fuel oil for instance, as disclosed in Example II, the quantity of the magnesium compound, expressed as Mg, is about 50 parts per million parts of fuel oil and the ratio of the copper compound, expressed as Cu, is about 2 parts per million parts of fuel oil.

The dosage range required for the purpose of the invention may also vary depending upon service conditions but with compositions of the type disclosed in Example I is usually within the range of 1/4 pound to 1 pound per ton of coal burned, and with compositions of the type employed in Example II is usually within the range of 1/4 pound to 2 pounds per thousand gallons of fuel oil. The optimum amounts are readily determined by usage. Once the minimum effective (the maximum salting out) dosage for a particular installation the amount can be increased in order to ascertain the optimum amount for the best overall operation. An increase beyond the optimum amount is not advantageous from the cost standpoint.

In all cases minimal amounts of the additive are used and the quantities of additive are a function of a percent of the weight of the carbonaceous fuel.

In general, the quantity of the magnesium compound, expressed as Mg, will predominate over the quantity of the copper compound, expressed as Cu, and the preferred weight ratio of the respective compounds, expressed as Mg:Cu, is approximately 25:1 but may vary over a relatively wide range, for example 5:1 to 35:1.

Although magnesium oxide is the preferred type of magnesium compound employed in the practice of the invention, it will be understood that the magnesium oxide may be replaced wholly or in part by other magnesium compounds, either organic or inorganic, which decompose under the combustion conditions to form magnesium oxide. Among the compounds which may be used for this purpose are magnesium hydroxide, magnesium carbonate, magnesium nitrate, and magnesium salts of fatty acids, including magnesium stearate, which are the compositions of magnesium oxide, magnesium laurate, magnesium stearate, magnesium nitrate, magnesium oleate, and the like.

Likewise, although copper oxychloride is preferably employed in the practice of the invention other compounds of metals which are effective in lowering the ignition temperature of carbon can be employed in chemically equivalent amounts. Examples of other copper compounds which can be employed are copper naphthenate, cuprous chloride, cupric chloride, copper oleate, copper linoleate, copper stearate, copper octoate, copper salts of mahogany acids and copper salts of oleic acid, and various types of copper compounds.

Where the composition is used as a fuel oil additive, good results are obtained by employing as the copper component a copper salt of 2-ethyl hexanoic acid or a copper salt of another branched chain acyclic aliphatic carboxylic acid containing 5 to 12 carbon atoms as disclosed in U. S. Patent 2,622,671.

The amounts of the copper compounds required in the practice of the invention are less than the effective amounts normally required when the same copper compounds are used as additives to fuel oil to prevent or reduce the formation of soot. In most instances these quantities are 20% to 50% less than the effective quantities for preventing or reducing the formation of soot. Since many copper compounds tend to produce sludging in fuel oil, the fact that smaller amounts are required in the practice of the invention reduces the tendency towards sludging and makes it possible to use copper compounds that would have undesirable side effects if they were employed in larger amounts as soot inhibitors.

The inorganic compounds of both magnesium and copper have the advantage that they do not introduce deleterious byproducts into the fuel oil or coal to which they are added.

Chemically equivalent quantities of cobalt compounds may be substituted wholly or in part for the corresponding copper compounds in the practice of the invention. Examples of suitable cobalt compounds are cobalt naphthenate, cobalt oxychloride, cobaltic chloride, cobalt nitrate, cobalt tetrachloride, cobalt sulfate, the cobalt salt of 2-ethyl hexanoic acid, cobalt oleate, cobalt stearate, cobalt linoleate, cobalt linolenate and the cobalt salts of branched chain acyclic aliphatic carboxylic acids having 5 to 12 carbon atoms and containing a carboxyl group attached to the carbon atom other than the central carbon atom of the longest hydrocarbon chain.

The corresponding compounds of manganese, iron and calcium are also effective in reducing soot formation when added to fuel oils and can be employed to replace the copper or cobalt compounds but with less desirable results. Examples of these materials are manganese naphthenate, iron naphthenate, calcium naphthenate, manganese octoate, iron octoate, calcium octoate and the homologues thereof.

