8.14 Heating, ventilation and air conditioning

8.14.1 Ventilation and heating

To allow fresh air from outside the vehicle to be circulated inside the cabin, a pressure difference must be created. This is achieved by using a plenum chamber. A plenum chamber by def nition holds a gas (in this case air) at a pressure higher than the ambient pressure. The plenum chamber on a vehicle is usually situated just below the windscreen, behind the bonnet. When the vehicle is moving, the airf ow over the vehicle will cause a higher pressure in this area. Suitable f aps and drains are utilised to prevent water entering the car through this opening.

By means of distribution trunking, control f aps and suitable 'nozzles', the air can be directed as required. This system is enhanced with the addition of a variable speed blower motor. When extra air is forced into a vehicle cabin, the interior pressure would increase if no outlet was available. Most passenger cars have the outlet grilles on each side of the vehicle above or near the rear quarter panels or doors.

Def nition

Plenum chamber: A pressurised housing containing a gas ouid (typically air) at positive pressure (pressure higher than surroundings). One function of a plenum can be to equalise pressure for more even distribution, because of irregular supply or demand.

8.14.2 Heating system – water-cooled engine

Heat from the engine is utilised to increase the temperature of the car interior. This is achieved by use of a heat exchanger, called the heater matrix. Because of the action of the thermostat in the engine cooling system, the water temperature remains broadly constant. This allows for the air being passed over the heater matrix to be heated by a set amount depending on the outside air temperature and the rate of airf ow. A source of hot air is therefore available for heating the vehicle interior. However, some form of control is required over how much heat (if any) is required. The method used on most modern vehicles is the blending technique. This is simply a control f ap, which determines how much of the air being passed into the vehicle is directed over the heater matrix. The main drawback of this system is the change in airf ow with vehicle speed. Some systems use a valve to control the hot coolant f owing to the heater matrix (Figure 8.71).

Def nition

HVAC: Heating, ventilation and air conditioning.

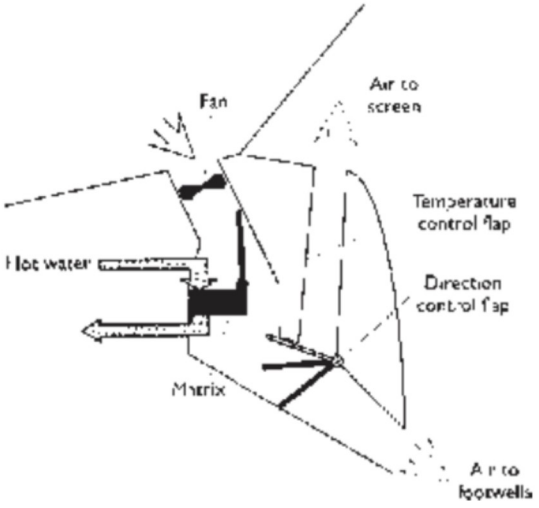


Figure 8.71 Heating and ventilation system

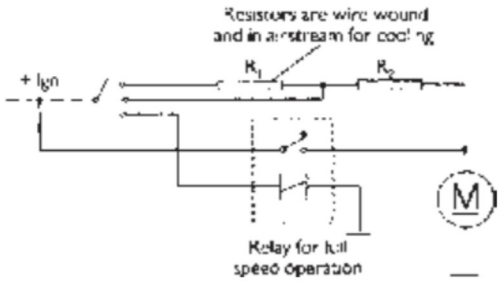


Figure 8.72 Three-speed motor control circuit

By a suitable arrangement of f aps, it is possible to direct air of the chosen temperature to selected areas of the vehicle interior. In general, basic systems allow the warm air to be adjusted between the inside of the windscreen and the driver and passenger footwells. Most vehicles also have small vents directing warm air at the driver's and front passenger's side windows. Fresh cool air outlets with directional nozzles are also f tted.

