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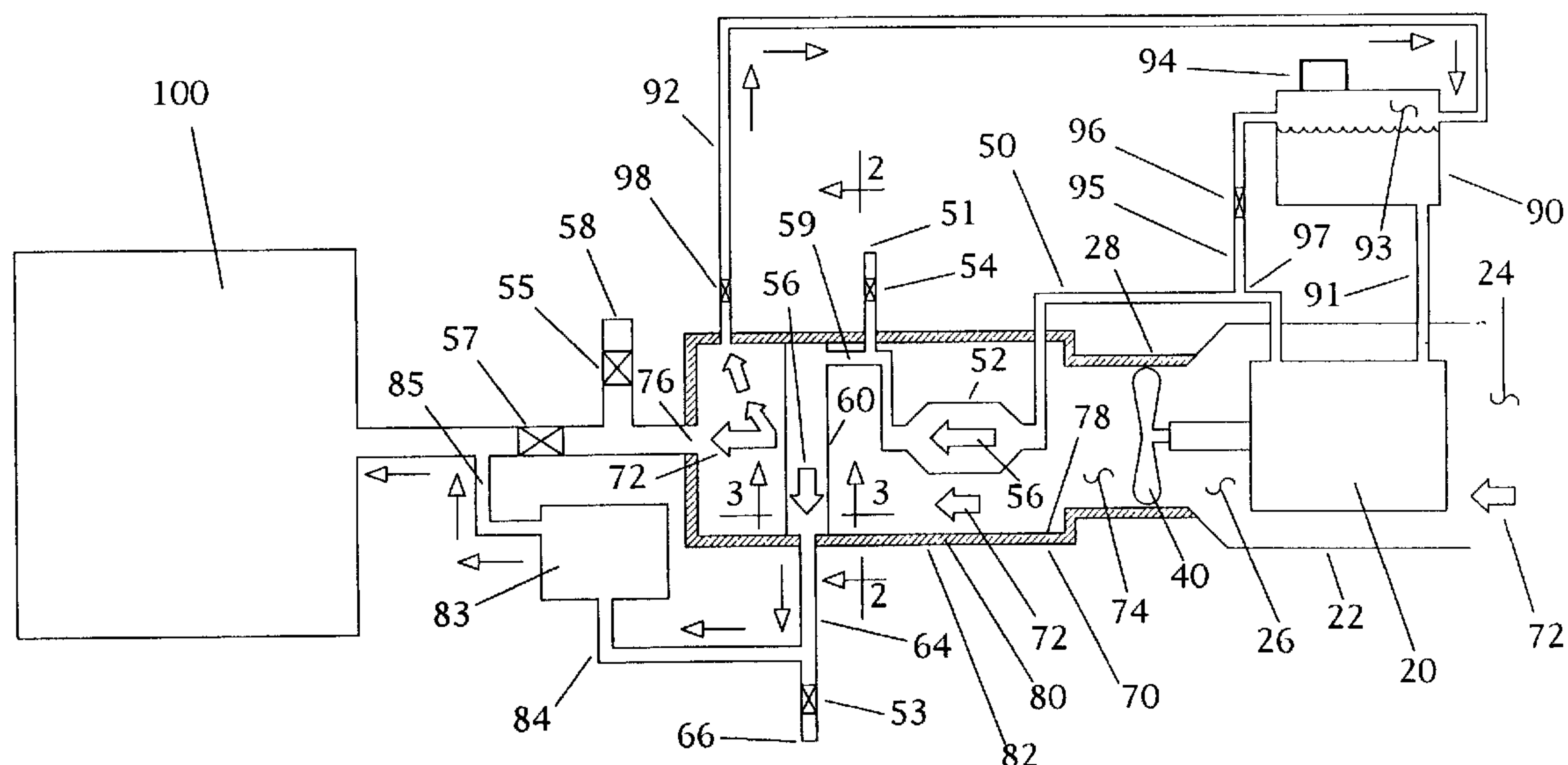
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(57) Abrégé/Abstract:

