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Commercial heat recovery — an appraisal

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HEAT recovery has always been practised in commercial buildings. It is only with increasing awareness of energy costs that designers and building operators have considered how to make more effective use of heat recovery to reduce their bills. As energy costs rise, compared with capital costs of equipment to recover and re-use that energy, more sophisticated ideas become viable, the range of options increases, and the choice of the most suitable system for any given application becomes more difficult. This appraisal considers the options which could be described as heat recovery and which are open to building services designers and operators.

FUNDAMENTALS FOR HEAT RECOVERY

It is convenient to define heat recovery as the process of reclaiming and re-using energy originally destined for some other purpose, for heating a space for comfort or for process heating. In the commercial world we are more concerned with the former end use for the heat energy, and so in general we can make better use of fairly low temperature, or 'low grade' heat.

The re-use of heat energy is often regarded as intrinsically 'a good thing,' without appreciating that it is not always advantageous. The conditions for a successful heat recovery installation are that:

(a) There must be heat available in the right quantities at the right temperature and at the right time.
(b) There must be a use for that heat once it has been recovered.
(c) There must be an economic case for the scheme; that is, the net present value of the energy savings should exceed that of the cost of installing the heat recovery measures.
(d) The operating staff must be educated on the reasons for the heat recovery scheme; carelessness or misunderstanding of the operation of plant or the building itself can undo all the efforts of a well meaning design.

It is impossible in an appraisal such as this to advise whether in a particular case these four conditions could be fulfilled. What it can do is to point out that certain options are available and that they should be explored, bearing in mind the above points.

INADVERTENT HEAT RECOVERY

Most buildings recover energy in the form of heat whether they want it or not. Electrical energy originally brought into the space for lighting or operating business machines either immediately or ultimately degrades to heat. This heat energy has therefore been recovered by the space. If the second condition for effective heat recovery, that there should be a use for that heat, is not fulfilled then the advertent heat recovery could be an embarrassment!

Cooling is required in such circumstances if comfortable conditions are to be maintained. This can often be accomplished without further energy consumption, but if the inadvertent heat recovery is associated with solar heat gains or metabolic gains from the people in the space, mechanical cooling may well be required, and further energy expended. So, some inadvertent heat recovery is not desirable.

Nevertheless, it often makes sense to recover this free heat to get it under the control of the system pending a decision on what to do with it. We will return to methods of achieving this later.

DELIBERATE HEAT RECOVERY

If the criteria for successful heat recovery are fulfilled, there are various mechanisms by which it can take place. The simplest method is to recirculate a proportion of the extract air from the space which has inadvertently picked up heat. Other methods depend on some device which is either active or passive, the distinction being between those which use further energy to function and those which do not. The active methods go beyond discrete devices for heat recovery, into systems where several components interact to give more flexible and more complete control of heat energy flows within a building, and the result can be even less dependent on paid for energy brought into the building. At this level the control philosophy must be carefully thought through if the heat recovery scheme is to be effective.

In this appraisal of heat recovery techniques I will examine each of these methods in turn.

AIR RECIRCULATION

This is the simplest form of heat recovery and in many cases the cheapest and most cost effective. Air from the extract duct is allowed into the supply duct. Hence, low grade heat in the extract air is used to reduce the amount of heat added to the supply air stream. Heat picked up from lighting, people and business machines which would otherwise be lost in the extract air is therefore recovered and re-used.

However, one must ask what the original reasons for the air handling system were. If one of its purposes was to disperse odours, or infectious airborne material, or high moisture content air, then obviously recirculation is not feasible. Likewise, if the system was trying to cool the space, then there is not much point in recirculating warm air. These points might seem self-evident, but it is necessary in a system which incorporates air recirculation to remember to allow for such circumstances in the control system.

In any case, there may be a better opportunity for energy reduction by reducing the volume of air supplied and extracted in the first place. In many circumstances, circulation volumes are set to suit the design conditions rather than those commonly experienced, and it makes sense to control the volume of air throughput to that required to perform its job. Variable speed motor drives and controls are more freely available than they used to be, and so the additional benefits of reduced energy consumption by the fan motors can be received.

