



(19) **United States**

(12) **Patent Application Publication**

Wilson

(10) **Pub. No.: US 2003/0005696 A1**

(43) **Pub. Date: Jan. 9, 2003**

(54) **INTERNAL COMBUSTION ENGINE
ENERGY EXTRACTION DEVICES**

Publication Classification

(76) Inventor: **Benjamin Raymond Wilson, Salem,
OR (US)**

(51) **Int. Cl.⁷ F01K 23/10**

(52) **U.S. Cl. 60/618**

Correspondence Address:
**BENJAMIN RAYMOND WILSON
SUITE 290
700 BELLEVUE STREET
SALEM, OR 97301 (US)**

(21) Appl. No.: **09/982,686**

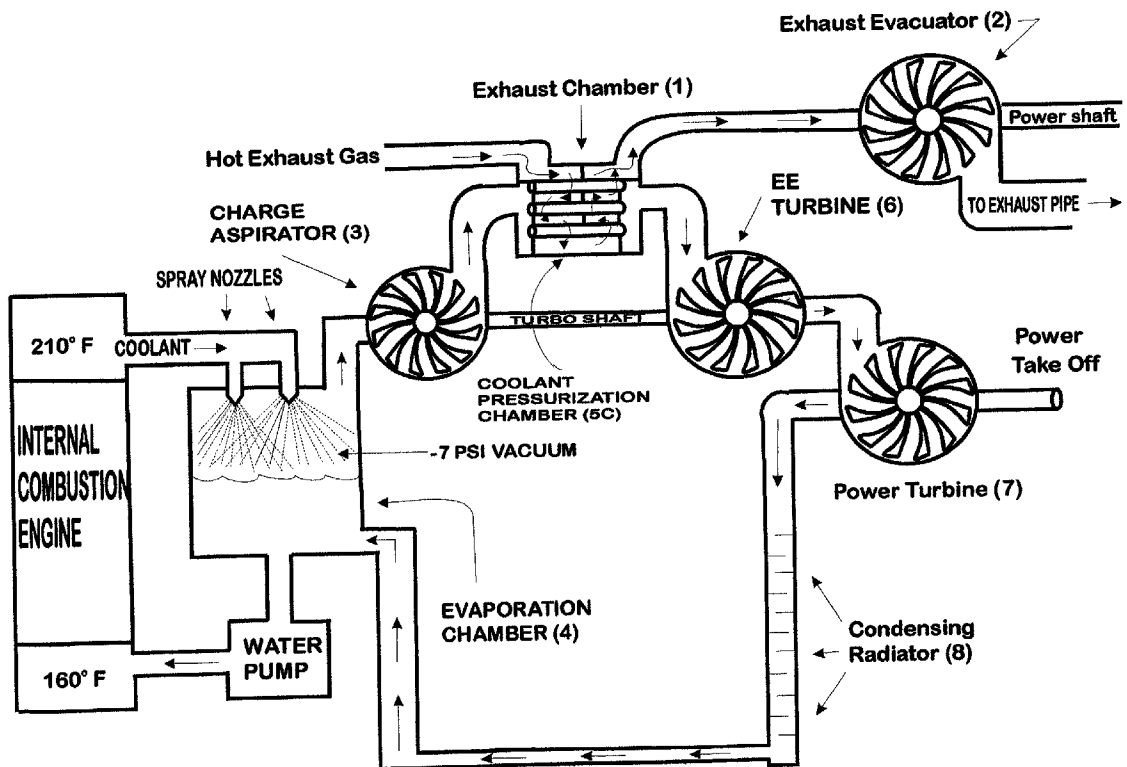
(22) Filed: **Oct. 18, 2001**

Related U.S. Application Data

(60) Provisional application No. 60/240,959, filed on Oct.
18, 2000.

(57) **ABSTRACT**

The “Internal Combustion Engine Energy Extractor” is a device that is extracts otherwise wasted heat from both the engine exhaust system and it’s cooling system. This heat is converted into mechanical energy, which is 1) used to power the “Extractor” and 2) may be used for auxiliary engine devices, such as an intake air supercharger or an electrical generator. The Energy Extractor by itself 1) increases engine efficiency and power by decreasing exhaust back pressure and 2) decreases engine wear by decreasing the cylinder and engine temperature.



