Electric heating

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30 kW resistance heating coils

Electric heating is a process in which electrical energy is converted to heat. Common applications include space heating, cooking, water heating and industrial processes. An **electric heater** is an electrical device that converts electric current to heat.[1] The heating element inside every electric heater is an electrical resistor, and works on the principle of Joule heating: an electric current passing through a resistor will convert that electrical energy into heat energy. Most modern electric heating devices use nichrome wire as the active element; the heating element, depicted on the right, uses nichrome wire supported by ceramic insulators.

Alternatively, a heat pump uses an electric motor to drive a refrigeration cycle, that draws heat energy from a source such as the ground or outside air and directs that heat into the space to be warmed. Some systems can be reversed so that the interior space is cooled and the warm air is discharged outside or into the ground.

Contents

Space heating

Space heating is used to warm the interiors of buildings. Space heaters are useful in places where air-handling is difficult, such as in laboratories. Several methods of electric space heating are used.

Radiant heaters


An electric radiative space heater

Electric radiant heating uses heating elements that reach a high temperature. The element is usually packaged inside a glass envelope resembling a light bulb and with a reflector to direct the energy output away from the body of the heater. The element emits infrared radiation that travels through air or space until it hits an absorbing surface, where it is partially converted to heat and partially reflected. This heat directly warms people and objects in the room, rather than warming the air. This style of heater is particularly useful in areas through which unheated air flows. They are also ideal for basements and garages where spot heating is desired. More generally, they are an excellent choice for task-specific heating.

Radiant heaters operate silently and present the greatest potential danger of ignition of nearby furnishings due to the focused intensity of their output and lack of overheat protection. In the United Kingdom, these appliances are sometimes called electric fires, because they were originally used to replace open fires.

The active medium of the heater depicted at the right is a coil of nichrome resistance wire inside a fused silica tube, open to the atmosphere at the ends, although models exist where the fused silica is sealed at the ends and the resistance alloy is not nichrome.

Convection heaters

In a convection heater, the heating element heats the air in contact with it by thermal conduction. Hot air is less dense than cool air, so it rises due to buoyancy, allowing more cool air to flow in to take its place. This sets up a convection current of hot air that rises from the heater, heats up the surrounding space, cools and then repeats the cycle. These heaters are sometimes filled with oil. They are ideally suited for heating a closed space. They operate silently and have a lower risk of ignition hazard if they make unintended contact with furnishings compared to radiant electric heaters.

Fan heaters

A fan heater, also called a forced convection heater, is a variety of convection heater that includes an electric fan to speed up the airflow. They operate with considerable noise caused by the fan. They have a moderate risk of ignition hazard if they make unintended contact with furnishings. Their advantage is that they are more compact than heaters that use natural convection.

Storage heating

A storage heating system takes advantage of cheaper electricity prices, sold during low demand periods such as overnight. In the United Kingdom, this is branded as Economy 7. The storage heater stores heat in clay bricks, then releases it during the day when required. Newer storage heaters are able to be used with various tariffs. Whilst they can still be used with economy 7, they can be used with day-time tariffs. This is in thanks to the modern design features that are added during manufacturing. Alongside new designs the use of a thermostat or sensor has improved the efficiency of the storage heater. A thermostat or sensor is able to read the temperature of the room, and change the output of the heater accordingly.

Water can also be used as a heat-storage medium.

Domestic electrical underfloor heating

An electric underfloor heating system has heating cables embedded in the floor. Current flows through a conductive heating material, supplied either directly from the line voltage (120 or 240 volts) or at low voltage from a transformer. The heated cables warm the flooring until it reaches the right temperature set by the floor thermostat. The flooring then heats the adjacent air, which circulates, heating other objects in the room (tables, chairs, people) by convection. As it rises, the heated air will warm the room and all its contents up to the ceiling. This form of heating gives the most consistent room temperature from floor to ceiling compared to any other heating system. A variation of this principle uses tubes filled with circulating hot water.

Lighting system

In large office towers, the lighting system is integrated with the heating and ventilation system. Waste heat from fluorescent lamps is captured in the return air of the heating system; in large buildings a substantial part of the annual heating energy is supplied by the lighting system. However, this waste heat becomes a liability when using air conditioning.

Heat pumps

A heat pump uses an electrically driven compressor to operate a refrigeration cycle that extracts heat energy from outdoor air, the ground or ground water, and moves that heat to the space to be warmed. A liquid contained within the evaporator section of the heat pump boils at low pressure, absorbing heat energy from the outdoor air or the ground. The vapor is then compressed by a compressor and piped into a condensor coil within the building to be heated. The heat from the hot dense gas is absorbed by the air in the building (and sometimes also used for domestic hot water) causing the hot working fluid to condense back into a liquid. From there the high pressure fluid is passed back to the evaporator section where it expands through an orifice and into the evaporator section, completing the cycle. In the summer months, the cycle can be reversed to move heat out of the conditioned space and to the outside air.

