# DOWNLOAD PDF PHASE CHANGE HEAT TRANSFER, 1993

## Chapter 1 : Changes of Phase, Heat, Temperature | Zona Land Education

*Heat Lecture 9 CM 12/7/ 2 Heat Transfer with Phase Change So far we have discussed heat transfer at a boundary due to a temperature difference between bulk temperatures.*

The charge air is intercooled to increase its density and, therefore, engine performance. Heat from the intercooling process is utilized to vaporize the liquid natural gas fuel. Heat exchange from the charge air to the liquid natural gas is accomplished with a phase changing heat transfer fluid. The heat transfer fluid boils at the intercooler and condenses at the fuel vaporizer to give precise temperature control at the intercooler surfaces without frost build-up. Heat is exchanged between compressed charge air and the fuel being consumed with the result that the density of charge air is advantageously increased and the fuel is vaporized and heated to near ambient conditions. A potential problem to be avoided is a tendency of frost to occur and build-up in the air circuit where the air contact surface is cooled by the cryogenic fuel at temperatures below freezing, i. The phase change heat transfer fluid is circulated between zones where it is chilled and condensed by heat exchange with the low temperature fuel and is boiled or evaporated by heat exchange with the compressed charge air. As disclosed, the temperature of the heat transfer fluid in the zone where it is cooling the charge air is conveniently and precisely controlled by regulating its vapor pressure to maintain the associated heat exchanger material in contact with charge air as close to the freezing point temperature as desired. Since the boiling or phase change point is directly related to its pressure it is relatively easy to maintain a desired operating temperature in this heat exchanger zone. Transient conditions in flow rates of the charge air or fuel do not have a significant effect on the accuracy of temperature control since a relatively small excess inventory of heat transfer fluid at both the evaporator and condenser zones is capable of accommodating transient flow conditions. This results from the relatively high heat of vaporization and condensation in the phase change of the heat transfer fluid. The phase change of the heat transfer fluid enables it to sacrifice or absorb high quantities of heat even for limited quantities of such material. The disclosed system includes a bypass circuit that operates to direct the heat transfer fluid to an alternate heat source for vaporization when the intercooling heat exchanger surfaces have been cooled by heat exchange with the heat transfer fluid to a critical minimum control temperature for the avoidance of frost build-up. The system further includes another bypass circuit that is employed to avoid excessive heating of the heat transfer fluid which could otherwise raise the temperature of the fuel above the temperature of the charge air supply by a significant temperature differential which could make it difficult to accurately control the air-fuel ratio. Vaporized fuel can be selectively introduced into the ullage space of the fuel tank to ensure that an adequate supply of fuel will be afforded to the engine. Reference can be made to the disclosure of aforementioned U. The vehicle 10 includes an internal combustion engine 11, preferably of the spark ignition, or pilot fuel injected ignition type, driving a set of propulsion wheels 12 through a drive train  A set of front wheels 14 can provide for steering of the vehicle in a known manner. The engine 11, in the illustrated example, is fitted with a conventional turbocharger  The turbocharger 16 utilizes energy from the exhaust of the engine 11 to compress charge air to be combusted by the engine  Charge air is drawn into an inlet 17 of the turbocharger 16 and is compressed to a pressure which when the engine is under load, is substantially above atmospheric pressure reaching, for example, 10 psig. Air compressed by the turbocharger 16 is substantially elevated in temperature as a result of the compression process which occurs externally of the engine  The charge air after compression in the turbocharger 16 is conducted by a supply conduit 18 to an intercooler 19 which is either of the air cooled type or of the water cooled type, both known in the art. A cooling fluid circuit for the intercooler 19 is shown at  The engine 11 is supplied fuel from a fuel tank 21, carried on the vehicle  The tank 21, fuel lines and associated componentry carrying the fuel to the engine 11 are cryogenically insulated as needed according to known techniques. Natural gas fuel 22 from the tank 21 is delivered successively through a shut-off valve 23, a heat exchanger 31 where it is vaporized and tempered and a line 26 to a throttle body fuel injector  A circuit 28 carrying a heat transfer fluid exchanges heat from the compressed charge air at a second stage intercooler 29 to the cryogenic LNG at the heat exchanger  As will be understood, the circuit 28, thus, beneficially cools the charge air and vaporizes the natural gas or methane fuel. The circuit 28 includes a liquid pump 32 that