Coolant Based Energy Extractor

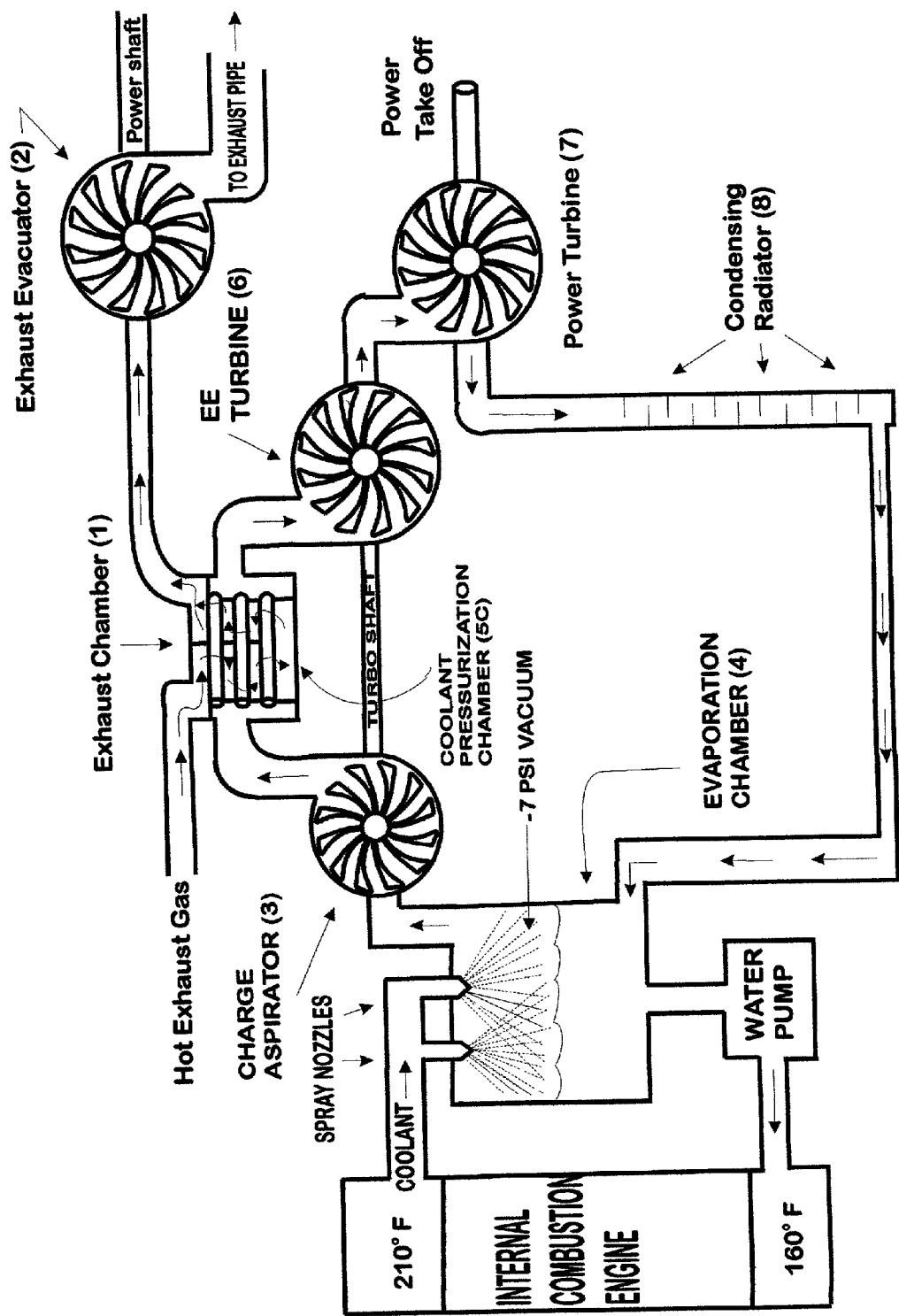


Figure 1: Coolant Based Energy Extractor

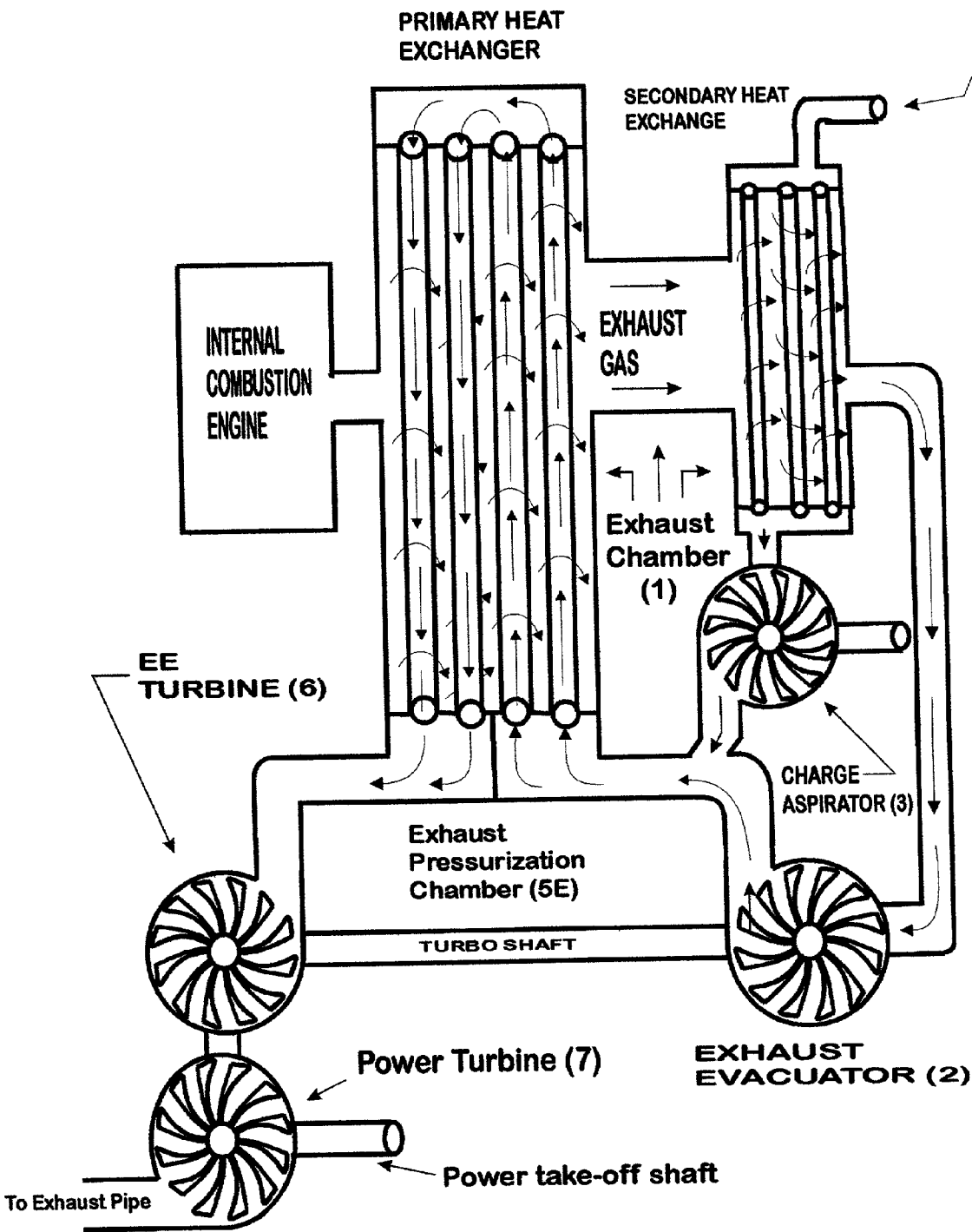


Figure 2: Exhaust based Energy Extractor

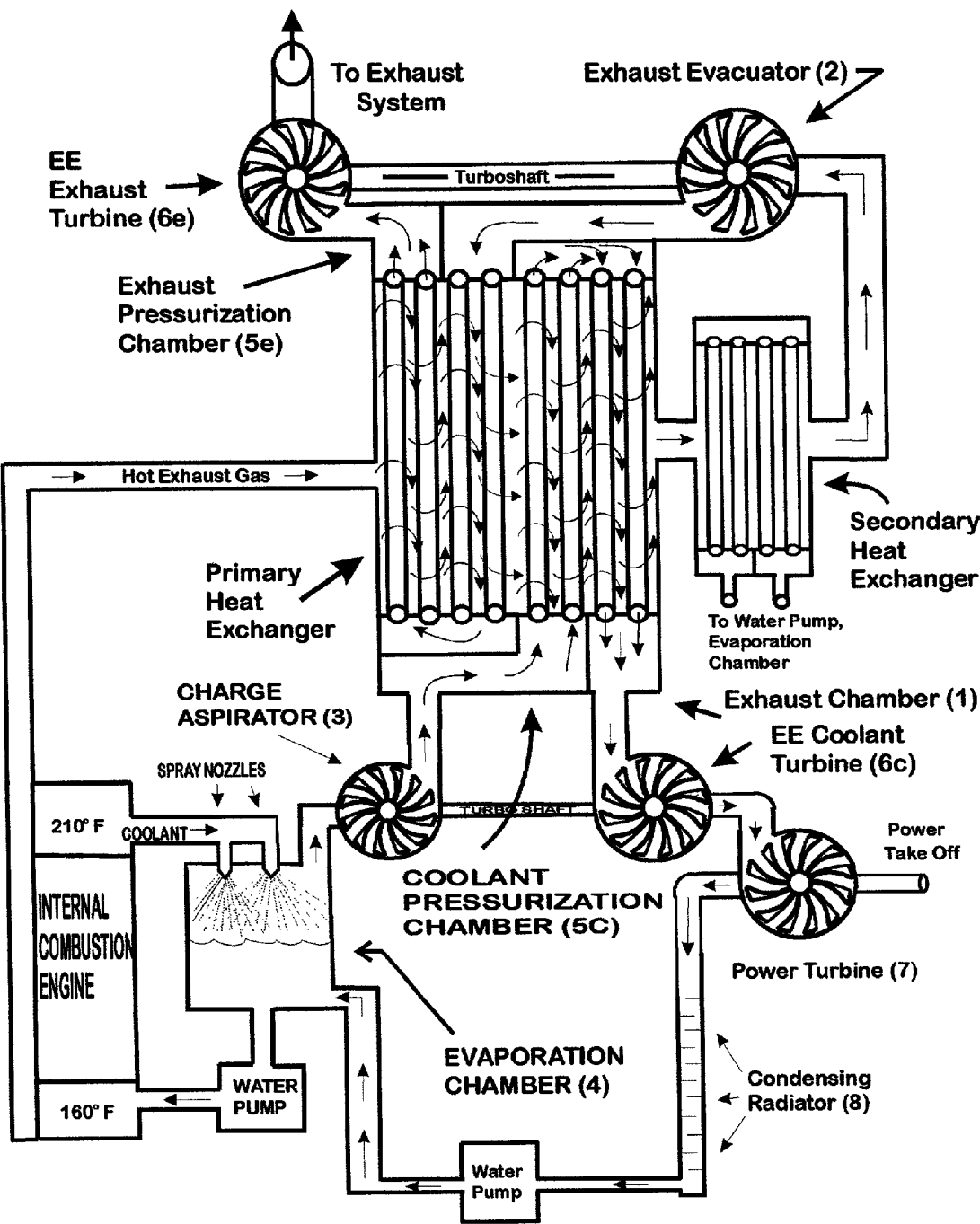


Figure 3: Combined Energy Extractor

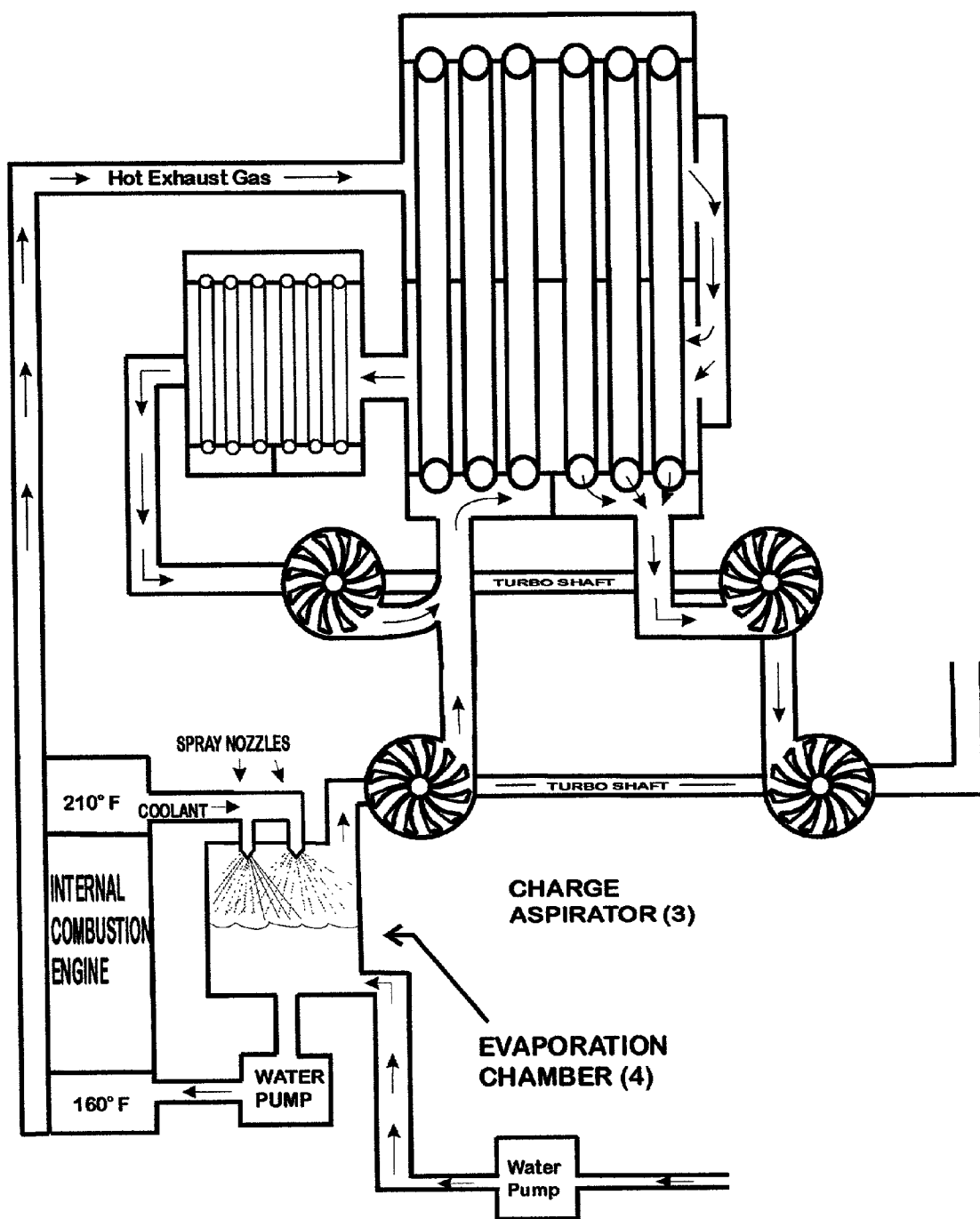


Figure 4: Gas Mix Energy Extractor

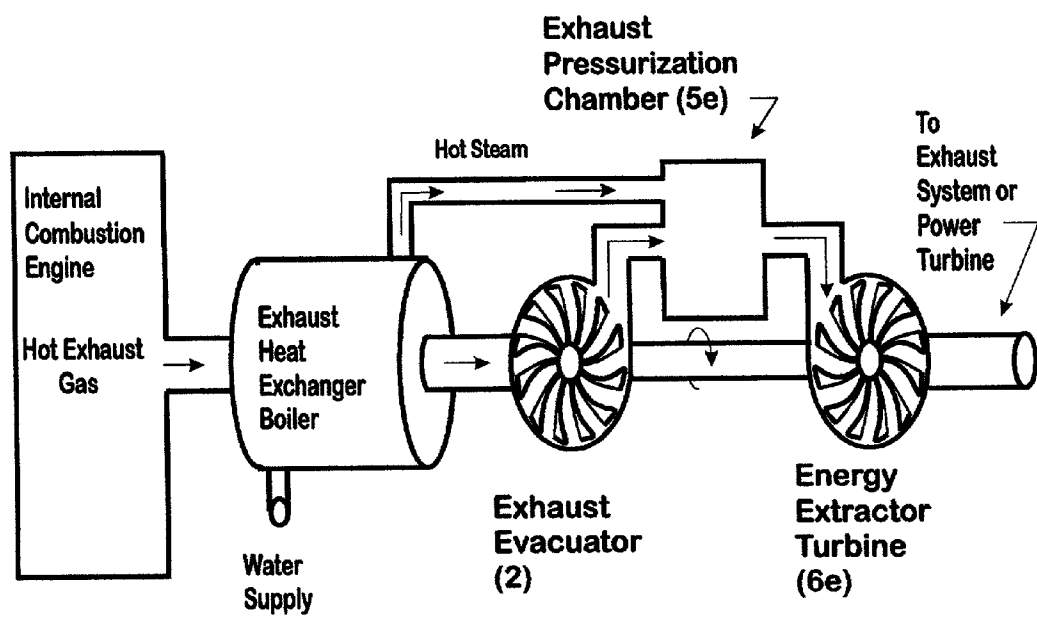


Figure 5: Exhaust Boiler Energy Extractor

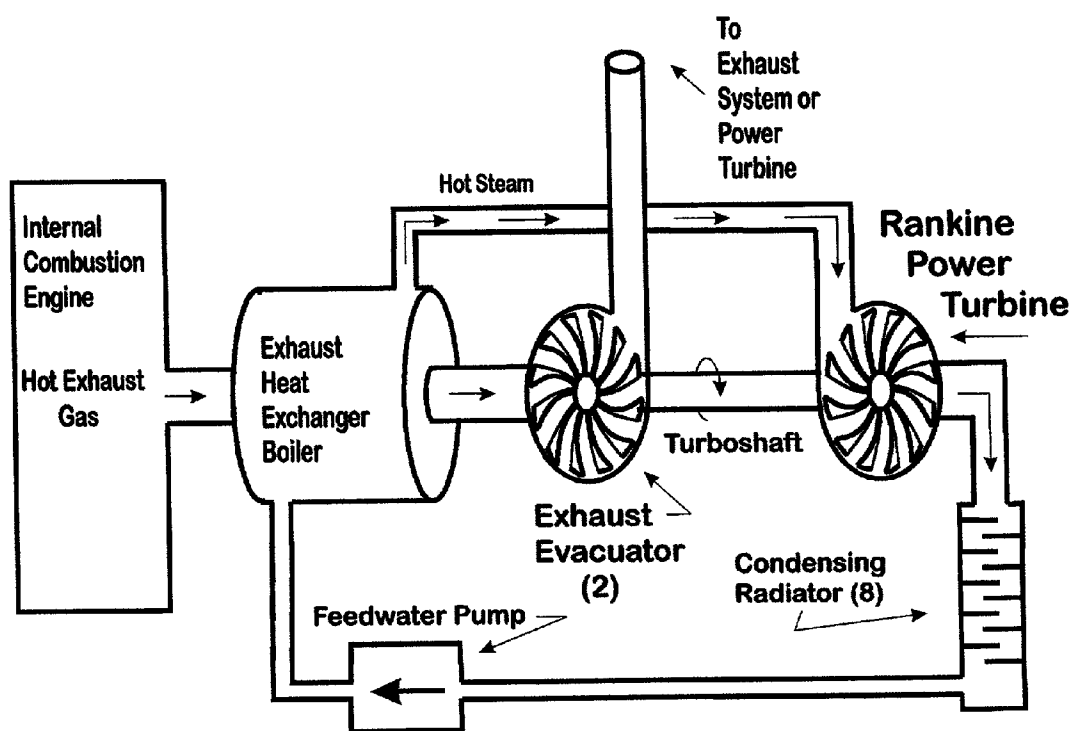


Figure 6: Exhaust Rankine Energy Extractor

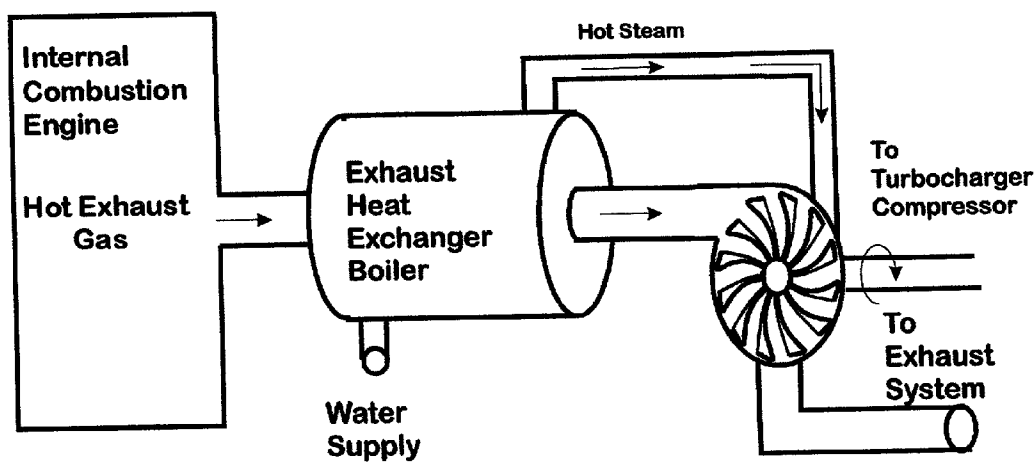


Figure 7: Steam Injection Energy Extractor

INTERNAL COMBUSTION ENGINE ENERGY EXTRACTION DEVICES

[0001] Reference: Provisional Patent Application 60/240, 959

BACKGROUND OF INVENTION

[0002] It is well known that the efficiency of internal combustion engines ranges between 25% and 40%. Spark ignition engines ("gas engines") will have efficiencies between 25% and 35%, while compression ignition engines ("diesel engines") will have efficiencies between 30% and 40%.

[0003] The portion of the fuel that is not converted into mechanical energy will be converted into excess heat and dissipated either by the cooling system (roughly one-half of the heat) or expelled into the environment in the form of hot exhaust gas (roughly the other half of the heat). A smaller amount of heat will be lost via convection from the engine itself. The proportion of the energy dissipated by the various routes varies with the type of engine and the type of cooling system employed.

[0004] Since shortly after the birth of the internal combustion engine attempts have been made to improve the efficiency of the internal combustion engine by recovering some of the dissipated heat and converting it into mechanical energy. The first patent on such a device was awarded in 1882; since then some 200 patents on a variety of inventions of this type have been awarded. None have functioned well enough to enjoy commercial success.

