ABSTRACT OF THE DISCLOSURE

A tobacco receiving liner for a smoking pipe consists of a liner insert of porous material, such as porous graphite, capable of withstanding temperatures of not less than 1900° C. and having the pores thereof exposed to the surface. Covering and bonded to the surface of the exposed pores is a coating of pyrolytic graphite, which enters into the pores and forms a primed surface on which a coating of pure pyrolytic graphite is applied. The layer of pure pyrolytic graphite is of a thickness of between about .5 mil and 15 mils.

This invention relates generally to smoking pipes, and particularly relates to a novel tobacco receiving liner used with a pipe. It is well known that many smoking pipes have bowls provided with a liner to improve the smoking qualities thereof. Patent No. 3,185,163 to Buckingham, assigned to the assignee of the present invention, discloses and claims a bowl liner for a smoking pipe consisting of pyrolytic graphite. Pyrolytic graphite consists of pure carbon and is usually deposited from a carbonaceous gas such as methane at elevated temperatures. It has unusual physical properties such as being anisotropic and is capable of withstanding temperatures of the order of 3000° F. or more.

Pyrolytic graphite is generally deposited in random layers which are disposed as a disarranged stack of cards or laminae. Accordingly, the pyrolytic graphite has highly anisotropic characteristics. Its mechanical and electrical properties depend upon the direction. It has become conventional practice to define as the a-b direction the plane at which the graphite is deposited, and the c direction at right angles to this plane. For example, pyrolytic graphite conducts heat very well in the a-b plane but is highly heat insulating in the c direction.

The pyrolytic graphite bowl liner disclosed in the Buckingham patent is a so called free-standing liner, that is, the entire liner consists of pyrolytic graphite. It is approximately 1/8" long and 1/4" in diameter. This pipe bowl liner is produced by depositing pyrolytic graphite on a male mandrel. The mandrel is made of normal or ordinary graphite and has a configuration corresponding to the desired inside shape of the finished liner. A smoking pipe having such a pipe bowl liner passes less tar and nicotine to the smoker than a conventional pipe. The tobacco smoke is cooler, the pipe bowl is easier to clean, the tobacco burns more evenly and there is no break-in period as is the case in a conventional wooden pipe bowl which must first be converted by repeated use into carbon. It should also be noted that since the tobacco burns more evenly and since the liner has a more even temperature, substantially no moisture is formed in the liner and, hence, there is substantially no drying-out period as is usually required between uses of a conventional pipe.

However, it has been found that the economical production of a pyrolytic bowl liner is beset by many problems. Since the liner consists entirely of pyrolytic graphite and has an appreciable thickness, the finished liner will tend to be out of round and may have considerably different wall thicknesses and outside configuration after it has been deposited. This is due to the fact that the deposition of a relatively thick layer of pyrolytic graphite is difficult to control. Also, an appreciable period of time is needed for the deposition during which there is a possibility that soot may be formed rather than pyrolytic graphite. As a result, a large percentage of liners is lost due to defects, such as soot, caused by imperfection of the deposition process. All of the liners must be machined after they are made which causes additional difficulties and increases the cost. Some pipe bowl liners must be rejected because there is delamination and cracking between individual layers of which the liner is made up.

It is, accordingly, an object of the present invention to provide a liner for a smoking pipe which has an outer surface of pyrolytic graphite, thereby to reduce the cost of manufacture and to permit better quality control without impairing the superior type of smoking afforded by a pyrolytic graphite liner.

Another object of the invention is to reduce the weight of the pipe by reducing the weight of the pyrolytic graphite liner.

A further object of the present invention is to provide a liner for a smoking pipe of the type disclosed where less tar and nicotine is passed to the smoker, which produces a cooler smoke, which has substantially no breaking-in period, where substantially no moisture is formed during smoking, which is relatively easy to clean, and where the tobacco burns more evenly than in conventional types of smoking pipes which do not have a pyrolytic graphite liner.

Thus, in accordance with the present invention, instead of making a liner for a smoking pipe entirely from pyrolytic graphite, it only has a coating of pyrolytic graphite. This, in turn, reduces the weight of the pipe by approximately 3 grams so that the pipe is easier to hold by the teeth of the smoker. This is due to the fact that the density of pyrolytic graphite is approximately 2.20 grams per cubic centimeter while that of ordinary graphite is only approximately 1.7 grams per cubic centimeter.