Where the circulation volume is reduced, or varied, the air distribution system must also be considered to ensure that air movement in the room space is still adequate. In the case of permanent reduction in volume then new, smaller diffusers and registers may be needed to maintain the same air throws as before (or perhaps to remedy defects that existed before!). With variabl

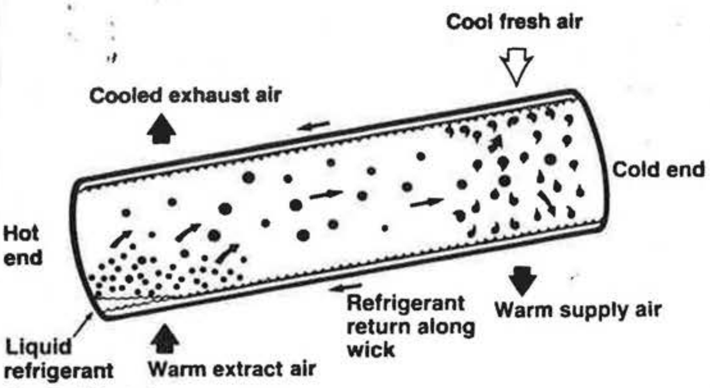


Fig. 2—Heat pipe.

wick and gravity.

It can be seen that the efficiency of operation will depend on the position of the heat pipe — where the evaporating end is below the condensing end, the unpumped liquid refrigerant return is obviously enhanced by gravity whereas when horizontal or inverted the return relies solely on the capillary action of the wick.

Efficiency of heat transfer at each end of any heat exchanger depends on how close the air streams are to the heat transfer medium. Unfortunately, the more intimate the contact between medium and air stream, the more resistance is presented to the air stream, and so the greater the fan power required. Although typically this has been optimised in the heat exchangers on offer, resistance is increased if dirt is allowed to accumulate on the plates or fins, and so the facility for cleaning is valuable. This is particularly important where kitchen extracts are involved, where grease build up might in any case constitute a fire hazard. Clear access for cleaning is useful and some crossflow heat exchangers can be demounted to allow inspection and cleaning.

ACTIVE HEAT EXCHANGERS

Passive heat exchangers benefit from simplicity of operation once installed, but suffer from inflexibility. Control of the amount of heat transfer is limited — remember that sometimes heat recovery is not even desirable. Where the flow of heat relies on the input of some other energy from outside the unit, that flow can be controlled more readily. The heat exchanger then becomes 'active'.

A good example is the thermal wheel, heat wheel or rotary heat exchanger (fig.3). Where other heat exchangers are recuperative, that is, heat transfer has to take place through some form of intermediate membrane or medium, the thermal wheel is a generator. A medium such as metal mesh or treated corrugated card is heated up in the waste heat air stream and then transports this heat gained to give it up in the supply air stream. To transform an essentially cyclic process into a continuous one, the heat transportation medium is made in the form of a circular disc, the two air streams are passed through opposite semi-circular segments of the disc, and the disc rotated by a small motor.

Various media available pick up sensible heat only, or sensible and latent heat by absorbing into the medium. The apparent problems of cross contamination between air streams are overcome by close tolerances between the edges of ducts and the wheel itself, and by a 'purge' segment between the extract and supply sides where contaminants are blown through in reverse flow. Air streams are generally arranged to oppose one another to dislodge any debris which falls onto the wheel surface.

Control over the rate of heat transfer can be maintained by varying the wheel's rotation speed relative to the air velocity through the medium.

Although efforts are made to avoid cross contamination, it is inevitable that some transfer of material occurs between air streams. This is particularly of concern where sterility is needed, such as in hospital surgical wards, or where moisture should not be transferred, as in swimming pools. In these cases recuperative (separated) methods must be used, so that only heat is transferred.

A further limitation of all the methods so far described is that the heat source and sink must be adjacent to one another. It can be inconvenient to arrange supply and extract air streams to run parallel to one another, particularly if retrofitting heat recovery into an existing building. This can be overcome by using a fluid medium to transport the heat between air streams.

The run around coil system (fig.4) comprises two finned tube coils connected by a piped circuit around which a water/glycol mixture of perhaps brine is pumped. Control of the amount of heat recovery is exercised by a three-way valve across the heating coil in the supply air stream.

It is normal to use a water based fluid as the heat transport medium for cheapness and familiarity, though in some cases oil based fluids are used. Where water is used, some form of anti-freeze is required as the heat rejection coil could be subjected to freezing outside air. ▶