A grain drying apparatus uses the heat of an engine to aid in the evaporative process. The grain drying apparatus provides an engine 20 which is used to power a fan 40. Waste heat generated by the engine is transferred to air driven by fan 40 through air duct 70 by three principle means. Air is initially warmed by contact with the engine and its radiator prior to entering the air duct 60. An exhaust pipe 50 and catalytic converter 52, carried by the engine, extends a part of the length of the elongated air duct 70, warming the air flow within the duct by contact. A finned heat exchanger tube 60, also carried within the elongated air duct, transfers heat to the air flow within the duct. An air intake pipe transfers air under pressure into a fuel tank, where the air mixes with fuel vapors. The air and fuel vapor mix is then transferred to the exhaust pipe, where combustion takes place, thereby increasing the heat flow from the finned heat exchanger. Cooled exhaust gas from the finned heat exchanger tube 60 is optionally routed through a dehydration canister and into the grain storage area where the treated exhaust gases displace the air, providing an atmosphere which protects the grain from bacteria, insects and rodents.

ABSTRACT

A grain drying apparatus uses the heat of an engine to aid in the evaporative process. The grain drying apparatus provides an engine 20 which is used to power a fan 40. Waste heat generated by the engine is transferred to air driven by fan 40 through air duct 70 by three principle means. Air is initially warmed by contact with the engine and its radiator prior to entering the air duct 60. An exhaust pipe 50 and catalytic converter 52, carried by the engine, extends a part of the length of the elongated air duct 70, warming the air flow within the duct by contact. A finned heat exchanger tube 60, also carried within the elongated air duct, transfers heat to the air flow within the duct. An air intake pipe transfers air under pressure into a fuel tank, where the air mixes with fuel vapors. The air and fuel vapor mix is then transferred to the exhaust pipe, where combustion takes place, thereby increasing the heat flow from the finned heat exchanger. Cooled exhaust gas from the finned heat exchanger tube 60 is optionally routed through a dehydration canister and into the grain storage area where the treated exhaust gases displace the air, providing an atmosphere which protects the grain from bacteria, insects and rodents.

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GRAIN DRYING APPARATUS

FIELD OF THE INVENTION

This invention relates to a grain drying apparatus which derives the
5 heat necessary to dry the grain from exhaust gases of engines driving dryer fans.

BACKGROUND

The need to dry grain before storage is well-known. Failure to
10 adequately dry grain can result in mold, contamination and insect infestation, which in turn will result in a reduction in storage life and consequently heavy financial losses.

Known grain drying systems have employed augers to stir the grain, and gas-fired heaters to provide the heat necessary to dry the grain.
15 Unfortunately, the fuel to operate gas-fired heaters and to turn augers results in substantial expense.

A further drawback to gas-fired heaters is contact between untreated exhaust gases and the grain being dried. Various exhaust gas constituents present in untreated exhaust gases, such as sulfur dioxide, moisture and
20 unburned hydrocarbons, if allowed to come in direct contact with the damp grain may cause a variety of undesirable reactions such as flavoring of the grain and acidification of residual water vapor.

What is needed is grain drying apparatus that does not require an expensive gas-fired heater or augers, that rapidly dries damp grain without
25 damaging it. The grain drying apparatus should also treat the exhaust gases in an inexpensive manner, thereby allowing the treated gases to be used to displace the ambient air from the grain storage area forming an unattractive environment for bacteria, insects and rodents.

Various approaches have been tried in the past in providing grain dryer
30 systems where heat is extracted from engines usually driving the grain combines, for example, systems of US Patents 4,021,929 and 4,209,918. Each system derives heat energy from the combine engine which is in turn converted into drawing air for the grain dryer in the combine bin.

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As to other devices for extracting heat from engine exhaust, US Patent 4,140,173 is of interest in describing a heating installation for a car interior. A catalytic converter system is described in US Patent 2,551,823 for driving heat from combusting an air/fuel mixture in a reactor and delivering that heat into the car compartment.

SUMMARY

10 The present invention is directed to an apparatus that satisfies the above needs. The grain drying apparatus of the present invention provides some or all of the following structures.

(A) An engine provides the power needed to operate a fan, and much of the heat needed to dry the grain.

15 (B) An engine enclosure is sized to carry the engine and to control the heat flow from the engine. The engine enclosure defines a cold air inlet and a warm air outlet.

