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AIR CONDITIONING

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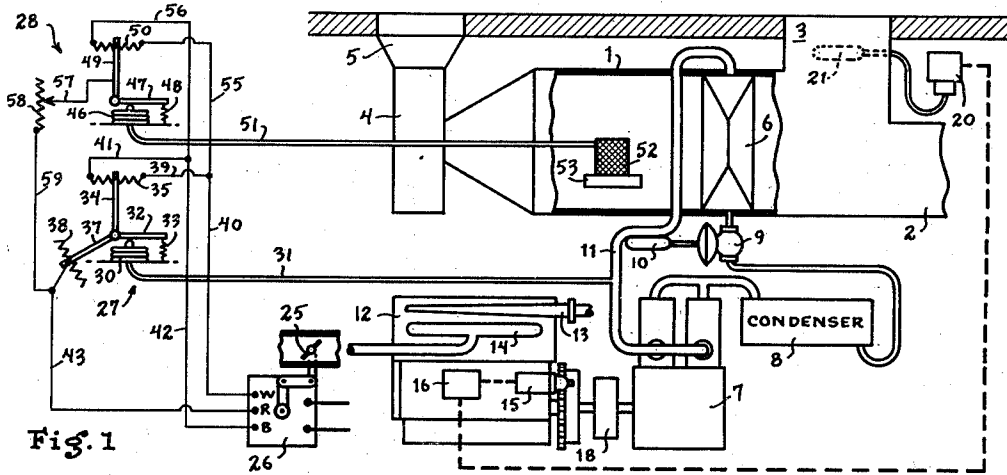


Fig. 1

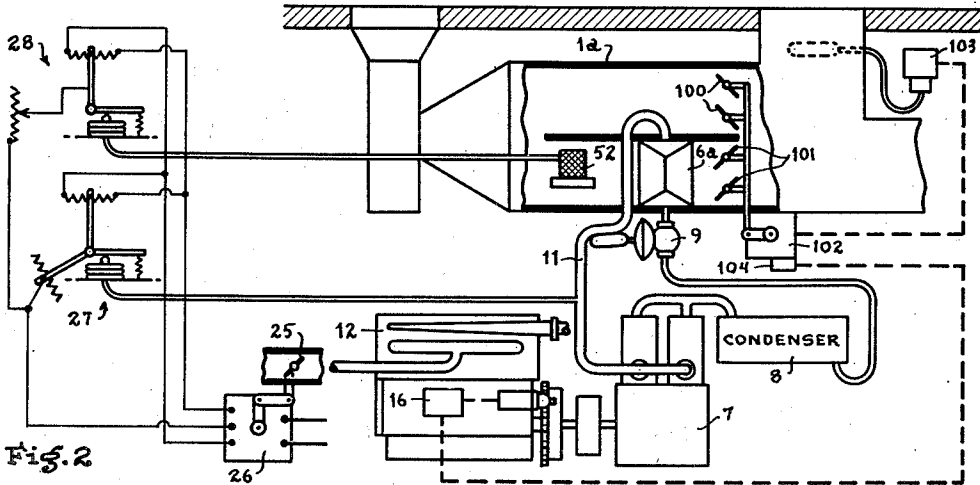


Fig. 2

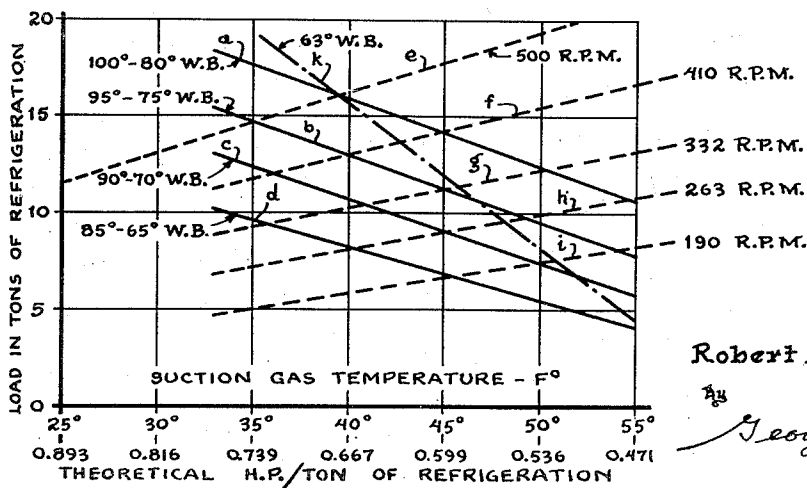


Fig. 3

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AIR CONDITIONING

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2 Claims. (Cl. 62-6)

This invention relates in general to air conditioning, and more particularly to automatic control of systems of this character.