One f nal facility, which is available on many vehicles, is the choice between fresh or recirculated air. The main reason for this is to decrease the time it takes to demist or defrost the vehicle windows, and simply to heat the car interior more quickly to a higher temperature. The other reason is that the outside air may not be very clean, for example, in heavy congested traff c.

8.14.3 Heater blower motors

The motors used to increase airf ow are simple permanent magnet two brush motors. The blower fan is often the centrifugal type, and in many cases, the blades are positioned asymmetrically to reduce resonant noise. Varying the voltage supplied controls motor speed. This is achieved by using dropping resistors. The speed in some cases is made 'inf nitely' variable, by the use of a variable resistor. In most cases, the motor is controlled to three or four set speeds.

Figure 8.72 shows a circuit diagram typical of a three-speed control system. The resistors are usually wire wound and are placed in the air stream to prevent overheating. These resistors will have low values in the region of 1 Ω or less (Figure 8.73).

8.14.4 Electronic heating control

Most vehicles that have electronic control of the heating system also include air conditioning, which is covered in the next section. However, a short description at this stage will help to lead into the more complex systems.

This system requires control of the blower motor, blend f ap, direction f aps and the fresh or recirculated air f ap. The technique involves one or a number of temperature sensors suitably positioned in the vehicle interior, to provide information for the ECU. The ECU responds to information received from these sensors and sets the controls to their optimum positions. The whole arrangement is in fact a simple closed loop feedback system with the air temperature closing the loop. The ECU has to compare the position of the temperature control switch with the information that is supplied by the sensors and either cool or heat the car interior as required.



Figure 8.73 Blower motor and fan

8.14.5 Air conditioning introduction

A vehicle f tted with air conditioning allows the temperature of the cabin to be controlled to the ideal or most comfortable value determined by the ambient conditions. The system as a whole still utilises the standard heating and ventilation components, but with the important addition of an evaporator, which both cools and dehumidif es the air.

Air conditioning can be manually controlled or, as is not often the case, combined with some form of electronic control. The system as a whole can be thought of as a type of refrigerator or heat exchanger. Heat is removed from the car interior and dispersed to the outside air. To understand the principle of refrigeration, the following terms and def nitions will be useful.

- Heat is a form of energy.
- Temperature means the degree of heat of an object.
- Heat will only f ow from a higher to a lower temperature.
- Heat quantity is measured in 'calories' (more often kcal).
- 1 kcal heat quantity changes the temperature of 1 kg of liquid water by 1 °C.
- Change of state is a term used to describe the changing of a solid to liquid, a liquid to a gas, a gas to a liquid or a liquid to a solid.
- Evaporation is used to describe the change of state from a liquid to a gas.
- Condensation is used to describe the change of state from gas to liquid.
- Latent heat describes the energy required to evaporate a liquid without changing its temperature (breaking of molecular bonds), or the amount of heat given off when a gas condenses back into a liquid without changing temperature (making of molecular bonds).

Latent heat in the change of state of a refrigerant is the key to air conditioning. A simple example of this is that if you put a liquid such as methylated spirits on your hand it feels cold. This is because it evaporates and the change of state (liquid to gas) uses heat from your body. This is why the process is often thought of as 'unheating' rather than cooling.