(C) An upper exhaust pipe delivers exhaust from the engine into a catalytic converter, which processes the exhaust gases.

20 (D) A lower exhaust pipe delivers the exhaust gases from the catalytic converter to a finned heat exchanger tube. Hot exhaust gases moving through the finned heat exchanger tube dissipate heat energy from the radially directed fins, thereby heating air moving within the elongated air duct, and cooling the exhaust.

25 (E) An upper exhaust conduit delivers cooled exhaust gases from the finned heat exchanger tube to a dehydration canister, where water is removed from the gases. The gases, having been treated by the catalytic converter and by the dehydration canister, may then be routed into the grain storage area by a lower exhaust conduit. The water, having been removed from the gases, may be collected or discharged, as desired.

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(F) An elongated air duct encloses the catalytic converter and

5 warm air outlet. Air is warmed as it moves through the air duct, by contact with the exhaust pipe, associated catalytic converter, and by contact with the finned heat exchanger tube. An insulating layer, adjacent to and surrounding the elongated air duct, reduces the radially outward heat flow from the duct, causing a greater percentage of the heat energy released by the engine, exhaust pipe, catalytic converter and finned heat exchanger to be removed by airflow within the elongated air duct.

10 (G) At least one fan, driven by the engine, drives air through the elongated air duct and into the grain drying or storage area.

(H) An air intake pipe diverts high pressure air from within the elongated air duct to an air space above the fuel tank. Fuel vapors are mixed then with the air, and the resulting mixture is diverted through fuel vapor delivery pipe into the upper exhaust pipe and catalytic converter for combustion. The heat of combustion results in additional heat transfer from the catalytic converter and finned heat exchanger to the air traveling within the elongated air duct.

20 It is therefore a primary advantage of the present invention to provide a novel grain drying apparatus that uses recycled heat from an internal combustion engine, and that does not require a gas-fired heater to provide heat for the grain drying process.

25 Another advantage of the present invention is to provide a grain drying apparatus having means to process exhaust gases including a catalytic converter and a dehydration canister which condition the exhaust gases for introduction into the grain storage area, thereby providing an artificial atmosphere which promotes grain storage.

30 Another advantage of the present invention is to provide a grain drying apparatus having an elongated air duct enclosing a catalytic converter and a finned heat exchanger tube, whereby heat energy may be transferred from exhausts gases moving through the finned heat exchanger tube to air moving through the air duct without the requirement of exhaust gases coming in contact with the grain.

A still further advantage of the present invention is to provide a grain drying apparatus having means to transfer a mixture of air and fuel vapor into the engine's exhaust pipe and catalytic converter for combustion, thereby producing additional heat for drying the grain.

5 According to an aspect of an invention, a grain drying apparatus comprises:

- (A) an engine;
- (B) an engine enclosure, sized to enclose the engine with a cold air inlet and a warm air outlet;
- 10 (C) an exhaust pipe carrying engine exhaust away from said engine and having first and second ends, the first end connected to the engine;
- (D) a finned heat exchanger tube having a first end in communication with the second end of the exhaust pipe and a second
- 15 end in communication with an exhaust port;
- (E) an elongated air duct, having a first end defining a cold air inlet in communication with said enclosure warm air outlet and a second end defining a warm air outlet, defines an air channel enclosing the finned heat exchanger;
- 20 (F) at least one fan, driven by the engine, for drawing air through said engine enclosure and driving air through the elongated air duct; and
- (G) a duct for delivery heated air from said elongate air duct to grain dryer storage.

25

DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawing where:

30 Figure 1 is a somewhat diagrammatic view of a version of the grain drying apparatus of the invention, showing the engine, engine enclosure, elongated air duct and finned heat exchanger tube, wherein various elements

including the length of the elongated air duct and finned heat exchanger are not shown to scale;

Figure 2 is a cross-sectional view of the elongated air duct, showing the finned heat exchanger, dehydration canister and upstream exhaust vent;
5 and

Figure 3 is a cross-sectional view of the finned heat exchanger tube, taken along the 2-2 lines of Figure 1.