circulates heat transfer fluid through various parts of the circuit  The pump 32 receives liquid heat transfer fluid from a liquid sump or reservoir 33 and directs it to a closed space or chamber 34 of the second stage intercooler 29 through a line  In the illustrated arrangement, the pump 32 is operated under the control of a float switch 37 to keep the inventory of liquid in the sump 33 at a predetermined normal operating level. The chamber 34 forms a boiler for the heat transfer fluid. Warm supply or charge air received from the first stage intercooler 19 transfers heat through heat conducting surfaces 39 of walls, fins or the like to the heat transfer fluid in the boiler chamber  The heat transfer fluid, received in the boiler chamber as a liquid, is vaporized and then conducted through a line 38 to the heat exchanger  At the heat exchanger 31, the heat transfer fluid vapor gives up heat to LNG flowing from the tank  The exchange of heat at the unit 31 causes the LNG to be vaporized and tempered and the heat transfer fluid vapor to be condensed to a liquid for return to the sump  The boiling point temperature of the heat transfer fluid in the boiler chamber 34 is maintained to cool surfaces 39 of the second stage intercooler heat exchanger 29 contacted by the engine charge air at just above the freezing temperature of water carried in the engine supply air to avoid frost build-up on these surfaces. In the illustrated embodiment, this is accomplished by regulating the pressure in the chamber 34 with a pressure relief valve  The pressure relief valve 41, of known construction, opens to release vapor from the chamber 34 to the line 38 to the heat exchanger 31 whenever the pressure exceeds a predetermined value. This relief pressure is selected for the particular heat transfer fluid being used to yield a temperature of such fluid which, as mentioned, results in temperatures on the air contacting surfaces 39 of the intercooler 29 that are at least slightly above a frost temperature. One material having properties suitable for use as the heat transfer fluid is propane. A liquid level or float control valve 42 maintains a limited excess volume of liquid heat transfer fluid in the boiler chamber  When the excess is sufficient, the valve 42 closes to prevent entry of additional heat transfer fluid; when the excess of the heat transfer fluid is depleted below a predetermined level, the valve 42 reopens to admit additional liquid heat transfer fluid. The heat transfer fluid circuit 28 includes a branch 44 with a heat exchanger 46 supplied with heat from an alternative heat source, besides that afforded by the charge air at the second stage intercooler  Such alternative heat source may be engine exhaust heat or engine jacket heat. The circuit 28 further includes a branch 47 for bypassing the alternative heat source heat exchanger 46 at appropriate times. A control valve 48 responsive to sensors 51 and 52 respectively monitoring the temperature of air delivered from the second stage intercooler 29 to the engine 11 and the temperature or pressure of the heat transfer fluid upstream of the heat exchanger  The valve 48 directs the heat transfer fluid through either the heat exchanger 46 or the bypass branch 47 or both these branches depending on the signals from the sensors 51, 52 to maintain the temperature of the heat transfer fluid vapor near the temperature of the air entering the turbocharger inlet 17 to supply the engine  This vapor temperature level facilitates temperature control of the natural gas fuel vapor as it leaves the heat exchanger 31 heated by the heat transfer fluid vapor and allows this fuel vapor to be maintained near the air supply temperature. A valve 53 responsive to pressure in the ullage space 54 of the fuel tank 21 admits vaporized LNG into the ullage space when the pressure is below a level necessary to supply adequate fuel to the engine  Introduction of this vaporized LNG adds enthalpy to the. LNG inventory in the fuel tank 21 resulting in a rise in vapor pressure which increases the delivery pressure of LNG to the heat exchanger 31 and downstream to the engine fuel injector  It should be evident that this disclosure is by way of example and that various changes may be made by adding, modifying or eliminating details without departing from the fair scope of the teaching contained in this disclosure. The invention is therefore not limited to particular details of this disclosure except to the extent that the following claims are necessarily so limited. Claims 4 I claim: A vehicle as set forth in claim 1, wherein the compressed charge air heat exchanger includes air contacting surfaces, and control means to regulate the temperature of the heat transfer fluid and, consequently, the temperature of the air contacting surfaces by controlling its pressure and thereby limiting the cooling Of the air contacting surfaces to a temperature that avoids build-up of frost. A vehicle as set forth in claim 1, wherein said heat transfer fluid circuit includes an auxiliary heat exchanger providing an alternative heat source for heating said heat transfer fluid from a source of heat separate from said charge air heat exchanger.