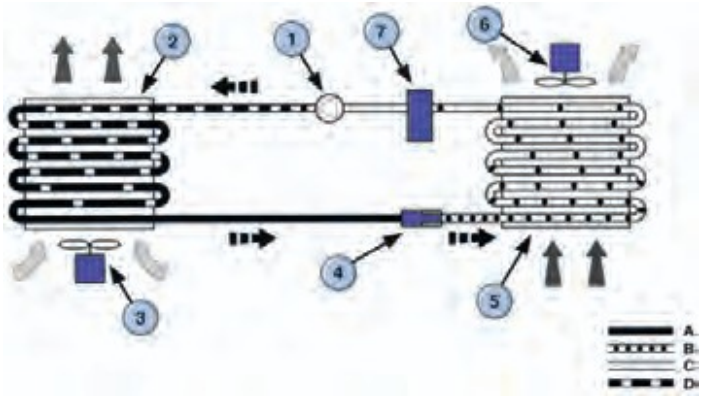


Figure 8.74 AC system layout: 1 – compressor; 2 – condenser; 3 – auxiliary (depending on model); 4 – fixed orifice tube; 5 – evaporator; 6 – heater/air conditioning blower; 7 – suction accumulator/drier; A – high-pressure warm liquid; B – low-pressure cool liquid; C – low-pressure, gaseous and cool; D – high-pressure, gaseous and hot. (Source: Ford Motor Company)



Figure 8.75 AC components

The refrigerant used in many air conditioning systems is known as R134A. This substance changes state from liquid to gas at −26.3 °C. R134A is hydrofluorocarbon (HFC) based rather than chlorofluorocarbon (CFC), due to the problems with atmospheric ozone depletion associated with CFC-based refrigerants. A key to understanding refrigeration is to remember that low-pressure refrigerant will have low temperature, and high-pressure refrigerant will have a high temperature.

Figure 8.74 shows the basic principle of an air conditioning – or refrigeration – system. The basic components are the evaporator, condenser and pump or compressor. The evaporator is situated in the car; the condenser is outside the car, usually in the air stream; and the compressor is driven by the engine.

As the pump operates, it will cause the pressure on its intake side to fall, which will allow the refrigerant in the evaporator to evaporate and draw heat from the vehicle interior. The high pressure or output of the pump is connected to the condenser. The pressure causes the refrigerant to condense (in the condenser), thus giving off heat outside the vehicle as it changes state. Figure 8.75 shows some typical components of an air conditioning system.

Key fact

On an AC system, the evaporator is situated in the car; the condenser is outside the car, usually in the air stream; and the compressor is driven by the engine.

8.14.6 Air conditioning overview

The operation of the system is a continuous cycle. The compressor pumps low pressure but heatladen vapour from the evaporator, compresses it and pumps it as a superheated vapour under high pressure to the condenser. The temperature of the refrigerant at this stage is much higher than the outside air temperature, hence it gives up its heat via the f ns on the condenser as it changes state back to a liquid.

This high-pressure liquid is then passed to the receiver drier where any vapour which has not yet turned back to a liquid is stored, and a desiccant bag removes any moisture (water) that is contaminating the refrigerant. The high-pressure liquid is now passed through the thermostatic expansion valve and is converted back to a low-pressure liquid as it passes through a restriction in the valve into the evaporator. This valve is the element of the system that controls the refrigerant f ow and hence the amount of cooling provided. As the liquid changes state to a gas in the evaporator, it takes up heat from its surroundings, thus cooling or 'unheating' the air that is forced over the f ns. The low-pressure vapour leaves the evaporator returning to the pump, thus completing the cycle.

If the temperature of the refrigerant increases beyond certain limits, condenser cooling fans can be switched in to supplement the ram air effect. A safety switch is f tted in the high-pressure side of most systems. It is often known as a high–low pressure switch, as it will switch off the compressor if the pressure is too high due to a component fault, or if the pressure is too low due to a leakage, thus protecting the compressor.

8.14.7 Automatic temperature control

Full temperature control systems provide a comfortable interior temperature in line with the passenger controlled input. The ECU has full control of fan speed, air distribution, air temperature, fresh or recirculated air and the air conditioning pump. These systems will soon be able to control automatic demist or defrost when reliable sensors are available. A single button currently will set the system to full defrost or demist.

A number of sensors are used to provide input to the ECU.