DESCRIPTION

10 Referring to Figure 1, a diagrammatic view of a grain drying apparatus constructed in accordance with the principles of the invention is seen. The grain drying apparatus provides an engine 20 which is used to power a fan 40. The engine 20 is housed within an engine enclosure 22. Waste heat generated by the engine is captured within the enclosure 22 where the
15 enclosure is in communication with an air duct 70. The captured waste heat is drawn through enclosure 22 and into air duct 70 by fan 40.

The air is warmed by three principle means. Initially, air is warmed by contact with the engine and its radiator housed in enclosure 22 prior to entering the elongated air duct 70. Air is further warmed by contact with an
20 exhaust pipe 50 and catalytic converter 52 which extend from the engine within the air duct 70. And finally, exhaust gases are routed from the exhaust pipe through the finned heat exchanger 60. The exhaust gases from the engine are either discharged into the atmosphere or processed by the catalytic converter and a dehydration canister, thereby making the gases
25 suitable for discharge into the grain storage area 100.

An engine 20 is typically gasoline- or diesel-powered, and is supplied by a fuel line 91 from a fuel tank 90, having a refill lid 94. The size of the engine depends on the application. In a typical application, the engine must drive one or more fans 40.

30 At least one fan 40, driven by a direct drive coupling or other power transfer means of the engine, propels the air flow 72 through the elongated air duct 70, where it is heated.

In a typical embodiment of the invention, the engine's radiator is located within the engine enclosure 22. An additional fan is used to cool the radiator in a normal way, thereby transferring heat energy into the air flow 72 drawn through enclosure 22 by fan 40.

5 An engine enclosure 22 is sized to carry the engine and its attached radiator in a generally tight-fitting manner. An engine enclosure having excessive size tends to result in excessive dissipation of the heat and hence reduces effectiveness in capturing heat given off by the engine. The engine enclosure defines a cold air or outside inlet 24 which allows cool air from the
10 atmosphere to enter the engine enclosure where the cooler air absorbs heat energy from the engine and radiator so as to increase in temperature. Having been warmed by the engine and its radiator, the warmed air exits the engine enclosure 22 through the warm air outlet 26 and into the duct 70.

 A heat conduit 28 which also functions as a cowling for fan 40, to
15 increase thereby its efficiency, allows warm air to leave the engine enclosure and enter the elongated air duct 70. The heat conduit provides a first end in communication with warm air outlet 26 of the engine enclosure and a second end in communication with the elongated air duct 70. A low air pressure area, to the rear or upstream end of the fan 40, draws air through the heat conduit
20 28, which is sized to allow passage of sufficient outside air to cool the engine.

 The elongated air duct 70 contains a directed air flow 72, which is driven by the fan 40. The elongated air duct provides a first end defining an air inlet 74 and a second end defining a warm air outlet 76, typically having a warm air release valve 57. As seen in Figure 1, the elongated air duct 70,
25 defines an air channel or heat exchange region enclosing an exhaust pipe 50 for carrying engine exhaust combustion gases away from the engine 20, catalytic converter 52, lower exhaust pipe 59 and finned heat exchanger 60.

 A warm air exhaust valve 55 regulates a warm air exhaust port 58, which may be used to route the air flow 72 into the atmosphere, if desired.

30 In a preferred embodiment, the elongated air duct 70 provides a double-wall construction, having an inner wall 78 and the outer wall 82. An insulating layer 80, carried between the inner and outer walls, slows heat loss

from within the air duct to the surrounding atmosphere, thereby increasing efficiency.

5 The exhaust pipe 50 which is shown as being uppermost relative to the air duct 70 has a first end carried by the engine, extends through an axial region of the air duct 70, as seen in Figure 1. The upper exhaust pipe typically carries a catalytic converter 52 or muffler. A lower exhaust pipe 59 below the catalytic converter transfers exhaust gases 56 from the catalytic converter to the finned heat exchanger tube 60. Both the exhaust pipes and catalytic converter transfer heat energy to the air flow 72 moving through the
10 air duct 70. If desired, particularly where the system is temporarily clogged, the exhaust may be vented to the atmosphere through an upstream exhaust vent 51, controlled by valve 54, prior to being routed through the finned heat exchanger tube. Valve 54 may be pressure-activated, turning on when pressure within the system is excessive.