Where the slag inhibiting compositions are to be added to fuel oil it may be desirable in some instances to include reducers of the polymerization of the oil, for example, nitrobenzene, the nitrophenolts and alpha or beta-naphthol. Likewise, sludge inhibitors may be incorporated with the concentrates, as, for example, tricresyl phosphate, hydroquinone, phenylenediamine and its derivatives, and the phosphorous-organic sulfur compounds derived by the reaction of paraffin or aliphatic alcoholic substances and phosphorus pentasulfide.

The invention also contemplates that the additive compositions be prepared in the form of briquettes containing an oil soluble binder such as, for example, paraffin, heavy fuel oils and/or microcrystalline wax with or without dispersants, such as, for instance, magnesium stearate, magnesium laurate and the like. Similarly, the compositions of the invention can be incorporated in coal briquettes where the finer coal particles are bound together by a suitable binder such as an asphaltic binder in the form of the materials are dispersed in.

The term "carbonaceous fuel" is employed herein to describe fuels in which carbon is the principal constituent and is intended to cover both powered fuels such as coal and petroleum fuel oils which are primarily hydrocarbons.

The term "fuel oil" is intended to include combustible oils which are liquid or are capable of being liquefied when preheated. Thus, many of the residual oils are semi-solid in nature and are heated to temperatures of say 180° F. in order to increase their fluidity before they are used as burning fuels. It will be understood that the term "fuel oil" includes these semi-solid types of residual oils as well as the liquid types of fuel oils.

While the invention is not limited to any theory, it is believed that the combined action of the active essential ingredients of the slag inhibiting additive composition in some way interferes with or alters the formation of sulfates of a type which would ordinarily produce adherent slag deposits. That the result is due to a combined or synergistic effect of the active essential components is indicated by the fact that neither magnesium oxide alone nor copper oxychloride alone will produce the desired result.

The invention is especially advantageous in making it possible to operate large steam boiler plants in power generating stations, refineries and other industrial and
municipal locations for long periods of time without the necessity for discontinuing the operation to remove fireside deposits. Heretofore slag deposits in steam generating units have presented a very troublesome problem. The problem has been especially acute where fuel oils have been employed. These slag deposits are not only difficult to remove but the "outage" or discontinuance of the steam generating operation during the period of removal of the slag deposits represents a great economic loss. The slag deposits reduce the efficiency of the operation and tend to decrease the life of the equipment.

The practice of the present invention reduces or prevents sticking of low melting ash particles and reduces or prevents sulfatic deposits. The practice of the invention also reduces adherent acidic deposits and provides a neutralizing action in economizer and air preheater sections of boiler furnaces whereby corrosion is reduced. The compositions employed in the practice of the invention are readily prepared in a form in which they can be fed to the combustion chamber or to the fuel while maintaining freedom from feeding difficulties in chemical vats, pumps, distribution lines and in fuel burning equipment.

By making it possible to operate steam generating units over much longer periods of time, the invention greatly assists in alleviating the difficulties encountered in the operation of steam generating units. The invention also makes it possible to remove old slag deposits that are not removable by ordinary cleaning methods.

The invention is hereby claimed as follows:

1. An additive composition for a carbonaceous fuel consisting essentially of an intimate mixture of a compound of a metal selected from the group consisting of copper, cobalt, manganese, iron and calcium which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the weight ratio of said magnesium compound, expressed as Mg, to said compound of a metal, expressed as said metal, being within the range of 5:1 to 35:1, and said additive composition being effective to inhibit slag formation when a fraction of a percent thereof by weight is added to a carbonaceous fuel.

2. An additive composition for a carbonaceous fuel consisting essentially of an intimate mixture of a compound of copper which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the weight ratio of said magnesium compound, expressed as Mg, to said copper compound, expressed as Cu, being within the range of 5:1 to 35:1 and said additive composition being effective to inhibit slag formation when a fraction of a percent thereof by weight is added to a carbonaceous fuel.