In the air conditioning art, it has become common to employ direct expansion coils for cooling air which is passed to a space being conditioned. In this type of system, compression type refrigeration is generally used, the system having the usual compressor for compressing the refrigerant and a condenser for condensing the compressed refrigerant, the liquified refrigerant then passing through an expansion valve into the cooling coil wherein it evaporates, thus absorbing heat from the air passing over the coil.

One form of control for systems of this type consists of a thermostat for starting and stopping the compressor, the compressor operating at constant speed when in operation. With this type of control, the temperature of the evaporating refrigerant in the cooling coil varies with the load upon the system. Thus during hot weather, the air passing over the cooling coil will be relatively hot which causes the refrigerant in the cooling coil to evaporate rapidly which in turn causes the pressure of the refrigerant therein to rise, thereby causing the temperature of the cooling coil to be relatively high. As the weather becomes cooler, the refrigerant in the cooling coil will evaporate at a slower rate which permits the compressor to "pump down" the pressure to a lower value which causes the refrigerant to evaporate at lower temperature. Therefore with this type of system, the cooling coil operates at progressively lower temperatures as the cooling load upon the system decreases. While this type of system provides satisfactory results, it is defective from an economy standpoint due to the cooling coil temperature lowering at light loads. The power necessary for operating a cooling system is dependent upon the difference in levels between which the heat is transferred, that is, upon the difference between the pressure at which the refrigerant evaporates in the evaporator and the pressure at which it condenses in the condenser. Therefore, the lower the pressure in the cooling coil, the more power required for producing the necessary cooling. Thus with a system of the type described, as the cooling load decreases, the cost of cooling per B. t. u. removed increases. This is entirely unnecessary for at such time the system could very easily carry the cooling load without increasing the cooling capacity of the cooling coil as occurs when its temperature lowers.

Another type of control arrangement for direct expansion systems consists of a controller re-

sponding to the suction pressure of the refrigeration system, this controller acting to vary the speed or output of the compressor in a manner to maintain the temperature of the evaporator constant. This arrangement while avoiding increasing the cost of refrigeration at light loads and providing satisfactory results nevertheless fails to take advantage of light load conditions for actually securing lower cost refrigeration.

It is an object of this invention to provide a control system for an air conditioning system which acts to maintain proper conditions within a conditioned space, and which operates the system in a manner to actually lower the cost of refrigeration as the load upon the system decreases.

In accordance with this invention, the temperature of the cooling coil is actually increased as the cooling load on the system decreases. That is, the cooling coil is operated under maximum load conditions at a minimum temperature for thereby securing the necessary cooling, and the temperature is progressively increased from the minimum value as much as possible as the load decreases.

It is a further object of this invention to provide a control system for air conditioning in which the effect of the cooling coil upon the space is controlled in accordance with space temperature as by placing it into and out of operation or varying the air flow across such coil, and in which the temperature of the cooling coil is raised and lowered depending upon the load imposed upon the coil.

Another object of the invention is the provision of a control system of the type just mentioned in which the temperature of the cooling coil is controlled by means of a device influenced by the heat content of the air discharged from the cooling coil, this device being preferably a wet bulb thermostat, or alternatively a dry bulb thermostat or a humidity responsive device.

Still another object of this invention consists in the provision of an air conditioning control system in which the refrigeration system is controlled by a device which acts to maintain the cooling coil temperature constant, this device being reset or adjusted by a device responding to the condition of the air discharged from the cooling coil for raising the temperature of the cooling coil as the air conditioning load decreases.

A further object of the invention consists of a method of air conditioning control which causes raising of the cooling coil temperature as the load decreases.

Other objects of the invention will become ap-

parent from the following description of the invention and the appended claims.