[0005] While some devices do provide a slight increase in internal combustion engine efficiency, all possess significant drawbacks. Some devices will cause the internal combustion engine to overheat and will shorten engine life; many devices will increase the cost of the engine far in excess of the economy gained from fuel savings, and most devices will not perform according to the claims of the patent.

[0006] The "Energy Extractor", as described in this patent application, incorporates a new and unique approach to recover heat energy from the internal combustion engine which results in a significant increase in engine efficiency. The device reduces the operating temperature of the engine and will prolong engine life. Energy Extractor technology, which may be implemented using readily available engine components, would increase the construction cost of an engine by only ten or twenty percent.

BRIEF SUMMARY OF INVENTION

[0007] Capsule Summary:

[0008] The "Energy Extractor" uses excess engine heat that is normally dissipated into the environment to produce steam. The steam powers a steam turbine: the turbine, in turn, drives a suction Pump which is used to suck the exhaust out of the cylinder when the exhaust valve is open. This increases the engine efficiency and also results in a greater amount of heat energy being recovered than would otherwise be possible. Power from the turbine may also be used for other devices. A second suction pump can be used to extract steam from the cooling system which may be superheated and used to Power auxiliary devices.

[0009] The "Energy Extractor" does just what the name implies; it extracts energy from the internal combustion engine. The extraction is done in two ways; 1) a "vacuum pump" is used to literally suck the exhaust out of the cylinders when the exhaust valve opens and 2) a second "vacuum pump" may be used to extract vapor from the engine coolant system. The heat energy present in the extracted exhaust and coolant vapor may then be converted to mechanical energy using a thermodynamic cycle, such as the Rankine cycle.

[0010] The "vacuum pumps" described here may be fabricated using the compressor sections of a typical turbo-charger.