3. An additive composition for a carbonaceous fuel consisting essentially of an intimate mixture of a compound of copper which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the weight ratio of said magnesium compound, expressed as Mg, to said copper compound, expressed as Cu, being approximately 25:1, and said additive composition being effective to inhibit slag formation when a fraction of a percent thereof by weight is added to a carbonaceous fuel.

4. An additive composition for a carbonaceous fuel consisting essentially of an intimate mixture of a compound of cobalt which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the weight ratio of said magnesium compound, expressed as Mg, to said cobalt compound, expressed as Co, being within the range of 5:1 to 35:1 and said additive composition being effective to inhibit slag formation when a fraction of a percent thereof by weight is added to a carbonaceous fuel.

5. An additive composition for a carbonaceous fuel consisting essentially of an intimate mixture of copper oxychloride and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the weight ratio of said magnesium compound, expressed as Mg, to copper oxychloride, expressed as Cu, being within the range of 5:1 to 35:1 and said additive composition being effective to inhibit slag formation when a fraction of a percent thereof by weight is added to a carbonaceous fuel.

6. An additive composition for a carbonaceous fuel consisting essentially of an intimate mixture of copper oxychloride and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the weight ratio of said magnesium compound, expressed as Mg, to copper oxychloride, expressed as Cu, being approximately 25:1 and said additive composition being effective to inhibit slag formation when a fraction of a percent thereof by weight is added to a carbonaceous fuel.

7. An additive composition for a carbonaceous fuel consisting essentially of an intimate mixture of copper oxychloride and magnesium oxide, the weight ratio of magnesium oxide, expressed as Mg, to copper oxychloride, expressed as Cu, being within the range of 5:1 to 35:1 and said additive composition being effective to inhibit slag formation when a fraction of a percent thereof by weight is added to a carbonaceous fuel.

8. An additive composition for a carbonaceous fuel consisting essentially of an intimate mixture of copper oxychloride and magnesium oxide, the weight ratio of magnesium oxide, expressed as Mg, to copper oxychloride, expressed as Cu, being approximately 25:1 and said additive composition being effective to inhibit slag formation when a fraction of a percent thereof by weight is added to a carbonaceous fuel.

9. A fuel additive consisting essentially of an intimate mixture of about 96% by weight commercial magnesium oxide and about 4% by weight of commercial copper oxychloride.

10. A fuel additive consisting essentially of an intimate mixture of approximately 91% by weight commercial magnesium oxide, 5% by weight magnesium stearate and 4% by weight commercial copper oxychloride.

11. A method of burning a carbonaceous fuel which comprises burning said fuel in the presence of a fraction of a percent by weight of said fuel of a composition of a compound of a metal selected from the group consisting of copper, cobalt, manganese, iron and calcium which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the weight ratio of said magnesium compound, expressed as Mg, to said compound of a metal, expressed as said metal, being within the range of 5:1 to 35:1, and said magnesium compound being effective to inhibit slag formation.

12. A method of removing and of inhibiting the formation of fireside deposits in the burning of a carbonaceous fuel which comprises burning said fuel in the presence of a fraction of a percent by weight of said fuel of a composition of a copper compound which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the weight ratio of said copper compound, expressed as Cu, to said magnesium compound, expressed as Mg, being within the range of 5:1 to 35:1, and said copper compound being effective to inhibit slag formation.
um oxide and magnesium compounds decomposing to magnesium oxide, under combustion conditions, the weight ratio of said magnesium compound, expressed as Mg, to said copper compound, expressed as Cu, being within the range of 5:1 to 35:1, the combined quantity of said copper compound and said magnesium compound being effective to inhibit slag formation.