For a full disclosure of this invention reference is made to the following detailed description and to the accompanying drawing, in which

Figure 1 illustrates diagrammatically one form of the invention,

Figure 2 illustrates a modified form of the invention, and in which

Figure 3 is a set of curves illustrating the function of the invention.

Referring to Figure 1 reference character 1 indicates an air conditioning chamber which may have a fresh air duct 2 and a return air duct 3 which leads from the enclosure being conditioned. This conditioning chamber also connects to a fan 4 which draws the air through the chamber and discharges it through a duct 5 to the conditioned space. Located in the chamber 1 is a direct expansion cooling coil 6. This cooling coil forms a part of a refrigeration system which includes a compressor 7, a condenser 8, and an expansion valve 9 which is preferably of the thermostatic type having a control bulb 10 located on the discharge pipe 11 which leads from the outlet of the evaporator or cooling coil 6 to the inlet of the compressor 7. The compressor 7 serves to compress refrigerant and to discharge it into the condenser 8 wherein it is condensed to liquid form, this liquid refrigerant then passing through the expansion valve 9 into the cooling coil 6 wherein it evaporates into the gaseous state thus absorbing heat from the air passing over the cooling coil, this gaseous refrigerant then passing through the suction line 11 back to the compressor.

The compressor 7 is driven by any suitable means and preferably may be driven by means of an internal combustion engine 12. This engine may be of usual form having an exhaust manifold 13 and an intake manifold 14, a starting motor 15 and a starting motor relay and ignition circuit generally indicated as 16. This apparatus includes the usual ignition system for an internal combustion engine and also an automatic starting relay for the starting motor 15 which may be of any suitable type such for example as that shown in the L. K. Loehr et al. Patent No. 1,773,913. This engine 12 is connected to the compressor 7 through any suitable unloading device 18 which may be a centrifugal clutch which permits the engine to start in an unloaded condition and which connects the engine to the compressor after the engine is rotating at or above a predetermined speed.

The starting and ignition apparatus 16 is controlled by means of a thermostat 20 which may be of the remote bulb type having a bulb 21 located in the return air duct 3 so as to respond to the temperature of the air in the conditioned space. This thermostat is of the two-position type having an electric switch which is closed when the space temperature rises to a predetermined value such as 75° F., this switch opening when the space temperature falls below this value. This thermostat is connected to the starting and ignition apparatus 16 and serves to energize the ignition for the engine and also the relay controlling the starting motor 15 when this switch is closed. This will cause rotation of the engine by the starting motor 15 and when the engine starts the starting relay will deenergize the starting motor 15. The engine will then run until the space temperature falls to the value at which the thermostatic switch opens, this acting to deenergize the engine ignition system for stopping the engine. The thermo-

stat 20 therefore serves to start the engine when space temperature rises above 75° F. while stopping the engine when the space temperature falls below this value. Of course this value is illustrative only and may be varied as desired without departing from the invention.

The speed of the engine 12 is controlled by means of a throttle valve 25 which may control the flow of fuel to the engine. This valve is positioned by means of an electric proportioning motor 26 which may be of the type shown in the Taylor Patent 2,028,110. This proportioning motor is controlled by means of a suction pressure controller generally indicated as 27, and is also controlled by means of a wet bulb discharge thermostat 28. Referring again to the proportioning motor 26 this motor is provided with a three-wire control circuit having terminals indicated as R, W, and B, and is adapted to assume intermediate positions depending upon the relative values of resistance connected between terminals R and W and between terminals R and B. For example, if equal values of resistance are connected between terminals R and W and between terminals R and B, the motor will assume the intermediate position in which the throttle valve is half open. However, if the resistance between terminals R and B is decreased without corresponding decrease in resistance between terminals R and W, the motor will operate to a new position in which the throttle valve is open wider, the position being proportionate to the new relationship between the resistances connected across these terminals. Conversely if the resistance between terminals R and W is decreased without corresponding decrease in resistance between terminals R and B, the motor 26 will rotate to a position in which the throttle valve 25 is closed to a greater extent.