[0011] The "vacuum pumps" utilized by the "Energy Extractor" have the effect of lowering the pressure and temperature of 1) the cylinder in the exhaust phase and 2) the coolant system. The advantages of a lowered exhaust pressure and temperature are readily apparent; a) less mechanical work is required by the engine to expel exhaust gas from the cylinder, and b) lower temperatures in the exhaust system will lead to longer component life.

[0012] There is also a more subtle advantage to exhaust evacuation; as exhaust is aspirated from the cylinder, the temperature of the remaining gas in the cylinder drops. The lower of the temperature of the residual gas, the less amount of heat will be transferred to the cylinder walls and coolant system, and more heat will be transferred to the exhaust gas that is aspirated. The heat that is recovered from the exhaust system is high quality heat; i.e., the temperature is quite high and the amount of energy available for conversion to mechanical work is high. In contrast, the heat that may be recovered from the coolant system is "low quality" heat; the temperature is low, and the energy available for conversion to mechanical work is low. Thus more energy is made available as "high quality heat"—from the exhaust—as opposed to "low quality heat"—from the cooling system. This is in direct contrast to a normal turbocharger, in which increased pressure and temperature in the exhaust system converts "high quality heat" into "low quality heat" in the cooling system.

DESCRIPTION OF DRAWINGS

[0013] FIG. 1: Coolant based Energy Extractor; Drawing of the manner in which steam is aspirated from the engine cooling system and then superheated to drive sequential steam turbines.

[0014] FIG. 2: Exhaust based Energy Extractor; Drawing demonstrating the manner in which the Energy Extractor can be used without involving an engine water cooling system.

[0015] FIG. 3: Combined Energy Extractor: Drawing demonstrating the manner in which the coolant based and exhaust based systems may be combined.

[0016] FIG. 4: Gas Mix Energy Extractor: Technique in which steam from an engine cooling system is combined with exhaust gas in to provide the "charge" that is used to drive a turbine after superheating.