On the other hand, the coefficient of expansion, particularly at elevated temperatures of ordinary graphite and pyrolytic graphite is quite different. Therefore, if a substrate or insert of porous material such, for example, as graphite is simply provided with a coating of pyrolytic graphite, the coating would simply peel off or flake off. Also, the heat conductivity of pyrolytic graphite in the a-b plane compared to the c direction or plane is 200 to 1. For this reason it is not sufficient to simply coat an insert or substrate of ordinary graphite or any other suitable porous material, such as ceramic, with pyrolytic graphite. What is needed is to create a tileng or priming zone between the insert and its coating.

This is effected in accordance with the present invention by first infiltrating the insert at a relatively low temperature to coat the inside of the pores of the insert. Subsequently, a coating may be applied at a relatively higher temperature. The infiltrate creates a tileng or priming zone between the material of the insert and the subsequently applied pyrolytic graphite coating which prevents flaking off or peeling off of the coating even at elevated temperatures.

It should be noted, that the coating of pyrolytic graphite in accordance with the present invention may be of the order of 0.5 to 15 mils thick. In spite of this relatively thin layer of pyrolytic graphite the heat conduction of the layer is very good because the coating is preferably oriented so that the a-b plane forms the surface of the liner. This also minimizes delamination or cracking.
between the insert and the coating. By making such a relatively thin coating, it will be apparent that the time of deposition is vastly reduced so that more liners can be made in a given time.

Thus, in accordance with the present invention, a tobacco receiving liner for a smoking pipe consists of an insert of porous material. This should be capable of withstanding temperatures of not less than 1900°F. For example, the insert may be ordinary porous graphite. This insert is then provided with a coating of pyrolytic graphite which is impervious to moisture and covers the pores of the insert. This coating may have a thickness of between 0.5 mil and 15 mils. Preferably, the pyrolytic graphite coating includes portions thereof which extend into adjacent portions of the insert of ordinary graphite, thereby to provide a strong and stable bond.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claim. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, wherein:

FIG. 2 is a section on a line 2-2 of FIG. 1 on an enlarged scale and showing the bowl of the pipe and the liner embodying the present invention;

FIG. 3 is a view in perspective of a smoking pipe provided with a liner in accordance with the present invention;

FIG. 4 is a view in perspective of a smoking pipe provided with a liner in accordance with the present invention;

Referring now to the drawings and particularly to FIGS. 1 and 2 there is illustrated a conventional smoking pipe 10 provided with a liner 11 embodying the present invention. The smoking pipe 10 has a bowl 12 and a hollow stem 14. The bowl 12 is provided with a smoke passage 15 for the smoke to pass from the bowl into the mouth of the smoker.

The liner 11 consists of an insert 16 of any suitable porous material capable of withstanding temperatures of not less than 1900°F, that is, the temperature at which the pyrolytic graphite is deposited. For example, the insert 16 may consist of a porous ceramic material but preferably consists of ordinary or normal porous graphite which has been machined to the desired configuration. The insert 16 is provided with an aperture 17 communicating with the smoke passage 15.

In accordance with the present invention the insert 16 is provided with a coating 18 extending over the entire outer surface of the insert and including the aperture 17. As mentioned before, the coating may have a thickness of between 0.5 mil and 15 mils. Preferably, the anisotropic pyrolytic graphite is oriented with its a-b plane along the surface of the bowl. Looked at in another way, the pyrolytic graphite is deposited in the form of laminae, like a deck of cards, the laminae being substantially parallel to the surface of the insert 16.

As mentioned before, there is a considerable difference in the coefficients of expansion, particularly at elevated temperatures or ordinary graphite and pyrolytic graphite. Thus, if just a coating of pyrolytic graphite is provided on the graphite liner, the coating is liable to delaminate or to peel off. Hence, in order to avoid this, in accordance with the present invention, there is created a tieing or priming zone between the graphite and the pyrolytic graphite. This zone provides a graded structure in the insert from pyrolytic carbon to pyrolytic graphite. Hence, this zone is created before the coating is applied to the substrate.

This is illustrated schematically in FIG. 3 to which reference is now made. As shown there, 20 indicates individual, unoriented grains or small particles of normal or ordinary graphite. Pores or voids are formed between the grains 20 of graphite. These are filled in adjacent the outer surface, as shown at 21, by a deposit of pyrolytic graphite infiltrated into the voids. Thus, a bond is formed wherein portions of the pyrolytic graphite coating are embedded in the voids of the insert. Eventually, an outer coating 22 is provided which has a smooth surface layer. This surface layer is substantially impervious to most liquids and gases and in particular is impervious to water and water vapor. Also it will not absorb tar or nicotine.