Referring to the suction pressure controller 27, this controller may consist of a bellows 30 which is connected to the suction line 11 by means of a tube 31. This bellows actuates a pivoted arm 32 which is biased by means of a spring 33, this arm 32 actuating a slider 34 which cooperates with a resistance 35 to form a control potentiometer for the motor 26. This arm 32 also actuates a corrector arm 37 which cooperates with a center-tapped corrector resistance 38 which serves to make the control of the motor 26 by the controller 27 more uniform. The right hand end of resistance 35 is connected to terminal W of the motor 26 by wires 39 and 40, while the left hand end of this resistance is connected to terminal B of the motor by wires 41 and 42. The corrector resistance 38 is connected to terminal R of motor 26 by wire 43. Thus the slider 34 of controller 27 is connected to terminal R of motor 26 through the slider 37, corrector resistance 38 and wire 43.

Assuming that the suction pressure or temperature of the cooling coil 6 is at an intermediate value, the slider 34 will engage the center of resistance 35 which serves to connect the left hand half of this resistance between terminals R and B while connecting the right hand half between terminals R and W. This will cause the throttle valve 25 to assume half open position for operating the engine at intermediate speed. If the suction pressure should increase, the bellows 30 will expand against spring 33 an amount proportionate to the increase in suction pressure, thereby causing the slider 34 to move to the left across resistance 35 which decreases the portion of the resistance 35 between terminals R and B while increasing the portion of this resistance

between terminals R and W. This will cause the motor 26 to open the throttle valve 25 wider for increasing the engine speed. Therefore as the suction pressure increases due to the load upon the cooling coil 6 increasing, the compressor speed will be increased for carrying the additional load. It will be apparent that upon decrease in suction pressure due to reduction in load upon the cooling coil 6, the controls described will operate in the opposite manner for decreasing the speed of engine 12. The suction pressure controller 27 therefore serves to vary the engine speed in a manner to just carry the load upon the cooling coil 6, serving to maintain the temperature of this cooling coil substantially constant.

Referring to the thermostat 28 this thermostat is provided for adjusting the control point of the suction pressure controller 27 in a manner to maintain a constant wet bulb temperature of the air leaving the cooling coil 6. This thermostat is diagrammatically illustrated as including a bellows 46 which actuates an arm 47 attached to a biasing spring 48. This arm 47 actuates a slider 49 which cooperates with a resistance 50 for forming a compensating potentiometer for the proportioning motor 26. The bellows 46 is attached by a capillary tube 51 to a control bulb located at the outlet of the cooling coil 6, this control bulb being covered by a wick 52 which is maintained wet by means of a water pan 53. The pressure in the bellows 46 therefore varies in accordance with the wet bulb temperature of the air being discharged from the cooling coil 6. The right hand end of the resistance 50 is connected to terminal W of motor 26 by wires 55 and 40, while the left hand end of this resistance is connected to terminal B by wires 56 and 42. The slider 49 is connected to terminal R by means of wire 57, adjusting rheostat 58, wire 59 and wire 43.

Assuming that the load upon the air conditioning system increases, that is, the temperature of the air passing over the cooling coil 6 increases, the temperature of the air leaving the cooling coil 6 will rise thereby causing expansion of the bellows 46 for shifting the slider 49 to the left across resistance 50. This will decrease the portion of the resistance 50 which is connected between terminals R and B of motor 26, while increasing the portion connected between terminals R and W. This action will cause the motor 26 to increase the opening of throttle valve 25 for thereby increasing the engine speed. It will be noted that this increase in engine speed occurs over and above any increase in speed caused by the suction pressure controller 27. Therefore the increased engine speed caused by the controller 28 will cause the suction pressure to begin falling and in response to this fall in suction pressure the suction pressure controller 27 will begin slowing down the engine speed until a point is reached wherein the suction pressure remains constant. Thus the action of the controller 28 in response to an increase in temperature of the air leaving the cooling coil is to in effect adjust the suction pressure controller 27 so as to maintain a lower suction pressure and consequently lower temperature of the cooling coil 6. It will be apparent that upon decrease in temperature of the discharge air, the controller 28 will act in the opposite manner for increasing the value of suction pressure maintained by the suction pressure controller 27.

The rheostat 58 serves to vary the effect of the thermostat 28 upon the control point of the controller 27, and by properly adjusting this rheostat the thermostat 28 may be made to vary the coil temperature just the proper amount for maintaining a constant discharge air temperature. For a more complete disclosure of the compensated control circuit for the proportioning motor reference is made to the copending application to John E. Haines, Serial No. 38,943, filed 10 September 3, 1935, now matured into Patent No. 2,173,331, issued September 19, 1939.