## Chapter 2 : USA - Phase-change heat transfer system - Google Patents

*Add tags for "Phase change heat transfer, presented at the ASME Winter Annual Meeting, New Orleans, Louisiana, November December 3, ". Be the first. Similar Items.*

A heat collector device is connected in series with a condenser and an accumulator. The accumulator includes apparatus for regulating the pressure therein. A fluid capable of phase change within the system travels among the collector, condenser, and accumulator. The heat transfer mechanism is inefficient and unreliable. The typical forced-liquid system requires a circulation pump which consumes electricity. The temperature differential between the collector and the water truck is quite large , e. The coolant is usually corrosive and subject to freezing. Many coolants are highly toxic hence hazardous should there be incursion to the hot water system. The controls are complicated and may not prevent transfer of heat from the condenser to the collector. The typical installation is neither optimum nor reliable. The thermal advantage of a phase-change system over a circulating-liquid system is apparent from corsideration of latent heat as opposed to sensible heat for energy transport. This means that the circulating rate of the fluid for the phase-change system can be a small fraction of that of a circulating liquid, along with comparable elimination of external pumping power. Reduction of the circulating rate in the circulating liquid system would produce higher collector temperatures, accompanied by higher collector losses. The standard pumped coolant system can neither maintain isothermal conditions within the collector nor provide the automatic maximum heat transfer in the transiently-cooled section of the tank when cold water enters caused by the increased condensing action at that point. Furthermore, the increase in heat transfer, as described above, in connection with a phase-change system, comes only from the collector; no heat is robbed from the upper portion of the tank which was previously heated. Thus, a beneficial stratification in the water tank is preserved despite the presence of the condenser. These and other difficulties experienced with the prior art devices have been obviated in a novel manner by the present invention. It is, therefore, an outstanding object of the invention to provide a completely self-regulating heat recovery and transfer system. Another object of this invention is the provision of a heat collection and transfer system which cannot freeze up. A further object of the present invention is the provision of a heat collection and transfer system with improved heat transfer capability by using the phase change of the heat transfer fluid. It is another object of the instant invention to provide a heat collection and transfer system which has no moving parts. A still further object of the invention is the provision of a heat collection and transfer system which is more reliable and easily maintained than the prior art. It is a further object of the invention to provide a heat collection and transfer system for which no outside controls are needed. It is a still further object of the present invention to provide a heat collection and transfer system which eliminates many expensive and troublesome components. Another object of the invention is the provision of a heat collection and transfer system which cannot lose heat from the condenser through the heat collector. Another object of the invention is the provision of a heat collection and transfer system using a heat transfer medium which is non-corrosive. Another object of the invention is the provision of a heat collection and transfer system using a heat transfer medium which has very low toxicity. Another object of the invention is the provision of a heat collection and transfer system having a collector which is self-balancing and isothermal. Another object of the invention is the provision of a heat collection and transfer system in which the stratification of the fluid to which heat is transferred in the condenser is improved. Another object of the invention is the provision of a heat transfer and collection system in which heat always flows directly to the coldest point, improving system efficiency. Another object of the invention is the provision of a heat transfer and collection system which will provide greater heat transfer and provide higher temperatures with otherwise unchanged collector and condenser capacities from more standard designs. With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of elements set forth in the claims appended hereto. Another object of the invention is the maintenance of high efficiency, when the system is used as a solar heat collector, for example, even if the collector becomes partially shielded from the sun such as caused by a tree or building during part of the day. Another object is the efficient operation of the system even if the installation requires some of the collector system to have difference orientations, i. Another object of this invention is to provide a good performance monitor for the system. Another