15 A finned heat exchanger tube 60 is connected at a first end to the catalytic converter 52 or to a lower exhaust pipe 59, and at a second end to the exhaust port 66 having a valve 53, which allows exhaust gases 56 to be vented to the atmosphere. The finned heat exchanger is designed to transfer efficiently the heat energy carried by the exhaust to the air flow 72 moving
20 through the elongated air duct 70.

The construction of the finned heat exchanger tube 60 is best seen in the cross-sectional view of Figure 3, where a steel tube having radially directed fins 62 defines a passage 64 through which cooling exhaust gases pass. The use of fins 62 increases the surface area of the heat exchanger
25 tube 60, and therefore the transfer of heat energy to the air flow 72.

Referring generally to Figure 1, it can be seen that a mixture of air and fuel vapors from the air space 93 above the fuel in the fuel tank 90 may be introduced into the exhaust pipe 50, which is then transferred to the catalytic converter 52. The mixture of air and fuel vapors burns, thereby increasing the
30 heat transfer to the air flow 72 through the elongated air duct 70.

Referring to the detail of Figure 1, a control valve 98 regulates the flow of air from the elongated air duct 70 into an air intake pipe 92. With the valve open, air flows through intake pipe 92 into the air space 93 above the fuel in

the fuel tank 90, where it mixes with fuel vapors. The mixture of air and fuel vapors is routed from the fuel tank through safety valve 96 in the fuel vapor delivery pipe 95. The safety valve prevents combustion of the fuel vapor in space 93, within the fuel tank. The air and fuel vapor mixture enters the
5 upper exhaust pipe 50 at fuel vapor entry port 97. The air and fuel vapor mixture is transferred by the upper exhaust pipe to the catalytic converter 52, where combustion of the air and fuel vapor mixture is completed.

Combustion of the air and fuel vapor mixture within the exhaust pipe 50 and catalytic converter 52 produces additional heat, which is transferred
10 through the finned heat exchanger tube 60, thereby additionally warming the air flow 72 passing through the elongated air duct 70.

In a preferred embodiment of the invention, a safety valve 96 prevents the air and fuel mixture in the fuel vapor delivery pipe 95 from burning, and resulting in combustion or explosion of the fuel carried in tank 90. The flow of
15 the air and fuel vapor mixture is restricted by safety valve 96 unless the pressure in the air space 93 above the fuel is sufficiently greater than the pressure in the exhaust pipe 50. This pressure differential causes a flow rate of the air and fuel vapor mixture that prevents fire from moving up the fuel vapor delivery pipe 95 and into the fuel tank 90.

20 The rate of air flow through the in-take pipe 92 and the fuel vapor delivery pipe 95 may be carefully regulated, by use of valves 96 and 98, to result in the desired level of combustion in the exhaust pipe 50 and catalytic converter 52. Additional fans may be used to regulate and increase the rate of air flow and direction within air intake and fuel vapor delivery pipes 92 and
25 95, if desired.

Optionally, an exhaust conduit 84 transfers cooled exhaust gases from the downstream end of the finned heat exchanger tube into a dehydration canister 83, where water is removed from the exhaust. A lower exhaust conduit 85 then transfers the dehydrated exhaust into the grain storage area.
30 Removal of the water from the exhaust gases tends to prevent bacterial degradation of the grain. Additionally, the gases may be treated in canister 83 to neutralize substances which would be noxious to the grain.

To operate a grain drying apparatus, the engine is started and operated until warm. Operation of the engine results in operation of the fan 40, which results in air flow through the air duct 70. As the engine warms, heat flows from the engine, through the heat conduit 28, into the air inlet 74 of the air duct 70. Heat is also transferred from the exhaust pipe 50 and catalytic converter 52 to air flowing through the air duct. Heat still remaining in the exhaust gases is also transferred to the air flow 72 by the finned heat exchanger 60. The exhaust gases as cooled by heat transfer with the air in duct 70, then exit from the exhaust port 66 and are discharged into the atmosphere. The air in duct 70 may optionally be heated to higher temperatures by allowing a mixture of air and fuel vapor to flow from the fuel vapor delivery pipe 95 to the exhaust pipe 50. The additional heat results when the catalytic converter ignites the added air and fuel vapor mixture. By closing down stream exhaust valve 53, exhaust gases may be routed through the dehydration canister 83, and into the grain storage area. This provides additional heat for drying, and also tends to prevent insect, rodent and other contaminants from spoiling the grain.