13. A method of removing and of inhibiting the formation of fireside deposits in the burning of a carbonaceous fuel which comprises burning said fuel in the presence of a fraction of a percent by weight of said fuel of an intimate mixture of a copper compound which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, expressed as Mg, to said copper compound, expressed as Cu, being within the range of 5:1 to 35:1, the quantity of said copper compound, expressed as Cu, being at least 2 parts per million parts by weight of fuel and the quantity of said magnesium compound, expressed as Mg, being at least 4 parts per million parts by weight of said fuel.

14. A method which comprises incorporating with pulverized coal a quantity of an intimate mixture of a copper compound which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, said quantity containing approximately 4 parts, expressed as Cu, of said copper compound per million parts by weight of said coal, and approximately 100 parts, expressed as Mg, of said magnesium compound per million parts by weight of said coal, and burning said coal.

15. A method which comprises incorporating with a fuel oil a quantity of an intimate mixture of a copper compound which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, said quantity containing approximately 2 parts, expressed as Cu, of said copper compound per million parts by weight of said fuel oil, and approximately 50 parts, expressed as Mg, of said magnesium compound per million parts by weight of said fuel oil, and burning said fuel oil.

16. A method which comprises incorporating with pulverized coal a quantity of an intimate mixture consisting essentially of approximately 96% by weight commercial magnesium oxide, 4% by weight commercial copper oxychloride, said quantity being between 1/2 pound of said mixture and 1 pound of said mixture per ton of said coal, and burning said coal.

17. A method which comprises incorporating with a fuel oil a quantity of a composition comprised of approximately 5% by weight of an intimate blend of approximately 91% by weight commercial magnesium oxide, 4% by weight commercial copper oxychloride and 5% by weight magnesium stearate, said quantity being between 1/2 pound and 2 pounds per thousand gallons of fuel oil, and burning the resultant composition.

18. A carbonaceous fuel containing an intimate mixture of a compound of a metal selected from the group consisting of copper, cobalt, manganese, iron and calcium which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, expressed as Mg, to said compound of a metal, expressed as said metal, being within the range of 5:1 to 35:1, the combined quantity of said first named metal compound and said magnesium compound being a fraction of a percent by weight of said fuel sufficient to inhibit slag formation when said fuel is burned.

19. A carbonaceous fuel containing an intimate mixture of a compound of a metal selected from the group consisting of copper, cobalt, manganese, iron and calcium which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the quantity of said first named metal compound, expressed as Cu, being at least 2 parts per million parts by weight of said fuel and the quantity of said magnesium compound, expressed as Mg, being at least 50 parts per million parts by weight of said fuel.

20. Pulverized coal containing a quantity of an intimate mixture of a copper compound which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the quantity of said copper compound, expressed as Cu, being at least 4 parts per million parts by weight of said coal and the quantity of said magnesium compound, expressed as Mg, being at least 50 parts per million parts by weight of said coal.

21. A fuel oil containing an intimate mixture of a copper compound which is effective in lowering the ignition temperature of carbon and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the quantity of said copper compound, expressed as Cu, being at least 2 parts per million parts by weight of said fuel oil and the quantity of said magnesium compound, expressed as Mg, being at least 50 parts per million parts by weight of said fuel oil.

22. A method for inhibiting slag formation on elements contacted by the combustion gases from burning a carbonaceous fuel which comprises burning said fuel while providing on said elements a protective coating resulting from exposure to said gases of a composition of a copper halide and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the weight ratio of said magnesium compound, expressed as Mg, to said copper halide, expressed as Cu, being within the range of 5:1 to 35:1.

23. A method for inhibiting slag formation on elements contacted by the combustion gases from burning a carbonaceous fuel which comprises burning said fuel while providing on said elements a protective coating resulting from exposure to said gases of a composition of a cobalt halide and a magnesium compound from the group consisting of magnesium oxide and magnesium compounds decomposing to magnesium oxide under combustion conditions, the weight ratio of said magnesium compound, expressed as Mg, to said cobalt halide, expressed as Co, being within the range of 5:1 to 35:1.

(References on following page)
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<table>
<thead>
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<th>Patent Number</th>
<th>Inventor(s)</th>
<th>Date</th>
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</table>

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