object of this invention is to provide an effective test for even very small leaks in the system. More generally, the invention relates to a heat collection and transfer system which utilizes the phase-change capability of a heat transfer medium and thus avoids the need for a pump for the heat transfer medium. Of course, the heat may be collected from any source, such as solar, exhaust gases, or heated waste water, and it may be transferred to any medium, such as water or gas, in the condenser. The single FIGURE of drawings represents a somewhat schematic view of an apparatus, embodying the principles of the present invention in a preferred embodiment. This condenser 11 may be immersed in a a relatively low temperature condensing fluid, such as water  The water may be held in an insulated tank or vessel 14, the tank having an upper outlet 15 and a lower inlet 16 for water to enter it. Situated below the condenser 11 and connected to the lower outlet 13 through a first conduit 26 is an accumulator 17, which, in the preferred embodiment, is of the bladder type. The accumulator may be located below or even above the collector, so long as it is connected to the system at a location which is below the collector, e. The accumulator 17 may have a bladder 18, an accumulator inlet 19, and a means 21 for regulating the pressure about the bladder 18 of the type manufactured under the trademark "EXTROL" by Amtrol Inc. The solar collector may comprise an upper outlet 23 which communicates with the condenser upper inlet 12 through a second conduit 27 and a lower inlet 24 which communicates with the accumulator inlet 19 by an extension of the first conduit  Within the solar collector itself may be an inside conduit 25 which connects the collector outlet 23 to the collector inlet 24 and which exposes a heat transfer medium 28, located at times within the conduit, to solar energy effects. This fluid heat transfer medium is located generally within a closed network formed by the condenser, the first conduit, the bladder, the solar collector conduit, and the second conduit. The operation and advantages of the invention will now be readily understood in view of the above description. In an initial state the fluid heat transfer medium 28 which in the preferred embodiment, is Freon would lie substantially within the bladder 18 of the accumulator  In this initial state, the fluid level of the Freon lies below the collector inlet  This forces the fluid Freon 28 up into the system, particularly into the solar collector conduit  In other words, the pressure applied to the bladder by the device 21 must be great enough to force effectively all of the medium 28 out of the accumulator 17 and up into the system for the system to transfer heat from the collector to the condensor. When the desired temperature of the condensing fluid 20 is reached, dependant upon the pressure exerted by the regulation device 21, the pressure in medium 28 will exceed the pressure exerted on the bladder by the device  Only at that point does the accumulator serve any "useful" purpose or even "exist" insofar as this system is concerned: The bladder will expand against and overcome the force in the pressurizing chamber and the accumulator will thus act as a "thermostatic switch" to shut down the system. Since there is no medium 28 in the collector under these conditions, no effective heat transfer will occur until the temperature of the fluid 20 diminishes to a level at which the bladder again forces all of the medium 28 back into the system. When the medium 28, e. This increases the vapor pressure in the closed network and the less dense vapor rises up the conduit of the collector, through the collector outlet 23 to the condenser, by way of the second conduit  In this initial instant the condensing fluid is cool. The Freon vapor condenses, thus imparting its energy through the condenser walls to the water. Because of the placement of the water tank above the collector 22 and accumulator 17, gravity forces the condensed liquid Freon back towards the bladder  At that time, the vapor pressure within the closed network will slightly exceed 70 psig. Because of this greater pressure being exerted within the bladder, the bladder 18 will expand and thereby lower the liquid level of the Freon within the remainder of the system. This will cause the bladder 18 to contract and the Freon will again be forced into the collector 22 and the cycle will begin again. The efficiency of the system is further enhanced by the self-balancing feature of the phase-change system which forces the collector 22 to operate isothermally and hence at the greatest efficiency. Due to the nature of the heat transfer medium, the heat transfer is concentrated at the coldest point within the hot water tank 14 and thus further increases system performance and efficiency. When some cold water enters through the cold water inlet 16, as hot water is removed through the hot water outlet 15, rapid condensation is caused around the lower part of the condenser 11, thus concentrating the heating at that point. This further lowers the vapor pressure and temperature