- Ambient temperature sensor mounted outside the vehicle to allow compensation for extreme temperature variation. This device is usually a thermistor.
- Solar light sensor mounted on the fascia panel. This device is a photodiode and allows a measurement of direct sunlight from which the ECU can determine whether to increase the air to the face vents.
- The in-car temperature sensors are simple thermistors but to allow for an accurate reading a small motor and fan can be used to take a sample of interior air and direct it over the sensing elements.
- A coolant temperature sensor is used to monitor the temperature of the coolant supplied to the heater matrix. This sensor is used to prevent operation of the system until coolant temperature is high enough to heat the vehicle interior.
- Driver input control switches.

The ECU takes information from all of the above sources and will set the system in the most appropriate manner as determined by the software. Control of the f aps can be either by solenoid controlled vacuum actuators or by small motors. The main blower motor is controlled by a heavy-duty power transistor and is constantly

Key fact

Control of the HVAC faps can be either by solenoid controlled vacuum actuators or by small motors.



Figure 8.76 Heated seat

variable. These systems are able to provide a comfortable interior temperature in exterior conditions ranging from −10 to +35 °C even in extreme sunlight.

8.14.8 Seat heating

The concept of seat heating is very simple. A heating element is placed in the seat, together with an on–off switch and a control to regulate the heat. However, the design of these heaters is more complex than f rst appears. The heater must meet the following criteria:

- The heater must only supply the heat loss experienced by the person's body.
- Heat is to be supplied only at the major contact points.
- Leather and fabric seats require different systems due to their different thermal properties.
- Heating elements must f t the design of the seat.
- The elements must pass the same rigorous tests as the seat, such as squirm, jounce and bump tests.

In order for the passengers (including the driver) to be comfortable, rigorous tests have been carried out to f nd the optimum heat settings and the best position for the heating elements. Many tests are carried out on new designs, using manikin with sensors attached, to measure the temperature and heat f ow (Figure 8.76).

The cable used for most heating elements consists of multi-strand alloyed copper. This cable may be coated with tin or insulated as the application demands. The heating element is laminated and bonded between layers of polyurethane foam.

8.14.9 Screen heating

Heating of the rear screen involves a very simple circuit. The heating elements consist of a thin metallic strip bonded to the glass. When a current is passed through the elements, heat is generated and the window will defrost or demist. This circuit can draw high current, 10–15 A being typical. Because of this, the circuit will often contain a timer relay to prevent the heater being left on for too long. The timer will switch off after 10–15 minutes. The elements are usually positioned to defrost the main area of the screen and the rest position of the rear wiper blade if f tted (Figure 8.77).

Front windscreen heating is being introduced on many vehicles. This of course presents more problems than the rear screen, as vision must not be obscured. The technology, drawn from the aircraft industry, involves very thin wires cast in to the glass. As with the heated rear window, this device can consume a large current and is operated by timer relay.

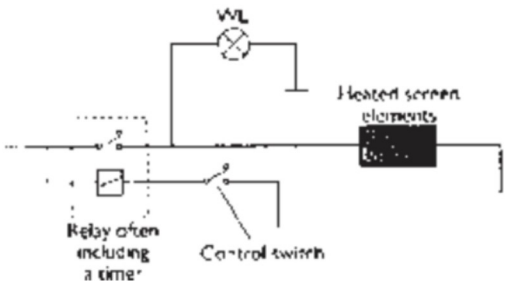


Figure 8.77 Screen heating circuit

8.15 Diagnostics – HVAC

8.15.1 Testing procedure (Figure 8.78)

The process of checking an air conditioning system is broadly as presented in Figure 8.79.

Safety f rst

Warning: Do not work on the refrigerant side of air conditioning systems unless you have been trained and have access to suitable equipment.