Heat pumps may obtain low-grade heat from the outdoor air in mild climates. In areas with average winter temperatures well below freezing, ground source heat pumps are more efficient than air source heat pumps because they can extract residual solar heat stored in the ground at warmer temperatures than is available from cold air.[2] According to the US EPA, geothermal heat pumps can reduce energy consumption up to 44% compared with air source heat pumps and up to 72% compared with electric resistance heating.[3] The high purchase price of a heat pump vs resistance heaters may be offset when air conditioning is also needed.

Liquid heating

Immersion heater

An immersion heater has an electrical resistance heating element encased in a tube and directly placed in the water (or other fluid) to be heated. The immersion heater may be placed in an insulated hot water tank. A temperature sensor within the tank triggers a thermostat to control the temperature of the water. Small portable immersion heaters may not have a control thermostat, since they are intended to be used only briefly and under control of an operator.

Small domestic immersion heater, 500 W

Domestic immersion heaters

Domestic immersion heaters, usually rated at 3 kilowatts and on a 1.5" British Standard Pipe screwplug in the UK, run on the normal domestic electricity supply, but consumers may also take advantage of a cheaper, off-peak electricity tariff such as Economy 7 (in the UK). In a typical off-peak installation, a lower immersion heater is connected to the separately switched off-peak heating circuit and an upper heater is connected to the normal circuit via its own switch. The consumer then has the option to top-up the available hot water supply at any time, rather than waiting for the cheaper supply to turn on (typically after midnight). A poorly insulated hot water cylinder will increase running costs because a consumer must pay for electricity used to replace lost heat.

Electric shower and tankless heaters also use an immersion heater (shielded or naked) that is turned on with the flow of water. A group of separate heaters can be switched in order to offer different heating levels. Electric showers and tankless heaters usually use from 3 to 7.5 kilowatts.

Irish-American comedian Des Bishop talks about his first encounter with a domestic immersion heater in one of his comedy routines.[4]

Industrial immersion heaters

Industrial immersion heaters can be either screwed or flanged. Screwed industrial immersion heaters, in the UK usually on a 2.25" British Standard Pipe are usually only rated up to approximately 24 kW, with 6 kW being considered the very top end that can be accommodated safely on a single phase supply. Flanged immersion heaters (such as those used in electric steam boilers) can be rated at up to 2000 kilowatts, or more, and require a three-phase supply.

Electrical immersion heaters may heat water immediately adjacent to the heating element high enough to promote the formation of scale, commonly calcium carbonate, in hard water areas. This accumulates on the element, and over time, as the element expands and contracts through its heating cycle, the scale cracks off and drops to the bottom of the tank, progressively filling up the tank. This reduces the tank's capacity and, where the immersion heater is secondary to the heating of the water by a coil fed from a gas or oil-fired boiler, can reduce the efficiency of the primary heating source by covering that other coil and in turn reducing its efficiency. Regular flushing-out of accumulated sediment can reduce this problem.

Such problems can be avoided at the design stage, by maximising the amount of hot element in the liquid, thus reducing the watts density. This reduces the working temperature of the surface of the element, reducing the build up of limescale. Watts density should be 40 W/in^2 ($6.2/cm^2$) or below in hard water areas, but can safely be 60 W/in^2 ($9.3/cm^2$) where hard water is not an issue.

Direct electric heat exchangers (DEHE)

The direct electric heat exchangers (DEHE) uses heating elements inserted into the "shell side" medium directly to provide the heating effect. Virtually all of the electric heat generated by the electric circulation heater is transferred into the medium, thus an electric heater is nearly 100 percent efficient. Direct electric heat exchangers or "circulation heaters" are used to heat liquids and gases in industrial processes.[5]

Electrode heater

With an electrode heater, there is no wire-wound resistance and the liquid itself acts as the resistance. This has potential hazards, so the regulations governing electrode heaters are strict.

Environmental and efficiency aspects

The efficiency of any system depends on the definition of the boundaries of the system. For an electrical energy customer the efficiency of electric space heating is almost 100% because almost all purchased energy is converted to building heat (the only exception being fan noise and indication lights which demand very little electricity and virtually none at all when compared to the extremely large energy draw of the heating itself). However, if a power plant supplying electricity is included, the overall efficiency drops drastically. For example, a fossil-fuel power station may only deliver 3 units of electrical energy for every 10 units of fuel energy released. Even though the electric heater is 100% efficient, the amount of fuel needed to produce electric heat is more than if the fuel was burned in a furnace or boiler at the building being heated. If the same fuel could be used for space heating by a consumer, it would be more efficient overall to burn the fuel at the end user's building. On the other hand replacing electric heating with fossil fuel burning heaters, isn't necessary good as it removes the ability to have renewable electric heating, this can be achieved by sourcing the electricity from a renewable source.