[0017] FIG. 5: Exhaust Boiler Energy Extractor: Simplified system for exhaust evacuation; requires a constant supply of water, however.

[0018] FIG. 6: Rankine Exhaust Energy Extractor: System using a Rankine Steam Cycle to recover exhaust heat and power an exhaust evacuator.

[0019] FIG. 7: Steam Injection Energy Extractor: Another technique for recovering exhaust heat. In this technique steam produced by steam heat is injected into a turbocharger to speed up the exhaust turbine and decrease the amount of exhaust back pressure.

SPECIFIC DETAILS ON ENERGY EXTRACTOR OPERATION

[0020]

Specific Details on Energy Extractor Operation

As the name implies, the Energy Extractor actively removes heat from the engine. Heat energy is extracted from the cooling system and from the exhaust system. This heat energy is then converted to mechanical energy to 1) power the extraction process, 2) provide energy for supercharging the intake manifold, and 3) provide power for other uses. The energy extraction process itself results in cooler engine operation and increased fuel efficiency.

Overview: The Energy Extractor actively removes heat from the engine and converts it to mechanical power.

[0021] As the name implies, the Energy Extractor actively removes heat from the engine. Heat energy is extracted from the cooling system and from the exhaust system. This heat energy is then converted to mechanical energy to 1) power the extraction process, 2) provide energy for supercharging the intake manifold, and 3) provide power for other uses. The energy extraction process itself results in cooler engine operation and increased fuel efficiency.

[0022] The Energy Extractor produces mechanical energy in two forms:

- [0023]** 1. The energy extractor aspirates exhaust gas from the engine cylinders. Instead of a positive pressure, the exhaust manifold will develop a partial vacuum. Instead of pistons forcing exhaust gas out against back pressure from the exhaust valves, the exhaust manifold, a turbocharger turbine, the catalytic converter, the muffler, and exhaust pipe, the exhaust gas will literally be sucked out of the engine. The engine no longer uses energy to function as an air pump.
- [0024]** 2. The energy extractor also aspirates steam from the engine cooling system. This ensures excellent engine cooling, and provides steam vapor for superheating from exhaust manifold heat.
- [0025]** 3. The energy extractor uses exhaust heat to pressurize both the exhaust gas and the steam to drive small turbines. This is similar to the manner in which a jet engine pressurizes air in the combustion

chamber and forces it out through a turbine. This pressurized gas or steam can be used to:

- [0026]** a. Power a turbine that pressurizes the intake manifold air, i.e., provide the energy for a supercharger. Note that while this would superficially resemble a turbocharger, the source of the energy to compress the incoming air would be coming from the energy extractor and not from the pressure of the exhaust manifold, which would be under a vacuum.
- [0027]** b. Power a turbine that propels a belt drive replacing the normal crankshaft driven belt drive in an engine.
- [0028]** c. Power a turbine that is connected to and augments that drive shaft. This is superficially similar to the use of "exhaust turbines" in many patents over the past thirty years.

[0029] It may be useful to review the operation of a gas turbine (jet engine) to help understand the operation of the Energy Extractor. Understanding the operation of a jet turbine is absolutely essential to understanding the operation of either the coolant or exhaust based systems.

[0030] The basic jet turbine is actually a very simple engine. It consists of essentially three parts; a compressor, a combustion chamber, and a turbine. The operation is relatively simple:

- [0031]** 1. Air that enters the engine is compressed (by the compressor, naturally) to a pressure of 300400 pounds per square inch. As the gas is compressed the temperature rises to over 10000 Fahrenheit.
- [0032]** 2. As the heated gas enters the combustion chamber it is mixed with jet fuel and spontaneous combustion occurs. The volume of the combustion chamber is greater than the volume of the compressor, and a constant pressure volume expansion of the combustion mixture occurs. Temperatures at this point may be well over 3000° F.
- [0033]** 3. The mixture is then expelled through the turbine stage. As the hot, pressurized gas rushes out it turns the blades of the turbine and produces rotational energy. The turbine then provides power to the compressor via the turbine shaft. A second shaft that exits out the back can be used to power various accessories. If the shaft is connected to a propeller, the engine is referred to as a turboprop. If it is connected to a helicopter rotor, it is known as a turboshaft engine.

[0034] There are two observations about jet engines that are essential to the understanding of the Energy Extractor. The first is this:

[0035] The Sole Function of the Duel is to Add Heat Energy to the Combustion Chamber.

[0036] It would be possible, though certainly impractical, to operate a jet turbine with electrical heating elements. This could be done by placing heating elements in the combustion chamber and heating the air from the compressor with electricity instead of burning petroleum products. It would also be possible, but wildly impractical and dangerous, to heat the air in the combustion chamber with nuclear energy,

such as by controlled fission. In neither of these cases would actual petroleum fuel be required.

[0037] The second vital observation about jet engines is:

[0038] If the Combustion Chamber does not Require Oxygen, then the Jet Engine could Operate in any Gaseous Environment.

[0039] The previously mentioned mythical electric and nuclear turbines could operate in a nitrogen, carbon dioxide, or neon atmosphere. Since the heat added to the combustion chamber comes from either the electrical elements or a nuclear reaction, there would be no need to have oxygen in the compressed atmosphere. Here's the important point; the engine could also operate with an air intake consisting of exhaust from an internal combustion engine or with steam from a boiler.

[0040] The final piece, missing so far, is the heat source for the combustion chamber. A very hot, reliable, and cheap source is readily available for the Energy Extractor. It is heat extracted from the exhaust system. This heat is supplied to the "combustion chamber" in two ways. First, there is an exhaust manifold/pressurization chamber heat exchanger. Second, exhaust heat is pumped into the chamber by the action of the compressor.

[0041] For purposes of further discussion, it may be helpful to visualize the coolant based Energy Extractor as a jet turbine engine that runs in a steam atmosphere. It sucks this steam out of the engine cooling system and heats it in the combustion chamber with heat from the exhaust system. The steam is expelled through a turbine, which operates the compressor and is routed to the radiator, which acts as a condenser.

[0042] The exhaust based Energy Extractor may be regarded as a jet turbine that sucks exhaust out of the engine and through a heat exchanger. The cooled exhaust gas is pumped into the combustion chamber and reheated with the heat from the heat exchanger. The reheated gas is routed through the EE exhaust turbine and then expelled to the environment.

[0043] Mechanical energy may be recovered from the turbine shafts of both of these "jet turbines." It is also possible to add a freewheeling exhaust turbine, much in the same manner that a turboshaft is powered by a jet turbine.

[0044] The energy extractors literally do what their name implies; they extract energy from both the exhaust and coolant systems. Exhaust is literally aspirated from the piston cylinder when the exhaust valve opens, with "exhaust back pressure" becoming "exhaust back vacuum".

[0045] Likewise, heat in the form of vapor is aspirated from the engine cooling system. The heat recovered in this manner is converted to mechanical energy by use of a turbine which 1) drives the "aspirators," and 2) provides power to engine accessories.

[0046] Both of these aspirating actions results in lower engine operating temperatures and maximum recovery of engine waste heat.

[0047] At this point it should be noted that for forty or fifty years there has been a large market for devices that decrease exhaust back-pressure. The astute reader will, of course, recognize that I am referring to exhaust headers. There is

good reason for this; mechanical engineering textbooks estimate that for increase in back-pressure of one psi there will be a decrease in gas mileage of two percent. Any device that decreases back-pressure will increase gas mileage.

[0048] At this point there are probably some thoughtful readers who are pondering the balance sheet associated with equipping an internal combustion engine with even a modest jet turbine or two. The starting price for the smallest commercially available new jet engine has been somewhere around \$40,000. Bolting one on the side of even a good size Diesel engine will likely produce significant sticker shock on the part of most buyers.