8.15.2 Air conditioning fault diagnosis table

Symptom	Possible fault
After stopping the compressorpressure falls quickly to approximately 195kPa and then falls gradually	Air in the system, or if no bubbles are seen in the sight glass as the condenser is cooled with watthen excessive refrigerant may be the fault
Discharge pressure low	Fault with the compressoror if bubbles are seen, low refrigerant
Discharge temperature is lower than normal	Frozen evaporator
Suction pressure too high	High pressure valve fault, excessive refrigerant or expansion valve open too long
Suction and discharge pressure too high	Excessive refrigerant in the system or condenser not working due to fan fault or cloggedsf
Suction and discharge pressure too low	Clogged or kinked pipes
Refrigerant loss	Oily marks (from the lubricant in the refrigerant) near joints or seals indicate leaks



Figure 8.78 Circuit voltage testing

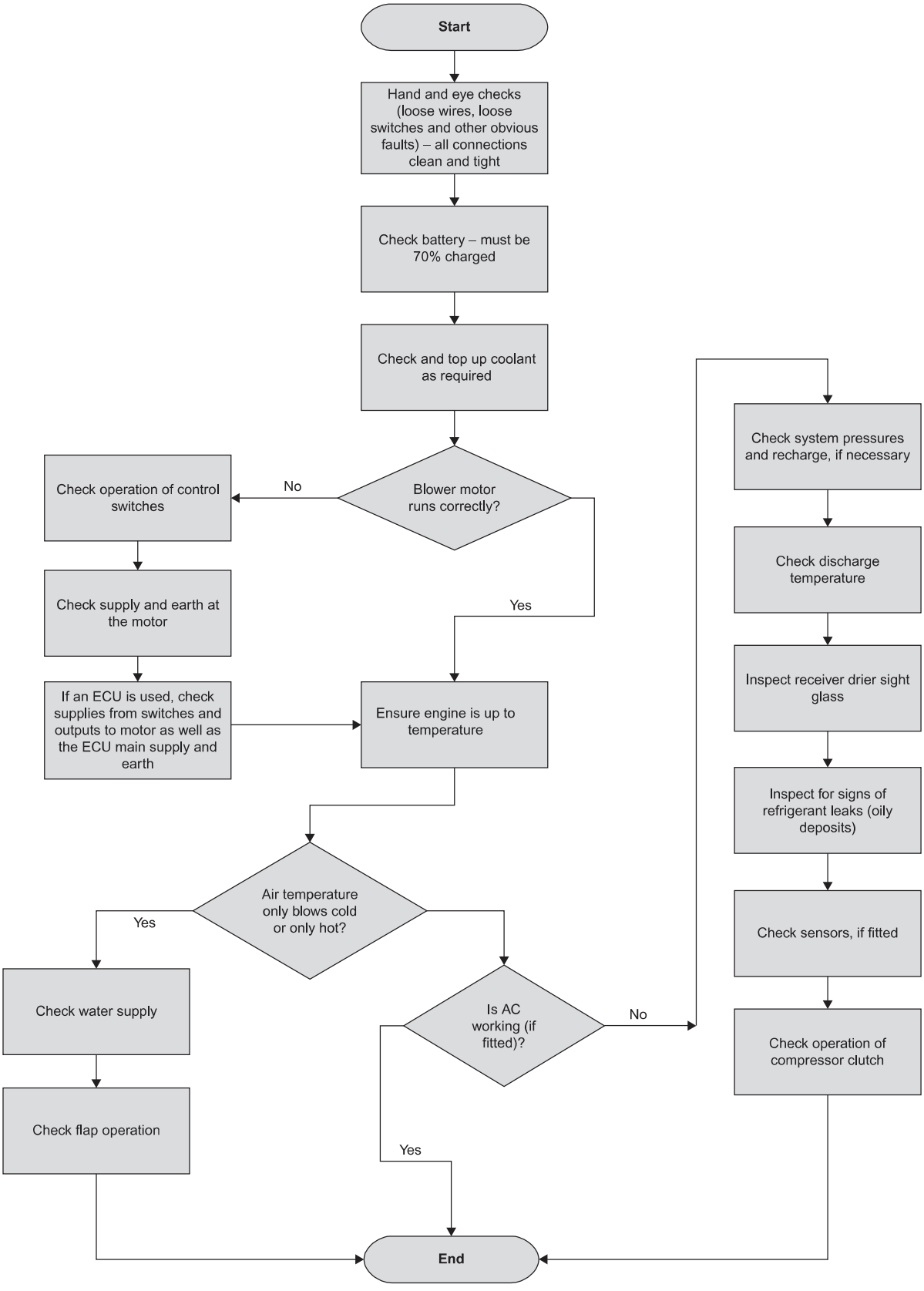


Figure 8.79 HVAC system diagnosis chart

8.15.3 Heating and ventilation fault diagnosis table

Symptom	Possible fault
Booster fan not operating at any speed	Open circuit fuse/supply/earth Motor inoperative/seized Dropping resistor(s) open circuit Switch open circuit Electronic speed controller not working
Booster fan only works o full speed	Dropping resistor(s) open circuit Switch open circuit Electronic speed controller not working
Control fap(s) will not move	Check vacuum connections (many work by vacuum-operated actuators) Inspect cables
No hot air	Matrix blocked Blend fap stuck