The liner 11 and its coating 18 may be made by a new process which is also disclosed and claimed in a pending application of the applicants, filed concurrently here-in, Ser. No. 559,781, entitled "Process of Coating Articles With Pyrolytic Graphite" and assigned to the assignee of the present application. This process may, for example, be carried out with the vacuum furnace illustrated schematically in FIG. 4.

This vacuum furnace, generally indicated at 30, has an outer container 31 within which is disposed a cylindrical body 32 of suitable heat insulating material. The insulating cylinder 32 may be surrounded by a heating coil 33 for electrically heating the insulating cylinder 32 and the material disposed within. A container 35 may be fitted within the insulating cylinder 32 and provided with a suitable inlet opening 36 and an outlet opening 37. A tube 38 may extend through the outer container 30 and the insulating cylinder 32 to feed a suitable gas into the vacuum furnace. This is preferably a carbonaceous gas such as methane (CH₄).

There may also be provided an exhaust stack 40 which also extends through the inner container 35, the heat insulating cylinder 32 and the outer container 30. This permits evacuation of the furnace and the removal of gases formed during the thermal decomposition of the carbonaceous gas fed into the furnace. There may also be arranged a stand 42 within the inner container 35 on which suitable inserts 43 may be disposed which are to be coated.

As pointed out before, the inner container 30 is preferably arranged to be evacuated so that the deposition process may take place at a reduced pressure. It should be noted that the furnace should consist of at least two individual liners 43 to be coated is considerably smaller than that necessary to provide a free-standing, pyrolytic graphite liner as disclosed in the Buckingham patent, previously referred to. Accordingly, the space available in the furnace 30 can be utilized more economically.

In addition, less time is required to coat the articles so that with a given furnace a larger number of liners can be coated in a given time.

After the chamber has been loaded with the inserts 43 to be coated, the pressure in the furnace is preferably reduced to a range from between 1 mm. to 350 mm. of mercury. Then the temperature of the chamber and of the inserts is elevated from ambient temperature to a temperature range of between 1950°F. and about 2400°F. After the desired temperature within the chamber has been reached, the furnace is held at this temperature for about 12 to 14 hours.

The purpose of this heating is to bake out impurities in the graphite liners which are, of course, uncoated. It has already been explained that ordinary graphite is porous and, hence, tends to adsorb gases and other
impurities which are preferably baked out. However, it should be noted that the baking-out process is not necessarily required to the practice of the process of the present invention.

After the impurities and adsorbed gases have been baked out, the temperature is then reduced to a range from about 900° C. to about 1350° C. If the initial heating step is omitted, the furnace is initially heated to a temperature between 900° C. and 1350° C. The pressure may be below about 0.5 mm. and about 350 mm. of mercury.

After the proper temperature has been reached, the pores or voids of the inserts are now infiltrated with pyrolytic graphite. To this end a suitable carbonaceous gas is flowed into the furnace. Preferably methane is used at a flow rate of say between about 0.1 cubic feet per hour and about 150 cubic feet per hour. It will be understood that the furnace is being pumped out to maintain the pressure within the selected pressure range.

The infiltration or coating of the internal pores of the inserts is carried out for a period of time between half an hour and two days. The period of time necessary will depend on various conditions such as the type of graphite used and the flow rate of the methane and the pressure that is being maintained. In any case, the methane undergoes a thermal decomposition, and free carbon atoms are formed as well as hydrogen gas which is removed. The free carbon atoms penetrate the voids of the insert and are bonded together by pyrolysis and by a strong mechanical bond. As explained before, this bond is facilitated by the prior outgassing of the graphite liner. It will be understood that the degree and depth of the infiltration depends on the time of coating, on the flow of the gas, the temperature, the pressure within the furnace as well as on the grade or type of graphite which is used.

After the graphite has been infiltrated in the manner described, the temperature is then raised again to a range between about 1500° C. and about 1900° C. Now, the previously infiltrated graphite, the pores or voids of which have been closed, is provided with an outer coating of a desired thickness. As explained before, the coating may have a thickness of between 0.5 mil and 15 mils. To this end, the gas flow is again maintained within the previous range, that is, from 0.2 cubic feet per hour to 150 cubic feet per hour of methane. The pressure is again maintained in the same range, that is, from 0.5 to 350 mm. of mercury.