in the Freon system. It also lowers the temperature in the collector 22 and increases further the efficiency of the collector. Furthermore, no heat is robbed from the upper part of the hot water tank 14 during this transient condition, thus preserving the beneficial stratification within the system. The above-mentioned features further allow cascading of hot water flow in two or more tanks while operating the Freon coils in parallel. The self regulation of the final temperature and the concentration of heating at the coldest point in the tanks enhance the operation. This also provides a lower profile for the tanks and hence will fit within a greater number of home designs. A novel feature of this system is that no heat energy can be transferred from the hot water tank 14 to the collector  This occurs because, if the collector 22 is cooler than the hot water 20, the liquid remains entirely within the collector and the vapor pressure is lower than that required to cause condensation within the condenser 11; hence no heat transfer can take place. If the water 20 surrounding the condensing coil 11 is cooler than the collector 22, condensing of the vapor will commence and efficient heat transfer will take place between the collector 22 and the water  From the above description it can be seen that the system provides its own thermostat, as well as providing a "thermodiode", so that heat can only flow in the proper direction. Further, the bladder accumulator prevents the release of Freon to the atmosphere and protects the system. An alternate configuration where the hot water storage tank cannot be placed above the collector utilizes a condenser located above the collector rather than within or attached to the storage tank. The heat is transferred from this condenser to the storage tank by means of a circulating pump for forcing circulation of the storage tank water through the condenser. This then provides many of the benefits of the above system even though the optimum location of the storage tank is precluded. A good performance monitor of the system is provided, since the pressure gauge within the pressure regulating devices 21 indicates the actual operating temperature of the collector until the regulated pressure is reached. It also indicates proper operation of the system. It is possible to provide an effective test for very small leaks in the system when Freon is used in the system, since a conventional commercial halogen-type leak detector functions very well. By its use, the integrity of the system is tested easily and effectively. It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described, but it is desired to include all such as properly come within the scope claimed. For example, the collector may be employed to collect heat from any suitable source, such as laundry waste water, furnace smoke stack gasses, etc. Similarly, the condenser may transfer the useful heat to any desired gas or liquid. Further, in the preferred or any alternate embodiment, the pressure regulating device 21 may be used to control the heat transfer medium pressure, and thus the temperature at the system output. Those skilled in the art will realize that the only limitation here will be based upon the side of the system, the volume of the heat transfer medium in the system, and the particular characteristics of the medium. A heat collection apparatus using phase-change heat transfer comprising: The apparatus of claim 1 wherein said removal means comprises an accumulator having a housing, flexible means within, and sealed to, the walls of the housing to provide a first, fluid-receiving volume on one side of the flexible means and a second, pressurizing volume on the other side of the flexible means, and means for exerting sufficient pressure in the second volume to force all phase-change fluid out of the first volume when the condensing fluid is below a predetermined temperature and for allowing such withdrawal of the phase-change fluid into the first volume when the predetermined temperature is achieved by the condensing fluid. The apparatus of claim 2 wherein the accumulator is located entirely below the heat collector. The apparatus of claim 2 wherein the accumulator is connected to said system at a location below the heat collector. Solar water heater making use of phase-change heat transfer, comprising: The apparatus of claim 6 wherein said heat collector means comprises solar energy collection means suitably oriented relative to the sun for collection of such energy. The apparatus of claim 6 wherein said pressure controlling means comprises means for accumulating a sufficient volume of said phase-change fluid as a liquid at a low point in the system, when the condensing fluid in said housing reaches a predetermined temperature, in a volume sufficient to effectively prevent further heating of the condensing fluid. The apparatus of claim 8 wherein said accumulating means comprises a variable volume fluid-containment means and means for exerting a selected pressure on said containment means for thus controlling and selecting said predetermined temperature of said condensing fluid.