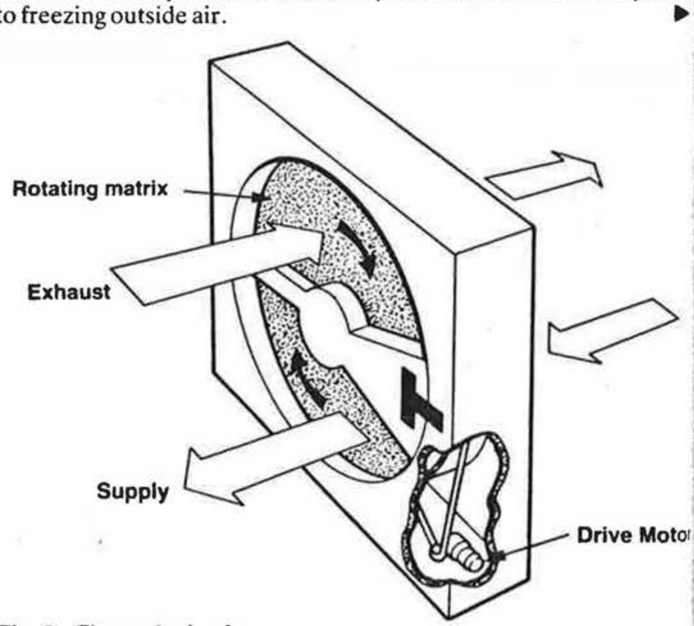


Fig. 3—Thermal wheel.

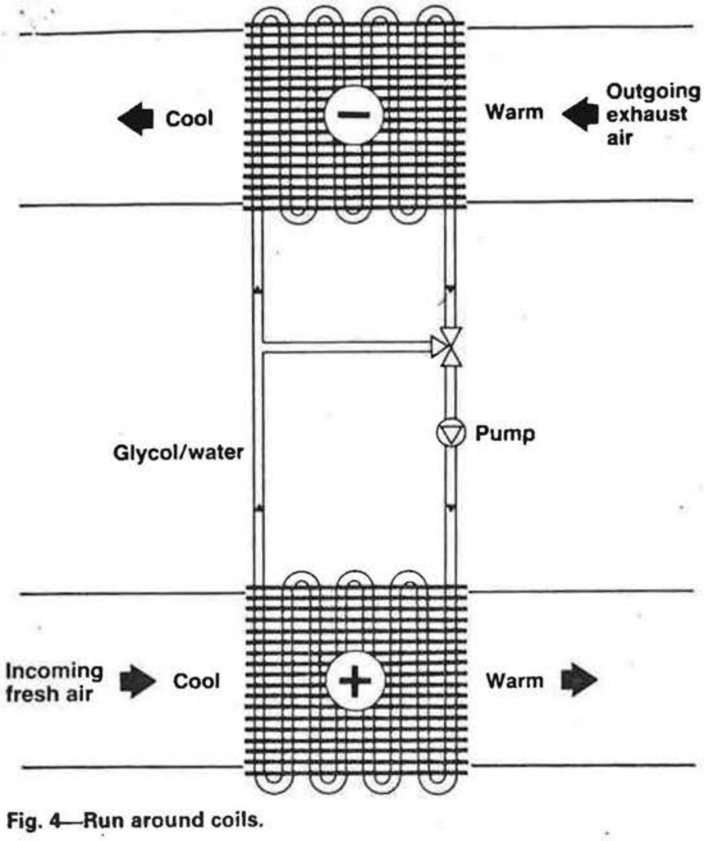


Fig. 4—Run around coils.

The two coils do not need to be adjacent to one another, and so there are no constraints on ductwork layout. However, as the pipework routes between heat pick up and heat re-use coils can be lengthy, the pipework should be insulated to avoid uncontrolled heat loss. This loss determines the ultimate efficiency of the system.

The practical operating efficiency of a run around coil system is about 50 per cent sensible heat transfer. This lower efficiency should be set against increased flexibility and ease of installation. For instance, it is possible to have more than one heat pick up point, or several heat rejection coils. Heat can be picked up from other sources than extract air; indeed the heat source and heat sink do not both have to be air.

Such elaborations tend to turn the run around coil from an active heat recovery device into a heat recovery system. If a system, rather than a series of discrete devices, is considered, then the designer should employ means of improving the efficiency and flexibility of the system.

HEAT PUMP SYSTEMS

An appropriate modification would be to substitute the water based heat transport medium with one which would give enhanced temperature differentials at each end: a refrigerant would be suitable. The result would be an internal source heat pump. In order to recover the motor losses it is best to use a hermetic or semi-hermetic machine.

Although the more usual configuration for an air-to-air hea pump is to use the outside air as the heat source, under certai circumstances an inside source is useful, and the heat pump the operates in heat recovery mode. Where there is a convenientl large volume of extract air that cannot be recirculated, then that a can be ducted over the evaporator coil of the heat pump to use as heat source. Unlike other heat exchangers which are limited to a efficiency related to the temperature difference between he source and heat sink, a heat pump's heat recovery ability is limite only by its potential to extract heat from the source with reasonable coefficient of performance and within the oth constraints related to the vapour compression cycle.