Referring now to the operation of the system as a whole, when the space temperature is below 75° the thermostat 28 will cause the engine 12 to be at rest and therefore no cooling of the space will occur. When the space temperature rises above the control point of thermostat 28, this thermostat will place the engine into operation, and the speed at which this engine operates will be determined by the suction pressure controller 27 and its compensating controller 28. Under maximum load conditions, the temperature of the air over the cooling coil will be at a maximum which causes the wet bulb temperature of the air discharging from the cooling coil to be at a maximum which will cause the thermostat 28 to adjust the suction pressure controller 27 for maintaining the cooling coil temperature at a minimum temperature for securing the necessary amount of cooling. At this time the refrigerant in the evaporator will evaporate at a high rate, thus causing the suction pressure to be high as compared with the adjustment of the suction pressure controller 27 by thermostat 28, and consequently the engine will operate at full speed. As the load upon the system decreases, that is, the temperature or quantity of the air passing over the cooling coil decreases, two reactions will occur. For one thing the wet bulb temperature of the air leaving the coil will decrease which will cause the controller 28 to raise the control point of the suction pressure controller 27. Also less refrigerant will be evaporated in the cooling coil 6, which will cause the suction pressure to fall. The suction pressure controller 27 will thus slow down the engine 12 to a point at which the suction pressure rises to the new setting of the suction pressure controller 27. Therefore as the load upon the system decreases, the suction pressure controller is reset to maintain a higher coil temperature and this controller will slow down the engine until the suction pressure rises to the new setting required by the discharge thermostat. Inasmuch as less cooling is necessary as the load decreases, it follows that the temperature of the cooling coil 6 may be increased while still obtaining the necessary cooling action. This positive increasing of the cooling coil temperature as the load on the system decreases reduces the operating cost of the system.

This savings in operating costs by raising the coil temperature in the manner specified is illustrated in Figure 3. Referring to this figure the load in tons of refrigeration are plotted as the ordinates of the graph, while the suction gas temperature is plotted as the abscissa. The theoretical horse power per ton of refrigeration varies in proportion to the suction gas temperature and this is also indicated. On this graph are the full line curves, a, b, c, and d which represent different values of the air condition. Thus curve a represents the condition at 100° F. dry bulb—80° wet bulb, and curves b, c, and d represent progressively lower temperature con-

ditions of the air. This graph also contains curves *e*, *f*, *g*, *h*, and *i*, which represent different compressor speeds. It should be noted that these latter curves indicate that the suction gas temperature lowers upon decrease in load if the compressor is operated at constant speed. For example, if the compressor is operated at 500 R. P. M. and the air is 100° dry bulb—80° wet bulb, the suction gas temperature resulting is illustrated at the intersection of curves *a* and *e* which is approximately 39° F. Now if the air temperature falls to 95° dry bulb—75° wet bulb the suction gas temperature will be that indicated at the intersection of curves *e* and *b* which is 35°. Therefore as pointed out before, if a compressor operates at constant speed, the suction gas temperature falls as the load upon the cooling coil decreases which causes the power required per ton of refrigeration to increase.

If the thermostat 28 is set to maintain a discharge temperature of 63° wet bulb the action of the system would be as indicated by curve *k*. Thus if the air condition is 100° dry bulb—80° wet bulb, the suction gas temperature will be 39°. If the air temperature falls to 95° dry bulb—75° wet bulb, the suction gas temperature will be that indicated at the intersection of curves *k* and *b* which is approximately 47°. Similarly upon further decrease in the air temperature, the temperature of the evaporator will rise and this will, as indicated, reduce the power required per ton of refrigeration and thereby secure a substantial savings in operating costs. In this connection it must be remembered that an air conditioning installation is designed for carrying the maximum load which occurs only infrequently, and during the majority of the time the system is operating only at partial load. The invention therefore provides for obtaining a decided reduction in operating expenses during the major portion of the cooling season.