## Chapter 3 : Phase-change material - Wikipedia

*After watching this lesson, you will be able to explain what heat transfer is and describe the various phase changes that can result from heat transfer in terms of the position of the molecules.*

Heat goes into the solid as it sublimates. None So, how could there be a change in heat during a state change without a change in temperature? During a change in state the heat energy is used to change the bonding between the molecules. In the case of melting, added energy is used to break the bonds between the molecules. In the case of freezing, energy is subtracted as the molecules bond to one another. These energy exchanges are not changes in kinetic energy. They are changes in bonding energy between the molecules. If heat is coming into a substance during a phase change, then this energy is used to break the bonds between the molecules of the substance. The example we will use here is ice melting into water. Immediately after the molecular bonds in the ice are broken the molecules are moving vibrating at the same average speed as before, so their average kinetic energy remains the same, and, thus, their Kelvin temperature remains the same. Below is a picture of solid ice melting into liquid water. The molecule of ice and the molecule of water the black balls are moving with the same rate of vibration in this diagram. This is meant to show that they have the same average speed and thus the same average kinetic energy since they have the same mass and thus the same Kelvin temperature. The motions are, though, greatly exaggerated. Actually, the motions of the molecules should be considered tiny vibrations. At the moment of melting the average kinetic energy of the molecules does not change. The heat is used to break the bonds between the ice molecules as they turn into a liquid phase. Since the average kinetic energy of the molecules does not change at the moment of melting, the temperature of the molecules does not change. Since both the ice and the water molecules have the same average kinetic energy at the time of melting, the temperatures of both are the same. Click this button to see the computer code for this animation. The program will then work as per your changes. Of course, your changes, especially random changes, can introduce errors, miscalculations, and browser crashes. The intention here is to conveniently show the inner workings of this program so that you understand how the diagram is drawn. Can you figure out how to change the code to make the molecules vibrate at a higher frequency? When heat is added to the ice these bonds are broken and the ice melts. The molecules afterward bond to one another with less strength and a different geometry, and water is formed. Now, before the melting, the molecules were actually moving when in the solid state. They were vibrating back and forth. They had an average kinetic energy. So they had a Kelvin temperature proportional to this average kinetic energy. After the melting the water molecules are still vibrating. And they have the same average kinetic energy as they had before the melting. So, the water is at the same temperature at the moment after the melting that the ice was at the moment before the melting. Heat came into the situation, but it was not used to change the kinetic energy of the molecules. It was used to change the bonding between the molecules. Breaking the bonds between the molecules of the ice requires energy, and this energy is the added heat. In a similar way heat enters a liquid to change the molecular bonding when the liquid boils or evaporates into a gas, and heat enters a solid to change the molecular bonding when it sublimates into a gas. In an inverse way heat leaves a gas to change the molecular bonding when the gas condenses into a liquid, and heat leaves a liquid to change the molecular bonding when it freezes into a solid. In none of these changes of state is the heat energy that is input or output used to change the speed of the molecules. The average speed of the molecules is the same before and after a phase change, and so is the average kinetic energy. Heat energy is transferred into the ice. The heat is used to break the bonds between molecules, not to increase the average kinetic energy of the molecules. Since the bonds among the ice molecules have been broken, water is formed. The water molecules, at this moment, have the same average kinetic energy as they did when they were ice. Since the ice and water molecules both have the same average kinetic energy, they are at the same Kelvin temperature.

## Chapter 4 : Numerical Methods for Free and Moving Boundary Problems

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*Phase change heat transfer is a broad field that finds applications in almost all of the engineering disciplines. Boiling and condensation are two of the most important phase.*