An internal air source heat pump can suffer from the sam frosting problems as an external air source heat pump, if th evaporating temperature is set low to maximise its heat recove potential. This also applies where extract air is discharged adjace to the outdoor coil rather than ducted over it, since the evaporati temperature must be low enough to pick up sufficient heat from th outside air as well as that part of the exhaust air which drifts over i If anything, frost formation can be worse where extract air is use wholly or partially as the source rather than outside air, as th extract usually has a higher moisture content due to latent he gains within the space.

Nevertheless, it is possible to overcome this problem by not bein greedy! If the evaporating temperature is higher than 32°F, so th frost formation does not occur, and the quantity of heat is there be used in exhaust air, then an air-to-air heat pump operating heat recovery mode will run at higher coefficients of performan than one using the outside air as a source. This usually mea applying it to those situations where air change rates are high, a internal gains are great.

As always, it is important to check that the times of he availability and requirement match. In many situations where t air change rate is high and the internal gains great, there is in fact

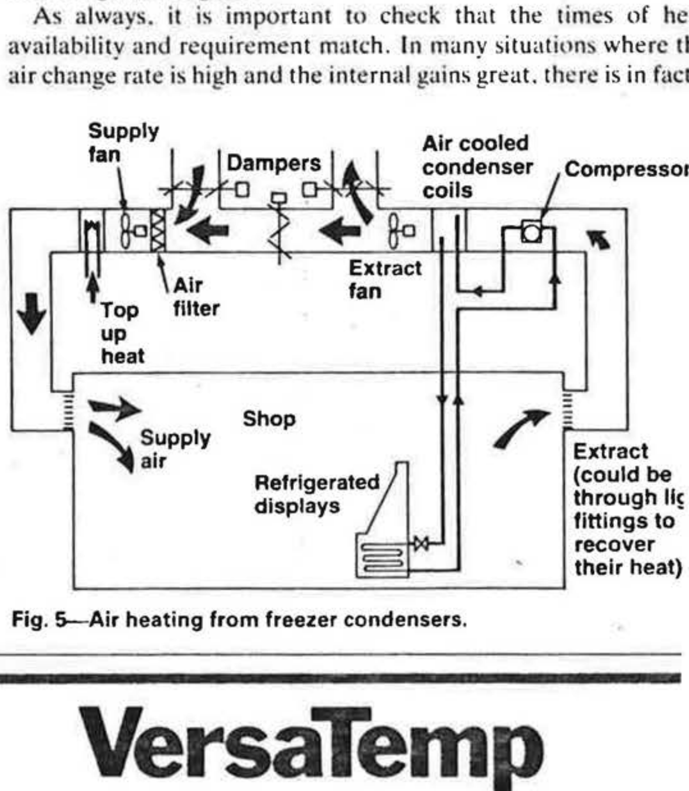


Fig. 5—Air heating from freezer condensers.

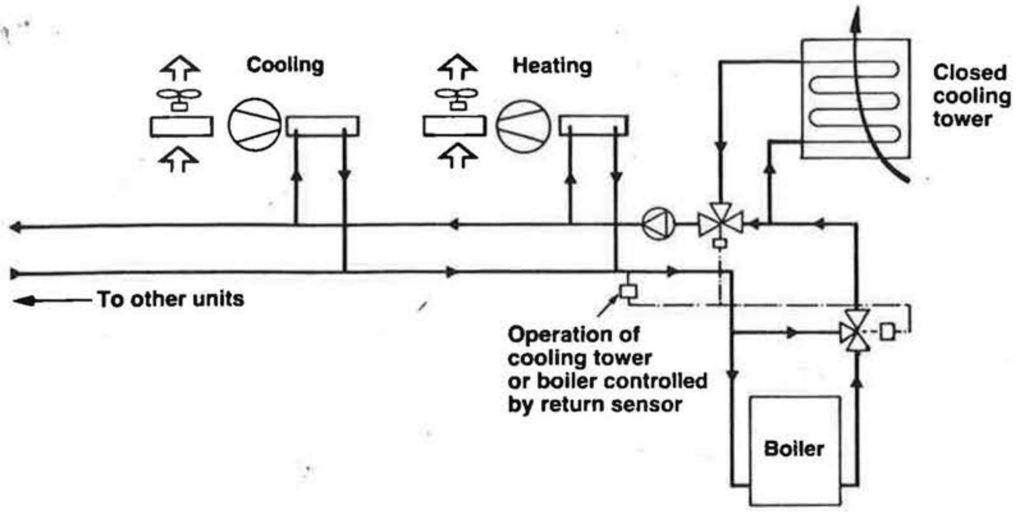


Fig. 6—Incremental system.

need for air conditioning rather than heat recovery for most of the time. For instance, a large open plan store might have a high rate of heat gain due to metabolic heat from customers and staff, display lighting etc, and so have plenty of heat available. However, the only time when the store needs heat is during the period before occupation, for preheat. This is before the heat is available, and so heat recovery is not feasible.