The heated air flow 72, leaving the air outlet 76, is then directed to a grain storage area 100 for drying damp or wet grain. In a typical application, the grain is stored in a silo or similar structure wherein the grain is supported off the ground by a screen. The heated air flow 72 is then directed into the silo at the ground level, below the stored grain. The warm, dry air then rises, through the stored grain, evaporating moisture carried by the grain.

The previously described versions of the present invention have many advantages, including a primary advantage of providing a novel grain drying apparatus that uses recycled heat from an internal combustion engine, and that does not require a gas-fired heater to provide heat for the grain drying process.

Another advantage of the present invention is to provide a grain drying apparatus having means to process exhaust gases including a catalytic converter and a dehydration canister which condition the exhaust gases for introduction into the grain storage area, thereby providing an artificial atmosphere which promotes grain storage.

Another advantage of the present invention is to provide a grain drying apparatus having an elongated air duct enclosing a catalytic converter and a finned heat exchanger tube, whereby heat energy may be transferred from exhaust gases moving through the finned heat exchanger tube to air moving
5 thought the air duct without the requirement of untreated exhaust gases coming in contact with the grain.

A still further advantage of the present invention is to provide a grain drying apparatus having means to transfer a mixture of air and fuel vapor into the engine's exhaust pipe and catalytic converter for combustion, thereby
10 producing additional heat for drying the grain.

Although the present invention has been described in considerable detail and with reference to certain preferred versions, other versions are possible. For example, while the above description makes reference to a catalytic converter, the apparatus would also be operable without such a
15 converter. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred versions disclosed.

Although preferred embodiments of the invention have been described herein in detail, it will be appreciated by those skilled in the art that variations may be made thereto without departing from the spirit of the invention or
20 scope of the appended claims.

Claims

1. A grain drying apparatus, comprising:
 - (A) an engine;
 - 5 (B) an engine enclosure, sized to enclose the engine with a cold air inlet and a warm air outlet;
 - (C) an exhaust pipe carrying engine exhaust away from said engine and having first and second ends, the first end connected to the engine;
 - 10 (D) a finned heat exchanger tube having a first end in communication with the second end of the exhaust pipe and a second end in communication with an exhaust port;
 - (E) an elongated air duct, having a first end defining a cold air inlet in conjunction with said enclosure warm air outlet and a second end
 - 15 defining a warm air outlet, defines an air channel enclosing the finned heat exchanger;
 - (F) at least one fan, driven by the engine, for drawing through said enclosure and driving air through the elongated air duct; and
 - (G) a duct for delivery heated air from said elongate air duct to a
 - 20 grain dryer storage.
2. The grain drying apparatus of claim 1 wherein a radiator portion of the engine is carried within the elongated air duct.
- 25 3. The grain drying apparatus of claim 1 wherein the exhaust port is in communication with a catalytic converter, whereby exhaust gases travel from the exhaust port into the catalytic converter.
4. The grain drying apparatus of claim 1 or 3 additionally comprising
- 30 means for introducing a mixture of air and fuel vapors into the exhaust pipe, thereby causing additional combustion and increasing the heat energy transfer from the finned heat exchanger tube.