After these conditions have been reached, the coating of the lining, a pyrolytic graphite or pyrolytic pipe, is held off the furnace for a period of time from approximately 1/4 hour to half a day. Again the period of time depends on the thickness of the coating desired as well as on the various previously referred to.

Now a uniform coating of pyrolytic graphite is provided over the infiltrated inserts.

Thus, the gradual transition exists between ordinary graphite or pyrolytic carbon and pyrolytic graphite due to the infiltration process. It may be said that this transition zone is created because for the coating step the temperature is raised from the infiltration step and the pressure may also be raised, although it may remain the same. After the desired thickness of the coating has been obtained, the gas flow is turned off and the chamber and liners are allowed to cool to ambient temperature and the pressure is raised to ambient. It should be particularly noted that no further machining or finishing of the insert is necessary. It is, of course, well known that pyrolytic graphite deposits in a dense, smooth layer which does not require finishing. The insert 1 may then be bonded into the bowl 12 of the smoking pipe with any suitable bonding material. The smoking pipe is then finished.

It will be appreciated that the production costs for a liner embodying the present invention are greatly reduced compared to those of a solid or free-standing pyrolytic pipe bowl insert. No machining is required to finish the insert. Rejects are very much reduced for such defects as spalling, delamination, foot or nodes. The furnace time is greatly reduced as well as the requirements for furnace space. It will also be appreciated that there is no need to deposit large amounts of excess graphite.

It should be noted that the above described deposition process will result in the laminae of the pyrolytic graphite being deposited parallel to the surface. In other words, the a-b plane of the pyrolytic graphite is parallel to the surface.

Tests have been carried out to compare the performance of a pipe having an insert coated with pyrolytic graphite in accordance with the present invention and a pipe having a liner consisting solely of pyrolytic graphite as disclosed and claimed in the Buckingham patent. These tests have shown that the percentage of tobacco passed as nicotine to the smoker for a pipe having an insert in accordance with the present invention is 0.01%. The corresponding percentage of tobacco passed as nicotine to the smoker for a pipe with a pyrolytic graphite insert is 0.24%. Hence, the nicotine yield for a pipe in accordance with the present invention is slightly lower than that passed by a pipe having an all pyrolytic graphite insert.

It has also been found that the smoke exit temperature is more uniform and generally lower for a pipe in accordance with the present invention than for a pipe having a pyrolytic graphite liner. Similarly, the pipe gavel temperatures at various points in the pipe, as measured with a thermocouple is generally considerably lower, that is, no more than 125° F. with a pipe in accordance with the present invention. The exit temperature of the pipe bowl is below 110° F. for a pipe in accordance with the present invention.

Thus, a pipe in accordance with the present invention includes an insert of a relatively cheap insulating material having a thin coating of dense pyrolytic graphite. Due to the unique thermal conductivity of the pyrolytic graphite it will conduct heat uniformly along the inside surface of the insert of the pipe. As a result, tar and nicotine boil off at the top of the burning tobacco, resulting in a cleaner smoke being passed to the smoker. In general, less nicotine and tar are passed through the pipe of the present invention as compared with one having a pyrolytic graphite liner.

Obviously, substantially no break-in period is necessary for the pipe of the invention because it consists of pure carbon. Since the coating is substantially impervious to moisture, it is not necessary to dry out the pipe to remove retained moisture in the pipe. This, in turn, means that the same pipe can be used all day rather than requiring the smoker to alternate between many different pipes. The insert is easy to clean because the coating is impervious to gases and liquids. At the same time the smoke passed to the smoker has a lower temperature.

The invention and its attendant advantages will be understood from the foregoing description and it will be apparent that various changes may be made in the form, construction and arrangement of the parts of the invention without departing from the spirit and scope thereof or sacrificing its material advantages. The arrangement hereinbefore described merely by way of example and we do not wish to be restricted to the specific form shown or uses mentioned except as defined in the accompanying claim, wherein various portions have been separated for clarity of reading and not for emphasis.

We claim:

1. In a smoking pipe, an outer bowl having an internal wall having a lining of pyrolytic graphite defining a tobacco holding chamber therein and an insert of carbon...
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7 graphite disposed between the internal wall of the outer bowl and the lining, the lining and the insert having surface configurations conforming with each other and with the internal wall of the outer bowl, the lining having external portions thereof embedded in adjacent portions of the insert for forming a bond therewith.

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