Many readers will be familiar with condenser heat recovery from refrigeration systems where, rather than rejecting the condenser heat to outside air, it is first offered to heat water for washing purposes or to warm supply air. Only when these are satisfied is the remainder rejected. It is easier in this circumstance to identify a simultaneous need for cooling and heating. For instance, a freezer store might have a requirement for hot washing water for food preparation, or a pub might might require a beer cooler and hot water for washing glasses. This can be provided by a water cooled desuperheater prior to the air cooled condenser. The water thus heated would then be passed through a coil in the bottom of a cylinder. Circulation within the cylinder while water is not being drawn off would then allow the whole volume to be heated.

Temperatures will be limited to what the desuperheater can supply, say 120°F, but this is adequate for most washing purposes. When higher temperatures are required, an instantaneous booster heater between the cylinder and draw-off point will provide t temperature elevation. Heating within the cylinder could lead high condensing pressures at the desuperheater.

An alternative way to use recovered condenser heat is to heat with it (fig.5). Frozen food shops, for example, often ha fluorescent instead of filament display lighting, and lower occu tion densities than give rise to high metabolic gains, so there i need for heating. Condensers remote from the freezer cabinets be set in the extract duct to give up their heat. Additional heat be recovered from compressors if these are mounted together o rack in the extract air stream. The heated extract air can then recirculated or exhausted, depending on the heat requirements the store, and the amount of additional heat energy minimis Consequently, the full heat rejection is still available at the condenser in the circuit to each freezer cabinet; the air damp either recover it or dump it as appropriate.

It might be considered that direct heat recovery, by dump

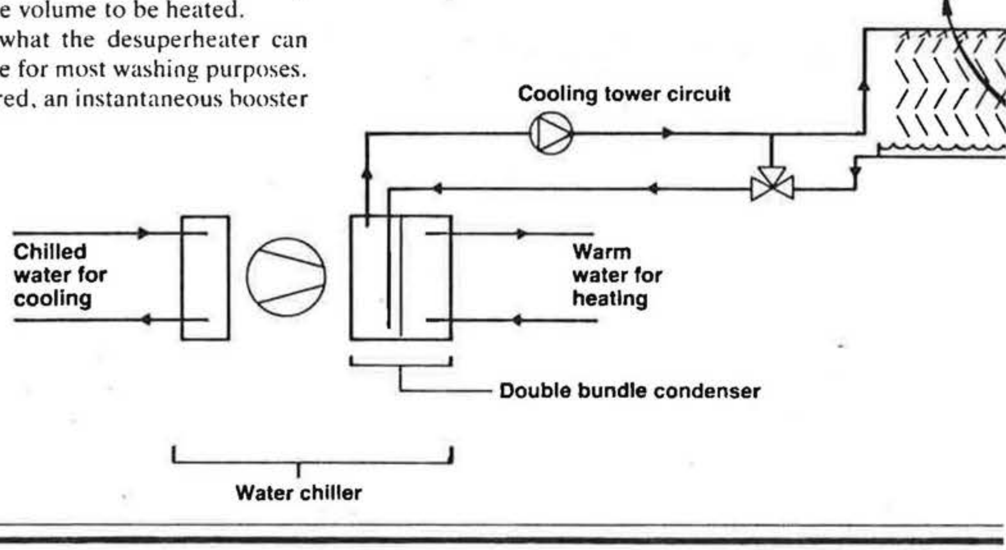
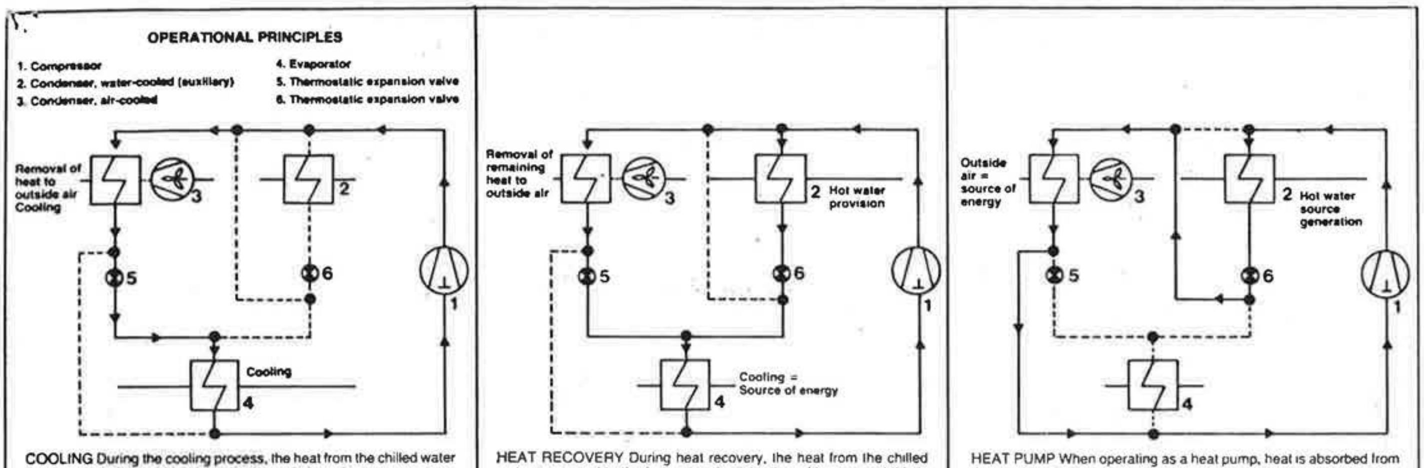