5. The grain drying apparatus of claim 1 wherein the exhaust port is in communication with a dehydration canister, whereby exhaust gases travel from the exhaust port into the dehydration canister.
- 5 6. A grain drying apparatus, for supplying a heated, moving air flow to an area of grain storage, the grain drying apparatus comprising:
 - (A) an engine;
 - (B) an engine enclosure, sized to carry the engine, defining a cold air inlet and a warm air outlet;
 - 10 (C) a catalytic converter, having a first end in communication with an exhaust pipe carried by the engine;
 - (D) a finned heat exchanger tube having a first end in communication with the catalytic converter and a second end in communication with an exhaust port;
 - 15 (E) an elongated air duct, having a first end defining a cold air inlet and a second end defining a warm air outlet, defines an air channel enclosing the finned heat exchanger;
 - (F) at least one fan, driven by the engine, for driving air through the elongated air duct;
 - 20 (G) an insulation layer, adjacent to and surrounding the elongated air duct, to reduce heat loss and to increase heat transfer from the elongated air duct; and
 - (H) means for introducing a mixture of air and fuel vapors into the catalytic converter, comprising an in-take pipe in communication with an air space within a fuel tank and a fuel vapor delivery pipe connecting the air space within the fuel tank with the exhaust pipe, thereby causing additional combustion and increasing the heat energy transfer from the finned heat exchanger.
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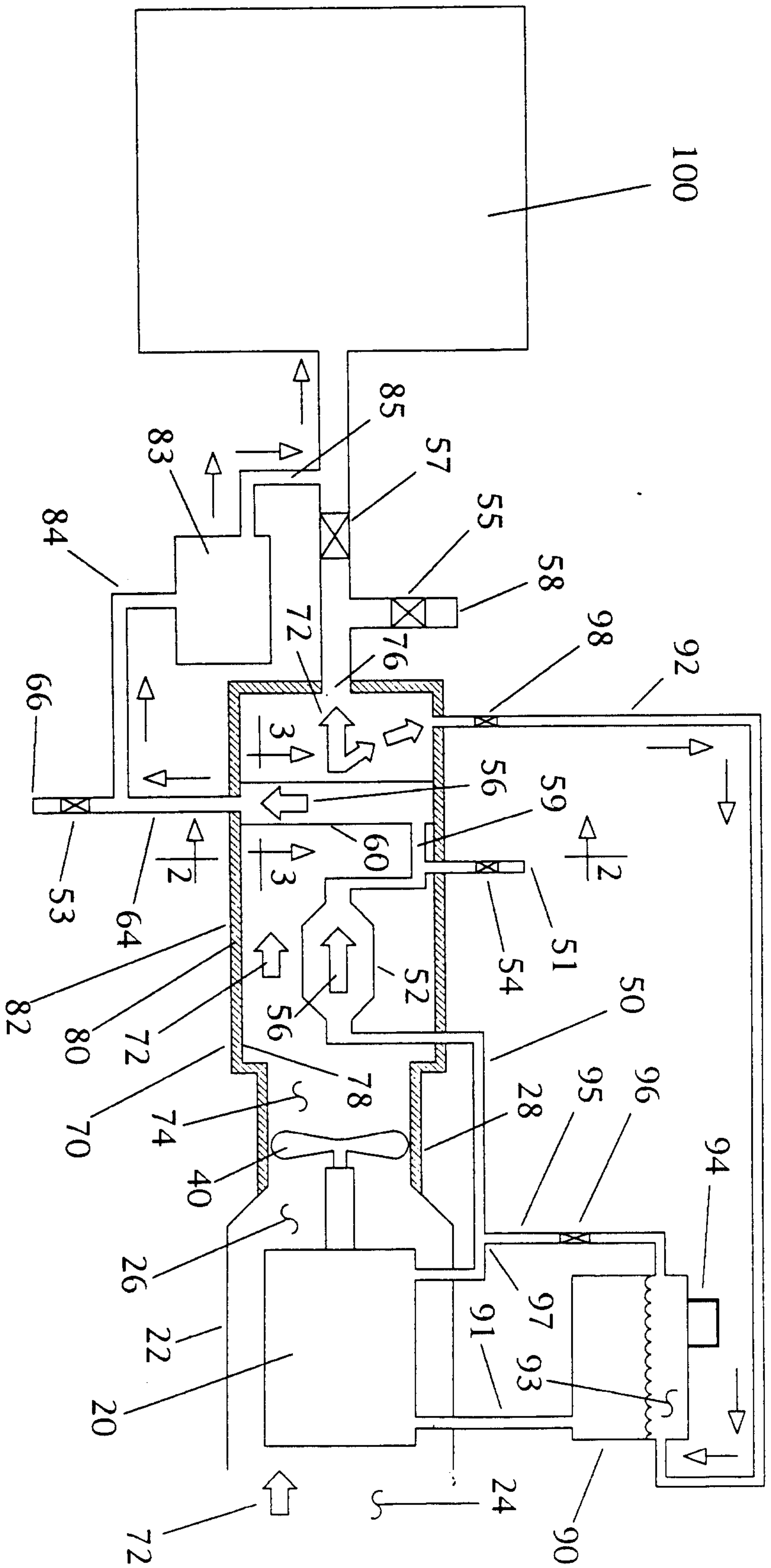