[0049] Fortunately, there is a readily available work-around to this monetary problem. A normal turbocharger can be converted into a small gas-turbine by adding a combustion chamber connecting its compressor and exhaust turbine sections. And as the reader is undoubtedly well aware, new turbochargers for either cars or large trucks may be purchased retail starting for around \$500.

[0050] With the concept of the non-fuel jet turbine firmly in mind, let's look at the individual parts of the Energy Extractor. For accuracy and convenience we will give new names to the parts of the "turbine". Depending upon the implementation, the compressor will be renamed either the exhaust evacuator or the charge aspirator. The combustion chamber will be dubbed either the exhaust pressurization chamber or the coolant pressurization chamber. The turbine will be referred to as the EE exhaust turbine or the EE coolant turbine.

[0051] Although the Energy Extractor has a variety of implementations, the basic building blocks consist of the following components:

[0052] Basic Components:

[0053] 1. An exhaust chamber

[0054] 2. An exhaust evacuator

[0055] 3. A charge aspirator

[0056] 4. An evaporation chamber

[0057] 5. A pressurization chamber

[0058] 6. An EE power turbine

[0059] Depictions of the various connections between the components will be found in **FIGS. 1, 2, 3, and 4.**

[0060] 1. Exhaust Chamber:

[0061] The exhaust gas will go to a one or two-stage exhaust chamber upon exiting the exhaust valves. The chamber is mounted to the engine heads in the same manner as an exhaust manifold and contains either one or two heat exchangers.

[0062] The first stage of the heat exchanger transfers heat to the exhaust pressurization chamber (5e) or the coolant pressurization chamber (5c). The chamber functions similarly in both the exhaust and coolant implementations. The pressurization chamber is analogous to a combustion chamber in a turbine engine, in that thermal energy is added to the gas that is delivered from the compressor stage. This stage of the exchanger drops the temperature of the exhaust gas to 300°-400° F.

[0063] Since there is a temperature drop of 600°-1600° F. across the heat exchanger, there will be a corresponding decrease in the volume and pressure of the exhaust gas—although not in the mass of the gas. This decrease in volume and pressure will contribute partially to the chamber operating in a partial vacuum.

[0064] In an ignition combustion engine (gas) engine under load, the temperature of the exhaust gas at this stage is normally about 1600°-1800° Fahrenheit. The exhaust temperature of a compression combustion (diesel) engine under load will only be about 800° Fahrenheit; however, because the diesel engine does not “throttle” the intake air the exhaust gas will have greater mass. With this in consideration, it can be seen that the heat content of the diesel exhaust, while perhaps not as great as a corresponding ignition exhaust, will certainly be greater than what exhaust gas temperatures would suggest.

[0065] An appropriate question to ask at this point is “How big do the primary and secondary heat exchangers have to be?” The answer may be a bit surprising, and can be roughly approximated from observations about heat dissipation in the cooling system.

[0066] As previously noted, at full load about one third of the energy of the fuel is converted to mechanical motion, one third is converted to heat and exhausted out the tailpipe, and the remaining one-third is dissipated as heat through the cooling system. As a rough approximation it can be seen that the amount of heat expelled in exhaust gas is about equal to the amount of heat dissipated through the radiator.

[0067] Under normal conditions the maximal coolant system temperature will be about 220° Fahrenheit. The highest ambient temperature will be no more than 120° F. Therefore, the minimal temperature gradient across which the radiator heat exchanger will operate is $(220-120)=100^{\circ}$ Fahrenheit.

[0068] In contrast, the exhaust chamber primary heat exchanger will be transferring heat across a temperature gradient that will be 400° F. at the absolute minimum and may be much higher. With a gradient of 400° F., only one-fourth as much heat exchanger surface area will be needed to transfer the same amount of heat. Thus, the size of the exhaust chamber heat exchanger will only need to be about one-fourth the size of the cooling system radiator.

[0069] A second stage heat exchanger may or may not be used, depending upon the particular embodiment. Various options will be discussed in a later section; for the time being, we will discuss the “air-charge” option.

[0070] 2. Exhaust Evacuator:

[0071] Another description of this stage might be the “exhaust heat pump,” inasmuch as it pumps hot exhaust gas from the cylinder (when the exhaust valve is open) and exhaust gas passages. It will generally consist of a centrifugal compressor much like that used in the compressor section of a turbocharger. The evacuator may, but does not necessarily have to be powered by the EE exhaust turbine. It may aspirate exhaust gas directly from the engine, or may aspirate the gas from the exhaust chamber after it has traversed the primary and secondary heat exchanger. Depending on the implementation, it either pumps it into the exhaust pressurization chamber (preferred implementation), through a secondary or tertiary heat exchanger, or expels the gas to the exhaust system.

[0072] The presence of a relative negative pressure at the inlet of the exhaust evacuator causes a drop in the temperature of the gas in the exhaust chamber. The relative positive pressure at the outlet of the exhaust aspirator causes a rise in the temperature of the gas in the pressurization chamber. In this manner exhaust gas and heat is pumped from the exhaust chamber to the pressurization chamber, where it can be used without increasing exhaust back pressure.

[0073] Several questions may be posed at this point. The first would be “how big does the exhaust evacuator have to be?” The approximate answer to this may be obtained merely by observation of a problem that has plagued small aircraft pilots for years.

[0074] The phenomena of carburetor icing is well understood and feared by piston aircraft pilots. The condition results because the piston engine aspirates air through the carburetor and intake manifold. This action causes a partial vacuum in the manifold.

[0075] As air rushes through the carburetor to fill the vacuum it expands and its pressure decreases. As the pressure decreases, the temperature of the air decreases. If there is water vapor present, it is possible for the temperature drop enough to actually cause vapor to condense and then to freeze on the carburetor passage way. As the ice accumulates it may choke off the carburetor and cause engine failure.

[0076] Most piston engine aircraft with carburetors will have a special control marked carburetor heat. When this is activated air heated by the engine is diverted through the carburetor to melt the ice. In spite of this, there are a number of small aircraft accidents each year from engine failure due to carburetor icing.

[0077] In this particular situation it is the engine acting as an air pump that produces the partial vacuum in the manifold and resultant drop in temperature. It should be noted, however, that the typical turbocharger can pump far more air than the pistons are able to aspirate; the result is that the intake manifold is under pressure instead of under a vacuum.

[0078] An exhaust evacuator with perhaps twice the capacity of a turbocharger that normally accompanies an engine should be able to evacuate enough exhaust to produce a marked decrease in pressure and temperature.

[0079] 3. Charge Aspirator:

[0080] Depending upon the type of “charge” that the Energy Extractor uses, this aspirator pumps either air, steam from a coolant water evaporation chamber, or an air/alcohol mixture from the second stage heat exchanger of the exhaust chamber. The charge is then ported to the pressurization chamber.

[0081] Similar to the exhaust aspirator, the charge aspirator may be driven by the EE coolant turbine, although it certainly could be powered by another source. The easiest implementation using a turbine could be done using a separate turbocharger with a turbine and compressor. The simplest implementation would involve a single turbine that powers both the exhaust evacuator and the charge aspirator.

[0082] 4. Evaporation Chamber:

[0083] The evaporation chamber partially takes the place of the cooling system radiator. It may be based upon either a nozzle design or a heat exchanger design. The charge

aspirator places the evaporation chamber under a partial vacuum, which decreases the boiling point of water. The steam (or working liquid) aspirated from the evaporation chamber is routed to the coolant pressurization chamber, where it is heated by the primary heat exchanger.

[0084] Nozzle Based Design:

[0085] It is well known that water that boils in cooling system water passages will compromise the absorption of heat from the water passage walls. This is because steam, with its greatly diminished density, will not absorb heat as efficiently as liquid water.