Fig. 7—Heat recovery from double bundle condenser.



COOLING During the cooling process, the heat from the chilled water is rejected to the outside air by the air cooled condenser.

HEAT RECOVERY During heat recovery, the heat from the chilled water is passed to the hot water circuit by the refrigerant and this is effected at a higher temperature in the auxiliary condenser. If the cooling capacity is greater than the heating demand, the remaining heat is rejected to the outside air via the air cooled condenser.

HEAT PUMP When operating as a heat pump, heat is absorbed from the outside air via the air cooled condenser and released at a higher level to the hot water circuit via the auxiliary condenser.

Fig. 8—Heat recovery with energy switching centre (reproduced, with permission, from the Energypak literature of the York Division of Borg-Warner Ltd.)

condenser heat direct from the freezer cabinets to the store would be far simpler. Unfortunately it may be that the heat is not always required by the store, and in any case the heat will be dumped where it will not be of great use in providing heating for the customers and staff. It is far better to get the heat under the control of the heating system itself, then it can be more effectively applied to parts of the store away from the freezer cabinets and distributed within the space where it is needed by the air system.

HEAT RECOVERY SYSTEMS

The principle of taking the recovered heat under the control of an environmental control system, pending a decision on whether to make use of it or not, underlies the method of operation of all heat recovery systems, as distinct from heat recovery devices. Most systems are variations on the heat pump theme, where condenser heat which is found to coincide with a heat requirement is recovered and re-used rather than rejected.

Whereas in the heat pump methods described up to now the heat transport medium has been refrigerant alone, the heat being re-used directly at the condenser, in most of the more complex systems it is necessary to use a further heat transport medium such as water. It is then possible to control smaller increments of heat input into more varied heat sinks than would be the case where the overriding control factor is that the condenser heat must be rejected.

INCREMENTAL SYSTEMS

Where water is used as a heat energy distribution medium, it is possible to connect a series of smaller devices to the system. This is the basis of the incremental heat pump system (fig.6), where individual reversible water-to-air heat pumps cool or heat their zones as demanded, rejecting heat to or absorbing heat from the common water circulation. Inasmuch as some zone units may be cooling while others are heating, the system recovers heat and

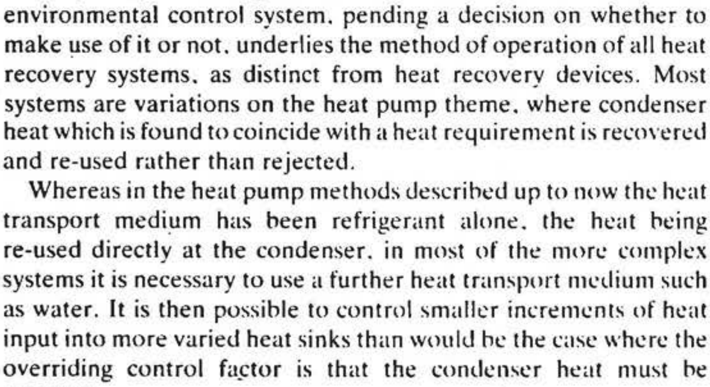


Fig. 9—Bivalent heating.

transfers it between zones. When there is an overall surfeit of heat as measured by the temperature of the heat distribution medium, the circulated water is passed through a closed cooling tower. When there is a deficit a boiler is used to top up heat.

Overall system control is simple, and the system has the interesting advantage that heat pump breakdowns can be dealt with on an individual unit basis. Zone control should be co-ordinated, otherwise it is possible for individual units to 'fight' one another — one unit heating and one cooling — if their controls have not been set up together.