FIG. 1

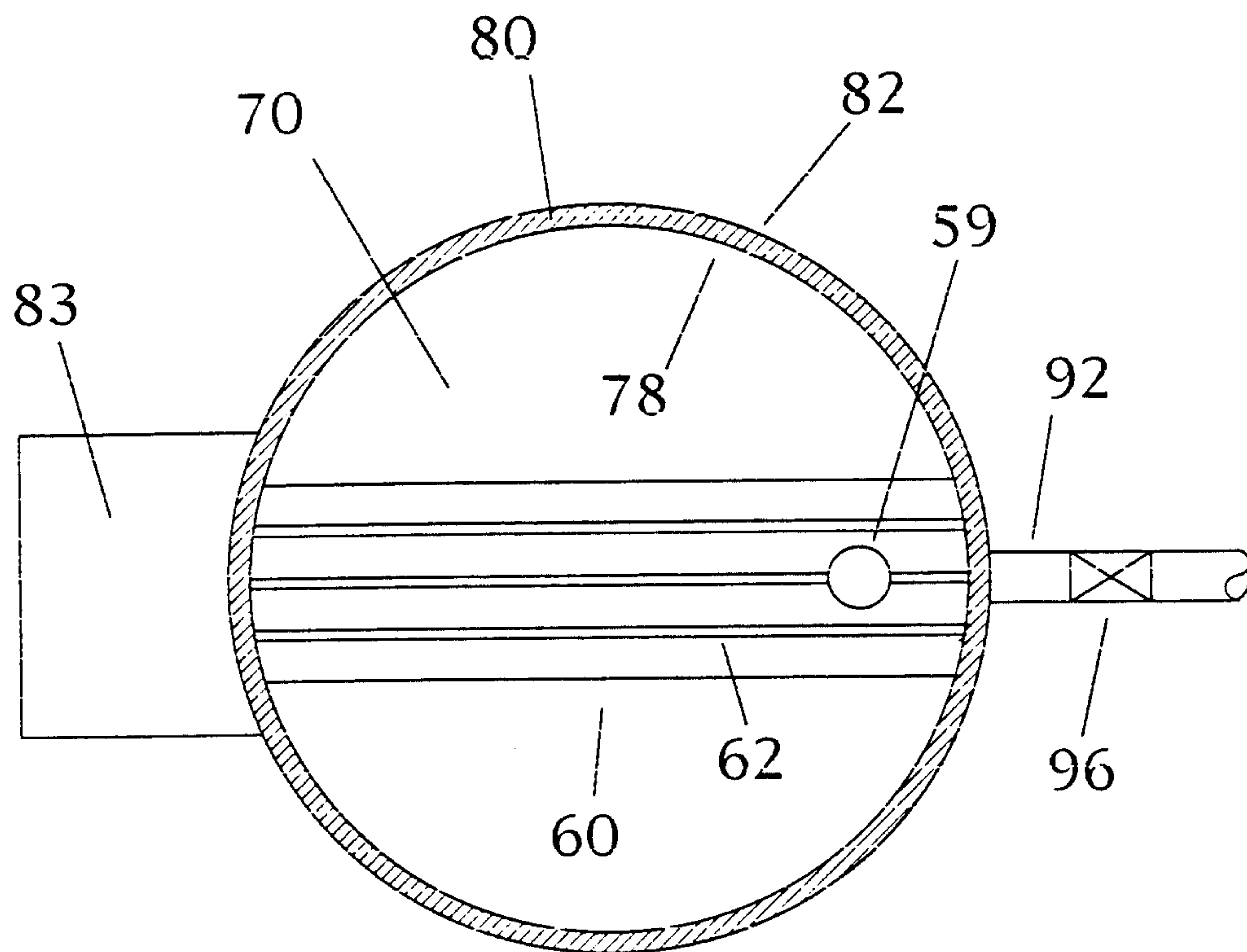


FIG. 2

FIG. 3