[0086] Because of this, water that is routed to the evaporation chamber from the engine will be fed into the chamber via pressure reduction nozzles. This will have two effects; it will keep the pressure of the water in the engine water passages significantly higher than the pressure in the evaporation chamber, which will prevent water vaporization boiling in the engine. With this design, there will be no need to redesign an engine's coolant passages. Secondly, the use of a water nozzle with an appropriate spray pattern will facilitate evaporation and cooling and minimize the sometime violent action of boiling water.

[0087] It should be noted that the water pump will require additional power to pump the water through the evaporation nozzles. However, at least a part of this power will be recovered in the form of the extra water vaporized by the nozzle action.

[0088] Heat Exchanger Design:

[0089] Instead of using a common working liquid for both engine cooling and operation of a "thermodynamic engine," it is possible to use separate circuits which exchange heat through an evaporation chamber heat exchanger. With this design engine coolant would circulate through the engine and a heat exchanger which would function like a typical engine radiator. Instead of transferring heat to air, the heat would be transferred to a "working liquid" to power the thermodynamic engine. The working liquid in the evaporation chamber would also be placed under a partial vacuum by the charge aspirator. Like the nozzle based design, the charge aspirator would prevent "heat reflection" from the vapor superheater and would facilitate working liquid evaporation by lowering the vaporization temperature with the partial vacuum. Also like the nozzle based design, the charge aspirator will pump the vaporized working liquid into the coolant pressurization chamber. While the working liquid may be a water/coolant mixture, other liquids could be used, such as an ammonia/water mixture or a refrigerant.

[0090] 5. Pressurization Chamber:

[0091] This is somewhat analogous to the combustion chamber of a jet engine. Mixing and heating of the various gases occur, depending upon the Energy Extractor implementation. As the mixture absorbs heat from the primary heat exchanger the effective volume of the gas increases, forcing it through the associated EE turbine.

[0092] For the coolant based implementation (5c), the only gas introduced into the pressurization chamber is steam aspirated from the evaporation chamber. After heating and pressurization, the steam is ported to the EE coolant turbine, possibly to a power turbine, and then to the condenser, or radiator.

[0093] For the exhaust based implementation (5e), the cooled exhaust gas and possibly a second cooling charge is ported into the chamber and then ported to the EE exhaust turbine and then to the environment.

[0094] 6. Energy Extractor (EE) Turbine Section:

[0095] This is analogous to the turbine on a jet engine or a turbocharger. It may be either axial or centrifugal, although the most common configuration will probably be centrifugal like the typical turbocharger turbine. The energy extractor turbine will receive steam from the coolant pressurization chamber (5c) or hot gas from the exhaust pressurization chamber (5e). The turbine will extract a portion of the kinetic energy from the exhaust/steam mixture and turn a shaft to power the exhaust or steam aspirator sections. Following its exit from the Energy Extractor turbine, the gas/steam mixture could be routed through a power turbine section.

[0096] One significant difference between the Energy Extractor turbine and the turbine on a jet engine or turbocharger is the working temperatures the unit encounters. The EE turbine will work at much lower temperatures. Temperatures will probably not exceed 800° F. for the exhaust turbine and 300° F. for the coolant turbine. With less thermal stress, closer tolerances should be possible than for a jet turbine or turbocharger.

[0097] 7. Power Turbine.

[0098] This would be analogous to the "free turbine" in a jet engine which provides power to either a propeller or a turboshaft. It is used to recover excess pressure power not utilized by the EE turbine. A typical application would be a turbocharger or an exhaust turbine. The turbocharger would return energy to the engine by pressurization of the air going to the intake manifold. An exhaust turbine setup could power an auxiliary generator or directly return power to the crankshaft through some type of coupling apparatus.

Energy Extractor Arrangements

[0099] The various Energy Extractor components may be assembled in a variety of arrangements. All of these arrangements have several common features; 1) an exhaust evacuator is used to aspirate exhaust gas from an exhaust heat exchanger and/or from the engine, 2) exhaust heat is used to power the exhaust evacuator using various techniques. In general, the more complex the system, the greater the energy recovery that may be expected.

[0100] Coolant Based System:

[0101] Please refer to FIG. #1. The coolant based Energy Extractor functions as follows:

[0102] 1. Coolant (most likely water and antifreeze) is pumped from a coolant reservoir through the engine coolant jacket. Leaving the cooling jacket, it is routed to the evaporation chamber (4). Note that this is a nozzle based evaporation chamber. The water/coolant mixture is introduced into the chamber through spray nozzles, which has the effect of a) keeping the coolant jacket pressure higher than that in the evaporation chamber, and b) facilitating evaporation by the use of a spray. The high pressure of the coolant in the engine jacket prevents localized coolant boiling with its attendant heating problems.

- [0103] 2. Evaporation is driven by the charge aspirator (3), which sucks coolant vapor out of the evaporation chamber and into the coolant pressurization chamber (5C). The vaporization causes cooling of the remaining coolant, which drains into a reservoir.
- [0104] 3. The vapor pumped into the coolant pressurization chamber by the charge aspirator is heated by the primary heat exchanger from the exhaust chamber (1). This has the effect of superheating the vapor. Since the vapor is pumped into the pressurization chamber by the charge aspirator, increased pressure and temperature are not reflected back to the cooling system.
- [0105] 4. From the pressurization chamber the vapor passes through the EE coolant turbine (6c). This is analogous to the turbine on a jet engine. Although it is not mandatory that the charge aspirator be powered by the turbine, it will probably be the most convenient implementation.
- [0106] 5. After exiting the Energy Extractor turbine, the vapor passes to the power turbine (7). This turbine will probably be used to power the exhaust evacuator, a supercharger, and possibly a auxiliary generator. It is also possible to direct this power to other applications.
- [0107] 6. Vapor which leaves the power turbine is passed to the condensing radiator (8) which is similar to a typical engine radiator. Here heat rejected from the system is discharged into the environment.
- [0108] 7. The condensed vapor is routed back to the coolant reservoir. A small pump may or may not be necessary to accomplish this.
- [0109] 8. Exhaust leaving the piston cylinders is introduced into the exhaust chamber (1). The primary heat exchanger transfers heat to the coolant pressurization chamber (5c) which contains coolant vapor from the charge aspirator.
- [0110] 9. Exhaust is aspirated from the exhaust chamber by the exhaust evacuator (2). This has the effect of "pumping" heat out of the cylinder and possibly to a secondary heat exchanger.
- [0111] Exhaust Based System
- [0112] Please refer to FIG. 2. The exhaust based Energy Extractor operates as follows:
- [0113] 1. Exhaust leaving the piston cylinders is introduced into the exhaust chamber (1). The exhaust chamber contains a primary and secondary heat exchanger. The primary heat exchanger, which first receives the exhaust gas and is therefore the hottest, transfers heat to the pressurization chamber. The secondary heat exchanger transfers heat to a cooling charge, which will be non-coolant water, air, or an air/fuel mixture. This ancillary fuel may be an alcohol such as methanol or ethanol. The cooling charge further lowers the exhaust gas temperature and pressure.
- [0114] 2. The exhaust gas is aspirated from the exhaust chamber by the exhaust evacuator (2), which pumps it into the exhaust pressurization chamber (4e). The evacuator, which resembles a compressor on a turbocharger, will generally be powered by the EE exhaust turbine (6e), although it may be powered by other methods. The aspiration of the gas from the exhaust chamber and by extension, the cylinder during the exhaust stroke, lowers the temperature of the exhaust gas all the way from the cylinder to the evacuator. If water is used as a cooling charge for the secondary heat exchanger, the resulting steam may be injected into the exhaust evacuator in a manner to augment its aspiration characteristics.
- [0115] 3. The charge aspirator (3) pumps air from the secondary heat exchanger. If desired, the aspirated air may also contain fuel vaporized by the secondary heat exchanger.
- [0116] 4. Upon leaving the exhaust evacuator the gas enters the exhaust pressurization chamber (5E). Here it is mixed with the cooling charge which is pumped into the chamber by the charge aspirator (3). The mixture is allowed to expand and receives heat via the primary heat exchanger from the exhaust chamber. Depending upon the implementation, there may be a catalytic converter or even a ignition device to ensure complete combustion of exhaust gas byproducts.
- [0117] 5. From the pressurization chamber the heated, pressurized gas is ported to the "EE Exhaust Turbine (6e)." This turbine, which resembles an exhaust turbine on a turbocharger, will probably provide shaft power for the exhaust evacuator and the charge aspirator.
- [0118] 6. After leaving the EE Exhaust Turbine (6e), the gas may pass through a power turbine (7). This may be used to drive a turbocharger, an auxiliary generator, or some other device that uses shaft power.
- [0119] 7. Upon leaving the power turbine the gas is discharged to the exhaust system.
- [0120] Combined Exhaust and Coolant Implementation
- [0121] Both the exhaust and coolant Energy Extractor systems may be combined (refer to FIG. 3). This more complex configuration will result in the most energy recovery possible. The primary heat exchanger must be modified to allow heat transfer to both the coolant pressurization chamber and the exhaust pressurization chamber.
- [0122] With this implementation there would be two basic Energy Extractor units; one would be driven by the exhaust EE turbine and power the exhaust aspirator; the other would be driven by the coolant steam EE turbine and power the charge aspirator. Auxiliary power from a power turbine could be taken from either the exhaust circuit or the coolant circuit.
- [0123] In the Combined Energy Extractor detailed in FIG. 3, the primary heat exchanger first transfers heat to the exhaust pressurization chamber (5e); the next section of the exchanger transfers heat to the coolant pressurization chamber (5c). Leaving the primary heat exchanger, the exhaust gas is further cooled by the secondary heat exchanger, which in this implementation circulates water from the evaporation chamber. This has the effect of increasing the amount of water vaporized for heating in the coolant pressurization chamber.
- [0124] Note that this particular design uses the nozzle based evaporation chamber. This same implementation could be done with the heat exchanger based evaporation chamber.