HEAT DISTRIBUTION IN CENTRAL PLANT HEAT RECOVERY SYSTEMS

Once water has been selected as the final heat distribution medium, the complete range of heat emitters open to designers of ordinary heating systems becomes available, with the proviso that they must be sized to cope with different flow and return temperatures. To make use of condenser heat, the heat distribution temperature must be lower than that normally employed in boiler systems, which means that heat emitters must be larger and hence more costly. This in itself can put the heat recovery system beyond an economic case, unless other measures such as improved insulation are taken at the same time.

Nevertheless, selecting lower flow and return temperatures such as 120°F/100°F can give other advantages in terms of flexibility of heat source as well as the possibility of using low grade recovered heat. External source heat pumps and other means of using ambient energy offer their heat at temperatures compatible with such a system. The opportunity also exists to pull down the temperature of a stored volume of water over a greater temperature differential, thereby increasing the releasable heat content of a given volume.

This is particularly valuable where cheap heat energy is available at a different time from the heat requirement. For instance, off peak electricity can be used to heat the store up to 190°F overnight and since its temperature can be allowed to fall to 100°F and still be useful, a given volume store can contribute three times more heat than one which serves a heating system with a mean temperature of 170°F.

CONTROL

Control of such a system must be related to the needs of the area requiring heat. In the days of cheap heat energy it was sufficient to size and commission heat emitters relative to one another and then control the overall building heat input by scheduling the flow temperature relative to outside temperature. Nowadays, where heat recovery is being practised, it is assumed that more precise matching of heat supply to heat requirement is needed. Each zone should have only as much heat as it requires supplied to it. Water should be supplied to the heat emitter *via* a three-way modulating