No cold air	Blend fap stuck Blocked intake
Reduced temperature when set to 'Hot'	Cooling system thermostat stuck open Heater matrix partially blocked Control fap not moving correctly

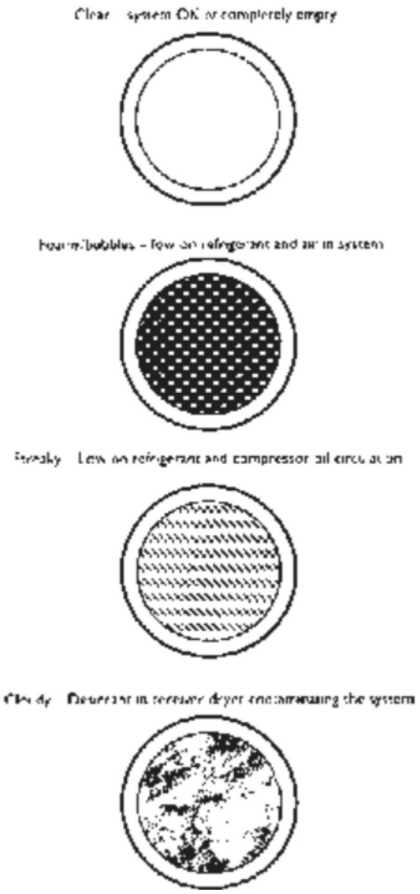


Figure 8.80 AC receiver drier sight glass

8.15.4 Air conditioning receiver

A very useful guide to diagnostics is the receiver drier sight glass. Figure 8.80 shows four possible symptoms and suggestions as to the possible fault.

8.16 Cruise control

8.16.1 Introduction

Cruise control is the ideal example of a closed loop control system as shown in Figure 8.81. The purpose of cruise control is to allow the driver to set the vehicle speed and let the system maintain it automatically. The system reacts to the measured speed of the vehicle and adjusts the throttle accordingly. The reaction time is important so that the vehicle's speed does not feel as if it is surging up and down.

Other facilities are included such as allowing the speed to be gradually increased or decreased at the touch of a button. Most systems also remember the last set

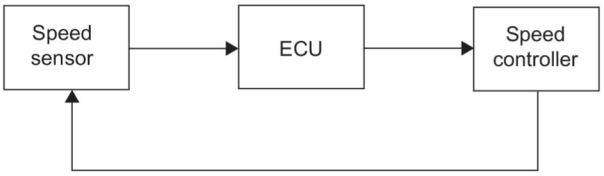


Figure 8.81 Cruise control – closed control loop negative feedback

Def nition

Negative feedback acts to reduce the input signal that caused it, is also known as a self-correcting or balancing loop. Negative feedback loops are goal seeking, for example, a temperature sensor in a system that compares actual temperature with desired temperature and acts to reduce the difference.