[0125] In this implementation the power turbine (7) is part of the coolant EE circuit. While this will probably be the source of most of the energy recovery, it would also be possible to also install a power turbine following the EE exhaust turbine in an attempt to recovery more exhaust gas energy.

[0126] Gas Mix Energy Extractor

[0127] Another method of implementing the Energy Extractor principles is illustrated in FIG. 4. With this technique steam aspirated from the evaporation chamber (4) by the charge aspirator (3) is mixed with exhaust gas which has passed through the exhaust chamber and the exhaust evacuator. This steam/exhaust gas mixture is routed to the exhaust pressurization chamber (5e) for superheating from the primary heat exchanger. The gas mixture is directed through the EE exhaust turbine and then the power turbine. In this particular example the power turbine is used to drive the charge aspirator.

[0128] There are a few advantages to this approach. One feature is the "water scrubbing" effect on the exhaust gas when it is mixed with steam aspirated from the evaporation chamber. As the steam condenses from the mixture, water soluble pollutants such as nitrous oxide should be removed in the condensate. A second advantage is that there are less components; no condensing radiator is used with this arrangement.

[0129] There are several disadvantages to this approach, though. First, a considerable amount of water will be required to make up for the loss of steam. As previously noted, about one-third of the energy released by fuel eventually is dissipated through the engine cooling system. One gallon of gasoline contains sufficient energy to vaporize about 15 gallons of water. If the energy normally dissipated by the cooling system is used to vaporize water, then five gallons of water will be vaporized for each gallon of gas. This would require that five gallons of water be available for each gallon of gasoline that is used.

[0130] It should be possible to recover some of the water from the exhaust condensate. Burning one gallon of gasoline will normally produce about one gallon of water. After mixing with the steam, it would be theoretically possible to recover six gallons of water from the exhaust for every gallon of gasoline that would be used.

[0131] Thermodynamic considerations also suggest that this particular approach probably won't result in as much energy recovery as with the Energy Extractor Coolant system implementation. Energy will have to be used to warm water from the ambient temperature to the temperature of vaporization, as opposed to the "closed loop system" in which water returned to the evaporation chamber will be close to the temperature of vaporization.

[0132] Exhaust Boiler Energy Extractor

[0133] The simplest installation of an Energy Extractor would involve just the exhaust system components. This approach forfeits any energy recovery from the cooling system. As previously noted, though, the exhaust extractor will have the effect of transferring some of the heat normally dissipated through the cooling system to be pumped into the exhaust Energy Extractor system. Because of this, the

amount of energy recovered may be greater than what would be predicted just from typical heat dissipation figures.

[0134] FIG. 5 diagrams an "exhaust boiler" Energy Extractor implementation. As with the gas mix Energy Extractor, exhaust gas is mixed with steam in the exhaust pressurization chamber. Additionally, the system requires water makeup; the water that is vaporized is lost through the exhaust system. A separate water tank would be required for use of this system. This particular type of installation might find application in recreational vehicles which normally have a good size water reservoir for domestic use.

[0135] This system is different than the previously mentioned implementations, though, in that the water is vaporized solely by the exhaust system. There is no separate superheating section. Because of this, the exhaust heat exchanger is appropriately described as a boiler.

[0136] The main advantage of this system is its simplicity. Complete installation will only require an exhaust heat exchanger boiler, a turbocharger, and a pressurization chamber. The engine cooling system will remain unchanged. As with the other implementations, the exhaust that leaves the Energy Extractor turbine may be routed through a power turbine for further energy recovery.

[0137] Rankine Exhaust Energy Extractor

[0138] FIG. 6 demonstrates the manner in which a Rankine Steam circuit could be used with an exhaust heat exchanger boiler and an exhaust evacuator. In this system there is no mixing of the exhaust gases and steam. An exhaust heat exchanger boiler is used to produce hot steam that is routed to a "Rankine power turbine." In this particular illustration a turbocharger turbine is used to recover power from the hot steam. The power turbine powers the exhaust evacuator (2). Exhaust aspirated through the evacuator may be routed through a second heat exchanger, a power turbine, or to the exhaust system.

[0139] Steam that exits the Rankine power turbine condenses in a condensing radiator (8). Condensate water is pumped back to the exhaust heat exchanger boiler by a feedwater pump. If so desired, the water could be routed through a secondary exhaust/feedwater heat exchanger to recover more energy.

[0140] Since heat exchangers are used instead of direct exhaust gas and steam mixing, it would be expected that this system would be somewhat less efficient in energy recovery than the corresponding exhaust boiler energy extractor. The obvious advantage is that since steam is not lost out the exhaust, no water reservoir is required for operation.

[0141] Steam Injection Energy Extractor

[0142] The absolute simplest Energy Extractor implementation is depicted in FIG. 7. As can be seen, this system can be constructed with just an exhaust heat exchanger boiler and an already installed turbocharger. High pressure steam from the exhaust boiler is introduced through the turbocharger turbine casing via a steam injector. The injector is positioned so the steam strikes the turbine impellers at nearly a tangential angle. This action causes the turbine to spin faster and decreases the exhaust back pressure normally seen with turbochargers.

[0143] Like the exhaust boiler Energy Extractor systems, this particular system is limited by its dependence on a water reservoir.

What I claim for my invention is:

1. The Coolant Based Energy Extractor implementation.
(See **FIG. 1**)

2. The Exhaust based Energy Extractor Implementation
(see **FIG. 2**).

3. The Combination Energy Extractor Implementation
(see **FIG. 3**).

4. The Gas Mix Energy Extractor (see **FIG. 4**).

5. The Exhaust Boiler Energy Extractor (see **FIG. 5**).

6. The Rankine Exhaust Energy Extractor (see **FIG. 6**).

7. The Steam Injector Energy Extractor (see **FIG. 7**).

* * * * *