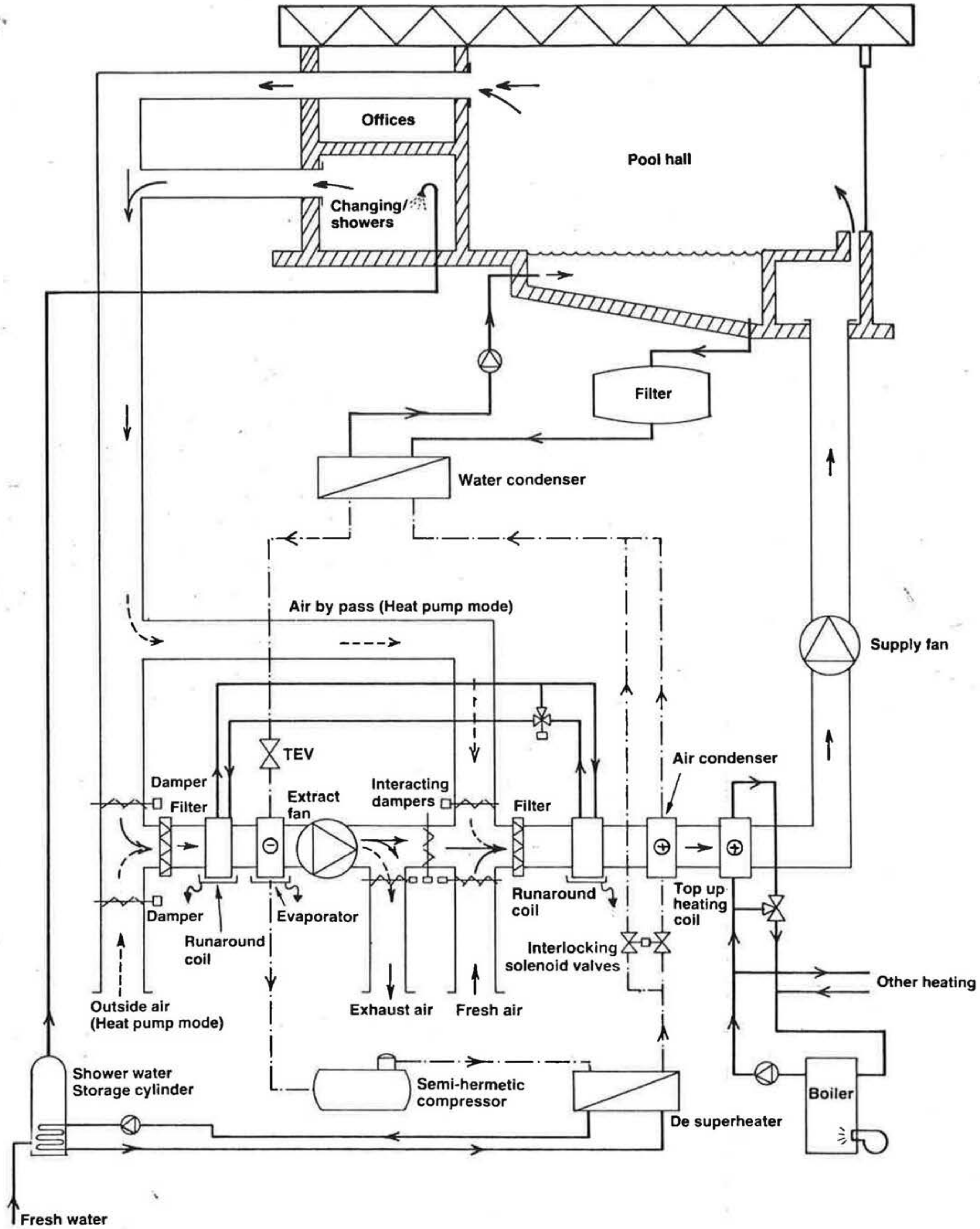


Fig. 10—Swimming pool heat recovery. — · — · — · —> Refrigerant lines. — — — — —> Air flow during outside air source heat pump mode

valve controlled by an appropriately positioned temperature sensor. The return temperature will then be an indication of how much heat is being taken up by the heat emitters and whether any more heat is needed.

The control decision on whether more or less heat is required by the heat distribution medium must be based on the temperature measured at one point, for example return temperature. Any other decisions, such as whether condenser heat should be rejected to the cooling tower, logically stem from this. There should be no attempt to control other elements of heat injection, say from a thermal store, based on temperature sensed at another point.

HEAT RECOVERY IN AIR CONDITIONING SYSTEMS

Where a central air conditioning system is installed, condenser heat is conventionally rejected at a cooling tower. On a building where the construction, orientation or mode of occupation dictate that there is either a cooling or a heating requirement, but never both simultaneously, then there would be no use for any recovered heat. However, in many air conditioned buildings there are core zones which require cooling all year round while the perimeter zones need heating or cooling depending on the season. In other buildings opposite sides may have opposing thermal requirements

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Heat recovery

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for instance, when the ambient temperature is low enough to require heating but strong afternoon sun on one facade of the building dictates cooling. In these cases heat recovery may well be viable.

There are two solutions to this problem. One is to use a double bundle condenser on the water chiller (fig.7), the 'dirty' side being connected to the cooling tower as normal practice, the other 'clean' side, giving its heat to the heat distribution system which is subsequently topped up from a thermal store or boiler if necessary. The second approach is to use a piece of equipment produced by a major British manufacturer which combines most of these functions (fig.8), serving as a switching centre to redirect heat energy to or from the outside air, from the chilled water circuit and to the heating circuit. It operates as an air-to-water heat pump for heating, or as an air cooled liquid chiller with heat recovery or heat rejection. An integrated controls package senses the conditions in the chilled and heating water circuits and selects the appropriate mode of operation.

Both approaches sooner or later need top up heat, the first when cooling requirements and hence condenser heat availability are low, the second when the total building heat requirement exceeds its capacity in air-to-water heat pump mode, or when defrosting. It is then opportune to introduce an alternative form of heating, operating in bivalent mode.

BIVALENT HEATING

It is often convenient when sizing heat recovery plant, especially that based on heat pumps, to select equipment not designed to handle the peak winter heating load as one would select a boiler in a conventional hot water heating system, but to choose it to deal with some intermediate load. For instance, when using the energy switching centre described earlier, the load factor on the equipment would be better if it were selected to meet the cooling requirement. The system designer would then just make use of whatever condenser heat was available, even though this might be less than the winter design day heat requirement. This procedure would give a more economical sizing for a capital intensive item of heat recovery equipment and would ensure that the unit is more fully utilised.

The problem then remains — how to heat the building when the first heat generator is insufficient? The difference is made up by a top-up heat generator, preferably one which is lower in capital cost, even though its unit heat cost is more. Often, it will prove possible to increase the size of the top up heat generator economically to provide standby heat generating capacity in case of mechanical breakdown or maintenance, although at such a time the heat generated could cost more than recovered heat.

Bivalent heating (fig.9), as this dual source heat generation scheme is named, called for careful setting up and proper understanding of the economic reasoning behind selections of heat generating mode. In general, recovered or heat pump heat will be cheaper than heat generated from a paid for source. However there are other decisions to be made, such as whether to use off peak electricity to generate heat to store for later use — all this points to an integrated control system, properly set up.

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Centre the bellows

WHEN fitting a replacement shaft seal to an open type compressor great care must be taken to ensure that the bellows section is correctly centred on the shaft. Some makers supply a centering tool that slips between the bellows and the shaft to keep the same distance all the way around. But if this type of tool is not available then ordinary feeler gauges can be used by simply checking the space at opposite sides, top and bottom.