Variations between countries generating electrical power affect concerns about efficiency and the environment. In France 10% is generated from fossil fuels, in Britain 80%.[6] The cleanliness and efficiency of electricity are dependent on the source.

In Sweden the use of direct electric heating has been restricted since the 1980s for this reason, and there are plans to phase it out entirely – see Oil phase-out in Sweden – while Denmark has banned the installation of direct electric space heating in new buildings for similar reasons.[7] In the case of new buildings, low-energy building techniques can be used which can virtually eliminate the need for heating, such as those built to the Passivhaus standard.

In Quebec, however, electric heating is still the most popular form of home heating. According to a 2003 Statistics Canada survey, 68% of households in the province uses electricity for space heating. More than 90% of all power consumed in Quebec is generated by hydroelectric dams, which have low greenhouse gases emissions compared to Fossil-fuel power stations. Low and stable rates are charged by Hydro-Québec, the provincially owned utility.[8]

To provide heat more efficiently, an electrically driven heat pump can raise the indoor temperature by extracting energy from the ground, the outside air, or waste streams such as exhaust air. This can cut the electricity consumption to as little as 35% of that used by resistive heating.[9] Where the primary source of electrical energy is hydroelectric, nuclear, or wind, transferring electricity via the grid can be convenient, since the resource may be too distant for direct heating applications (with the notable exception of Solar thermal energy).

Economic aspects

The operation of electric resistance heaters to heat an area for long periods is costly in many regions. However, intermittent or partial day use can be more cost efficient than whole building heating due to superior zonal control.

Example: A lunch room in an office setting has limited hours of operation. During low use periods a "monitor" level of heat (50 °F or 10 °C) is provided by the central heating system. Peak use times between the hours of 11:00–14:00 are heated to "comfort levels" (70 °F or 21 °C). Significant savings can be realized in overall energy consumption, since infrared radiation losses through thermal radiation are not as large with a smaller temperature gradient both between this space and unheated outside air, as well as between the refrigerator and the (now cooler) lunch room.

Economically, electric heat can be compared to other sources of home heating by multiplying the local cost per kilowatt hour for electricity by the number of kilowatts the heater uses. E.g.: 1500 watt heater at 12 cents per kilowatt hour 1.5x12=18 cents per hour. When comparing to burning fuel it may be useful to convert kilowatts to BTUs, 1.5 kW x 3412.142=5118 BTU.

Industrial electric heating

Electric heating is widely used in industry.[10]

Advantages of electric heating methods over other forms include precision control of temperature and distribution of heat energy, combustion not used to develop heat, and the ability to attain temperatures not readily achievable with chemical combustion. Electric heat can be accurately applied at the precise point needed in a process, at high concentration of power per unit area or volume. Electric heating devices can be built in any required size and can be located anywhere within a plant. Electric heating processes are generally clean, quiet, and do not emit much byproduct heat to the surroundings. Electrical heating equipment has a high speed of response, lending it to rapid-cycling mass-production equipment.

The limitations and disadvantages of electric heating in industry include the higher cost of electrical energy compared to direct use of fuel, and the capital cost of both the electric heating apparatus itself and the infrastructure required to deliver large quantities of electrical energy to the point of use. This may be somewhat offset by in-plant (on-site) efficiency gains in using less energy overall to achieve the same result.

Design of an industrial heating system starts with assessment of the temperature required, the amount of heat required, and the feasible modes of transferring heat energy. In addition to conduction, convection and radiation, electrical heating methods can use electric and magnetic fields to heat material.

Methods of electric heating include resistance heating, electric arc heating, induction heating, and dielectric heating. In some processes (for example, arc welding), electric current is directly applied to the workpiece. In other processes, heat is produced within the workpiece by induction or dielectric losses. As well, heat can be produced then transferred to the work by conduction, convection or radiation.

Industrial heating processes can be broadly categorized as low-temperature (to about 400 °C or 752 °F), medium temperature (between 400 and 1,150 °C or 752 and 2,102 °F), and high temperature (beyond 1,150 °C or 2,102 °F). Low temperature processes include, baking and drying, curing finishes, soldering, molding and shaping plastics. Medium temperature processes include melting plastics and some non-metals for casting or reshaping, as well as annealing, stress-relieving and heat-treating metals. High-temperature processes include steelmaking, brazing, welding, casting metals, cutting, smelting and the preparation of some chemicals.

See also

- Central heating
- Diathermy
- Dielectric heating
- Electric Train Heating
- Electroslag welding
- Electroslag remelting
- Energy conservation
- Heater (types of heaters)
- HVAC
- Infrared heater
- Microwave oven
- Renewable energy
- Thermal efficiency
- Thermal immersion circulator
- Underfloor heating

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