In some cases it may be desired to control the temperature in the space by means of dampers controlling the flow of air across the cooling coil so as to avoid the use of on-off type control as in Figure 1. In such cases the arrangement shown in Figure 2 may be utilized. Referring to this figure the conditioning chamber 1*a* is provided with a by-pass around the cooling coil 6*a* and the flow of air through the by-pass and through the cooling coils is controlled by means of a by-pass damper 100 and a face damper 101 which are positioned by means of a proportioning motor 102. This proportioning motor is in turn positioned by means of a potentiometer type return air thermostat 103, this thermostat serving to cause the motor 102 to position the dampers for increasing the flow of air through the cooling coil 6*a* upon rise in return air temperature while decreasing the flow of air through this coil upon fall in temperature. The proportioning motor 102 is additionally provided with an auxiliary switch 104, which switch is arranged so as to open whenever the face damper 101 becomes closed. This switch 104 is connected to the engine starting and ignition apparatus 16 and corresponds to the thermostat 20 of Figure 1. The remainder of the system is exactly the same as in Figure 1 and accordingly is not described here. Like parts are provided with like reference numerals.

The operation of the system of Figure 2 is similar to that of Figure 1. When the space temperature is below the setting of thermostat 103, this thermostat causes the proportioning

motor 102 to completely close the face damper 101 and open the by-pass damper 100, which prevents flow of air across the cooling coil 6*a*. At this time the auxiliary switch 104 is open and consequently the engine 12 is out of operation. As the space temperature begins rising within the control range of thermostat 103, this thermostat causes the damper motor 102 to begin opening the face damper 101 and to close the auxiliary switch 104 for starting the engine 16. The speed of the engine will now be controlled by the suction pressure controller 27 and the compensating wet bulb thermostat 28, which cause the motor 26 to position the throttle valve 25 in exactly the same manner as described in detail in connection with Figure 1. It will be apparent that the arrangement of Figure 2 will modulate the temperature of the air supplied to the conditioned space in accordance with the temperature in the space for thereby maintaining a constant space temperature, and that during normal operation the controllers 27 and 28 will control the engine speed in accordance with the load actually applied to the cooling coil 6*a*.

From the foregoing description it will be apparent that this invention provides an air conditioning control system and method of control which maintains the temperature of a conditioned space at the desired value and which also adjusts the operation of the system so as to secure maximum economy with the equipment provided. While the invention is of particular utility in direct expansion type systems, as shown, it is not limited to systems of this type but is also applicable to indirect type of systems wherein chilled water or brine is passed through the cooling coil. While I have shown and described only two forms of my invention, it will be apparent that various changes may be made without departing from the scope of the invention. I therefore desire to be limited only by the scope of the appended claims.

I claim as my invention:

1. In an air conditioning system, in combination, a direct expansion cooling coil, means for passing air over said cooling coil and discharging it into a space being conditioned, a compressor connected to said cooling coil, a variable speed prime mover for driving said compressor, means responsive to a condition of the air in said space which is affected by said cooling coil for controlling the effect of said cooling coil upon the air in said space for thereby maintaining said space condition at the desired value, a speed controller for said prime mover, control means for said speed controller including a device influenced by the temperature of said cooling coil for varying the speed of said prime mover in a manner for maintaining the temperature of said cooling coil constant, adjusting means for adjusting the temperature of said cooling coil maintained by said control means, and means located in the air discharged from said cooling coil and influenced by the heat content thereof for actuating said adjusting means in a manner to raise the temperature of the cooling coil upon decrease in said heat content and vice versa.

2. In an air conditioning system, in combination, a direct expansion cooling coil, means for passing air over said cooling coil and discharging it into a space being conditioned, a compressor connected to said cooling coil, a variable speed prime mover for driving said compressor, means responsive to a condition of the air in said space which is affected by said cooling coil for control-

ling the effect of said cooling coil upon the air in said space for thereby maintaining said space condition at the desired value, a speed controller for said prime mover, control means for said speed controller including a device influenced by the temperature of said cooling coil for varying the speed of said prime mover in a manner for maintaining the temperature of said cooling coil constant, adjusting means for adjusting the tem-

perature of said cooling coil maintained by control means, and means located in the air discharged from said cooling coil and influenced by the wet bulb temperature thereof for actuating said adjusting means in a manner to raise the temperature of the cooling coil upon decrease in said wet bulb temperature and vice versa. 5

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